GAM RUN 12-005 MAG: MODELED AVAILABLE GROUNDWATER FOR THE OGALLALA AQUIFER IN GROUNDWATER MANAGEMENT AREA 1

by Marius Jigmond
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 463-8499
August 21, 2012

Cynthia K. Ridgeway, the Manager of the Groundwater Availability Modeling Section, is responsible for oversight of work performed by Marius Jigmond under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on August 21, 2012.

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EXECUTIVE SUMMARY:

An updated Groundwater Availability Model (GAM) for the Ogallala Aquifer (northern portion) developed by INTERA, Inc. (Kelley and others, 2010) has been approved by the Texas Water Development Board (TWDB). Accordingly, the TWDB has conducted a GAM model run and is issuing updated modeled available groundwater numbers as requested by members of Groundwater Management Area 1. This model run supersedes model run 09-026 (Oliver, 2011) with respect to results extracted from the groundwater availability model for the northern portion of the Ogallala Aquifer. Estimates of modeled available groundwater extracted from the groundwater availability model for the southern portion of the Ogallala Aquifer remain unchanged.

In addition, legislation that became effective September 1, 2011 changed the definition and meaning of “Managed Available Groundwater” to “Modeled Available Groundwater.” Modeled available groundwater represents estimates of total pumping as presented in the former “Managed Available Groundwater” report 09-026 (Oliver, 2011). The modeled available groundwater for the Ogallala Aquifer, as a result of the desired future conditions adopted by Groundwater Management Area 1, declines from 3,666,259 acre-feet per year in 2010 to 2,151,403 acre-feet per year in 2060. This report summarizes modeled available groundwater by county, groundwater conservation district, river basin, and geographic area for each decade between 2010 and 2060. The pumping estimates were extracted from the Groundwater Availability Model Run performed by INTERA, Inc. (Kelley and others, 2010) as part of the recalibration process.

REQUESTOR:

Mr. John R. Spearman, chairman of Groundwater Management Area 1.

DESCRIPTION OF REQUEST:

In a letter dated December 22, 2011, Mr. Spearman requested that the updated groundwater flow model for the Ogallala Aquifer (northern portion) be considered for adoption as an official GAM by TWDB. TWDB has adopted the updated model as the official GAM and is issuing revised modeled available groundwater estimates. The modeled available groundwater estimates are based on the desired future conditions for the Ogallala Aquifer as described in Resolution 2009-01 and adopted July 7, 2009:

- **"40 [percent] volume in storage remaining in 50 years in the following:**
    - **North Plains [Groundwater Conservation District] consisting of all or parts of the following counties: Dallam, Hartley, Moore and Sherman; and**
    - **Parts of the following counties that are not in a Groundwater Conservation District will also fall under the 40/50 [desired future condition], those counties being Dallam, Hartley and Moore**
- **50 [percent] volume in storage remaining in 50 years in the following:**
    - **High Plains Underground Water Conservation District consisting of parts of the following counties: Armstrong, Potter and Randall;**
    - **North Plains [Groundwater Conservation District] consisting of all or parts of the following counties: Hansford, Hutchinson, Lipscomb and Ochiltree;**
    - **Panhandle Groundwater Conservation District consisting of all or part of the following counties: Armstrong, Carson, Donley, Gray, Hutchinson, Potter, Roberts and Wheeler; and**
    - **All or parts of the following counties that are not in a Groundwater Conservation District will also fall under the 50/50 [desired future condition], those counties being Hutchinson, Oldham and Randall**
- **80 [percent] volume in storage remaining in 50 years in Hemphill County; provided that, in the event it is legally determined that the roughly 390-acre tract of land located in southwest Hemphill County and described more particularly in Attachment A (the "390-acre tract") lies within the jurisdiction of the Panhandle Groundwater Conservation District and not within the jurisdiction of the Hemphill County Underground Water Conservation District, then the Desired Future Condition for the 390-acre tract shall be 50 [percent] volume in storage remaining in 50 years and the Desired Future Condition for the remainder of Hemphill County shall be 80 [percent] volume in storage remaining in 50 years"**

The three geographic areas defined in the above desired future conditions statement are shown in Figure 1. Please note that the Attorney General of Texas, Opinion No. GA-0792, dated August 26, 2010, indicates the roughly 390-acre tract of land located in southwest Hemphill County lies within the jurisdiction of the Hemphill County

Underground Water Conservation District. As such the 80 percent volume in storage remaining in 50 years condition applies to the entire Hemphill County.

