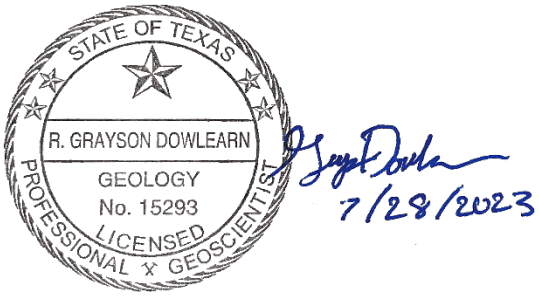
GAM RUN 23-015: MCMULLEN GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN

Micaela Pedrazas, GIT and Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-463-3075
July 28, 2023



This page is intentionally blank

GAM RUN 23-015: MCMULLEN GROUNDWATER CONSERVATION DISTRICT GROUNDWATER MANAGEMENT PLAN

Micaela Pedrazas, GIT and Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-463-3075
July 28, 2023

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 McMullen 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 McMullen Groundwater Conservation District should be adopted by the district on or before October 6, 2023 and submitted to the executive administrator of the TWDB on or before November 5, 2023. The current management plan for the McMullen Groundwater Conservation District expires on January 4, 2024.

The management plan information for the aquifers within McMullen Groundwater Conservation District was extracted from three groundwater availability models. We used the groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Panday and others, 2023) 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 central and southern portions of the Gulf Coast Aquifer System (Shi and Boghici, 2023) to estimate the management plan information for the Gulf Coast Aquifer System.

This report replaces the results of GAM Run 17-011 (Shi, 2017). Values may differ from the previous report as a result of using updated groundwater availability models and 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, 2, 3, 4, and 5 summarize the groundwater availability model data required by statute. Figures 1, 3, 5, 7, and 9 show the area of the model from which the values in Tables 1, 2, 3, 4, and 5 were extracted. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, 4, and 5. If the McMullen 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 McMullen Groundwater Conservation District management plan. Water budgets were extracted for the historical calibration period for the Carrizo-Wilcox, Queen City, and Sparta aquifers (1981 through 2017) using ZONEBUDGET for MODFLOW 6 (Langevin and others, 2021). Water budgets were extracted for the historical calibration period for the Yegua-Jackson Aquifer (1980 through 1997) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). Water budgets were extracted for the historical calibration period for the Gulf Coast Aquifer System (1981 through 2015) using ZONEBUDGET for MODFLOW USG Version 1.0 (Panday and others, 2013). 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 3.01 of the groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (Panday and others, 2023) to analyze the Carrizo-Wilcox, Queen City and Sparta aquifers. See Panday and others (2023) for assumptions and limitations of the model.
- The groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers contains nine layers:
    - Layer 1 represents Quaternary Alluvium
    - Layer 2 represents Younger units
    - Layer 3 represents the Sparta Aquifer and equivalent units
    - Layer 4 represents the Weches Formation (confining unit)
    - Layer 5 represents the Queen City Aquifer and equivalent units
    - Layer 6 represents the Reklaw Formation (confining unit)
    - Layers 7 through 9 represent the Carrizo-Wilcox Aquifer and equivalent units

- Water budget values for the district were determined for the Carrizo-Wilcox Aquifer (Layer 7 through 9, collectively), the Queen City Aquifer (Layer 5), and the Sparta Aquifer (Layer 3).
- Water budget terms were averaged for the historical calibration period 1981 through 2017 (stress periods 3 through 39).
- The model was run with MODFLOW-6 (Langevin and others, 2017).

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 Frio Formation of the Catahoula Group separates the Yegua-Jackson Aquifer from the Gulf Coast Aquifer System within the McMullen Groundwater Conservation District. This separation prevents direct exchange between the Yegua-Jackson Aquifer and the Gulf Coast Aquifer System within the district.
- 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 central and southern portions of the Gulf Coast Aquifer System (Shi and Boghici, 2023) to analyze the Gulf Coast Aquifer System. See Shi and Boghici (2023) 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 and younger overlying units
    - Layer 2 represents the Evangeline Aquifer
    - Layer 3 represents the Burkeville confining unit
    - Layer 4 represents the Jasper Aquifer and the upper sandy portion 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 1981 through 2015 (stress periods 2 through 36).
- The model was run with MODFLOW-USG (Panday and others, 2013).

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 aquifers located within McMullen 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, 2, 3, 4, and 5. Figures 1, 3, 5, 7, and 9 show the area of the model from which the values in Tables 1, 2, 3, 4, and 5 were extracted. Figures 2, 4, 6, 8, and 10 provide a generalized diagram of the groundwater flow components provided in Tables 1, 2, 3, 4, and 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 Carrizo-Wilcox Aquifer for the McMullen 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	3,230
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	5,414
Estimated net annual volume of flow between each aquifer in the district	To Carrizo-Wilcox Aquifer from Carrizo-Wilcox equivalent units	496
	To Carrizo-Wilcox Aquifer from Reklaw confining unit	220

