GAM Task 13-031: Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 8

by Jerry Shi, Ph.D., P.G., Robert G. Bradley, P.G., Shirley Wade, Ph.D., P.G., Ian Jones, Ph.D., P.G., Roberto Anaya, P.G., and Chelsea Seiter-Weatherford
Texas Water Development Board
Groundwater Resources Division
Jerry Shi: (512) 463-5076
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The seals appearing on this document were authorized by Jianyou (Jerry) Shi, P.G. 11113, Robert G. Bradley, P.G. 707, Shirley Wade, P.G. 525, Ian Jones, P.G. 477, Roberto Anaya, P.G. 480, and Cynthia K. Ridgeway, P.G. 471 on January 15, 2014. Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by Chelsea Seiter-Weatherford under her direct supervision.

The total estimated recoverable storage in this report was calculated as follows: the Trinity and Woodbine aquifers (Jerry Shi); Hickory, Ellenburger-San Saba, and Marble Falls aquifers (Robert G. Bradley); Brazos River Alluvium Aquifer (Shirley Wade); Edwards (Balcones Fault Zone) Aquifer (Ian Jones); Blossom Aquifer (Roberto Anaya); and Nacatoch Aquifer (Chelsea Seiter-Weatherford and Jerry Shi).

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INTRODUCTION:

As required by Texas Water Code § 36.108, the Texas Water Development Board (TWDB) shall provide the total estimated recoverable storage (TERS) for all of the aquifers in a groundwater management area as part of the process that groundwater conservation districts follow to develop its desired future conditions. This task report summarizes the calculation of the total estimated recoverable storage for the Hickory, Ellenburger-San Saba, Marble Falls, Trinity, Edwards (Balcones Fault Zone), Woodbine, Nacatoch, Blossom, and Brazos River Alluvium aquifers in Groundwater Management Area 8.

DEFINITION OF TOTAL ESTIMATED RECOVERABLE STORAGE:

The total estimated recoverable storage is defined as the estimated amount of groundwater in an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume, in other words, we assume that only 25 to 75 percent of groundwater held in an aquifer can be removed by pumping.

The total recoverable storage was estimated for the portion of each aquifer in Groundwater Management Area 8 within the official lateral aquifer boundaries as published in the TWDB Report 380 (George and others, 2011). Total estimated recoverable storage values may include a mixture of water quality types, including fresh, brackish, and saline groundwater, because the available data and the existing groundwater availability models do not permit the differentiation of different water quality types. These values do not take into account the

effects of land surface subsidence, degradation of water quality, or any changes to surface water-groundwater interaction that may occur due to pumping.

METHODS:

To estimate the total recoverable storage of an aquifer, the total storage of the aquifer within the official aquifer boundary was calculated first. The total storage is the volume of groundwater removed by pumping that completely drains the aquifer.

Aquifers can be either unconfined or confined (Figure 1). A well screened in an unconfined aquifer will have a water level equal to the water level outside the well. Thus, unconfined aquifers have water levels in the aquifers. A confined aquifer is bounded by low permeable geologic units at the top and bottom, and the aquifer is under hydraulic pressure above the ambient atmospheric pressure. The water level in a well screened in a confined aquifer will be above the top of the aquifer. As a result, calculation of total storage is different between unconfined and confined aquifers. For an unconfined aquifer, the total storage is equal to the volume of groundwater that makes the water level fall to the aquifer bottom. For a confined aquifer, the total storage contains two parts. The first part is the groundwater released from the aquifer when the water level falls from above the top of the aquifer to the top of the aquifer. The reduction of hydraulic pressure in the aquifer causes expansion of groundwater and deformation of aquifer solids. The aquifer is still fully saturated to this point. The second part, just like unconfined aquifer, is the groundwater released from the aquifer when the water level falls from the top to the bottom of the aquifer. Given the same aquifer area and water level drop, the amount of water released in the second part is much greater than the first part. The difference is quantified by two parameters: storativity related to confined aquifer and specific yield related to unconfined aquifer. For example, storativity values range from 10^{-5} to 10^{-3} for most confined aquifers, while the specific yield values can be 0.01 to 0.3 for most unconfined aquifers. The equations for calculating the total storage are presented below:

- for unconfined aquifers

$$Total\ Storage\ = V_{drained} = Area \times S_y \times (Water\ Level - Bottom)$$
$$= Area \times S_y \times \text{Aquifer Saturated Thickness}$$

- for confined aquifers

$$Total\ Storage\ = V_{confined} + V_{drained}$$

- confined part

$$V_{confined} = Area \times [\, S \times (Water\ Level - Top)]$$

or

$$V_{confined} = Area \times [\, S_s \times (\mathrm{Top} - \mathrm{Bottom}) \times (Water\ Level - Top)]$$

- unconfined part

$$V_{drained} = Area \times \left[S_y \times (Top - Bottom)\right]$$

where:

- $V_{drained}$ = storage volume due to water draining from the formation (acre-feet)
- $V_{confined}$ = storage volume due to elastic properties of the aquifer and water(acre-feet)
- *Area* = area of aquifer (acre)
- *Water Level* = groundwater elevation (feet above mean sea level)
- *Top* = elevation of aquifer top (feet above mean sea level)
- *Bottom* = elevation of aquifer bottom (feet above mean sea level)
- S_y = specific yield (no units)
- S_s = specific storage (1/feet)
- *S* = storativity or storage coefficient (no units)

As presented in the equations, calculation of the total storage requires data such as aquifer top, aquifer bottom, aquifer storativity (for confined conditions), aquifer specific yield (for unconfined conditions), and water level. If a groundwater availability model is available, then this information is extracted from the input and output files of the model on a cell-by-cell basis. If an aquifer is simulated as confined, then the specific yield is not included in the model input file and this value is estimated using other resources and documentation. A FORTRAN-90 program was developed and used to expedite the calculation. This approach was used for the total storage calculation of the Trinity, Edwards (Balcones Fault Zone), Woodbine, and Nacatoch aquifers.

For an aquifer without a groundwater availability model, the published geologic and hydrologic data were interpreted using SURFER™ or Esri® ArcGIS™ spatial analysis tool to develop the input data for the storage calculation. This approach was used for the total storage calculation of the Hickory, Ellenburger-San Saba, Marble Falls, Blossom, and Brazos River Alluvium aquifers.

After calculating the total aquifer storage, the total recoverable storage for the aquifer was calculated as the product of the total aquifer storage and an estimated factor ranging from 25 percent to 75 percent.

PARAMETERS AND ASSUMPTIONS:

HICKORY AQUIFER

- The Hickory Aquifer within Groundwater Management Area 8 is under unconfined conditions in outcrop and confined conditions in the subcrop areas.
- The water levels from the TWDB Groundwater Database (2013) were used to create the water level grid using Surfer® software.
- For the outcrop area, the base of the Hickory Aquifer from the Source Water Assessment Project (SWAP) data (United States Geological Survey, 2002b) was used to create the grid file using Surfer® software.
- For the subcrop area, the top and bottom of the Hickory Aquifer were from Standen and others (2007).
- The aquifer top and bottom averages for each county were calculated using zonal statistics from Esri® ArcGIS™ 10.1.
- The storage coefficient of the aquifer was estimated to be 1×10^{-5} which is within the range presented in Bluntzer (1992).
- The specific yield of the aquifer was estimated to be 0.03, based on porosity measurements presented in Bluntzer (1992).

ELLENBURGER-SAN SABA AQUIFER

- The Ellenburger-San Saba Aquifer within Groundwater Management Area 8 is under unconfined conditions in outcrop and confined conditions in the subcrop areas.
- The water levels from the TWDB Groundwater Database (2013) were used to create the water level grid using Surfer® software.
- For the outcrop area, the base of the Ellenburger-San Saba Aquifer from the Source Water Assessment Project (SWAP) data (United States Geological Survey, 2002a) was used to create the grid file using Surfer® software.

- For the subcrop area, the top and bottom elevations of the Ellenburger-San Saba Aquifer were from Standen and others (2007).
- The aquifer top and bottom averages for each county were calculated using zonal statistics from Esri® ArcGIS™ 10.1.
- The storage coefficient of the aquifer was assigned the value of 0.0022 (Bluntzer, 1992).
- The specific yield of the aquifer was estimated to be 0.03, based on porosity measurements presented in Bluntzer (1992).

MARBLE FALLS AQUIFER

- The Marble Falls Aquifer within Groundwater Management Area 8 is assumed to be under unconfined conditions.
- The average saturated thickness was estimated to be 80 feet based on available data (Texas Water Development Board, 2013; Texas Department of Licensing and Regulation, 2013).
- Like other carbonate rocks in the region studied by Bluntzer (1992), the specific yield for the Marble Falls Aquifer was estimated to be 0.03.

TRINITY AQUIFER

- Version 1.01 of the groundwater availability model for the northern portion of the Trinity and Woodbine aquifers (R.W. Harden & Associates, Inc. and others, 2004) was used to estimate the total recoverable storage for the Trinity Aquifer.
- This groundwater availability model includes seven layers which represent the Woodbine Aquifer (Layer 1), the Fredericksburg/Washita groups confining unit (Layer 2), the Paluxy Formation (Layer 3), the Glen Rose Formation confining unit (Layer 4), the Hensell Formation (Layer 5), the Pearsall/Cow Creek/Hammett/Sligo formations confining unit (Layer 6), and Hosston Formation (Layer 7). In some parts of the study area various combinations of the layers represent the Antlers Formation.
- Model layers 3, 4, 5, 6, and 7 were used to calculate the total estimated recoverable storage for the Trinity Aquifer.

EDWARDS (BALCONES FAULT ZONE) AQUIFER

- Version 1.01 of the groundwater availability model for the northern segment of the Edwards (Balcones Fault Zone) Aquifer (Jones, 2003) was used to estimate the total recoverable storage for the Edwards (Balcones Fault Zone) Aquifer.
- This groundwater availability model includes one layer which represents the Edwards (Balcones Fault Zone) Aquifer.

