UVALDE COUNTY
UNDERGROUND WATER
CONSERVATION DISTRICT

GROUNDWATER MANAGEMENT PLAN
2016-2021

District Mission

The Uvalde County Underground Water Conservation District (UCUWCD) strives to protect the quality of, conserve, enhance, manage and promote the beneficial use of the groundwater resources of Uvalde County for the benefit of the citizens and the economy and to minimize waste.

Time Period for the Plan

This plan becomes effective upon adoption by the Board of Directors and replaces the previously adopted management plan. This plan will be implemented and will remain in effect for five years from the date of approval by the Texas Water Development Board (TWDB).

Guiding Principles

The District recognizes that the groundwater resources of this region are of vital importance to the residents and the economy, and that this resource must be managed effectively. A basic understanding of the nature of the aquifers and their hydrogeologic characteristics, as well as the quantity of the groundwater resources, is the foundation from which to develop prudent planning measures. This management plan is intended as a tool to focus the programs and plans of the District to conserve the county's valuable groundwater resources while allowing their prudent use.

About the District

The Uvalde County UWCD was created pursuant to Section 59, Article 16 of the Texas Constitution and validated by the 73rd Legislature under Article 2, Senate Bill 1477. The District has the same boundaries as the County of Uvalde.

The District Board of Directors is composed of eight members elected to staggered four-year terms. Elections for directors are held in November. Two directors are elected from each of the county precincts. The Board of Directors holds regular quarterly meetings. Called board meetings are held when necessary, at the District offices in the First State Bank of Uvalde Bank Building located at 200 East Nopal, Suite 203, in Uvalde, Texas. Meetings of the Board of Directors are public. Meetings are noticed and held in accordance with public meeting requirements.

The District's Authority to Regulate Groundwater

The District derives its authority to manage groundwater use within the District by virtue of the powers granted and authorized in the District enabling act of the 73rd Legislature under Article 2, Senate Bill 1477. The District, acting under authority of the enabling legislation, assumes all the rights and responsibilities of a groundwater conservation district as specified in Chapter 36 of the Texas Water Code. The District has adopted rules that specify the process, procedures, practices, and requirements for obtaining a permit from the District. Tables 1. and 2. provide information about the modeled availability of groundwater in Uvalde County.

Regulation of the Edwards Balcones Fault Zone (BFZ) aquifer within Uvalde County is the responsibility of the Edwards Aquifer Authority (EAA). The Uvalde County UWCD has no jurisdiction over the management of the Edwards (BFZ) aquifer. The District does and will coordinate with the EAA on matters of common interest related to the aquifer, including monitoring water use and cooperating in research with the EAA and other organizations such as the United States Geological Survey (USGS) and the Natural Resources Conservation Service (NRCS).

Water Resources of the District

Surface water in the District comes primarily from the Nueces River and its tributaries.

Groundwater is found in both major and local aquifers in the District. Major aquifers include the Edwards (BFZ), Edwards-Trinity (Plateau), Carrizo-Wilcox and Trinity aquifers. Local aquifers include the Leona Gravel, Buda Limestone, Anacacho Limestone, and Austin Chalk. There is significant production from the Buda Limestone, Austin Chalk and Leona Gravel aquifers in areas of the District west of the Knippa Gap which produce sufficient yields for irrigation and other uses. The remaining local aquifers mostly supply domestic and livestock where water is not available from other aquifers.

A report completed for the District in 2010[1] concludes that prior studies of the western sub-basin clearly demonstrate that the Edwards (BFZ) aquifer is in hydraulic communication with the Buda Limestone, Austin Chalk and Leona Gravel local aquifers, and that index well J-27, although completed in the Edwards (BFZ) aquifer, can indicate declines in groundwater levels in the those minor aquifers that adversely impact the water resource. When the level in index well J-27 drops below 860 feet msl, recharge to the Leona gravels and discharge to Soldiers Camp Springs to the Nueces River decline measurably. However, it is difficult to distinguish how much interaction and leakage occurs between the formations because of local structural and geological characteristics, including regional fracturing and faulting as well as local erosion and deposition over geologic time.

Historic Water Use in the District

Historic surface water use within the District between 2000 and 2013 varied from highest total use of 2,448 acre-feet in 2008 to lowest total use of 604 acre-feet in 2012.

Historic groundwater use is reported from the four major aquifers in Uvalde County and does not include production from the local aquifers, which is not quantified except to the extent that there have been inflows from them into the major aquifers.

Total groundwater use within the district between 2000 through 2013 has varied from highest use of 105,682 acre- in 2009 to lowest use of 43,916 acre-feet in 2007. The largest use is for irrigation.

See Appendix A. *Estimated Historical Water Use and 2012 State Water Plan Dataset*, Uvalde County Underground Water Conservation District, TWDB, January 14, 2016

[1] Green, Ronald T. and Bertetti, F. Paul, *Development of a Candidate Drought Contingency Plan for Uvalde County, Texas*, Geosciences and Engineering Division, Southwest Research Institute, San Antonio, TX, May 2010

Groundwater Recharge From Precipitation, Discharges to Springs and Surface Water Bodies, and Flows Into and Out of the District within each Aquifer and Between Aquifers in the District

Summarized information from Groundwater Availability Model (GAM) run results showing estimated annual amounts of groundwater recharge from precipitation, and estimated annual volumes of discharges to surface water bodies and of flows into, out of and between aquifers for the Hill Country portion of the Trinity Aquifer, the Edwards-Trinity (Plateau) Aquifer, and the Carrizo-Wilcox Aquifer are found in Tables, 1, 2, and 3, respectively, on pages 8-12 of TWDB GAM Run 15-006, dated June 26, 2015.

GAM Run 15-006 is attached to this Plan as Appendix B.

