JEFF DAVIS COUNTY UNDERGROUND WATER CONSERVATION DISTRICT

MANAGEMENT PLAN

2018-2023

Adopted October 23, 2018

DISTRICT MISSION

The Jeff Davis County Underground Water Conservation District will strive to develop, promote, and implement water conservation and management strategies to protect water resources for the benefit of the citizens, economy, and environment of the District.

TIME PERIOD FOR THIS PLAN

This plan becomes effective upon adoption by the District Board of Directors and approved by the Texas Water Development Board (TWDB) affirming the plan is administratively complete. This plan replaces the existing plan adopted by the District Board of Directors on November 5, 2013. This District management plan will remain in effect until December 02, 2023 or until a revised plan is approved by the TWDB, whichever is earlier.

STATEMENT OF GUIDING PRINCIPLES

The District recognizes that the groundwater resources of the county are of vital importance. The preservation of this most valuable resource can be managed in a prudent and cost-effective manner through education, regulations, and permitting. The greatest threat to prevent the District from achieving the stated mission is inappropriate management, based in part on the lack of understanding of local conditions. 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. The goals of this plan can best be achieved through guidance from the locally elected board members who have an understanding of local conditions as well as technical support from the Texas Water Development Board and qualified consulting agencies. This management plan is intended as a tool to focus the thoughts and actions of those given the responsibility for the execution of the District activities.

General Description of the District

History

The citizens of Jeff Davis County through an election created the District, November 2, 1993. The current Board of Directors are Johnny Wofford - Chairman, Jim Espy - Vice-Chairman, Jim Dyer- Secretary, Bud Coffey and Tres McElroy. The District Manager is Janet Adams. Jeff Davis County Underground Water Conservation District (JDCUWCD) covers all of Jeff Davis County. The agricultural community dominates the county’s economy. The agricultural income is derived mainly from cattle. Tourism and hunting also contribute to the income of the county.

Location and Extent

Jeff Davis County, having areal extent of 2,258 square miles, with 100 % being in the District is located in west Texas. The county is bounded on the east by Pecos County, on the north by Reeves County, on the west by Culberson County, and on the south by Brewster and Presidio Counties. Fort Davis, which is located on the east side of the county, is the county seat. Valentine, is the only other town in the county is located in the west portion of the county.

Topography

Jeff Davis County is located in the mountains of West Texas. The county has the highest average elevation in the state of Texas with one mile or higher altitudes. The county consists of peaks, canyons, and plateaus.

Groundwater Resources of Jeff Davis County

In the Jeff Davis County Underground Water Conservation District, the Texas Water Development Board lists several aquifers, which account for the known groundwater resources of the District. These include the Edwards-Trinity (Plateau), the West Texas Bolsons, of which there are several divisions, and the Igneous areas of the District. Due to the lack of scientific study, the aquifers are not well defined geographically. The TWDB also lists a small portion of the Cenozoic Pecos Alluvium Aquifer along the northeastern boundary of the District.

Not included in the table below are two very minor aquifers in Jeff Davis County.

1. Capitan Reef
   12,100 acres - Areal Extent
   341 estimated acre feet of recharge annually

2. Rustler Aquifer
   101,881 acres – Areal Extent
   780 estimated acre feet of recharge

Additional Amount of Natural/Artificial Recharge That Would Feasibly Be Achieved

The additional amount of natural or artificial recharge that would be realized from implementation of feasible weather modification would be an 8% increase in rainfall. This would result in a 703.5 acre feet increase in recharge. This data was obtained from the direct gathering of evidence of the High Plains Water District of their weather modification program.

Water exported out of Jeff Davis County Underground Conservation District is as follows from Jeff Davis County:

Year	acre-feet /year
2017	948
2016	985
2015	983
2014	907
2013	1,078
2012	1,336
2011	866
2010	796
2009	839
2008	1,070
2007	992
2006	939
2005	983
2004	1,182
2003	1,232
2002	1,282
2001	1,184
2000	1,225
1999	1,073
1998	1,154

This data was obtained from meters read by JDCUWCD.

Groundwater Availability Modeling Estimates

Please refer to Appendix B-- GAM RUN 12-023 and Appendix C--GAM RUN 16-030 MAG

Estimated Historical Groundwater use in Jeff Davis County

Please refer to Appendix A.

Projected Surface Water Supplies

Please refer to Appendix A.

Projected Water Demands

Please refer to Appendix A.

Projected Water Supply Needs

There are no projected water supply needs identified in the most recent state water plan

Please refer to Appendix A.

Projected Water Management Strategies

There are two water management strategies in the district: one for the Town of Valentine to drill a well in the West Texas Bolsons Aquifer, and another for the Fort Davis WSC to drill a well in the Igneous Aquifer.

Please refer to Appendix A.

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 the resource user groups, public and private. In consideration of the economic and cultural activities occurring within the District, the District will identify and engage in such activities and practices, that if implemented would result a reduction of groundwater use. An observation network shall be established and maintained in order to monitor changing storage conditions of groundwater supplies within the District. The District will make regular assessments of water supply and groundwater storage conditions and will report those conditions to the Board and to the public. The district will undertake, as necessary and co-operate with investigations of the groundwater resources within the District and will make the results of investigations available to the public upon adoption of the Board.

The District has rules to regulate groundwater withdrawals by means of production limits. The District may deny a well construction permit or limit groundwater withdrawals in accordance with the guidelines stated in the rules of the District. In making a determination to deny a permit or limit groundwater withdrawals, the District will consider the public benefit against individual hardship after considering all appropriate testimony.

The relevant factors to be considered in making a determination to deny a permit or limit groundwater withdrawals will include:
1) The purpose of the rules of the District
2) The equitable distribution of the resources
3) The economic hardship resulting from grant or denial of a permit or the terms prescribed by the permit

In pursuit of the District's mission of protecting the resource, the District may require reduction of groundwater withdrawals to amounts, which will not cause harm to the aquifer. To achieve this purpose, the District may, at the Board's discretion amend or revoke any permit after notice and hearing. The determination to seek the amendment or revocation of a permit by the District will be based on aquifer conditions observed by the District. The District will enforce the terms and conditions of permits and the rules of the District by enjoining the permit holder in a court of competent jurisdiction as provide for in TWC 36.102.

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 all District activities. All 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 will adopt rules relating to the permitting of wells and the production of groundwater. The rules adopted by the District shall be pursuant to TWC 36 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.

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

The District will seek the cooperation in the implementation of the plan and 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 water management entity.

The methodology that the District will use to trace 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 (during last monthly Board of Directors meeting each fiscal year, beginning December 31, 2000). The report will include the number of instances each activity was engaged in during the year, referenced to the expenditure of staff time and budget so that the effectiveness and efficiency of each activity may be evaluated.

The annual report will be maintained on file at the District office.

GOALS, MANAGEMENT OBJECTIVES
And PERFORMANCE STANDARDS

Goal
1.0 Providing the Most Efficient Use of Groundwater.

Management Objective
1.1 Each year, require meters to be installed on all new production wells.

Performance Standard
1.1a - Each year, provide a report to the Board of Directors indicating the number of meters installed on new wells in the District and the location and ownership.

Management Objective
1.2 All current existing rules and regulations will be reviewed and amended to address the needs of the District every three years.

Performance Standard
1.2a - Each year, report to the Board of Directors the number of changes required to keep District rules updated to District needs.

Goal
2.0 Controlling and Preventing Waste of Groundwater.

Management Objective
2.1 Each year, investigate all reports of wasteful practices within the District.

Performance Standards
2.1a - Each year, locate all complaint sites on a District map.

2.1b - Each year, provide a report to the Board of Directors indicating the number of complaint sites.

Management Objective
2.2 Each year, register all new wells drilled in the District.

Performance Standards
2.2a - District will maintain files including information on the drilling and completion of all new wells in the District.

2.2b - Annually report to the Board of Directors on the number of new wells registered during the year.

Goal
3.0 Implement management strategies that will address drought conditions.

Management Objective
3.1 - The District will monitor the Palmer Drought Severity Index (PDSI) by Texas Climatic Divisions and https://waterdatafortexas.org//drought. If PDSI indicates that the District will experience severe drought conditions, the District will notify all public water suppliers within the District.

Performance Standard
3.1a - The District staff will monitor the PDSI and report the number of times the PDSI is less than 1 (mild drought) to the District Board on a quarterly basis.

Goal
4.0 Implement management strategies that will promote water conservation.

Management Objective
4.1 Disperse educational information yearly regarding the current conservation practices for efficient use of water resources.

Performance Standard
4.1a - Each year, report to the Board of Directors the number of water conservation literature packets handed out.

Goal
5.0 Rainwater Harvesting, Recharge Enhancement, Precipitation Enhancement, and Brush Control where appropriate.

Management Objective: Rainwater Harvesting
5.1 Provide demonstrations on the rainwater harvesting system installed at District office.

Performance Standards
5.1a - District staff will provide information about rainwater harvesting through demonstrations of the system installed at District office

5.1b – Each year, report to the Board of Directors the number of demonstrations given on rainwater harvesting.

Recharge Enhancement
5.2 Not Applicable – not cost effective

Precipitation Enhancement
5.3 Not Applicable – not cost effective

Brush Control
5.4 Not Applicable – not cost effective

Goal
6.0 Addressing the Desired Future Conditions.

Management Objective
6.1 Conduct water level measurements at least annually on observation wells within the District

Performance Standards
6.1a Annually evaluate water level trends to insure that the aquifers conditions comply with the desired future conditions of the District

SB - 1 MANAGEMENT GOALS DETERMINED NOT-APPLICABLE

Goal
1.0 Control and prevention of subsidence.

The rigid geologic framework of the region precludes significant subsidence from occurring.

Goal
2.0 Addressing natural resource issues that impact the use and availability of groundwater or that are impacted by the use of groundwater

The District has no documented occurrences of endangered or threatened species dependent upon groundwater resources.

Goal
3.0 Addressing conjunctive surface water management issues.

There is no surface water within the District.

SUMMARY DEFINITIONS

"Board" - the Board of Directors of the Jeff Davis County Underground Water Conservation District.

"District" - the Jeff Davis County Underground Water Conservation District.

"TWDB" - Texas Water Development Board.

"Waste" - as defined by Chapter 36 of the Texas Water Code means any one or more of the following:

1. Withdrawal of groundwater from a groundwater reservoir at a rate and in a amount that causes or threatens to cause intrusion into the reservoir of water unsuitable for agricultural, gardening, domestic, or stock raising purposes;

2. The flowing or producing of wells from a groundwater reservoir if the water produced is not used for a beneficial purpose;

3. Escape of groundwater from a groundwater reservoir to any other reservoir or geologic strata that does not contain groundwater;

4. Pollution or harmful alteration of groundwater in a groundwater reservoir by salt water or by other deleterious matter admitted from another stratum or from the surface of the ground;

5. Willfully or negligently causing, suffering, or allowing groundwater to escape into a river, creek, natural watercourse, depression, lake, reservoir, drain, sewer, street, highway, road, or road ditch, or onto any land other than that of the owner of the well unless such discharge is authorized by permit, rule, or order issued by the commission under Chapter 26 of the Texas Water Code;

6. Groundwater pumped for irrigation that escapes as irrigation tail water onto land other than that of the owner of the well unless permission has been granted by the occupant of the land receiving the discharge.

7. For water produced from an artesian well "waste" has the meaning assigned by Section 11.205 of the Texas Water Code.

Appendix

A

Estimated Historical Water Use And 2017 State Water Plan Datasets:

Jeff Davis County Underground Water Conservation District

by Stephen Allen
Texas Water Development Board
Groundwater Division
Groundwater Technical Assistance Section
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(512) 463-7317
July 5, 2018

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 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)
   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 7/5/2018. 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).

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.

JEFF DAVIS COUNTY

All values are in acre-feet

Year	Source	Municipal	Manufacturing	Mining	Steam Electric	Irrigation	Livestock	Total
2016	GW	1,123	0	0	0	620	298	2,041
	SW	0	0	0	0	85	16	101
2015	GW	1,200	0	0	0	667	293	2,160
	SW	0	0	0	0	73	15	88
2014	GW	1,254	0	0	0	732	287	2,273
	SW	0	0	0	0	45	15	60
2013	GW	1,252	0	0	0	662	316	2,230
	SW	0	0	0	0	76	17	93
2012	GW	1,205	0	0	0	1,180	394	2,779
	SW	0	0	0	0	45	21	66
2011	GW	1,149	0	0	0	250	446	1,845
	SW	0	0	0	0	50	24	74
2010	GW	600	0	0	0	233	444	1,277
	SW	0	0	0	0	50	23	73
2009	GW	620	0	0	0	1,655	422	2,697
	SW	0	0	0	0	45	22	67
2008	GW	545	0	0	0	2,102	470	3,117
	SW	5	0	0	0	0	25	30
2007	GW	493	0	0	0	2,113	375	2,981
	SW	5	0	0	0	95	20	120
2006	GW	552	0	0	0	3,383	359	4,294
	SW	0	0	0	0	55	19	74
2005	GW	526	0	0	0	3,370	375	4,271
	SW	1	0	0	0	68	20	89
2004	GW	448	0	0	0	3,438	377	4,263
	SW	1	0	0	0	0	20	21
2003	GW	508	0	0	0	2,725	361	3,594
	SW	0	0	0	0	45	19	64
2002	GW	471	0	0	0	1,924	489	2,884
	SW	0	0	0	0	0	26	26
2001	GW	511	0	0	0	224	514	1,249
	SW	17	0	0	0	0	27	44

Projected Surface Water Supplies TWDB
2017 State Water Plan Data

JEFF DAVIS COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	Source Name	2020	2030	2040	2050	2060	2070
E	IRRIGATION, JEFF DAVIS	RIO GRANDE	RIO GRANDE OTHER LOCAL SUPPLY	50	50	50	50	50	50
E	LIVESTOCK, JEFF DAVIS	RIO GRANDE	RIO GRANDE LIVESTOCK LOCAL SUPPLY	25	25	25	25	25	25
	Sum of Projected Surface Water Supplies (acre-feet)			**75**	**75**	**75**	**75**	**75**	**75**

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.

