GAM RUN 21-010 MAG: MODELED AVAILABLE GROUNDWATER FOR THE AQUIFERS IN GROUNDWATER MANAGEMENT AREA 4

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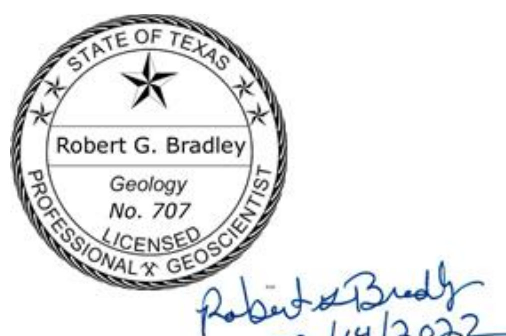
Texas Water Development Board
Groundwater Division
(512) 463-5808
January 21, 2022



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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 for the groundwater conservation districts (Tables 1, 3, 5, 7, 9, and 11) and in the regional water planning process (Tables 2, 4, 6, 8, 10, and 12)). 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,
- 11,331 to 11,336 acre-feet per year in the Igneous Aquifer,
- 7,327 acre-feet per year in the Marathon Aquifer, and
- 57,754 to 58,580 acre-feet per year in the West Texas Bolsons Aquifer (Salt Basin and Presidio and Redford Bolsons combined).

Within the West Texas Bolsons Aquifer in Culberson County GCD, the modeled available groundwater for Lobo Flat, Wildhorse Flat, and Michigan Flat are:

- 11,087 to 11,112 acre-feet per year in Lobo Flat, and
- 24,422 to 24,638 acre-feet per year in Wildhorse Flat.

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 29, 2021.

REQUESTOR:

Groundwater Conservation District members of Groundwater Management Area 4.

DESCRIPTION OF REQUEST:

In the *Resolution for Adoption of Desired Future Conditions for the Aquifers in Groundwater Management Area 4* dated June 17, 2021, the District Members of Groundwater Management Area 4 provided the TWDB with the desired future conditions of the relevant aquifers in Groundwater Management Area 4. The 2021 desired future conditions are identical with the 2016 desired future conditions, and are reproduced below:

Brewster County Groundwater Conservation District (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 Groundwater Conservation District (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 Underground Water Conservation District No.1 (2010-2060)

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

Jeff Davis County Underground Water Conservation District (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 Underground Water Conservation District (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].

The following stipulations from the 2016 desired future conditions also apply to the 2021 desired future conditions.

> "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 2008 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 and Brewster counties), 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 2016, and the applicable groundwater availability models and analytical methodology to calculate modeled available groundwater are unchanged. With the exception of the West Texas Bolsons Aquifer (years 2060 and 2070, where modeled available groundwater increased slightly), 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), GAM Run 16-030 (Boghici and Bradley, 2018), and GAM Run 16-030_Addendum (Wade, 2020).

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

Chapter 36 of the Texas Water Code defines "modeled available groundwater" as 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 (Boghici and Bradley, 2018, 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 2060 (2020 to 2070 for the Regional Water Planning Area (RWPA) table.

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.
- Desired future conditions were assumed met when the average drawdowns were within 1 foot of the adopted desired future condition.
- Drawdowns were averaged over the official aquifer extent.
- All active model cells were included in drawdown averaging.
- Used a predictive run that included modeled available groundwater volumes from cycle 2 of the desired future conditions process from neighboring groundwater management areas 3 and 7.
- Grid file vintage: 01/06/2020.

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 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 for the desired future condition simulations. 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).
- Per Clarification Letter 2017-1208, TWDB used 2005 as the baseline year for predictive model runs and drawdown averaging.
- Time interval for drawdown averaging was 2005-2060.
- Desired future conditions were assumed met when average drawdowns are within 1 foot of the adopted desired future conditions.
- Drawdowns were averaged over model extent.

- Dry model cells were excluded from drawdowns' averaging.
- Used a predictive run that included modeled available groundwater volumes from cycle 2 of the desired future conditions process from neighboring groundwater management areas 2, 3, and 7.
- Grid file vintage: 08/26/2015.

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.
- See GAM Task 10-028 (Oliver, 2010) for a full description of the methods and assumptions used in the groundwater availability model simulations.
- 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.
- Per Clarification Letter 2017-1208, we used 2000 as the baseline year for predictive model runs and drawdown averaging. Time interval for drawdown averaging was 2000-2050, equivalent to 2010-2060 due to minimal change in water levels in wells from 2000 to 2010.
- Desired future conditions were assumed met when the average drawdowns are within 1 foot of the adopted desired future conditions
- Drawdowns were averaged over model extent.
- 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).

- Modeled available groundwater values are slightly changed for 2060 and 2070 when compared with those reported in GAM Run 16-030 (Boghici and Bradley, 2018). This is because the previously reported values were determined by extrapolating the 2010-2050 trend shown in Oliver (2010), while the current values have been extracted from the model run output directly.
- This predictive run was unique to Groundwater Management Area 4.
- Grid file vintage: 01/20/2020.

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 (Narasimhan and others, 2008) 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 (Layer3).
- See GAM Task 10-028 (Oliver, 2010) for a full description of the methods and assumptions used in the groundwater availability model simulations.
- The simulation was set up using average recharge as described in Beach and others (2004) and was run from 2000 to 2060.
- Per Clarification Letter 2017-1208, we used 2000 as the baseline year for predictive model runs and drawdown averaging. Time interval for drawdown averaging: 2000-2050, equivalent to 2010-2060 due to minimal change in water levels in wells from 2000 to 2010.
- For the West Texas Bolsons in Culberson County, we used the methodology and calculations described in GAM Run 16-030_Addendum (Wade, 2020) to split modeled available groundwater by individual Flats: Lobo, Wild Horse, and Michigan. Later on, at the request of Culberson County Groundwater Conservation District, we combined the totals for Wild Horse and Michigan flats, and reported them under Wild Horse Flat only in Tables 11 and 12.
- Drawdowns were averaged over model extent.
- Desired future conditions were assumed met when the average drawdowns were within 1 foot of the adopted desired future conditions.
- 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).
- Modeled available groundwater values are slightly changed for 2060 and 2070 when compared with those reported in GAM Run 16-030 (Boghici and Bradley, 2018). This is because the previously reported values were determined by extrapolating the 2010-2050 trend shown in Oliver (2010), while the current values have been extracted from the model run output directly.
- Predictive run was unique to Groundwater Management Area 4.
- Grid file vintage: 01/20/2020.

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 2008. A new model run simulation was completed to determine the modeled available groundwater that achieved the desired future condition.
- 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).
- See Wade and Jigmond (2013) for assumptions and limitations of the groundwater availability model.
- The recharge used for the simulation represents average recharge from 1948 through 2008 (end year of model calibration). Pumping was adjusted in all model layers and 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 there have been minimal changes in water levels in the few wells with available data from 2008 through 2010. Therefore, consistent with the clarifications received from the Groundwater Management Area 4 on December 7, 2017, we assumed that a 2008-to-2058 predictive simulation is equivalent to a 2010-to-2060 predictive simulation.
- Drawdowns were calculated by subtracting 2008 simulated water levels from 2058 simulated water levels which were then averaged for all active model cells in Layer 1 and Layer 2 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.
- Predictive run was unique to Groundwater Management Area 4.
- Grid file vintage: 1/20/2020.