Modeled Available Groundwater in District Aquifers

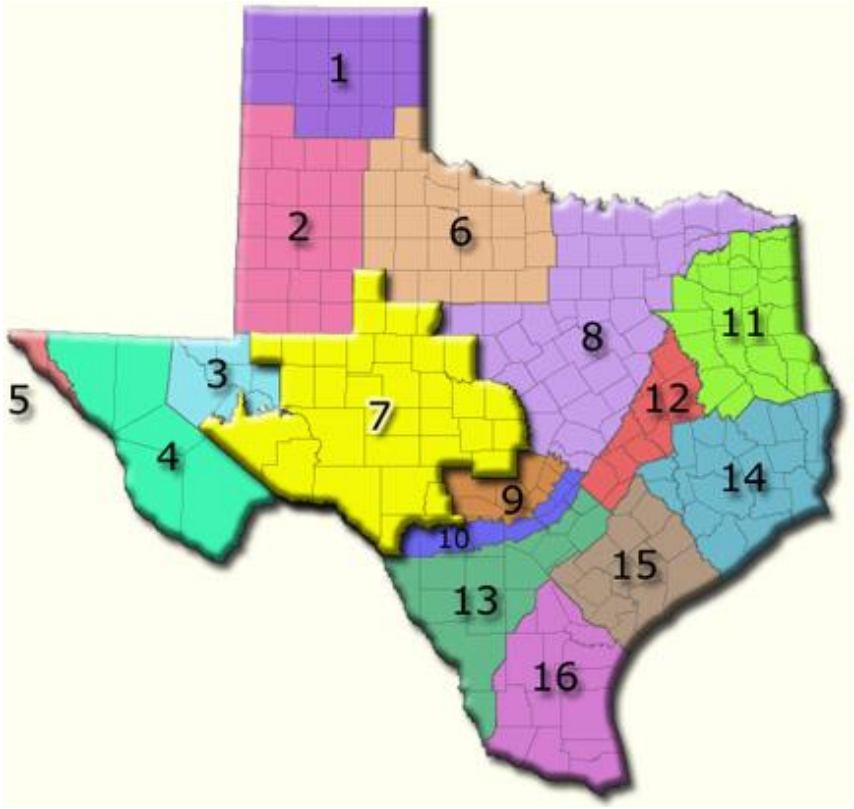
Modeled Available Groundwater (MAG) in the district is defined in Section 36.001 of the Texas Water code as "the amount of water that the executive administrator determines may be produced on an average annual basis to achieve a desired future condition established under Section 36.108."

The Uvalde County UWCD is required, pursuant to Section 36.108, to meet at least annually with other groundwater conservation districts in Groundwater Management Areas (GMAs) designated by the TWDB, to participate in joint planning and adoption of DFCs for its aquifers.

Tables 1 and 2 present modeled available groundwater values for the district.

Figure 1.

Groundwater Management Areas of the State



The DFCs are submitted to the TWDB, which through the use of Groundwater Availability Models (GAMs) determines the MAGs for each aquifer in each district. Uvalde County UWCD is unique in that it is located within the boundaries of three GMAs 7, 10, and 13, requiring coordination with 32 (29 unique) other groundwater conservation districts (GCDs). These include: 20 GCDs in GMA 7; 5 GCDs in GMA 10; and 7 GCDs in GMA 13 (Figure 1).

The DFCs for the aquifers located within District boundaries were adopted by the relevant Groundwater Management Areas prior to September 1, 2010 as follows:

1) Carrizo-Wilcox Aquifer: An average drawdown of twenty-three (23) feet within the District from 2010 to 2060.

2) Edwards-Trinity (Plateau) Aquifer: Total net decline in water levels within the Uvalde County UWCD at the end of the 2010-2060 period shall not exceed seven (7) feet below 2010 water levels in the aquifer.

3) Trinity Aquifer: The Trinity aquifer is irrelevant in that portion of the District within the boundaries of GMA7: well drawdown during average recharge conditions not to exceed twenty (20) feet (including exempt and non-exempt uses) below 2010 water levels in that portion of the District within the boundaries of GMA 10.

4) Leona Gravel, Austin Chalk and Buda Limestone aquifers: Average well drawdown of zero (0) feet (including exempt and non-exempt uses) on the basis that there has been no long-term drawdown of these local aquifers from recent historic pumping, the aquifers are connected among themselves and with the Edwards (BFZ) aquifer, and are in equilibrium and self-regulating.

TABLE 1.

MODELED AVAILABLE GROUNDWATER IN MAJOR AQUIFERS IN THE DISTRICT
2010-2060
(acre-feet/year)

AQUIFER	YEAR					
	2010	2020	2030	2040	2050	2060
Carrizo-Wilcox	2,971	1,230	828	828	828	828
Edwards-Trinity(Plateau)	1,635	1,635	1,635	1,635	1,635	1,635
Trinity	639	639	639	639	639	639
TOTAL	**5,245**	**3,504**	**3,102**	**3,102**	**3,102**	**3,102**

Source: TWDB
GR 10-012 MAG Carrizo- Wilcox Aquifer
August 2, 2012
GR 10-043 MAG. v. 2. Edwards-Trinity (Plateau) Aquifer
November 12, 2012
GTA AA 10-29 MAG Trinity Aquifer
November 29, 2011

TABLE 2.

MODELED AVAILABLE GROUNDWATER IN LOCAL AQUIFERS IN THE DISTRICT
2010-2060
(acre-feet/year)

AQUIFER	YEAR					
	2010	2020	2030	2040	2050	2060
Austin Chalk	2,935	2,935	2,935	2,935	2,935	2,935
Buda Limestone	758	758	758	758	758	758
Leona Gravel	9,385	9,385	9,385	9,385	9,385	9,385
TOTAL	**13,078**	**13,078**	**13,078**	**13,078**	**13,078**	**13,078**

Source: TWDB
GTA AA 10-26 MAG Austin Chalk Aquifer 8/19/2011
GTA AA 10-27 MAG Buda Limestone Aquifer 8/19/2011
AA10-28 MAG Leona Gravel Limestone 2/4/2013

Projected Surface Water Supply within the District

Surface Water supply within the District from the Nueces River and its tributaries is projected to be 1,362 acre-feet throughout the period 2010-2016. Of this amount 720 acre-feet will be used annually for irrigation, 642 acre-feet for livestock.

See Appendix A. *Estimated Historical Water Use and 2012 State Water Plan Dataset,*
Uvalde County Underground Water Conservation District
TWDB, January 14, 2016
Projected Surface Water Supplies

Projected Water Demands within the District

Estimates of projected water demand are based on anticipated patterns of population growth and migrations that are applied to standardized estimated water use rates for the recognized categories of water use and anticipated increases in efficiency and conservation in agricultural water use. Total water demand may ultimately be met by either surface water or groundwater supplies. The estimate of projected total water demand in the District over the next 50 years decreases from 65,886 acre-feet in 2010 to 57,042 acre-feet in 2060, with significant decreases in irrigation use of about 10,000 acre-feet, a very small increase in municipal use in the City of Uvalde, and about 960 acre-feet of increased use in the County Other category, which includes the public water supplies for the cities of Utopia and Concan.

See Appendix A, *Estimated Historical Water Use and 2012 State Water Plan Dataset,*
Uvalde County Underground Water Conservation District
TWDB, January 14, 2016
Projected Water Demands

The District estimates the normal use of irrigation water in Uvalde County at two and one-half acre-feet per irrigated acre. The NRCS estimates that there are 15,429 acres of land irrigated by groundwater from the Leona Gravel, Austin Chalk and Buda Limestone aquifers. Annual production of groundwater from these aquifers within the jurisdiction of the District is estimated to be 38,572 acre-feet. The remaining demand is supplied from the Carrizo-Wilcox, Edwards (BFZ), Edwards-Trinity (Plateau) and Trinity aquifers.

The Edwards Aquifer Authority enabling legislation allows recharge credits to be obtained by political subdivisions adding recharge to the Edwards (BFZ) Aquifer. Should the Edwards(BFZ) Aquifer Recharge program be implemented by use of groundwater from an aquifer other than the Edwards (BFZ) Aquifer, groundwater that is now used for other purposes could be diverted to recharge to the Edwards (BFZ) Aquifer, and could therefore materially impact the availability of groundwater for beneficial use within the District, and substantially impact historic use and accepted conservation practices. The District will evaluate such projects, taking into account all applicable statutory and regulatory criteria, to ensure that the yield and quality of groundwater in the District are not jeopardized and the rights and interests of groundwater users in the District are protected.

