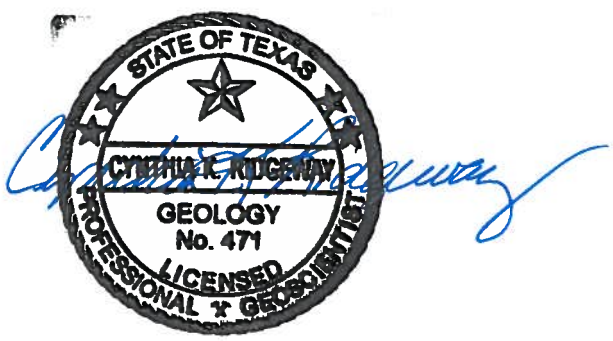
GAM RUN 10-056 MAG: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 6

by Wade Oliver[1], David Thorkildsen, P.G.[2], and Sarah Backhouse [3]
Texas Water Development Board
Groundwater Resources Division
(512) 463-3132[1]
(512) 936-0871[2]
(512) 936-2387[3]
December 6, 2011



The seals appearing on this document were authorized by Cynthia K. Ridgeway, P.G. 471, and David Thorkildsen, P.G. 705 on December 6, 2011. Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and Interim Director of the Groundwater Resources Division and is responsible for oversight of work performed by employees under her direct supervision.

This page is intentionally blank.

GAM RUN 10-056 MAG: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 6

by Wade Oliver[1], David Thorkildsen, P.G.[2], and Sarah Backhouse [3]
Texas Water Development Board
Groundwater Resources Division
(512) 463-3132[1]
(512) 936-0871[2]
(512) 936-2387[3]
December 6, 2011

EXECUTIVE SUMMARY:

The modeled available groundwater for the Blaine Aquifer as a result of the desired future conditions adopted by the members of Groundwater Management Area 6 is approximately 238,000 acre-feet per year. This is shown divided by county, river basin, and regional water planning area in Table 4 for use in the regional water planning process. Modeled available groundwater is summarized by county, regional water planning area, river basin, and groundwater conservation district in tables 5 through 8. For areas included in the groundwater availability model, the pumping estimates were extracted from Groundwater Availability Modeling Task 11-006, Scenario 9, which meets the desired future conditions adopted by the members of Groundwater Management Area 6. For Clear Fork Groundwater Conservation District and the portions of King County outside of the area where the groundwater availability model is applicable, a water balance approach was used to estimate modeled available groundwater.

REQUESTOR:

Mr. Mike McGuire of Rolling Plains Groundwater Conservation District on behalf of Groundwater Management Area 6

DESCRIPTION OF REQUEST:

In a letter dated August 13, 2010, Mr. McGuire provided the Texas Water Development Board (TWDB) with the desired future conditions of the Seymour and Blaine aquifers in Groundwater Management Area 6. After an analysis using the groundwater availability model for the Seymour and Blaine aquifers, TWDB notified Mr. McGuire on

January 6, 2011 that some desired future conditions were not compatible with one another. In a letter dated July 28, 2011, Mr. McGuire provided the TWDB with amended desired future conditions for the aquifers based on the modeling analysis documented in Groundwater Availability Modeling (GAM) Task 11-006 (Oliver, 2011). The desired future conditions for the Blaine Aquifer, as described in Resolution 2010-005 and amended in Resolution 2011-002, are described below:

1. *The Desired Future Condition for Fisher County, located within the Clear Fork Groundwater Conservation District, is that condition whereby the total decline in water levels will be no more than 4 feet over the next 50 years*

2. *The Desired Future Condition for that part of Childress County located in Gateway Groundwater Conservation District; Cottle, Foard, and Hardeman Counties, also located within Gateway Groundwater Conservation District, is that condition whereby the total decline in water levels will be no more than 2 feet over the next 50 years*

3. *The Desired Future Condition for that part of Childress County located in the Mesquite Groundwater Conservation District; Collingsworth and Hall counties, also located within the Mesquite Groundwater Conservation District, is that condition whereby 80 percent of the current volume in storage will remain in 50 years (2060)*

4. *The Desired Future Condition for King, not located within a Groundwater Conservation District, is that condition whereby the total decline in water levels will be no more than 7 feet over the next 50 years*

5. *Desired Future Conditions for Dickens, Knox, Motley, Stonewall, and Wilbarger Counties, located in GMA-6, are not relevant for joint planning purposes.*

In response to receiving the adopted desired future conditions, the TWDB has estimated the modeled available groundwater for the Blaine Aquifer in Groundwater Management Area 6.