JEFF DAVIS COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
E	COUNTY-OTHER, JEFF DAVIS	RIO GRANDE	168	163	158	156	155	155
E	FORT DAVIS	RIO GRANDE	297	292	288	286	285	285
E	IRRIGATION, JEFF DAVIS	RIO GRANDE	2,560	2,547	2,534	2,521	2,504	2,490
E	LIVESTOCK, JEFF DAVIS	RIO GRANDE	495	495	495	495	495	495
	Sum of Projected Water Demands (acre-feet)		**3,520**	**3,497**	**3,475**	**3,458**	**3,439**	**3,425**

Projected Water Supply Needs TWDB 2017
State Water Plan Data

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

JEFF DAVIS COUNTY

All values are in acre-feet

RWPG	WUG	WUG Basin	2020	2030	2040	2050	2060	2070
E	COUNTY-OTHER, JEFF DAVIS	RIO GRANDE	504	509	514	516	517	517
E	FORT DAVIS	RIO GRANDE	46	51	55	57	58	58
E	IRRIGATION, JEFF DAVIS	RIO GRANDE	797	810	823	836	853	867
E	LIVESTOCK, JEFF DAVIS	RIO GRANDE	0	0	0	0	0	0
	Sum of Projected Water Supply Needs (acre-feet)		**0**	**0**	**0**	**0**	**0**	**0**

Projected Water Management Strategies TWDB 2017
State Water Plan Data

JEFF DAVIS COUNTY

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

Water Management Strategy	Source Name [Origin]	2020	2030	2040	2050	2060	2070
COUNTY-OTHER, JEFF DAVIS, RIO GRANDE (E)							
TOWN OF VALENTINE - ADDITIONAL GROUNDWATER WELL	WEST TEXAS BOLSONS AQUIFER [JEFF DAVIS]	65	65	65	65	65	65
		65	**65**	**65**	**65**	**65**	**65**
FORT DAVIS, RIO GRANDE (E)							
FORT DAVIS WSC - ADDITIONAL GROUNDWATER WELL	IGNEOUS AQUIFER [JEFF DAVIS]	274	274	274	274	274	274
FORT DAVIS WSC - ADDITIONAL TRANSMISSION LINE	IGNEOUS AQUIFER [JEFF DAVIS]	114	114	114	114	114	114
		388	**388**	**388**	**388**	**388**	**388**
Sum of Projected Water Management Strategies (acre-feet)		**453**	**453**	**453**	**453**	**453**	**453**

Appendix

B

GAM RUN 12-023: JEFF DAVIS COUNTY UNDERGROUND WATER CONSERVATION DISTRICT MANAGEMENT PLAN

by Marius Jigmond
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 463-8499
August 10, 2012

CyntMa K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by Marius Jigmond under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on August 10, 2012.

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GAM RUN 12-023: JEFF DAVIS COUNTY UNDERGROUND WATER CONSERVATION DISTRICT MANAGEMENT PLAN

by Marius Jigmond
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 463-8499
August 10, 2012

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h), 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.

The purpose of this report is to provide Part 2 of a two-part package of information to Jeff Davis County Underground Water Conservation District for its groundwater management plan. The groundwater management plan for the Jeff Davis County Underground Water Conservation District is due for approval by the executive administrator of the TWDB before December 16, 2013.

This report discusses the methods, assumptions, and results from model runs using the groundwater availability models of the Edwards-Trinity (Plateau) and Pecos Valley aquifers, the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) aquifers, and the West Texas Bolsons (Red Light Draw,

Green River Valley, and Eagle Flat) Aquifer. Tables 1 through 4 summarize the groundwater availability model data required by the statute, and figures 1 through 3 show the area of each model from which the values in the respective tables were extracted. This model run replaces the results of GAM Run 08-29 (Ridgeway, 2008). GAM Run 12-023 meets current standards set after the release of GAM Run 08-29 and it is based on the most current groundwater district boundaries and water budget extraction methods. If after review of the figures, the Jeff Davis County Underground Water Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB immediately.

METHODS:

Groundwater availability models of the Edwards-Trinity (Plateau) and Pecos Valley aquifers (1981 – 2000), the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) aquifers (1980 – 2000), and the West Texas Bolsons (Red Light Draw, Green River Valley, and Eagle Flat) Aquifer (Steady state) were run for this analysis (Anaya and Jones, 2009, Harbaugh, 1996, Harbaugh and others, 2000). Water budgets for each year of the transient[1] model period were extracted (Harbaugh, 1990), as applicable, and 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 portions of the aquifers located within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Edwards-Trinity (Plateau) and Pecos Valley Aquifers

- Version 1.01 of the groundwater availability model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers was used for this analysis. See Anaya and Jones (2009) for assumptions and limitations of the model.
- The model has two layers which represent the Edwards portions of the Edwards-Trinity (Plateau) Aquifer and Pecos Valley Aquifer in layer one, and Trinity portions of the Edwards-Trinity (Plateau) Aquifer in layer two. Water budgets for the district have been determined separately for the Edwards-Trinity (Plateau) Aquifer and Pecos Valley Aquifer.

[1] The groundwater availability model of the West Texas Bolsons (Red Light, Green River, and Eagle Flat) Aquifer does not contain a transient simulation due to lack of data when the model was built. The steady-state simulation was used to extract results.

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) is 143 feet for the transient calibration period. This represents 6 percent of the range of measured water levels (Anaya and Jones, 2009).

Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) Aquifers

- Version 1.01 of the groundwater availability model of the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) aquifers was used. See Beach and others (2004) for assumptions and limitations of the groundwater availability model.

- The model includes three layers representing the West Texas Bolsons Aquifer (layer 1), Igneous Aquifer (layer 2), and Cretaceous and Permian units (layer 3) (Beach and others, 2004, Oliver, 2009).

- Of the three layers, individual water budgets for the district were determined for the West Texas Bolsons Aquifer and Igneous Aquifer (layers 1 and 2).

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) in the groundwater availability model is 35 feet for the West Texas Bolsons Aquifer, and 35 feet for the Igneous Aquifer for the transient calibration period. These root mean square errors represent four and three percent, respectively, of the range of measured water levels (Beach and others, 2004).

West Texas Bolsons (Red Light Draw, Green River Valley, and Eagle Flat) Aquifer

- Version 1.01 of the groundwater availability model of the West Texas Bolsons (Red Light Draw, Green River Valley, and Eagle Flat) aquifer was used. See Beach and others (2008) for assumptions and limitations of the groundwater availability model.

- The model includes three layers representing the West Texas Bolsons Aquifer (layer 1), Cretaceous and Permian units (layer 2), and Cretaceous and Paleozoic units (layer 3).

- Of the three layers, individual water budgets for the district were determined for the West Texas Bolsons Aquifer (layer 1).

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the groundwater availability model is 56 feet for the West Texas Bolsons Aquifer for the steady-state calibration period. The mean absolute error represents seven percent of the range of measured water levels (Beach and others, 2008).

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 runs in the district, as shown in tables 1 through 4. The components of the modified budget include:

- 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 drains (springs).

- Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.

- Flow between aquifers—the flow between aquifers or confining units within the district. 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.

The information needed for the District's management plan is summarized in tables 1 through 4. 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 district or county boundaries, 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 (see figures 1 through 3).

TABLE 1. SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR JEFF DAVIS COUNTY UNDERGROUND WATER 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	14,860
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	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	5,902
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	20,070
Estimated net annual volume of flow between each aquifer in the district[2]	From Edwards-Trinity (Plateau) Aquifer into Pecos Valley Aquifer	1,749
	From Edwards-Trinity (Plateau) into other formations	21

[2] The total estimated net annual volume of flow from Edwards-Trinity (Plateau) to Pecos Valley Aquifer and other formations is 1,770 acre-feet per year.

TABLE 2. SUMMARIZED INFORMATION FOR THE PECOS VALLEY AQUIFER THAT IS NEEDED FOR JEFF DAVIS COUNTY UNDERGROUND WATER 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*	*Results*
Estimated annual amount of recharge from precipitation to the district	Pecos Valley Aquifer	361
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Pecos Valley Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Pecos Valley Aquifer	0
Estimated annual volume of flow out of the district within each aquifer in the district	Pecos Valley Aquifer	2,780
Estimated net annual volume of flow between each aquifer in the district	From Edwards-Trinity (Plateau) Aquifer into Pecos Valley Aquifer	1,749

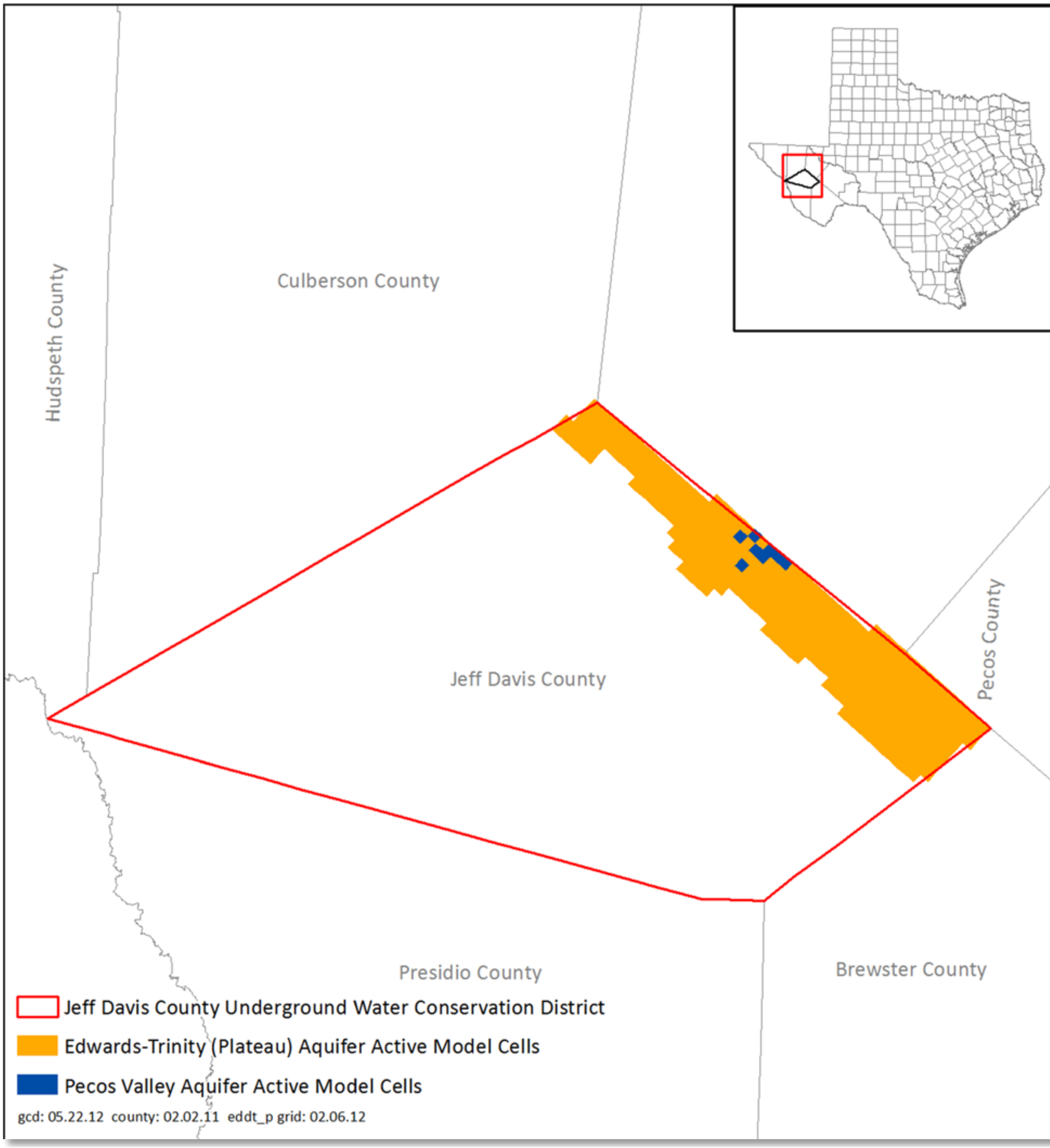

FIGURE 1. AREA OF THE GROUNDWATER AVAILABILITY MODEL OF THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFERS FROM WHICH THE INFORMATION IN TABLES 1 AND 2 WAS EXTRACTED.

