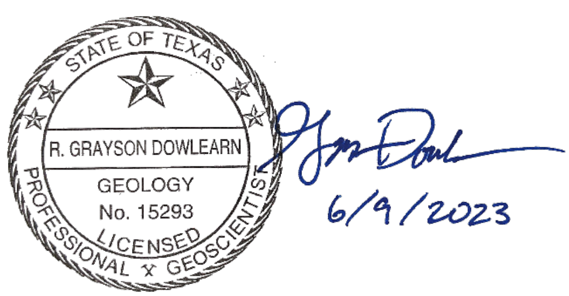
GAM RUN 23-005: BLUEBONNET GROUNDWATER CONSERVATION DISTRICT MANAGEMENT PLAN

Dwight Zedric Q. Capus, GIT and Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-936-2404
June 9, 2023



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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 Bluebonnet 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 Bluebonnet Groundwater Conservation District should be adopted by the district on or before August 2, 2023 and submitted to the TWDB Executive Administrator on or before September 1, 2023. The current management plan for the Bluebonnet Groundwater Conservation District expires on October 31, 2023.

The management plan information for the aquifers within Bluebonnet Groundwater Conservation District was extracted from four groundwater availability models. We used the groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Young and Kushnereit, 2020; Young and others, 2018) to estimate management plan information for the Carrizo-Wilcox, Queen City, and Sparta aquifers. We used the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010) to estimate management plan information for the Yegua-Jackson Aquifer. We used the groundwater availability model for the northern portion of the Gulf Coast Aquifer System (Kasmarek, 2013) to estimate the management plan information for the Gulf Coast Aquifer System. We used the groundwater availability for the Brazos River Alluvium Aquifer (Ewing and Jigmond, 2016) to estimate the management plan information for the Brazos River Alluvium Aquifer.

This report replaces the results of GAM Run 17-020 (Wade, 2017) because it includes results from the updated groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Young and Kushnereit, 2020; Young and others, 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 6 summarize the groundwater availability model data required by statute. Figures 1, 3, 5, 7, 9 and 11 show the areas of the respective models from which the values in Tables 1 through 6 were extracted. Figures 2, 4, 6, 8, 10, and 12 provide a generalized diagram of the groundwater flow components provided in Tables 1 through 6. If, after review of the figures, the Bluebonnet Groundwater Conservation District determines that the district boundaries used in the assessment do not reflect current conditions, please notify the TWDB 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 Texas Water Code § 36.1071(h), the groundwater availability models mentioned above were used to estimate information for the Bluebonnet Groundwater Conservation District management plan. Water budgets were extracted for the historical calibration period for the Carrizo-Wilcox, Queen City, and Sparta aquifers (1980 through 2010) and the Brazos River Alluvium Aquifer (1980 through 2012) using ZONEBUDGET for MODFLOW USG Version 1.0 (Panday and others, 2013). Water budgets were extracted for the historical calibration period for the Yegua-Jackson Aquifer (1980 through 1997) and Gulf Coast Aquifer System (1980 through 2009) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). 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:

Carrizo-Wilcox, Queen City, and Sparta aquifers

- We used version 3.02 of the groundwater availability model for the Carrizo-Wilcox, Queen City, and Sparta aquifers (Young and Kushnereit, 2020; Young and others, 2018) to analyze the Sparta, Queen City and Carrizo-Wilcox aquifers. See Young and Kushnereit (2020) and Young and others (2018) for assumptions and limitations of the model.
- The groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers contains ten layers:
    - Layer 1 represents the Colorado River and Brazos River alluvium
    - Layer 2 represents the shallow flow system of all units in layers 3 through 10
    - Layer 3 represents the Sparta Aquifer and equivalent units
    - Layer 4 represents the Weches Formation
    - Layer 5 represents the Queen City Aquifer and equivalent units
    - Layer 6 represents the Reklaw Formation
    - Layers 7 through 10 represent the Carrizo-Wilcox Aquifer and equivalent units.

- Individual water budgets for the district were determined for the Sparta Aquifer (layers 2 and 3), the Queen City Aquifer (layers 2 and 5), and the Carrizo-Wilcox Aquifer (layers 2 and 7 through 10, collectively).
- The MODFLOW River package was used to simulate the groundwater exchange with major rivers and perennial streams. Outflow from ephemeral streams, intermittent streams, and seeps were simulated using the MODFLOW Drain package. The evapotranspiration package was used to simulate groundwater evapotranspiration from the model.
- The model was run with MODFLOW-USG (Panday and others, 2013).
- Water budget terms were averaged for the period 1980 through 2010 (stress periods 52 through 82).

Yegua-Jackson Aquifer

- We used version 1.01 of the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010) to analyze the Yegua-Jackson Aquifer. See Deeds and others (2010) for assumptions and limitations of the model.
- The groundwater availability model for the Yegua-Jackson Aquifer contains five layers:
    - Layer 1 represents the Yegua-Jackson Aquifer outcrop, the Catahoula Formation, and other younger overlying units
    - Layer 2 represents the upper portion of the Jackson Group
    - Layer 3 represents the lower portion of the Jackson Group
    - Layer 4 represents the upper portion of the Yegua Group
    - Layer 5 represents the lower portion of the Yegua Group
- An overall water budget for the district was determined for the Yegua-Jackson Aquifer (layers 1 through 5, collectively).
- The Catahoula Formation within the Bluebonnet Groundwater Conservation District falls within the Gulf Coast Aquifer System, which allows us to estimate the exchange between the Yegua-Jackson Aquifer and the Gulf Coast Aquifer System in this assessment.
- Water budget terms were averaged for the period 1980 through 1997 (stress periods 10 through 27).
- The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

Gulf Coast Aquifer System

- We used version 1.01 of the groundwater availability model for the northern portion of the Gulf Coast Aquifer System (Kasmarek, 2013) to analyze the Gulf Coast Aquifer System. See Kasmarek (2013) for assumptions and limitations of the model.
- The groundwater availability model for the Gulf Coast Aquifer System contains four layers:
    - Layer 1 represents the Chicot Aquifer
    - Layer 2 represents the Evangeline Aquifer
    - Layer 3 represents the Burkeville Confining Unit
    - Layer 4 represents the Jasper Aquifer and parts of the Catahoula Formation in direct hydrologic communication with the Jasper Aquifer
- Water budgets for the district were determined for the Gulf Coast Aquifer System (Layers 1 through 4 collectively).
- Water budget terms were averaged for the period 1980 through 2009 (stress periods 16 through 78).
- The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

Brazos River Alluvium Aquifer

- We used version 1.01 of the groundwater availability model for the Brazos River Alluvium Aquifer (Ewing and Jigmond, 2016) to analyze the Brazos River Alluvium Aquifer. See Ewing and Jigmond (2016) for assumptions and limitations of the model.
- The groundwater availability model for the Brazos River Alluvium Aquifer contains three layers:
    - Layers 1 and 2 represent the Brazos River Alluvium Aquifer.
    - Layer 3 represents the surficial portions of the Gulf Coast Aquifer System as well as older confining geologic units within Bluebonnet Groundwater Conservation District.

- Perennial rivers and streams were simulated using the MODFLOW Streamflow-Routing package and ephemeral streams were simulated using the MODFLOW River package. Springs were simulated using the MODFLOW Drain package.
- Water budget terms were averaged for the period 1980 through 2012 (stress periods 32 through 127).
- The model was run with MODFLOW- USG (Panday and others, 2013).