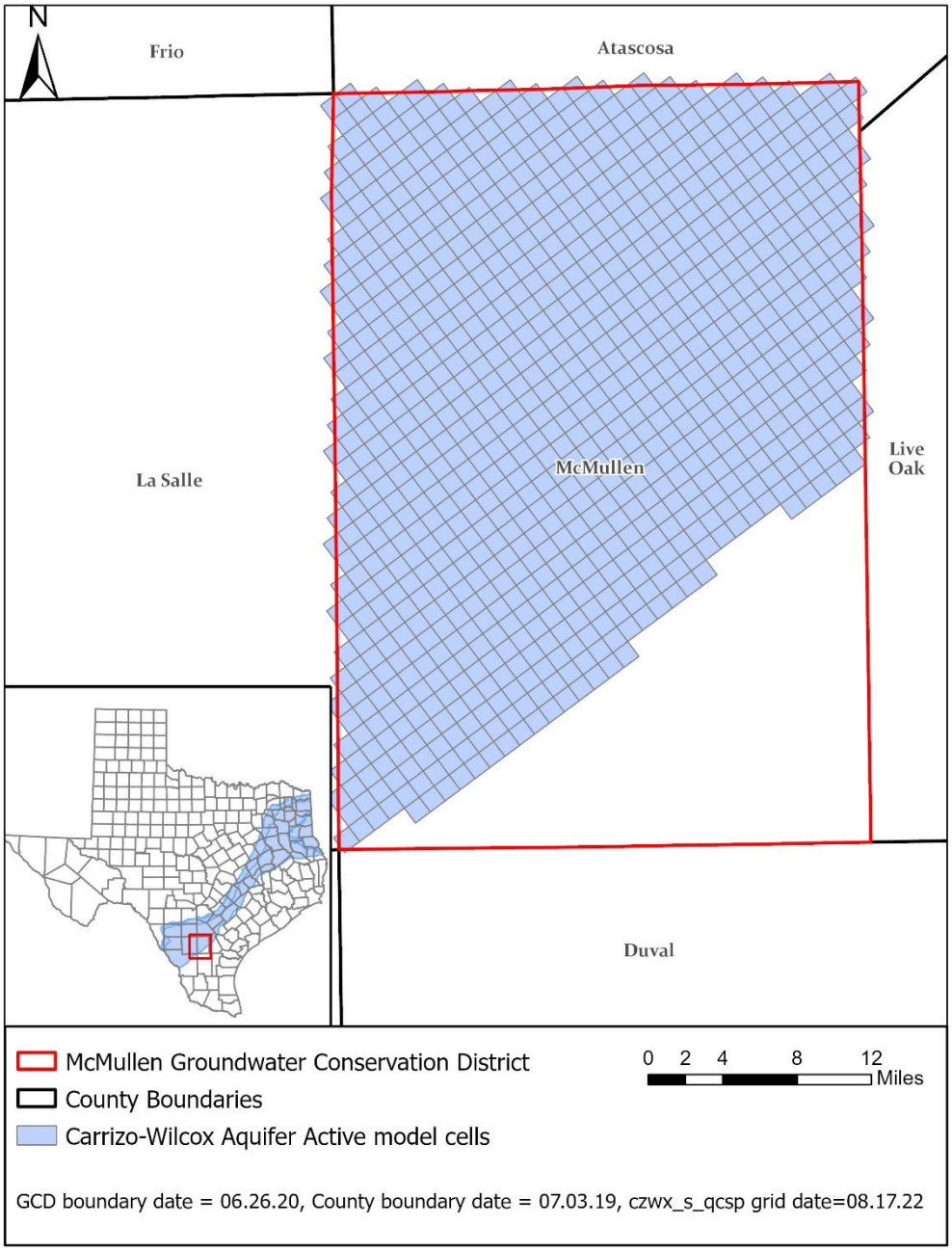
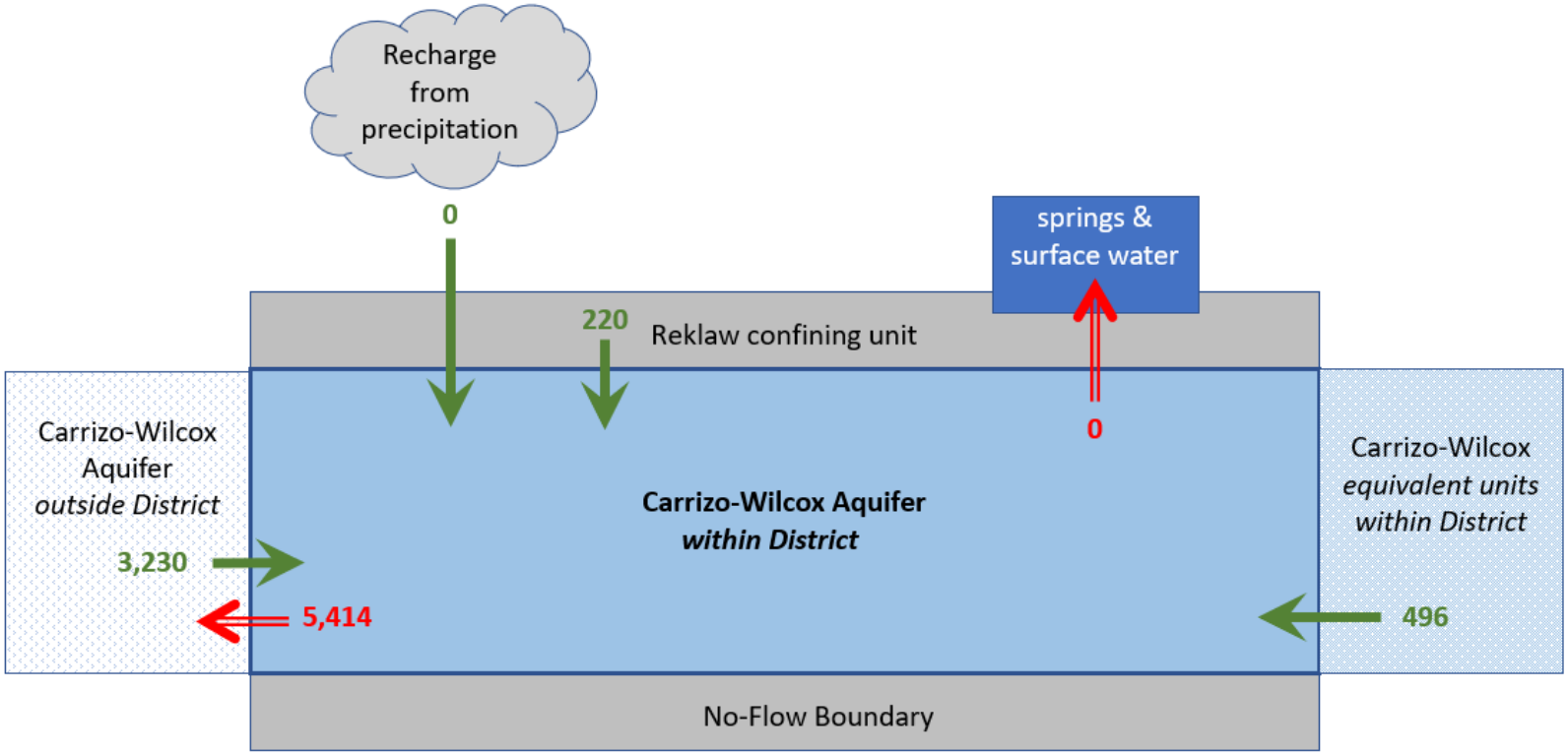


Figure 1: Area of the groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 1 was extracted (the Carrizo-Wilcox Aquifer extent within the district boundary).