METHODS:

The Ogallala Aquifer within Groundwater Management Area 1 is covered by two GAMs. The GAM for the northern portion of the Ogallala Aquifer, documented in Dutton and others (2001), Dutton (2004), and Kelley and others (2010) covers the majority of Groundwater Management Area 1 and includes the Rita Blanca Aquifer. The GAM for the southern portion of the Ogallala Aquifer, documented in Blandford and others (2003) and Blandford and others (2008), covers the remaining areas of the Ogallala Aquifer within Groundwater Management Area 1. The area covered by each of the groundwater availability models is shown in Figure 2. Notice that there is an area in Potter and Randall counties where the two models overlap. Since the model for the northern portion of the Ogallala Aquifer is the primary model for Groundwater Management Area 1, results from the northern model were preferentially used over the results from the southern model in the overlap area.

The previously completed availability model run (Kelley and others, 2010) documents the model results reviewed by members of Groundwater Management Area 1. This new model run honors the above desired future conditions. The model run for the northern portion of the Ogallala Aquifer presented in this report divides the modeled available groundwater by county, groundwater conservation district, geographic area, and river basin within Groundwater Management Area 1. Note that Groundwater Management Area 1 is entirely contained within the Panhandle Regional Water Planning Area (Region A). The locations of these areas are shown in Figure 3.

For the southern portion of the Ogallala Aquifer, which covers portions of Oldham, Potter, Randall, and Armstrong counties, the Groundwater Availability Model Run 08-016 Supplement (Smith, 2008) was previously completed and meets the above request. Since completion of the model run, however, the groundwater availability model for the southern portion of the Ogallala Aquifer has been updated (Blandford and others, 2008). For this reason, the updated groundwater availability model was used to reassess these areas. This report documents the methods used in the updated groundwater availability model run for the southern portion of the Ogallala Aquifer in addition to reporting modeled available groundwater for Groundwater Management Area 1.

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 required to develop after soliciting input from applicable groundwater conservation districts, will be provided in a separate report.

PARAMETERS AND ASSUMPTIONS:

Northern Portion of the Ogallala Aquifer

The parameters and assumptions for the GAM run for the northern portion of the Ogallala Aquifer are described below:

- We used version 3.01 of the GAM for the northern portion of the Ogallala Aquifer. This model is an update to the previous versions documented in Dutton and others (2001) and Dutton (2004). See Kelley and others (2010), Dutton (2004), and Dutton and others (2001) for assumptions and limitations of the GAM.
- The GAM for the northern portion of the Ogallala Aquifer has only one layer which collectively represents the Ogallala and Rita Blanca aquifers. As described in the Resolution 2009-01 adopted by the members of Groundwater Management Area 1, the adopted desired future conditions apply to both the Ogallala and Rita Blanca aquifers. In both the desired future conditions statement and this report as a whole the Ogallala and Rita Blanca aquifers are referred to collectively as the "Ogallala Aquifer."
- The root mean squared error (a measure of the difference between simulated and measured water levels during model calibration) for the model for the northern portion of the Ogallala Aquifer is 45.7 feet. This represents 1.6 percent of the range of measured water levels across the model area.
- Cells were assigned to individual counties, groundwater conservation districts, and river basins as shown in the February 3, 2012 version of the file that associates the model grid to political and natural boundaries for the northern portion of the Ogallala. Note that some minor corrections were made to county

and groundwater conservation district grid cell assignments compared to the original Groundwater Availability Model Run 09-001 (Smith, 2009).

- See section 4.2 of Kelley and others (2010) for additional details about the pumping in the model run for the northern portion of the Ogallala Aquifer that meets the above desired future conditions.