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving an aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Carrizo-Wilcox, Queen City, Sparta, Yegua-Jackson, Gulf Coast Aquifer System, and the Brazos River Alluvium aquifers located within Bluebonnet Groundwater Conservation District and averaged over the historical calibration periods, as shown in Tables 1 through 6.

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 6. Figures 1, 3, 5, 7, 9 and 11 show the areas of the respective models from which the values in Tables 1 through 6 were extracted. Figures 2, 4, 6, 8, 10, and 12 provide a generalized diagram of the groundwater flow components provided in Tables 1 through 6. 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 Carrizo-Wilcox Aquifer for the Bluebonnet 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	Carrizo-Wilcox Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Carrizo-Wilcox Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Carrizo-Wilcox Aquifer	1,488
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	361
Estimated net annual volume of flow between each aquifer in the district	From Carrizo-Wilcox Aquifer to Reklaw Confining Unit	35
	From Carrizo-Wilcox Aquifer to Carrizo-Wilcox equivalent units	988

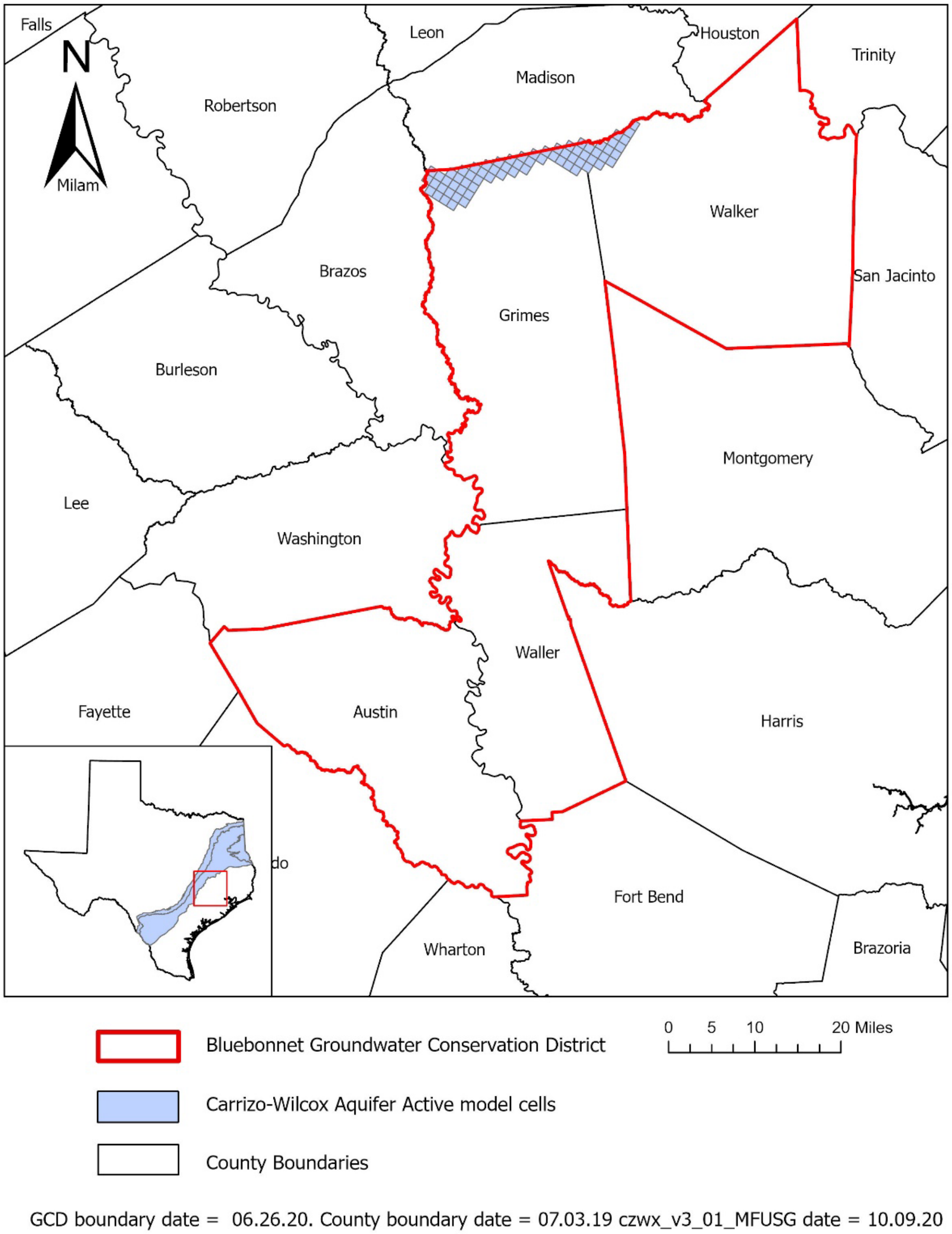
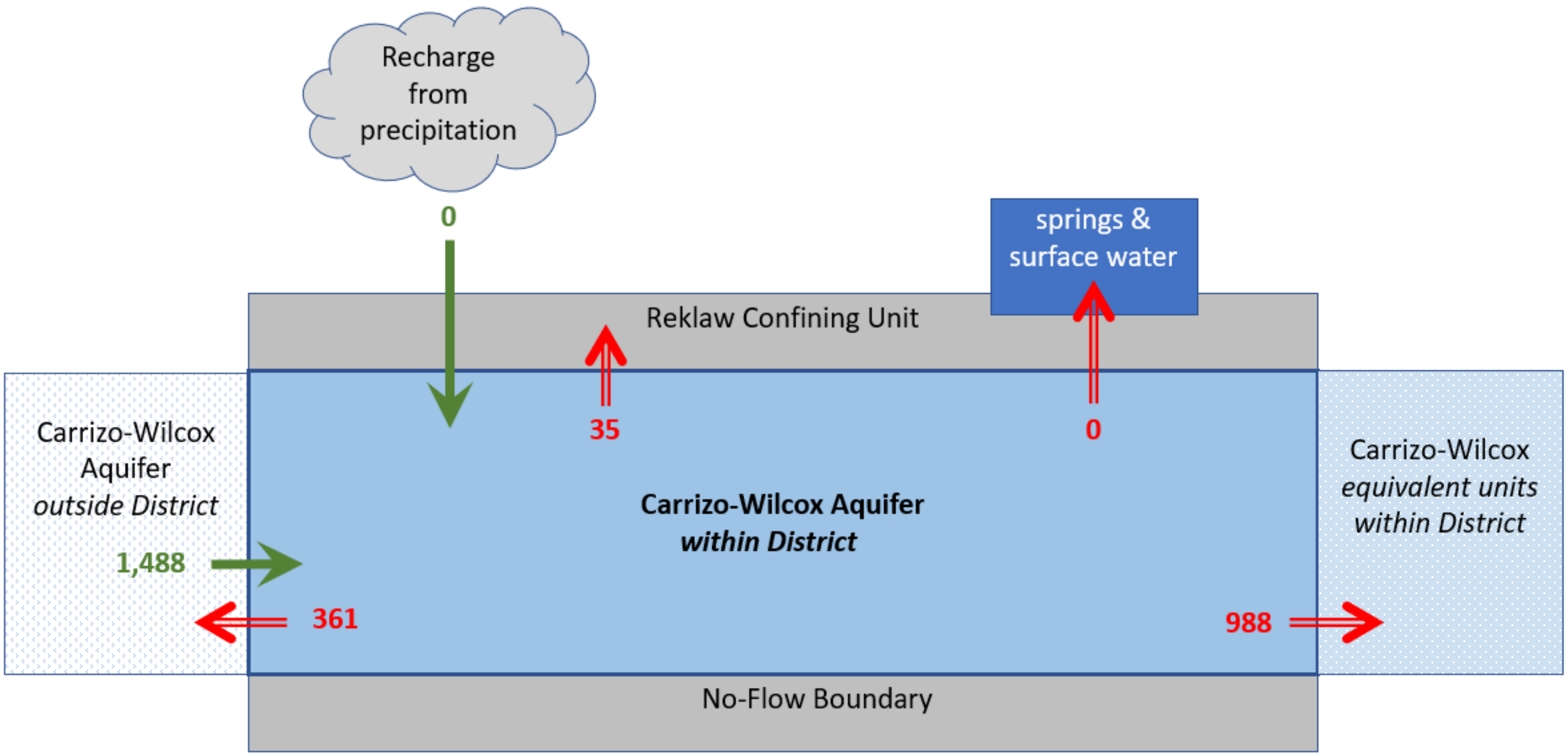


Figure 1: Area of the groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 1 was extracted (the Carrizo-Wilcox Aquifer extent within the district boundary).



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 Carrizo-Wilcox Aquifer within the Bluebonnet Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 2: Summarized information for the Queen City Aquifer for the Bluebonnet 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	Queen City Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Queen City Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Queen City Aquifer	327
Estimated annual volume of flow out of the district within each aquifer in the district	Queen City Aquifer	213
Estimated net annual volume of flow between each aquifer in the district	To Queen City Aquifer from Reklaw confining unit	118
	From Queen City Aquifer to Weches confining unit	259
	To Queen City Aquifer from Queen City equivalent units	14

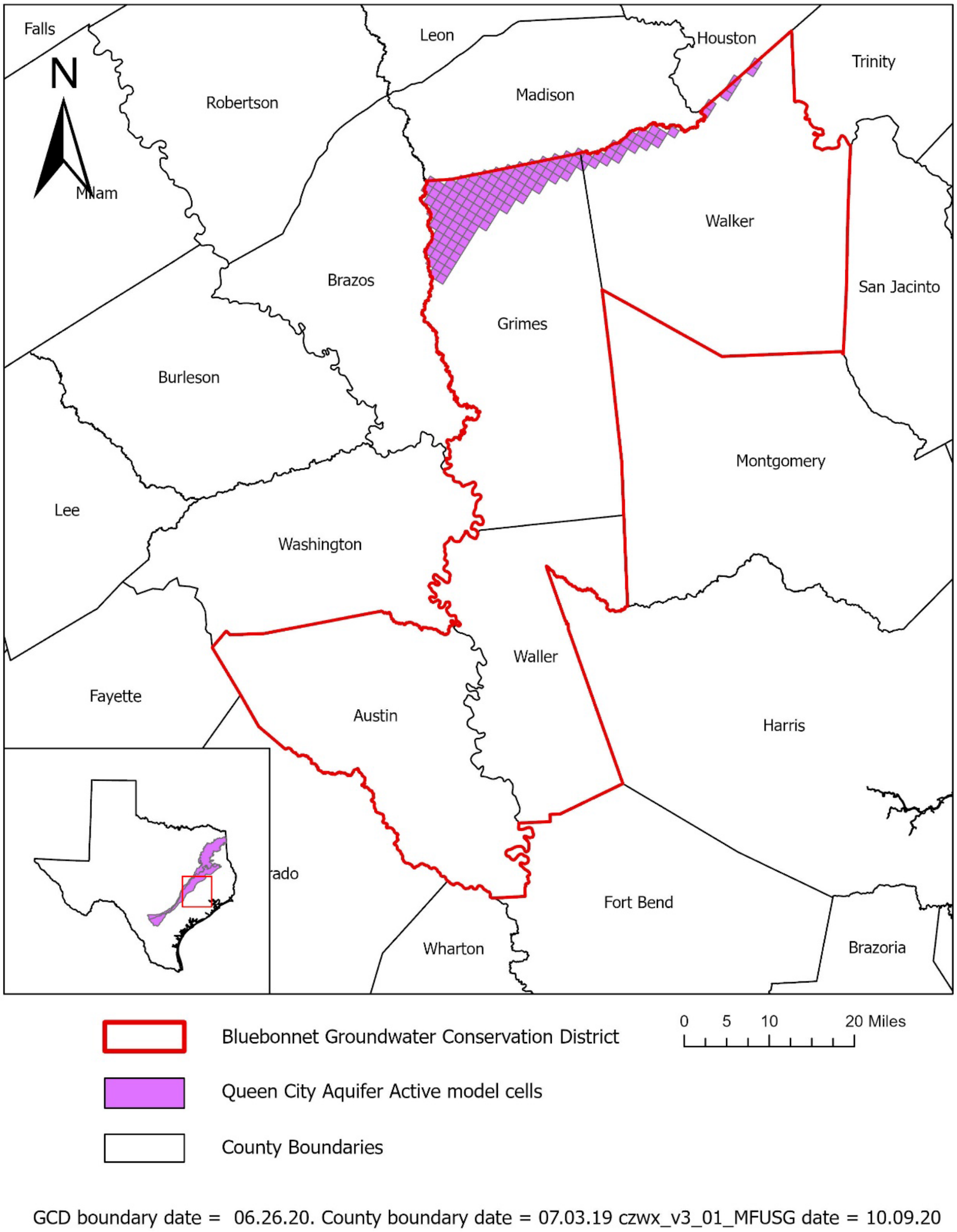
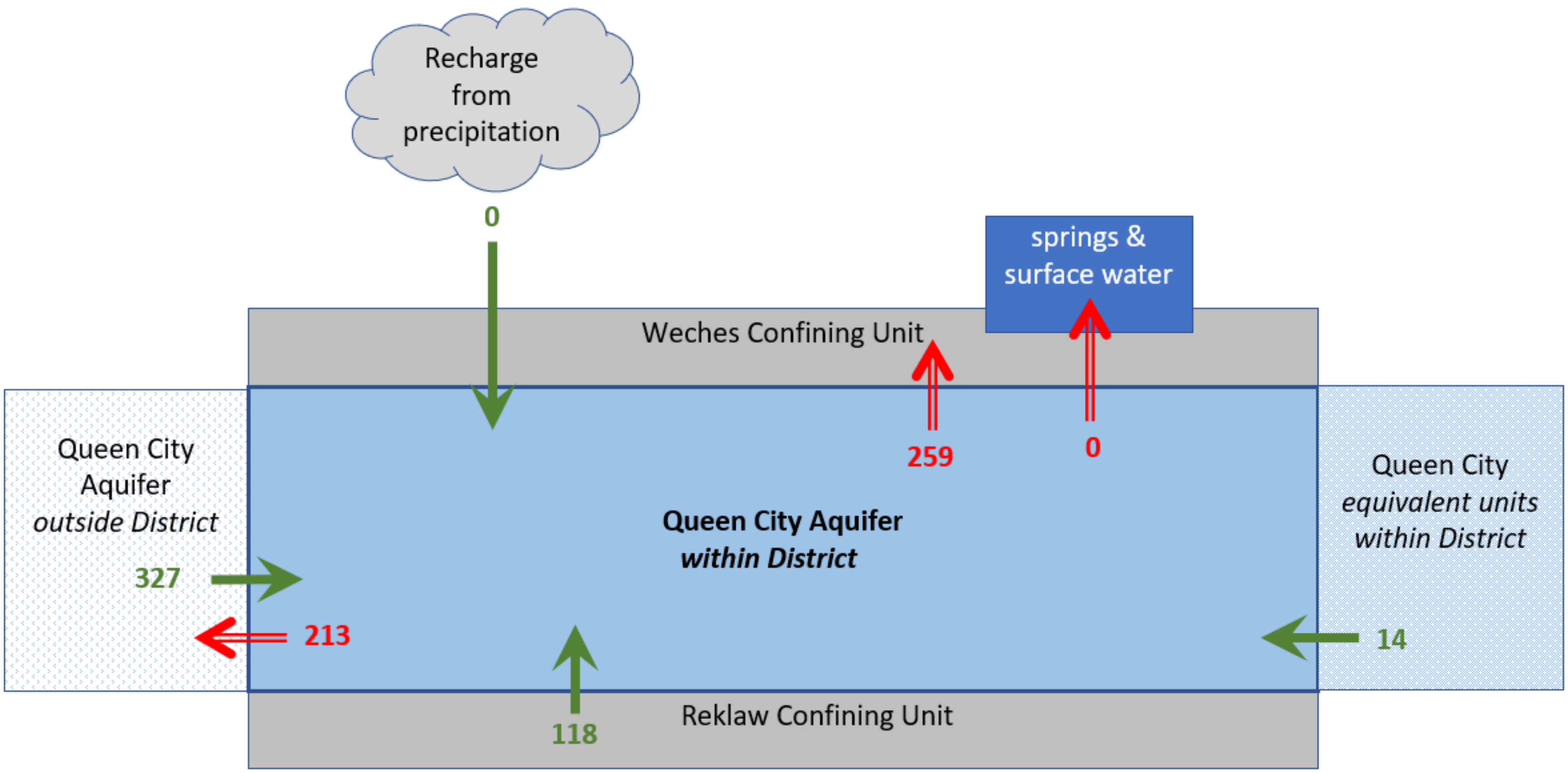


Figure 3: Area of the groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 2 was extracted (the Queen City Aquifer extent within the district boundary).



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 Queen City Aquifer within Bluebonnet Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 3: Summarized information for the Sparta Aquifer for the Bluebonnet 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	Sparta Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Sparta Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Sparta Aquifer	200
Estimated annual volume of flow out of the district within each aquifer in the district	Sparta Aquifer	453
Estimated net annual volume of flow between each aquifer in the district	From Sparta Aquifer to Cook Mountain confining unit	460
	To Sparta Aquifer from Weches confining unit	594
	To Sparta Aquifer from Sparta equivalent units	67

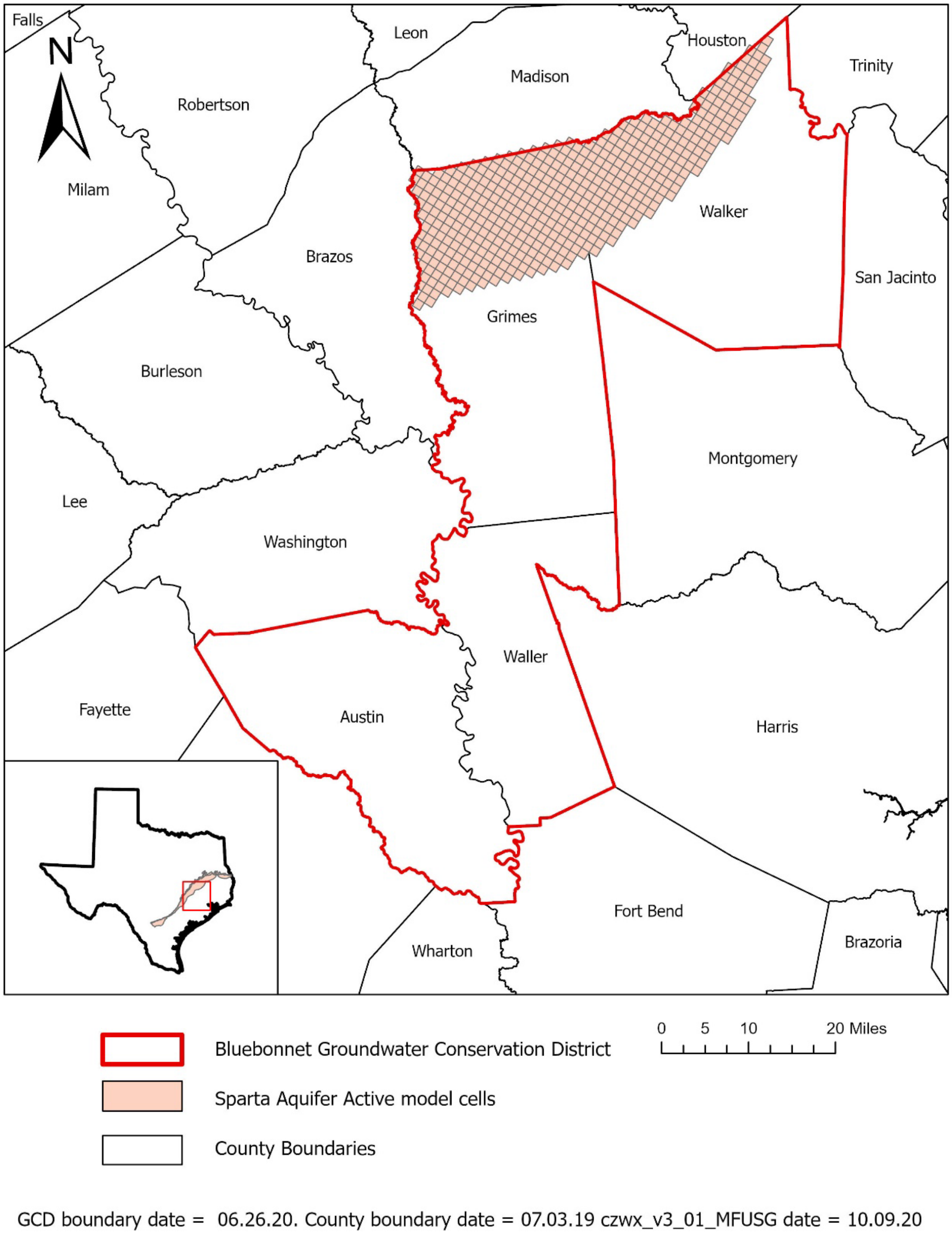
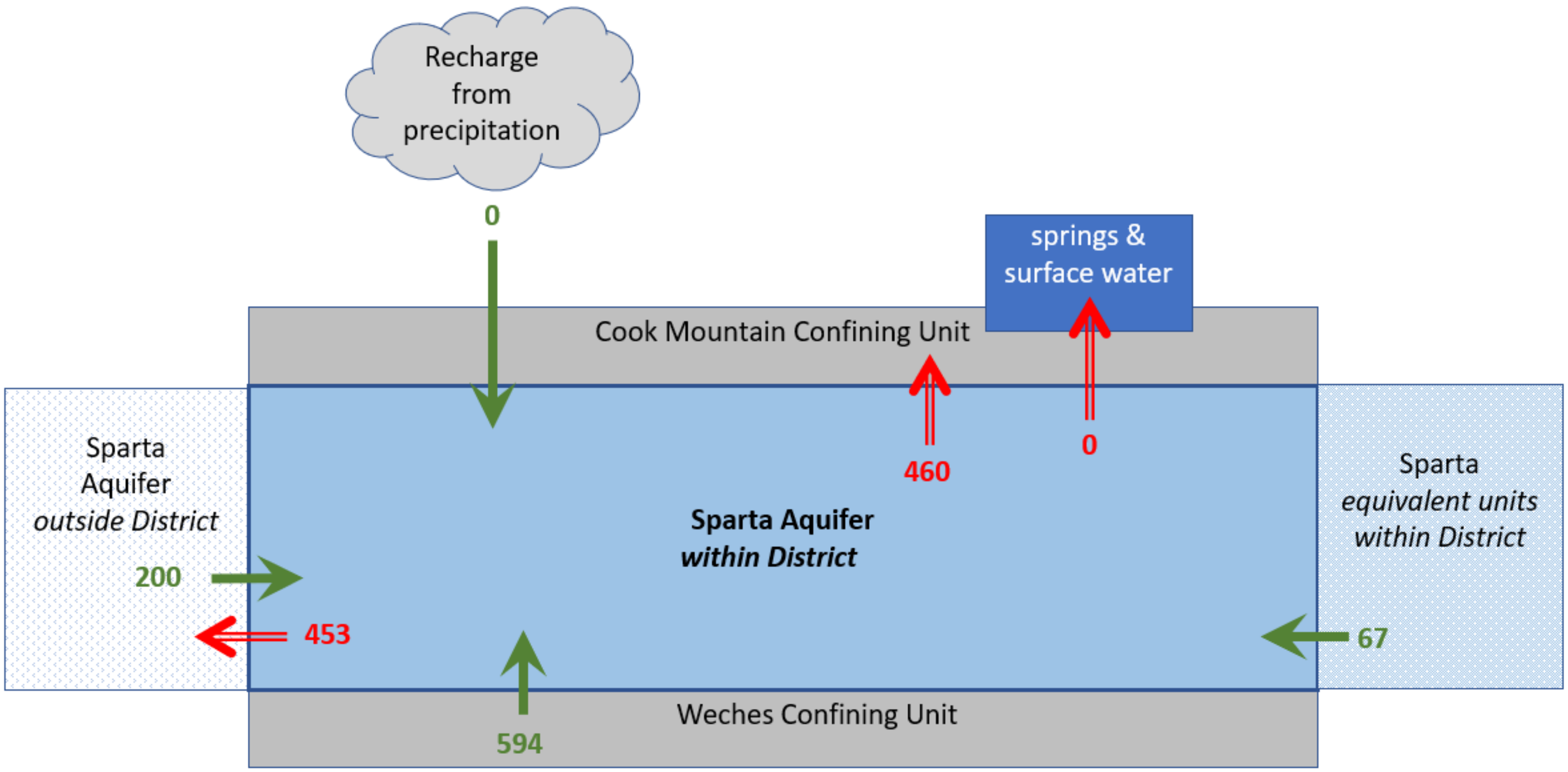