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 McMullen Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 2: Summarized information for the Queen City Aquifer for the McMullen 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	567
Estimated annual volume of flow out of the district within each aquifer in the district	Queen City Aquifer	748
Estimated net annual volume of flow between each aquifer in the district	To Queen City Aquifer from Queen City equivalent units	2,459
	From Queen City Aquifer to Weches confining unit	2,050
	From Queen City Aquifer to Reklaw confining unit	108

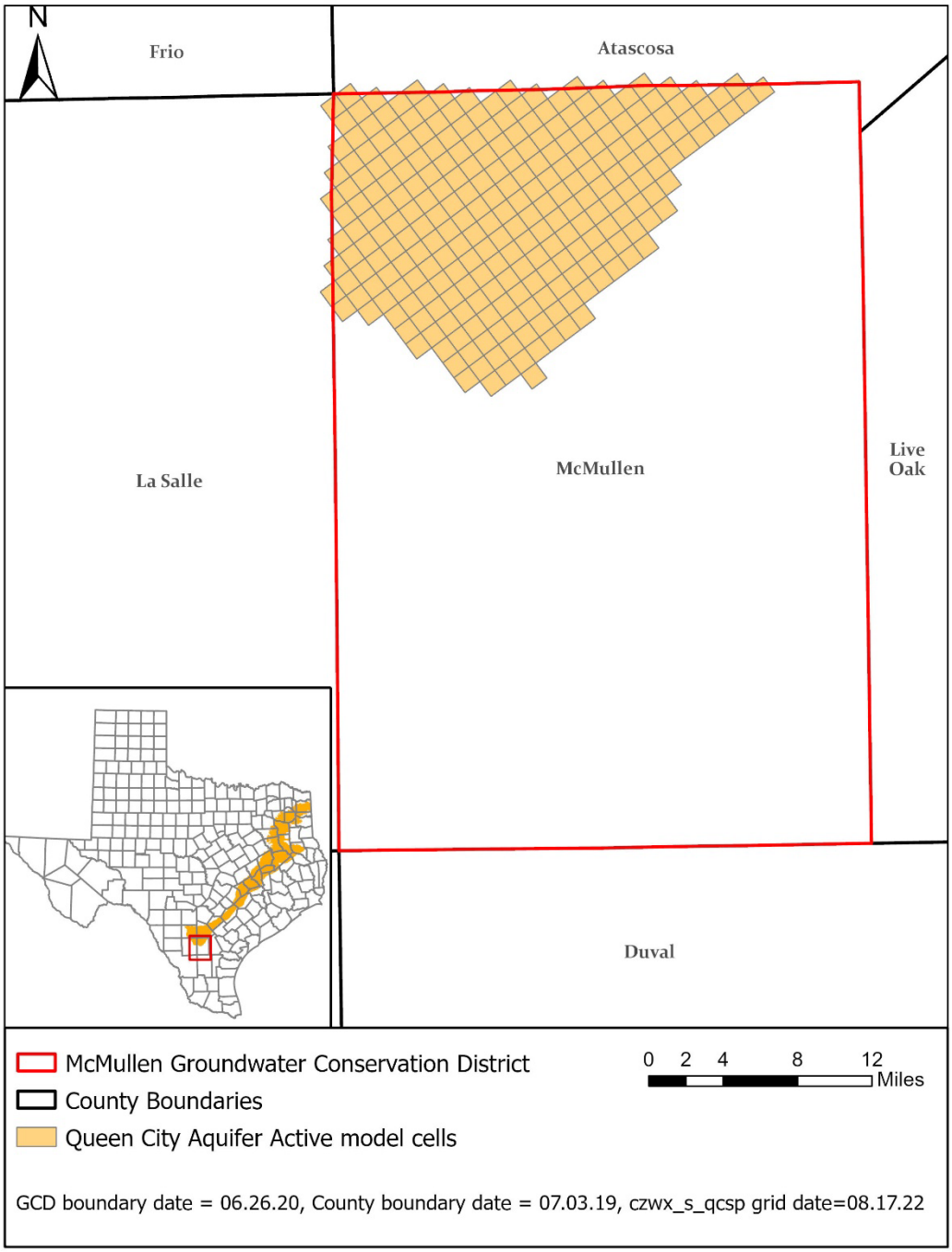
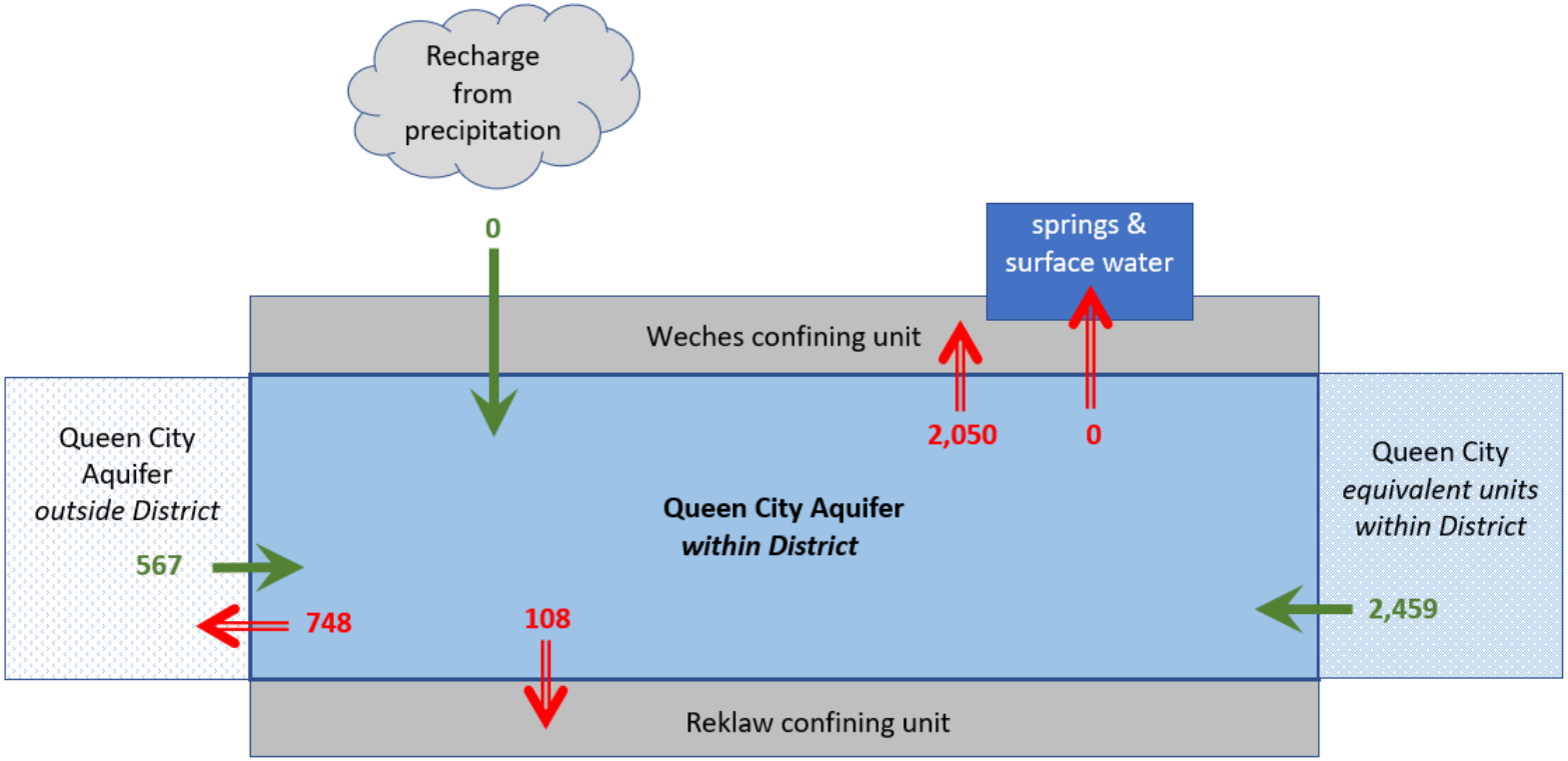