Southern Portion of the Ogallala Aquifer

The parameters and assumptions for the GAM run for the southern portion of the Ogallala Aquifer are described below:

- We used version 2.01 of the GAM for the southern portion of the Ogallala Aquifer, which also includes the Edwards-Trinity (High Plains) Aquifer. This model is an expansion on and update to the previously developed groundwater availability model for the southern portion of the Ogallala Aquifer described in Blandford and others (2003). See Blandford and others (2008) and Blandford and others (2003) for assumptions and limitations of the GAM.
- The model includes four layers representing the southern portion of the Ogallala Aquifer and the Edwards-Trinity (High Plains) Aquifer. However, only Layer 1 of the model, representing the Ogallala Aquifer, is active within Groundwater Management Area 1. For this reason, results are only presented for the Ogallala Aquifer from the GAM.
- The mean absolute error (a measure of the difference between simulated and measured water levels during model calibration) for the Ogallala Aquifer in 2000 is 33 feet. This represents 1.8 percent of the range of measured water levels across the model area.
- Cells were assigned to individual counties, groundwater conservation districts, and river basins as shown in the September 14, 2009 version of the file that associates the model grid to political and natural boundaries for the southern portion of the Ogallala Aquifer and Edwards-Trinity (High Plains) Aquifer.

The pumping for areas outside of Groundwater Management Area 1 is the same as described for the “base” scenario in GAM Run 09-023 (Oliver, 2010).

RESULTS:

Table 1 contains modeled available groundwater for the Ogallala Aquifer within Groundwater Management Area 1. It contains pumping totals from the groundwater availability models for the northern and southern portions of the Ogallala Aquifer subdivided by county, groundwater conservation district, and river basin. These areas are shown in figure 1. Note that all of Groundwater Management Area 1 is within the Panhandle Regional Water Planning Area (Region A). For this reason results have not been divided by Regional Water Planning Area.

Table 2 shows modeled available groundwater summarized by county and geographic area within Groundwater Management Area 1 and the total for the area as a whole. The modeled available groundwater for Groundwater Management Area 1 in 2010 is 3,666,259 acre-feet per year. This declines to 2,151,403 acre-feet of pumping per year by 2060 due to reductions in pumping necessary to minimize the occurrence of dry cells. A model cell becomes inactive when the water level in the cell drops below the base of the aquifer. In this situation, pumping cannot occur for the remainder of the model simulation.

Table 3 shows modeled available groundwater summarized by groundwater conservation district and geographic area. Geographic areas are shown in figure 3.

Table 4 shows modeled available groundwater summarized by geographic area. The decline in the volume of water stored in the Ogallala Aquifer over 50 years for each of these areas matches the desired future condition adopted by the members of Groundwater Management Area 1. For Area 1, which consists of Dallam, Sherman, Hartley, and Moore counties modeled available groundwater declines from 1,387,054 acre-feet per year to 691,874 acre-feet per year between 2010 and 2060. For Area 2, consisting of Hemphill County, pumping remains relatively constant between 42,000 and 45,000 acre-feet per year. For Area 3, which encompasses the remaining counties in Groundwater Management Area 1, modeled available groundwater declines from 2,234,035 to 1,416,370 acre-feet per year for the same time period.

Table 5 shows the results summarized by river basin. Between 2010 and 2060, the estimated total pumping declines from 3,027,060 to 1,739,871 acre-feet per year in the Canadian River basin. In the Red River basin for the same time period, modeled available groundwater declines from 639,199 to 411,532 acre-feet per year.

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.

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 the groundwater model was designed to address regional scale questions, the results are most effective on a regional scale. The TWDB makes no warranties or representations relating to the actual conditions of any aquifer at a particular location or at a particular time.

It is important for groundwater conservation districts to monitor future groundwater pumping as well as whether or not they are achieving their desired future conditions. Because of the limitations of the model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine the 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:

Blandford, T.N., Blazer, D.J., Calhoun, K.C., Dutton, A.R., Naing, T., Reedy, R.C., and Scanlon, B.R., 2003, Groundwater availability of the southern Ogallala aquifer in Texas and New Mexico—Numerical simulations through 2050: Final report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 158 p.

Blandford, T.N., Kuchanur, M., Standen, A., Ruggiero, R., Calhoun, K.C., Kirby, P., and Shah, G., 2008, Groundwater availability model of the Edwards-Trinity (High Plains) Aquifer in Texas and New Mexico: Final report prepared for the Texas Water Development Board by Daniel B. Stephens & Associates, Inc., 176 p.

Dutton, A., 2004, Adjustments of parameters to improve the calibration of the Og-N model of the Ogallala Aquifer, Panhandle Water Planning Area: Bureau of Economic Geology, The University of Texas at Austin, 9 p.