METHODS:

As described in Oliver (2011), the boundary of the Blaine Aquifer in the model was the official boundary during model development in 2004. Though the official boundary of the Blaine Aquifer has since changed, the model is only applicable in areas within this older boundary. The locations of Groundwater Management Area 6, the Blaine Aquifer, and the groundwater availability model cells representing the aquifer are

shown in Figure 1. Figure 2 shows the location of the Blaine Aquifer relative to regional water planning areas, river basins, and groundwater conservation districts.

The desired future conditions above cover areas both included in the groundwater availability model and outside of the model. Where applicable, the model was used to estimate modeled available groundwater. In other areas (Fisher County and the non-modeled areas of King County), a water balance approach was used. Each of these methods is described individually below.

Groundwater Availability Modeling Approach

As described above, the TWDB previously completed GAM Task 11-006 using the groundwater availability model for the Seymour and Blaine aquifers to assist the members of Groundwater Management Area 6 in developing desired future conditions (Oliver, 2011). One of the simulations in GAM Task 11-006, Scenario 9, meets each of the desired future conditions above where the model is applicable. Because of this, the results for Scenario 9 were used for developing the modeled available groundwater estimates in these areas. Some additional details about the model simulation are included below:

- We used version 1.01 of the groundwater availability model for the Seymour and Blaine aquifers. See Ewing and others (2004) for assumptions and limitations of the model
- The results presented here were taken directly from the Scenario 9 groundwater availability model simulation in GAM Task 11-006. See Oliver (2011) for additional details about the methods and assumptions associated with the model run.
- The model includes two layers representing the Seymour Aquifer (Layer 1) and the Blaine Aquifer and other Permian sediments (Layer 2).
- The root mean squared error (a measure of the difference between simulated and measured water levels during model calibration) for the entire model for the period of 1990 to 1999 is 19.6 feet for the Seymour Aquifer and 26.4 feet for the Blaine Aquifer. This represents one percent and three percent of the range of measured water levels, respectively (Ewing and others, 2004).
- Average annual recharge conditions were assumed in the simulation based on 1975 to 1999 climate data.

Water Balance Approach

For areas containing the Blaine Aquifer, but not applicable in the groundwater availability model, a water balance approach was used to estimate modeled available groundwater. These areas include Clear Fork Groundwater Conservation District (Fisher County) and portions of King County (Figure 1).

A transient water balance for the saturated portion of an aquifer is described by Freeze and Cherry (1979, p.365):

$$Q(t) = R(t) - D(t) + \frac{dS}{dt}$$

where $Q(t)$ = total rate of groundwater withdrawal

$R(t)$ = total rate of groundwater recharge to the basin

$D(t)$ = total rate of groundwater discharge from the basin

$\frac{dS}{dt}$ = rate of change of storage in the saturated zone of the basin

For this analysis, it is assumed that

$$R(t) = R(r) + R(e)$$

where $R(r)$ = rejected recharge for the basin

$R(e)$ = effective recharge

Effective recharge is the amount of water that enters an aquifer and is available for development (Muller and Price, 1979, p. 5). Rejected recharge is the amount of total (or potential) recharge that discharges from an aquifer because it is overfull and cannot accept more water (Theis, 1940, p. 1). For this analysis, it is assumed that:

$$R(r) \cong D(t)$$

Therefore, the total rate of groundwater withdrawal equals effective recharge plus the change in storage of the aquifer, or

$$Q(t) = R(e) + \frac{dS}{dt}$$

The annual effective recharge was calculated by multiplying the outcrop area by the average precipitation (1971–2000) and the effective recharge rate developed for the