RESULTS:[1]

The results for the groundwater conservation districts (Tables 1, 3, 5, 7, 9, and 11), reflect 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 modeled available groundwater values have been populated past the dates defined by the desired future conditions resolutions using predictive model run 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 that achieves the desired future conditions adopted by Groundwater Management Area 4 is:

- 101,400 acre-feet per year from 2020 to 2060/2080 (Tables 1 and 2) for the Bone Spring-Victorio Peak Aquifer. 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.
- 8,163 acre-feet per year from 2020 to 2060/2080 (Tables 3 and 4) for the Capitan Reef Complex Aquifer. This value includes 583 acre-feet per year in Brewster County; 7,580 acre-feet per year in Culberson County.
- 1,394 acre-feet per year from 2020 to 2060/2080 (Tables 5 and 6) for the Edwards-Trinity (Plateau) Aquifer.
- 11,336 to 11,331/11,331 acre-feet per year between 2020 and 2060/2080 (Tables 7 and 8) for the Igneous Aquifer.
- 7,327 acre-feet per year from 2020 to 2060/2080 (Tables 9 and 10) for the Marathon Aquifer.
- 58,580 to 57,754 acre-feet per year between 2020 and 2060/2080 (Tables 11 and 12) for the West Texas Bolsons (including the Salt Bolson and Presidio and Redford Bolsons).

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[1] Note: Since the desired future conditions were defined by Groundwater Management Area 4 only to year 2060, the groundwater pumping volumes reported past 2060 in Tables 1-12 may not honor said desired future conditions. The 2070 and 2080 pumping volumes are reported here as *Groundwater Availability* for use by the regional water planning areas.

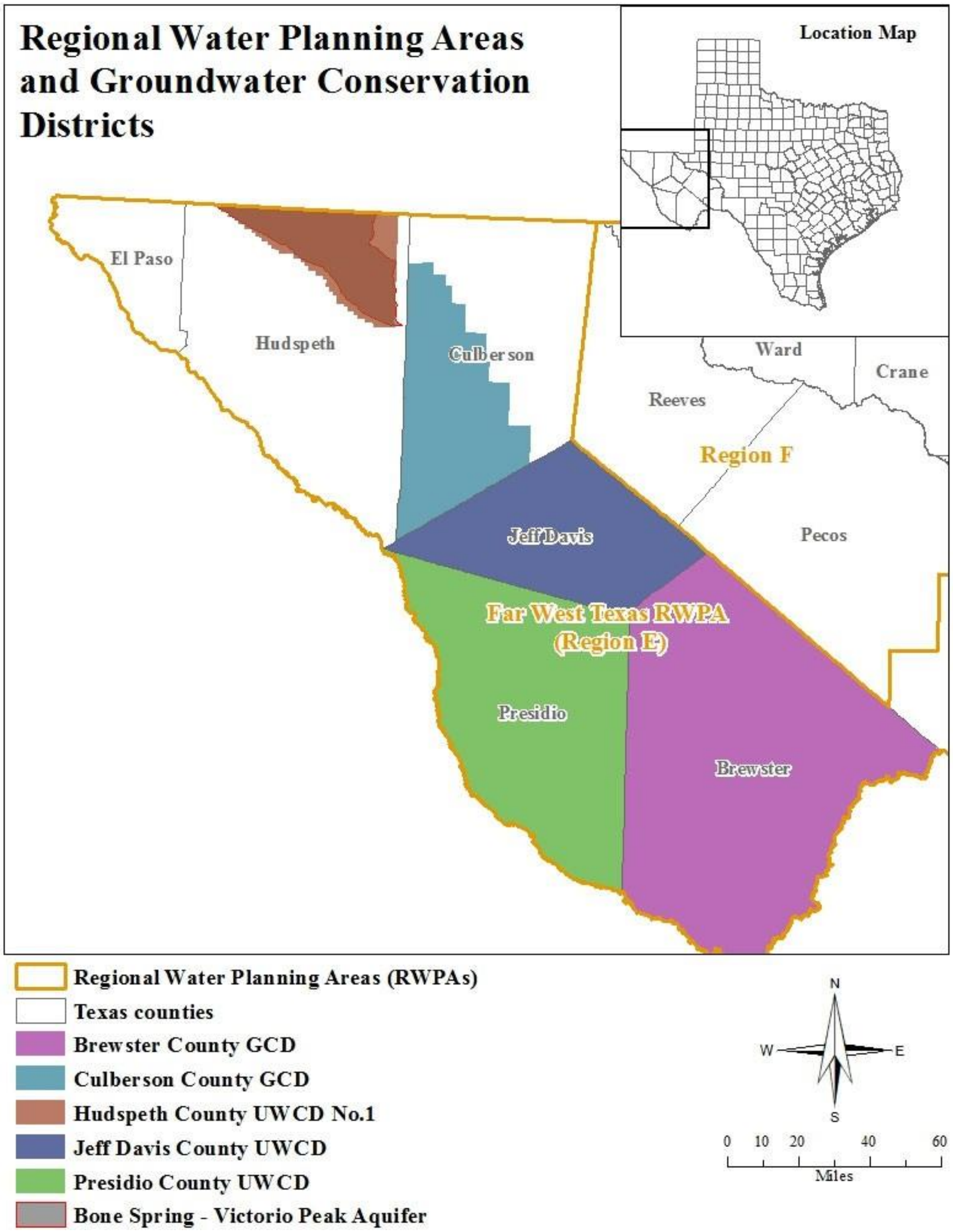

FIGURE 1. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD), AND COUNTIES IN THE VICINITY OF THE BONE SPRING–VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

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

TABLE 1. MODELED AVAILABLE GROUNDWATER FOR THE BONE SPRING- VICTORIO PEAK AQUIFER IN GROUNDWATER MANAGEMENT AREA 4SUMMARIZED BY UNDERGROUND WATER CONSERVATION DISTRICT (UWCD) 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
Hudspeth County UWCD	Hudspeth	101,400	101,400	101,400	101,400	101,400
No district-County	Hudspeth	0	0	0	0	0
Total		**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 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070	2080
Hudspeth	E	Rio Grande	101,400	101,400	101,400	101,400	101,400	101,400	101,400
Total			**101,400**	**101,400**	**101,400**	**101,400**	**101,400**	**101,400**	**101,400**

