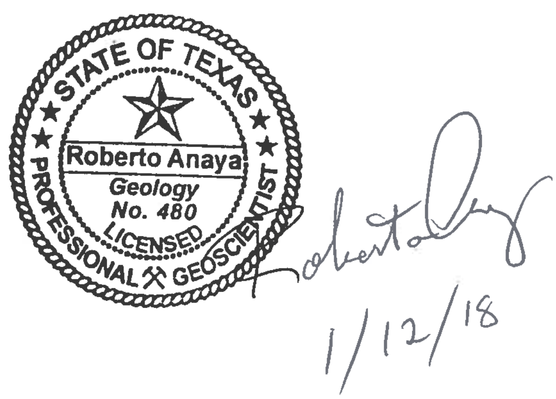
GAM Run 17-009: Hill Country Underground Water Conservation District Groundwater Management Plan

Roberto Anaya, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Availability Modeling Department
512-463-6115
January 12, 2018



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EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2015), states that, in developing its groundwater management plan, a groundwater conservation district shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board (TWDB) in conjunction with any available site-specific information provided by the district for review and comment to the Executive Administrator.

The TWDB provides data and information to the Hill Country Underground Water Conservation District in two parts. Part 1 is the Estimated Historical Water Use/State Water Plan dataset report, which will be provided to you separately by the TWDB Groundwater Technical Assistance Department. Please direct questions about the water data report to Mr. Stephen Allen at 512-463-7317 or stephen.allen@twdb.texas.gov. Part 2 is the required groundwater availability modeling information and this information includes:

1. the annual amount of recharge from precipitation, if any, to the groundwater resources within the district;
2. for each aquifer within the district, the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers; and
3. the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

The groundwater management plan for the Hill Country Underground Water Conservation District should be adopted by the district on or before April 30, 2018, and submitted to the

Executive Administrator of the TWDB on or before May 30, 2018. The current management plan for the Hill Country Underground Water Conservation District expires on July 29, 2018.

We used the groundwater availability models for the Edwards-Trinity (Plateau) and Pecos Valley aquifers version 1.01 (Anaya and Jones, 2009) and the Minor Aquifers of the Llano Uplift Region (Shi and others, 2016) to estimate the management plan information for the aquifers within the Hill Country Underground Water Conservation District. This report replaces the results of GAM Run 12-015 (Jones, 2012). GAM Run 17-009 meets current standards set after the release of GAM Run 12-015 and includes updated information for the Edwards-Trinity (Plateau) Aquifer groundwater availability model using an updated grid attribute tableand results from the recently released groundwater availability model for the Minor Aquifers of the Llano Uplift Region (Shi and others, 2016). Tables 1 through 4 summarize the groundwater availability model data required by statute and Figures 1 through 4 show the area of the models from which the values in the tables were extracted. If, after review of the figures, the Hill Country Underground Water Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB at your earliest convenience.

METHODS:

In accordance with the provisions of the Texas State Water Code, Section 36.1071, Subsection (h), the groundwater availability models mentioned above were used to estimate information for the Hill Country Underground Water Conservation District management plan. Water budgets were extracted for the historical model periods for the Edwards-Trinity (Plateau) Aquifer, and the Trinity Aquifer (1980 through 1999) using ZONEBUDGET Version 3.01 (Harbaugh, 2009) and from the groundwater availability model for the Minor Aquifers of the Llano Uplift Region (Shi and others, 2016) (1981 through 2010) using ZONEBUDGET USG Version 1.00 (Panay and others, 2013). The average annual water budget values for recharge, surface-water outflow, inflow to the district, and outflow from the district for the aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Edwards-Trinity (Plateau) Aquifer

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers. See Anaya and Jones (2009) for assumptions and limitations of the model.
- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains 2 layers: Layer 1 (the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer System, and layer 2 (comprised of the undifferentiated Trinity Group hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer System). The two layers were combined for calculating water budget flows in the Edwards-Trinity (Plateau) Aquifer System within the district.
- The model was run with MODFLOW-96 (Harbaugh and others, 1996).

Trinity Aquifer

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers. See Anaya and Jones (2009) for assumptions and limitations of the model.
- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains 2 layers. However, only layer 2 (comprised of the undifferentiated Trinity Group hydrostratigraphic units) was used for calculating water budget flows in the Hill Country portion of the Trinity Aquifer within the district.
- We used the groundwater availability model for the Edwards-Trinity (Plateau) instead of the groundwater availability model for the Hill Country portion of the Trinity Aquifer because the Edwards-Trinity (Plateau) Aquifer model covers the entire geographical areas of district. Both groundwater availability models are aligned with different model grid orientations which prevent combining the results from each without double accounting or omitting important water budget information.
- The model was run with MODFLOW-96 (Harbaugh and others, 1996).

Ellenburger-San Saba and Hickory Aquifers

- We used version 1.01 of the groundwater availability model for the Minor Aquifers in the Llano Uplift Region. See Shi and others (2016) for assumptions and limitations of the model.

- The groundwater availability model for the Minor Aquifers in Llano Uplift Region contains eight layers:

    - Layer 1 — the Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits
    - Layer 2 — confining units
    - Layer 3 — the Marble Falls Aquifer and equivalent
    - Layer 4 — confining units
    - Layer 5 — the Ellenburger-San Saba Aquifer and equivalent
    - Layer 6 — confining units
    - Layer 7 — the Hickory Aquifer and equivalent
    - Layer 8 — confining (Precambrian) units

- Perennial rivers and reservoirs were simulated using MODFLOW-USG river package. Springs were simulated using MODFLOW-USG drain package. For this management plan, groundwater discharge to surface water includes groundwater leakage to the river and drain boundaries.

- The model was run with MODFLOW-USG beta (development) version (Panday and others, 2013).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifers according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Edwards-Trinity (Plateau), Trinity, Ellenburger-San Saba, and Hickory aquifers located within Hill Country Underground Water Conservation District and averaged over the historical calibration periods, as shown in Tables 1through 4.

1. Precipitation recharge—the areally distributed recharge sourced from precipitation falling on the outcrop areas of the aquifers (where the aquifer is exposed at land surface) within the district.

2. Surface-water outflow—the total water discharging from the aquifer (outflow) to surface-water features such as streams, reservoirs, and springs.

3. Flow into and out of district—the lateral flow within the aquifer between the district and adjacent counties.

4. Flow between aquifers—the net vertical flow between the aquifer and adjacent aquifers or confining units. This flow is controlled by the relative water levels in each aquifer and aquifer properties of each aquifer or confining unit that define the amount of leakage that occurs.

The information needed for the district's management plan is summarized in Tables 1 through 4. It is important to note that sub-regional water budgets are not exact. This is due to the size of the model cells and the approach used to extract data from the model. To avoid double accounting, a model cell that straddles a political boundary, such as a district or county boundary, is assigned to one side of the boundary based on the location of the centroid of the model cell. For example, if a cell contains two counties, the cell is assigned to the county where the centroid of the cell is located.

TABLE 1. SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER FOR HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Edwards-Trinity (Plateau) Aquifer	17,396
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	12,935
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	4,431
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	8,810
Estimated net annual volume of flow between each aquifer in the district	From the Edwards-Trinity (Plateau) Aquifer to the Trinity Aquifer	1,073
	From the Edwards-Trinity (Plateau) Aquifer to the Ellenburger-San Saba Aquifer	949[1]
	From the Edwards-Trinity (Plateau) Aquifer to the Hickory Aquifer	11[2]

[1] The estimated net annual volume of flow between the Edwards-Trinity (Plateau) and the Ellenburger-San Saba aquifers was calculated from version 1.01 of the groundwater availability model for the Minor Aquifers in the Llano Uplift Region.

[2] The estimated net annual volume of flow between the Edwards-Trinity (Plateau) and the Hickory aquifers was calculated from version 1.01 of the groundwater availability model for the Minor Aquifers in the Llano Uplift Region.

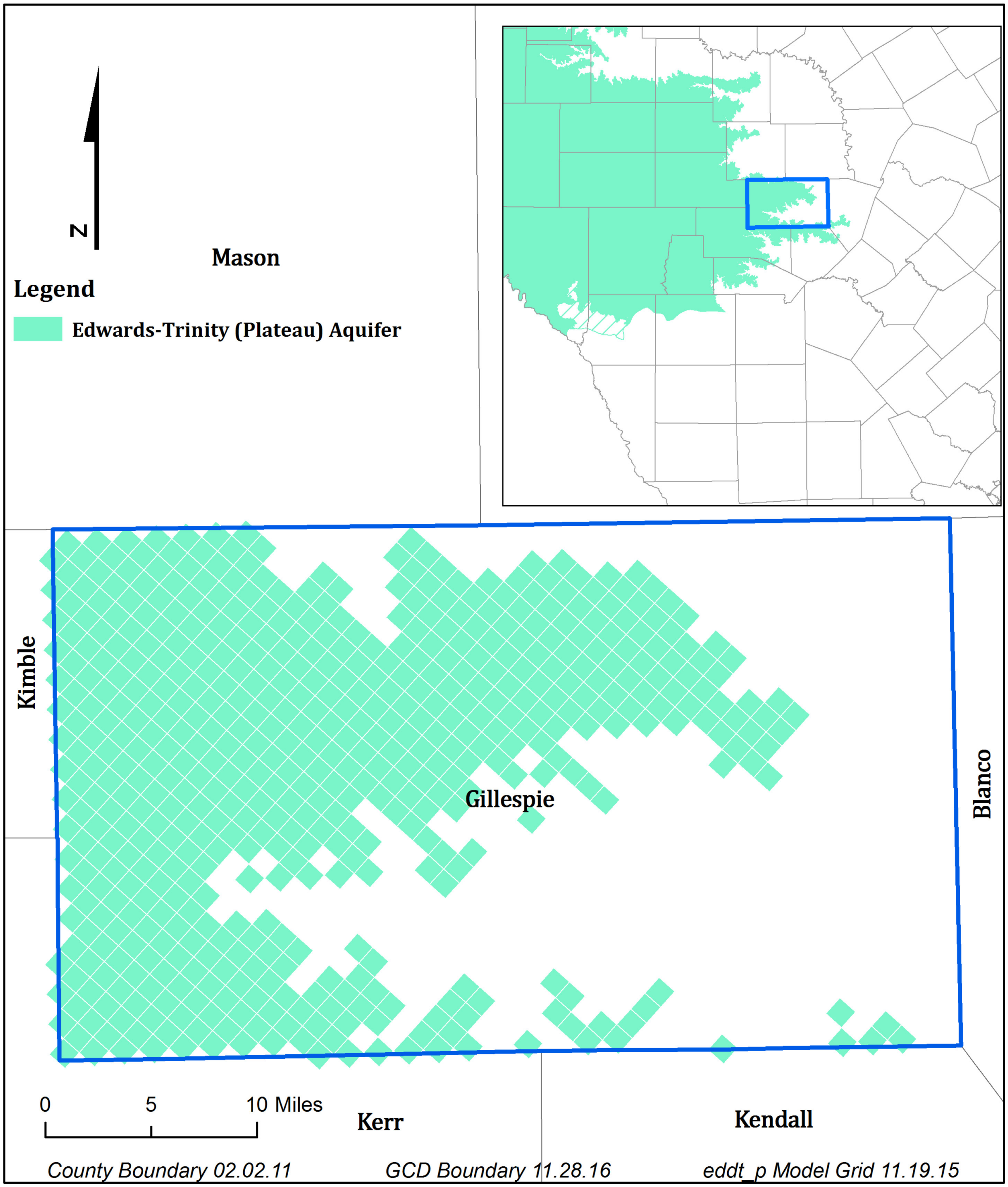

FIGURE 1. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFERS FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE EDWARDS-TRINITY (PLATEAU) AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 2. SUMMARIZED INFORMATION FOR THE TRINITY AQUIFER FOR HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Trinity Aquifer	28,756
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Trinity Aquifer	25,625
Estimated annual volume of flow into the district within each aquifer in the district	Trinity Aquifer	412
Estimated annual volume of flow out of the district within each aquifer in the district	Trinity Aquifer	1,473
Estimated net annual volume of flow between each aquifer in the district	From the Edwards-Trinity (Plateau) Aquifer to the Trinity Aquifer	1,073
	From the Trinity Aquifer to the Ellenburger-San Saba Aquifer	91[3]

[3] The estimated net annual volume of flow between the Trinity and the Ellenburger-San Saba aquifers was calculated from version 1.01 of the groundwater availability model for the Minor Aquifers in the Llano Uplift Region.

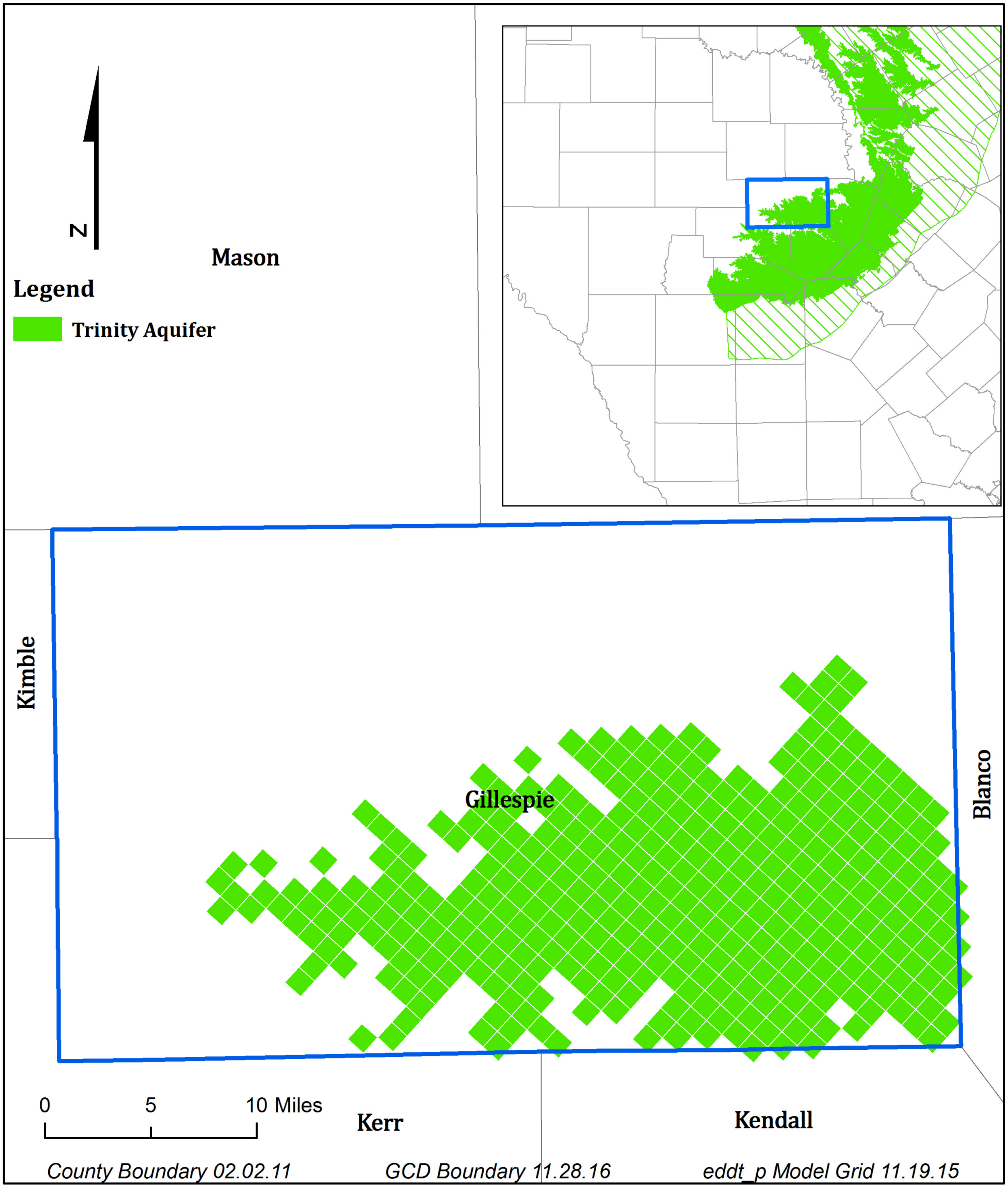

FIGURE 2. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFERS FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE TRINITY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 3. SUMMARIZED INFORMATION FOR THE ELLENBURGER-SAN SABA AQUIFER FOR HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Ellenburger-San Saba Aquifer	941
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Ellenburger-San Saba Aquifer	1,594
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	613
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	8,215
Estimated net annual volume of flow between each aquifer in the district	From Edwards-Trinity (Plateau) Aquifer to Ellenburger-San Saba Aquifer	949
	From Trinity Aquifer to Ellenburger-San Saba Aquifer	91
	From Quaternary Alluvium to Ellenburger-San Saba Aquifer	13
	From confining unit between Cretaceous aquifers and Marble Falls Formation to Ellenburger-San Saba Aquifer	29
	From Ellenburger-San Saba Aquifer to Marble Falls Formation brackish zone	152
	From confining unit between Marble Falls Formation and Ellenburger-San Saba Aquifer to Ellenburger-San Saba Aquifer	33,835
	From Ellenburger-San Saba Aquifer to Ellenburger-San Saba brackish zone	1,421
	From Ellenburger-San Saba Aquifer to confining unit between Ellenburger-San Saba and Hickory aquifers	23,701
	From Hickory Aquifer to Ellenburger-San Saba Aquifer	3,381
	From Pre-Cambrian confining unit to Ellenburger-San Saba Aquifer	629

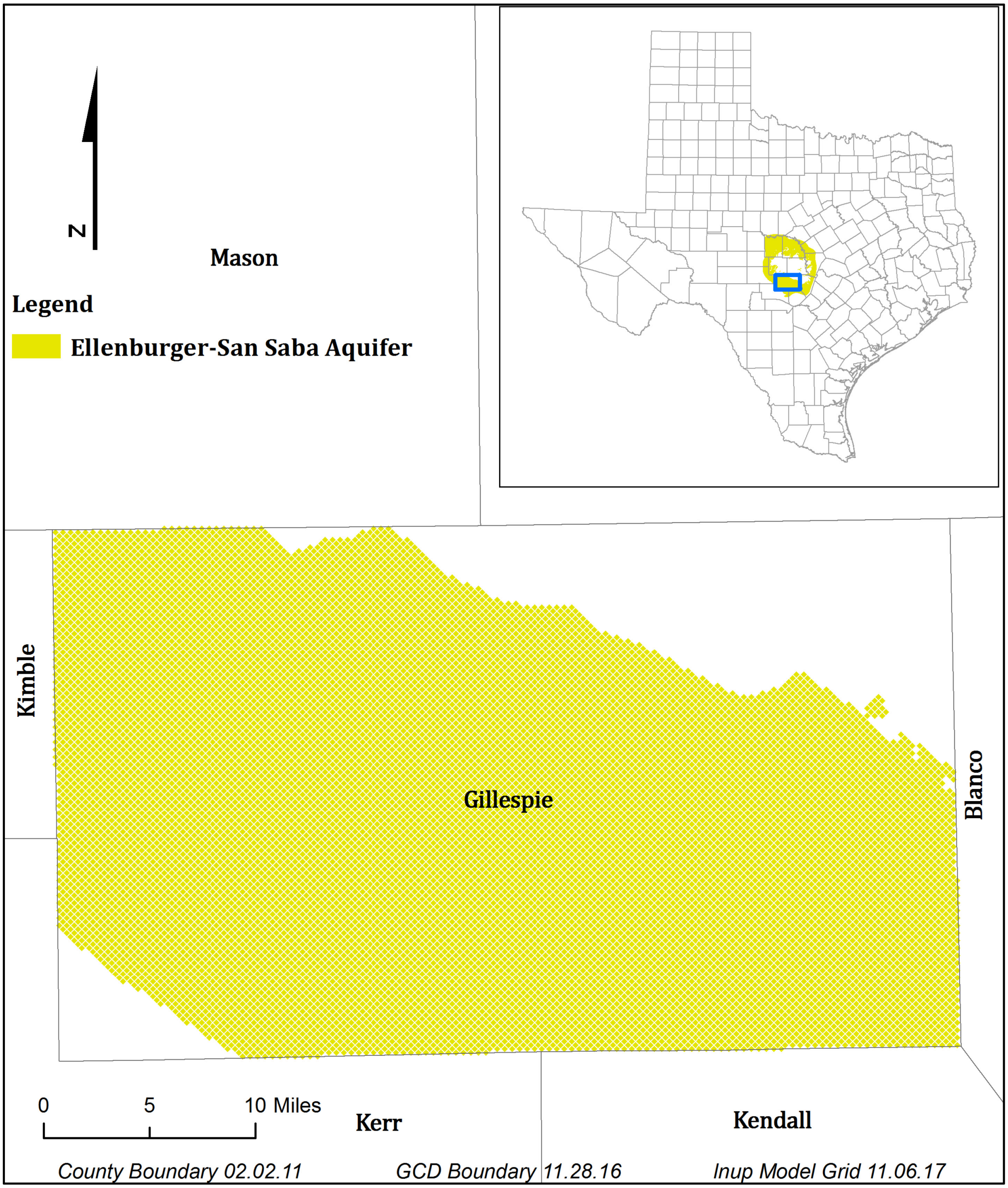

FIGURE 3. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE ELLENBURGER-SAN SABA EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 4. SUMMARIZED INFORMATION FOR THE HICKORY AQUIFER FOR HILL COUNTRY UNDERGROUND WATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN. ALL VALUES ARE REPORTED IN ACRE-FEET PER YEAR AND ROUNDED TO THE NEAREST 1 ACRE-FOOT.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Hickory Aquifer	263
Estimated annual volume of water that discharges from the aquifer to springs and any surface-water body including lakes, streams, and rivers	Hickory Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	1,472
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	17,803
Estimated net annual volume of flow between each aquifer in the district	From Edwards-Trinity (Plateau) Aquifer to Hickory Aquifer	11
	From Hickory Aquifer to Marble Falls Formation brackish zone	122
	From Hickory Aquifer to confining unit between Marble Falls Formation and Ellenburger-San Saba Aquifer	32
	From Hickory Aquifer to Ellenburger-San Saba Aquifer	3,381
	From Ellenburger-San Saba Aquifer brackish zone to Hickory Aquifer	291
	From confining unit between Ellenburger-San Saba and Hickory aquifers to Hickory Aquifer	25,288
	From Hickory Aquifer to Hickory Aquifer brackish zone	289
	From Hickory Aquifer to Pre-Cambrian confining unit	4,893

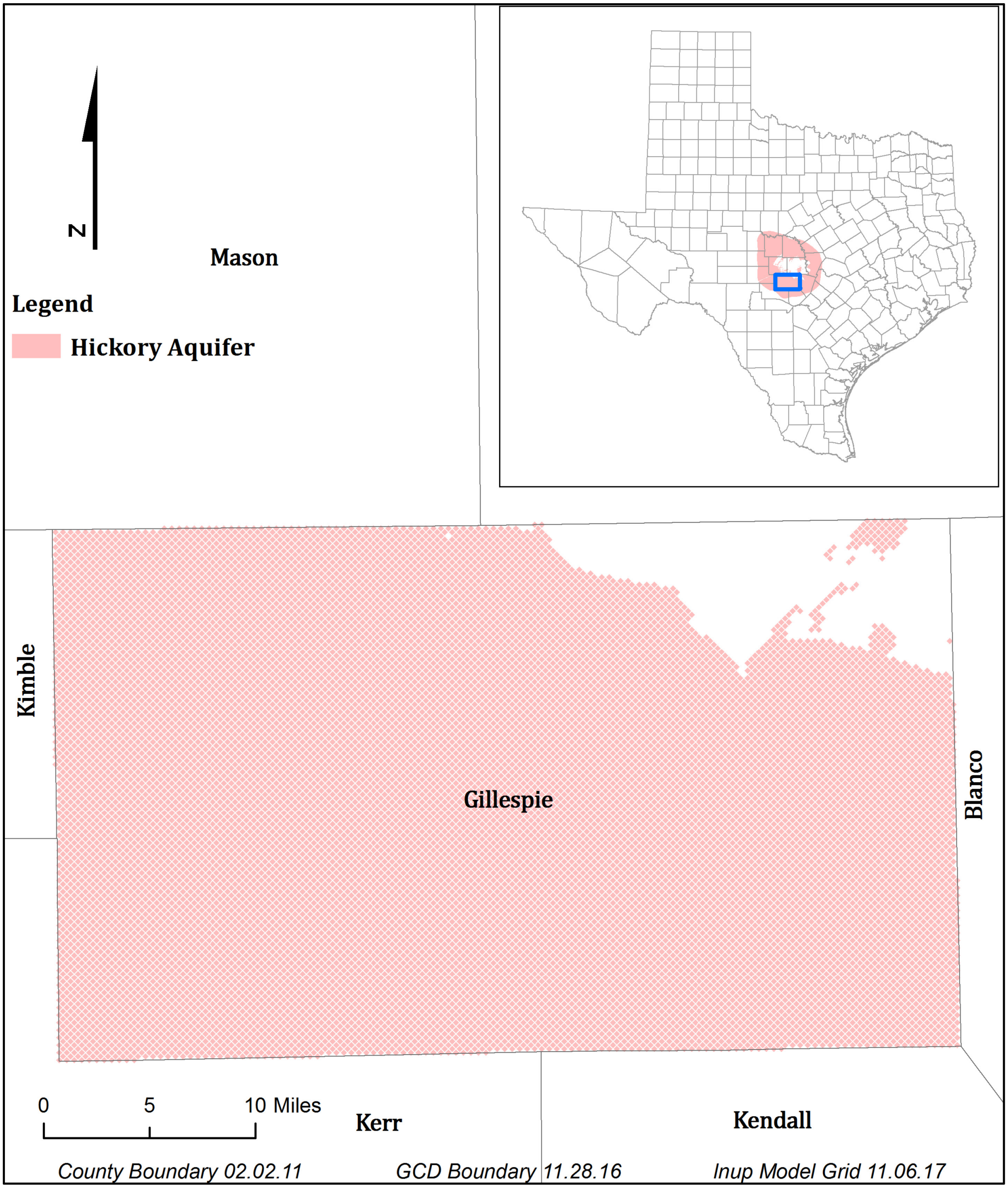

FIGURE 4. AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE MINOR AQUIFERS OF THE LLANO UPLIFT REGION FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE HICKORY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

LIMITATIONS:

The groundwater models used in completing this analysis are the best available scientific tools that can be used to meet the stated objectives. To the extent that this analysis will be used for planning purposes and/or regulatory purposes related to pumping in the past and into the future, it is important to recognize the assumptions and limitations associated with the use of the results. In reviewing the use of models in environmental regulatory decision making, the National Research Council (2007) noted:

> *"Models will always be constrained by computational limitations, assumptions, and knowledge gaps. They can best be viewed as tools to help inform decisions rather than as machines to generate truth or make decisions. Scientific advances will never make it possible to build a perfect model that accounts for every aspect of reality or to prove that a given model is correct in all respects for a particular regulatory application. These characteristics make evaluation of a regulatory model more complex than solely a comparison of measurement data with model results."*

A key aspect of using the groundwater model to evaluate historic groundwater flow conditions includes the assumptions about the location in the aquifer where historic pumping was placed. Understanding the amount and location of historic pumping is as important as evaluating the volume of groundwater flow into and out of the district, between aquifers within the district (as applicable), interactions with surface water (as applicable), recharge to the aquifer system (as applicable), and other metrics that describe the impacts of that pumping. In addition, assumptions regarding precipitation, recharge, and interaction with streams are specific to particular historic time periods.

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

It is important for groundwater conservation districts to monitor groundwater pumping and overall conditions of the aquifer. Because of the limitations of the groundwater model and the assumptions in this analysis, it is important that the groundwater conservation districts work with the TWDB to refine this analysis in the future given the reality of how the aquifer responds to the actual amount and location of pumping now and in the future. Historic precipitation patterns also need to be placed in context as future climatic conditions, such as dry and wet year precipitation patterns, may differ and affect groundwater flow conditions.

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