Projected Water Supply Needs

Water supply needs within the District, that is, demand in excess of supply, are projected to increase from a deficit in supply of 3,299 acre-feet in 2010 to a deficit of 3,372 acre-feet in 2060. Most of the deficit will be supply for the City of Uvalde- 3,263 acre-feet by 2060, with of 109 acre-feet for Sabinal in 2060. Irrigation, livestock, manufacturing, mining and county other are projected to have surplus supplies.

See Appendix A. *Estimated Historical Water Use and 2012 State Water Plan Dataset*, Uvalde County Underground Water Conservation District TWDB, January 14, 2016, Projected Water Supply Needs

Projected Water Management Strategies in the 2012 State Water Plan to Meet Needs of Water User Groups

The projected water supplies and demand estimates for Uvalde County in the 2012 State Water Plan indicate that projected demands exceed projected supplies. Water management strategies are projects or procedures that if implemented will produce additional water to meet the identified needs of water user groups. The total amount of groundwater and surface water resulting from implementation of the water management strategies recommended for Uvalde County in the 2012 State Water Plan is anticipated to provide 4,178 acre-feet in 2010, increasing to 6,306 acre-feet in 2060. Transfers from the Edwards (BFZ) Aquifer and municipal water conservation are the primary strategies identified.

See Appendix A. *Estimated Historical Water Use and 2012 State Water Plan Dataset*, Uvalde County Underground Water Conservation District, TWDB, January 14, 2016, Projected Water Management Strategies

Management of Groundwater Supplies

The District will manage the supply of groundwater within the District in order to conserve the resource while seeking to maintain the economic viability of all resource user groups.

A. Duplicative permits. The District has adopted and will enforce rules to restrict total production for irrigation to two acre-feet per acre on a tract of land. In reviewing an application, and before issuing a permit, the District shall take into consideration the amount of water already permitted for irrigation, regardless of source or the permitting authority, so that the total allocation of water to the tract of land shall not exceed, cumulatively, a total of two acre-feet/acre/year. Further, production allocation already made by the District shall be reduced to the extent that another permitting authority grants groundwater or surface water rights which would result in total permits exceeding two acre-feet per acre.

B. Waste. In consideration of economic and cultural activities occurring within the District, the District has developed rules that identify and monitor waste. The District will promote water- saving practices and the installation and use of water-saving devices and irrigation equipment.

C. Research and Data Collection. All ongoing TWDB, USGS, and EAA observation studies and data collected will be monitored in order to gain additional information regarding changing storage conditions of groundwater supplies within the District jurisdiction. The District will work cooperatively with investigations of groundwater resources within the District and will make the results of investigations available to the public upon acceptance of the information by the District's Board. Preliminary or draft data may be made available under circumstances where the data is identified as draft and preliminary and where the District believes the information may be useful and beneficial. The District will employ all technical resources at its disposal to evaluate the groundwater resources available within the District and to determine the effectiveness of conservation measures. The District has obtained metering equipment from the TWDB for implementation of a program to help local groundwater users determine groundwater usage from the various aquifers of the District.

D. Aquifer Recharge. The District shall not allow recharge of an aquifer under its jurisdiction if the water being placed into the aquifer is of inferior quality to water residing in the formation.

Other Economically Feasible Water Management Strategies for Uvalde County

Additionally, based on data obtained from a study by Dr. Bill Dugas in association with the Seco Creek Water Quality Demonstration Project, recharge could be increased by an estimated 40,000 gallons per acre per year through extensive brush management followed by enhanced grazing practices. The implementation of these feasible methods on 500 acres would equate to approximately 62 acre-feet per year of increased recharge.

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 guidepost for determining the direction or priority for District operations and activities. Operations of the District, all agreements entered into by the District and any additional planning efforts in which the District may participate will be consistent with the provisions of this plan.

The District has adopted rules relating to the permitting of wells and the production of groundwater and continues to review and revise those rules in accordance with the best scientific evidence available and pursuant to changes in state laws and regulations. The rules adopted by the District shall be pursuant to Chapter 36 of the Texas Water Code and the provisions of this plan. All rules will be adhered to and enforced. The promulgation and enforcement of the rules will be based on the best technical evidence available. District Rules may be viewed on the District website at http://www.uvaldecountyuwcd.org/District_Rules.html .

The District shall treat all citizens indiscriminately. Citizens may apply to the District for discretion in enforcement of the rules on grounds of adverse economic effect or unique local conditions. In granting of discretion to any rule, the Board of Directors shall consider the potential for adverse effect on adjacent landowners. The exercise of said discretion by the District Board shall not be construed as limiting the power of the District Board.

The District will seek cooperation in the implementation of this plan and the management of groundwater supplies within the District. All activities of the District will be undertaken in cooperation and coordinated with the appropriate state, regional or local management entity."

METHODOLOGY TO TRACK PROGRESS TOWARDS ACHIEVING DISTRICT MANAGEMENT GOALS

The District manager will prepare an annual report on District performance in achieving the management goals. The annual report will be presented to the Board of Directors during the first quarterly Board of Directors meeting each fiscal year. The report will include the number of instances in which each objective activity was engaged in during the year so that the effectiveness of each activity may be evaluated. The annual report will be maintained on file at the District office and made available to the public upon adoption by the Board.

MANAGEMENT GOALS, OBJECTIVES AND PERFORMANCE STANDARDS

Goal 1.0 To Provide for the Most Efficient Use of Groundwater in the District

Management Objective
1.1 On at least one occasion each year the district will provide educational materials promoting and explaining conservation methods and concepts for the efficient use of water.

Performance Standards
1.1a. Number of annual events where conservation material was provided through service organizations
1.1b. Record of brochure titles available at the district office during the year

Management Objective
1.2 Each year the District will provide informative speakers on at least two occasions to school or civic groups to raise public awareness of practices that promote the efficient use of groundwater.

Performance Standard
1.2 Number of programs provided to school or civic groups each year.

Goal 2.0 To Control and Prevent the Waste of Groundwater.

Management Objective
2.1 Each year the District will provide, on at least six occasions, educational materials concerning waste, which is prohibited under District Rules, to the local newspapers and the general public.

Performance Standard
2.1 The number of newspaper articles and/or public service announcements concerning waste which the District publishes each year in a newspaper of general circulation in Uvalde County.

Management Objective
2.2 The District will investigate all written reports of groundwater waste within five working days from the date the report is filed with the District.

Performance Standard
2.2 The number of times a written groundwater waste report is filed with the district, with a log of date filed and date investigated.