Blaine Aquifer in Ewing and others (2004). This is shown in Table 1. The change in storage in the aquifer is calculated from the change in water levels (the desired future conditions), the aquifer properties that define how much water is released from storage for a given change in water level, and the area covered by the aquifer. The storage properties – specific yield for unconfined areas and storage coefficient for confined areas – were derived from the groundwater availability model. The annual change in storage was then calculated by dividing the total change in storage by 50 years (Table 2).

As shown in the equation above, the estimated annual groundwater withdrawal consistent with the desired future conditions (modeled available groundwater) is the sum of the annual effective recharge and the annual volume of water released from storage (Table 3). Some additional details about estimating modeled available groundwater using the water balance approach are included below:

- The average annual precipitation for each area shown in Table 1 was determined from the Texas Climatic Atlas (Narasimhan and others, 2008) which is the average for the years 1971 to 2000.
- Annual effective recharge is 1.6 percent of annual precipitation (Ewing and others, 2004).
- Outcrop areas are calculated as unconfined areas of the aquifer and subcrop areas are calculated as confined areas of the aquifer.
- Specific yield of the aquifer is estimated to be 0.15 and the storage coefficient is estimated to be 0.01 (Ewing and others, 2004).
- The specified average water-level decline is assumed to be uniform across the aquifer.

Modeled Available Groundwater and Permitting

As defined in Chapter 36 of the Texas Water Code, “modeled available groundwater” is the estimated average amount of water that may be produced annually to achieve a desired future condition. Groundwater conservation districts are required to consider modeled available groundwater, along with several other factors, when issuing permits in order to manage groundwater production to achieve the desired future condition(s). The other factors districts must consider include annual precipitation and production patterns, the estimated amount of pumping exempt from permitting, existing permits, and a reasonable estimate of actual groundwater production under existing permits. The estimated amount of pumping exempt from permitting, which the Texas Water Development Board is now required to develop after soliciting input from applicable groundwater conservation districts, will be provided in a separate report.

RESULTS:

The modeled available groundwater for the Blaine Aquifer in Groundwater Management Area 6 as a result of the above desired future conditions is approximately 238,000 acre-feet per year between 2010 and 2060. Table 4 contains the modeled available groundwater subdivided by county, regional water planning area, and river basin for use in the regional water planning process. Tables 5, 6, 7, and 8 show the modeled available groundwater for the Blaine Aquifer summarized by county, regional water planning area, river basin, and groundwater conservation district, respectively, within Groundwater Management Area 6. Note that tables 4 through 8 include the estimated modeled available groundwater using both the groundwater availability model (from Oliver, 2011) and the water balance approach described in this report.

LIMITATIONS:

The groundwater model used in developing estimates of modeled available groundwater is the best available scientific tool that can be used to estimate the pumping that will achieve the desired future conditions. Although the groundwater model used in this analysis is the best available scientific tool for this purpose, it, like all models, has limitations. 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 develop estimates of modeled available groundwater is the need to make assumptions about the location in the aquifer where future pumping will occur. As actual pumping changes in the future, it will be necessary to evaluate the amount of that pumping as well as its location in the context of the assumptions associated with this analysis. Evaluating the amount and location of future pumping is as important as evaluating the changes in groundwater levels, spring flows, and other metrics that describe the condition of the groundwater resources in the area that relate to the adopted desired future condition.

As described above, different assumptions were used for the water balance approach used for the Clear Fork Groundwater Conservation District (Fisher County) and portions of King County (Figure 1). For example, this approach does not consider

impacts to the aquifer from neighboring areas or evaluate whether individual conditions are physically compatible.

Given these limitations, users of this information are cautioned that the modeled available groundwater numbers should not be considered a definitive, permanent description of the amount of groundwater that can be pumped to meet the adopted desired future condition. Because the application of these models 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 future groundwater pumping as well as whether or not they are achieving their desired future conditions. 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 these modeled available groundwater numbers given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future.

