GAM Run 15-004: Evergreen Underground Water Conservation District Management Plan

by Rohit R. Goswami, Ph.D.
Texas Water Development Board
Groundwater Resources Division
Groundwater Availability Modeling Section
(512) 463-0495
June 30, 2015

Cynthia K. Ridgeway is the Manager of the Groundwater Availability Modeling Section and is responsible for oversight of work performed by Rohit R. Goswami under her direct supervision. The seal appearing on this document was authorized by Cynthia K. Ridgeway, P.G. 471 on June 30, 2015.

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EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h) (Texas Water Code, 2011), 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. Information derived from groundwater availability models that shall be included in the groundwater management plan includes:

- the annual amount of recharge from precipitation to the groundwater resources within the district, if any;
- 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
- the annual volume of flow into and out of the district within each aquifer and between aquifers in the district.

This report—Part 2 of a two-part package of information from the TWDB to the Evergreen Underground Water Conservation District—fulfills the requirements noted above. Part 1 of the two-part package is the Estimated Historical Water Use/State Water Plan data report. The District will receive this data report from the TWDB Groundwater Technical Assistance Section. Questions about the data report can be directed to Mr. Stephen Allen, stephen.allen@twdb.texas.gov, (512) 463-7317.

The groundwater management plan for the Evergreen Underground Water Conservation District should be adopted by the district on or before February 2, 2016 and submitted to the executive administrator of the TWDB on or before March 03, 2016. The current management plan for the Evergreen Underground Water Conservation District expires on May 02, 2016.

This report discusses the methods, assumptions, and results from model runs using the groundwater availability models for the Edwards (Balcones Fault Zone) Aquifer (Thorkildsen and McElhaney,1992; Klemt and others, 1979; Lindgren and others, 2004),the southern portion of the Carrizo-Wilcox, Queen City and Sparta aquifers (Kelley and others, 2004), the Yegua-Jackson Aquifer (Deeds and others, 2010), and the central portion of the Gulf Coast Aquifer System (Chowdhury and others, 2004). This model run replaces the results of GAM Run 10-015 (Aschenbach, 2010). GAM Run 15-004 meets current standards set after the release of GAM Run 10-015.

Tables 1 through 6 summarize the groundwater availability model data required by statute, and Figures 1 through 6 show the area of the models from which the values in the tables were extracted. If after review of the figures, the Evergreen 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 for the Edwards (Balcones Fault Zone) Aquifer (Thorkildsen and McElhaney,1992; Klemt and others, 1979; Lindgren and others, 2004), the southern portion of the Carrizo-Wilcox, Queen City and Sparta aquifers (Kelley and others, 2004), the Yegua-Jackson Aquifer (Deeds and others, 2010), and the central portion of the Gulf Coast Aquifer (Chowdhury and others, 2004) were run for this analysis. Evergreen Underground Water Conservation District water budgets were extracted for the historical model period used for calibration of the models 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, net inter-aquifer flow (upper), and net inter-aquifer flow (lower) for the portion of the aquifers located within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Edwards (Balcones Fault Zone) Aquifer using the model initially developed for the Edwards Aquifer Authority

- Version 1.01 of the groundwater availability model for San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer initially developed for the Edwards Aquifer Authority. See Lindgren and others (2004) for assumptions and limitations of the model.

- The groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer contains only one layer representing the Edwards (Balcones Fault Zone) Aquifer and the associated limestone.

- This model was run to analyze the groundwater flow entering and leaving Evergreen Underground Water Conservation District.

- Conduit flow was simulated in the model by an increase in hydraulic conductivity as described in Lindgren and others (2004). The locations of these conduits caused inflation in the values for the lateral inflow and outflow as discussed in the Results section.

- The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

Edwards (Balcones Fault Zone) Aquifer using the GWSIM-IV model

- See Thorkildsen and McElhaney (1992) and Klemt and others (1979) for assumptions and limitations of the GWSIM-IV groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer.

- The GWSIM-IV groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer contains only one layer representing the Edwards (Balcones Fault Zone) Aquifer and the associated limestone.

- This model was run to analyze the groundwater flow entering and leaving Evergreen Underground Water Conservation District.

- The model does a good job of reproducing spring flow at Comal Springs, but underestimates spring flow at San Marcos Springs. This is because San Marcos Springs is fed by a regional component of groundwater flow and a local component of groundwater flow, with the local component of flow being the dominant component. The model includes the regional component of flow but only approximates the local component of flow.

- Recharge rates are based on U.S. Geological Survey estimates of historical recharge from 1934 to 1989.

- The pumping for each of the 56 years in the model is based on estimates of historical pumping.

- For the GWSIM-IV water budget terms, recharge and pumping volumes are from the model input files. Lateral flows, leakage, and reduction in recharge volumes are taken from the model output files. GWSIM-IV reduces recharge when calculated heads exceed the elevation of the top of the aquifer.

Carrizo-Wilcox, Queen-City, and Sparta aquifers

- Version 2.01 of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers was used for this analysis. See Deeds and others (2003) and Kelley and others (2004) for assumptions and limitations of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers.

- This groundwater availability model includes eight layers which generally represent the Sparta Aquifer (Layer 1), the Weches Confining Unit (Layer2), the Queen City Aquifer (Layer 3), the Reklaw Confining Unit (Layer 4), the Carrizo Aquifer (Layer 5), the Upper Wilcox Aquifer and top of the Middle Wilcox Aquifer where the Upper Wilcox is missing (Layer 6), the Middle Wilcox Aquifer (Layer 7), and the Lower Wilcox Aquifer (Layer 8). Individual water budgets for the District were determined for the Sparta Aquifer (Layer 1), the Queen City Aquifer (Layer 3), and the Carrizo-Wilcox Aquifer (Layer 5 to Layer 8 collectively).