Figure 3: Area of the groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 2 was extracted (the Queen City Aquifer extent within the district boundary).



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 McMullen Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 3: Summarized information for the Sparta Aquifer for the McMullen 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	60
Estimated annual volume of flow out of the district within each aquifer in the district	Sparta Aquifer	90
Estimated net annual volume of flow between each aquifer in the district	From Sparta Aquifer to Sparta equivalent units	26
	From Sparta Aquifer to Younger units	109
	To Sparta Aquifer from Weches confining unit	173

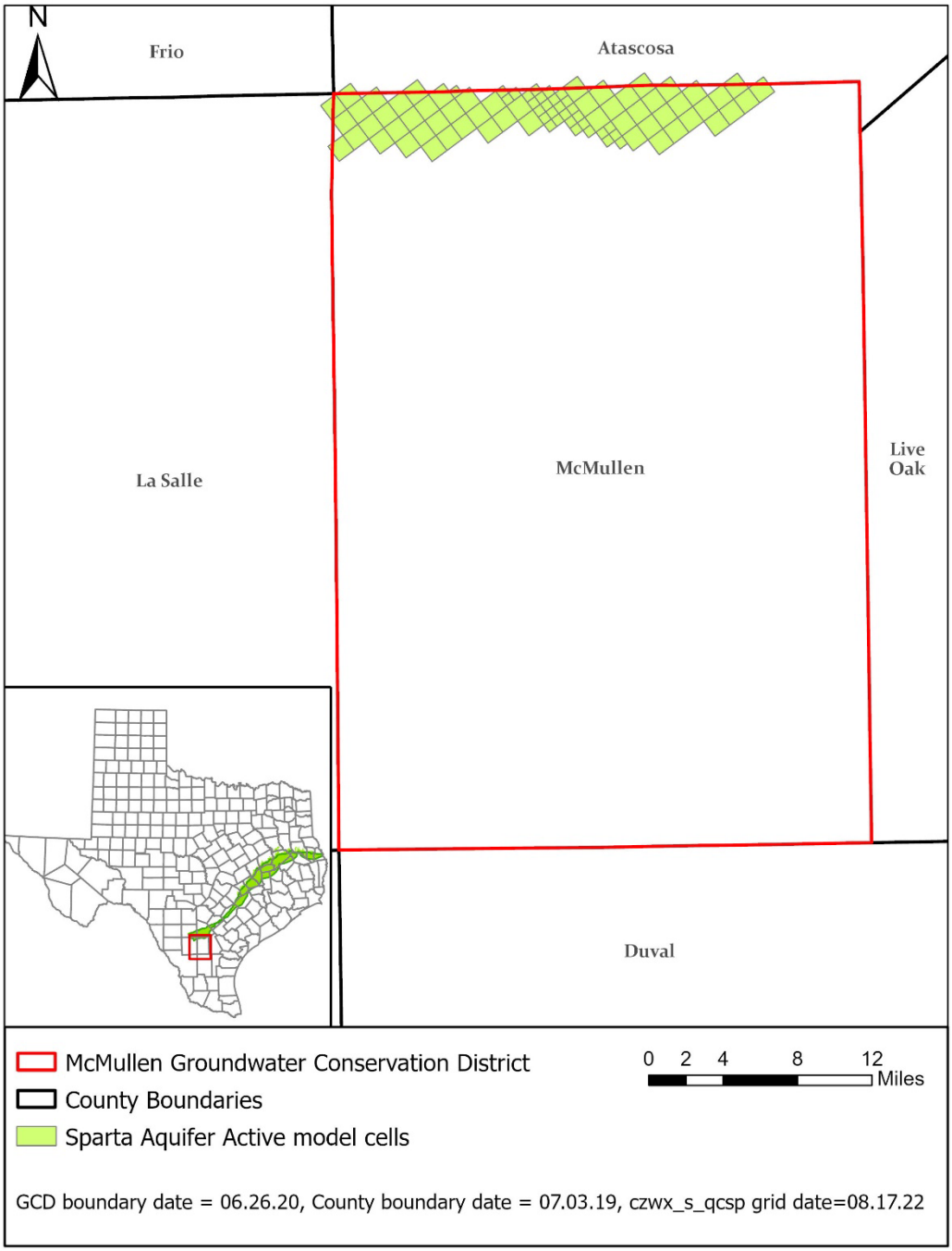
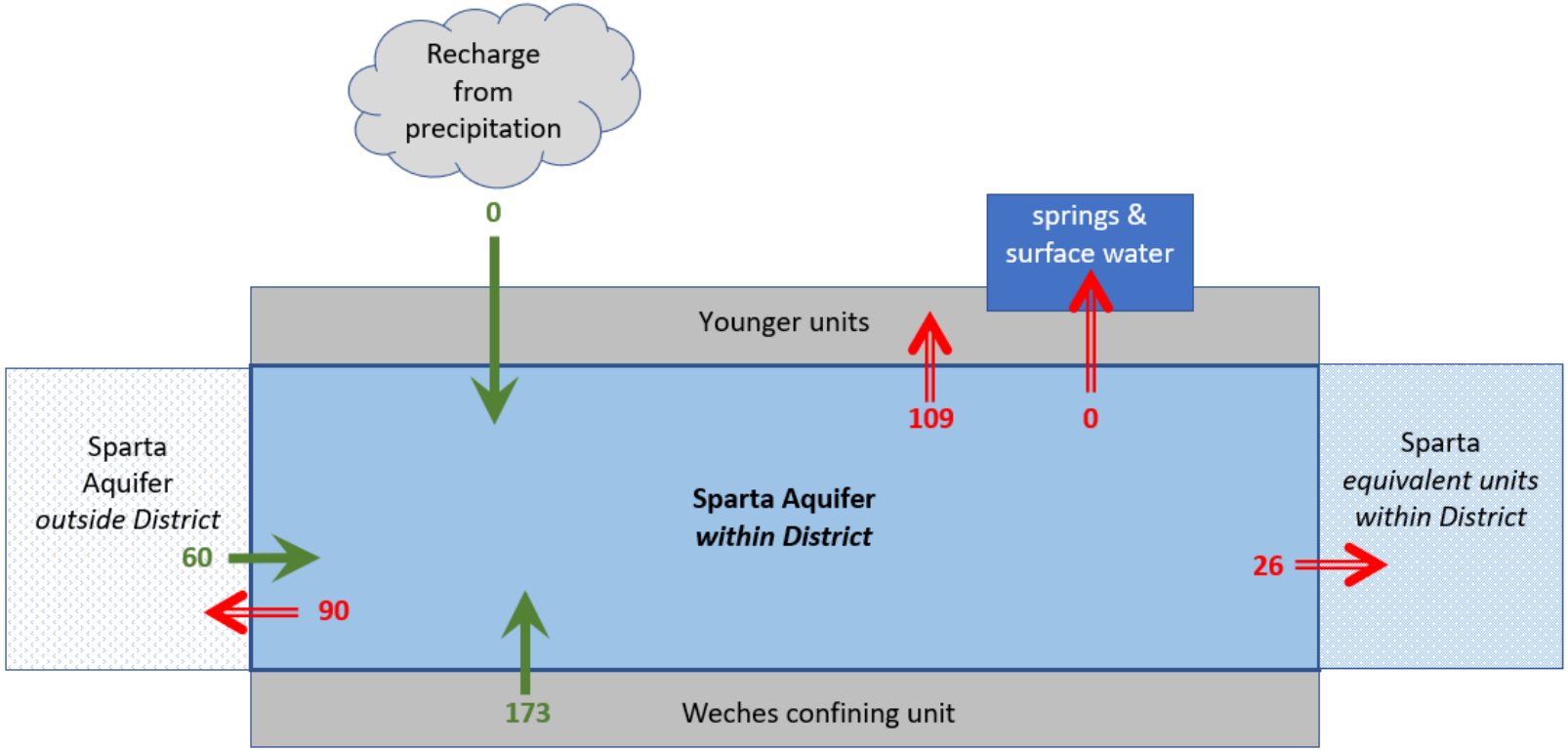


Figure 5: Area of the groundwater availability model for the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers from which the information in Table 3 was extracted (the Sparta Aquifer extent within the district boundary).