WOODBINE AQUIFER

- Version 1.01 of the groundwater availability model for the northern portion of the Trinity and Woodbine aquifers (R.W. Harden & Associates, Inc. and others, 2004) was used to estimate the total recoverable storage for the Woodbine Aquifer.
- This groundwater availability model includes seven layers which represent Woodbine Aquifer (Layer 1), the Fredericksburg/Washita groups confining unit (Layer 2), the Paluxy Formation (Layer 3), the Glen Rose Formation confining unit (Layer 4), the Hensell Formation (Layer 5), the Pearsall/Cow Creek/Hammett/Sligo formations confining unit (Layer 6), and Hosston Formation (Layer 7). In some parts of the study area various combinations of the layers represent the Antlers Formation.
- Model layer 1 was used to calculate the total estimated recoverable storage for the Woodbine Aquifer.

NACATOCH AQUIFER

- Version 1.01 of the groundwater availability model for the Nacatoch Aquifer (Beach and others, 2009) was used to estimate the total recoverable storage for the Nacatoch Aquifer.
- This groundwater availability model includes two layers which represent the Midway, alluvium and terrace deposits (Layer 1) and the Nacatoch Aquifer (Layer 2).
- Model layer 2 was used to calculate the total estimated recoverable storage for the Nacatoch Aquifer.

BLOSSOM AQUIFER

- The aquifer top and bottom elevations were based on interpretations from McLaurin (1988) and modified using spatial analysis of data from the United States Geological Survey digital elevation model (DEM), the Geologic Atlas of Texas, and the top of the Woodbine Formation as interpreted by R.W. Harden & Associates, Inc. and others (2004).
- Water elevation data were obtained from TWDB groundwater database downloads http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp in July 2013. To increase the number of control points used to interpret the average water level, data were selected from winter months between 2005 and 2010. Stream channel elevations were also used to further refine and add control points to the average water level interpretations.
- The spatially distributed saturated aquifer thickness and water level depth above the confined portion of the aquifer were calculated using the spatially interpreted top and bottom of the aquifer and the average 2005 to 2010 winter water level.
- The storativity values ranging from 0.000001 to 0.000112 and a specific yield value 0.2 were obtained from the Source-Water Assessment Program – Decision Support System (SWAP–DSS) database (Ulery and Others, 2011).
- The total estimated recoverable storage for each county were then calculated using spatial analysis tools within Esri® ArcGIS™ 10.2 software.

BRAZOS RIVER ALLUVIUM AQUIFER

- The Brazos River Alluvium Aquifer is under water table or unconfined conditions in most places (George and others, 2011).
- The thickness of the Brazos River Alluvium Aquifer was from data presented in Shah and Houston (2007).
- Water depth data were from TWDB groundwater database downloads http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp in July 2013. All available water depth data were used to calculate the average.
- The aquifer thickness averages for each county were then calculated using zonal statistics from Esri® ArcGIS™ 10.1.

- Average saturated aquifer thickness was then calculated using the average aquifer thickness subtracting the average water depth.
- The specific yield value of the aquifer was assigned a value of 0.15 according to Cronin and Wilson (1967).

RESULTS:

HICKORY AQUIFER

Figure 2 shows the official boundary of the Hickory Aquifer in Groundwater Management Area 8. Table 1 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. The total estimated recoverable storage for the Hickory Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 2.

ELLENBURGER-SAN SABA AQUIFER

Figure 3 shows the official boundary of the Ellenburger-San Saba Aquifer in Groundwater Management Area 8. Table 3 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. The total estimated recoverable storage for the Ellenburger-San Saba Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 4.

MARBLE FALLS AQUIFER

Figure 4 shows the official boundary of the Marble Falls Aquifer in Groundwater Management Area 8. Table 5 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. The total estimated recoverable storage for the Marble Falls Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 6.

TRINITY AQUIFER

Figure 5 shows the official boundary of the Trinity Aquifer and the active MODFLOW model cells to represent the aquifer. Table 7 represents the total estimated recoverable storage for the official aquifer in each county located in Groundwater Management Area 8. Figure 6 shows the

groundwater conservation districts associated with the Trinity Aquifer in Groundwater Management Area 8. The total estimated recoverable storage for the Trinity Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 8.

EDWARDS (BALCONES FAULT ZONE) AQUIFER

Figure 7 shows the official boundary of the Edwards (Balcones Fault Zone) Aquifer and the active MODFLOW model cells to represent the portion of the aquifer in Groundwater Management Area 8. Table 9 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. Figure 8 shows the groundwater conservation district associated with the Edwards (Balcones Fault Zone) Aquifer in Groundwater Management Area 8. The total estimated recoverable storage for the aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 10.

WOODBINE AQUIFER

Figure 9 shows the official boundary of the Woodbine Aquifer boundary and the active MODFLOW model cells to represent the aquifer in Groundwater Management Area 8. Table 11 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. Figure 10 shows the groundwater conservation districts associated with the Woodbine Aquifer in Groundwater Management Area 8. The total estimated recoverable storage for the Woodbine Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 12.

NACATOCH AQUIFER

Figure 11 shows the official boundary of the Nacatoch Aquifer and the active MODFLOW model cells to represent the aquifer in Groundwater Management Area 8. Table 13 represents the total estimated recoverable storage for the official aquifer in each county located in Groundwater Management Area 8. Figure 12 shows the groundwater conservation district associated with the Nacatoch Aquifer in Groundwater Management Area 8. The total estimated recoverable storage for the Nacatoch Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 14.

BLOSSOM AQUIFER

Figure 13 shows the official boundary of the Blossom Aquifer located in Groundwater Management Area 8. Table 15 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. The total estimated recoverable storage for the aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 16.

BRAZOS RIVER ALLUVIUM AQUIFER

Figure 14 shows the official boundary of the Brazos River Alluvium Aquifer in Groundwater Management Area 8. Table 17 represents the total estimated recoverable storage for the aquifer in each county located in Groundwater Management Area 8. The total estimated recoverable storage for the Brazos River Alluvium Aquifer by groundwater conservation district in Groundwater Management Area 8 is presented in Table 18.

LIMITATIONS

The groundwater models used in completing this analysis are the best available scientific tools 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."*

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.

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TABLE 1. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Brown	220,000	55,000	165,000
Burnet	6,600,000	1,650,000	4,950,000
Lampasas	2,800,000	700,000	2,100,000
Mills	630,000	157,500	472,500
Travis	33,000	8,250	24,750
Williamson	17,000	4,250	12,750
Total	**10,300,000**	**2,575,000**	**7,725,000**

TABLE 2. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	270,000	67,500	202,500
Central Texas GCD	6,600,000	1,650,000	4,950,000
Fox Crossing WD[1]	630,000	157,500	472,500
Saratoga UWCD[2]	2,800,000	700,000	2,100,000
Total	**10,300,000**	**2,575,000**	**7,725,000**

[1] WD = Water District

[2] UWCD = Underground Water Conservation District

TABLE 3. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Brown	420,000	105,000	315,000
Burnet	8,100,000	2,025,000	6,075,000
Lampasas	8,500,000	2,125,000	6,375,000
Mills	2,300,000	575,000	1,725,000
Total	**19,320,000**	**4,830,000**	**14,490,000**

TABLE 4. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	420,000	105,000	315,000
Central Texas GCD	8,100,000	2,025,000	6,075,000
Fox Crossing WD[3]	2,300,000	575,000	1,725,000
Saratoga UWCD[4]	8,500,000	2,125,000	6,375,000
Total	**19,320,000**	**4,830,000**	**14,490,000**

[3] WD = Water District
[4] UWCD = Underground Water Conservation District

TABLE 5. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE MARBLE FALLS AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Burnet	38,000	9,500	28,500
Lampasas	39,000	9,750	29,250
Total	**77,000**	**19,250**	**57,750**

TABLE 6. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE MARBLE FALLS AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Central Texas GCD	38,000	9,500	28,500
Saratoga GCD	39,000	9,750	29,250
Total	**77,000**	**19,250**	**57,750**

TABLE 7. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bell	59,000,000	14,750,000	44,250,000
Bosque	40,000,000	10,000,000	30,000,000
Brown	2,600,000	650,000	1,950,000
Burnet	11,000,000	2,750,000	8,250,000
Callahan	1,800,000	450,000	1,350,000
Collin	88,000,000	22,000,000	66,000,000
Comanche	8,300,000	2,075,000	6,225,000
Cooke	45,000,000	11,250,000	33,750,000
Coryell	34,000,000	8,500,000	25,500,000
Dallas	77,000,000	19,250,000	57,750,000
Delta	11,000,000	2,750,000	8,250,000
Denton	64,000,000	16,000,000	48,000,000
Eastland	1,600,000	400,000	1,200,000
Ellis	78,000,000	19,500,000	58,500,000
Erath	20,000,000	5,000,000	15,000,000
Falls	36,000,000	9,000,000	27,000,000
Fannin	79,000,000	19,750,000	59,250,000
Grayson	63,000,000	15,750,000	47,250,000
Hamilton	22,000,000	5,500,000	16,500,000
Hill	52,000,000	13,000,000	39,000,000
Hood	11,000,000	2,750,000	8,250,000
Hunt	12,000,000	3,000,000	9,000,000
Johnson	35,000,000	8,750,000	26,250,000
Kaufman	9,400,000	2,350,000	7,050,000

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Lamar	77,000,000	19,250,000	57,750,000
Lampasas	12,000,000	3,000,000	9,000,000
Limestone	11,000,000	2,750,000	8,250,000
McLennan	59,000,000	14,750,000	44,250,000
Milam	22,000,000	5,500,000	16,500,000
Mills	8,500,000	2,125,000	6,375,000
Montague	7,800,000	1,950,000	5,850,000
Navarro	39,000,000	9,750,000	29,250,000
Parker	22,000,000	5,500,000	16,500,000
Red River	44,000,000	11,000,000	33,000,000
Rockwall	4,900,000	1,225,000	3,675,000
Somervell	6,000,000	1,500,000	4,500,000
Tarrant	49,000,000	12,250,000	36,750,000
Taylor	630,000	157,500	472,500
Travis	39,000,000	9,750,000	29,250,000
Williamson	77,000,000	19,250,000	57,750,000
Wise	20,000,000	5,000,000	15,000,000
Total	**1,359,530,000**	**339,882,500**	**1,019,647,500**