Goal 3.0 Addressing Natural Resource Issues that Impact the Use and Availability of Groundwater and are Impacted by the Use of Groundwater

Management Objective
3.1 Each year the District will cooperate with interested parties and appropriate agencies to disseminate information to landowners and the public on aquifer recharge or weather modification by conducting one informational public meeting on one of the topics, including information on such projects, if any, available to the public, and information on District rules governing such projects.

Performance Standard
3.1 Number of public meetings or presentations conducted annually in which information on aquifer recharge or weather modifications is made available, including District Rules governing such projects.

Management Objective
3.2 Issuance of well construction permits, or preregistation of exempt wells, prior to the drilling of all new wells for all aquifers under the District's jurisdiction.

Performance Standard
3.2 The number of permits of well construction permits issued within 90 days of the filing of administratively complete applications, and the number of registrations completed within 20 days of notification of drilling of exempt wells.

Goal 4.0 Addressing Drought Conditions

Management Objective
4.1 Annually monitor the Palmer Drought Severity Index (PDSI), notifying all District public water suppliers of severe drought conditions when they occur.

Performance Standard
4.1 Report the current drought status of the District to the Board of Directors at quarterly meetings and the number of times that letters are sent to public water suppliers warning of severe drought conditions.

Management Objective
4.2 Publish a public service announcement in a newspaper of general circulation in Uvalde County, notifying area residents of drought conditions and recommending conservation measures.

Performance Standard
4.2 Annually report to the Board of Directors the number of times area residents are notified of severe drought conditions in the local newspaper

Goal 5.0 (a) Addressing Conservation

Management Objectives
5.(a) 1. At least once annually the District will provide educational literature promoting water conservation in a public educational presentation.

Performance Standard
5.(a) 1. Report to Board of Directors annually number of times water conservation information was distributed to area residents or in public informational or educational meetings.

Goal 5.0 (b) Addressing Recharge Enhancement

Management Goal
5.(b) 1 Each year the District will cooperate with interested parties and appropriate agencies to disseminate information to landowners and the public on aquifer recharge by publishing, at least once a year, information about a public meeting concerning aquifer recharge or notifying the public of written materials available at the District office on the topic.

Performance Standard
5.(b)1 Number of newspaper announcements of public meeting or availability of materials at the District office including District Rules governing such projects.

Goal 5.0 (c) Addressing rainwater harvesting

Management Objective
5.(c) 1 The District will display rainwater harvesting manuals publicly at the district office and at least once annually provide notice in the District newsletter that manuals on rainwater harvesting is available to residents in the District office.

Performance Standard
5.(c)1 Report to the Board of Directors annually on the number of times notice was published in the District newsletter about the availability of Rainwater Harvesting manuals in the District office.

Management Objective
5.(c)2 Include information on rainwater harvesting in one public education presentation annually.

Performance Standards
5.(c)2 Report to Board of Directors annually the number of educational presentations that included rainwater harvesting information.

Goal 5.0 (d) Addressing Precipitation Enhancement

Management Objective
5.(d)1 Each year the District will cooperate with interested parties and appropriate agencies to disseminate information to landowners and the public on weather modification by publishing, at least once a year, information about a public meeting concerning aquifer recharge or notifying the

public of written materials available at the District office on the topic.

Performance Standard
5.(d)1 Number of newspaper announcements of public meeting or availability of materials at the District office.

Goal 5.0 (e) Addressing Brush Control

Management Objective
5.(e)1 Meet once annually with NRCS to discuss prioritizing brush control for EQIP funds or other federal conservation funding.

Performance Standards
5.(e)1 Report to Board of Directors annually on the number of meetings held with NRCS officials regarding priority conservation funding for brush control.

Goal 6.0 Addressing the Desired Future Conditions of the District Aquifers.

Management Objective
6.1 Desired Future conditions for the District have been adopted as of September 1, 2010 pursuant to the joint planning process set forth in Section 36.108 of the Texas Water Code. The District will review annually all well registration and permit records to assess whether the District is on target to implement the MAGs for District Aquifers received from the TWBD following adoption of Desired Future Conditions.

Performance Standard
6.1 The Districts' Annual report will include discussion of the District's permit and well registration totals and evaluate whether the District is on track to maintain the Desired Future Conditions estimates over the 50-year period.

Management Objective
6.2 The District will annually sample water levels in at least five monitor wells and will compare five-year water level averages based on these sample to the corresponding five-year increment of its Desired Future Conditions to track its progress in achieving Desired Future Conditions.

Performance Standard
6.2 The District will maintain a log of the annual water level samples taken each year and upon obtaining a record of water levels for five consecutive years and calculating the averages therefrom, the District will include a discussion of its comparison of water level averages to the corresponding five-year period of its Desired Future Condition levels to track progress in achieving Desired Future Conditions.

36.1071 (a) Management Goals Not Applicable to the District

Goal 1.0 Controlling and Preventing Subsidence
The rigid geologic framework of the region precludes significant subsidence from occurring. This goal is not applicable to the operation of the District.

Goal 2.0 Addressing Conjunctive Surface Water Management Issues

The amount of surface water use in Uvalde County is limited to domestic and livestock use and run-of-the river irrigations rights under the jurisdiction of the TCEQ. There are no local surface water entities distributing or regulating surface water use in the district with whom to meet and co-ordinate planning and effort.

Statement of Commitment by Uvalde County Underground Water Conservation District to Effectuation of the District Groundwater Management Plan.

The District will implement the provisions of this plan and/or future amendments and will utilize the provisions of this plan, or amended plan, as guidance for implementation of District goals, in promulgating District Rules and selecting, evaluating, and carrying our district programs, activities and hydrogeologic studies.

Appendix A

Estimated Historical Water Use And 2012 State Water Plan Datasets:

Uvalde County Underground Water Conservation District

by Stephen Allen
Texas Water Development Board
Groundwater Resources Division
Groundwater Technical Assistance Section
stephen.allen@twdb.texas.gov
(512) 463-7317
January 14, 2016

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 part 1 are:

1. Estimated Historical Water 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)

   reports 2-5 are from the 2012 Texas State Water Plan (SWP)

Part 2 of the 2-part package is the groundwater availability model (GAM) report. 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 2012 SWP data available as of 1/14/2016. Although it does not happen frequently, neither of these datasets are static so they are subject to change pending the availability of more accurate WUS data or an amendment to the 2012 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 2012 SWP dataset can be verified by contacting Sabrina Anderson (sabrina.anderson@twdb.texas.gov or 512-936-0886).

For additional questions regarding this data, please contact Stephen Allen (stephen.allen@twdb.texas.gov or 512-463-7317) or Rima Petrossian (rima.petrossian@twdb.texas.gov or 512-936-2420).

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

Groundwater and surface water historical use estimates are currently unavailable for calendar year 2014. TWDB staff anticipates the calculation and posting of these estimates at a later date.