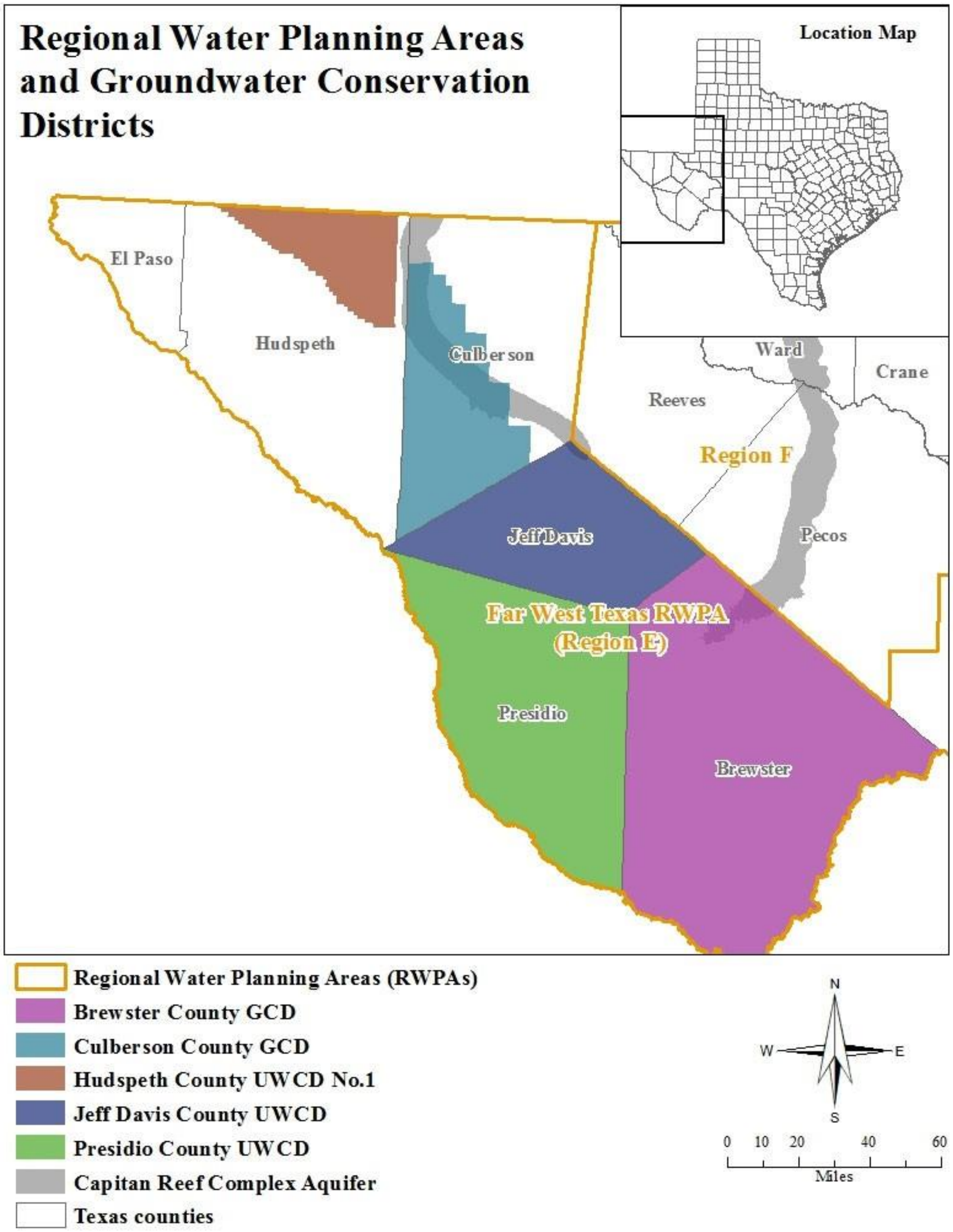

FIGURE 3. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD), AND COUNTIES IN THE VICINITY OF THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

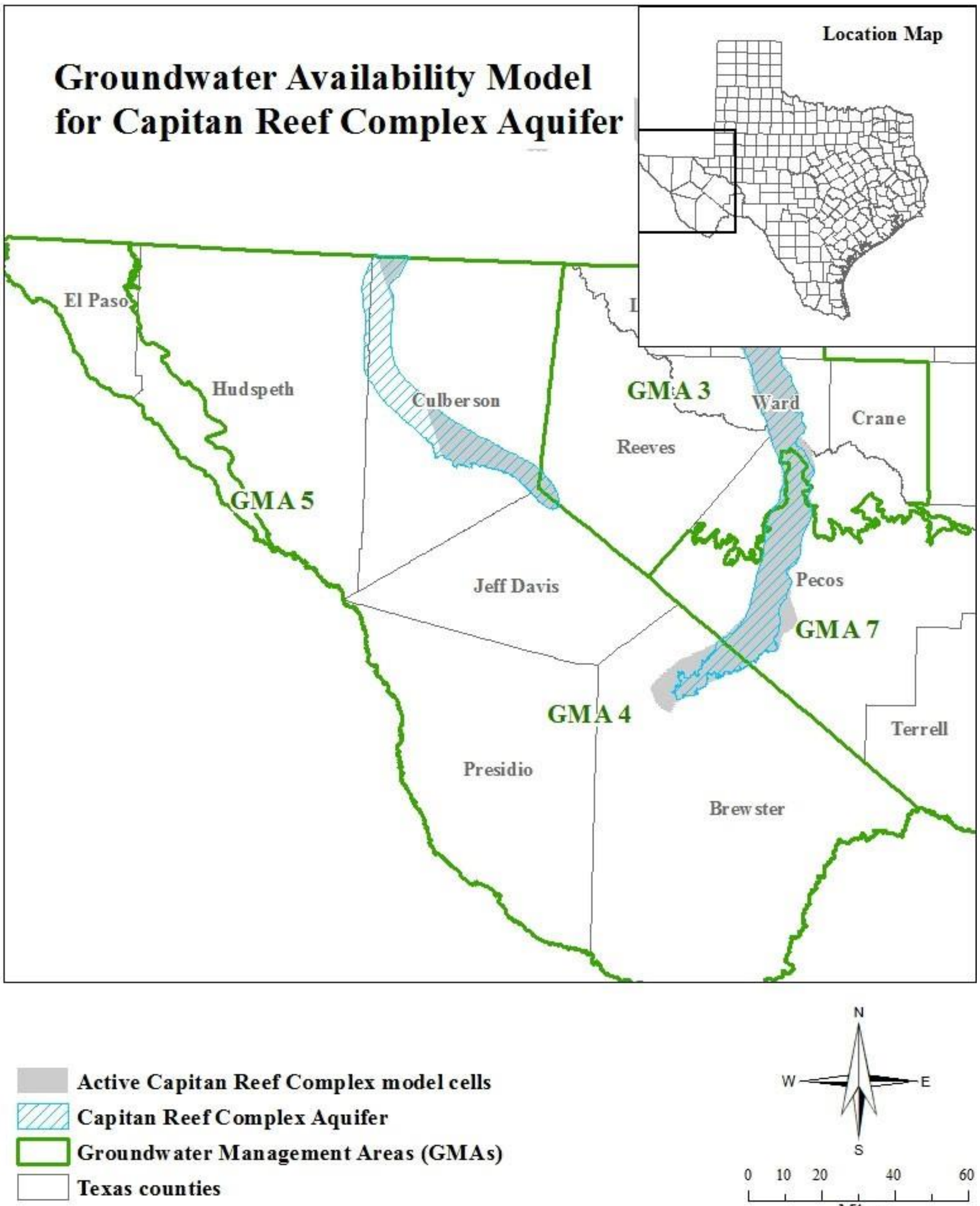

FIGURE 4. AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE CAPITAN REEF COMPLEX AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