Dutton, A., Reedy, R., and Mace, R., 2001, Saturated thickness of the Ogallala aquifer in the Panhandle Water Planning Area—Simulation of 2000 through 2050 Withdrawal Projections: prepared for the Panhandle Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 54 p.

Kelley, V.A., Jones, T., Fryar, D., Dutton, A., and Deeds, N., Northern Ogallala GAM update to support 2011 water plan prepared for the Panhandle Area Water Planning Group, 106 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., 2010, GAM Run 09-023: Texas Water Development Board, GAM Run 09-023 Draft Report, 30 p.

Oliver, W., 2011, GAM Run 09-026: Texas Water Development Board, GAM Run 09-026 Draft Report, 20 p.

Smith, R., 2008, Supplement to GAM Run 08-16: Texas Water Development Board, GAM Run 08-16 Supplement Report, 24 p.

Smith, R., 2009, GAM Run 09-001: Texas Water Development Board, GAM Run 09-001 Draft Report, 28 p.

TABLE 1: MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE OGALLALA AND RITA BLANCA AQUIFERS IN GROUNDWATER MANAGEMENT AREA 1. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY COUNTY, GROUNDWATER CONSERVATION DISTRICT (GCD), AND RIVER BASIN. UWCD REFERS TO UNDERGROUND WATER CONSERVATION DISTRICT.

County	District	Basin	Year					
			2010	2020	2030	2040	2050	2060
Armstrong	High Plains UWCD No. 1	Red	8,301	8,301	8,301	8,301	8,241	8,186
	Panhandle GCD	Red	44,587	37,066	32,778	29,115	25,920	23,142
Carson	Panhandle GCD	Canadian	96,113	81,718	73,958	66,324	59,324	53,120
		Red	93,885	89,424	80,108	71,529	63,665	56,289
Dallam	North Plains GCD	Canadian	314,814	277,174	245,338	216,215	188,745	163,943
	No District	Canadian	89,793	75,300	63,738	54,102	46,068	39,548
Donley	Panhandle GCD	Red	82,437	74,540	70,208	64,373	58,707	53,537
Gray	Panhandle GCD	Canadian	43,874	39,813	36,848	33,749	30,659	27,766
		Red	147,516	120,860	109,180	98,784	89,135	80,128
Hansford	North Plains GCD	Canadian	284,588	262,271	240,502	218,405	197,454	177,536
Hartley	North Plains GCD	Canadian	424,813	368,430	319,149	276,075	238,186	205,137
	No District	Canadian	27,646	21,118	17,852	15,019	12,780	10,961
Hemphill*	Hemphill County UWCD	Canadian	24,763	22,931	22,969	23,262	23,412	23,642
		Red	20,407	18,828	19,429	19,515	19,577	19,517
Hutchinson	North Plains GCD	Canadian	61,306	58,383	50,723	44,360	39,048	34,580
	Panhandle GCD	Canadian	14,798	13,968	14,414	14,293	13,865	13,194
	No District	Canadian	85,918	64,082	59,436	53,496	47,662	42,664
Lipscomb	North Plains GCD	Canadian	290,510	283,794	273,836	256,406	237,765	219,100
Moore	North Plains GCD	Canadian	193,001	186,154	162,142	137,321	114,658	95,490
	No District	Canadian	14,304	13,200	11,845	10,296	8,915	7,623
Ochiltree	North Plains GCD	Canadian	269,463	246,475	224,578	203,704	183,227	164,265
Oldham	No District	Canadian	20,553	19,360	18,722	17,694	16,406	15,198
		Red	3,952	3,122	2,885	2,772	2,306	2,269
Potter	High Plains UWCD No. 1	Canadian	1,731	1,118	1,041	1,041	1,041	740
		Red	3,521	2,664	1,147	326	326	326
	Panhandle GCD	Canadian	26,810	20,926	19,580	17,919	16,277	14,710
		Red	3,351	2,164	1,770	1,489	1,270	1,080
Randall	High Plains UWCD No. 1	Red	61,381	57,858	56,203	51,346	47,118	39,007
	No District	Red	28,773	27,756	26,195	24,352	21,763	19,377
Roberts	Panhandle GCD	Canadian	419,579	372,950	350,415	321,680	290,903	261,482
		Red	15,380	17,951	18,202	17,565	16,609	15,557
Sherman	North Plains GCD	Canadian	322,683	300,908	263,747	229,122	197,480	169,172
Wheeler	Panhandle GCD	Red	125,708	119,556	114,817	107,697	100,289	93,117
Total			**3,666,259**	**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**

*Hemphill county 2010 is taken from simulation year 2011

TABLE 2: MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE OGALLALA AND RITA BLANCA AQUIFERS IN GROUNDWATER MANAGEMENT AREA 1. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY COUNTY AND GEOGRAPHIC AREA.

County	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Armstrong	3	52,888	45,367	41,079	37,416	34,161	31,328
Carson	3	189,998	171,142	154,066	137,853	122,989	109,409
Dallam	1	404,607	352,474	309,076	270,317	234,813	203,491
Donley	3	82,437	74,540	70,208	64,373	58,707	53,537
Gray	3	191,390	160,673	146,028	132,533	119,794	107,894
Hansford	3	284,588	262,271	240,502	218,405	197,454	177,536
Hartley	1	452,459	389,548	337,001	291,094	250,966	216,098
Hemphill*	2	45,170	41,759	42,398	42,777	42,989	43,159
Hutchinson	3	162,022	136,433	124,573	112,149	100,575	90,438
Lipscomb	3	290,510	283,794	273,836	256,406	237,765	219,100
Moore	1	207,305	199,354	173,987	147,617	123,573	103,113
Ochiltree	3	269,463	246,475	224,578	203,704	183,227	164,265
Oldham	3	24,505	22,482	21,607	20,466	18,712	17,467
Potter	3	35,413	26,872	23,538	20,775	18,914	16,856
Randall	3	90,154	85,614	82,398	75,698	68,881	58,384
Roberts	3	434,959	390,901	368,617	339,245	307,512	277,039
Sherman	1	322,683	300,908	263,747	229,122	197,480	169,172
Wheeler	3	125,708	119,556	114,817	107,697	100,289	93,117
Total		**3,666,259**	**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**

*Hemphill county 2010 is taken from simulation year 2011

TABLE 3: MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE OGALLALA AND RITA BLANCA AQUIFERS IN GROUNDWATER MANAGEMENT AREA 1. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY GROUNDWATER CONSERVATION DISTRICT (GCD) AND GEOGRAPHIC AREA. UWCD REFERS TO UNDERGROUND WATER CONSERVATION DISTRICT.

District	Geographic Area	Year					
		2010	2020	2030	2040	2050	2060
Hemphill County UWCD*	2	45,170	41,759	42,398	42,777	42,989	43,159
High Plains UWCD No. 1	3	74,934	69,941	66,692	61,014	56,726	48,259
North Plains GCD	1	1,255,311	1,132,666	990,376	858,733	739,069	633,742
	3	905,867	850,923	789,639	722,875	657,494	595,481
Panhandle GCD	3	1,114,038	990,936	922,278	844,517	766,623	693,122
No District	1	131,743	109,618	93,435	79,417	67,763	58,132
	3	139,196	114,320	107,238	98,314	88,137	79,508
Total		**3,666,259**	**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**

*Hemphill county 2010 is taken from simulation year 2011

TABLE 4: MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE OGALLALA AND RITA BLANCA AQUIFERS IN GROUNDWATER MANAGEMENT AREA 1. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY GEOGRAPHIC AREA.

Geographic Area	Year					
	2010	2020	2030	2040	2050	2060
1	1,387,054	1,242,284	1,083,811	938,150	806,832	691,874
2*	45,170	41,759	42,398	42,777	42,989	43,159
3	2,234,035	2,026,120	1,885,847	1,726,720	1,568,980	1,416,370
Total	**3,666,259**	**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**

*Hemphill county 2010 is taken from simulation year 2011

TABLE 5: MODELED AVAILABLE GROUNDWATER BY DECADE FOR THE OGALLALA AND RITA BLANCA AQUIFERS IN GROUNDWATER MANAGEMENT AREA 1. RESULTS ARE IN ACRE-FEET PER YEAR AND ARE DIVIDED BY RIVER BASIN.