UVALDE COUNTY

All values are in acre-fee/year

Year	Source	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
2013	GW	4,901	3	49	0	49,494	1,727	56,174
	SW	0	0	0	0	462	245	707
2012	GW	5,380	3	86	0	72,263	2,007	79,739
	SW	0	0	0	0	368	236	604
2011	GW	6,112	3	1,087	0	82,968	2,205	92,375
	SW	0	0	1,050	0	491	270	1,811
2010	GW	5,162	3	1,146	0	52,156	2,141	60,608
	SW	0	0	1,129	0	390	261	1,780
2009	GW	5,578	3	1,092	0	96,802	2,207	105,682
	SW	0	0	1,090	0	698	248	2,036
2008	GW	5,539	0	1,125	0	75,016	2,282	83,962
	SW	0	0	1,051	0	1,103	294	2,448
2007	GW	4,425	3	112	0	36,649	2,727	43,916
	SW	0	0	0	0	358	336	694
2006	GW	6,114	3	147	0	72,872	950	80,086
	SW	0	0	0	0	0	330	330
2005	GW	5,121	3	147	0	58,087	1,837	65,195
	SW	0	0	0	0	400	339	739
2004	GW	4,401	3	269	0	66,399	947	72,019
	SW	0	0	0	0	377	522	899
2003	GW	4,860	154	126	0	67,820	952	73,912
	SW	0	0	0	0	425	557	982
2002	GW	5,143	760	378	0	88,392	974	95,647
	SW	0	0	0	0	1,804	579	2,383
2001	GW	5,750	760	329	0	83,276	954	91,069
	SW	0	0	0	0	1,700	592	2,292
2000	GW	7,903	379	200	0	56,967	1,894	67,343
	SW	0	0	0	0	1,094	642	1,736

Projected Surface Water Supplies
TWDB 2012 State Water Plan Data

UVALDE COUNTY

All values are in acre-feet/year

RWPG	WUG	WUG Basin	Source Name	2010	2020	2030	2040	2050	2060
L	IRRIGATION	NUECES	NUECES RIVER COMBINED RUN-OF-RIVER IRRIGATION	720	720	720	720	720	720
L	LIVESTOCK	NUECES	LIVESTOCK LOCAL SUPPLY	642	642	642	642	642	642
	Sum of Projected Surface Water Supplies (acre-feet/year)			**1,362**	**1,362**	**1,362**	**1,362**	**1,362**	**1,362**

Projected Water Demands
TWDB 2012 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.

UVALDE COUNTY

All values are in acre-feet/year

RWPG	WUG	WUG Basin	2010	2020	2030	2040	2050	2060
L	SABINAL	NUECES	407	403	398	393	389	389
L	UVALDE	NUECES	6,087	6,124	6,144	6,148	6,150	6,178
L	LIVESTOCK	NUECES	1,284	1,284	1,284	1,284	1,284	1,284
L	IRRIGATION	NUECES	55,791	53,609	51,513	49,498	47,563	45,703
L	MINING	NUECES	313	345	364	383	401	418
L	MANUFACTURING	NUECES	432	455	473	490	505	538
L	COUNTY-OTHER	NUECES	1,572	1,867	2,110	2,305	2,425	2,532
	Sum of Projected Water Demands (acre-feet/year)		**65,886**	**64,087**	**62,286**	**60,501**	**58,717**	**57,042**

Projected Water Supply Needs
TWDB 2012 State Water Plan Data

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

UVALDE COUNTY

All values are in acre-feet/year

RWPG	WUG	WUG Basin	2010	2020	2030	2040	2050	2060
L	COUNTY-OTHER	NUECES	1,277	982	739	544	424	317
L	IRRIGATION	NUECES	14,680	16,862	18,958	20,973	22,908	24,768
L	LIVESTOCK	NUECES	0	0	0	0	0	0
L	MANUFACTURING	NUECES	943	920	902	885	870	837
L	MINING	NUECES	105	73	54	35	17	0
L	SABINAL	NUECES	-127	-123	-118	-113	-109	-109
L	UVALDE	NUECES	-3,172	-3,209	-3,229	-3,233	-3,235	-3,263
	Sum of Projected Water Supply Needs (acre-feet/year)		**-3,299**	**-3,332**	**-3,347**	**-3,346**	**-3,344**	**-3,372**

Projected Water Management Strategies
TWDB 2012 State Water Plan Data

UVALDE COUNTY

WUG, Basin (RWPG)

All values are in acre-feet/year

Water Management Strategy	Source Name [Origin]	2010	2020	2030	2040	2050	2060
COUNTY-OTHER, NUECES (L)							
MUNICIPAL WATER CONSERVATION	CONSERVATION [UVALDE]	0	0	0	33	73	137
SABINAL, NUECES (L)							
DROUGHT MANAGEMENT	DROUGHT MANAGEMENT [UVALDE]	20	0	0	0	0	0
EDWARDS TRANSFERS	EDWARDS-BFZ AQUIFER [UVALDE]	127	123	118	113	109	109
MUNICIPAL WATER CONSERVATION	CONSERVATION [UVALDE]	34	65	92	116	139	145
UVALDE, NUECES (L)							
DROUGHT MANAGEMENT	DROUGHT MANAGEMENT [UVALDE]	304	0	0	0	0	0
EDWARDS TRANSFERS	EDWARDS-BFZ AQUIFER [UVALDE]	3,172	3,209	3,229	3,233	3,235	3,263
MUNICIPAL WATER CONSERVATION	CONSERVATION [UVALDE]	521	1,017	1,471	1,882	2,269	2,652
Sum of Projected Water Management Strategies (acre-feet/year)		**4,178**	**4,414**	**4,910**	**5,377**	**5,825**	**6,306**

Appendix B

GAM Run 15-006: Uvalde County Underground Water Conservation District Management Plan

by Bernard Bahaya, E.I.T
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 936-0883
June 26, 2015

Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by Bernard Bahaya under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on June 26, 2015.

This page is intentionally blank

GAM RUN 15-006: UVALDE COUNTY UNDERGROUND WATER CONSERVATION DISTRICT MANAGEMENT PLAN

by Bernard Bahaya, E.I.T
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 936-0883
June 26, 2015

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. Information derived from groundwater availability models that shall be included in the groundwater management plan includes:

- the annual amount of recharge from precipitation to the groundwater resources within the district, if any;
- 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
- the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

This report—Part 2 of a two-part package of information from the TWDB to the Uvalde County Underground Water Conservation District—fulfills the requirements noted above. Part 1 of the two-part package is the Estimated Historical Water Use/State Water Plan data report. The District will receive this data report from the TWDB Groundwater Technical Assistance Section. Questions about the data report can be directed to Mr. Stephen Allen, stephen.allen@twdb.texas.gov, (512) 463-7317.

The groundwater management plan for the Uvalde County Underground Water Conservation District should be adopted by the district on or before July 5, 2016 and submitted to the executive administrator of the TWDB on or before August 4, 2016. The current management plan for the Uvalde Underground Water Conservation District expires on October 3, 2016.