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 McMullen Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 4: Summarized information for the Yegua-Jackson Aquifer for the McMullen 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	7,101
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	13,081
Estimated annual volume of flow into the district within each aquifer in the district	Yegua-Jackson Aquifer	4,964
Estimated annual volume of flow out of the district within each aquifer in the district	Yegua-Jackson Aquifer	3,735
Estimated net annual volume of flow between each aquifer in the district	To Yegua-Jackson Aquifer from Yegua-Jackson equivalent units	579
	To Yegua-Jackson Aquifer from Catahoula Formation	309

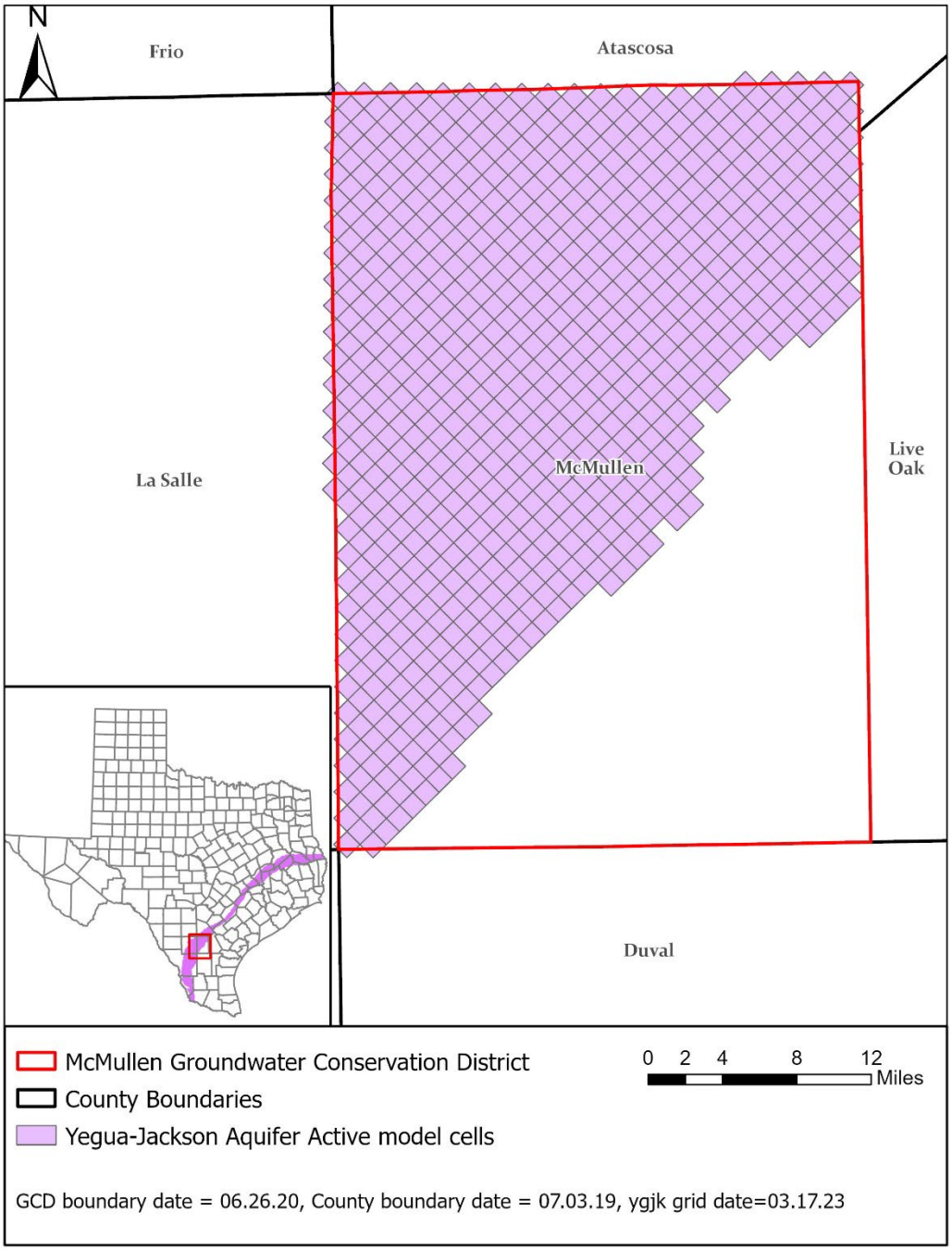
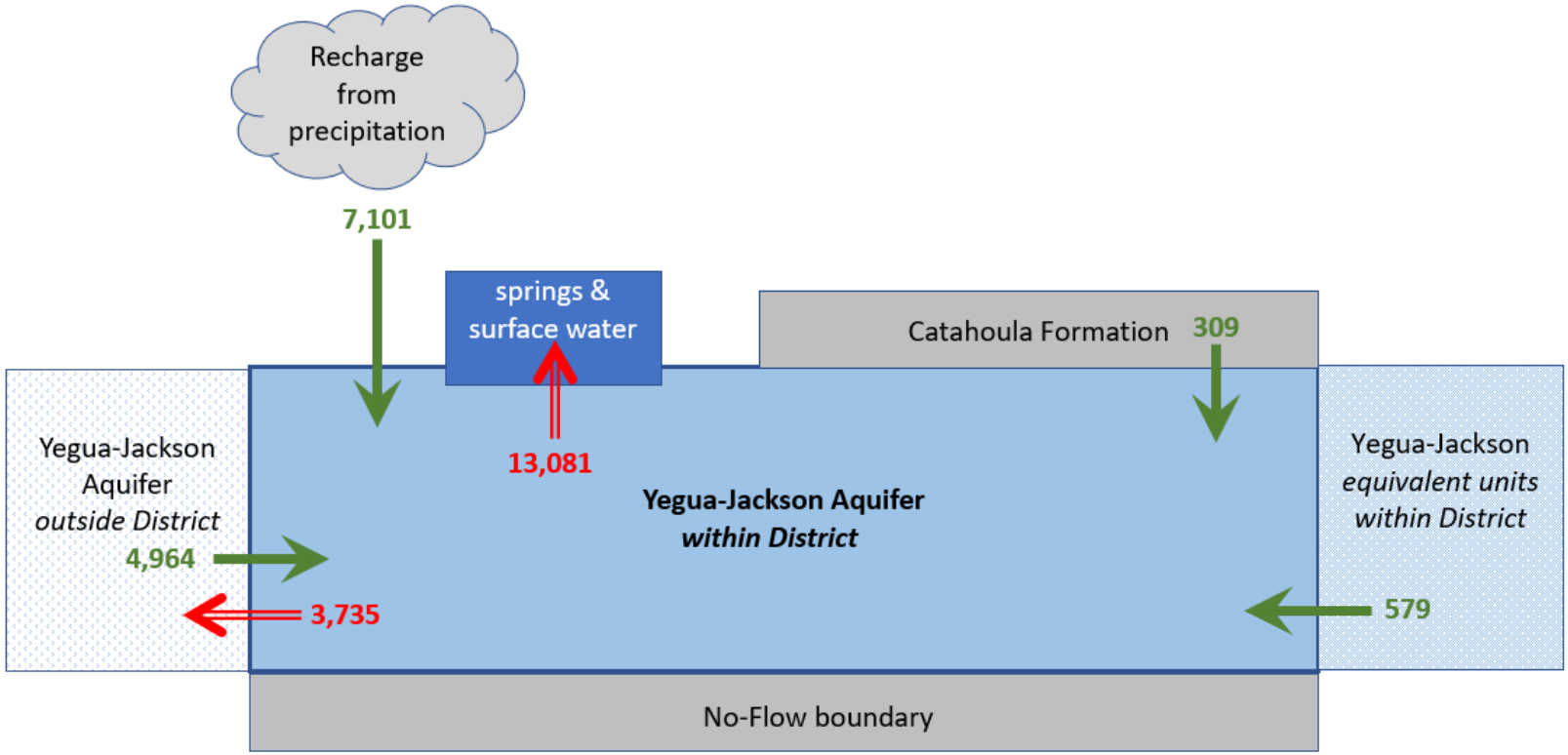


Figure 7: Area of the groundwater availability model for the Yegua-Jackson Aquifer from which the information in Table 4 was extracted (the Yegua-Jackson Aquifer extent within the district boundary).



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 McMullen Groundwater Conservation District. Flow values are expressed in acre-feet per year.

Table 5: Summarized information for the Gulf Coast Aquifer System for the McMullen 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	7,618
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	5,035
Estimated annual volume of flow into the district within each aquifer in the district	Gulf Coast Aquifer System	12,048
Estimated annual volume of flow out of the district within each aquifer in the district	Gulf Coast Aquifer System	16,500
Estimated net annual volume of flow between each aquifer in the district	From Gulf Coast Aquifer System to underlying units	523,463

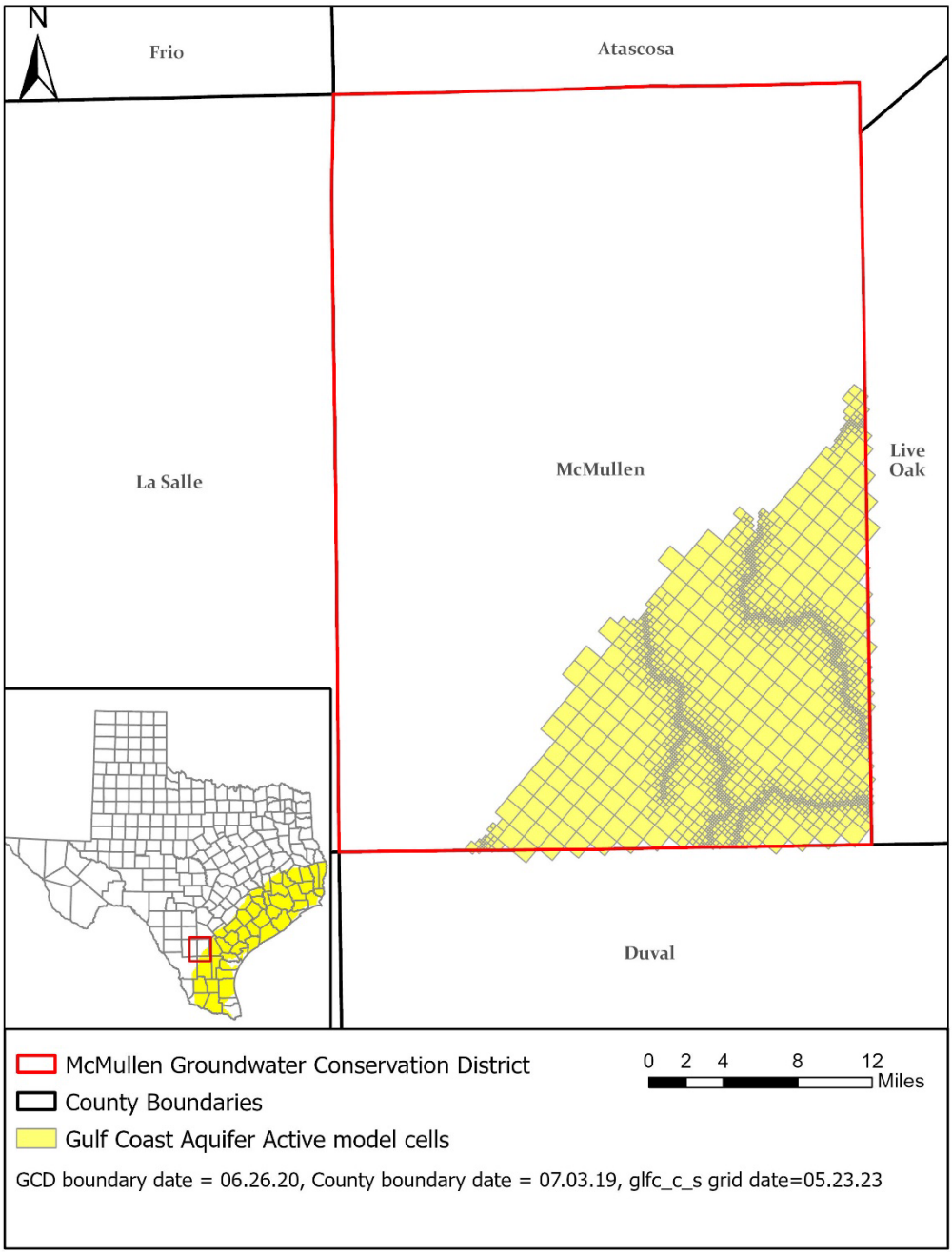
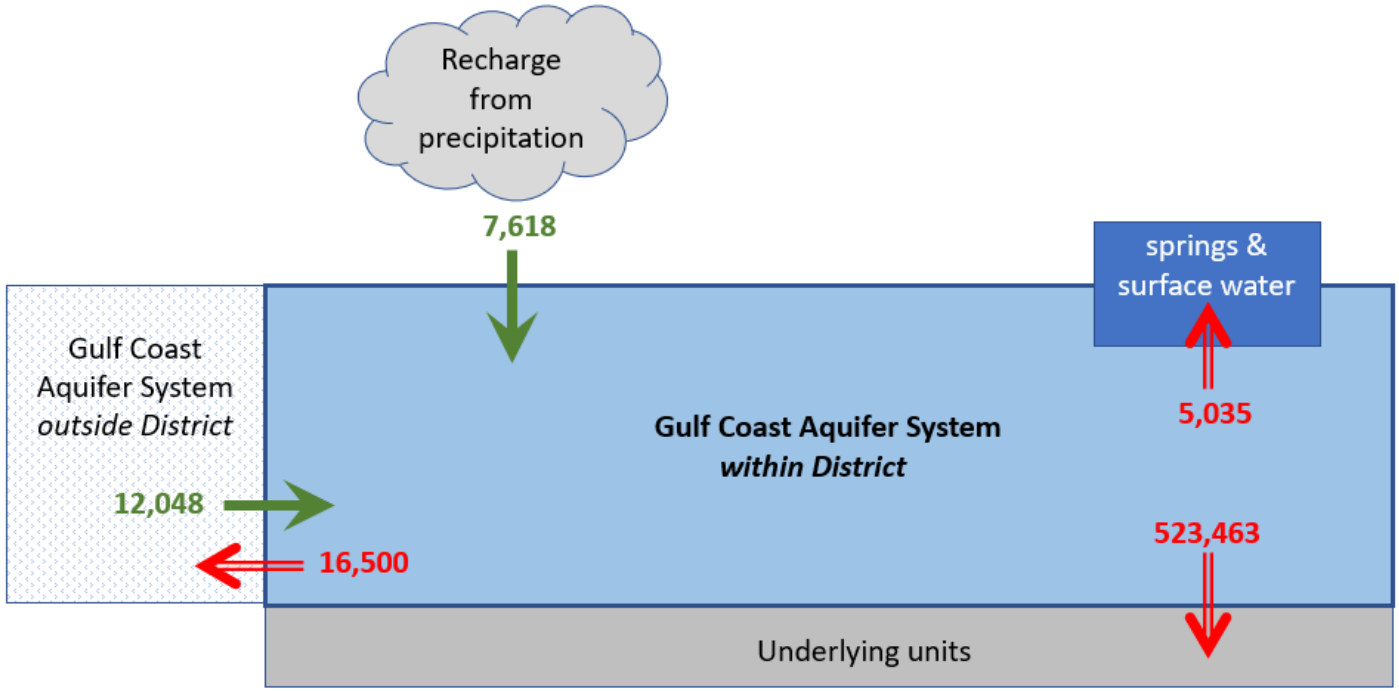