Figure 5: Area of the groundwater availability model for the central portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 3 was extracted (the Sparta Aquifer extent within the district boundary).



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 Sparta Aquifer within the Bluebonnet Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 4: Summarized information for the Yegua-Jackson Aquifer that is needed for the Bluebonnet 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	Yegua-Jackson Aquifer	47,268
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Yegua-Jackson Aquifer	38,660
Estimated annual volume of flow into the district within each aquifer in the district	Yegua-Jackson Aquifer	6,828
Estimated annual volume of flow out of the district within each aquifer in the district	Yegua-Jackson Aquifer	14,764
Estimated net annual volume of flow between each aquifer in the district	To Yegua-Jackson Aquifer from Gulf Coast Aquifer System	178
	To Yegua-Jackson Aquifer from Yegua-Jackson equivalent units	513

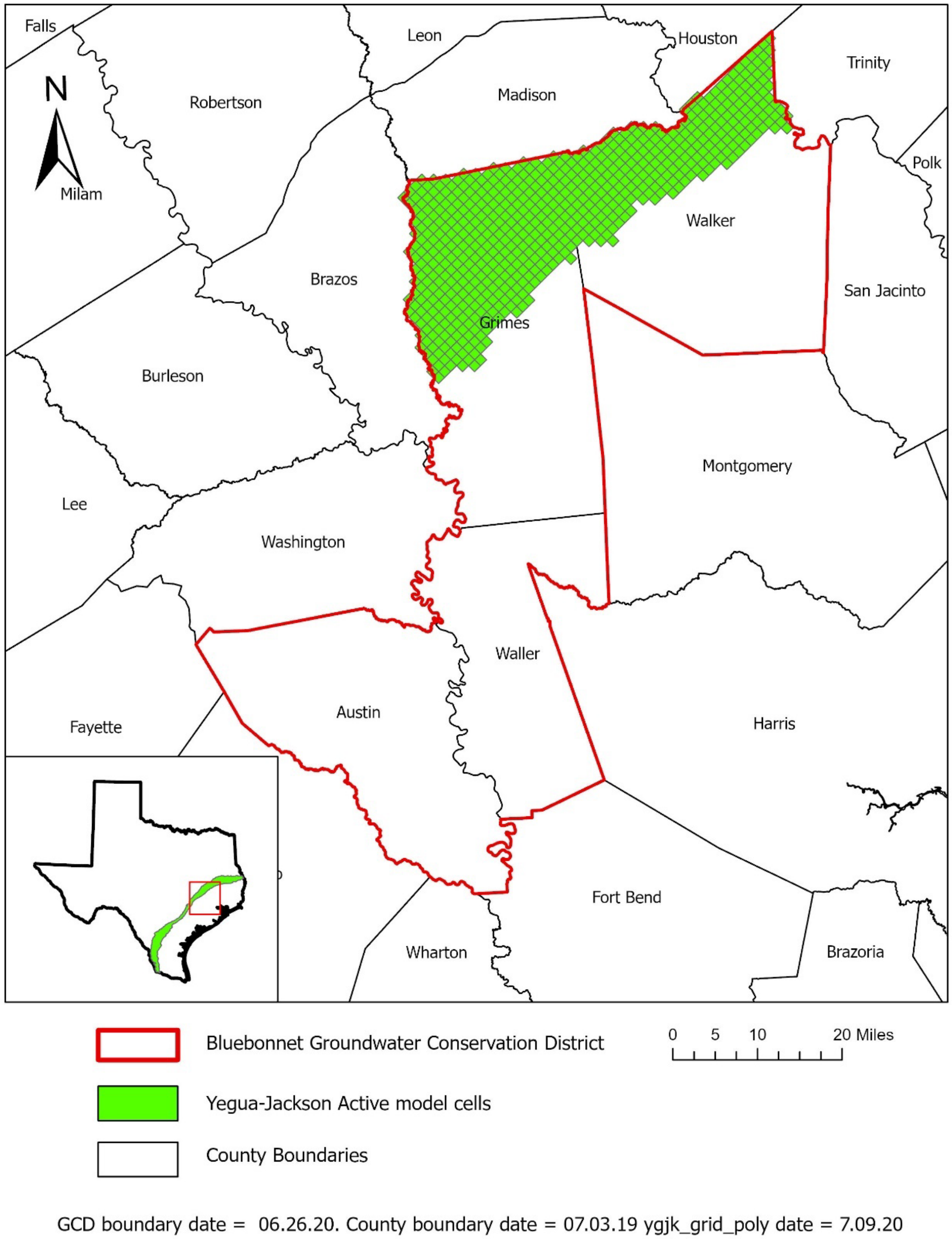
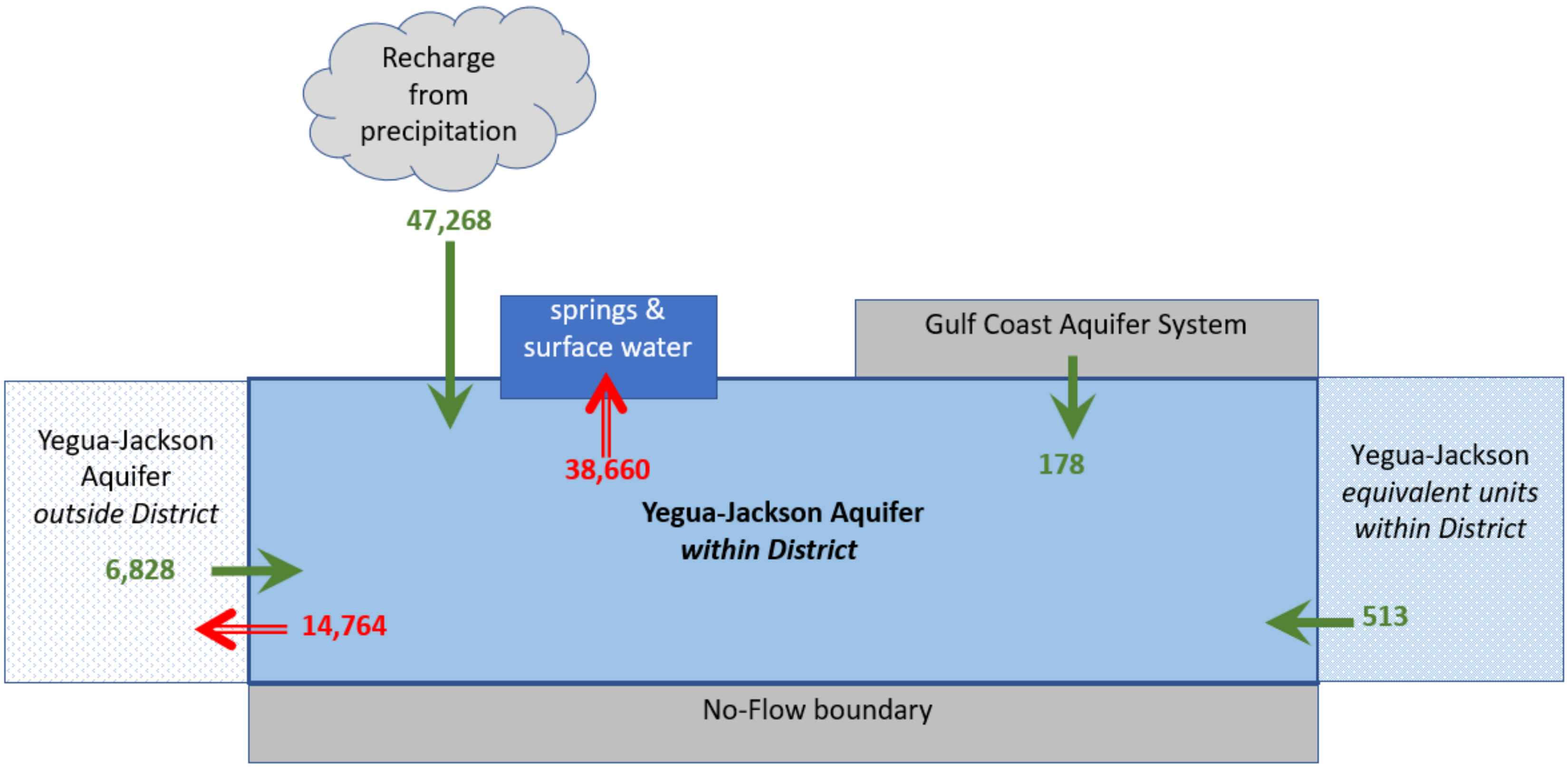


Figure 7: Area of the groundwater availability model for the Yegua-Jackson Aquifer from which the information in Table 4 was extracted (the Yegua-Jackson Aquifer extent within the district boundary).



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 Yegua-Jackson Aquifer within the Bluebonnet Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 5: Summarized information for the Gulf Coast Aquifer System for the Bluebonnet 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	Gulf Coast Aquifer System	46,741
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Gulf Coast Aquifer System	5,728
Estimated annual volume of flow into the district within each aquifer in the district	Gulf Coast Aquifer System	12,491
Estimated annual volume of flow out of the district within each aquifer in the district	Gulf Coast Aquifer System	49,022
Estimated net annual volume of flow between each aquifer in the district	From Gulf Coast Aquifer System to Yegua-Jackson Aquifer	178*
	From Gulf Coast Aquifer System to Brazos River Alluvium Aquifer	9,533**

**Budget value comes from the groundwater availability model for the Yegua-Jackson Aquifer (Deeds and others, 2010).*

***Budget value comes from the groundwater availability model for the Brazos River Alluvium Aquifer (Ewing and Jigmond, 2016).*