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 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070	2080
Brewster	E	Rio Grande	583	583	583	583	583	583	583
Culberson	E	Rio Grande	7,580	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**	**8,163**

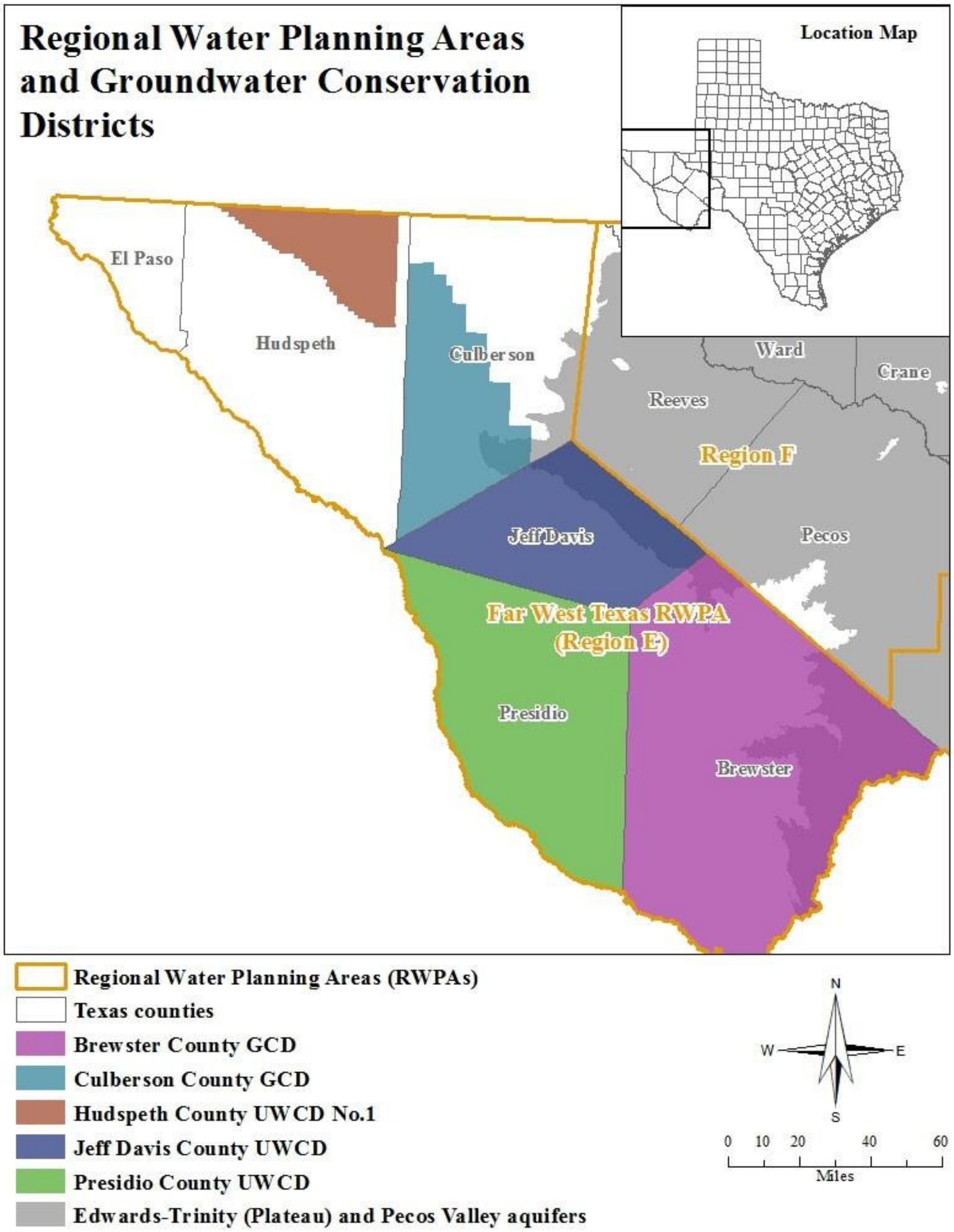

FIGURE 5. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATIONDISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD), AND COUNTIES IN THE VICINITY OF THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

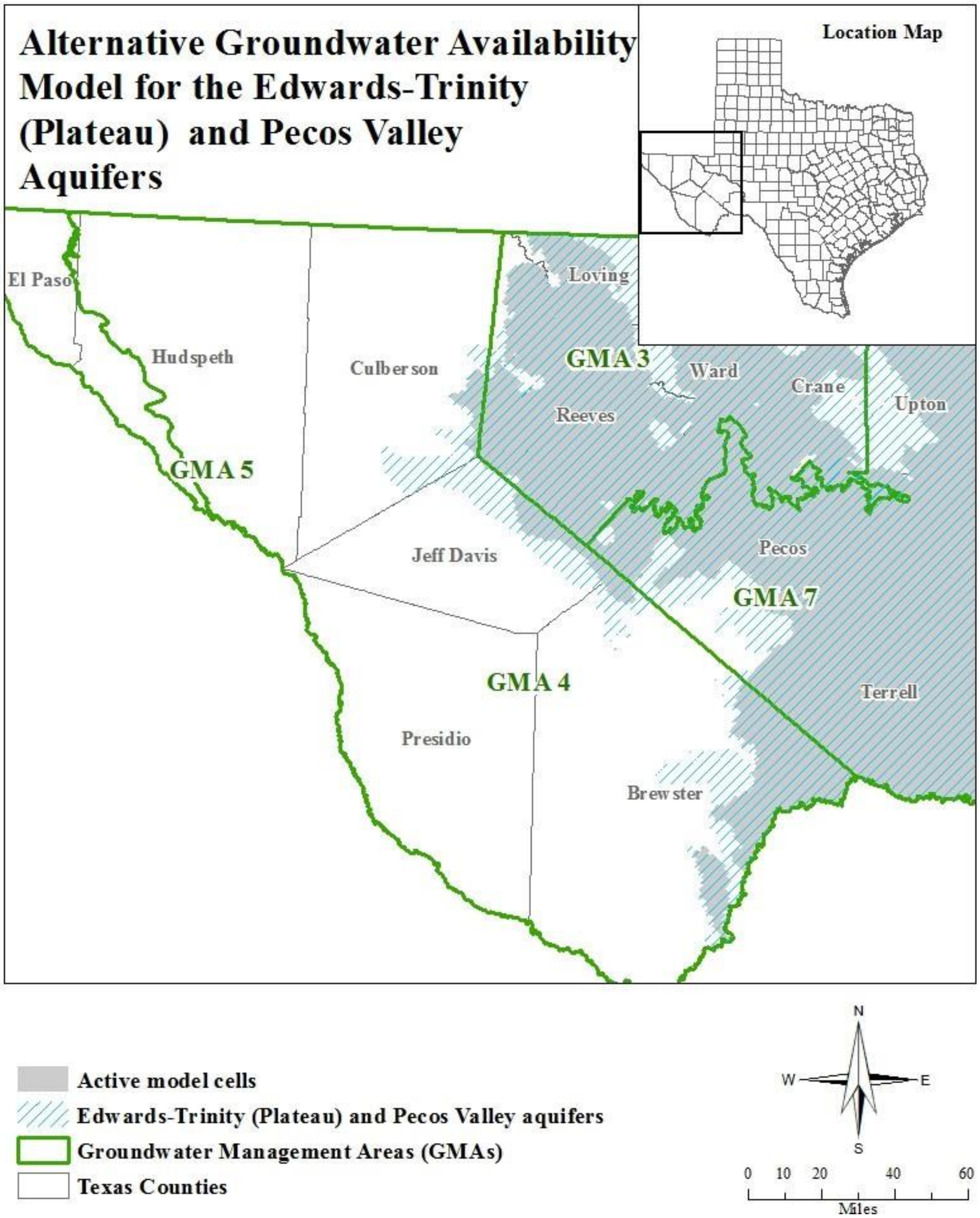

FIGURE 6. AREAS COVERED BY THE ALTERNATIVE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