REFERENCES:

Anaya, R., 2001, GAM technical memo 01-01(rev a): Texas Water Development Board technical memorandum, 2 p.

Ewing, J.E., Jones, T.L., Pickens, J.F., Chastain-Howley, A., Dean, K.E., Spear, A.A., 2004, Groundwater availability model for the Seymour Aquifer: Final report prepared for the Texas Water Development Board by INTERA, Inc., 533 p.

Freeze, R. A., and Cherry, J. A., 1979, Groundwater: Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 p.

Muller, D. A., and Price, R. D., 1979, Ground-water availability in Texas, estimates and projections through 2030: Texas Department of Water Resources Report 238, 77 p.

Narasimhan, B., Srinvasan, R., Quiring, S., and Nielsen-Gammon, J.W., 2008, Digital Climatic Atlas of Texas: Texas A&M University, Texas Water Development Board contract, Report 2005-483-5591, 108 p.

National Research Council, 2007, Models in Environmental Regulatory Decision Making. Committee on Models in the Regulatory Decision Process, National Academies Press, Washington D.C., 287 p.

Oliver, W., 2011, GAM Task 11-006, Texas Water Development Board GAM Task Report, 26 p.

Theis, C.V., 1940, The source of water derived from wells: Essential factors controlling the response of an aquifer to development: Civil Engineering 10, pp. 277-280.

Texas Water Development Board, 2007, Water for Texas – 2007 – Volumes I-III; Texas Water Development Board Document No. GP-8-1, 392 p.

TABLE 1: CALCULATION OF ESTIMATED ANNUAL EFFECTIVE RECHARGE FOR AREAS NOT INCLUDED IN THE GROUNDWATER AVAILABILITY MODEL FOR THE BLAINE AQUIFER. NOTE THAT THIS CALCULATION ONLY APPLIED TO OUTCROP AREAS.

County	*Basin*	*Outcrop/ Subcrop*	*Average Annual Precipitation (inches - feet)*	*Effective recharge rate (percent)*	*Area (acres)*	*Estimated Annual Effective Recharge (acre-feet per year)*
Fisher	Brazos	Outcrop	23 – 1.9	1.6	112,853	3,431
King	Brazos	Outcrop	24 – 2.0	1.6	130,527	4,177
King	Red	Outcrop	24 – 2.0	1.6	65,336	2,091
Total					**308,716**	**9,699**

TABLE 2: CALCULATION OF THE ESTIMATED ANNUAL VOLUME OF STORAGE DECLINE CONSISTENT WITH THE DESIRED FUTURE CONDITIONS FOR AREAS NOT INCLUDED IN THE GROUNDWATER AVAILABILITY MODEL FOR THE BLAINE AQUIFER.

County	*Basin*	*Outcrop/ Subcrop*	*Specified 50-year Water-Level Decline (feet)*	*Estimated Storage Coefficient (unitless)*	*Area (acres)*	*Estimated Annual Volume of Storage Decline (acre-feet per year)*
Fisher	Brazos	Outcrop	4	0.15	112,853	1,354
Fisher	Brazos	Subcrop	4	0.01	346,200	277
King	Brazos	Outcrop	7	0.15	130,527	2,741
King	Brazos	Subcrop	7	0.01	42,446	59
King	Red	Outcrop	7	0.15	65,336	1,372
King	Red	Subcrop	7	0.01	7,282	10
Total					**704,644**	**5,814**

TABLE 3: CALCULATION OF THE ESTIMATED PUMPING CONSISTENT WITH THE DESIRED FUTURE CONDITIONS FOR AREAS NOT INCLUDED IN THE GROUNDWATER AVAILABILITY MODEL FOR THE BLAINE AQUIFER. ALL VALUES ARE IN ACRE-FEET PER YEAR.