TABLE 3. SUMMARIZED INFORMATION FOR THE IGNEOUS AQUIFER THAT IS NEEDED FOR JEFF DAVIS COUNTY UNDERGROUND WATER 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*	*Results*
Estimated annual amount of recharge from precipitation to the district	Igneous Aquifer	26,043[3]
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Igneous Aquifer	2,566
Estimated annual volume of flow into the district within each aquifer in the district	Igneous Aquifer	611
Estimated annual volume of flow out of the district within each aquifer in the district	Igneous Aquifer	4,322
Estimated net annual volume of flow between each aquifer in the district[4]	From Igneous Aquifer into overlying West Texas Bolsons Aquifer	1,726
	From Igneous Aquifer into underlying Cretaceous and Permian units	14,342

[3] Recharge applied with the recharge package to the Igneous Aquifer is both direct precipitation recharge and alluvial fan/stream bed recharge.

[4] The total estimated net annual volume of flow from Igneous Aquifer to West Texas Bolsons Aquifer and other formations is 16,068 acre-feet per year.

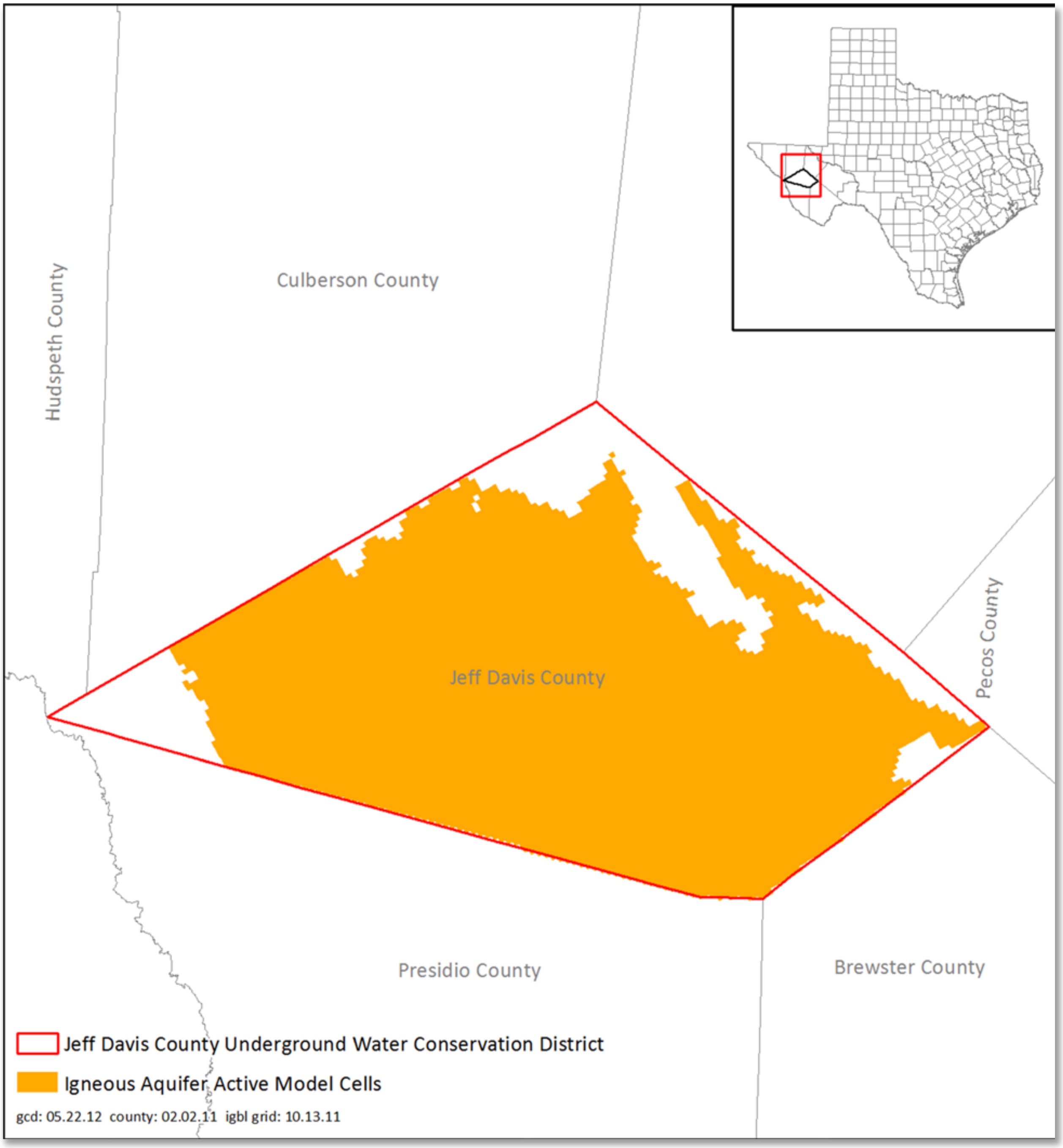

FIGURE 2. AREA OF THE GROUNDWATER AVAILABILITY MODEL OF THE IGNEOUS AND WEST TEXAS BOLSONS AQUIFERS FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED.

TABLE 4. SUMMARIZED INFORMATION FOR THE WEST TEXAS BOLSONS AQUIFER THAT IS NEEDED FOR JEFF DAVIS COUNTY UNDERGROUND WATER 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*	*Results*
Estimated annual amount of recharge from precipitation to the district	West Texas Bolsons Aquifer	153[5]
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	West Texas Bolsons Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	West Texas Bolsons Aquifer	4,188
Estimated annual volume of flow out of the district within each aquifer in the district	West Texas Bolsons Aquifer	7,422
Estimated net annual volume of flow between each aquifer in the district[6]	From Igneous Aquifer into overlying West Texas Bolsons Aquifer	1,726
	From Cretaceous and Permian units into overlying West Texas Bolsons Aquifer	11

[5] It is assumed that precipitation recharge directly to the West Texas Bolsons Aquifer is zero. The recharge package suggests, on average, 153 acre-feet per year from alluvial fan/stream bed infiltration enters the aquifer in the district.

[6] The total estimated net annual volume of flow from Igneous Aquifer and Cretaceous and Permian units to West Texas Bolsons Aquifer is 1,737 acre-feet per year.

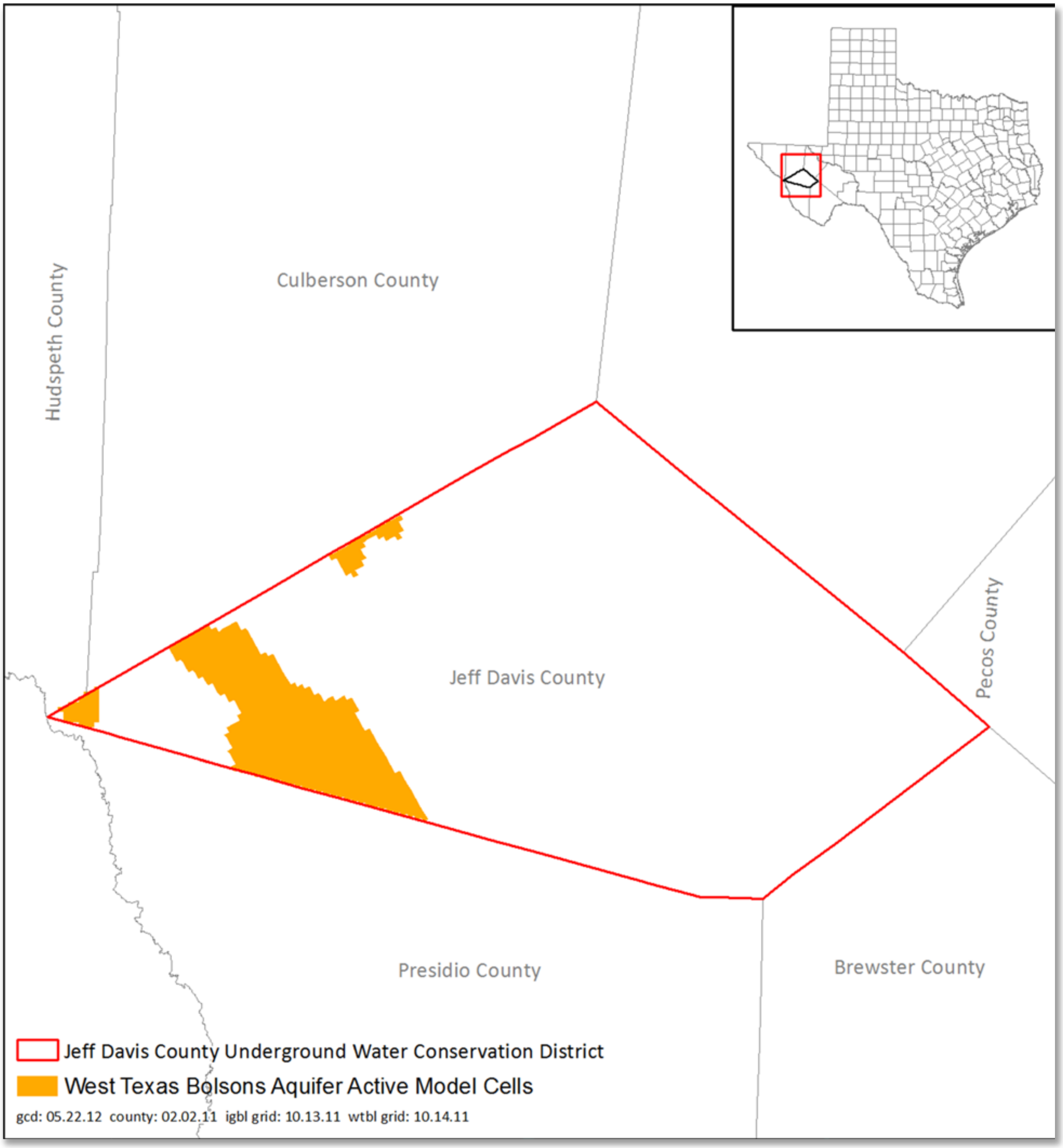

FIGURE 3. AREA OF THE GROUNDWATER AVAILABILITY MODEL OF THE IGNEOUS AND WEST TEXAS BOLSONS AQUIFERS AND GROUNDWATER AVAILABILITY MODEL OF THE WEST TEXAS BOLSONS AQUIFER FROM WHICH THE INFORMATION IN TABLE 4 WAS EXTRACTED.

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 streamflow are specific to a particular historic 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 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.

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Appendix

C

GAM RUN 16-030 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 4

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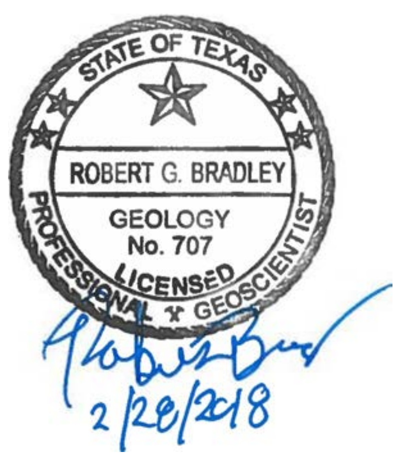
February 28, 2018



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GAM Run 16-030 MAG: Modeled Available Groundwater for the Aquifers in Groundwater Management Area 4

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(512) 463-5808
February 28, 2018

EXECUTIVE SUMMARY:

The modeled available groundwater for the relevant aquifers of Groundwater Management Area 4—the Bone Spring-Victorio Peak, Capitan Reef Complex, Edwards-Trinity (Plateau), Igneous, Marathon, and West Texas Bolsons aquifers—are summarized by decade for use in the regional water planning process (Tables 2, 4, 6, 8, 10, and 12) and for the groundwater conservation districts (Tables 1, 3, 5, 7, 9, and 11). The modeled available groundwater estimates are 101,400 acre-feet per year in the Bone Spring-Victorio Peak Aquifer, 8,163 acre-feet per year in the Capitan Reef Complex Aquifer, 1,394 acre-feet per year in the Edwards-Trinity (Plateau) Aquifer, range from 11,333 to 11,329 acre-feet per year in the Igneous Aquifer, 7,327 acre-feet per year in the Marathon Aquifer, and range from 58,577 to 57,881 acre-feet per year in the West Texas Bolsons Aquifer (Salt Basin and Presidio and Redford Bolsons combined). The modeled available groundwater estimates were extracted from results of model runs using the following groundwater availability models and alternative models: Bone Spring-Victorio Peak, Eastern Arm of the Capitan Reef Complex, Edwards-Trinity (Plateau), Igneous and West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat), and West Texas Bolsons (Presidio and Redford) aquifers. Analytical methods were used to calculate the modeled available groundwater for the Capitan Reef Complex Aquifer in Culberson County and for the Marathon Aquifer. The explanatory report and other materials submitted to the Texas Water Development Board (TWDB) were determined to be administratively complete on October 9, 2017.

Groundwater Management Area 4 responded to a request for clarifications by the TWDB in December 2017 (see the “Description of Request” section below for details).

REQUESTOR:

Ms. Janet Adams, Chair of Groundwater Management Area 4.