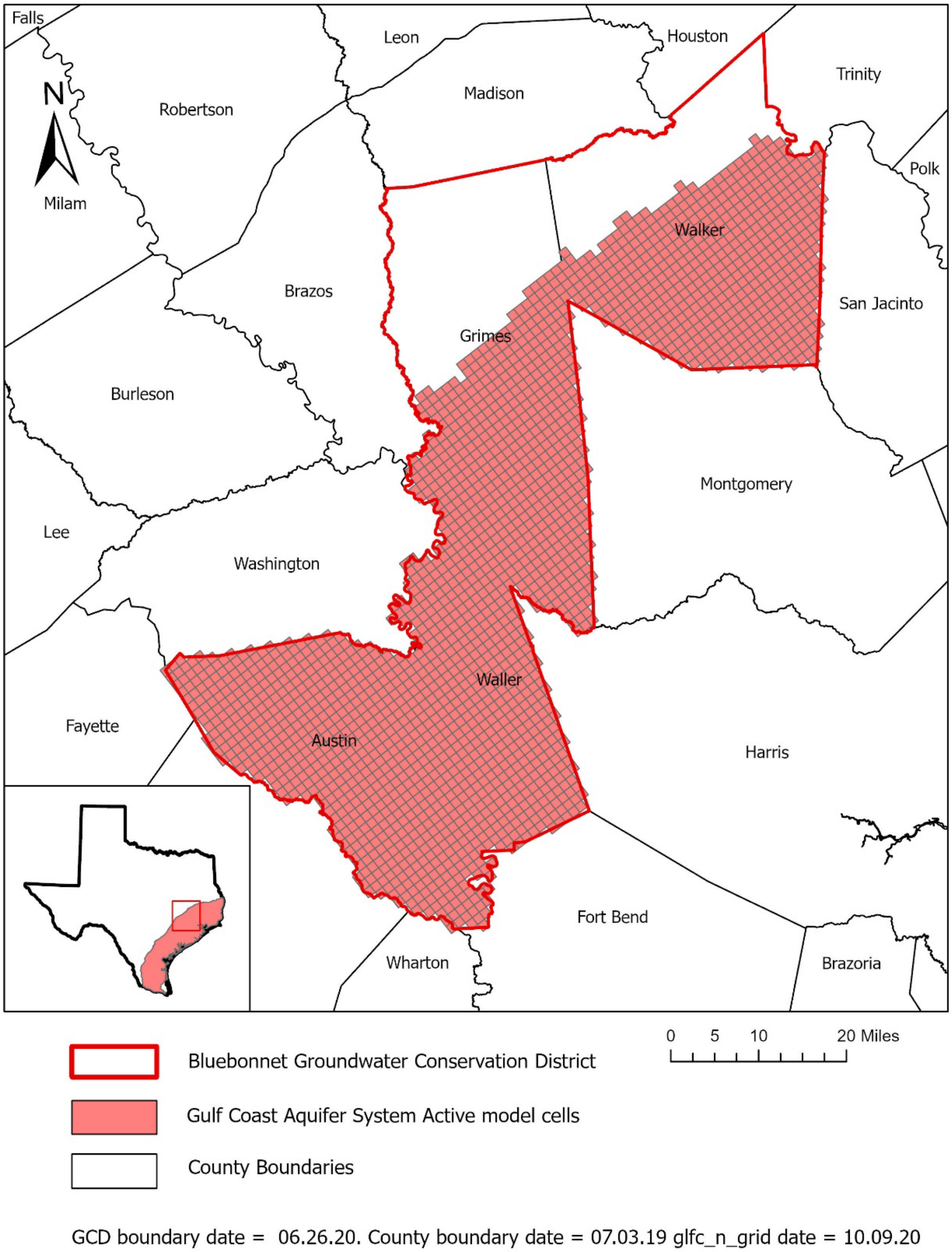
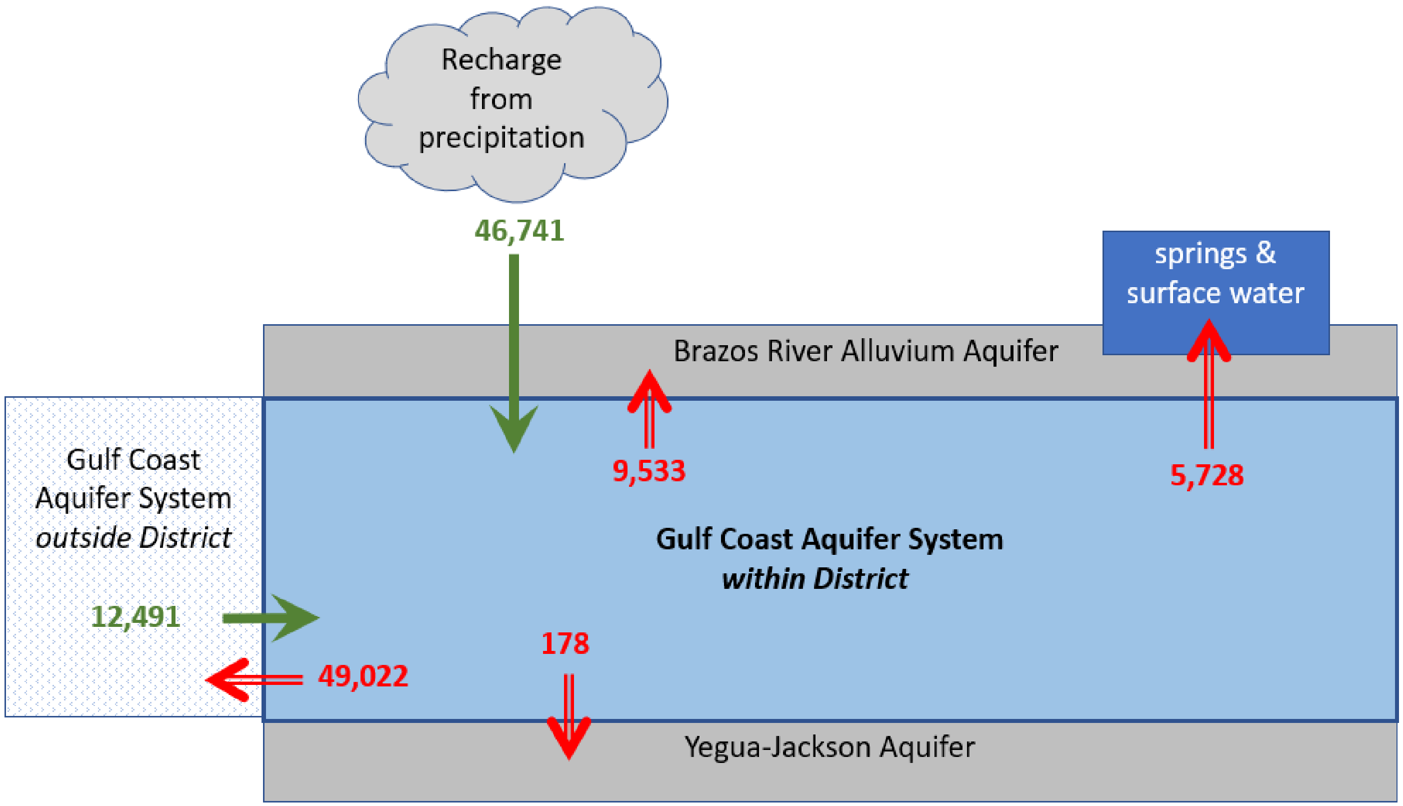


Figure 9: Area of the groundwater availability model for the northern portion of the Gulf Coast Aquifer System from which the information in Table 5 was extracted (the Gulf Coast Aquifer System extent with the district boundary).