County	*Basin*	*Outcrop/ Subcrop*	*Estimated Annual Effective Recharge*	*Estimated Annual Volume of Storage Decline*	*Estimated Pumping in Non-Modeled Areas*
Fisher	Brazos	Outcrop	3,431	1,354	4,785
Fisher	Brazos	Subcrop	-	277	277
King	Brazos	Outcrop	4,177	2,741	6,918
King	Brazos	Subcrop	-	59	59
King	Red	Outcrop	2,091	1,372	3,463
King	Red	Subcrop	-	10	10
Total			**9,699**	**5,814**	**15,513**

TABLE 4: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER IN GROUNDWATER MANAGEMENT AREA 6. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY COUNTY, REGIONAL WATER PLANNING AREA, AND RIVER BASIN.

County	*Region*	*Basin*	*Year*					
			2010	*2020*	*2030*	*2040*	*2050*	*2060*
Childress	A	Red	15,206	15,206	15,206	15,206	15,206	15,206
Collingsworth	A	Red	185,376	185,376	185,376	185,376	185,376	185,376
Cottle	B	Red	4,469	4,469	4,469	4,469	4,469	4,469
Fisher	G	Brazos	5,062	5,062	5,062	5,062	5,062	5,062
Foard	B	Red	23	23	23	23	23	23
Hall	A	Red	11,509	11,509	11,509	11,509	11,509	11,509
Hardeman	B	Red	5,198	5,198	5,198	5,198	5,198	5,198
King	B	Brazos	6,977	6,977	6,977	6,977	6,977	6,977
		Red	3,863	3,863	3,863	3,863	3,863	3,863
Total			**237,684**	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**

TABLE 5: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER BY COUNTY FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

County	*Year*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Childress	15,206	15,206	15,206	15,206	15,206	15,206
Collingsworth	185,376	185,376	185,376	185,376	185,376	185,376
Cottle	4,469	4,469	4,469	4,469	4,469	4,469
Fisher	5,062	5,062	5,062	5,062	5,062	5,062
Foard	23	23	23	23	23	23
Hall	11,509	11,509	11,509	11,509	11,509	11,509
Hardeman	5,198	5,198	5,198	5,198	5,198	5,198
King	10,841	10,841	10,841	10,841	10,841	10,841
Total	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**

TABLE 6: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER BY REGIONAL WATER PLANNING AREA FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

Region	*Year*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
A	212,091	212,091	212,091	212,091	212,091	212,091
B	20,531	20,531	20,531	20,531	20,531	20,531
G	5,062	5,062	5,062	5,062	5,062	5,062
Total	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**

TABLE 7: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER BY RIVER BASIN FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

Basin	*Year*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Brazos	12,039	12,039	12,039	12,039	12,039	12,039
Red	225,644	225,644	225,644	225,644	225,644	225,644
Total	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**

TABLE 8: MODELED AVAILABLE GROUNDWATER FOR THE BLAINE AQUIFER BY GROUNDWATER CONSERVATION DISTRICT (GCD) FOR EACH DECADE BETWEEN 2010 AND 2060. RESULTS ARE IN ACRE-FEET PER YEAR.

District	*Year*					
	2010	*2020*	*2030*	*2040*	*2050*	*2060*
Clear Fork GCD	5,062	5,062	5,062	5,062	5,062	5,062
Gateway GCD	16,786	16,786	16,786	16,786	16,786	16,786
Mesquite GCD	204,995	204,995	204,995	204,995	204,995	204,995
No District	10,841	10,841	10,841	10,841	10,841	10,841
Total	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**	**237,684**