This report discusses the methods, assumptions, and results from model runs using the groundwater availability models for the Edwards-Trinity (Plateau) and the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Kelley and others, 2004). Please note that the Edwards (Balcones Fault Zone) Aquifer occurs within the boundaries of the Uvalde County Underground Water Conservation District but is excluded from this report because the district does not have jurisdiction over that aquifer. This model run replaces the results of GAM Run 10-022 (Aschenbach, 2010). GAM Run 15-006 meets current standards set after the release of GAM Run 10-022. Tables 1, 2, and 3 summarize the groundwater availability model data required by statute, and figures 1, 2, and 3 show the area of the models from which the values in the tables were extracted. If after review of the figures, the Uvalde County Underground Water Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB at your earliest convenience.

The Trinity Aquifer underlies the Edwards (Balcones Fault Zone) Aquifer within the district boundaries. However, the underlying portion of the Trinity Aquifer in Uvalde County is not fully modeled or exclusively calibrated in any of our existing groundwater availability models. Information for the Trinity Aquifer underlying the Edwards (Balcones Fault Zone) Aquifer is being provided separately from the Groundwater Technical Assistance Section of the TWDB.

METHODS:

In accordance with the provisions of the Texas State Water Code, Section 36.1071, Subsection (h), the groundwater availability models for the Edwards-Trinity (Plateau) (Anaya and Jones, 2009), and the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Kelley and others, 2004) were run for this analysis. Uvalde County Underground Water Conservation District water budgets were extracted for the historical model period (1981 through 2000 for the Edward-Trinity (Plateau) Aquifer and 1980 through 1999 for the southern portion of the Carrizo-Wilcox Aquifer) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface water outflow, inflow to the district, outflow from the district, net inter-aquifer flow (upper), and net inter-aquifer flow (lower) for the portion of the aquifer located within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Edwards – Trinity (Plateau) Aquifer and Hill Country portion of the Trinity Aquifer

- Version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer was used. See Anaya and Jones (2009) for assumptions and limitations of this model.

- The Edwards-Trinity (Plateau) Aquifer model includes two layers representing the Edwards Group and associated limestone hydrostratigraphic units (Layer 1) and the undifferentiated Trinity Group hydrostratigraphic units (Layer 2). The water budget for the Hill Country portion of the Trinity Aquifer (Figure 1) was determined using Layer 2. An individual water budget for the district was determined for the Edwards-Trinity (Plateau) Aquifer (Figure 2; Layer 1 and Layer 2 collectively).

- The General-Head Boundary (GHB) package of MODFLOW was used to represent flow out of the study area and into the Edwards (Balcones Fault Zone) Aquifer or the deeper Trinity units. For simplicity, the GHB that corresponds to Layer 1 was used to represent the flow from the Edwards portion of the Edwards-Trinity (Plateau) Aquifer, across the Balcones Fault Zone (BFZ) and into the portion of the Edwards (BFZ) Aquifer within the Edwards Aquifer Authority (EAA) district. This flow is included in the management plan requirement for "estimated annual volume of flow out of the district within each aquifer in the district." The GHB in Layer 2 was used to represent the flow from the Trinity portion of the Edwards-Trinity (Plateau) Aquifer, across the Balcones Fault Zone and into an unmodeled area of the deeper Trinity Aquifer units. This flow is not specifically listed in the management plan requirement tables, but it is included in the text for reference.

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

Carrizo-Wilcox, Queen City, and Sparta Aquifers

- Version 2.01 of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers was used for this analysis. See Deeds and others (2003) and Kelley and others (2004) for assumptions and limitations of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers.

- This groundwater availability model includes eight layers, which represent the Sparta Aquifer (Layer 1), the Weches Confining Unit (Layer 2), the Queen City Aquifer (Layer 3), the Reklaw Confining Unit (Layer 4), the Carrizo Aquifer (Layer 5), the Upper Wilcox Aquifer, (Layer 6), the Middle Wilcox Aquifer (Layer 7), and the Lower Wilcox Aquifer (Layer 8).

- An overall water budget for the Uvalde Underground Water Conservation District was determined for the Carrizo-Wilcox Aquifer (Layers 5 through 8 collectively. The Sparta and Queen City aquifers are not present in Uvalde Underground Water Conservation District.

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the model results for the aquifers located within the district and averaged over the duration of the calibration and verification portion of the model run in the district, as shown in tables 1 and 2.

- 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.

- Surface water outflow—The total water discharging from the aquifer (outflow) to surface water features such as streams, reservoirs, and springs.

- Flow into and out of district—The lateral flow within the aquifer between the district and adjacent counties or between the district and the Edwards (Balcones Fault Zone) Aquifer managed by the Edwards Aquifer Authority.

- 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 or confining unit and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs. “Inflow” to an aquifer from an overlying or underlying aquifer will always equal the “Outflow” from the other aquifer.

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 HILL COUNTRY PORTION OF THE TRINITY AQUIFER THAT IS NEEDED FOR THE UVALDE COUNTY 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	Trinity Aquifer	6,404
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Trinity Aquifer	4,415
Estimated annual volume of flow into the district within each aquifer in the district	Trinity Aquifer	10,629
Estimated annual volume of flow out of the district within each aquifer in the district	Trinity Aquifer	10,131*
Estimated net annual volume of flow between each aquifer in the district	From Trinity Aquifer to Edwards (Balcones Fault Zone) Aquifer	Not Applicable**
	From Hill Country portion Trinity Aquifer to the Edwards-Trinity (Plateau) Aquifer	3,649

*Includes head dependent flow to Edwards (Balcones Fault Zone) Aquifer from Layer 2

**Not applicable because flow leaving the Trinity Aquifer to the Edwards (Balcones Fault Zone) Aquifer is considered flow leaving the district (from Uvalde County Underground Water Conservation District to The Edwards Aquifer Authority).