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 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070	2080
Brewster	E	Rio Grande	1,394	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**	**1,394**

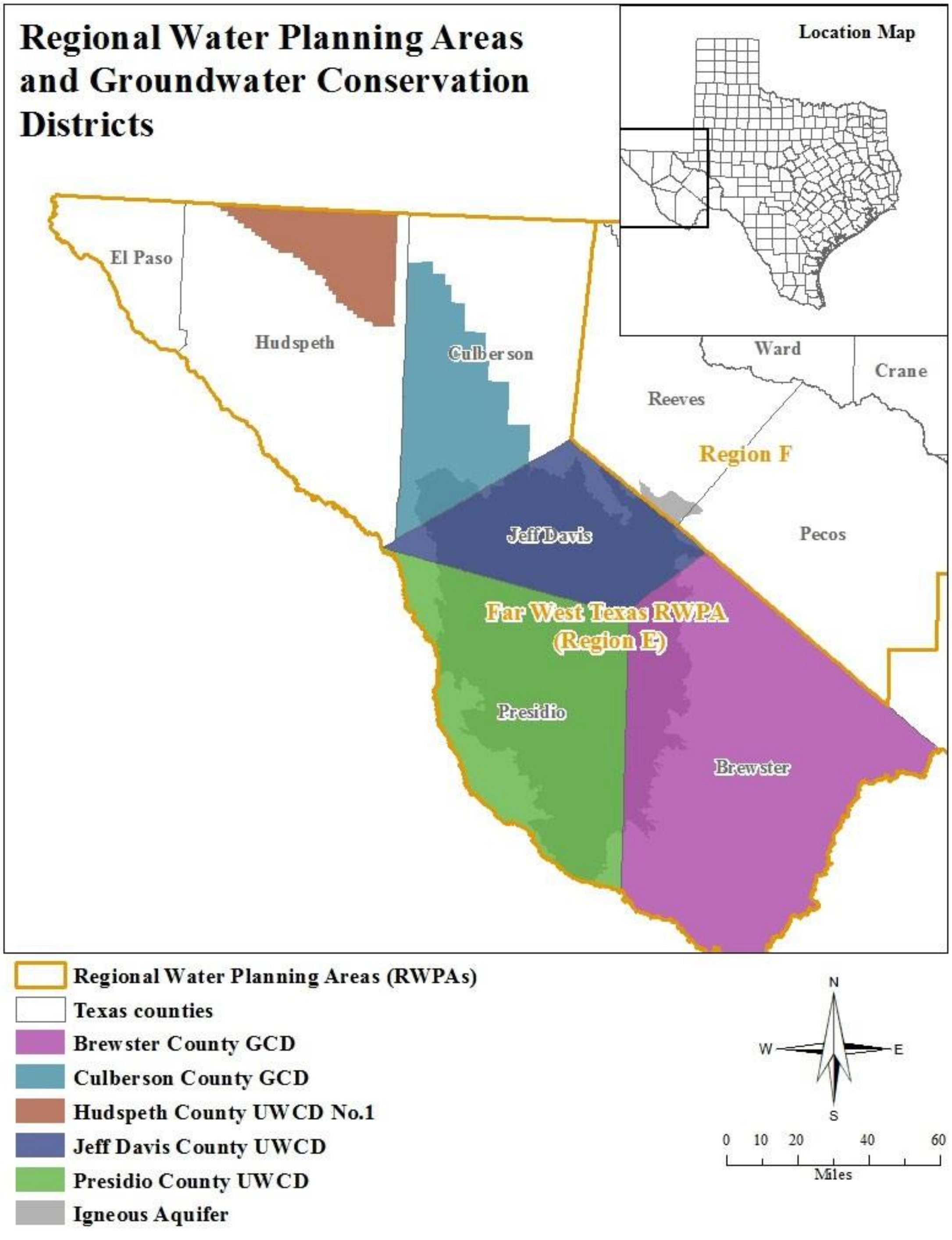

FIGURE 7. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD), AND COUNTIES IN THE VICINITY OF THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

