# GAM Task 13-036 (Revised): Total Estimated Recoverable Storage for Aquifers in Groundwater Management Area 13

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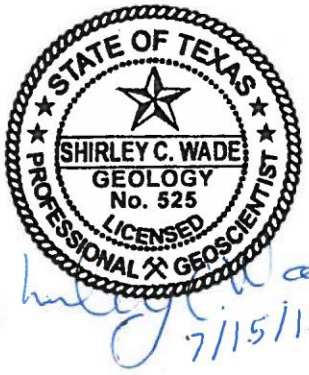
July 15, 2013





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# GAM TASK 13-036 (REVISED): TOTAL ESTIMATED RECOVERABLE STORAGE FOR AQUIFERS IN GROUNDWATER MANAGEMENT AREA 13

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## *EXECUTIVE SUMMARY:*

Texas Water Code, §36.108 (d) (Texas Water Code, 2011) states that, before voting on the proposed desired future conditions for a relevant aquifer within a groundwater management area, the groundwater conservation districts shall consider the total estimated recoverable storage as provided by the executive administrator of the Texas Water Development Board (TWDB) along with other factors listed in §36.108 (d). Texas Administrative Code Rule §356.10 (Texas Administrative Code, 2011) defines the total estimated recoverable storage as the estimated amount of groundwater within an aquifer that accounts for recovery scenarios that range between 25 percent and 75 percent of the porosity-adjusted aquifer volume.

This report discusses the methods, assumptions, and results of an analysis to estimate the total recoverable storage for the Trinity, Edwards (Balcones Fault Zone), Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, and Gulf Coast (including parts of the Catahoula Formation) aquifers within Groundwater Management Area 13. Tables 1 through 14 summarize the total estimated recoverable storage required by the statute. Figures 2 through 8 indicate the official extent of the aquifers in Groundwater Management Area 13 used to estimate the total recoverable storage.

## *DEFINITION OF TOTAL ESTIMATED RECOVERABLE STORAGE:*

The total estimated recoverable storage is defined as the estimated amount of groundwater within 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 within an aquifer can be removed by pumping.

The total recoverable storage was estimated for the portion of the aquifer within the official lateral aquifer boundaries as delineated by 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.

## *METHODS:*

To estimate the total recoverable storage of an aquifer, we first calculated the total storage in an aquifer within the official aquifer boundary. 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 or in the aquifer. Thus, unconfined aquifers have water levels within 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 at a well screened in a confined aquifer will be above the top of the aquifer. As a result, calculation of total storage is also different between unconfined and confined aquifers. For an unconfined aquifer, the total storage is equal to the volume of groundwater removed by pumping 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 by pumping 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

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

- 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)

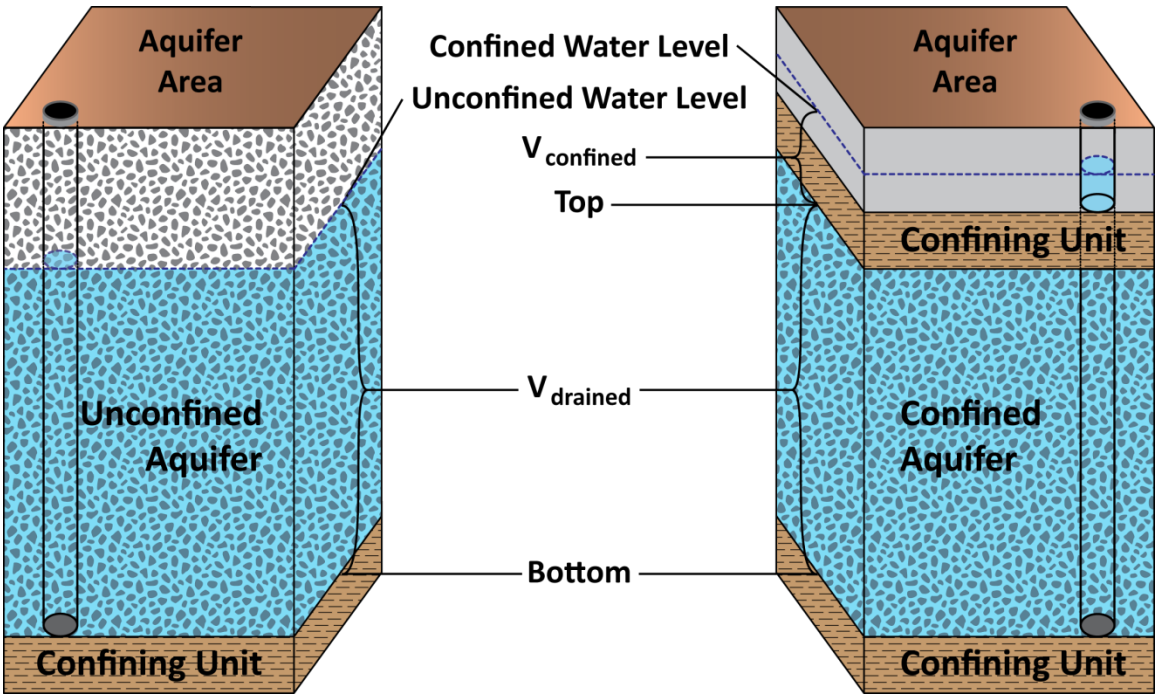


**FIGURE 1. SCHEMATIC GRAPH SHOWING THE DIFFERENCE BETWEEN UNCONFINED AND CONFINED AQUIFERS.**

As presented in the equations, calculation of the total storage requires data, such as aquifer top, aquifer bottom, aquifer storage properties, and water level. For the Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, and Catahoula Formation (part of the Gulf Coast Aquifer System) in Groundwater Management Area 13, we extracted this information from existing groundwater availability model input and output files on a cell-by-cell basis. For aquifers without groundwater availability model(s), an analogous approach is used. For the Trinity Aquifer in Groundwater Management Area 13 we used Surfer® software to create surfaces for the water level, top of aquifer, and base of aquifer, using existing data or references. We then used these surfaces to make the volume calculations based on published estimates of storage coefficient and specific yield. Finally, the total recoverable storage was calculated as the product of the total storage and an estimated factor ranging from 25 percent to 75 percent.