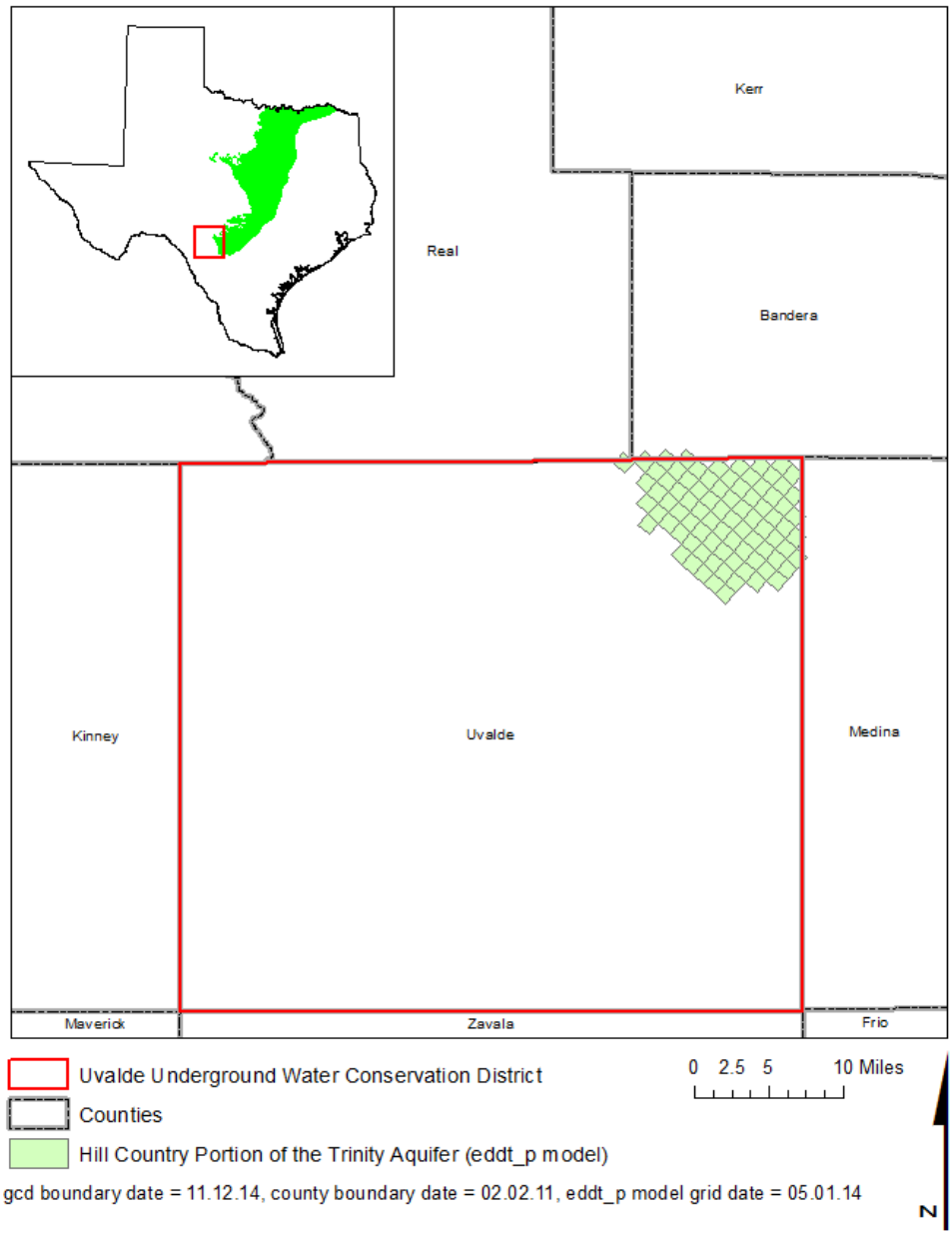


FIGURE 1 AREA OF THE GROUNDWATER AVAILABILITY MODEL THAT INCLUDES THE HILL COUNTRY PORTION OF THE TRINITY AQUIFER FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE TRINITY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 2 SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR THE UVALDE COUNTY 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	Edwards-Trinity (Plateau) Aquifer	8,436
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	10,346
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	20,903
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	24,570*
Estimated net annual volume of flow between each aquifer in the district	From the Hill Country portion of the Trinity Aquifer to the Edwards-Trinity (Plateau) Aquifer	3,649

*Includes flow to or from the Edwards (Balcones Fault Zone) Aquifer

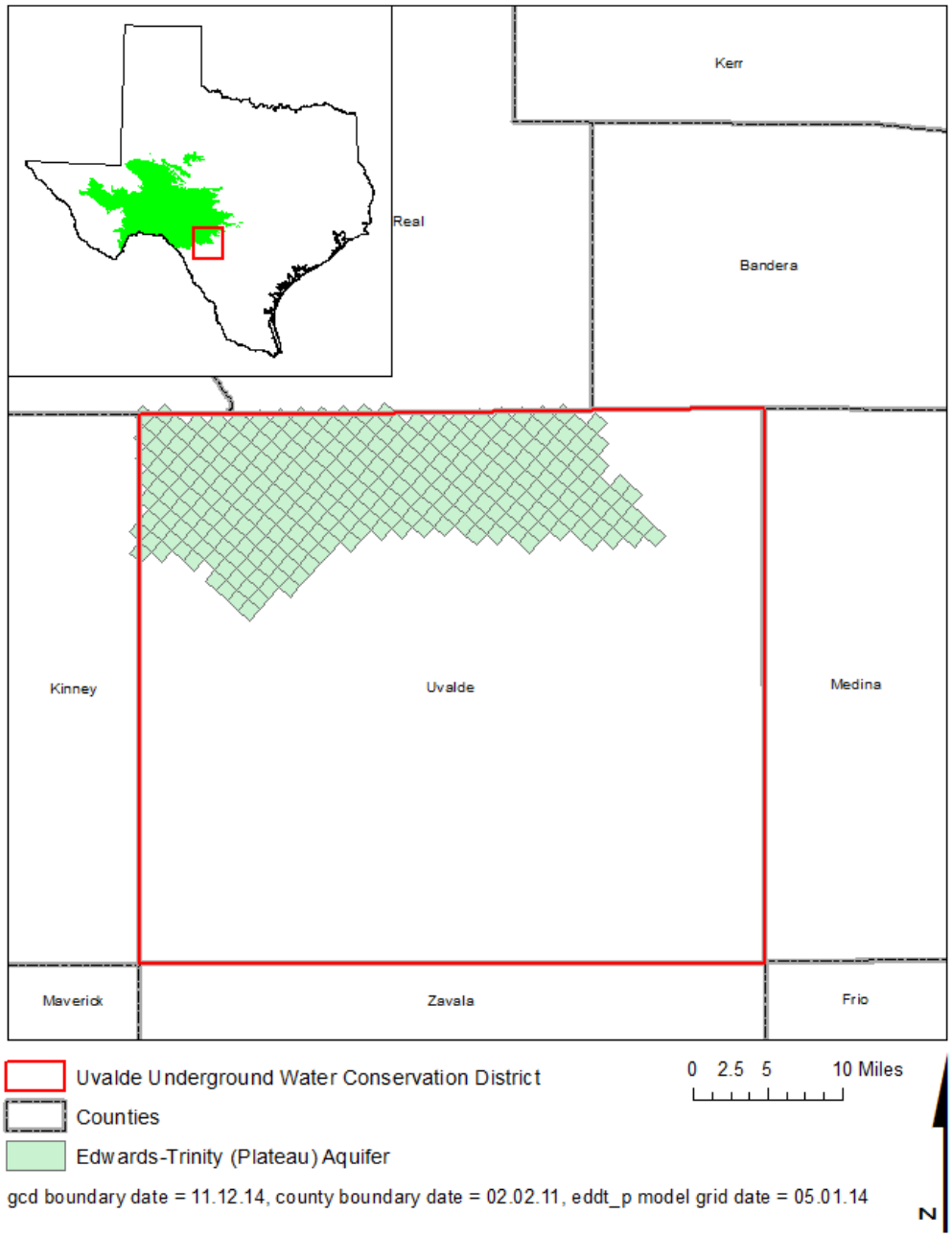


FIGURE 2 AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS- TRINITY (PLATEAU) AQUIFER FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE EDWARDS-TRINITY (PLATEAU) AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 3 SUMMARIZED INFORMATION FOR THE CARRIZO-WILCOX AQUIFER THAT IS NEEDED FOR THE UVALDE COUNTY 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	Carrizo-Wilcox Aquifer	3,003
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Carrizo-Wilcox Aquifer	29
Estimated annual volume of flow into the district within each aquifer in the district	Carrizo-Wilcox Aquifer	251*
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	9,074*
Estimated net annual volume of flow between each aquifer in the district	From Carrizo-Wilcox Aquifer to Underlying Units	not applicable **

*Due to resolution of delineation of outcrop boundary an additional 1,029 acre-feet of net flow may be contributed to these categories.