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 Gulf Coast Aquifer System within the Bluebonnet Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 6: Summarized information for the Brazos River Alluvium Aquifer for the Bluebonnet 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	Brazos River Alluvium Aquifer	15,047
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Brazos River Alluvium Aquifer	65,704
Estimated annual volume of flow into the district within each aquifer in the district	Brazos River Alluvium Aquifer	14,135
Estimated annual volume of flow out of the district within each aquifer in the district	Brazos River Alluvium Aquifer	11,590
Estimated net annual volume of flow between each aquifer in the district	To Brazos River Alluvium Aquifer from Gulf Coast Aquifer System	9,533

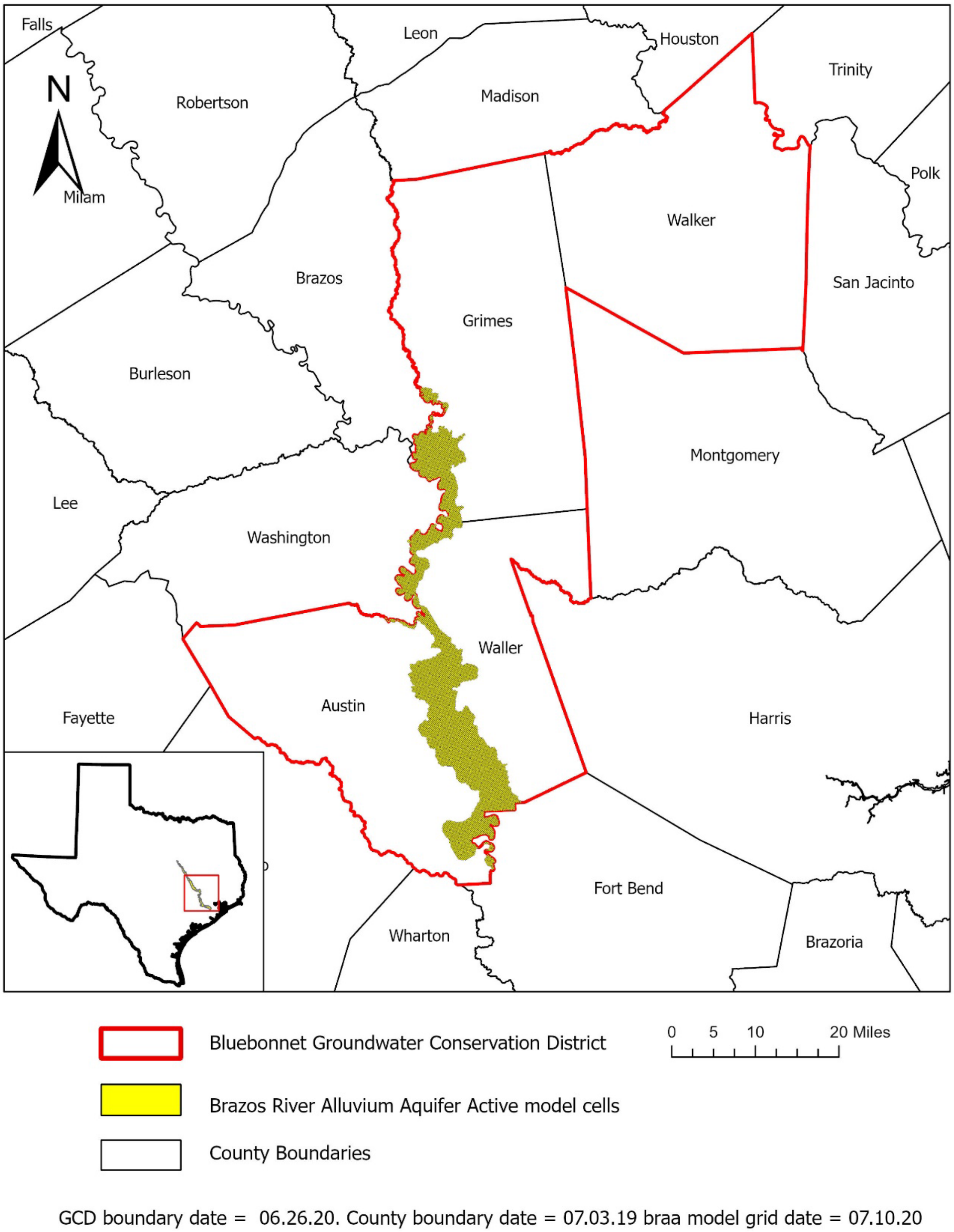
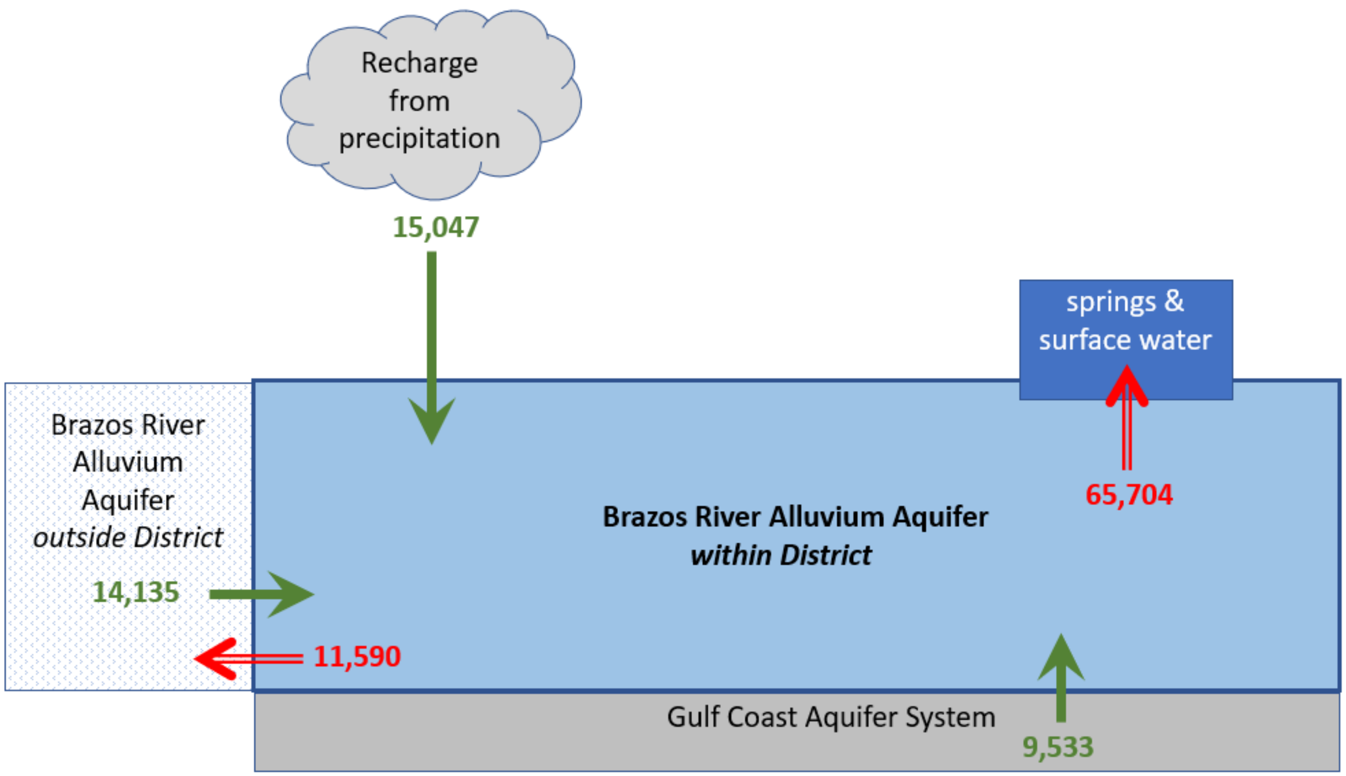


Figure 11: Area of the groundwater availability model for the for the Brazos River Alluvium Aquifer from which the information in Table 6 was extracted (the Brazos River Alluvium Aquifer extent within the district boundary).



Caveat: This diagram only includes the water budget items provided in Table 6. 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 12: **Generalized diagram of the summarized budget information from Table 6, representing directions of flow for the Brazos River Alluvium Aquifer within the Bluebonnet 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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