TABLE 8. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. THE TOTAL ESTIMATED RECOVERABLE STORAGE VALUES BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR AN AQUIFER MAY NOT BE THE SAME BECAUSE THE NUMBERS HAVE BEEN ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	470,000,000	117,500,000	352,500,000
Central Texas GCD	11,000,000	2,750,000	8,250,000
Clearwater UWCD[5]	59,000,000	14,750,000	44,250,000
Fox Crossing Water District	8,500,000	2,125,000	6,375,000
Middle Trinity GCD	100,000,000	25,000,000	75,000,000
North Texas GCD	200,000,000	50,000,000	150,000,000
Northern Trinity GCD	49,000,000	12,250,000	36,750,000
Post Oak Savannah GCD	22,000,000	5,500,000	16,500,000
Prairielands GCD	170,000,000	42,500,000	127,500,000
Red River GCD	140,000,000	35,000,000	105,000,000
Saratoga UWCD	12,000,000	3,000,000	9,000,000
Southern Trinity GCD	59,000,000	14,750,000	44,250,000
Upper Trinity GCD	61,000,000	15,250,000	45,750,000
Total	**1,361,500,000**	**340,375,000**	**1,021,125,000**

[5] UWCD = Underground Water Conservation District

TABLE 9. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bell	11,000	2,750	8,250
Travis	5,900	1,475	4,425
Williamson	78,000	19,500	58,500
Total	**94,900**	**23,725**	**71,175**

TABLE 10. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. THE TOTAL ESTIMATED RECOVERABLE STORAGE VALUES BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR AN AQUIFER MAY NOT BE THE SAME BECAUSE THE NUMBERS HAVE BEEN ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	84,000	21,000	63,000
Clearwater UWCD[6]	11,000	2,750	8,250
Total	**95,000**	**23,750**	**71,250**

[6] UWCD = Underground Water Conservation District

TABLE 11. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE WOODBINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Collin	32,000,000	8,000,000	24,000,000
Cooke	1,200,000	300,000	900,000
Dallas	30,000,000	7,500,000	22,500,000
Denton	8,900,000	2,225,000	6,675,000
Ellis	25,000,000	6,250,000	18,750,000
Fannin	39,000,000	9,750,000	29,250,000
Grayson	32,000,000	8,000,000	24,000,000
Hill	6,700,000	1,675,000	5,025,000
Hunt	8,200,000	2,050,000	6,150,000
Johnson	4,500,000	1,125,000	3,375,000
Kaufman	4,700,000	1,175,000	3,525,000
Lamar	21,000,000	5,250,000	15,750,000
McLennan	900,000	225,000	675,000
Navarro	3,400,000	850,000	2,550,000
Red River	4,500,000	1,125,000	3,375,000
Rockwall	46,000	11,500	34,500
Tarrant	5,300,000	1,325,000	3,975,000
Total	**227,346,000**	**56,836,500**	**170,509,500**

TABLE 12. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE WOODBINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. THE TOTAL ESTIMATED RECOVERABLE STORAGE VALUES BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR AN AQUIFER MAY NOT BE THE SAME BECAUSE THE NUMBERS HAVE BEEN ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	72,000,000	18,000,000	54,000,000
North Texas GCD	42,000,000	10,500,000	31,500,000
Northern Trinity GCD	5,300,000	1,325,000	3,975,000
Prairielands GCD	36,000,000	9,000,000	27,000,000
Red River GCD	71,000,000	17,750,000	53,250,000
Southern Trinity GCD	900,000	225,000	675,000
Total	**227,200,000**	**56,800,000**	**170,400,000**

TABLE 13. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE NACATOCH AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bowie	2,100,000	525,000	1,575,000
Delta	100,000	25,000	75,000
Ellis	66	17	50
Franklin	7,300	1,825	5,475
Hopkins	330,000	82,500	247,500
Hunt	550,000	137,500	412,500
Kaufman	120,000	30,000	90,000
Lamar	12,000	3,000	9,000
Navarro	95,000	23,750	71,250
Rains	18,000	4,500	13,500
Red River	580,000	145,000	435,000
Rockwall	280	70	210
Total	**3,912,646**	**978,162**	**2,934,485**

TABLE 14. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE NACATOCH AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. THE TOTAL ESTIMATED RECOVERABLE STORAGE VALUES BY GROUNDWATER CONSERVATION DISTRICT AND COUNTY FOR AN AQUIFER MAY NOT BE THE SAME BECAUSE THE NUMBERS HAVE BEEN ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	3,900,000	975,000	2,925,000
Prairielands GCD	66	17	50
Total	**3,900,066**	**975,017**	**2,925,050**

TABLE 15. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE BLOSSOM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bowie	910,000	227,500	682,500
Lamar	970,000	242,500	727,500
Red River	5,200,000	1,300,000	3,900,000
Total	**7,080,000**	**1,770,000**	**5,310,000**

TABLE 16. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE BLOSSOM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	7,080,000	1,770,000	5,310,000
Total	**7,080,000**	**1,770,000**	**5,310,000**

TABLE 17. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE BRAZOS RIVER ALLUVIUM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

County	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
Bosque	9,600	2,400	7,200
Falls	160,000	40,000	120,000
Hill	6,600	1,650	4,950
McLennan	90,000	22,500	67,500
Milam	8,700	2,175	6,525
Total	**274,900**	**68,725**	**206,175**

TABLE 18. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT FOR THE BRAZOS RIVER ALLUVIUM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT FIGURES.

Groundwater Conservation District (GCD)	*Total Storage (acre-feet)*	*25 percent of Total Storage (acre-feet)*	*75 percent of Total Storage (acre-feet)*
No GCD	160,000	40,000	120,000
Middle Trinity GCD	9,600	2,400	7,200
Post Oak Savannah GCD	8,700	2,175	6,525
Prairielands GCD	6,600	1,650	4,950
Southern Trinity GCD	90,000	22,500	67,500
Total	**274,900**	**68,725**	**206,175**

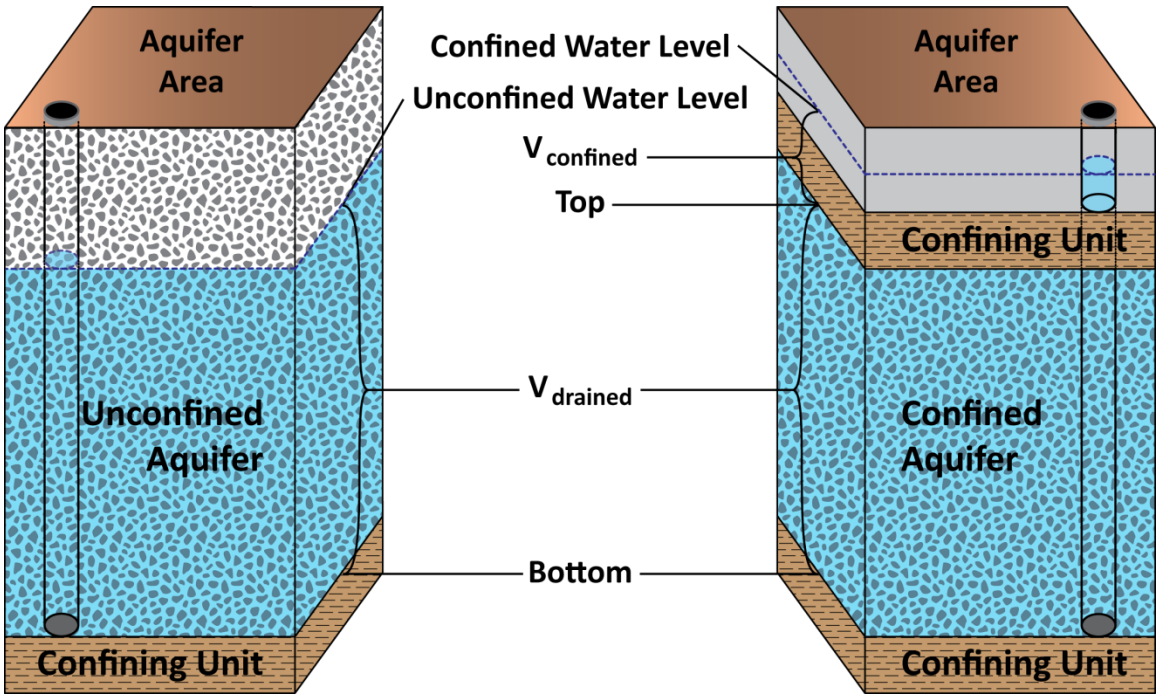

FIGURE 1. SCHEMATIC GRAPH SHOWING THE DIFFERENCE BETWEEN UNCONFINED AND CONFINED AQUIFERS.

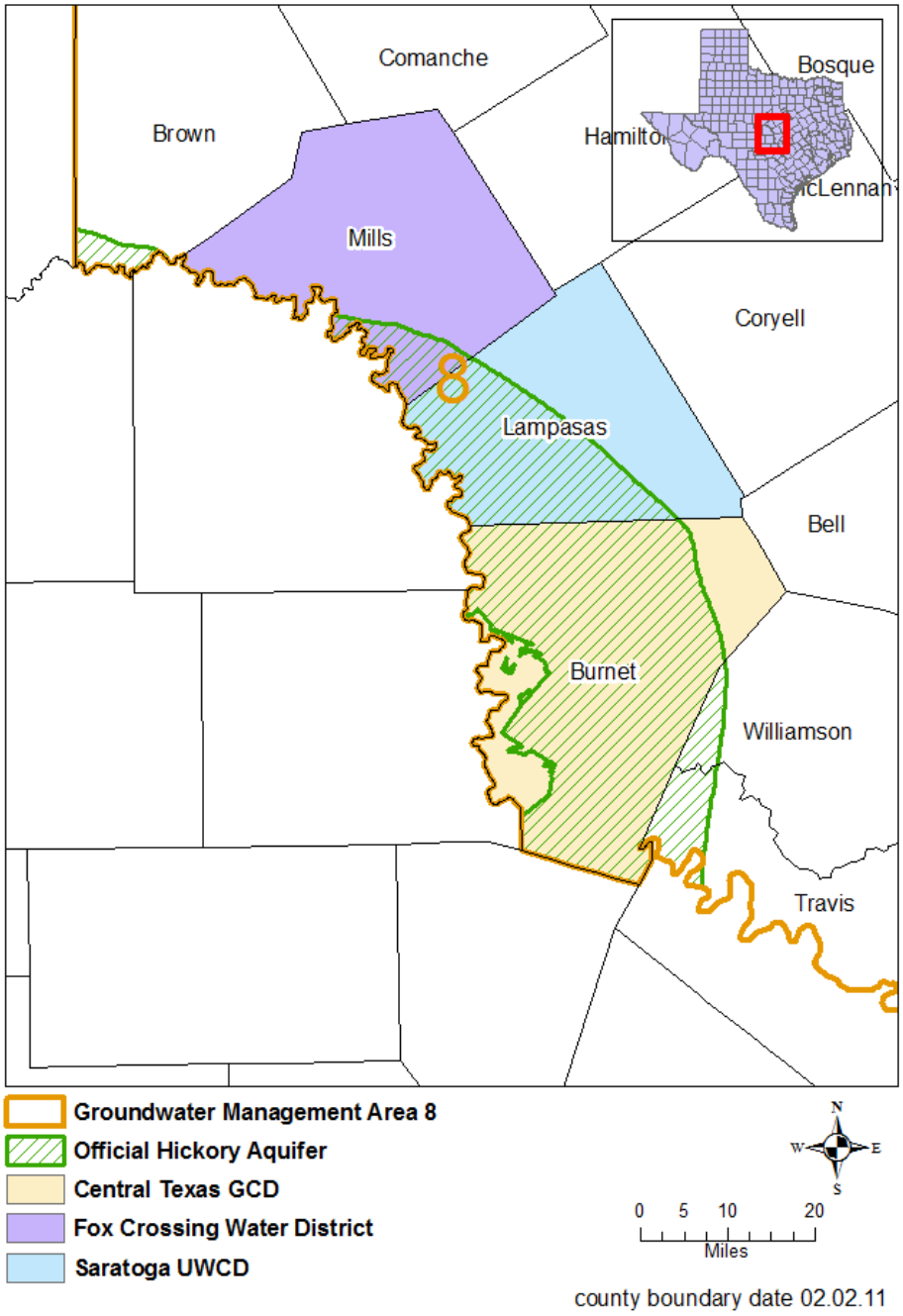

FIGURE 2. EXTENT OF THE HICKORY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

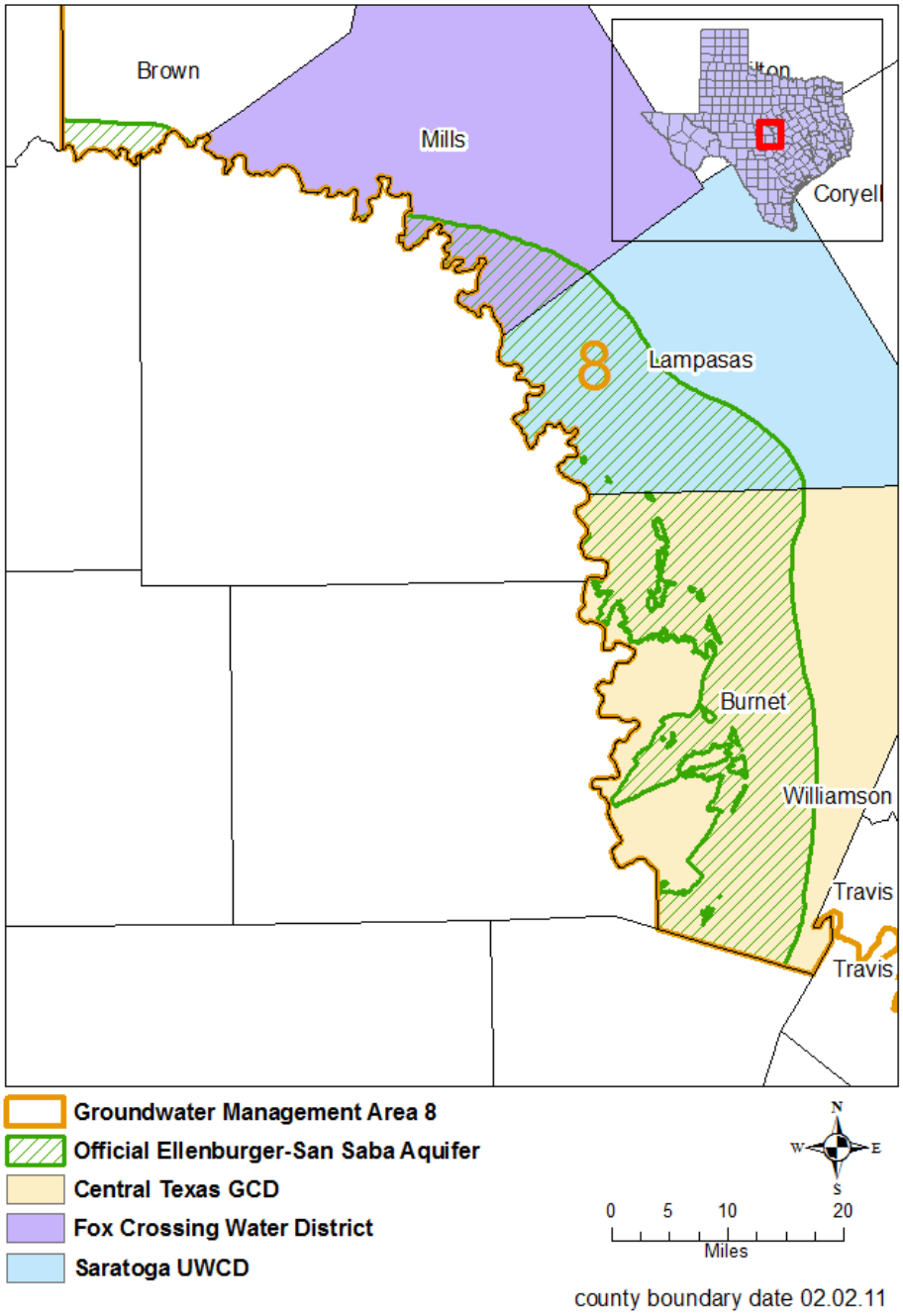

FIGURE 3. EXTENT OF THE ELLENBURGER-SAN SABA AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

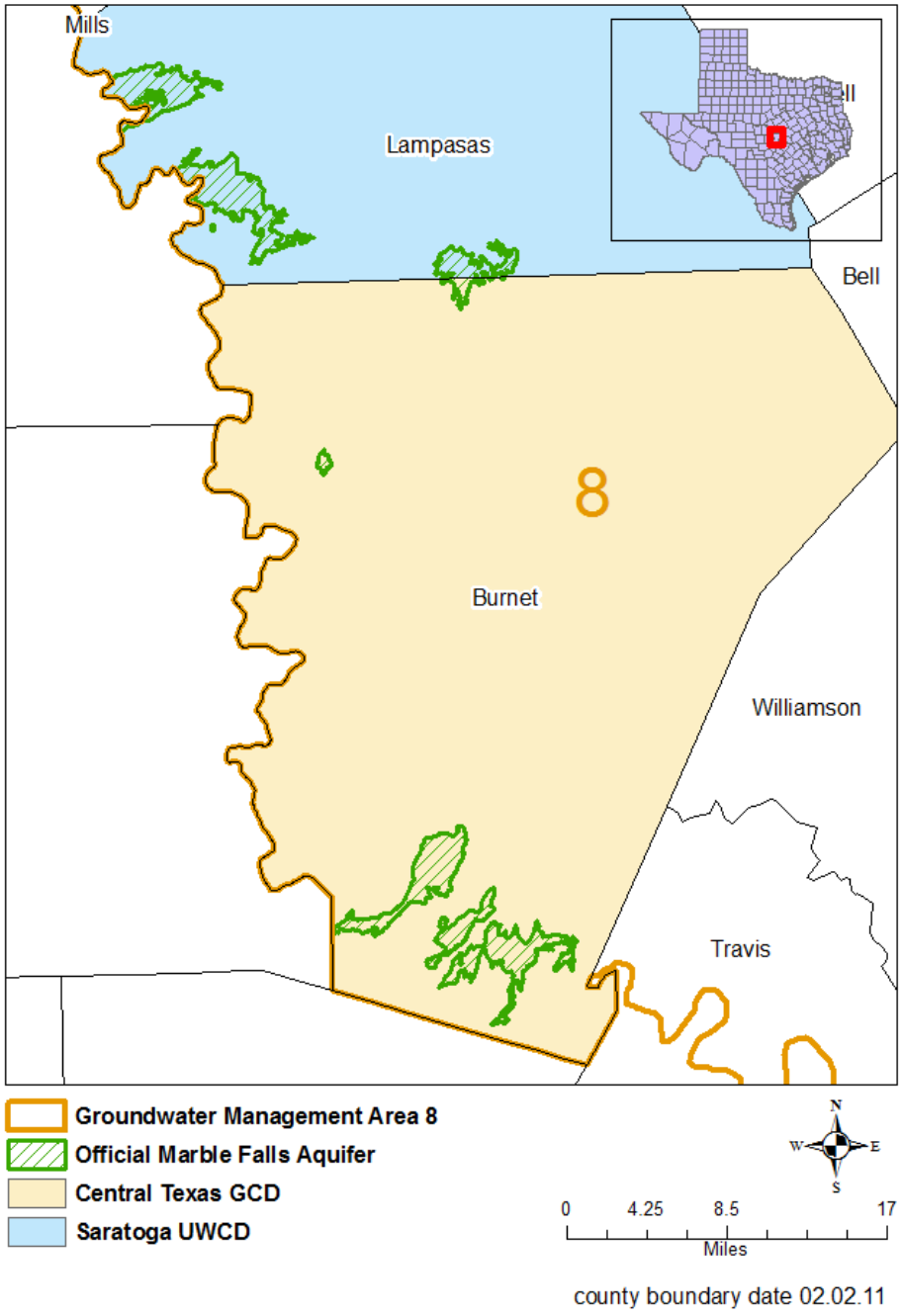

FIGURE 4. EXTENT OF THE MARBLE FALLS AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

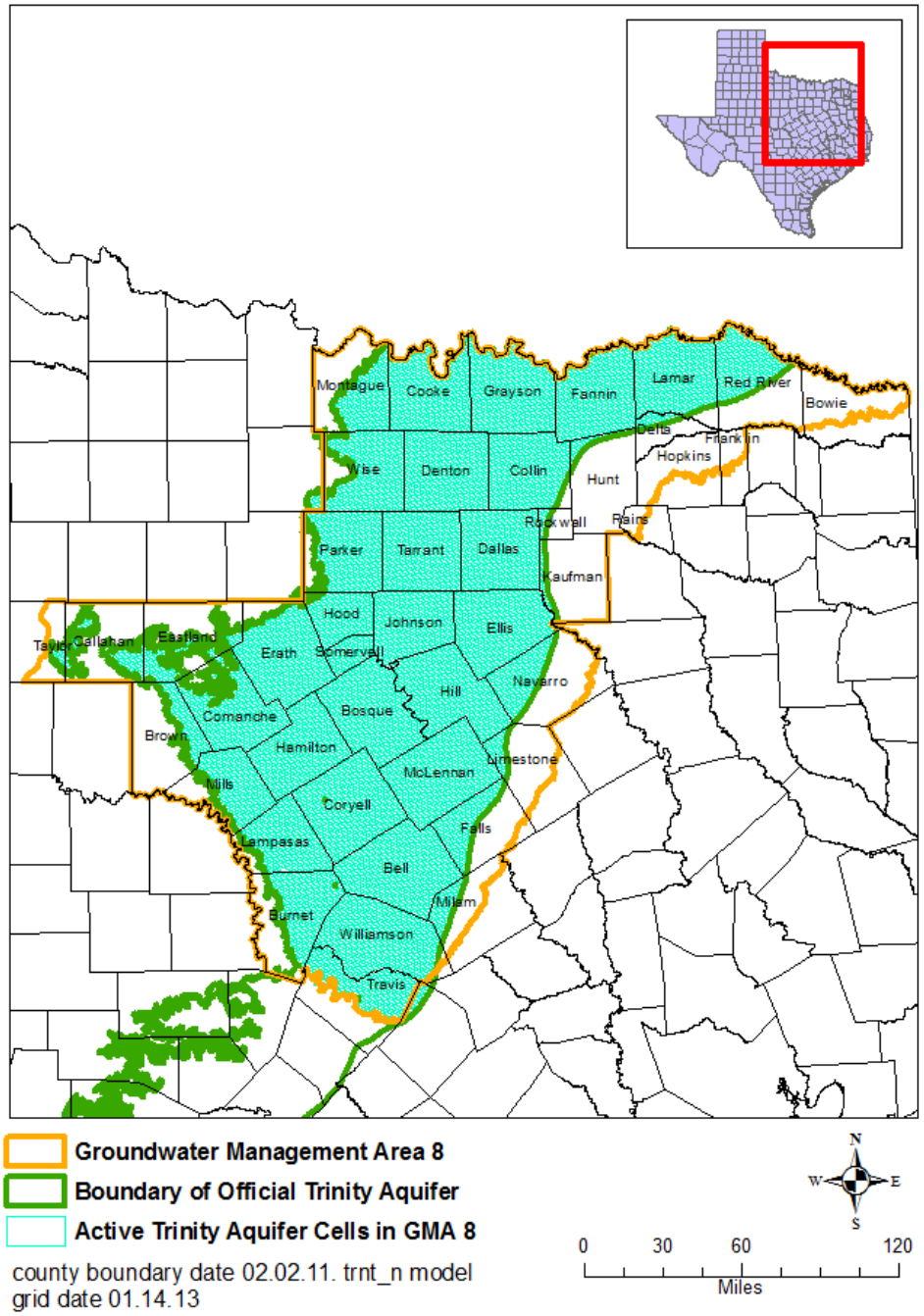

FIGURE 5. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE NORTH TRINITY AND WOODBINE AQUIFERS USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA (GMA) 8.

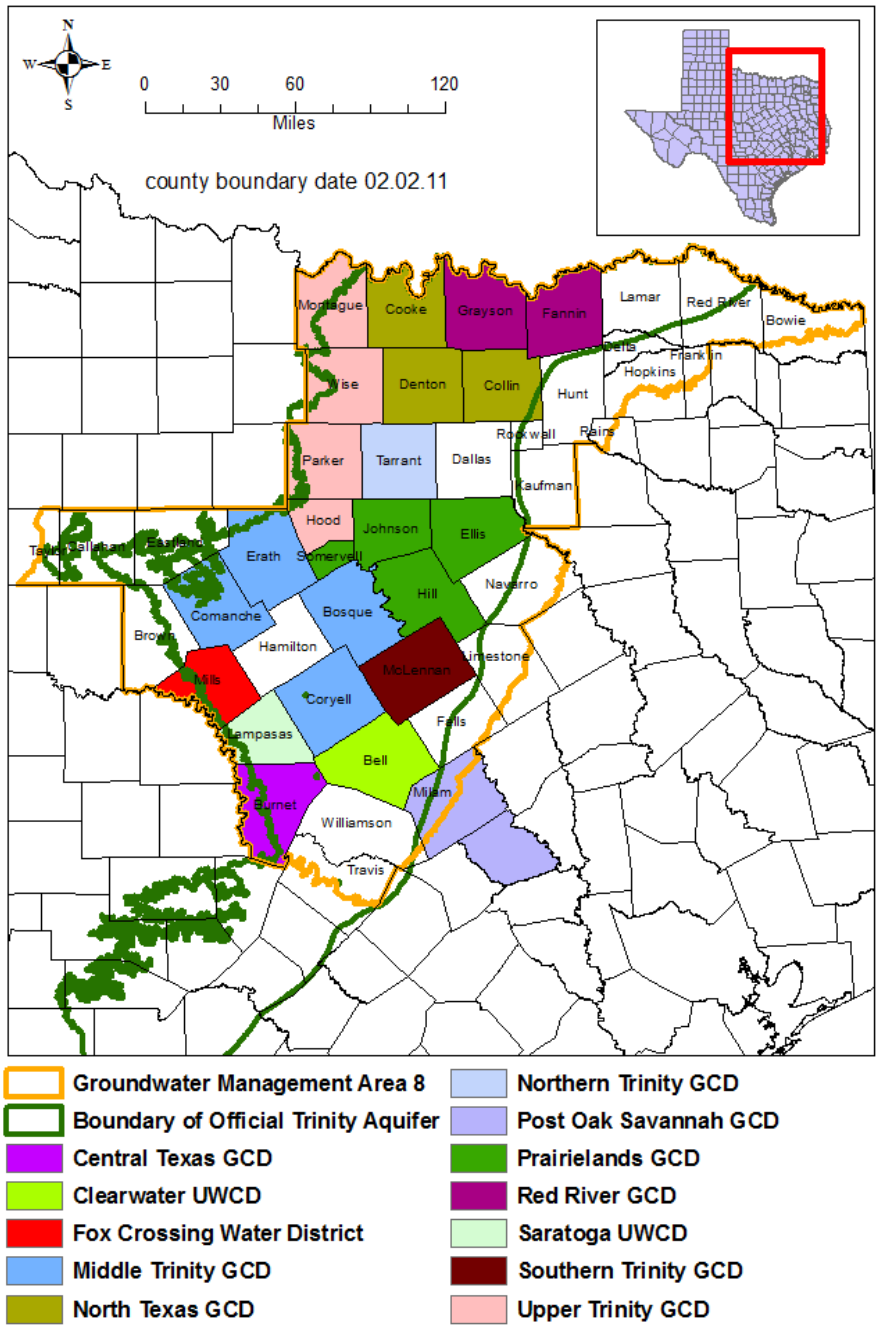

FIGURE 6. GROUNDWATER DISTRICTS ASSOCIATED WITH THE TRINITY AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

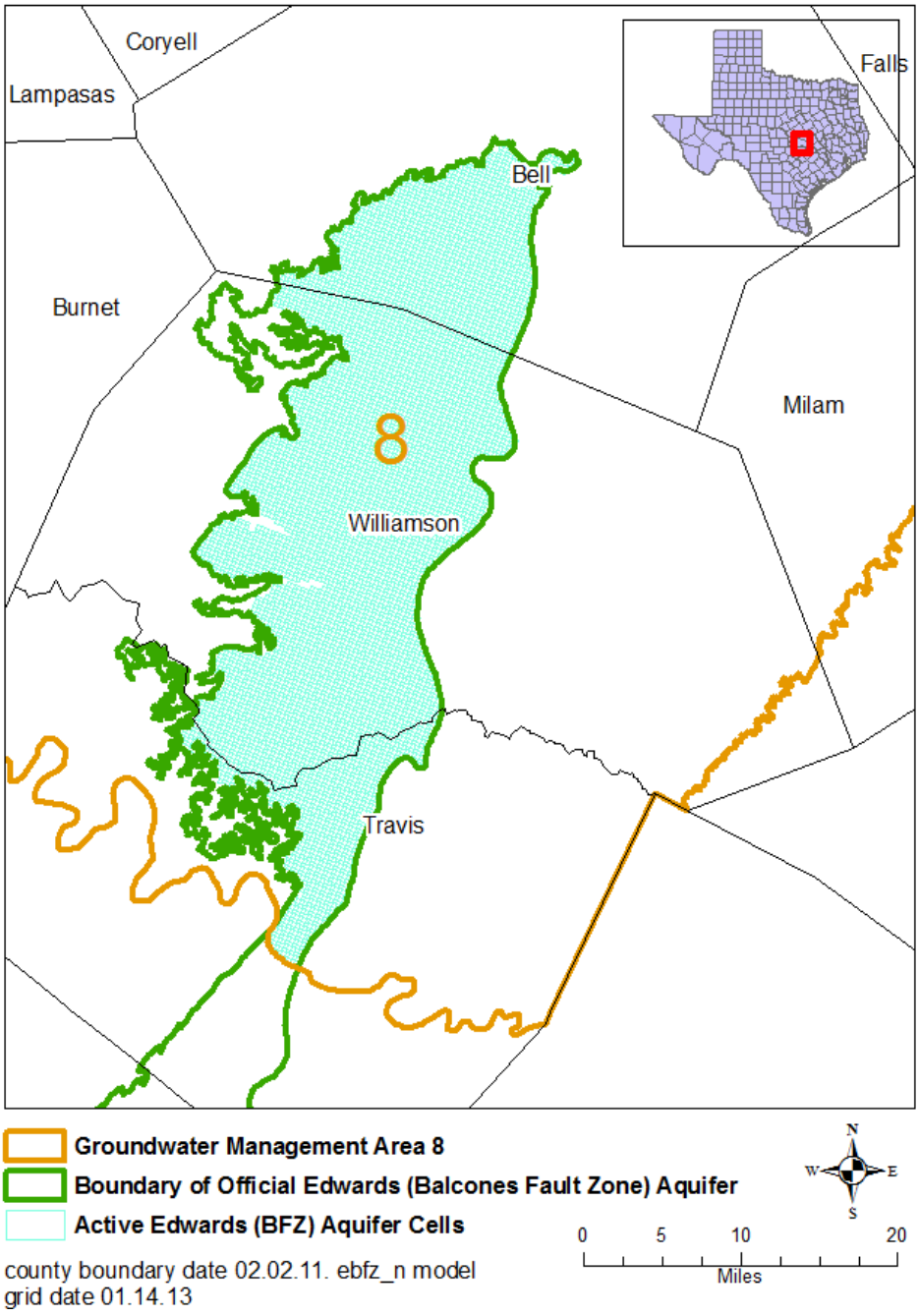

FIGURE 7. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE NORTHERN SEGMENT OF EDWARDS (BALCONES FAULT ZONE) AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

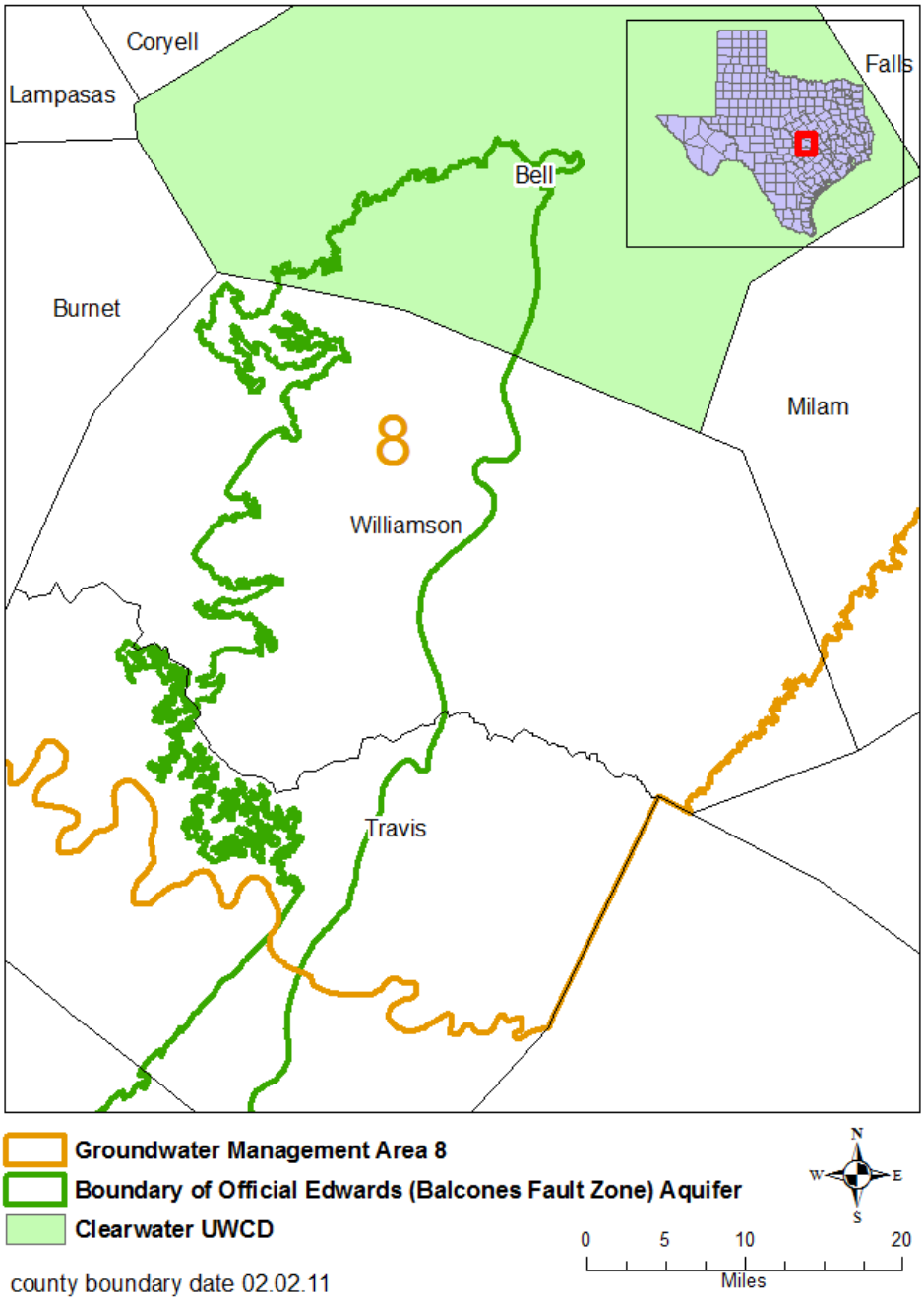

FIGURE 8. GROUNDWATER DISTRICT ASSOCIATED WITH THE EDWARDS (BALCONES FAULT ZONE) AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

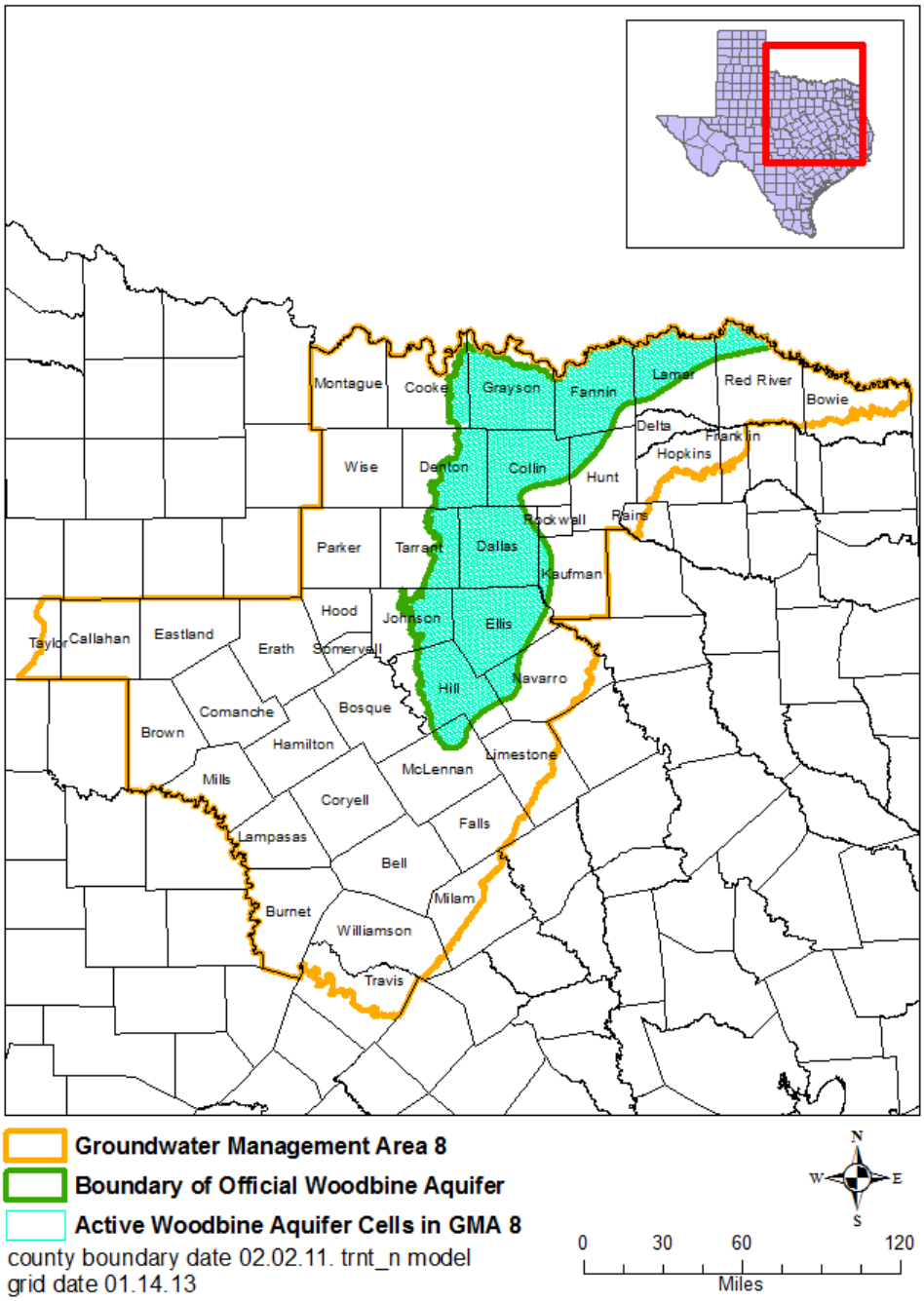

FIGURE 9. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE THE NORTHERN PORTION OF THE TRINITY AND WOODBINE AQUIFERS USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE WOODBINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

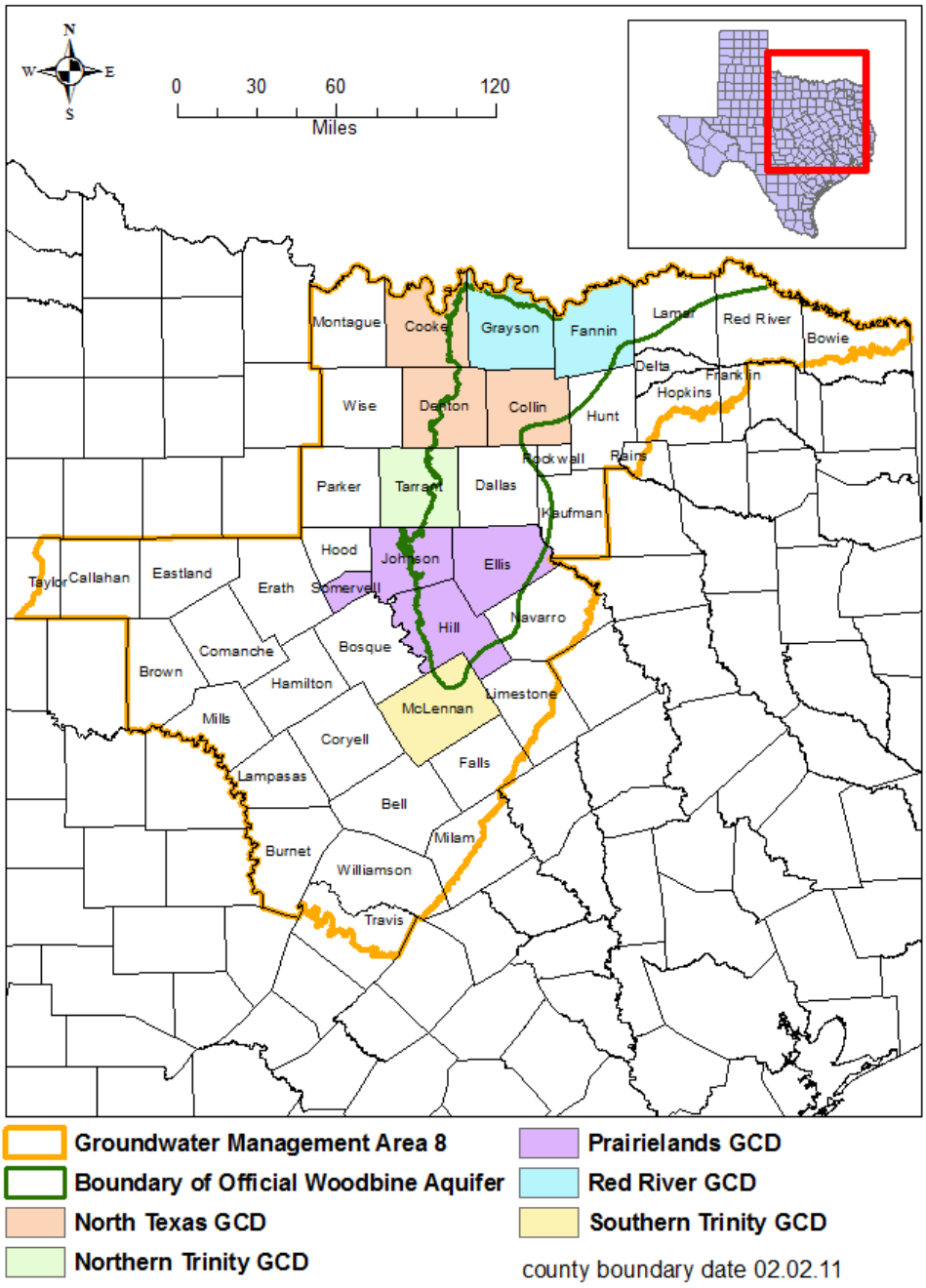

FIGURE 10. GROUNDWATER DISTRICT ASSOCIATED WITH THE WOODBINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

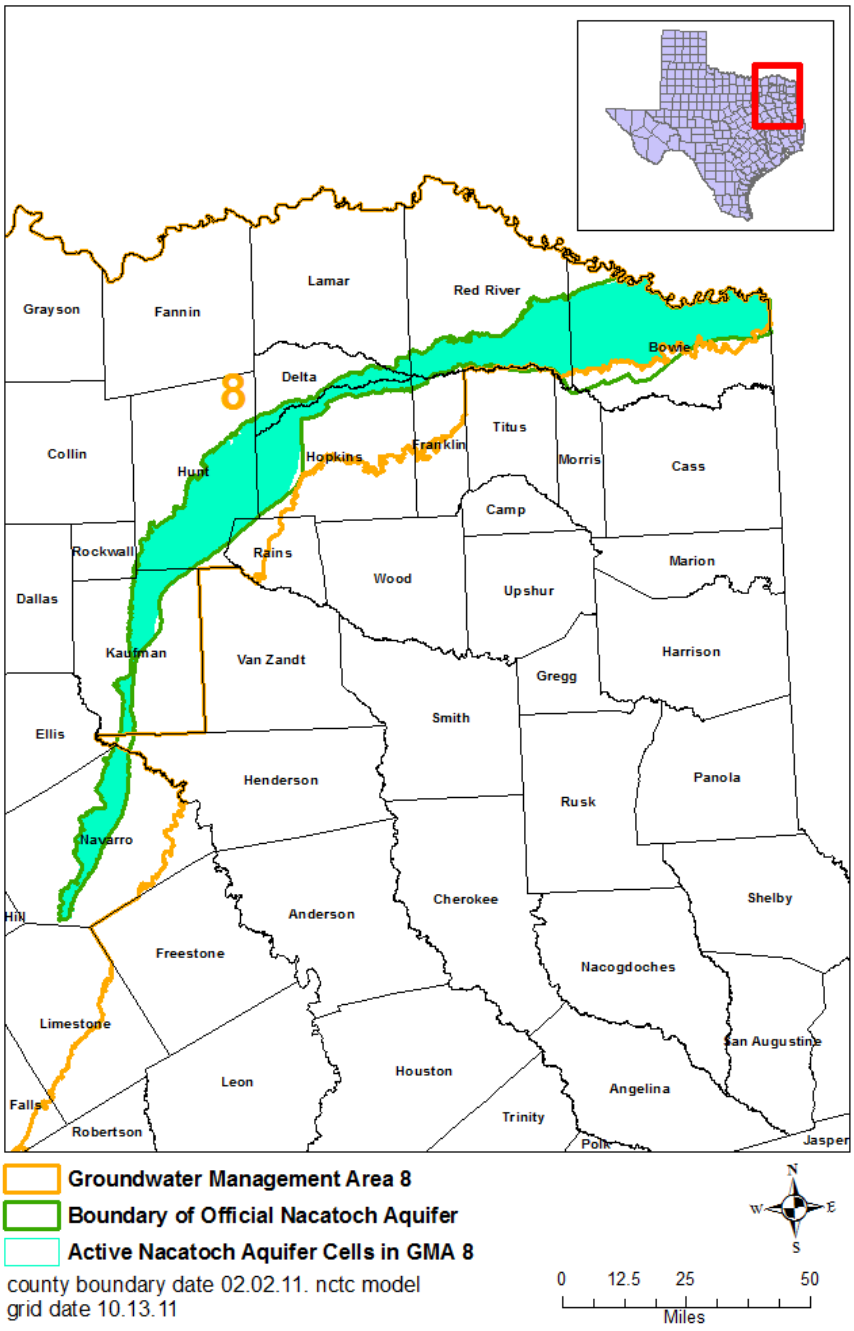

FIGURE 11. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE NACATOCH AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE NACATOCH AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