Basin	Year					
	2010	2020	2030	2040	2050	2060
Canadian*	3,027,060	2,730,073	2,470,833	2,210,483	1,963,875	1,739,871
Red*	639,199	580,090	541,223	497,164	454,926	411,532
Total	**3,666,259**	**3,310,163**	**3,012,056**	**2,707,647**	**2,418,801**	**2,151,403**

*Hemphill county 2010 is taken from simulation year 2011

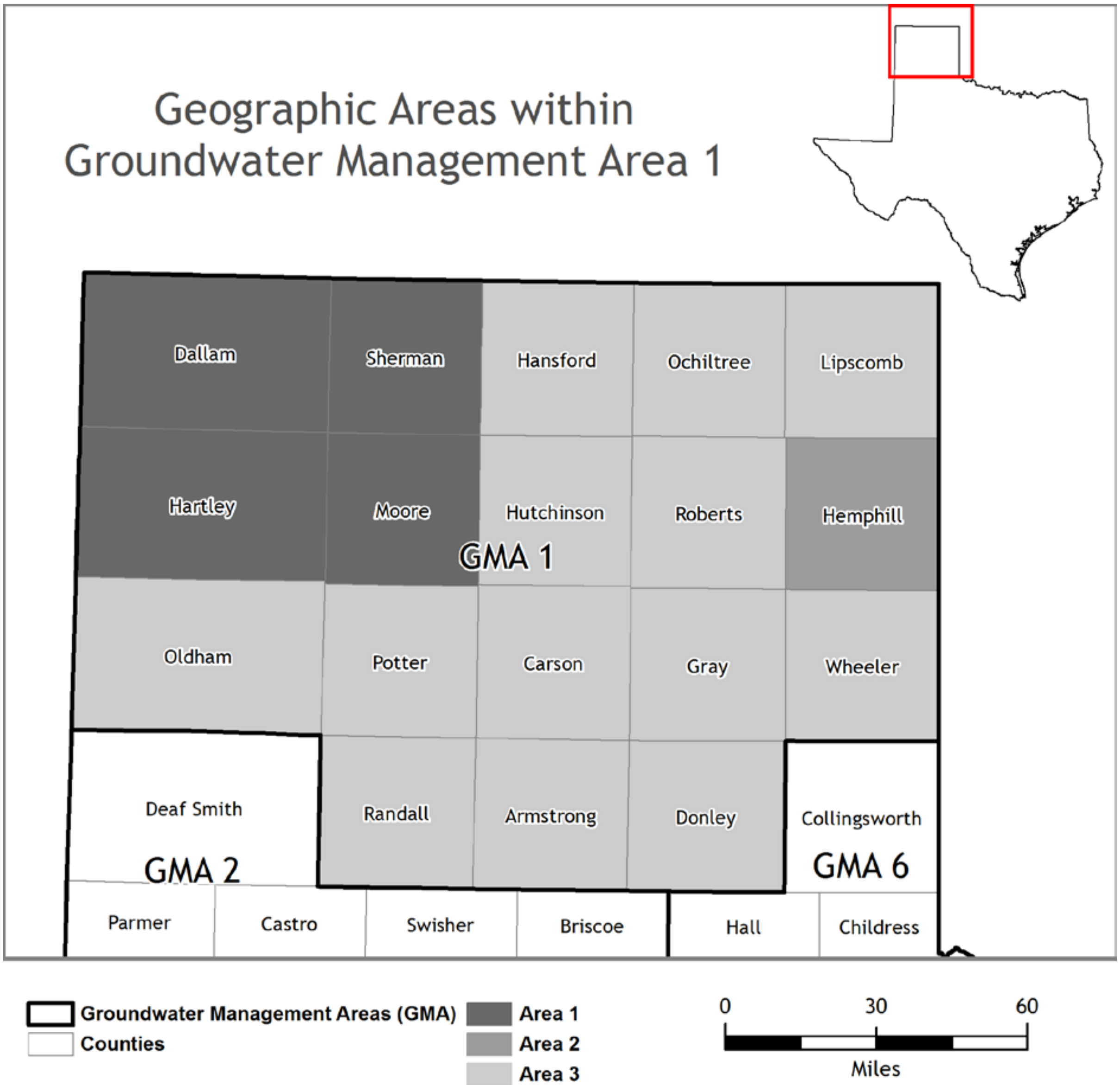

FIGURE 1: MAP SHOWING GEOGRAPHIC AREAS DEFINED BY GROUNDWATER MANAGEMENT AREA 1 IN THE DESIRED FUTURE CONDITIONS PROCESS FOR THE OGALLALA AQUIFER.