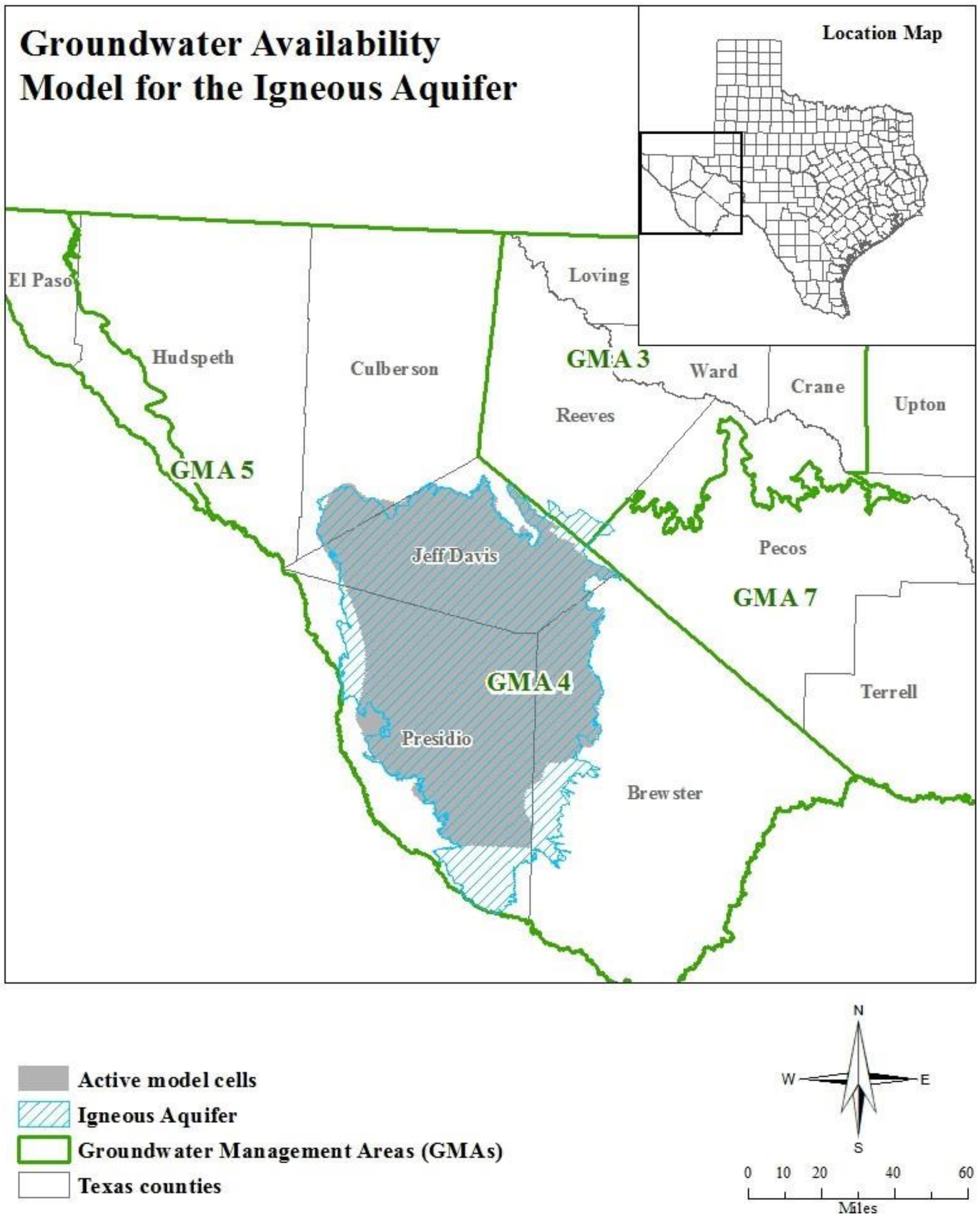

FIGURE 8. AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

TABLE 7. MODELED AVAILABLE GROUNDWATER FOR THE IGNEOUS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD), UNDERGROUND WATER CONSERVATION DISTRICT (UWCD), 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	2,587	2,587	2,586	2,583	2,582
Culberson County GCD	Culberson	99	99	99	99	99
Jeff Davis County UWCD	Jeff Davis	4,585	4,585	4,585	4,585	4,585
Presidio County UWCD	Presidio	4,065	4,065	4,065	4,065	4,065
Total		**11,336**	**11,336**	**11,335**	**11,332**	**11,331**

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 2080. VALUES ARE IN ACRE-FEET PER YEAR

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070	2080
Brewster	E	Rio Grande	2,587	2,587	2,586	2,583	2,582	2,582	2,582
Culberson	E	Rio Grande	99	99	99	99	99	99	99
Jeff Davis	E	Rio Grande	4,585	4,585	4,585	4,585	4,585	4,585	4,585
Presidio	E	Rio Grande	4,065	4,065	4,065	4,065	4,065	4,065	4,065
Total			**11,336**	**11,336**	**11,335**	**11,332**	**11,331**	**11,331**	**11,331**

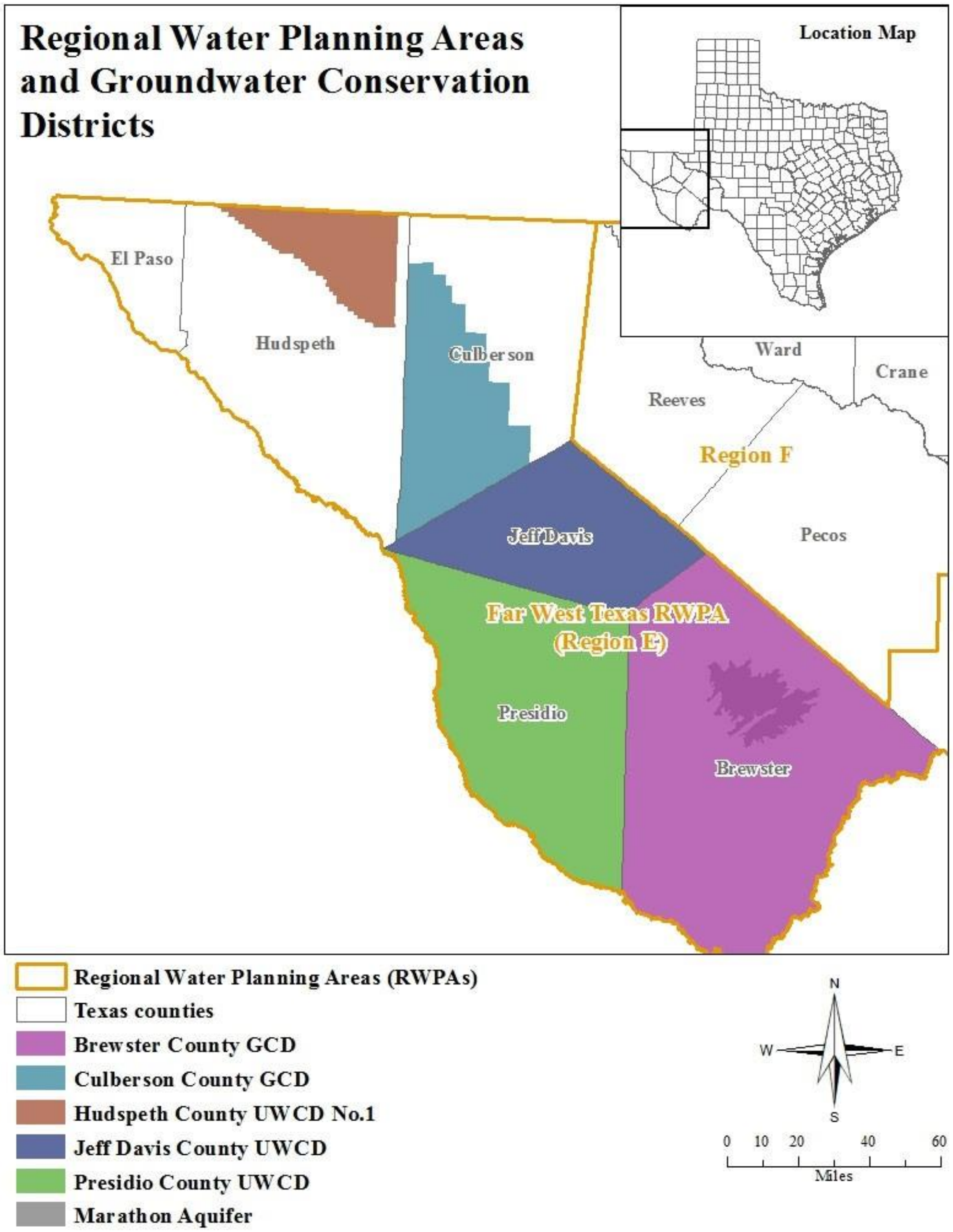

FIGURE 9. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD), AND COUNTIES IN THE VICINITY OF THE MARATHON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

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

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.

County	RWPA	River Basin	2020	2030	2040	2050	2060	2070	2080
Brewster	E	Rio Grande	7,327	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**	**7,327**

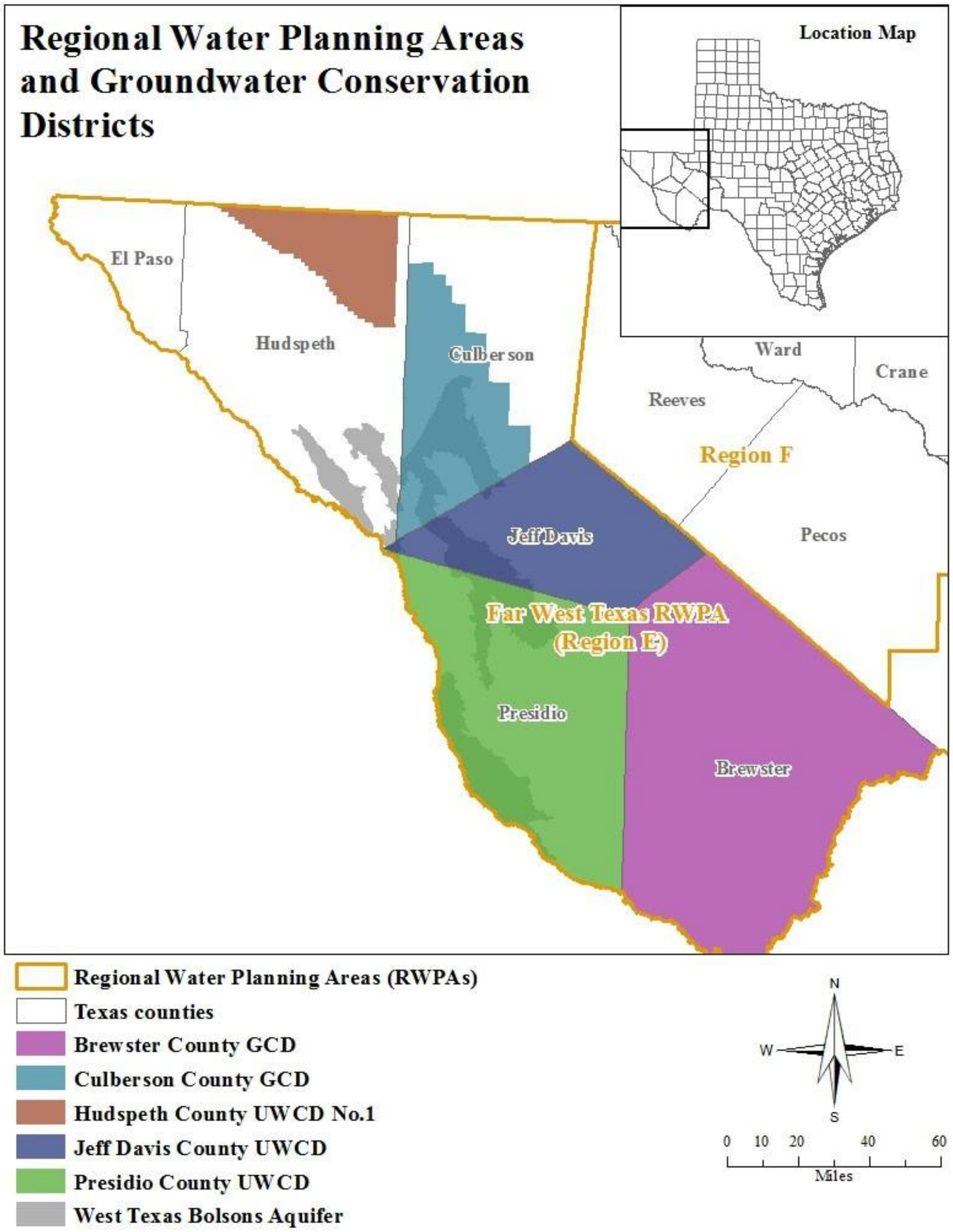

FIGURE 11. REGIONAL WATER PLANNING AREAS (RWPAS), GROUNDWATER CONSERVATION DISTRICTS (GCDS), UNDERGROUND WATER CONSERVATION DISTRICTS (UWCD) AND COUNTIES IN THE VICINITY OF THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

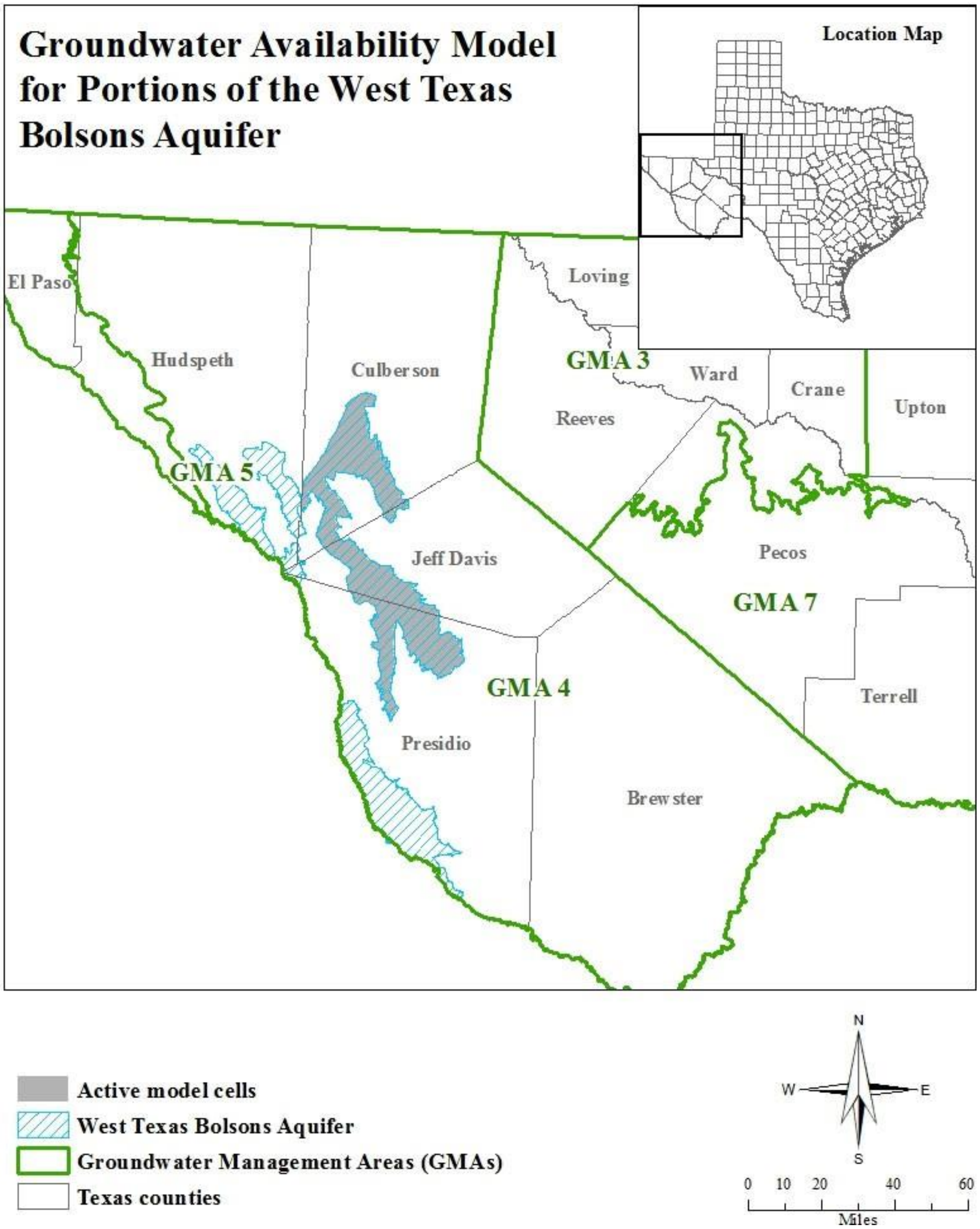

FIGURE 12. AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR WILD HORSE FLAT, MICHIGAN FLAT, RYAN FLAT, AND LOBO FLAT PORTIONS OF THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