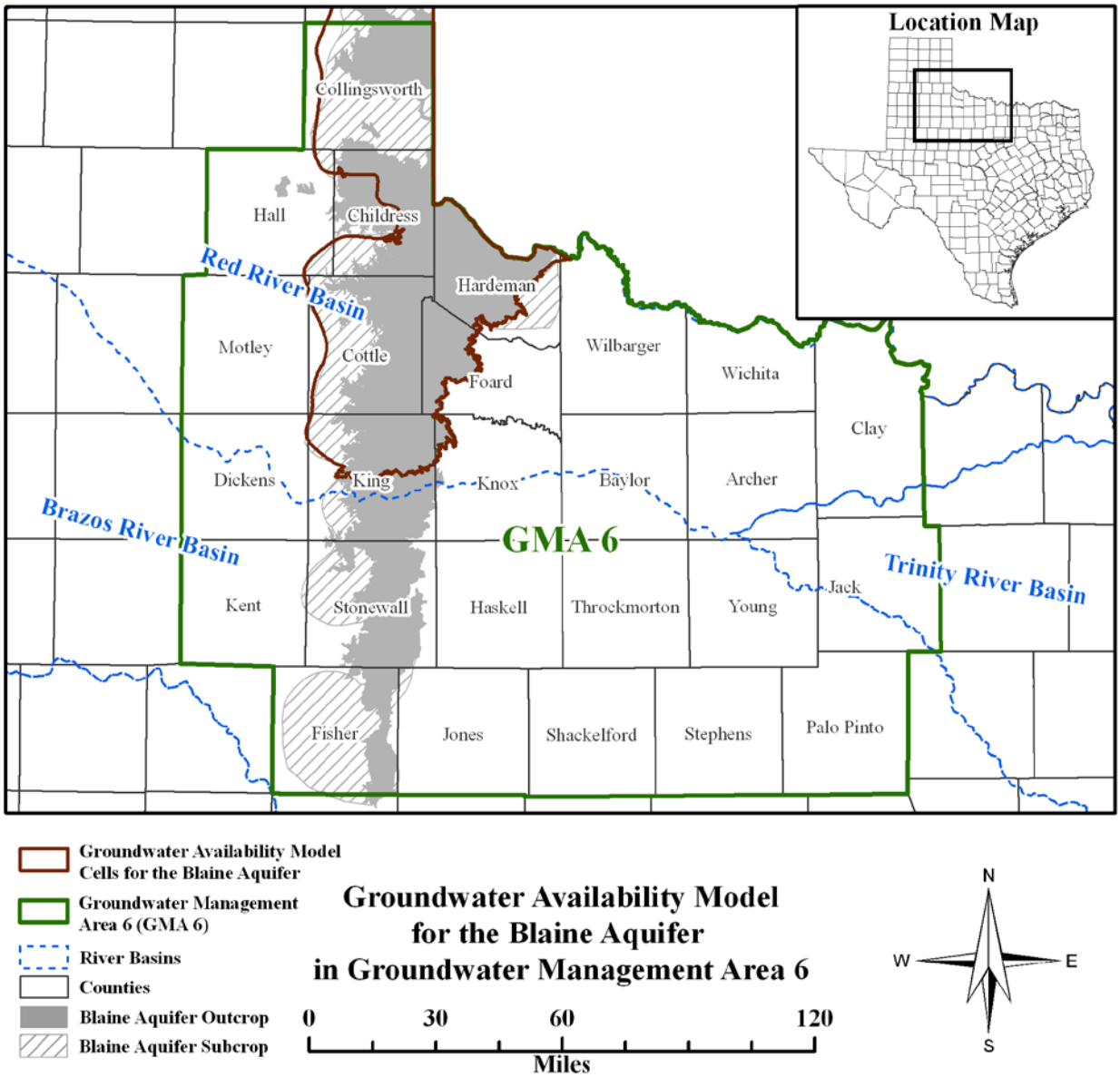


FIGURE 1: MAP SHOWING GROUNDWATER MANAGEMENT AREA 6, THE BOUNDARY OF THE BLAINE AQUIFER ACCORDING TO THE 2007 STATE WATER PLAN (TWDB, 2007), AND THE GROUNDWATER AVAILABILITY MODEL CELLS THAT REPRESENT THE AQUIFER.