## *PARAMETERS AND ASSUMPTIONS:*

### *Trinity Aquifer*

- The Trinity Aquifer within Groundwater Management Area 13 is under confined conditions throughout the area.
- The potentiometric surface is based on the water-level measurements from several sources (Holt, C.L.R, 1956, p.129; Welder and Reeves, 1962, p. 129; TWDB, 2013, and Texas Department of Licensing and Regulation, 2013). Because all of the measurements are located north of the study area and not within the Groundwater Management Area 13 area, an estimate of the head at the southern boundary was made using the head gradient from the available water levels. These estimates were included with the water-level measurements to create a potentiometric surface grid in Surfer® software to calculate the total head above the top of the aquifer.
- We used the base of the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer from the associated groundwater availability model (Lindgren and others, 2004) as the top of the Trinity Aquifer within the area. The base of the Trinity Aquifer is from Plate 4 in Flawn and others (1961). These surfaces were created as grids in Surfer® software and used to calculate aquifer thickness.
- No storage data was discovered for the area, but because the calculations include all of the Trinity Aquifer as a whole, we used conservative estimates for a storage coefficient of $1 \times 10^{-5}$ and a specific yield of 0.01 based on Trinity Aquifer references (Johnson, 1967; Jones and others, 2009; Hunt and others, 2010).
- The confined volume is calculated by taking the difference in the potentiometric surface and top of the Trinity Aquifer to estimate total estimated head. This value is multiplied by a storage coefficient of $1 \times 10^{-5}$ resulting in the total storage volume for the portion above the top of the aquifer.
- The unconfined drained volume is calculated by taking the aquifer thickness and multiplied by a specific yield of 0.01.
- Zonal statistics in ArcMap 10.1 software summed the data from grid calculations by county.

### *Edwards (Balcones Fault Zone) Aquifer*

- We used version 1.01 of the groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer to estimate the total recoverable storage for the aquifer. See Lindgren and others (2004) for assumptions and limitations of the groundwater availability model.
- This groundwater availability model includes one layer which represents the Edwards (Balcones Fault Zone) Aquifer.
- The confined portion of the Edwards (Balcones Fault Zone) Aquifer includes water ranging in total dissolved solids concentration from 250 milligrams per liter (mg/L) to more than 250,000 mg/L (Lindgren and others, 2004). The down-dip boundary of the model is based on the 10,000 mg/L total dissolved solids concentration line and is assumed to represent the limit of groundwater flow in the confined zone of the aquifer (Lindgren and others, 2004).

### *Carrizo-Wilcox, Queen City, and Sparta aquifers*

- We used version 2.01 of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers to estimate the total recoverable storage for the Carrizo-Wilcox, Queen City, and Sparta aquifers. See Deeds and others (2003) and Kelley and others (2004) for assumptions and limitations of the groundwater availability model.
- This groundwater availability model includes eight layers which generally represent the Sparta Aquifer (Layer 1), the Weches Confining Unit (Layer 2), the Queen City Aquifer (Layer 3), the Reklaw Confining Unit (Layer 4), the Carrizo Aquifer (Layer 5), the Upper Wilcox Formation (Layer 6), the Middle Wilcox Formation (Layer 7), and the Lower Wilcox Formation (Layer 8). To develop the estimates for the total estimated recoverable storage, we used Layer 1 (Sparta Aquifer), Layer 3 (Queen City Aquifer), and Layers 5 through 8 (Carrizo-Wilcox Aquifer system).
- The down-dip boundary of the model is based on the location of the Wilcox Growth Fault Zone, which is considered to be a barrier to flow (Kelley and others, 2004). This boundary is relatively deep and in the portion of the aquifer that is characterized as brackish to saline; consequently, the model includes parts of the formation beyond

potable portions of the aquifer. The groundwater in the official extent of the Carrizo-Wilcox, Queen City, and Sparta aquifers ranges from fresh to brackish in composition (Kelley and others, 2004).

### *Yegua-Jackson Aquifer and the Catahoula Formation portion of the Gulf Coast Aquifer System*

- We used version 1.01 of the groundwater availability model for the Yegua-Jackson Aquifer to estimate the total recoverable storages of the Yegua-Jackson Aquifer and parts of the Catahoula Formation. See Deeds and others (2010) for assumptions and limitations of the groundwater availability model.
- This groundwater availability model includes five layers which represent the outcrop section for the Yegua-Jackson Aquifer and the Catahoula Formation and other younger overlying units (Layer 1), the upper portion of the Jackson Group (Layer 2), the lower portion of the Jackson Group (Layer 3), the upper portion of the Yegua Group (Layer 4), and the lower portion of the Yegua Group (Layer 5). To develop the estimates for the total estimated recoverable storage in the Yegua-Jackson Aquifer, we used layers 1 through 5; however, we only used model cells in Layer 1 that represent the outcrop area of the Yegua-Jackson Aquifer. We also used selected model cells in Layer 1 to develop the estimates for the total estimated recoverable storage in the Catahoula Formation, which is considered part of the Gulf Coast Aquifer system, for Zapata County as the groundwater availability models for the Gulf Coast Aquifer System did not fully model this area.
- The down-dip boundary for the Yegua-Jackson Aquifer in this model was set to approximately coincide with the extent of the available geologic data, well beyond any active portion (groundwater use) of the aquifer (Deeds and others, 2010). Consequently, the model extends into zones of brackish and saline groundwater. The groundwater in the official extent of the Yegua-Jackson Aquifer ranges from fresh to brackish in composition (Deeds and others, 2010).

### *Gulf Coast Aquifer*

- We use version 1.01 of the groundwater availability model for the central portion of the Gulf Coast Aquifer System for this analysis for Gonzales County. See Chowdhury and others (2004) and Waterstone and others (2003) for assumptions and limitations of the groundwater availability model.
- The model for the central portion of the Gulf Coast Aquifer System assumes partially penetrating wells in the Evangeline Aquifer due to a lack of data for aquifer properties in the deeper section of the aquifer located closer to the Gulf of Mexico.
- This groundwater availability model includes four layers, which generally represent the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer including parts of the Catahoula Formation (Layer 4).
- As depicted by Kalaswad and Arroyo (2006), groundwater in the Gulf Coast Aquifer System ranges from fresh to saline. The reported values in this report for flow terms include fresh (less than 1,000 milligrams per liter total dissolved solids) and brackish (1,000 to 10,000 milligrams per liter total dissolved solids) groundwater.