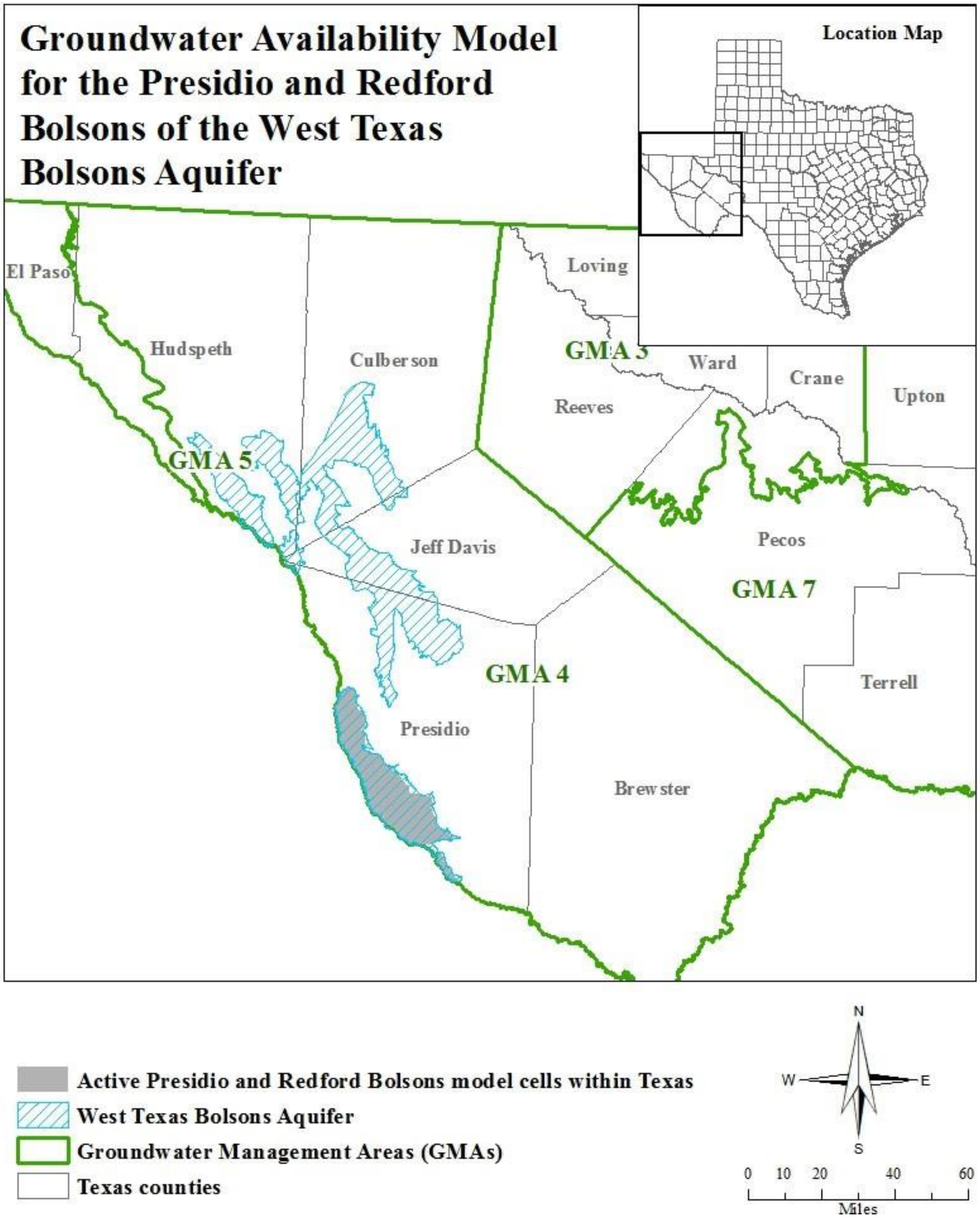

FIGURE 13. AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODEL FOR THE PRESIDIO AND REDFORD PORTIONS OF THE WEST TEXAS BOLSON AQUIFER IN GROUNDWATER MANAGEMENT AREA 4.

TABLE 11. MODELED AVAILABLE GROUNDWATER FOR THE WEST TEXAS BOLSONS AQUIFER IN GROUNDWATER MANAGEMENT AREA 4 SUMMARIZED BY GROUNDWATER CONSERVATION DISTRICT (GCD), UNDERGROUND WATER CONSERVATION DISTRICT (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	2060
Culberson County GCD	Culberson	Lobo Flat	11,112	11,112	11,097	11,092	11,087
		Wild Horse Flat	24,638	24,566	24,504	24,459	24,422
Culberson County GCD total			**35,750**	**35,678**	**35,601**	**35,551**	**35,509**
Jeff Davis County UWCD	Jeff Davis	Ryan Flat	6,056	6,056	5,989	5,961	5,942
Jeff Davis County UWCD total			**6,056**	**6,056**	**5,989**	**5,961**	**5,942**
Presidio County UWCD	Presidio	Ryan Flat	9,113	8,983	8,835	8,711	8,642
		Presidio and Redford Bolsons	7,661	7,661	7,661	7,661	7,661
Presidio County UWCD total			**16,774**	**16,644**	**16,496**	**16,372**	**16,303**
GMA 4 TOTAL			**58,580**	**58,378**	**58,086**	**57,884**	**57,754**

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 2080. VALUES ARE IN ACRE-FEET PER YEAR.

County	RWPA	River Basin	Aquifer Segment	2020	2030	2040	2050	2060	2070	2080
Culberson	E	Rio Grande	Lobo Flat	11,112	11,112	11,097	11,092	11,087	11,061	11,040
		Rio Grande	Wild Horse Flat	24,638	24,566	24,504	24,459	24,422	24,358	24,307
Culberson County total				**35,750**	**35,678**	**35,601**	**35,551**	**35,509**	**35,419**	**35,347**
Jeff Davis	E	Rio Grande	Ryan Flat	6,056	6,056	5,989	5,961	5,942	5,904	5,876
Jeff Davis County total				**6,056**	**6,056**	**5,989**	**5,961**	**5,942**	**5,904**	**5,876**
Presidio	E	Rio Grande	Ryan Flat	9,113	8,983	8,835	8,711	8,642	8,586	8,503
			Presidio and Redford	7,661	7,661	7,661	7,661	7,661	7,661	7,661
Presidio County total				**16,774**	**16,644**	**16,496**	**16,372**	**16,303**	**16,247**	**16,164**
GMA 4 TOTAL				**58,580**	**58,378**	**58,086**	**57,884**	**57,754**	**57,570**	**57,387**

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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