DESCRIPTION OF REQUEST:

In a letter dated September 26, 2017, Ms. Janet Adams provided the TWDB with the desired future conditions of the relevant aquifers in Groundwater Management Area 4. The desired future conditions, adopted September 20, 2017 by the groundwater conservation districts within Groundwater Management Area 4, are reproduced below:

Brewster County GCD [Groundwater Conservation District]: for the period from 2010-2060

- 3 feet drawdown for the Edwards-Trinity (Plateau) Aquifer.
- 10 feet drawdown for the Igneous Aquifer.
- 0-foot drawdown for the Marathon Aquifer.
- 0-foot drawdown for the Capitan Reef Complex Aquifer.

Culberson County GCD [Groundwater Conservation District]: for the period from 2010-2060

- 50 feet drawdown for the Capitan Reef Complex Aquifer.
- 78 feet drawdown for the [Salt Basin portion of the] West Texas Bolsons Aquifer.
- 66 feet drawdown for the Igneous Aquifer.

Hudspeth County UWCD [Underground Water Conservation District] No.1

- 0-foot drawdown for the period from 2010 until 2060 for the Bone Spring-Victorio Peak Aquifer, averaged across the portion of the aquifer within the boundaries of the District.

Jeff Davis County UWCD [Underground Water Conservation District]: for the period from 2010-2060

- 20 feet drawdown for the Igneous Aquifer.
- 72 feet drawdown for the [Salt Basin portion of the] West Texas Bolsons Aquifer.

Presidio County UWCD [Underground Water Conservation District]: for the period from 2010-2060

- 14 feet drawdown for the Igneous Aquifer.
- 72 feet drawdown for the [Salt Basin portion of the] West Texas Bolsons Aquifer.
- 72 feet drawdown for the Presidio-Redford Bolson [portion of the West Texas Bolsons].

In response to requests for clarifications from the TWDB on December 5, 2017, December 8, 2017, and February 5, 2018 the Groundwater Management Area 4 Chair, Ms. Janet Adams, indicated the following preferences for calculating modeled available groundwater volumes in Groundwater Management Area 4:

- For the Bone Spring-Victorio Peak Aquifer (Hudspeth County), the TWDB will use the results reported in GAM Run 10-061 and the assumptions described in GAM Task 10-006;
- For the Capitan Reef Complex Aquifer (Brewster and Culberson counties), the TWDB will use the Capitan Reef Complex Aquifer (Eastern Arm) groundwater availability model for Brewster County and the analytical approach (AA 09-08) for Culberson County. For Brewster County we will use 2005 as the baseline year and for Culberson County we will use the assumptions described in AA 09-08. The TWDB will assume the desired future condition in Brewster County is met if the average simulated drawdown value is within 3 feet.
- For the Edwards-Trinity (Plateau) Aquifer (Brewster County), the TWDB will use the single layer groundwater flow model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers, with 2005 as the baseline year and the assumptions described in GR 10-048.
- For the Igneous Aquifer and Salt Basin Portion of the West Texas Bolsons Aquifer (Brewster, Culberson, Jeff Davis, and Presidio counties), the TWDB will use the Igneous and West Texas Bolsons aquifers groundwater availability model, with 2000 as the baseline year and the assumptions described in report GR 10-037 MAG.
- For Presidio and Redford Bolsons portion of the West Texas Bolsons Aquifer, the TWDB will use the West Texas Bolsons Aquifer (Presidio and Redford Bolsons) groundwater availability model, with 2007 as the baseline year.
- The Red Light Draw, Green River Valley, and Eagle Flat portions of the West Texas Bolsons Aquifer are considered non-relevant for the purposes of joint planning because there are no groundwater conservation districts with jurisdiction over this portion of the minor aquifer.

METHODS:

The desired future conditions for the Bone Spring-Victorio Peak, Capitan Reef Complex (Culberson County only), Marathon, Igneous, Edwards-Trinity (Plateau), and West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) aquifers are identical to the ones adopted in 2011, and the applicable groundwater availability models and

analytical methodology to calculate modeled available groundwater are unchanged. Therefore, the modeled available groundwater volumes presented for those aquifers are the same as those shown in the previous analytical assessments and model runs—GAM Task 10-061 (Oliver, 2011c), AA 09-08 (Wuerch and Davidson, 2010), AA 09-09
(Thorkildsen and Backhouse, 2010), GAM Run 10-048 (Oliver, 2012), and GAM Run 10-037 (Oliver, 2011a), and GAM Run 10-036 (Oliver, 2011b). The TWDB ran two new groundwater availability models, not previously available, for the Capitan Reef Complex (Eastern Arm) and West Texas Bolsons (Presidio and Redford Bolsons) aquifers. The modeled available groundwater volumes for these aquifers differ from the modeled available groundwater volumes previously calculated using analytical assessments.

Where analytical aquifer assessments were used, modeled available groundwater volumes were determined by summing estimates of effective recharge and the change in aquifer storage. See Freeze and Cherry (1979, p.365) for details regarding this analytical method.

Where groundwater availability models were used, the TWDB identified groundwater pumping scenarios that could achieve the adopted desired future conditions in Groundwater Management Area 4. The TWDB extracted simulated water levels for baseline years (see Parameters and Assumptions section for more information) and subsequent decades. The simulated drawdowns in all active model cells were averaged by aquifer for each county and groundwater conservation district. If water levels dropped below the base of the model cells during the predictive simulations, these cells became “dry cells”. In some instances, dry cells were included in drawdown averages; in other instances they were not. See the “Parameters and Assumptions” section for more details on the treatment of dry cells in each of the model runs.

The calculated drawdown averages compared well with the desired future conditions and verified that the desired future conditions adopted by the districts can be achieved—within the assumptions and limitations associated with each groundwater availability model.
Modeled available groundwater volumes were determined by extracting pumping rates by decade from the model results using ZONEBUDGET Version 3.01 (Harbaugh, 2009). Annual pumping rates were divided by county, river basin, regional water planning area, and groundwater conservation district within Groundwater Management Area 4 (Figures 1 through 13 and Tables 1 through 12).

Modeled Available Groundwater and Permitting

As defined in Chapter 36 of the Texas Water Code, “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.

PARAMETERS AND ASSUMPTIONS:

Bone Spring-Victorio Peak Aquifer

- The previous modeled available groundwater (Oliver, 2011c) was calculated using three separate flow models run under a variety of climatic and pumping scenarios. See Hutchison (2008) for assumptions and limitations of the three groundwater flow models.
- The models have one layer representing the Bone Spring-Victorio Peak Aquifer, a portion of the Capitan Reef Complex Aquifer, and the Diablo Plateau.
- Hutchison (2008) ran all three models using pumping ranging from 0 to 125,000 acre-feet per year and climatic information from tree ring data ranging from 1000 to 1988.
- The results of the 144 simulations were plotted to establish a relationship between pumping and drawdown (Hutchison, 2010). Modeled available groundwater was the sum of net pumping and the estimated irrigation return flow (approximately 30 percent of the net pumping, according to the Hudspeth County Underground Water Conservation District No. 1) for each desired future condition. Additional information on the application of irrigation return flow is described in GAM Run 10-061 MAG (Oliver, 2011c).
- Because the analysis used was statistically based, the starting and ending period can apply for any 50-year planning horizon. Therefore, we applied the values to 2020 to 2070.

Capitan Reef Complex Aquifer (Brewster County only)

- Version 1.01 of the groundwater availability model of the Eastern Arm of the Capitan Reef Complex Aquifer was used, with a baseline year of 2005. See Jones (2016) for assumptions and limitations of the groundwater availability model. A new model run simulation was completed to determine modeled available groundwater that achieved the desired future condition.
- 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 recharge used for the model simulation represents average recharge from 1931 through 2005 (last year of model calibration).
- Available water-level data from 2005 to 2010 for the Capitan Reef Complex Aquifer indicates that water level changes have been minimal. Therefore, applying the clarifications received from the Groundwater Management Area 4 on December 7, 2017, we concluded that a 2005-to-2055 predictive simulation is equivalent to a 2010-to-2060 predictive simulation.
- Drawdowns were then averaged in Groundwater Management Area 4 based on the official aquifer boundaries. We assumed the desired future condition was met if the average drawdown value was within 3 feet.

Capitan Reef Complex Aquifer (Culberson County only)

- There is no groundwater availability model for the Capitan Reef Complex Aquifer in Culberson County.
- The annual total pumping estimates were calculated as the sum of the annual effective recharge amount and the annual volume of water depleted from the aquifer based on the desired future condition.
- Recharge was assumed to be evenly distributed across the outcrop of the aquifer.
- Effective recharge estimates were based on springflow and surface hydrology, groundwater pumpage and water-level changes, and precipitation estimates.
- Annual volumes of water taken from storage were calculated by dividing the total volume of depletion, based on the draft desired future condition, by 50 years. For this report, we assumed the 50 years was 2010 to 2060.
- Calculated water-level declines were assumed to be uniform across the aquifer within its footprint area, and these calculated water-level declines did not exceed aquifer thickness.
- A detailed description of all parameters and assumptions is available in AA 09- 08 (Wuerch and others, 2011).

Edwards-Trinity (Plateau) Aquifer (Brewster County)

- The alternate groundwater flow model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers was used with a baseline year of 2005. This model is an update to the previously developed groundwater availability model documented in Anaya and Jones (2009). See Hutchison and others (2011) and Anaya and Jones (2009) for assumptions and limitations of the model.
- 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 recharge used for the model simulation represents average recharge as described in Hutchison and others (2011).
- Drawdowns were calculated by subtracting 2005 simulated water levels from 2060 simulated water levels, which were then averaged based on the official aquifer boundaries in Groundwater Management Area 4. Drawdowns for cells with water levels below the base elevation of the cell (dry cells) were excluded from the averaging.
- A detailed description of all parameters and assumptions is available in GAM Run 10-048 (Oliver, 2012).

Igneous Aquifer

- Version 1.01 of the groundwater availability flow model for the Igneous and parts of the West Texas Bolson aquifers was used for this analysis with year 2000 as baseline. See Beach and others (2004) for assumptions and limitations of the model.
- The model includes three layers representing the Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat portions of the West Texas Bolsons Aquifer (Layer 1), the Igneous Aquifer (Layer 2), and the underlying Cretaceous and Permian units (Layer3). Some areas of Layer 2 outside the boundary of the Igneous Aquifer are active in order to allow flow between Layer 1 and Layer 3.
- The averaging of drawdowns and modeled available groundwater calculations were based on model extent as opposed to the official aquifer footprint. The Igneous Aquifer model extent is a smoothed and somewhat smaller version of the official footprint of the Igneous Aquifer. A comparison of these two areas is shown in Figure 8.
- The predictive run was set up using average recharge as described in Beach and others (2004) and was run from 2000 to 2050.

- Cells were assigned to individual counties, river basins, regional water planning areas, and groundwater conservation districts as shown in the August 3, 2010, version of the file that associates the model grid to political and natural boundaries for the Igneous Aquifer. Note that some minor adjustments were made to the file to better reflect the relationship of model cells to political boundaries.
- See GAM Task 10-028 (Oliver, 2010) for a full description of the methods and assumptions used in the groundwater availability model simulations. The predictive model run for this analysis resulted in water levels in some model cells dropping below the base elevation of the cell during the simulation. These cells were excluded from the averaging of drawdowns, which in turn resulted in progressively lower pumping values through time. This is illustrated by the decline in modeled available groundwater (see Tables 7 and 8).

Marathon Aquifer

- The annual total pumping estimates was calculated as the sum of the annual effective recharge amount and the annual volume of water depleted from the aquifer based on the desired future condition.
- Recharge was assumed to occur evenly across the aerial extent of the aquifer.
- Average annual precipitation (1971 through 2000) from the Climatic Atlas of Texas (Larkin and Bomar, 1983) was used to calculate annual effective recharge volumes.
- The draft annual total pumping estimates are the sum of the annual effective recharge amount and the annual volume of water depleted from the aquifer based on the draft desired future condition. Annual volumes were calculated by dividing the total volume by 50 years. For this report, we assumed the 50 years was 2010 to 2060.
- Calculated water level declines were estimated uniformly across the aquifer.
- A detailed description of all parameters and assumptions is available in AA 09- 09 (Thorkildsen and Backhouse, 2010).

[Salt Basin portion of the] West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat, and Lobo Flat) Aquifer

- Version 1.01 of the groundwater availability flow model for the Igneous and parts of the West Texas Bolson aquifers was used for this analysis with year 2000 as baseline. See Beach and others (2004) for assumptions and limitations of the model.

- The model includes three layers representing the Wild Horse Flat, Michigan Flat, Ryan Flat and Lobo Flat portions of the West Texas Bolsons Aquifer (Layer 1), the Igneous Aquifer (Layer 2), and the underlying Cretaceous and Permian units (Layer 3).
- The simulation was set up using average recharge as described in Beach and others (2004) and was run from 2000 to 2050.
- Cells were assigned to individual counties, river basins, regional water planning areas, and groundwater conservation districts as shown in the August 3, 2010, version of the file that associates the model grid to political and natural boundaries for the Igneous and West Texas Bolson Aquifers. Note that some minor adjustments were made to the file to better reflect the relationship of model cells to political boundaries.
- See GAM Task 10-028 (Oliver, 2010) for a full description of the methods and assumptions used in the groundwater availability model simulations. The predictive model run for this analysis resulted in water levels in some model cells dropping below the base elevation of the cell during the simulation. These cells have been excluded from the averaging of drawdowns, which in turn resulted in progressively lower pumping values through time. This is illustrated by the decline in modeled available groundwater (see Tables 11 and 12).

West Texas Bolsons (Presidio and Redford) Aquifer

- Version 1.01 of the groundwater availability model of the Presidio and Redford bolsons of the West Texas Bolsons Aquifer was used with a baseline year of 2007. A new model run simulation was completed to determine the modeled available groundwater that achieved the desired future condition.
- See Wade and Jigmond (2013) for assumptions and limitations of the groundwater availability model.
- The model includes three layers representing the Rio Grande Alluvium (Layer 1), West Texas Bolsons (Presidio and Redford) Aquifer (Layer 2), and Tertiary and Cretaceous units (Layer 3).
- The recharge used for the simulation represents average recharge from 1948 through 2007 (end year of model calibration). Pumping was scaled by an equal factor and simultaneously on both the United States and the Mexico sides of the aquifer during the predictive run simulations.
- An analysis of the Presidio and Redford bolsons indicate that the changes in water levels in the few wells with available data from 2007 through 2010 have

been minimal. Therefore, in observance of the clarifications received from the Groundwater Management Area 4 on December 7, 2017, we assumed that a 2007-to-2057 predictive simulation is equivalent to a 2010-to-2060 predictive simulation.

- Drawdowns were calculated by subtracting 2007 simulated water levels from 2057 simulated water levels which were then averaged for all active model cells within the official aquifer boundary in Presidio County. Drawdowns in model cells located in Mexico were excluded from averaging. We assumed the desired future condition was met if the average drawdown value was within 1 foot.

RESULTS:

The results for the groundwater conservation districts (Tables 1, 3, 5, 7, 9, and 11), reflects the ending year discussed in the Parameters and Assumption Section of this report. For planning purposes (Tables 2, 4, 6, 8, 10, and 12), the values may have been populated past the dates noted in Parameters and Assumption Section using the trend of results. Tables 1 through 12 show the combination of modeled available groundwater summarized (1) by groundwater conservation district and county; and (2) by county, river basin, and regional water planning area for use in the regional water planning process.

The modeled available groundwater for the Bone Spring-Victorio Peak Aquifer that achieves the desired future conditions adopted by Groundwater Management Area 4 is 101,400 acre-feet per year from 2020 to 2070 (Tables 1 and 2). These volumes represent total pumping, defined as the sum of net pumping and the irrigation return flow. Hudspeth County Underground Water Conservation District No. 1 estimates that irrigation return flow is about 30 percent of net pumping.

The modeled available groundwater for the Capitan Reef Complex Aquifer that achieves the desired future conditions adopted by Groundwater Management Area 4 is 8,163 acre-feet per year from 2020 to 2060/2070 (Tables 3 and 4). This value includes 583 acre-feet per year in Brewster County; 7,580 acre-feet per year in Culberson County.

The modeled available groundwater for the Edwards-Trinity (Plateau) Aquifer that achieves the desired future conditions adopted by Groundwater Management Area 4 is 1,394 acre-feet per year from 2020 to 2060/2070 (Tables 5 and 6).

The modeled available groundwater for the Igneous Aquifer that achieves the desired future conditions adopted by Groundwater Management Area 4 decreases from 11,333 to 11,329 acre-feet per year between 2020 and 2050 (Tables 7 and 8). In the counties comprising Groundwater Management Area 4, the modeled available groundwater from 2020 to 2060 is as follows: a decline from 2,586 to 2,583 acre-feet per year in Brewster

County; 99 acre-feet per year in Culberson County; 4,584 acre-feet per year in Jeff Davis County; 4,063 acre-feet per year in Presidio County.

The modeled available groundwater for the Marathon Aquifer that achieves the desired future conditions adopted by Groundwater Management Area 4 is 7,327 acre-feet per year from 2020 to 2060/2070 (Tables 9 and 10).

The modeled available groundwater for the West Texas Bolsons (including the Salt Bolson and Presidio and Redford Bolsons) that achieves the desired future conditions adopted by Groundwater Management Area 4 decreases from 58,577 acre-feet per year to 57,881 acre- feet per year between 2020 and 2050 (Tables 11 and 12).

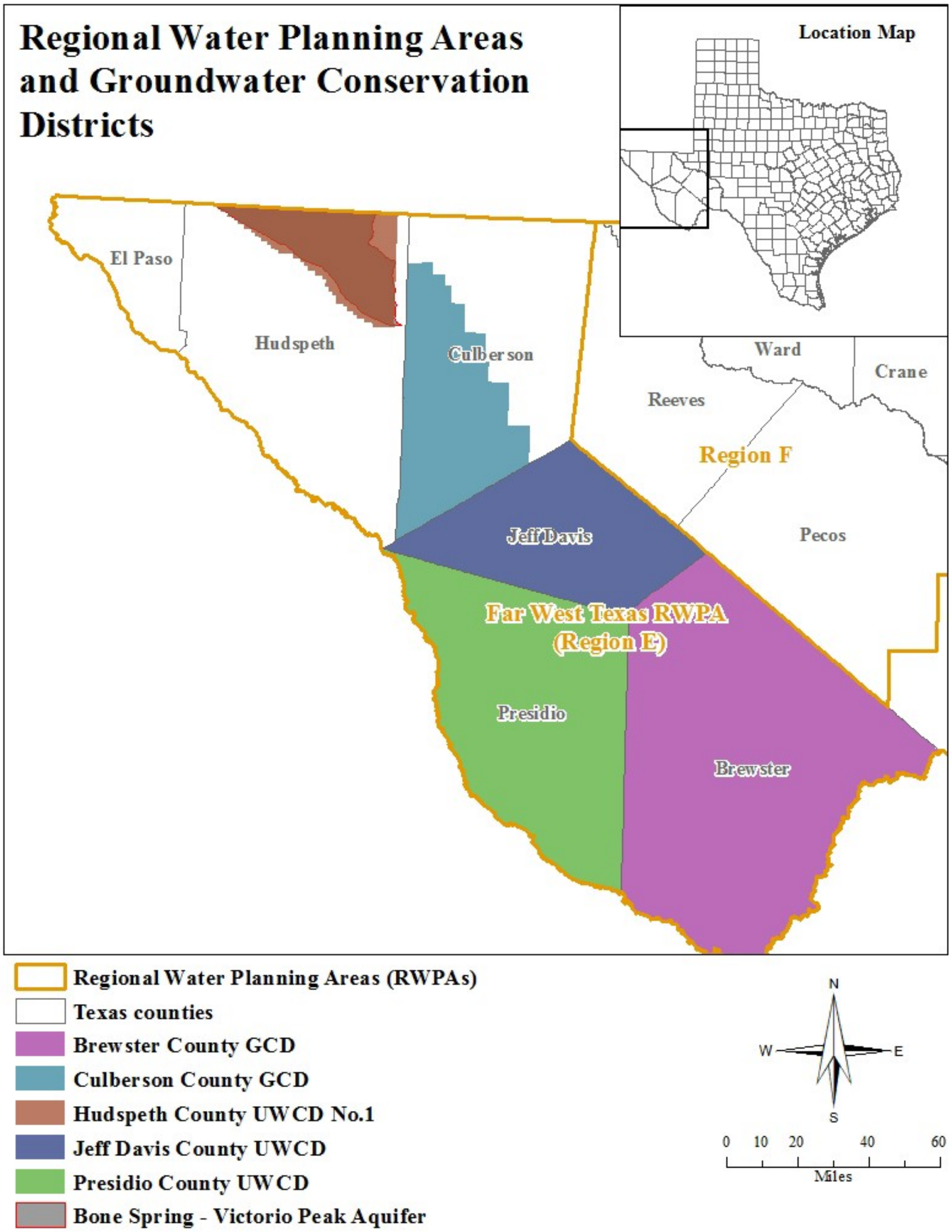

FIGURE 1. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE BONE SPRING–VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

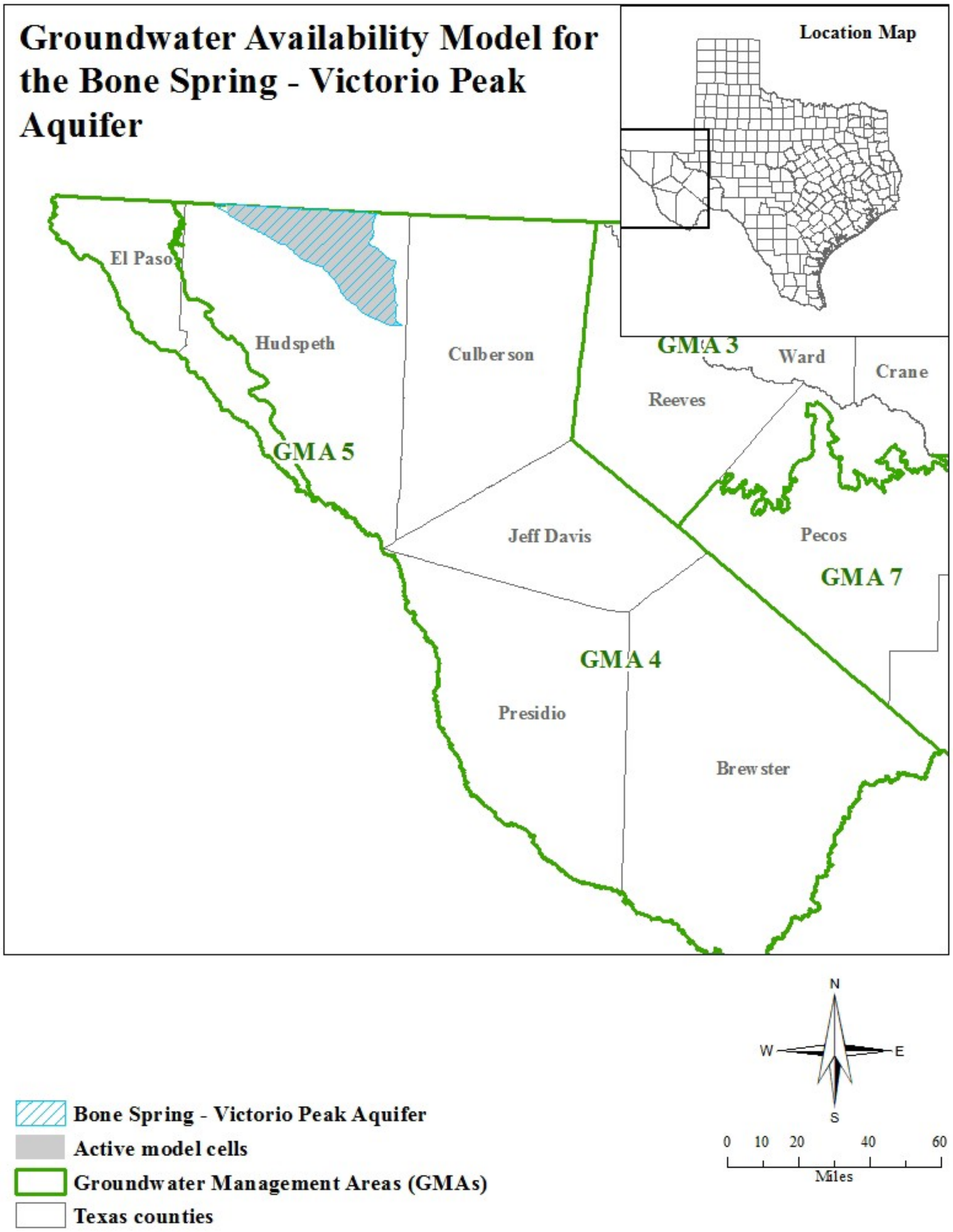

FIGURE 2. MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE BONE SPRING-VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

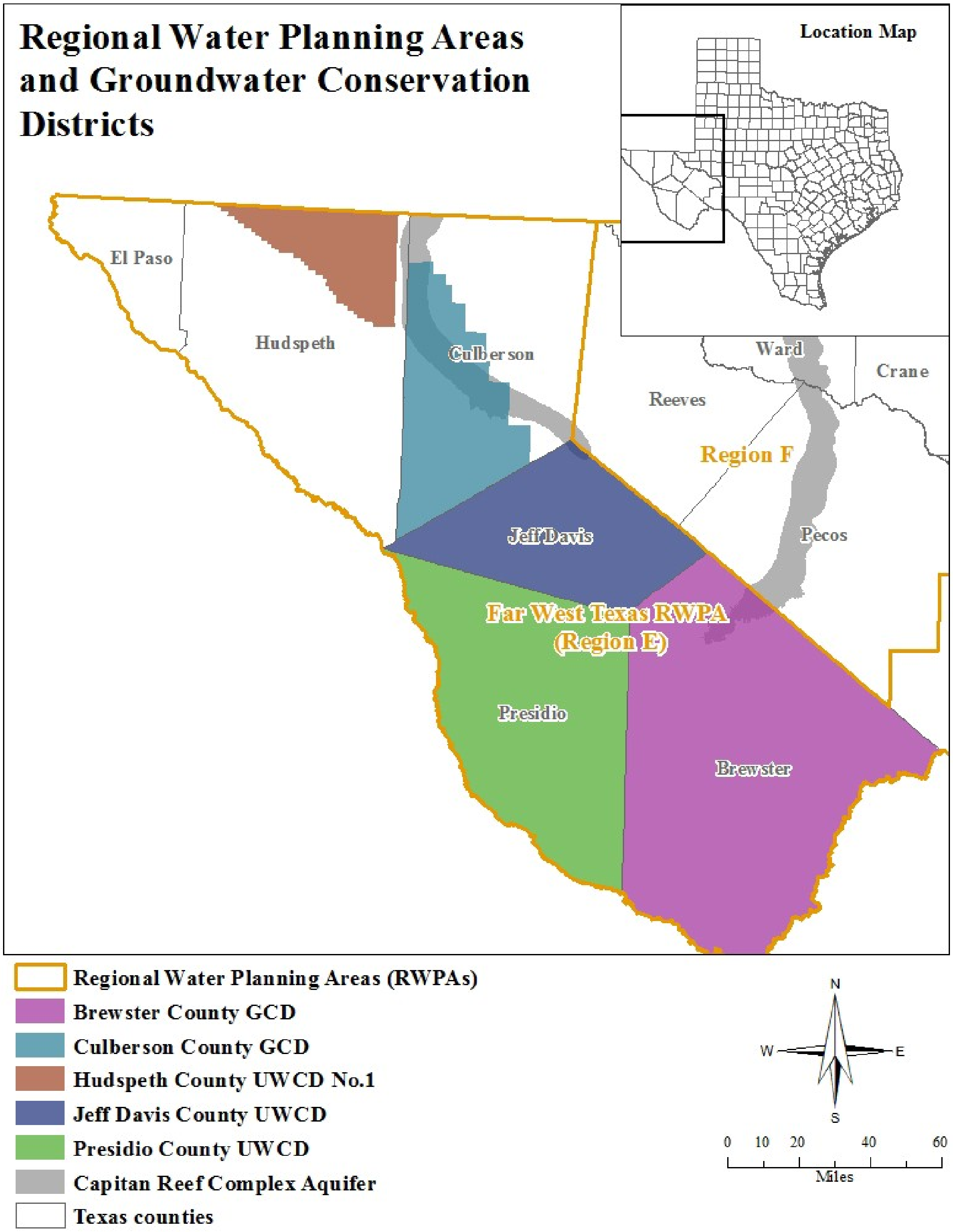

FIGURE 3. **MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATIONDISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.**

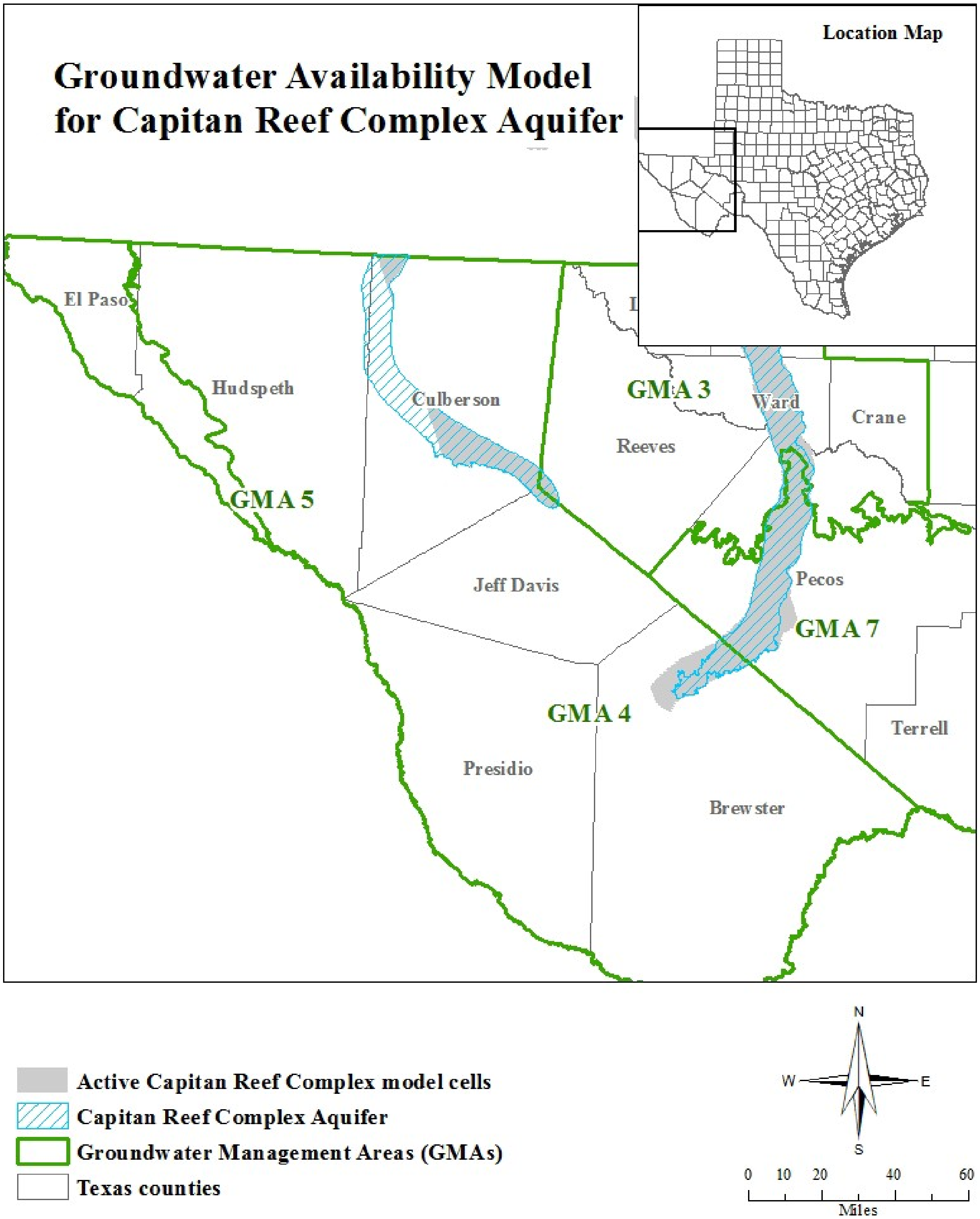

FIGURE 4. **MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.**

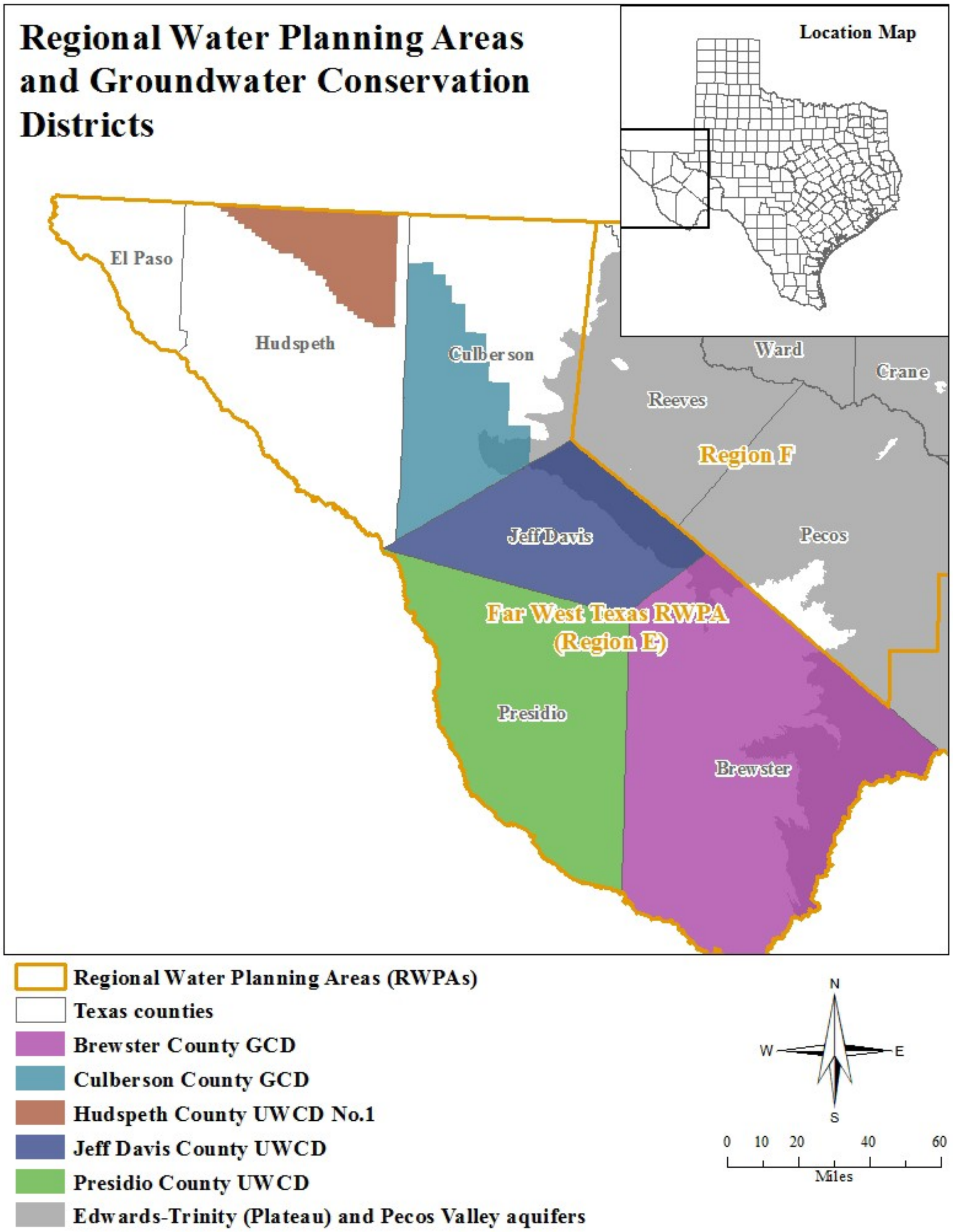

FIGURE 5. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATIONDISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

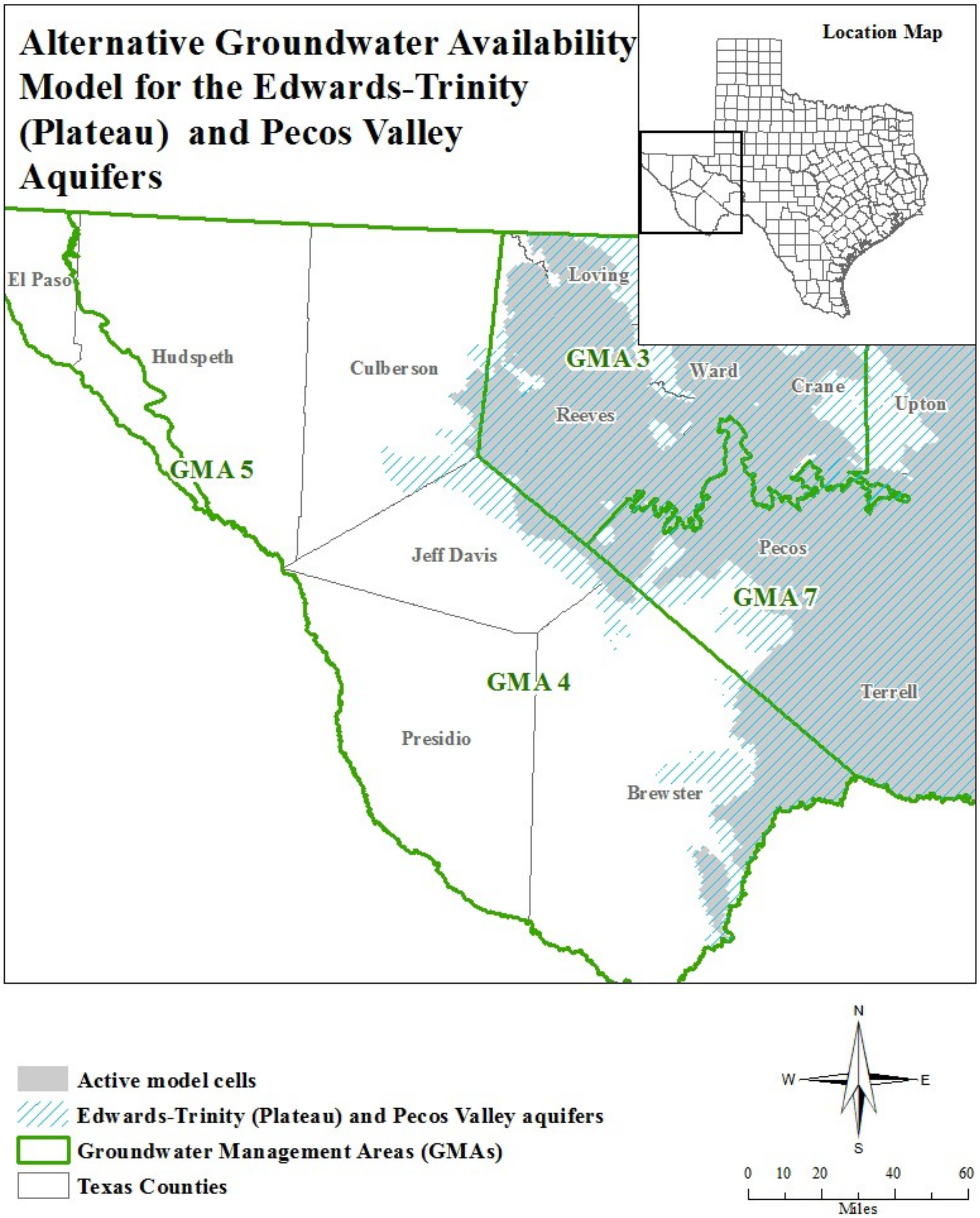

FIGURE 6. MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

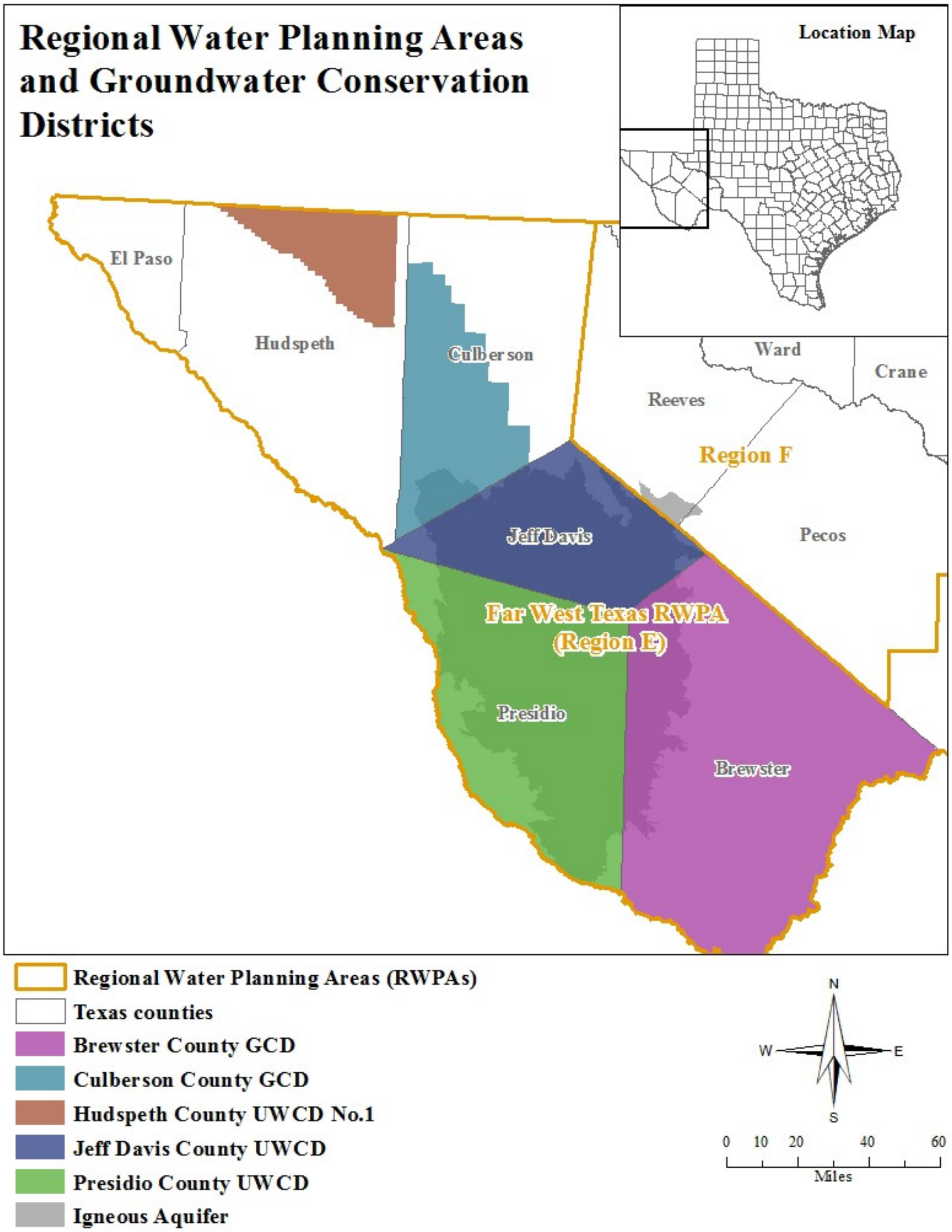

FIGURE 7. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

FIGURE 8. MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

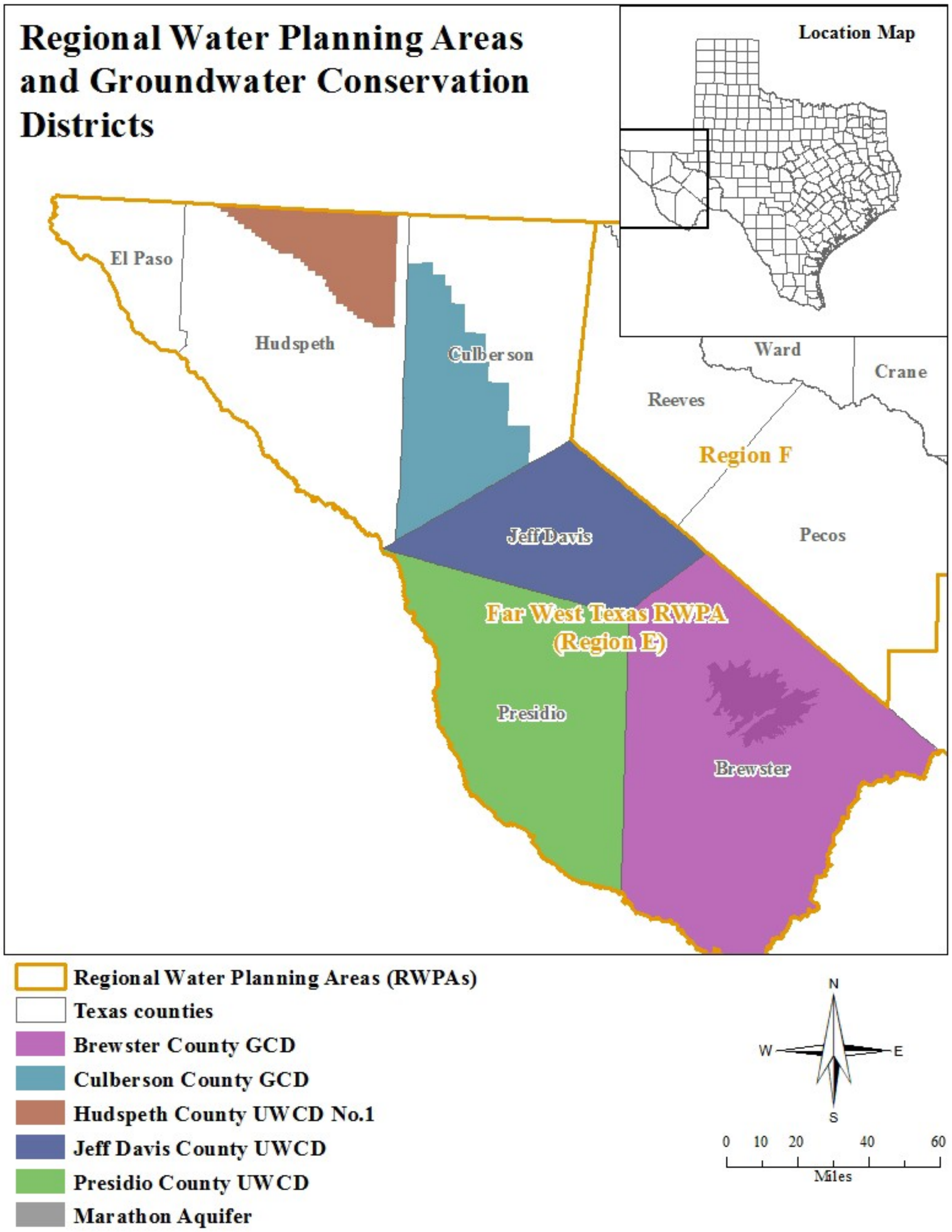

FIGURE 9. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE MARATHON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

FIGURE 10. MAP SHOWING GROUNDWATER MANAGEMENT AREAS (GMAS) AND COUNTIES IN THE VICINITY OF THE MARATHON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

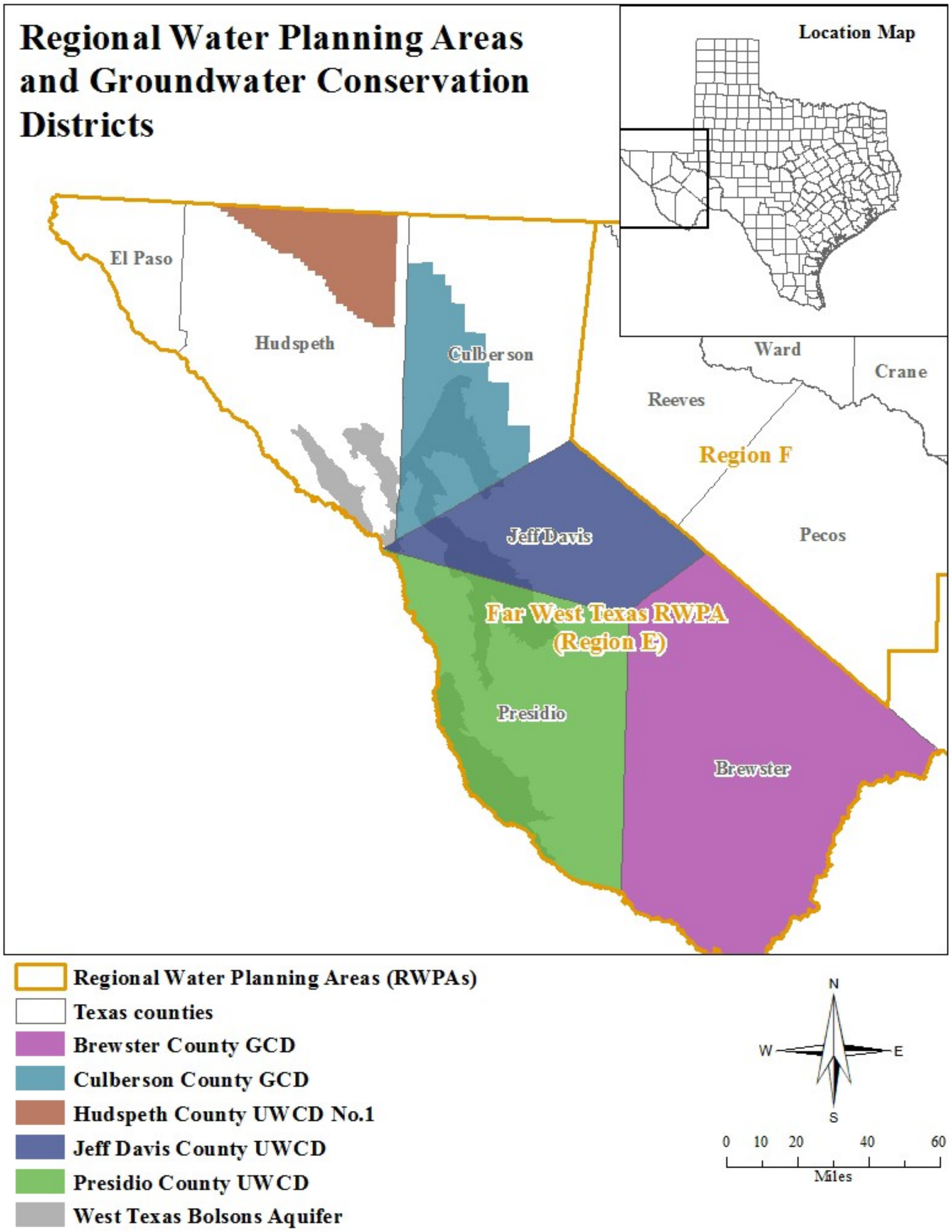

FIGURE 11. MAP SHOWING REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATIONDISTRICTS (GCDS), AND COUNTIES IN THE VICINITY OF THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

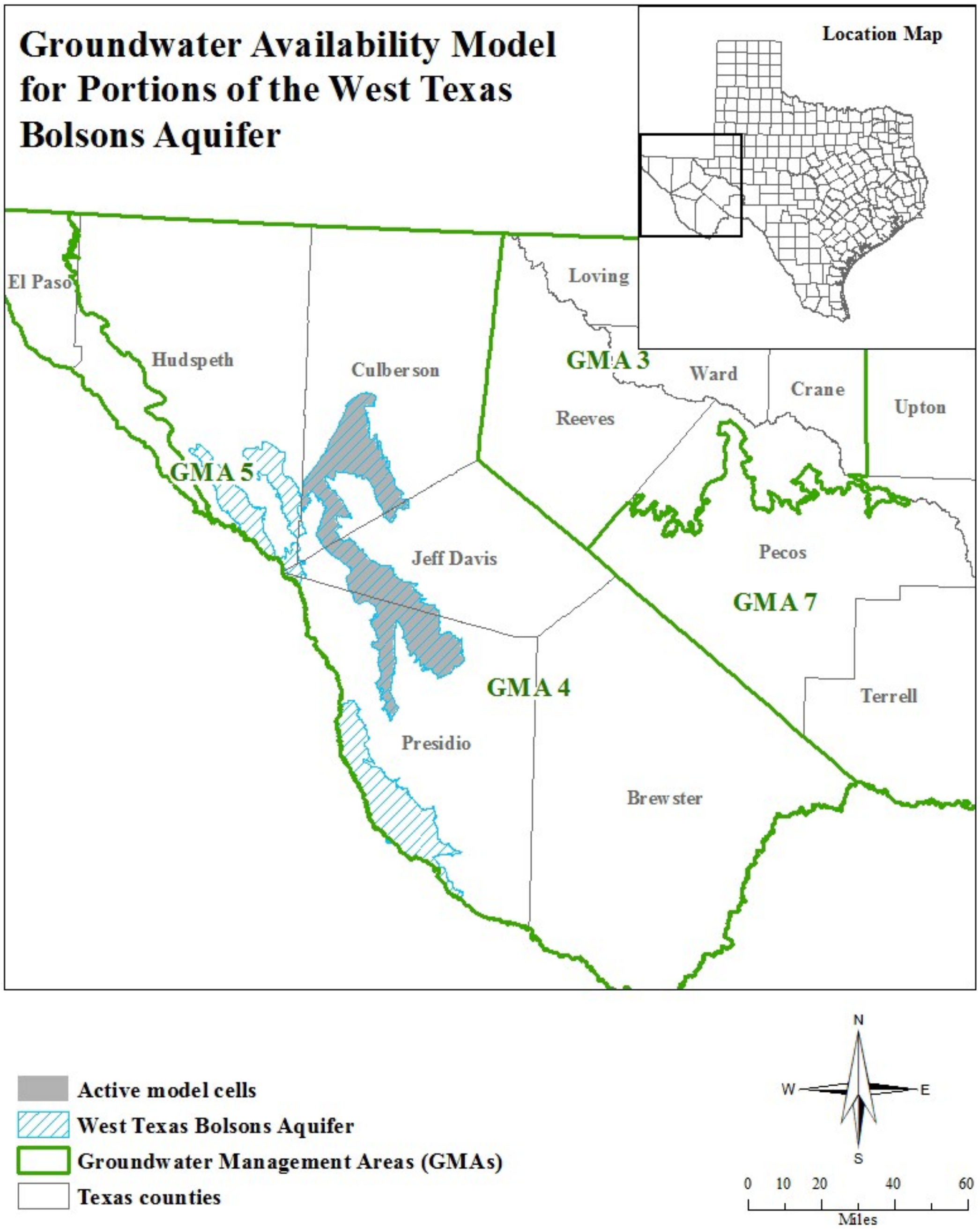

FIGURE 12. MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR PORTIONS OF THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

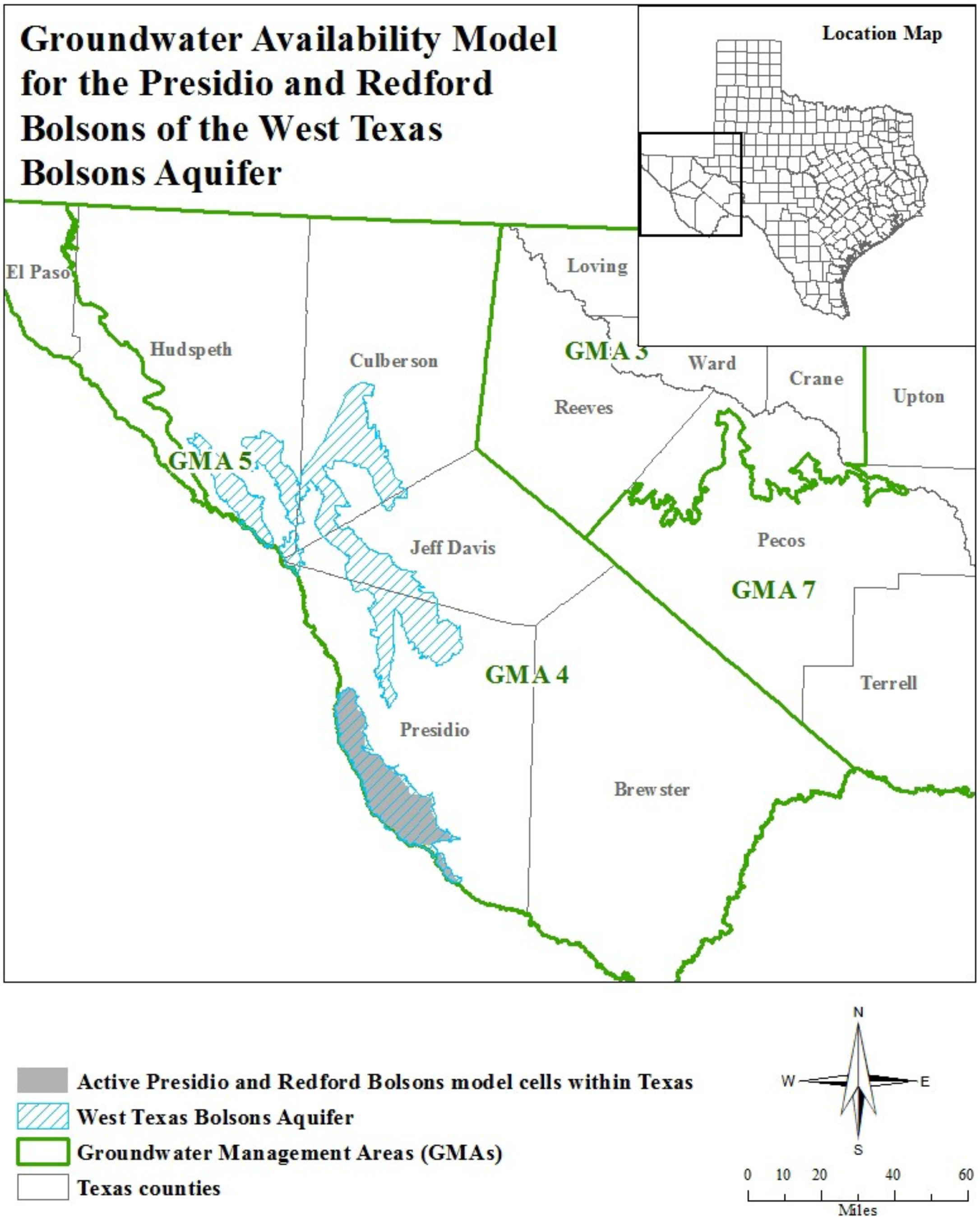

FIGURE 13. MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE PRESIDIO AND REDFORD PORTIONS OF THE WEST TEXAS BOLSON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

TABLE 1. MODELED AVAILABLE GROUNDWATER FOR THE BONE SPRING-VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (UWCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2020	2030	2040	2050	2060	2070
Hudspeth County UWCD	Hudspeth	101,400	101,400	101,400	101,400	101,400	101,400
No district-County	Hudspeth	0	0	0	0	0	0
Total		**101,400**	**101,400**	**101,400**	**101,400**	**101,400**	**101,400**

TABLE 2. MODELED AVAILABLE GROUNDWATER FOR THE BONE SPRING-VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Hudspeth	E	Rio Grande	101,400	101,400	101,400	101,400	101,400	**101,400**
Total			**101,400**	**101,400**	**101,40**	**101,400**	**101,400**	**101,400**

TABLE 3. MODELED AVAILABLE GROUNDWATER FOR THE CAPITAN AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2020	2030	2040	2050	2060
Brewster County GCD	Brewster	583	583	583	583	583
Culberson County GCD	Culberson	7,580	7,580	7,580	7,580	7,580
Total		**8,163**	**8,163**	**8,163**	**8,163**	**8,163**

TABLE 4. MODELED AVAILABLE GROUNDWATER FOR THE CAPITAN AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070.
VALUES ARE IN ACRE-FEET PER YEAR. NOTE: THE VALUES LISTED IN THIS TABLE HAVE BEEN POPULATED PAST THE DATES NOTED IN PARAMETERS AND ASSUMPTIONS SECTION (SEE TABLE 3) USING THE TREND OF RESULTS.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Brewster	E	Rio Grande	583	583	583	583	583	583
Culberson	E	Rio Grande	7,580	7,580	7,580	7,580	7,580	7,580
Total			**8,163**	**8,163**	**8,163**	**8,163**	**8,163**	**8,163**

TABLE 5. MODELED AVAILABLE GROUNDWATER FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2020	2030	2040	2050	2060
Brewster County GCD	Brewster	1,394	1,394	1,394	1,394	1,394
Total		**1,394**	**1,394**	**1,394**	**1,394**	**1,394**

TABLE 6. MODELED AVAILABLE GROUNDWATER FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR. NOTE: THE VALUES LISTED IN THIS TABLE HAVE BEEN POPULATED PAST THE DATES NOTED IN PARAMETERS AND ASSUMPTIONS SECTION (SEE TABLE 5) USING THE TREND OF RESULTS.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Brewster	E	Rio Grande	1,394	1,394	1,394	1,394	1,394	1,394
Total			**1,394**	**1,394**	**1,394**	**1,394**	**1,394**	**1,394**

TABLE 7. MODELED AVAILABLE GROUNDWATER FOR THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD, UWCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2050.
VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2020	2030	2040	2050
Brewster County GCD	Brewster	2,586	2,586	2,585	2,583
Culberson County GCD	Culberson	99	99	99	99
Jeff Davis County UWCD	Jeff Davis	4,584	4,584	4,584	4,584
Presidio County UWCD	Presidio	4,064	4,064	4,064	4,063
Total		**11,333**	**11,333**	**11,332**	**11,329**

TABLE 8. MODELED AVAILABLE GROUNDWATER FOR THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070.
VALUES ARE IN ACRE-FEET PER YEAR. NOTE: THE VALUES LISTED IN THIS TABLE HAVE BEEN POPULATED PAST THE DATES NOTED IN PARAMETERS AND ASSUMPTIONS SECTION (SEE TABLE 7) USING THE TREND OF RESULTS.

County	RWPA	River Basin	2020	2030	2040	2050
Brewster	E	Rio Grande	2,586	2,586	2,585	2,583
Culberson	E	Rio Grande	99	99	99	99
Jeff Davis	E	Rio Grande	4,584	4,584	4,584	4,584
Presidio	E	Rio Grande	4,064	4,064	4,064	4,063
Total			**11,333**	**11,333**	**11,332**	**11,329**

TABLE 9. MODELED AVAILABLE GROUNDWATER FOR THE MARATHON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND COUNTY FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

Groundwater Conservation District	County	2020	2030	2040	2050	2060
Brewster County GCD	Brewster	7,327	7,327	7,327	7,327	7,327
Total		**7,327**	**7,327**	**7,327**	**7,327**	**7,327**

TABLE 10. MODELED AVAILABLE GROUNDWATER FOR THE MARATHON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), AND RIVER BASIN FOR EACH DECADE BETWEEN 2020 AND 2070. VALUES ARE IN ACRE-FEET PER YEAR. NOTE: THE VALUES LISTED IN THIS TABLE HAVE BEEN POPULATED PAST THE DATES NOTED IN PARAMETERS AND ASSUMPTIONS SECTION (SEE TABLE 9) USING THE TREND OF RESULTS.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070
Brewster	E	Rio Grande	7,327	7,327	7,327	7,327	7,327	7,327
Total			**7,327**	**7,327**	**7,327**	**7,327**	**7,327**	**7,327**

TABLE 11. MODELED AVAILABLE GROUNDWATER FOR THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD, UWCD), COUNTY, AND AQUIFER SEGMENT FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR. THE SALT BASIN PORTION OF THE WEST TEXAS BOLSONS AQUIFER INCLUDES WILD HORSE, MICHIGAN, LOBO FLATS, AND RYAN FLAT.

Groundwater Conservation District	County	Aquifer Segment	2020	2030	2040	2050
Culberson County GCD	Culberson	Wild Horse, Michigan, and Lobo Flats	35,749	35,678	35,601	35,550
Jeff Davis County UWCD	Jeff Davis	Ryan Flat	6,055	6,055	5,989	5,960
Presidio County UWCD	Presidio	Ryan Flat	9,112	8,982	8,834	8,710
Presidio County UWCD	Presidio	Presidio and Redford Bolsons	7,661	7,661	7,661	7,661
Total			**58,577**	**58,376**	**58,085**	**57,881**

TABLE 12. MODELED AVAILABLE GROUNDWATER FOR THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY COUNTY, REGIONAL WATER PLANNING AREA (RWPA), RIVER BASIN, AND AQUIFER SEGMENT FOR EACH DECADE BETWEEN 2020 AND 2060. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Aquifer Segment	2020	2030	2040	2050
Culberson	E	Rio Grande	Wild Horse, Michigan, and Lobo Flats	35,749	35,678	35,601	35,550
Jeff Davis	E	Rio Grande	Ryan Flat	6,055	6,055	5,989	5,960
Presidio	E	Rio Grande	Ryan Flat	9,112	8,982	8,834	8,710
Presidio	E	Rio Grande	Presidio and Redford Bolsons	7,661	7,661	7,661	7,661
Total				**58,577**	**58,376**	**58,085**	**57,881**

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 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 streamflow are specific to a particular historic 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.

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