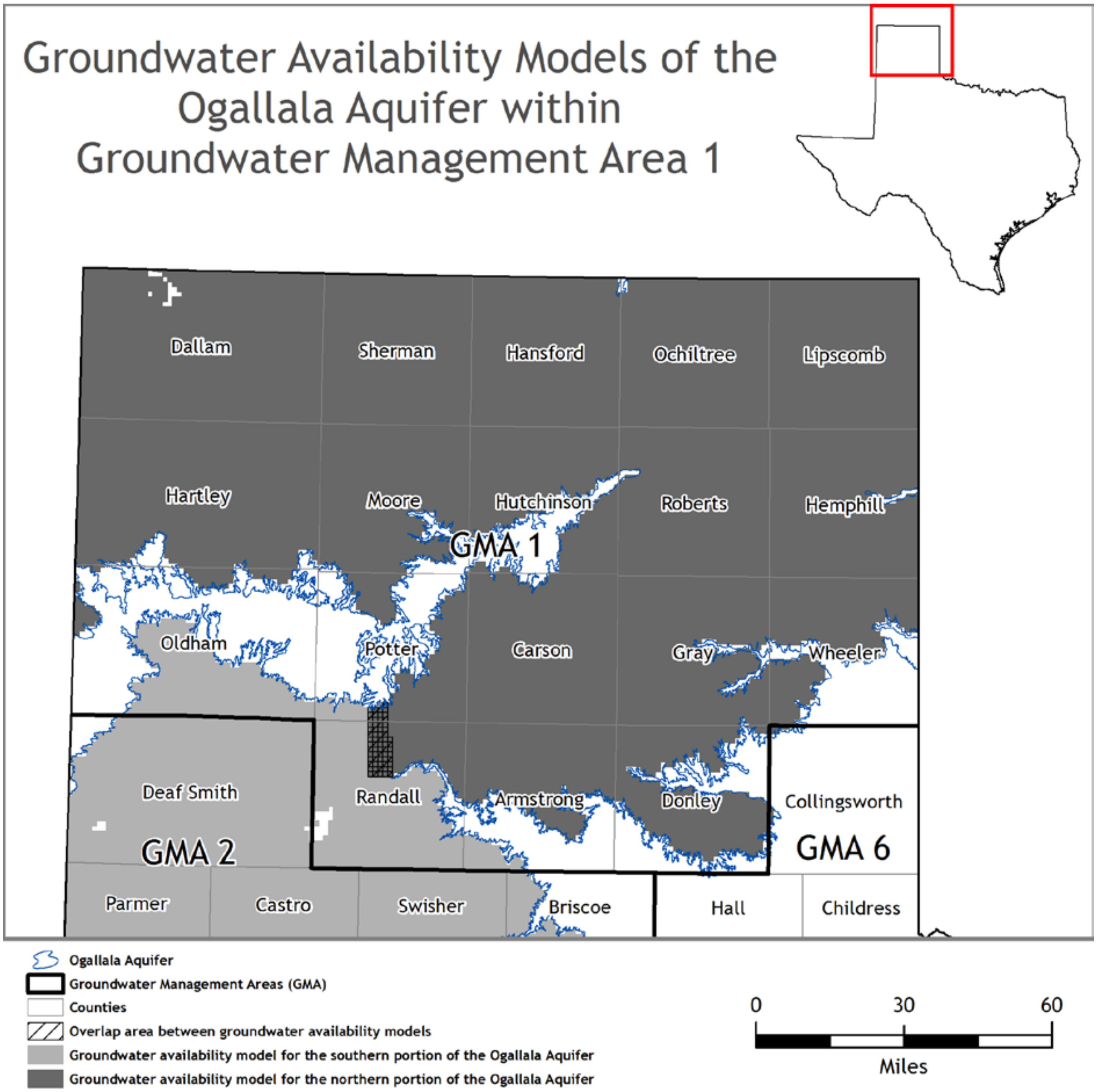

FIGURE 2: MAP SHOWING THE AREAS COVERED BY THE GROUNDWATER AVAILABILITY MODELS FOR THE NORTHERN AND SOUTHERN PORTIONS OF THE OGALLALA AQUIFER.