** Model assumes no-flow condition at the base of the Carriz0-Wilcox Aquifer.

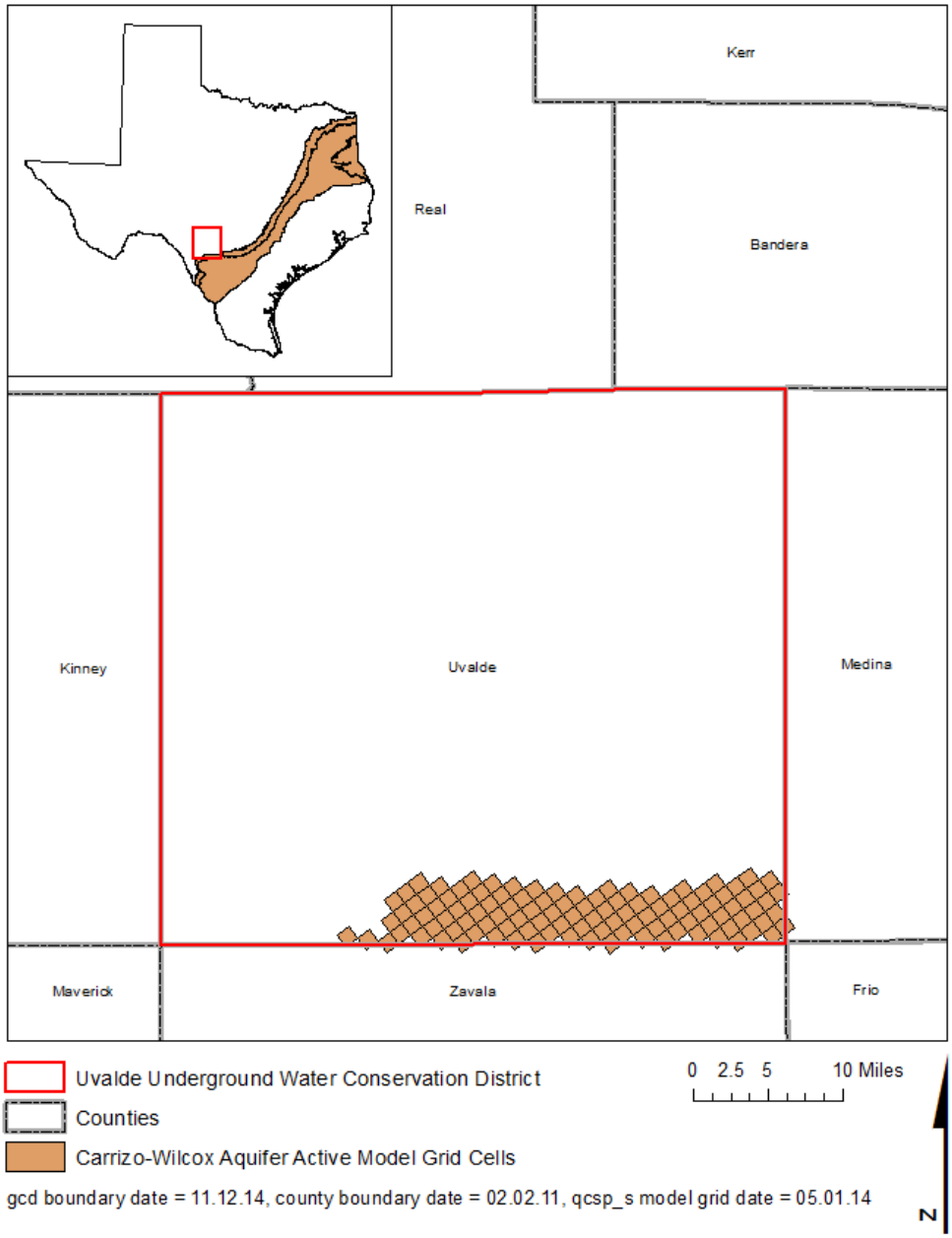


FIGURE 3 AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PART OF THE CARRIZO-WILCOX AQUIFER FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE CARRIZO-WILCOX AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

LIMITATIONS:

The groundwater model(s) used in completing this analysis is the best available scientific tool that can be used to meet the stated objective(s). 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 historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historic 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 historic 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. 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.

REFERENCES:

Anaya, R., and Jones, I., 2009, Groundwater Availability Model for the Edwards-Trinity (Plateau) and Pecos Valley Aquifers of Texas: Texas Water Development Board Report 373, 103 p., http://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R373/R373

Aschenbach, Eric, 2010, GAM Run 10-022: Texas Water Development Board, GAM Run 10-022 Report, 8 p., http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR10-22.pdf.

Deeds, N., Kelley, V., Fryar, D., Jones, T., Whallon, A.J., and Dean, K.E., 2003, Groundwater Availability Model for the Southern Carrizo-Wilcox Aquifer: Contract report to the Texas Water Development Board, 452 p., http://www.twdb.texas.gov/groundwater/models/gam/czwx_s/CZWX_S_Full_Report.pdf.

Harbaugh, A. W., 2009, Zonebudget Version 3.01, A computer program for computing subregional water budgets for MODFLOW ground-water flow models, U.S. Geological Survey Groundwater Software.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, The U.S. Geological Survey modular ground-water model-User guide to modularization concepts and the ground-water flow process: U.S. Geological Survey, Open-File Report 00-92.

Jones, Ian. C., Anaya, R. and Wade, S., 2009, Groundwater Availability Model for the Hill County Portion of the Aquifer System, Texas: Numerical Simulations through 1999- Model Report, 196 p., http://www.twdb.texas.gov/groundwater/models/gam/trnt_h/TRNT_H_2009_Update_Model_Report.pdf.

Kelley, V.A., Deeds, N.E., Fryar, D.G., and Nicot, J.P., 2004, Groundwater availability models for the Queen City and Sparta aquifers: Contract report to the Texas Water Development Board, 867 p., http://www.twdb.texas.gov/groundwater/models/gam/qcsp/QCSP_Model_Report.pdf.

National Research Council, 2007, Models in Environmental Regulatory Decision Making Committee on Models in the Regulatory Decision Process, National Academies Press, Washington D.C., 287 p., http://www.nap.edu/catalog.php?record_id=11972.

Texas Water Code, 2011, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf