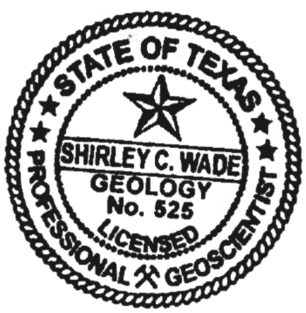
GAM RUN 23-017: BLANCO-PEDERNALES GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Dwight Zedric Q. Capus, GIT and Shirley Wade, Ph.D., P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-936-2404
August 30, 2023



Shirley C. Wade
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EXECUTIVE SUMMARY:

Texas Water Code § 36.1071(h), 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 Blanco-Pedernales Groundwater 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, which includes:

1. the annual amount of recharge from precipitation, if any, to the groundwater resources within the district;

2. the annual volume of water that discharges from the aquifer to springs and any surface-water bodies, including lakes, streams, and rivers, for each aquifer within the district; 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 Blanco-Pedernales Groundwater Conservation District should be adopted by the district on or before October 25, 2023 and submitted to the executive administrator of the TWDB on or before November 24, 2023. The current management plan for the Blanco-Pedernales Groundwater Conservation District expires on January 23, 2024.

We used three groundwater availability models for the Blanco-Pedernales Groundwater Conservation District. Information for the Hickory, Ellenburger-San Saba, and Marble Falls aquifers is from version 1.01 of the groundwater availability model for the minor aquifers of the Llano Uplift (Shi and others, 2016). Information for the Trinity Aquifer is from the groundwater availability model for the Hill Country portion of the Trinity Aquifer (Jones and others, 2011), hereafter called the southern portion of the Trinity Aquifer, and the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2009). Information for the Edwards-Trinity (Plateau) Aquifer is from version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2009).

This report replaces the results of GAM Run 18-003 (Ballew, 2018). Values may differ from the previous report as a result of routine updates to the spatial grid file used to define county, groundwater conservation district, and aquifer boundaries, which can impact the calculated water budget values. Additionally, the approach used for analyzing model results is reviewed during each update and may have been refined to better delineate groundwater flows. Tables 1 through 5 summarize the groundwater availability model data required by statute. Figures 1, 3, 5, 7, and 9 show the area of the models from which the values in Tables 1 through 5 were extracted. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1 through 5. If the Blanco-Pedernales Groundwater Conservation District determines that the district boundaries used in the assessment do not reflect current conditions after reviewing the figures, please notify the TWDB Groundwater Modeling Department at your earliest convenience.

The flow components presented in this report do not represent the full groundwater budget. If additional inflow and outflow information would be helpful for planning purposes, the district may submit a request in writing to the TWDB Groundwater Modeling Department for the full groundwater budget.

METHODS:

In accordance with the provisions of the Texas Water Code § 36.1071(h), the groundwater availability models mentioned above were used to estimate information for the Blanco-Pedernales Groundwater Conservation District management plan. Water budgets were extracted for the historical model periods in the respective groundwater availability models. For the Hickory, Ellenburger-San Saba, and Marble Falls aquifers, water budgets were extracted over the historical calibration period (1981 through 2010) using ZONEBUDGET USG Version 1.00 (Panday and others, 2013). Water budgets were extracted using ZONEBUDGET Version 3.01 (Harbaugh, 2009) for the Trinity Aquifer historical calibration period (1981 through 1997), and for the Edwards-Trinity (Plateau) Aquifer historical calibration period (1981 through 2000). The average annual water budget values for recharge, surface-water outflow, inflow to the district, outflow from the district, and the flow between aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Groundwater availability model for the minor aquifers of the Llano Uplift

- We used version 1.01 of the groundwater availability model for the minor aquifers in the Llano Uplift (Shi and others, 2016) to analyze the Hickory, Ellenburger-San Saba, and Marble Falls aquifers. See Shi and others (2016) for assumptions and limitations of the model.
- The groundwater availability model for the minor aquifers in the Llano Uplift contains eight layers:
    - Layer 1 represents the Trinity Aquifer, Edwards-Trinity (Plateau) Aquifer, and younger alluvium deposits
    - Layer 2 represents Permian and Pennsylvanian confining units
    - Layer 3 represents the Marble Falls Aquifer and equivalent units
    - Layer 4 represents Mississippian confining units
    - Layer 5 represents the Ellenburger-San Saba Aquifer and equivalent units
    - Layer 6 represents Cambrian confining units
    - Layer 7 represents the Hickory Aquifer and equivalent units

    - Layer 8 represents Precambrian units

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

- Individual water budgets for the district were determined for the Marble Falls Aquifer (Layer 3), Ellenburger-San Saba Aquifer (Layer 5), and the Hickory Aquifer (Layer 7).

- Water budget terms were averaged for the period 1981 through 2010 (stress periods 2 through 31).

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

Groundwater availability model for the southern portion of the Trinity Aquifer

- We used version 2.01 of the groundwater availability model for the southern portion of the Trinity Aquifer for the portion of the Trinity Aquifer covered by the model within the Blanco-Pedernales Groundwater Conservation District. See Jones and others (2011) for assumptions and limitations of the groundwater availability model. See Figure 7 for the area of the aquifer covered by this model.

- The groundwater availability model includes four layers, representing (from top to bottom):

    1. The Edwards Group of the Edwards-Trinity (Plateau) Aquifer,

    2. the Upper Trinity hydrostratigraphic unit,

    3. the Middle Trinity hydrostratigraphic unit, and

    4. the Lower Trinity hydrostratigraphic unit.

- We determined the overall water budget for the outcrop area of the southern portion of the Trinity Aquifer (Layers 2 through 4 collectively) within Blanco-Pedernales Groundwater Conservation District. Layer 1 is not present in the district.

- Water budgets were estimated by averaging over the period 1981 to 1997 (stress periods 2 through 18).

- Only the outcrop area of the southern portion of the Trinity Aquifer was modeled. The down-dip extent that underlies the Edwards (Balcones Fault Zone) Aquifer is not modeled.

- The model was run using MODFLOW-96 (Harbaugh and McDonald, 1996).

Groundwater availability model of the Edwards-Trinity (Plateau) and Pecos Valley aquifers

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (Anaya and Jones, 2009) to analyze the Edwards-Trinity (Plateau) Aquifer and the portion of the Trinity Aquifer not covered by the groundwater availability model of the southern portion of the Trinity Aquifer. 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 the following two layers in the Blanco-Pedernales Groundwater Conservation District:

    - Layer 1 represents the Edwards Group and equivalent limestone hydrostratigraphic units of the Edwards-Trinity (Plateau) Aquifer

    - Layer 2 represents the Trinity Group hydrostratigraphic units or equivalent units of the Edwards-Trinity (Plateau) and Trinity aquifers

- The two layers were combined for calculating water budget flows in the Edwards-Trinity (Plateau) Aquifer within the district and were divided into zones representing the lateral extents of the Edwards-Trinity (Plateau) and Trinity aquifers.

- Layer 2 of the model, which represents the Trinity Aquifer within Blanco-Pedernales Groundwater Conservation District, was used for the water budget calculations for the Trinity Aquifer. See Figure 7 for the portion of the Trinity Aquifer covered by this model.

- Water budget terms were averaged for the period 1981 through 2000 (stress periods 2 through 21).

- The model was run with MODFLOW-96 (Harbaugh and McDonald, 1996).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Hickory, Ellenburger-San Saba, Marble Falls, Trinity, and Edwards-Trinity (Plateau) aquifers located within the Blanco-Pedernales Groundwater Conservation District and averaged over the historical calibration period, as shown in Tables 1, 2, 3, 4, and 5.

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 5. Figures 1, 3, 5, 7, and 9 show the area of the models from which the values in Tables 1 through 5 were extracted. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1 through 5. 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 Hickory Aquifer that is needed for the Blanco-Pedernales Groundwater 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	2,089
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Hickory Aquifer	15,721
Estimated annual volume of flow into the district within each aquifer in the district	Hickory Aquifer	7,607
Estimated annual volume of flow out of the district within each aquifer in the district	Hickory Aquifer	7,260
Estimated net annual volume of flow between each aquifer in the district	From Hickory Aquifer to Trinity Aquifer	61
	From Hickory Aquifer to Quaternary alluvium	19
	From Hickory Aquifer to Marble Falls equivalent units	24
	From Hickory Aquifer to Mississippian Confining unit	39
	From Hickory Aquifer to Ellenburger-San Saba Aquifer	4,159
	From Hickory Aquifer to Ellenburger-San Saba Equivalent	975
	To Hickory Aquifer from Cambrian Confining unit	4,117
	To Hickory Aquifer from Hickory equivalent unit	2,530
	From Hickory Aquifer to Precambrian confining unit	484

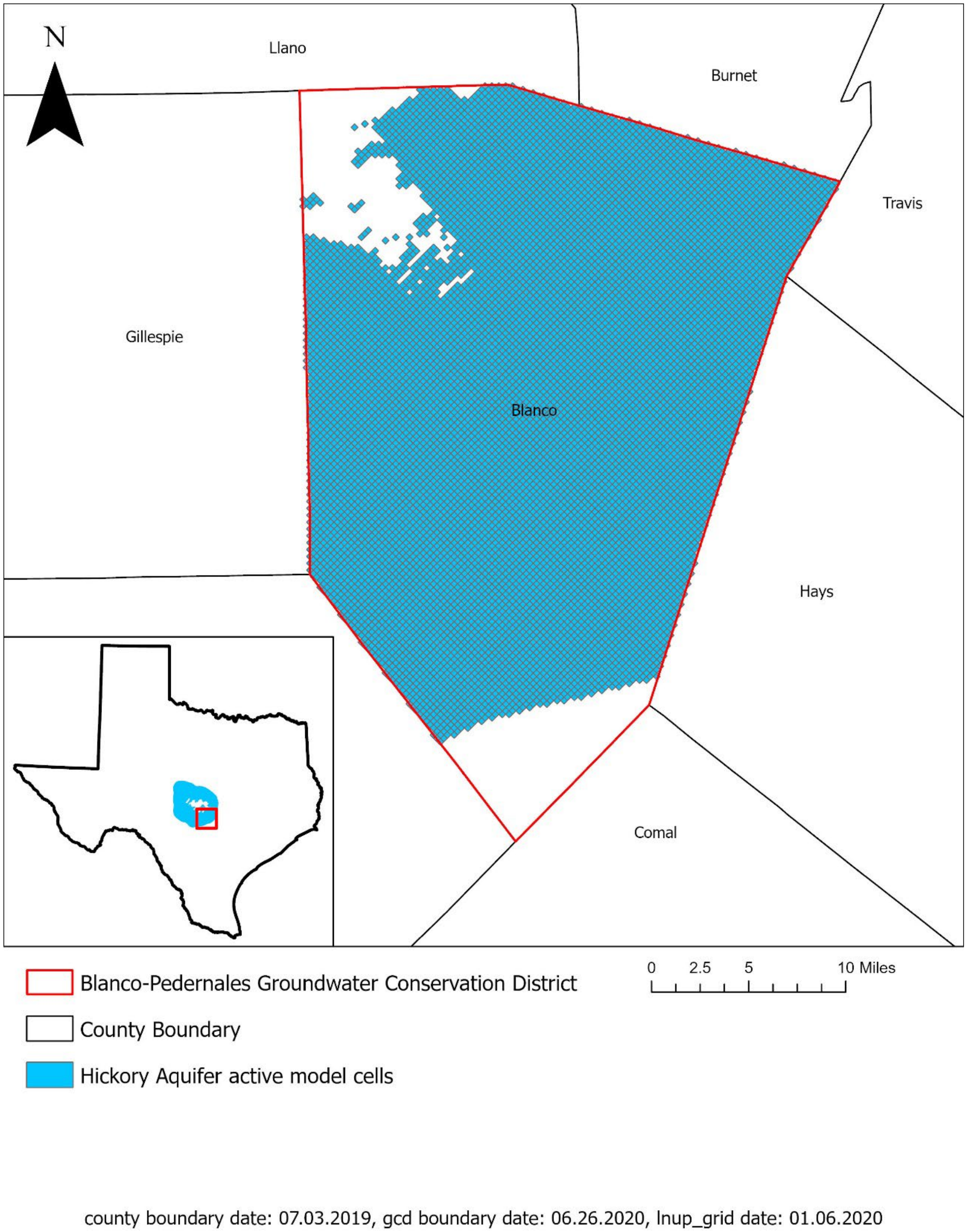
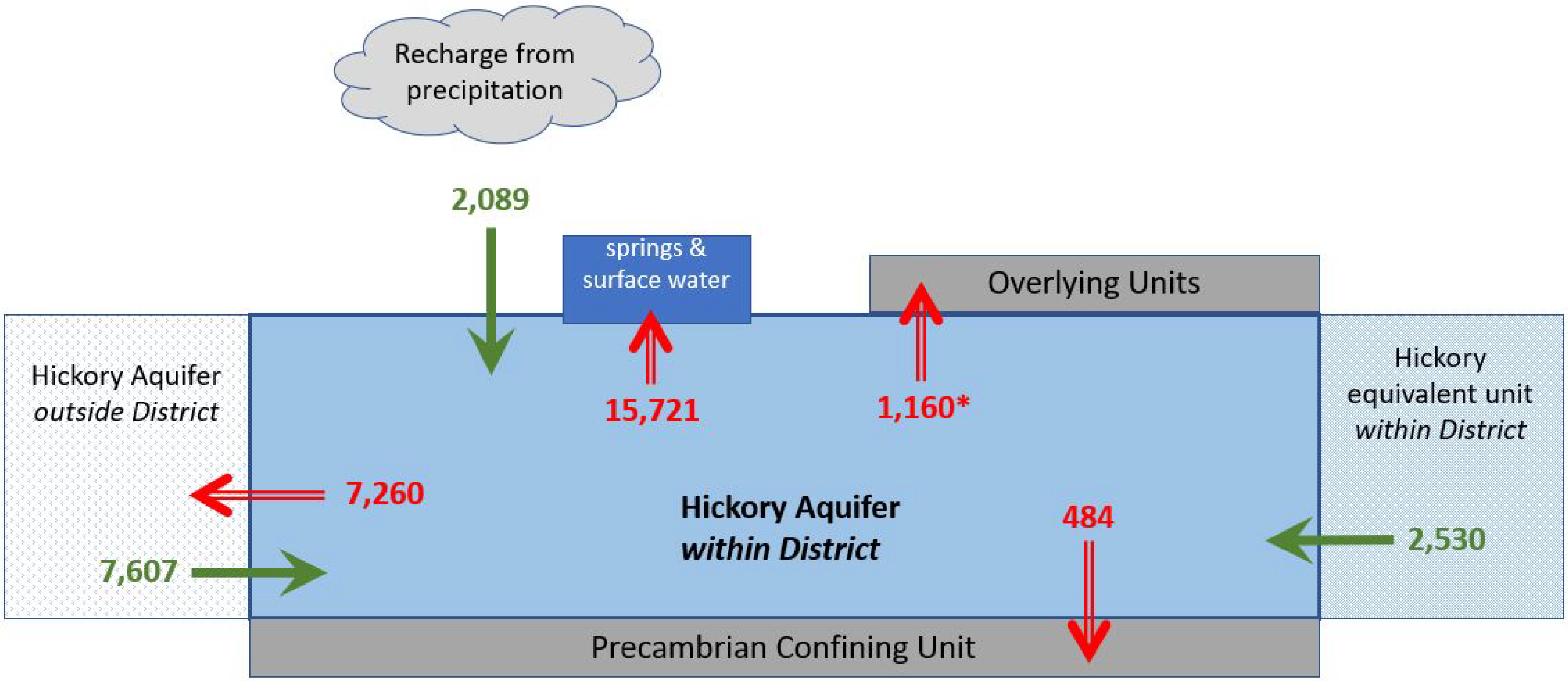


Figure 1: Area of the groundwater availability model for the minor aquifers in the Llano Uplift from which the information in Table 1 was extracted (the Hickory Aquifer extent within the district boundary).



*Flow to Overlying units within district includes net flow of 61 acre-feet per year from Hickory Aquifer to Trinity Aquifer, 19 acre-feet per year from Hickory Aquifer to Quaternary alluvium, 24 acre-feet per year from Hickory Aquifer to Marble Falls equivalent units, 39 acre-feet per year from Hickory Aquifer to Ellenburger-San Saba Aquifer, 4,159 acre-feet per year from Hickory Aquifer to Ellenburger-San Saba Aquifer, 975 acre-feet per year from Hickory Aquifer to Ellenburger-San Saba Aquifer Equivalent, and 4,117 acre-feet per year to Hickory Aquifer from Cambrian Confining unit.

Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 2: Generalized diagram of the summarized budget information from Table 1, representing directions of flow for the Hickory Aquifer within the Blanco-Pedernales Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 2: Summarized information for the Ellenburger-San Saba Aquifer that is needed for the Blanco-Pedernales Groundwater 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	16,482
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	24,178
Estimated annual volume of flow into the district within each aquifer in the district	Ellenburger-San Saba Aquifer	6,907
Estimated annual volume of flow out of the district within each aquifer in the district	Ellenburger-San Saba Aquifer	12,406
Estimated net annual volume of flow between each aquifer in the district	To Ellenburger-San Saba Aquifer from Trinity Aquifer	990
	To Ellenburger-San Saba Aquifer from Quaternary alluvium	75
	From Ellenburger-San Saba Aquifer to Permian/Pennsylvanian Confining Unit	374
	From Ellenburger-San Saba Aquifer to Marble Falls Aquifer	480
	To Ellenburger-San Saba Aquifer from Marble Falls equivalent units	242
	From Ellenburger-San Saba Aquifer to Mississippian Confining unit	2,930
	From Ellenburger-San Saba Aquifer to Ellenburger-San Saba equivalent units	609
	From Ellenburger-San Saba Aquifer to Cambrian Confining unit	598
	To Ellenburger-San Saba Aquifer from Hickory Aquifer	4,159
	To Ellenburger-San Saba Aquifer from Precambrian confining unit	516

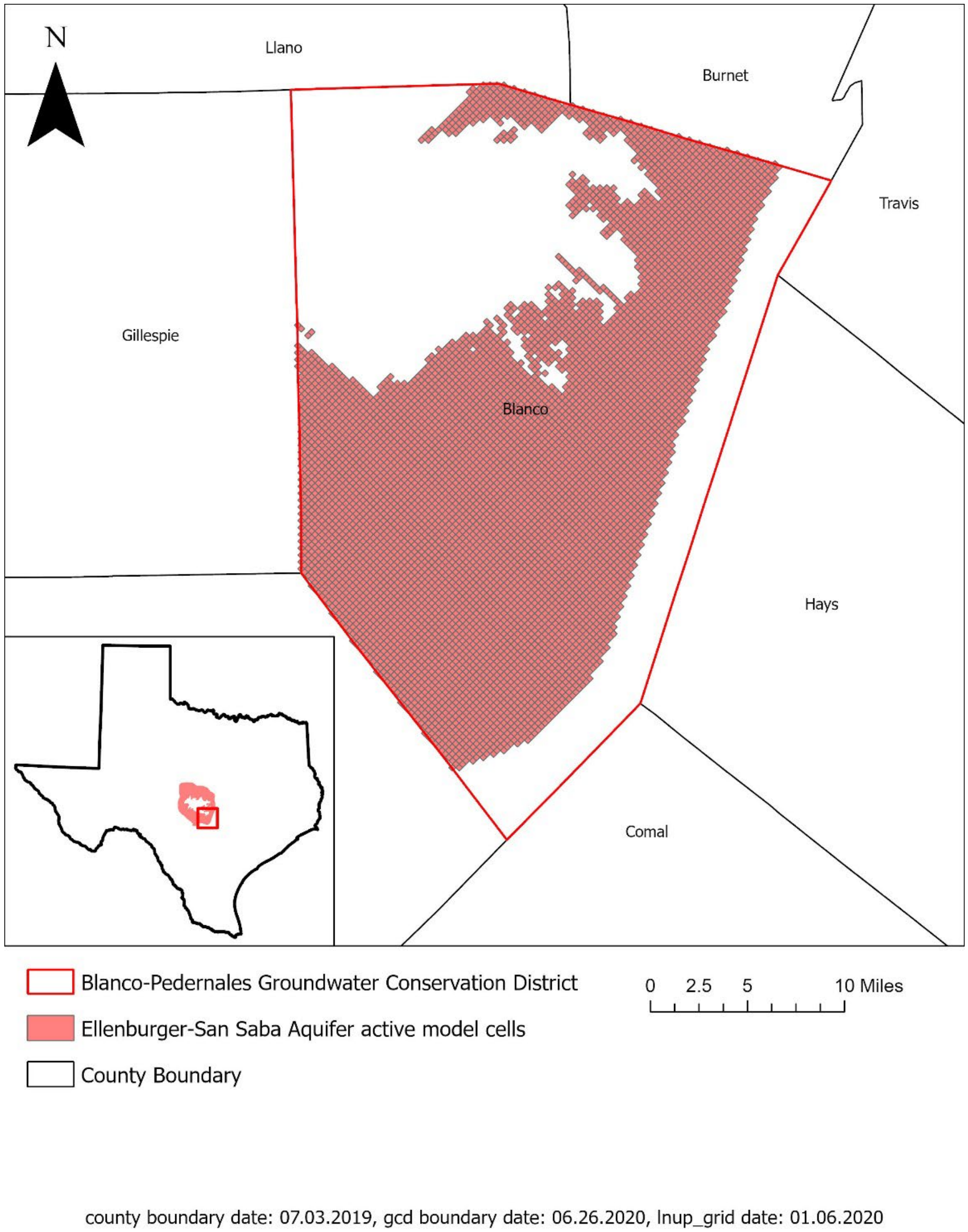
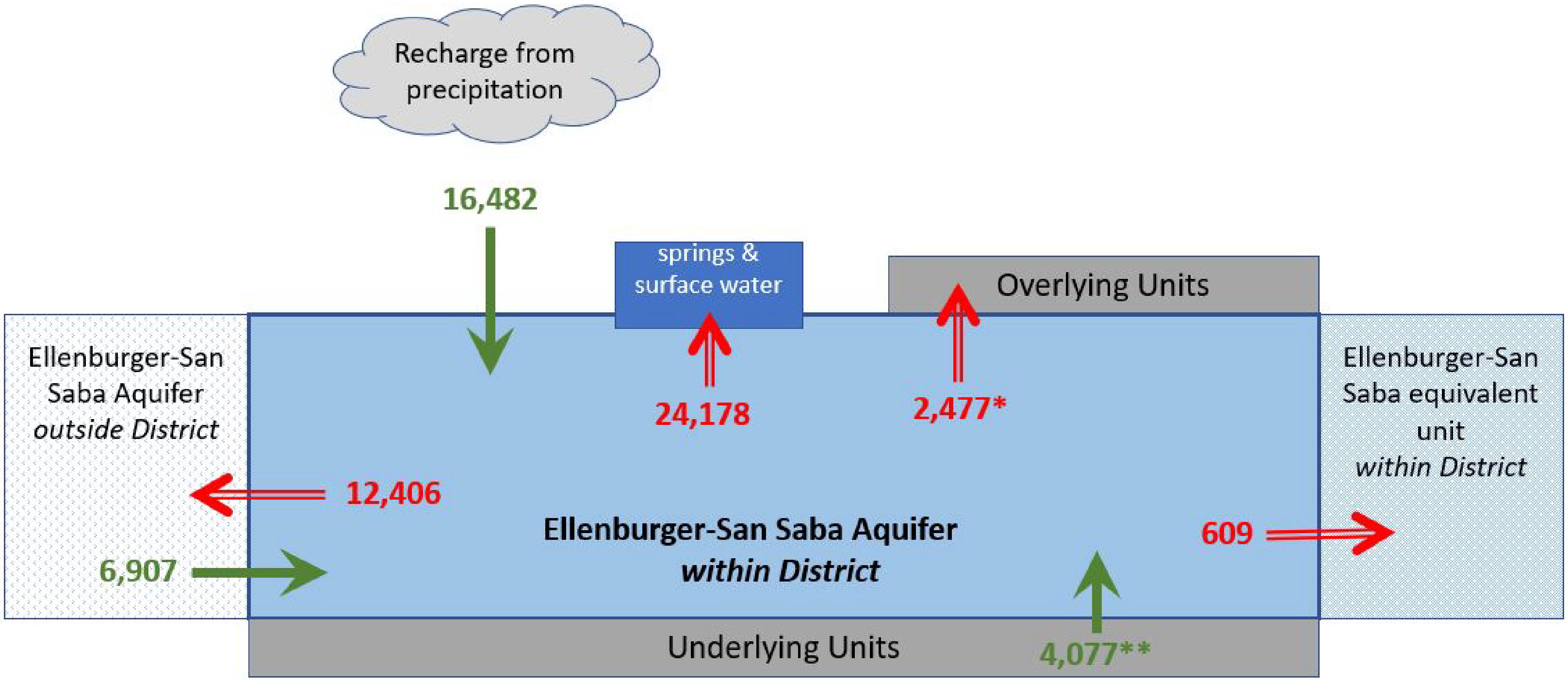


Figure 3: Area of the groundwater availability model for the minor aquifers in the Llano Uplift from which the information in Table 2 was extracted (the Ellenburger-San Saba Aquifer extent within the district boundary).



*Flow to Overlying units within district includes net flow of 990 acre-feet per year from Trinity Aquifer, 242 acre-feet per year from Marble Falls equivalent units, 75 acre-feet from Quaternary Alluvium, 374 acre-feet per year to Permian and Pennsylvanian Confining Unit, 480 acre-feet per year to Marble Falls Aquifer, and 2,930 acre-feet per year to Mississippian Confining Unit.

**Flow from Underlying units within district includes net flow of 598 acre-feet per year to Cambrian Confining Unit, 4,159 acre-feet per year from Hickory Aquifer, and 516 acre-feet per year from Precambrian Confining Unit.

Caveat: This diagram only includes the water budget items provided in Table 2. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 4: Generalized diagram of the summarized budget information from Table 2, representing directions of flow for the Ellenburger-San Saba Aquifer within the Blanco-Pedernales Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 3: Summarized information for the Marble Falls Aquifer that is needed for the Blanco-Pedernales Groundwater 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	Marble Falls Aquifer	199
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Marble Falls Aquifer	7,745
Estimated annual volume of flow into the district within each aquifer in the district	Marble Falls Aquifer	NA
Estimated annual volume of flow out of the district within each aquifer in the district	Marble Falls Aquifer	NA
Estimated net annual volume of flow between each aquifer in the district	To Marble Falls Aquifer from Marble Falls equivalent unit	945
	From Marble Falls Aquifer to Permian and Pennsylvanian Confining unit	148
	To Marble Falls Aquifer from Mississippian Confining unit	5,878
	To Marble Falls Aquifer from Ellenburger-San Saba Aquifer	480
	To Marble Falls Aquifer from Cambrian Confining Unit	2

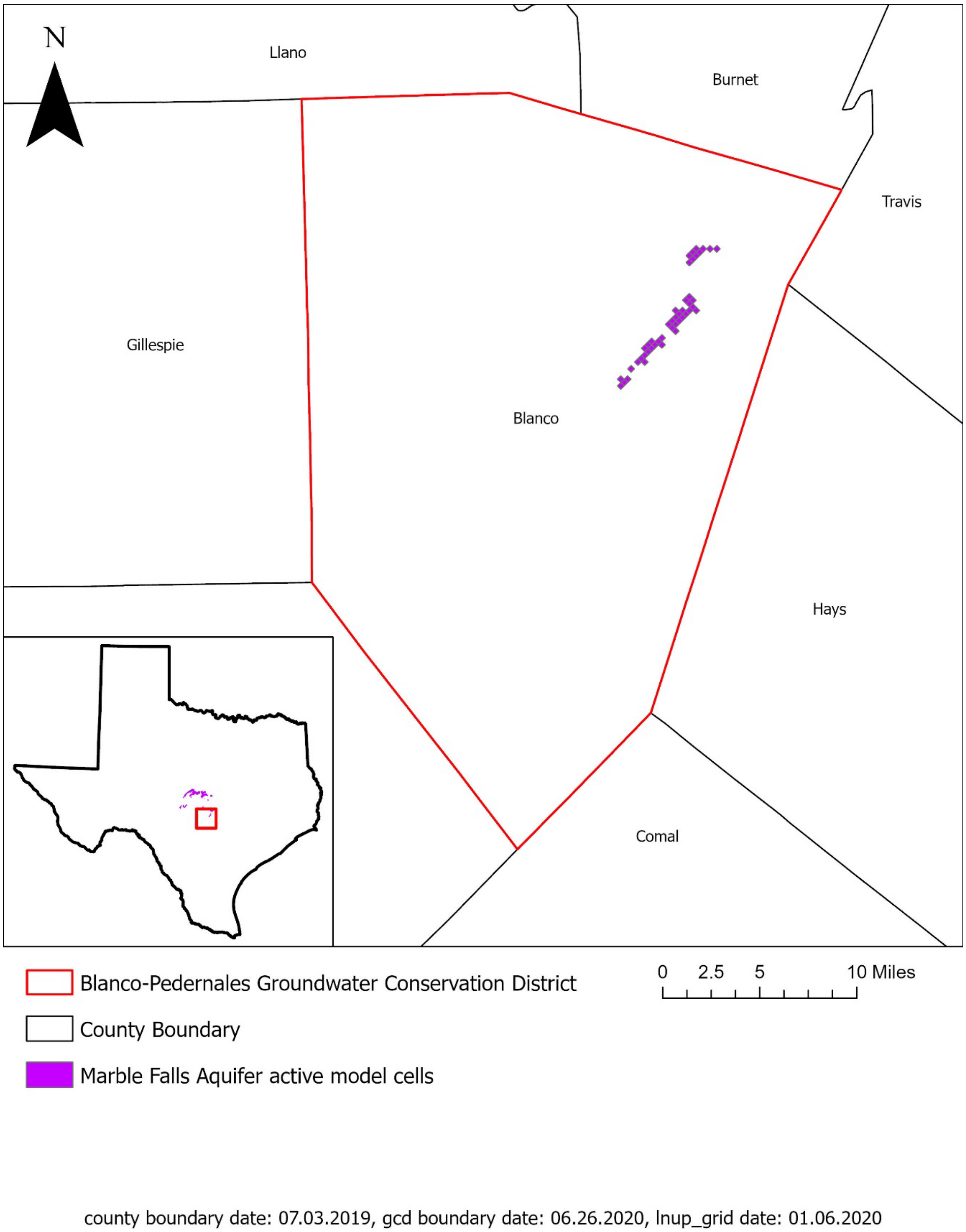
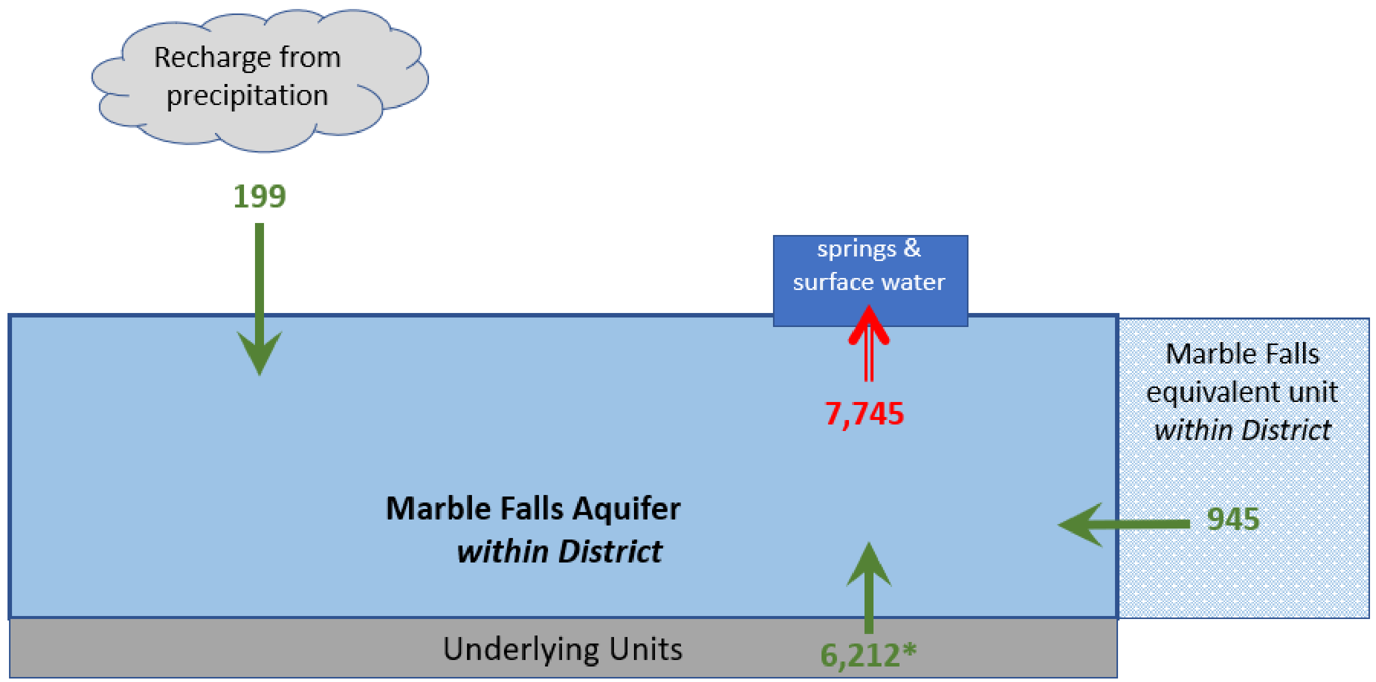


Figure 5: Area of the groundwater availability model for the minor aquifers of the Llano Uplift from which the information in Table 3 was extracted (the Marble Falls Aquifer extent within the district boundary).



* Flow from Underlying units within district includes net flow of 148 acre-feet per year from Marble Falls Aquifer to Permian and Pennsylvanian Confining unit, 5,878 acre-feet per year to Marble Falls Aquifer from Mississippian Confining unit, 480 acre-feet per year to Marble Falls Aquifer from Ellenburger-San Saba Aquifer, and 2 acre-feet per year to Marble Falls Aquifer from Cambrian Confining Unit.

Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 6: Generalized diagram of the summarized budget information from Table 3, representing directions of flow for the Marble Falls Aquifer within the Blanco-Pedernales Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 4: Summarized information for the Trinity Aquifer that is needed for the Blanco-Pedernales Groundwater 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	37,189†
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Trinity Aquifer	26,966†
Estimated annual volume of flow into the district within each aquifer in the district	Trinity Aquifer	6,768†
Estimated annual volume of flow out of the district within each aquifer in the district	Trinity Aquifer	15,616†
Estimated net annual volume of flow between each aquifer in the district	From Trinity Aquifer to Edwards-Trinity (Plateau) Aquifer	188*
	From Trinity Aquifer to Ellenburger-San Saba Aquifer	990**
	To Trinity Aquifer from Hickory Aquifer	61**

†Flow values are combined results from the groundwater availability model for the southern portion of the Trinity Aquifer and the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers.
*Flow value from the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer
** Flow values come from the groundwater availability model for the minor aquifers of the Llano Uplift.

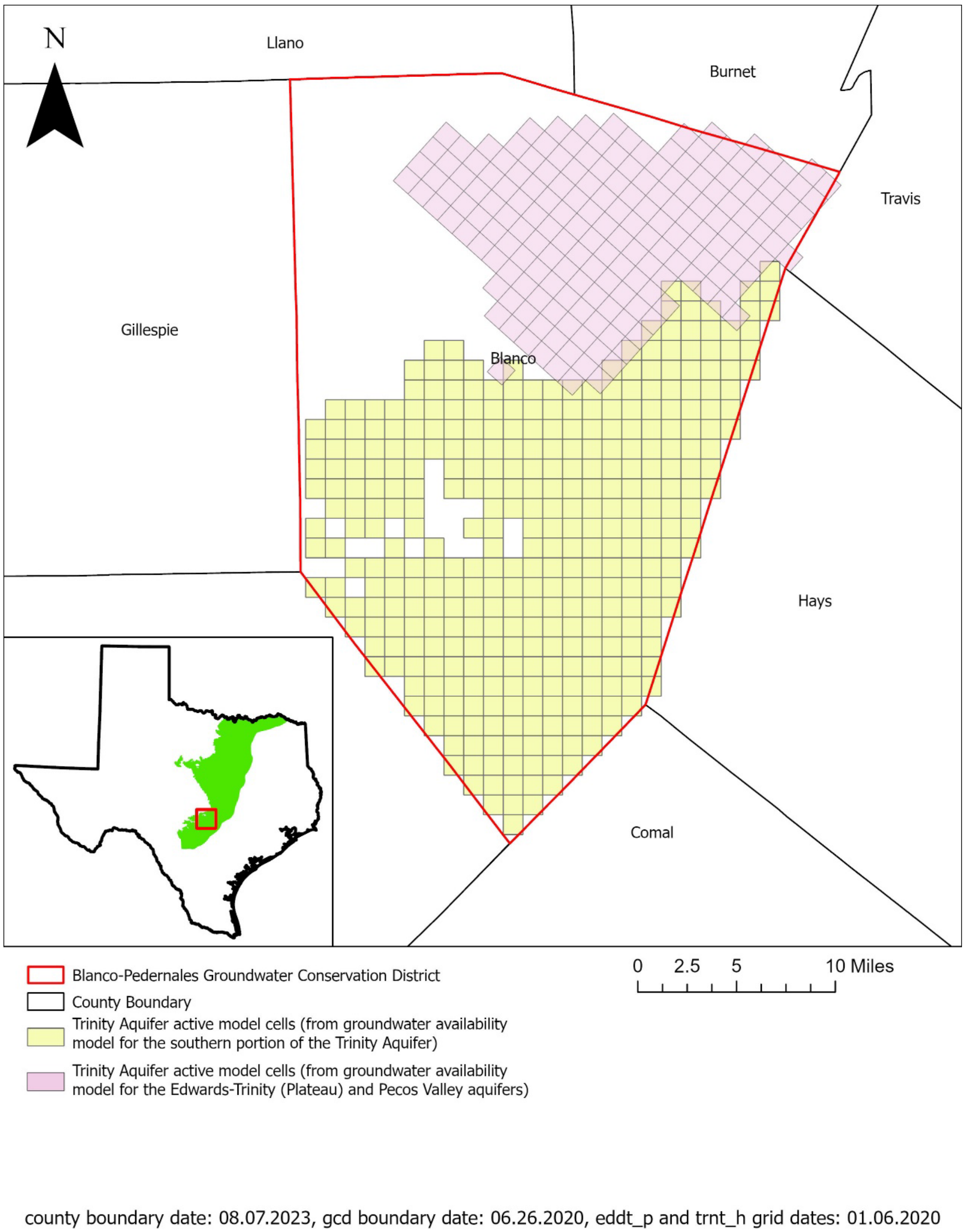
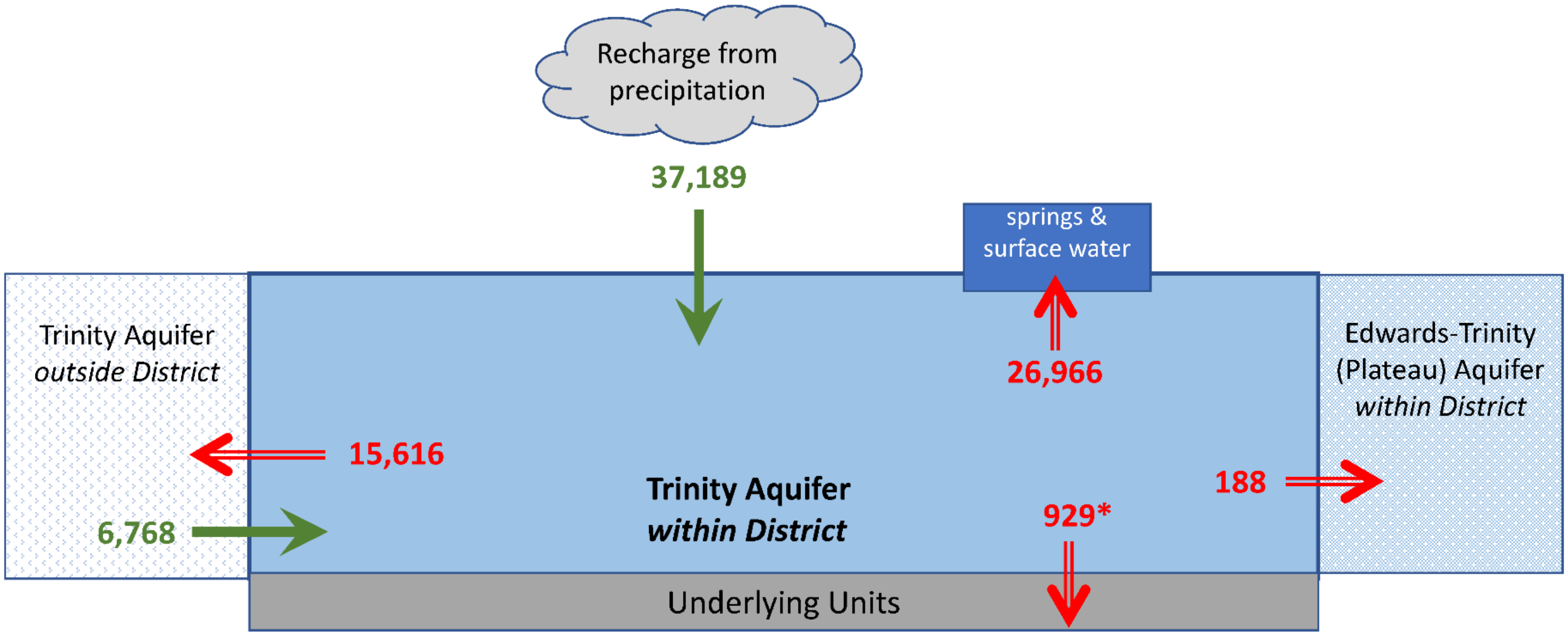


Figure 7: Area of the groundwater availability models for the Edwards-Trinity (Plateau) and Pecos Valley aquifers (shown in pink) and the southern portion of the Trinity Aquifer (shown in yellow) from which the information in Table 4 was extracted (the Trinity Aquifer extent within the district boundary).



*Flow to underlying units within district includes net flow of 990 acre-feet per year from Trinity to Ellenburger-San Saba Aquifer, and 61 acre-feet per year to Trinity Aquifer from Hickory Aquifer.

Caveat: This diagram only includes the water budget items provided in Table 4. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 8: Generalized diagram of the summarized budget information from Table 4, representing directions of flow for the Trinity Aquifer within the Blanco-Pedernales Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 5: Summarized information for the Edwards-Trinity (Plateau) Aquifer that is needed for the Blanco-Pedernales Groundwater 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	571
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	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	0
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	206
Estimated net annual volume of flow between each aquifer in the district	To Edwards-Trinity (Plateau) Aquifer from Trinity Aquifer	188