## *RESULTS:*

Tables 1 through 14 summarize the total estimated recoverable storage required by statute. The county and groundwater conservation district total estimates are rounded to two significant digits. Figure 2 indicates the extent of the Trinity Aquifer in Groundwater Management Area 13 used to estimate the total recoverable storage information. Figures 3 through 8 indicate the extent of the groundwater availability models in Groundwater Management Area 13 for the Edwards (Balcones Fault Zone), Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson aquifers, and Gulf Coast Aquifer System, from which the storage information was extracted.

**TABLE 1. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE TRINITY AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 35,000 | 8,750 | 26,250 |
| Bexar | 660,000 | 165,000 | 495,000 |
| Medina | 3,900,000 | 975,000 | 2,925,000 |
| Uvalde | 110,000 | 27,500 | 82,500 |
| Total | 4,705,000 | 1,176,250 | 3,528,750 |

**TABLE 2. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[1] FOR THE TRINITY AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| No District | 660,000 | 165,000 | 495,000 |
| Evergreen UWCD[2] | 35,000 | 8,750 | 26,250 |
| Medina County GCD | 3,900,000 | 975,000 | 2,925,000 |
| Uvalde County UWCD | 110,000 | 27,500 | 82,500 |
| Total | 4,705,000 | 1,176,250 | 3,528,750 |

[1] 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 digits.
[2] UWCD is the abbreviation for Underground Water Conservation District.

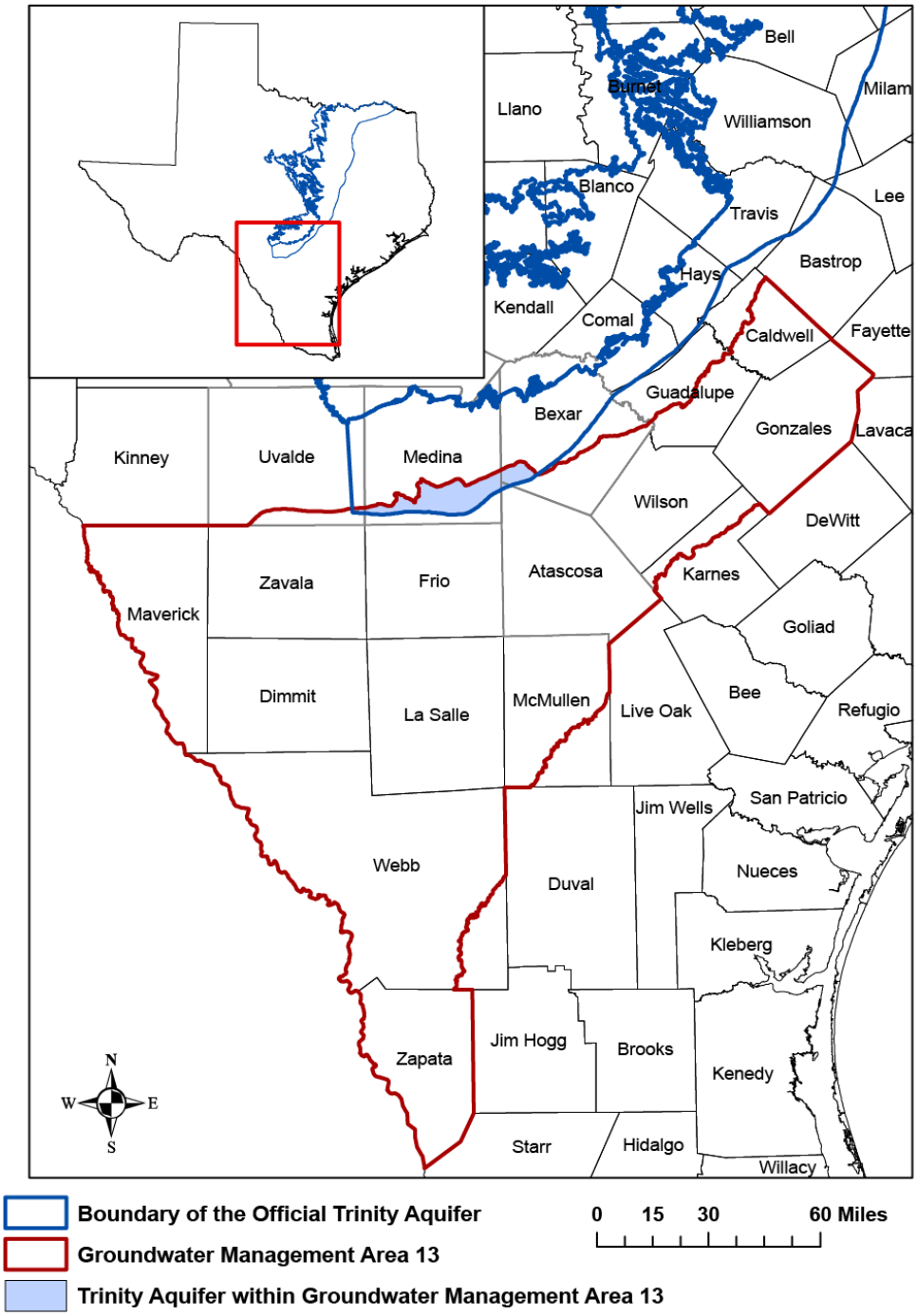


**FIGURE 2 AREA OF THE TRINITY AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLES 1 AND 2) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 3. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 29,000 | 7,250 | 21,750 |
| Bexar | 130,000 | 32,500 | 97,500 |
| Frio | 240,000 | 60,000 | 180,000 |
| Medina | 1,200,000 | 300,000 | 900,000 |
| Uvalde | 110,000 | 27,500 | 82,500 |
| Zavala | 9,400 | 2,350 | 7,050 |
| Total | 1,718,400 | 429,600 | 1,288,800 |

**TABLE 4. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[3] FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Edwards Aquifer Authority | 1,500,000 | 375,000 | 1,125,000 |
| Evergreen UWCD[4] | 240,000 | 60,000 | 180,000 |
| Wintergarden GCD | 9,400 | 2,350 | 7,050 |
| Total | 1,749,400 | 437,350 | 1,312,050 |

[3] 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 digits.
[4] UWCD is the abbreviation for Underground Water Conservation District.

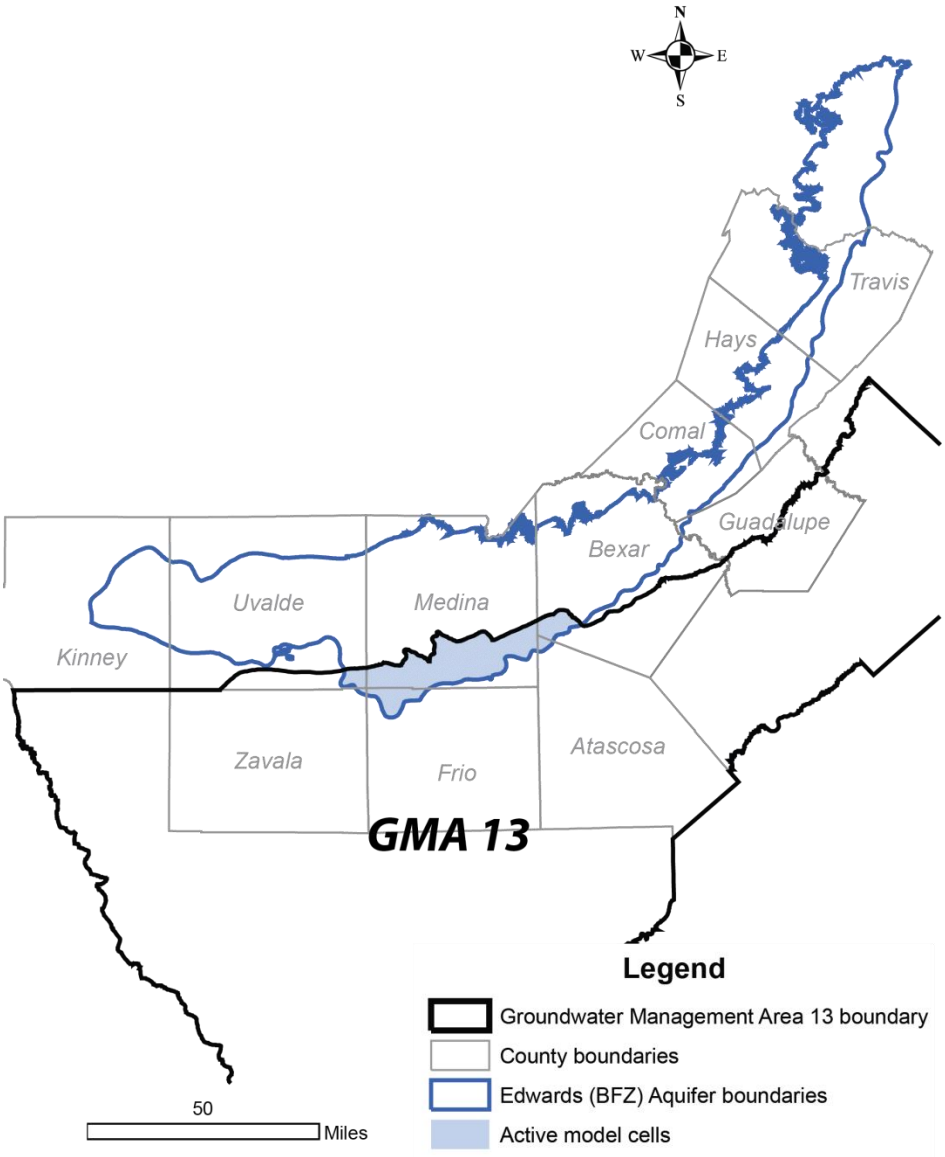


**FIGURE 3. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SAN ANTONIO SEGMENT OF THE EDWARDS (BALCONES FAULT ZONE) AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER (TABLES 3 AND 4) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 5. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE CARRIZO-WILCOX AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 230,000,000 | 57,500,000 | 172,500,000 |
| Bexar | 9,000,000 | 2,250,000 | 6,750,000 |
| Caldwell | 22,000,000 | 5,500,000 | 16,500,000 |
| Dimmit | 130,000,000 | 32,500,000 | 97,500,000 |
| Frio | 120,000,000 | 30,000,000 | 90,000,000 |
| Gonzales | 200,000,000 | 50,000,000 | 150,000,000 |
| Guadalupe | 18,000,000 | 4,500,000 | 13,500,000 |
| Karnes | 46,000,000 | 11,500,000 | 34,500,000 |
| La Salle | 320,000,000 | 80,000,000 | 240,000,000 |
| Maverick | 1,700,000 | 425,000 | 1,275,000 |
| McMullen | 250,000,000 | 62,500,000 | 187,500,000 |
| Medina | 6,200,000 | 1,550,000 | 4,650,000 |
| Uvalde | 820,000 | 205,000 | 615,000 |
| Webb | 380,000,000 | 95,000,000 | 285,000,000 |
| Wilson | 150,000,000 | 37,500,000 | 112,500,000 |
| Zavala | 68,000,000 | 17,000,000 | 51,000,000 |
| **Total** | 1,951,720,000 | 487,930,000 | 1,463,790,000 |

**TABLE 6. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[5] FOR THE CARRIZO-WILCOX AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| No District | 400,000,000 | 100,000,000 | 300,000,000 |
| Evergreen UWCD | 540,000,000 | 135,000,000 | 405,000,000 |
| Gonzales County UWCD[6] | 200,000,000 | 50,000,000 | 150,000,000 |
| Guadalupe County GCD | 18,000,000 | 4,500,000 | 13,500,000 |
| McMullen GCD | 250,000,000 | 62,500,000 | 187,500,000 |
| Medina County GCD | 6,200,000 | 1,550,000 | 4,650,000 |
| Plum Creek CD[7] | 7,000,000 | 1,750,000 | 5,250,000 |
| Uvalde County UWCD | 820,000 | 205,000 | 615,000 |
| Wintergarden GCD | 520,000,000 | 130,000,000 | 390,000,000 |
| **Total** | 1,942,020,000 | 485,505,000 | 1,456,515,000 |

[5] 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 digits.
[6] UWCD is the abbreviation for Underground Water Conservation District.
[7] CD is the abbreviation for Conservation District.

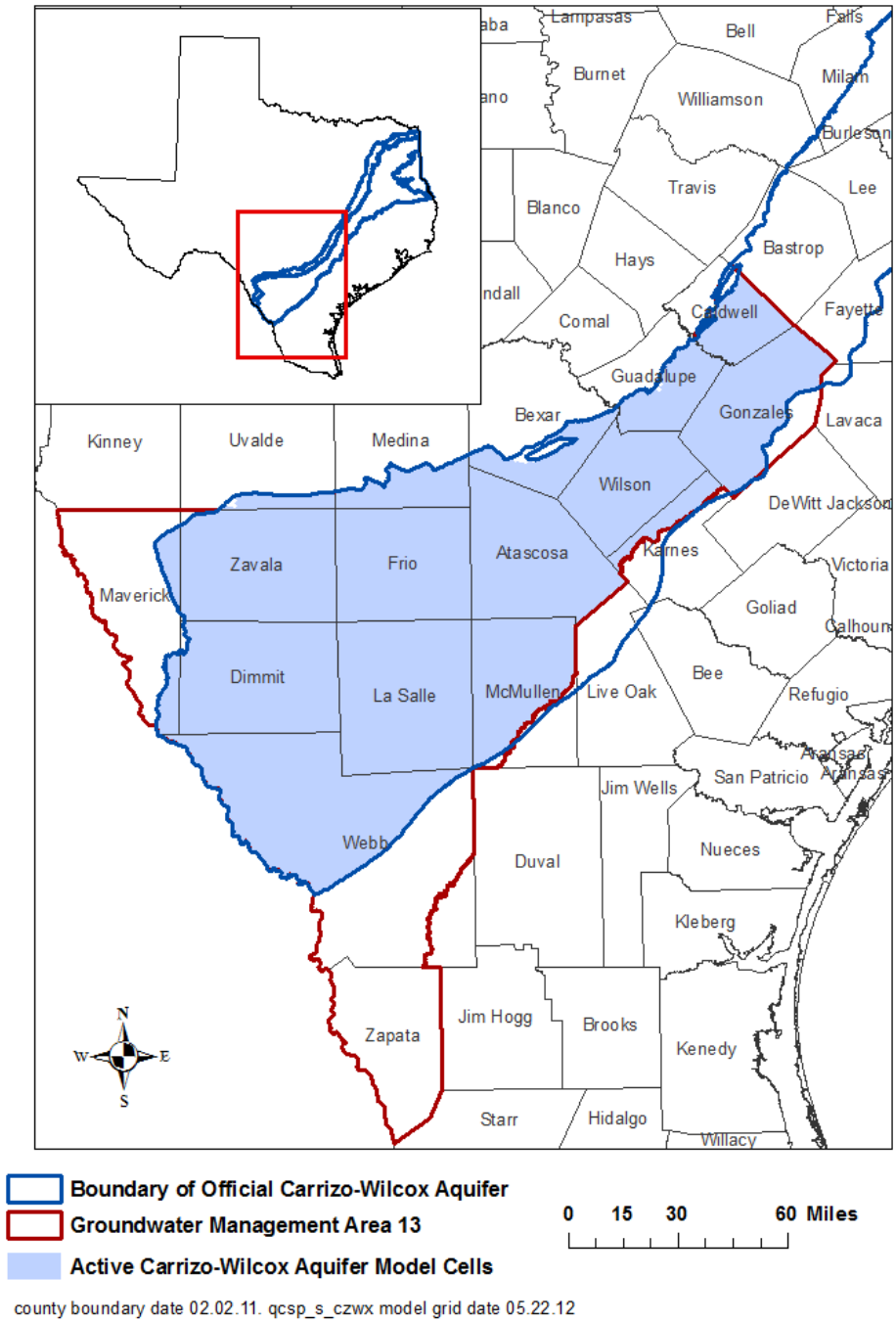


**FIGURE 4. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PART OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE CARRIZO-WILCOX AQUIFER (TABLES 5 AND 6) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 7. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE QUEEN CITY AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 83,000,000 | 20,750,000 | 62,250,000 |
| Caldwell | 430,000 | 107,500 | 322,500 |
| Frio | 45,000,000 | 11,250,000 | 33,750,000 |
| Gonzales | 26,000,000 | 6,500,000 | 19,500,000 |
| Guadalupe | 2,800 | 700 | 2,100 |
| La Salle | 15,000,000 | 3,750,000 | 11,250,000 |
| McMullen | 33,000,000 | 8,250,000 | 24,750,000 |
| Wilson | 24,000,000 | 6,000,000 | 18,000,000 |
| **Total** | 226,432,800 | 56,608,200 | 169,824,600 |

**TABLE 8. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[8] FOR THE QUEEN CITY AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Evergreen UWCD[9] | 150,000,000 | 37,500,000 | 112,500,000 |
| Gonzales County UWCD | 26,000,000 | 6,500,000 | 19,500,000 |
| Guadalupe County GCD | 2,800 | 700 | 2,100 |
| McMullen GCD | 33,000,000 | 8,250,000 | 24,750,000 |
| Plum Creek CD[10] | 50,000 | 12,500 | 37,500 |
| Wintergarden GCD | 15,000,000 | 3,750,000 | 11,250,000 |
| **Total** | 224,052,800 | 56,013,200 | 168,039,600 |

[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 digits.
[9] UWCD is the abbreviation for Underground Water Conservation District.
[10] CD is the abbreviation for Conservation District.

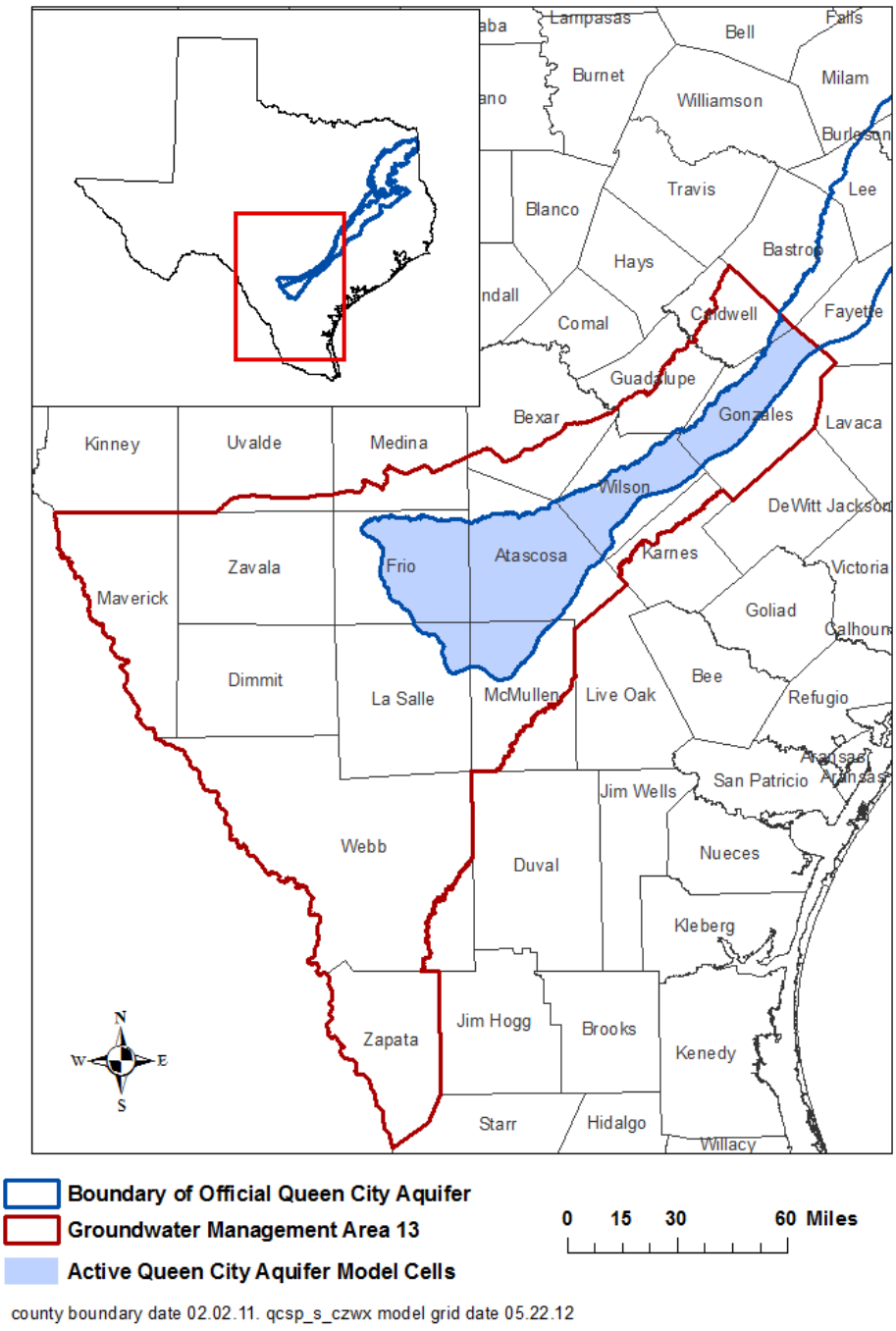


**FIGURE 5. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PART OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE QUEEN CITY AQUIFER (TABLES 7 AND 8) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 9. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE SPARTA AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 12,000,000 | 3,000,000 | 9,000,000 |
| Frio | 2,600,000 | 650,000 | 1,950,000 |
| Gonzales | 5,600,000 | 1,400,000 | 4,200,000 |
| La Salle | 1,600,000 | 400,000 | 1,200,000 |
| McMullen | 1,700,000 | 425,000 | 1,275,000 |
| Wilson | 2,500,000 | 625,000 | 1,875,000 |
| **Total** | 26,000,000 | 6,500,000 | 19,500,000 |

**TABLE 10. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[11] FOR THE SPARTA AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Evergreen UWCD[12] | 17,000,000 | 4,250,000 | 12,750,000 |
| Gonzales County UWCD | 5,600,000 | 1,400,000 | 4,200,000 |
| McMullen GCD | 1,700,000 | 425,000 | 1,275,000 |
| Wintergarden GCD | 1,600,000 | 400,000 | 1,200,000 |
| **Total** | 25,900,000 | 6,475,000 | 19,425,000 |

[11] 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 digits.
[12] UWCD is the abbreviation for Underground Water Conservation District.

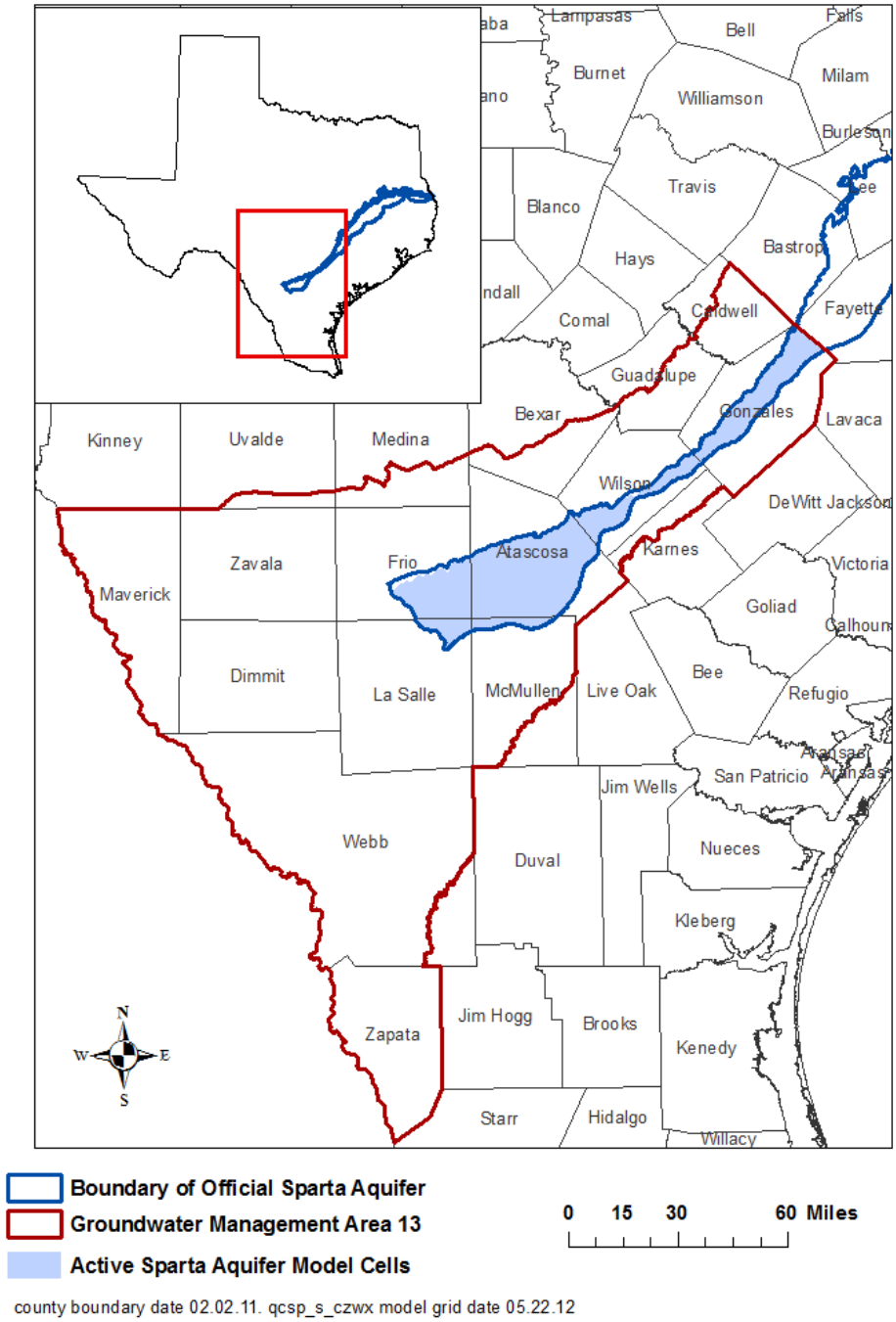


**FIGURE 6. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PART OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS USED TO ESTIMATE TOTAL RECOVERABLE STORAGE FOR THE SPARTA AQUIFER (TABLES 9 AND 10) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 11. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE YEGUA-JACKSON AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Atascosa | 40,000,000 | 10,000,000 | 30,000,000 |
| Frio | 75,000 | 18,750 | 56,250 |
| Gonzales | 32,000,000 | 8,000,000 | 24,000,000 |
| Karnes | 19,000,000 | 4,750,000 | 14,250,000 |
| La Salle | 56,000,000 | 14,000,000 | 42,000,000 |
| McMullen | 96,000,000 | 24,000,000 | 72,000,000 |
| Webb | 210,000,000 | 52,500,000 | 157,500,000 |
| Wilson | 6,800,000 | 1,700,000 | 5,100,000 |
| Zapata | 83,000,000 | 20,750,000 | 62,250,000 |
| **Total** | 542,875,000 | 135,718,750 | 407,156,250 |

**TABLE 12. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[13] FOR THE YEGUA-JACKSON AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District (GCD)* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| No District | 310,000,000 | 77,500,000 | 232,500,000 |
| Evergreen UWCD[14] | 66,000,000 | 16,500,000 | 49,500,000 |
| Gonzales County UWCD | 23,000,000 | 5,750,000 | 17,250,000 |
| McMullen GCD | 96,000,000 | 24,000,000 | 72,000,000 |
| Wintergarden GCD | 56,000,000 | 14,000,000 | 42,000,000 |
| **Total** | 551,000,000 | 137,750,000 | 413,250,000 |

[13] The total estimated recoverable storages values by groundwater conservation district and county for an aquifer may not be the same because the numbers have been rounded to two significant digits.
[14] UWCD is the abbreviation for Underground Water Conservation District.

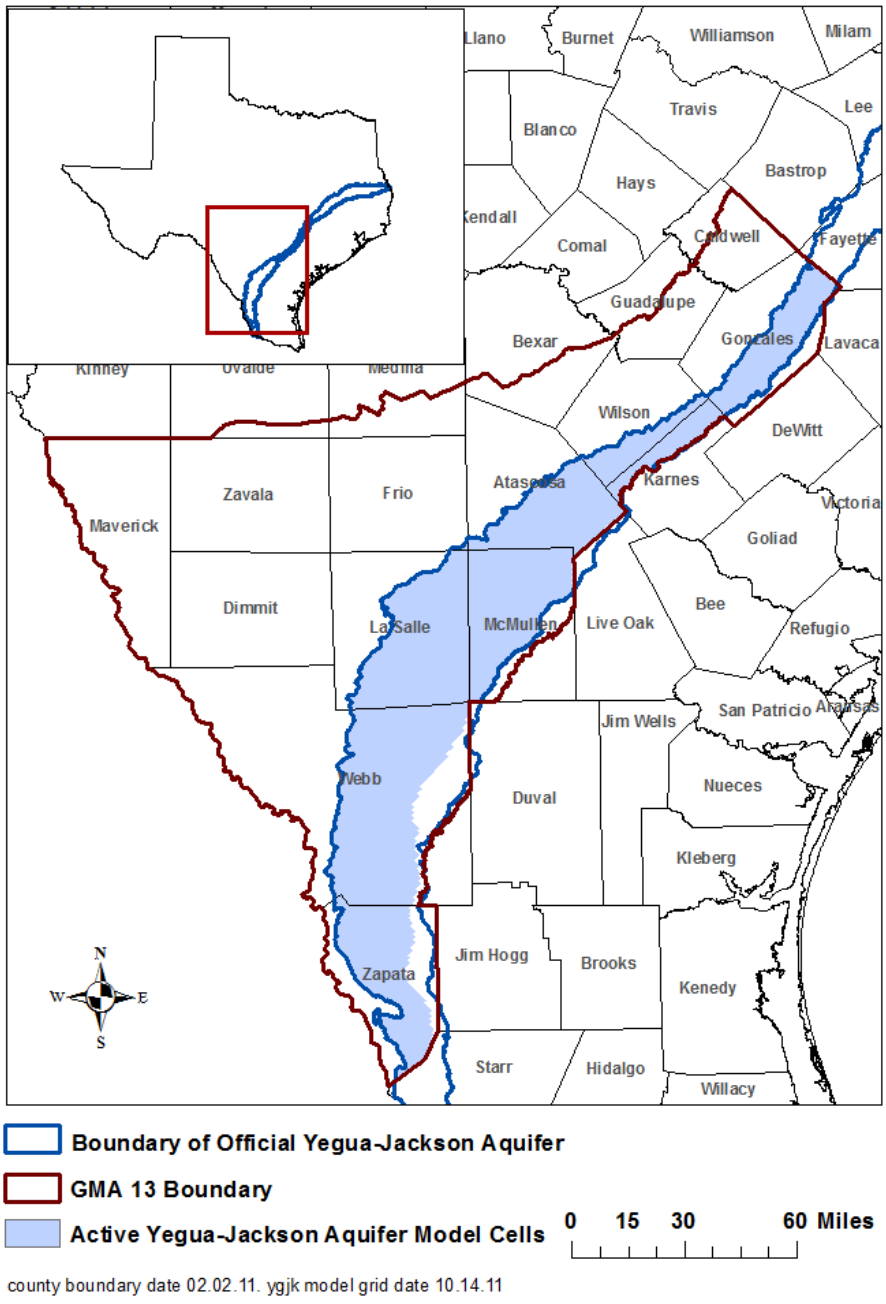


**FIGURE 7. EXTENT OF THE GROUNDWATER AVAILABILITY MODEL FOR THE YEGUA-JACKSON AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLES 11 AND 12) FOR THE YEGUA-JACKSON AQUIFER AND CATAHOULA FORMATION PORTION OF THE GULF COAST AQUIFER SYSTEM (TABLES 13 AND 14) WITHIN GROUNDWATER MANAGEMENT AREA 13.**

**TABLE 13. TOTAL ESTIMATED RECOVERABLE STORAGE BY COUNTY FOR THE GULF COAST AQUIFER SYSTEM[15] WITHIN GROUNDWATER MANAGEMENT AREA 13. COUNTY TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *County* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| Gonzales | 360,000 | 90,000 | 270,000 |
| Zapata | 2,100,000 | 525,000 | 1,575,000 |
| Total | 2,460,000 | 615,000 | 1,845,000 |

**TABLE 14. TOTAL ESTIMATED RECOVERABLE STORAGE BY GROUNDWATER CONSERVATION DISTRICT[16] FOR THE GULF COAST AQUIFER SYSTEM WITHIN GROUNDWATER MANAGEMENT AREA 13. GROUNDWATER CONSERVATION DISTRICT TOTAL ESTIMATES ARE ROUNDED TO TWO SIGNIFICANT DIGITS.**

| *Groundwater Conservation District* | *Total Storage (acre-feet)* | *25% of Total Storage (acre-feet)* | *75% of Total Storage (acre-feet)* |
|---|---|---|---|
| No District | 2,410,000 | 602,500 | 1,807,500 |
| Gonzales County UWCD[17] | 51,000 | 12,750 | 38,250 |
| **Total** | 2,461,000 | 615,250 | 1,845,750 |

[15] Estimates for Zapata County are from the Catahoula portion of Layer 1 in the Groundwater Availability Model for the Yegua-Jackson Aquifer.
[16] 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 digits.
[17] UWCD is the abbreviation for Underground Water Conservation District.

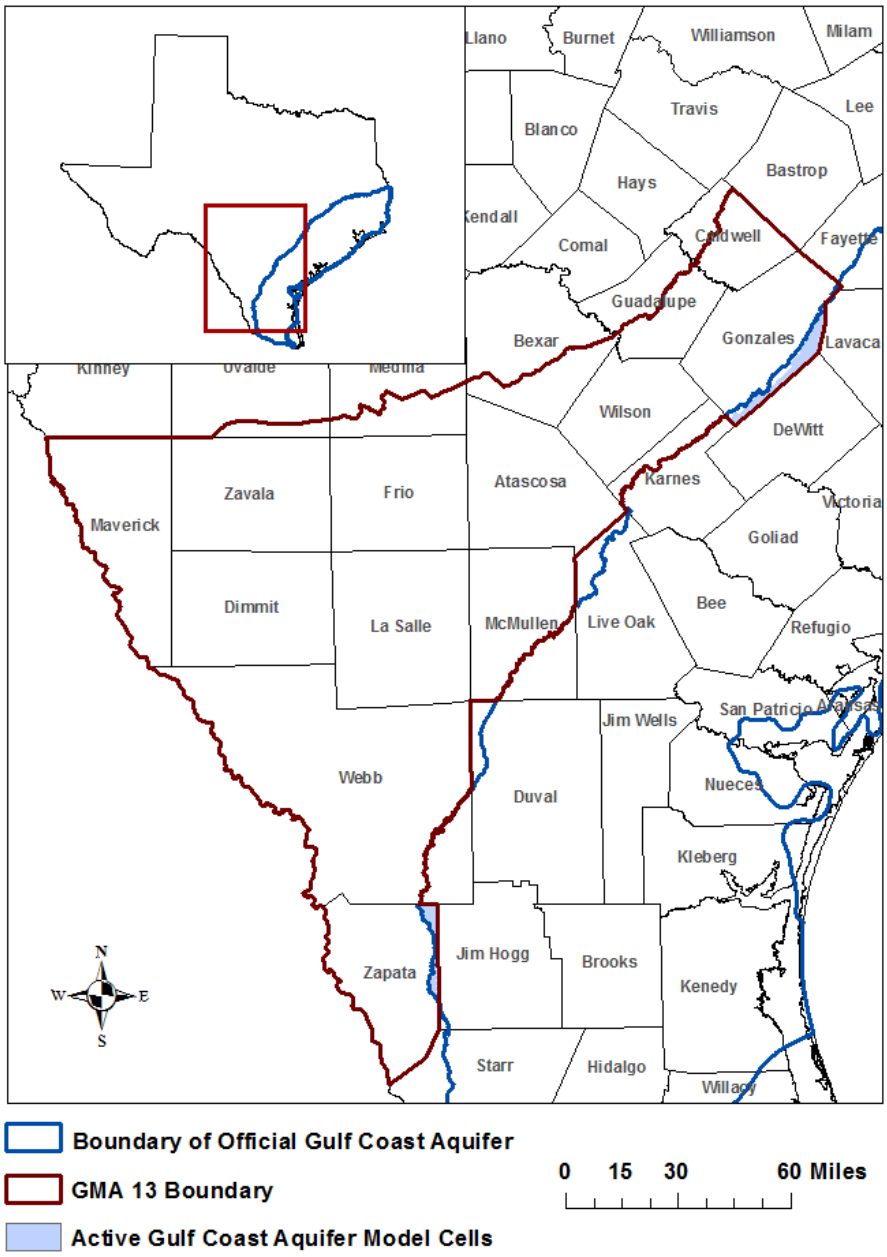


**FIGURE 8. EXTENT OF THE GROUNDWATER AVAILABILITY MODELS FOR THE YEGUA-JACKON (CATAHOULA IN LAYER 1) AND CENTRAL PORTION OF THE GULF COAST AQUIFER USED TO ESTIMATE TOTAL RECOVERABLE STORAGE (TABLES 13 AND 14) FOR THE GULF COAST AQUIFER WITHIN GROUNDWATER MANAGEMENT AREA 13.**

## *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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