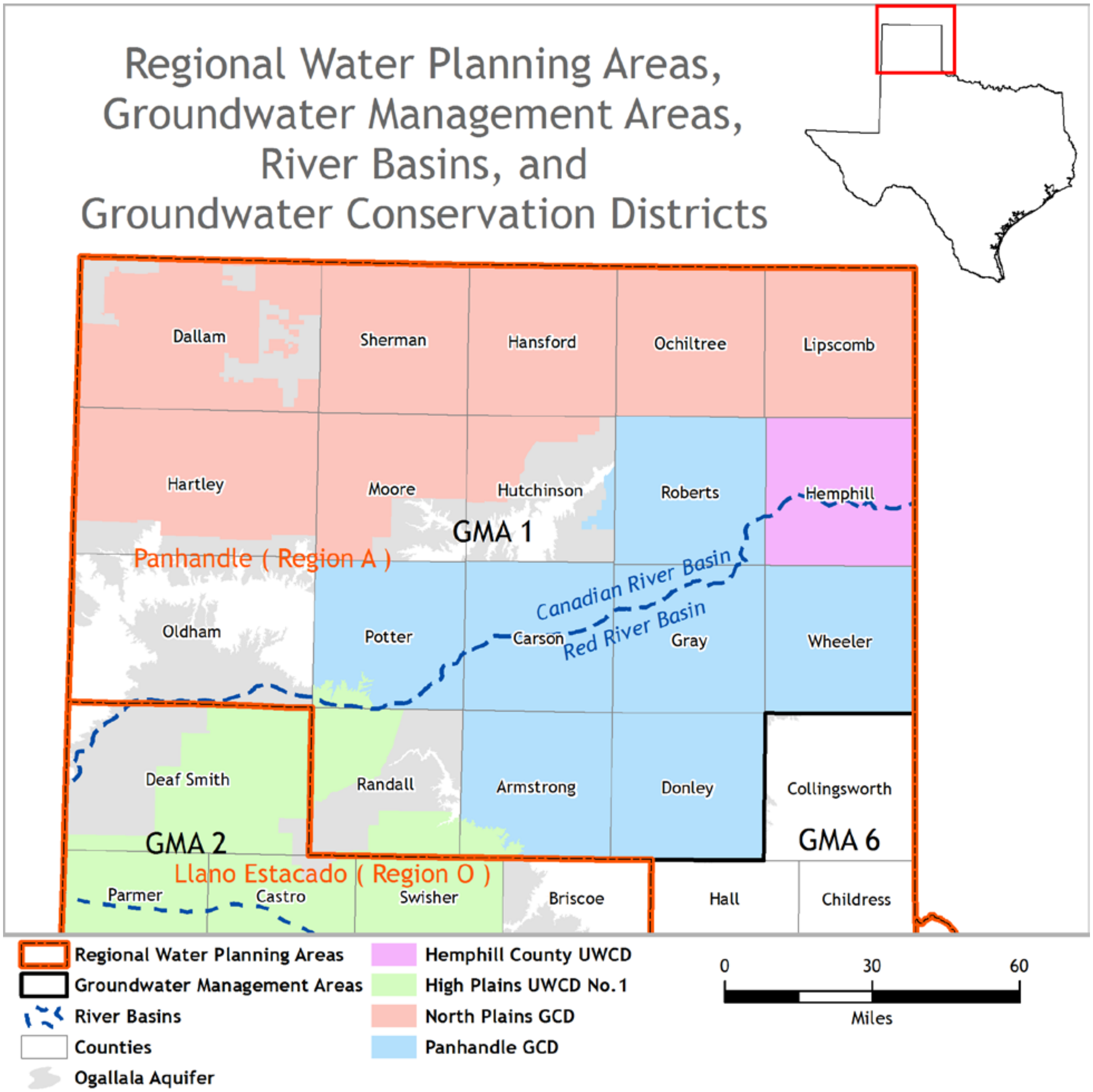

FIGURE 3: MAP SHOWING REGIONAL WATER PLANNING AREAS, GROUNDWATER MANAGEMENT AREAS, RIVER BASINS, AND GROUNDWATER CONSERVATION DISTRICTS.