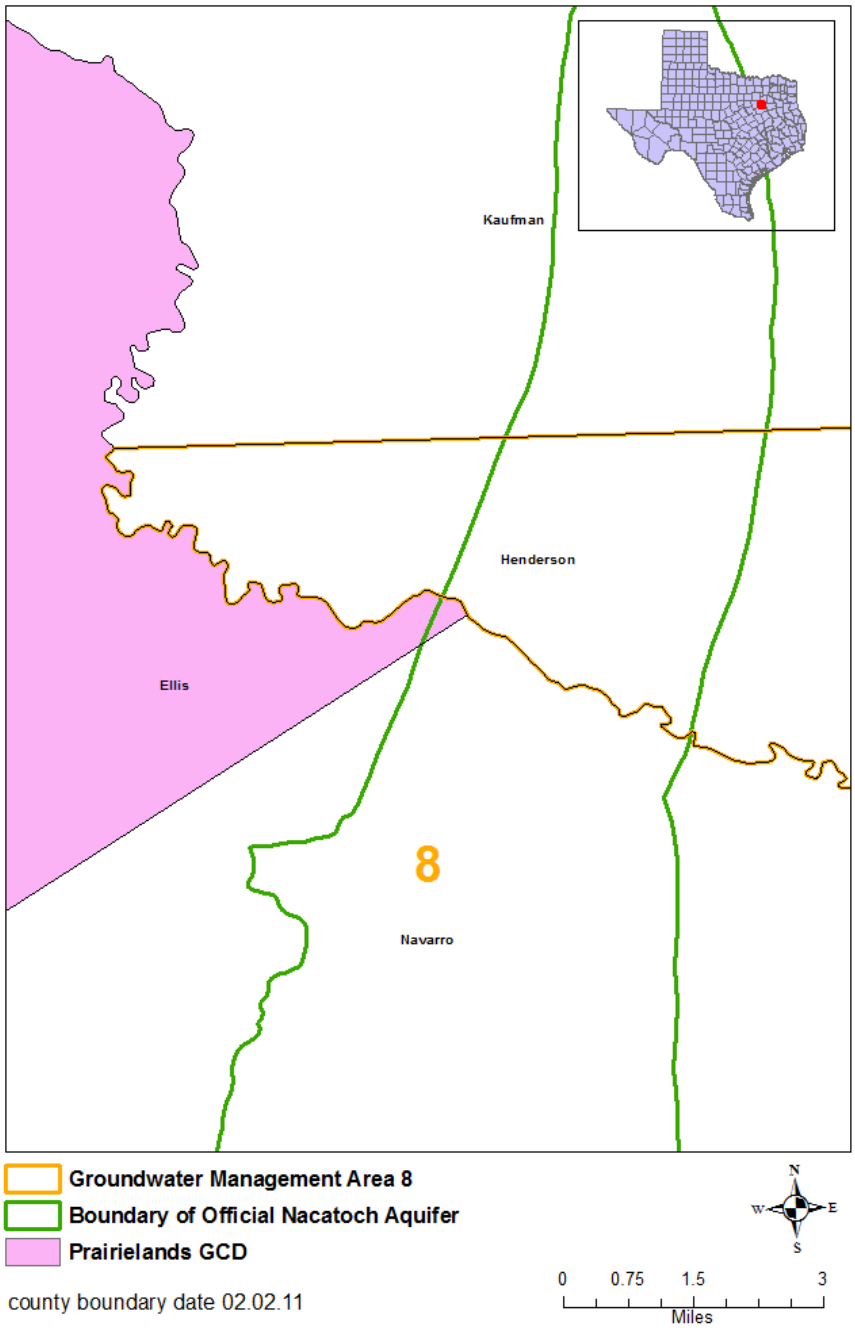

FIGURE 12. GROUNDWATER DISTRICT ASSOCIATED WITH THE NACATOCH AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

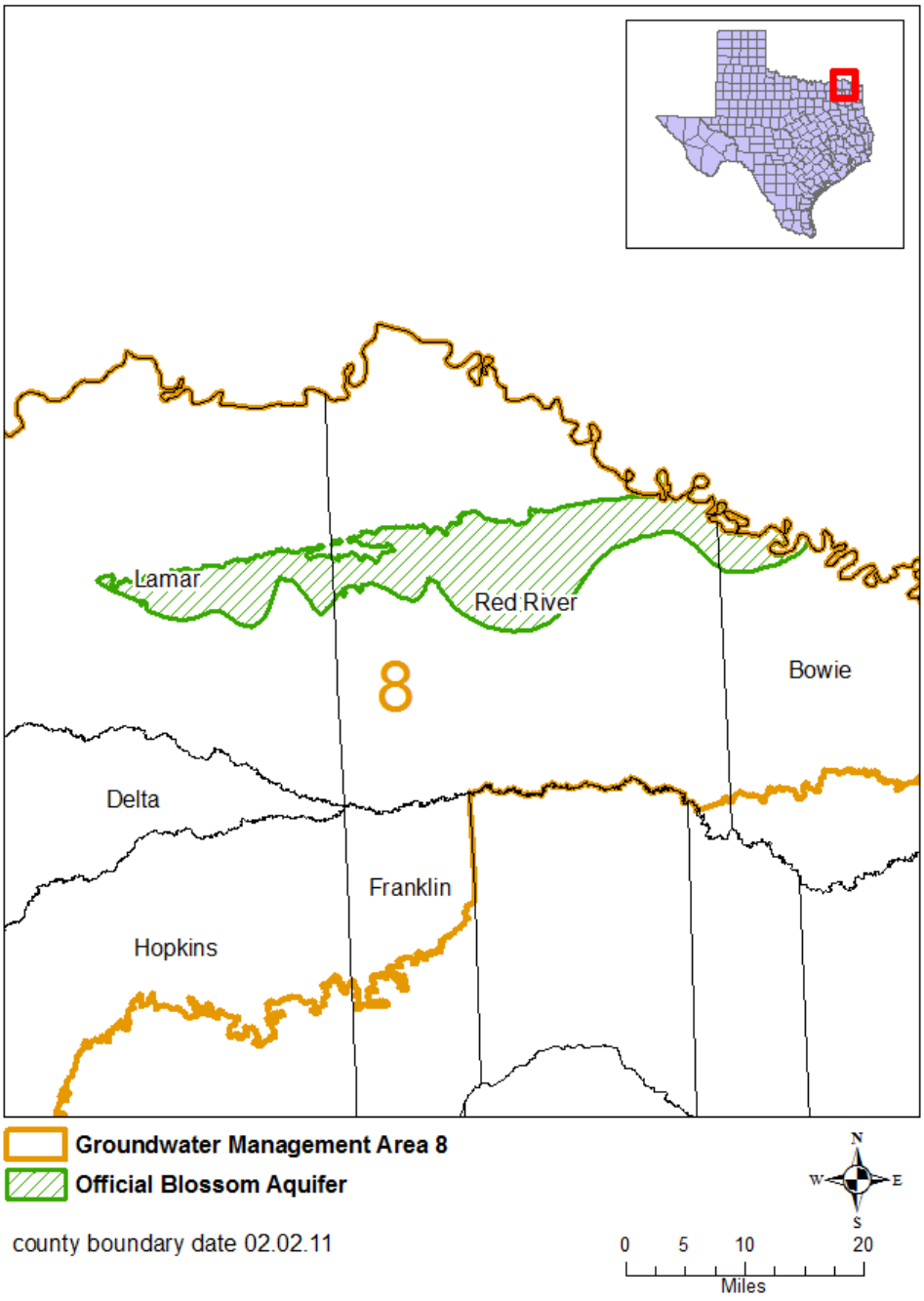

FIGURE 13. EXTENT OF THE BLOSSOM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.

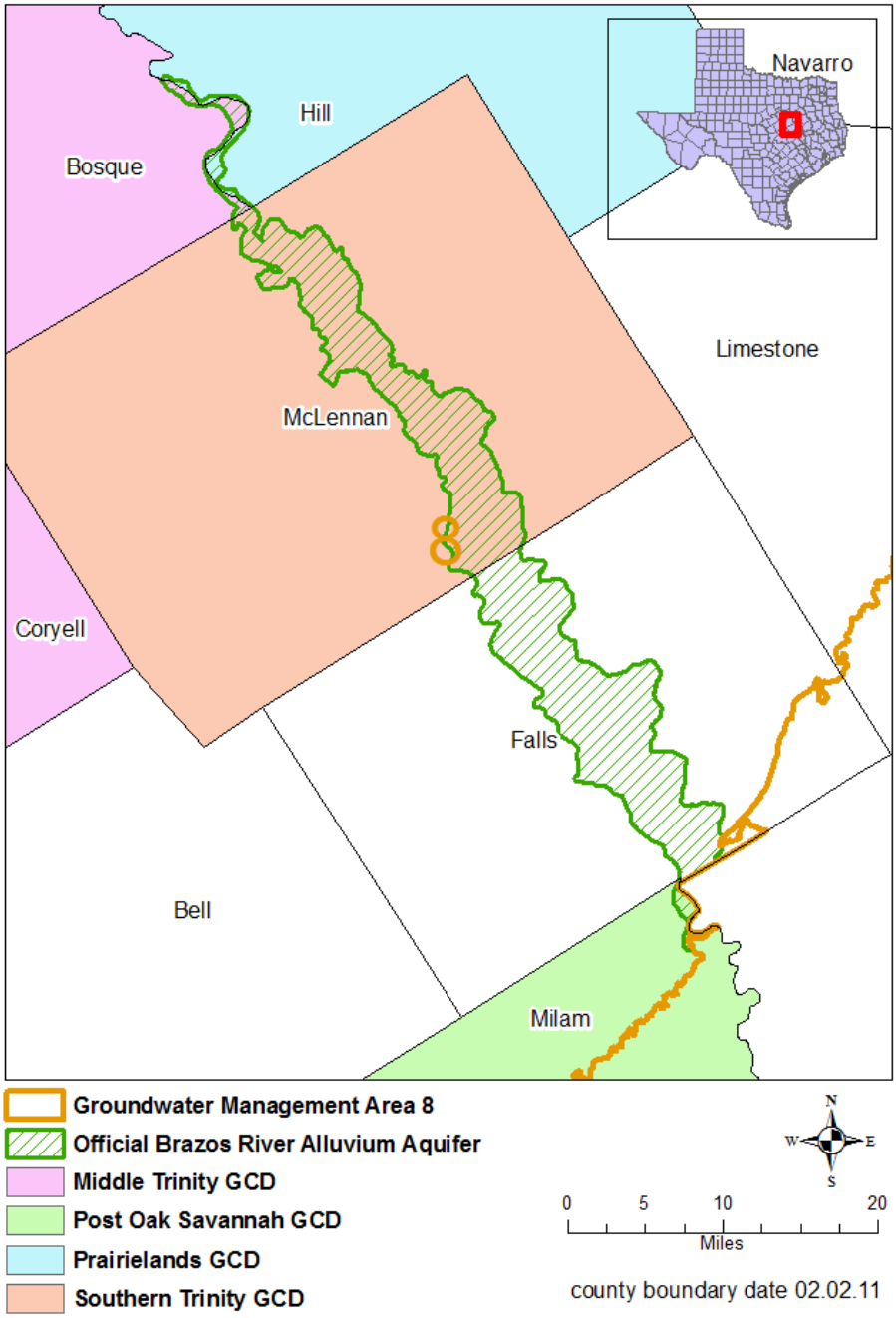

FIGURE 14. EXTENT OF THE BRAZOS RIVER ALLUVIUM AQUIFER IN GROUNDWATER MANAGEMENT AREA 8.