Figure 9: Area of the groundwater availability model for the central and southern portions of the Gulf Coast Aquifer System from which the information in Table 5 was extracted (the Gulf Coast Aquifer System extent with the district boundary).



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 McMullen 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.

REFERENCES:

Deeds, N. E., Yan, T., Singh, A., Jones, T. L., Kelley, V. A., Knox, P. R., and Young, S. C., 2010, Groundwater availability model for the Yegua-Jackson Aquifer: Final report prepared for the Texas Water Development Board by INTERA, Inc., 582 p., http://www.twdb.texas.gov/groundwater/models/gam/ygjk/YGJK_Model_Report.pdf.

Harbaugh, A. W., Banta, E. R., Hill, M. C., and McDonald, M. G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p.

Harbaugh, A. W., 2009, Zonebudget Version 3.01, A computer program for computing subregional water budgets for MODFLOW ground-water flow models, U.S. Geological Survey Groundwater Software.

Langevin, C.D., Hughes, J.D., Banta, E.R., Provost, A.M., Niswonger, R.G., and Panday, Sorab, 2017, MODFLOW 6 Modular Hydrologic Model: U.S. Geological Survey Software, https://doi.org/10.5066/F76Q1VQV

Langevin, C.D., Hughes, J.D., Banta, E.R., Provost, A.M., Niswonger, R.G., and Panday, Sorab, 2021, ZONEBUDGET for MODFLOW 6, 14 p., https://doi.org/10.5066/F76Q1VQV

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., http://www.nap.edu/catalog.php?record_id=11972.

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013, MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods, book 6, chap. A45, 66 p.

Panday, S., Wyckoff, R., Martell, G., Schorr, S., Zivic, M., Hutchinson, W.R., and Rumbaugh, J., 2023, Update to the groundwater availability model for the southern portion of the Queen City, Sparta, and Carrizo-Wilcox aquifers: Final numerical model report prepared for the Texas Water Development Board by GSI Environmental, Inc., 388 p., http://www.twdb.texas.gov/groundwater/models/gam/czwx_s/South_QCSCW_ModelRpt_Final_w_appendicies.pdf

Shi, J., 2017, GAM Run 17-011: McMullen Groundwater Conservation District Management Plan, 18 p., http://www.twdb.texas.gov/groundwater/docs/GAMruns/GR17-011.pdf?d=47965.5

Shi, J. and Boghici, R., 2023, Numerical Model Report: Groundwater Availability Model for the Central and Southern Portions of the Gulf Coast Aquifer System in Texas. Texas Water Development Board, 143p., http://www.twdb.texas.gov/groundwater/models/gam/glfc_c_s/Central_Southern_Gulf_Coast_Aquifer_System_Numerical_Model_Report_Final.pdf

Texas Water Code § 36.1071