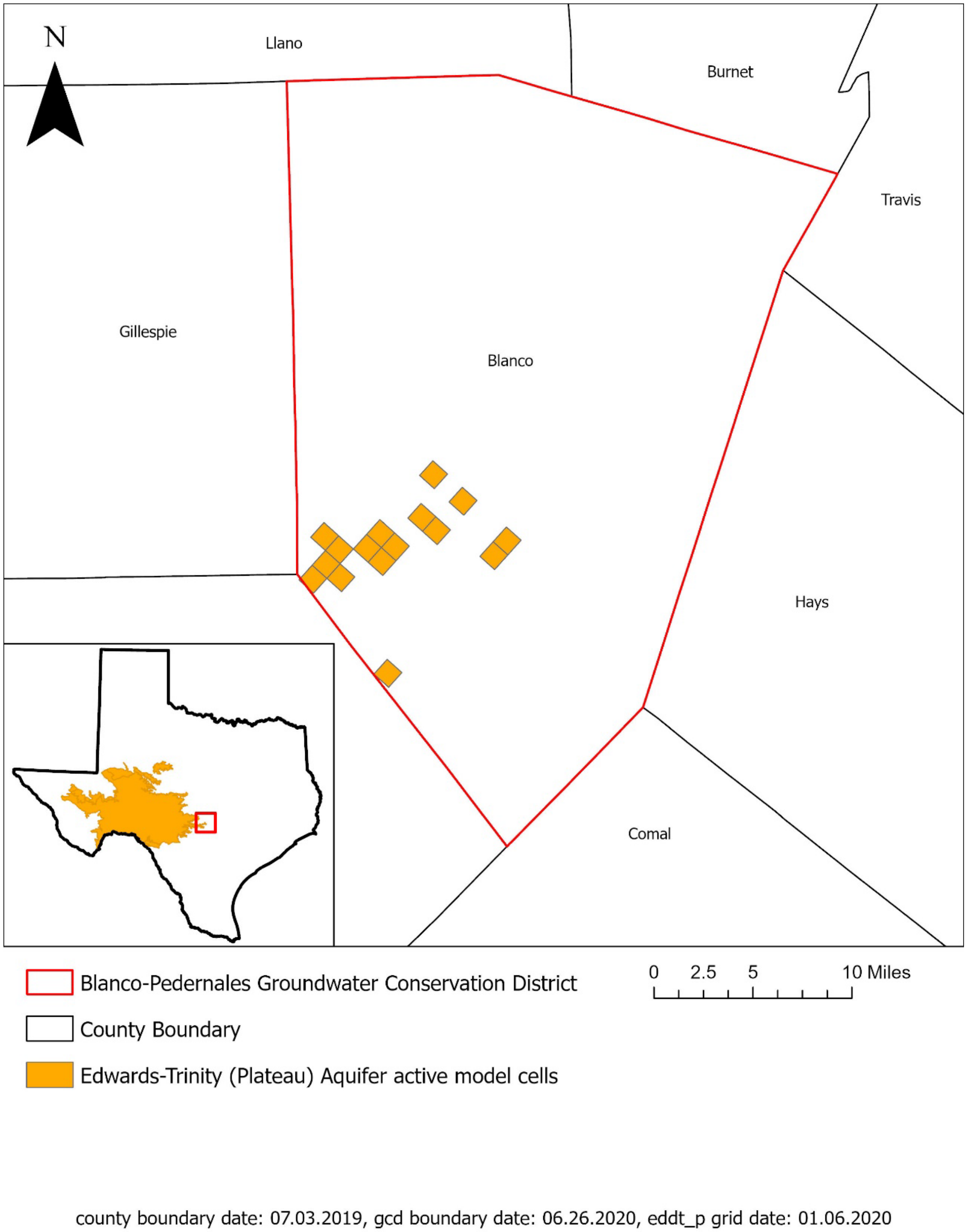
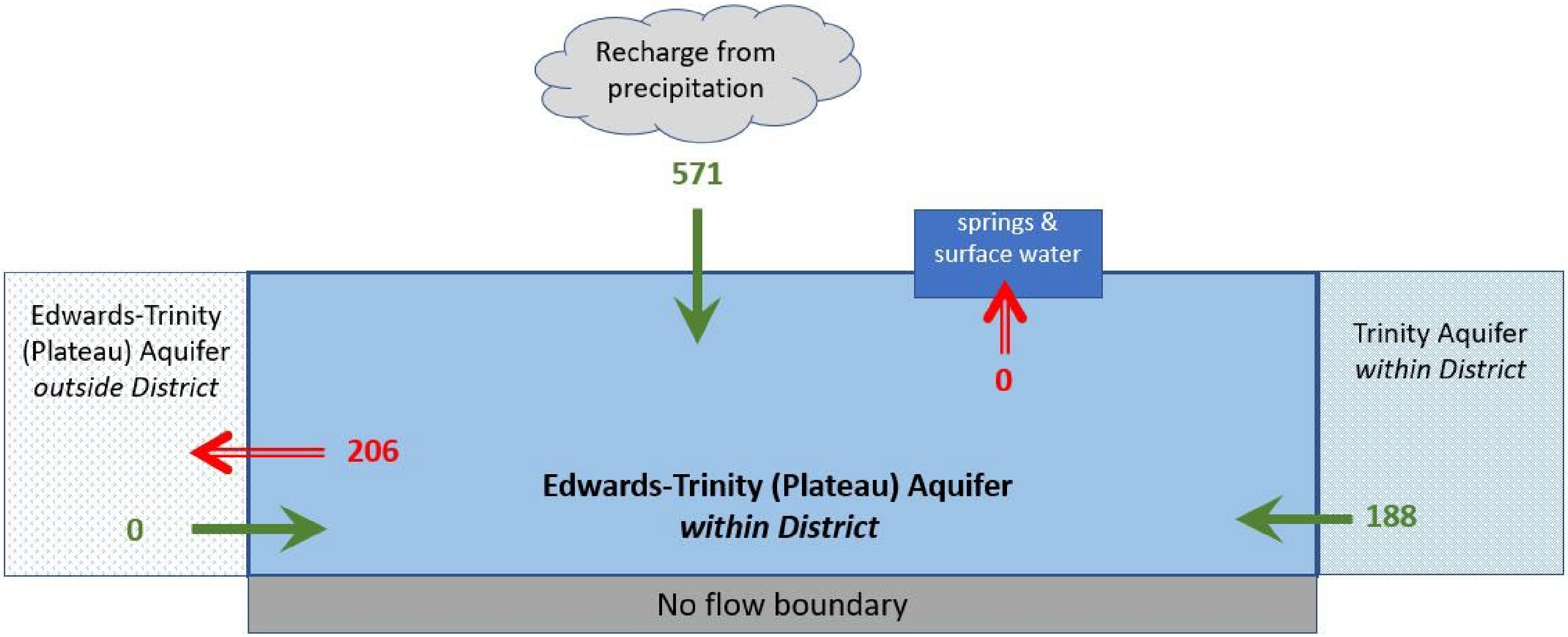


Figure 9: Area of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers from which the information in Table 5 was extracted (the Edwards-Trinity [Plateau] Aquifer extent within the district boundary).



Caveat: This diagram only includes the water budget items provided in Table 5. A complete water budget would include additional inflows and outflows. For a full groundwater budget, please submit a request in writing to the Groundwater Modeling Department.

Figure 10: **Generalized diagram of the summarized budget information from Table 5, representing directions of flow for the Edwards-Trinity (Plateau) Aquifer within the Blanco-Pedernales Groundwater Conservation District. Flow values are expressed in acre-feet per year.**

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 historical 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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Texas Water Code § 36.1071