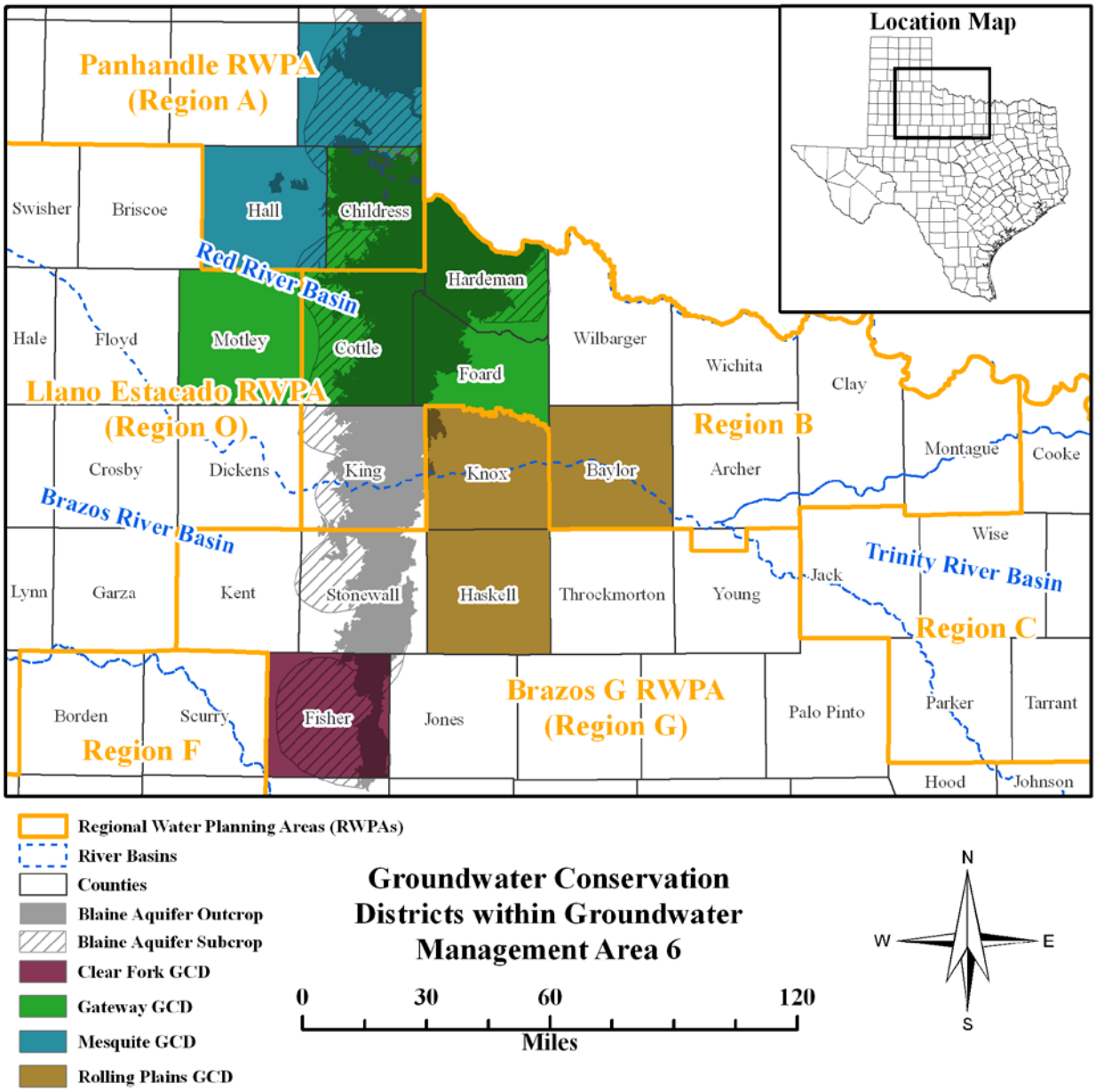


FIGURE 2: MAP SHOWING GROUNDWATER CONSERVATION DISTRICTS, REGIONAL WATER PLANNING AREAS, COUNTIES, AND RIVER BASINS IN AND NEIGHBORING GROUNDWATER MANAGEMENT AREA 6.