- Groundwater in the Carrizo-Wilcox, Queen City, and Sparta aquifers ranges from fresh to brackish in composition (Kelley and others, 2004). Groundwater with total dissolved solids of less than 1,000 milligrams per liter are considered fresh and total dissolved solids of 1,000 to 10,000 milligrams per liter are considered brackish.

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

Yegua-Jackson Aquifer

- Version 1.01 of the groundwater availability model for the Yegua-Jackson Aquifer was used for this analysis. See Deeds and others (2010) for assumptions and limitations of the groundwater availability model.
- This groundwater availability model includes five layers which represent the outcrop section for the Yegua-Jackson Aquifer and younger overlying units

(Layer 1), the upper portion of the Jackson Group (Layer 2), the lower portion of the Jackson Group (Layer 3), the upper portion of the Yegua Group (Layer 4), and the lower portion of the Yegua Group (Layer 5).

- An overall water budget for the district was determined for the Yegua-Jackson Aquifer (Layer 1 to Layer 5 collectively for the portions that represent the Yegua-Jackson Aquifer).

- The model was run with MODFLOW-2000 (Harbaugh and others, 2000).

Gulf Coast Aquifer System

- Version 1.01 of the groundwater availability model for the central part of the Gulf Coast Aquifer System was used for this analysis. See Chowdhury and others (2004) and Waterstone and others (2003) for assumptions and limitations of the groundwater availability model.

- The model for the central portion of the Gulf Coast Aquifer System assumes partially penetrating wells in the Evangeline Aquifer due to lack of data for aquifer properties in the deeper, lower section of the aquifer. This means the areas where wells are drilled into the Evangeline Aquifer are represented using data collected and the deeper portions of the aquifer need future studies to understand the aquifer properties in more detail.

- This groundwater availability model includes four layers which generally represent the Chicot Aquifer (Layer 1), the Evangeline Aquifer (Layer 2), the Burkeville Confining Unit (Layer 3), and the Jasper Aquifer including parts of the Catahoula Formation (Layer 4).

- 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 model results for the aquifers located within the district and averaged over the duration of the calibration and verification portion of the model run in the district, as shown in Tables 1 through 6.

- 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.

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

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

- 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 or confining unit 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. 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.

Comparison of the Edwards Aquifer Authority and the GWSIM-IV groundwater availability models conducted on the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer

The Edwards Aquifer Authority and the GWSIM-IV groundwater availability models cover the same general area in the northwestern part of the district.

Conduit flows represent the major flow paths in karst aquifers, such as the Edwards (Balcones Fault Zone) Aquifer, and were simulated in the Edwards Aquifer Authority model of the Edwards (Balcones Fault Zone) Aquifer by increasing hydraulic conductivity (typically to a range between 2,000 and 300,000 feet per day) as described in Lindgren and others (2004). A simulated conduit in the Edwards Aquifer Authority model crosses the northwestern tip of Atascosa County and enters north-central Frio County based on the conduit locations from Figure 7 in Lindgren and others (2004), which were based on those inferred in Worthington (2004). The result of the conduits passing in and out of the district is that values for lateral inflow and outflow are highly inflated and appear unreasonable.

The GWSIM-IV model of the Edwards (Balcones Fault Zone) Aquifer is a regional groundwater model mainly calibrated to regional spring discharge such as Comal and San Marcos springs. The model was not originally designed to be used for subregional county or groundwater conservation district level flow budgets. However, the recharge and pumping volumes from the model input files and lateral flows, leakage, and reduction in recharge volumes from the model output files have been joined to the model grid in ArcGIS based on the cell ID for the data point. This enables the calculation of the parameters required for the management plan on a subregional basis.

Because the aquifer is not exposed at land surface within the district boundaries, the estimated annual amount of recharge from precipitation to the district for both models is zero. In addition, the estimated annual volume of water that discharges from springs and any surface water body to the district for both models is zero.

The estimated annual volume of flow into the district for the Edwards Aquifer Authority model is 273,625 acre-feet per year for both Atascosa and Frio counties. The estimated annual volume of flow into the district for the GWSIM-IV model is 70 acre-feet per year, and this flow is solely for Atascosa County based on the extent of the GWSIM-IV model grid (see Figure 1).

The estimated annual volume of flow out of the district for the Edwards Aquifer Authority model is 273,663 acre-feet per year for both Atascosa and Frio counties. The estimated annual volume of flow out of the district for the GWSIM-IV model is zero.

The Edwards Aquifer Authority model simulates flow between the Trinity Aquifer using the MODFLOW Well Package. However, the Trinity Aquifer is barely mapped within the Evergreen Underground Water Conservation District boundaries, and any interaction is not applicable in this case. Therefore, the estimated net annual volume of flow between aquifers in the district for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer using the Edwards Aquifer Authority model is considered to be zero. The GWSIM-IV model does not incorporate a flow component to other aquifers, so the estimated net annual volume of flow between aquifers in the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer using the GWSIM-IV model is also zero.

Since the two models cover the same general area, and the GWSIM-IV model does not include conduits, the lateral flows are not inflated as occurs in the Edwards Aquifer Authority model. Therefore, the GWSIM-IV model is believed to be more appropriate than the Edwards Aquifer Authority model and should be used to meet the management plan requirements (see Table 1).

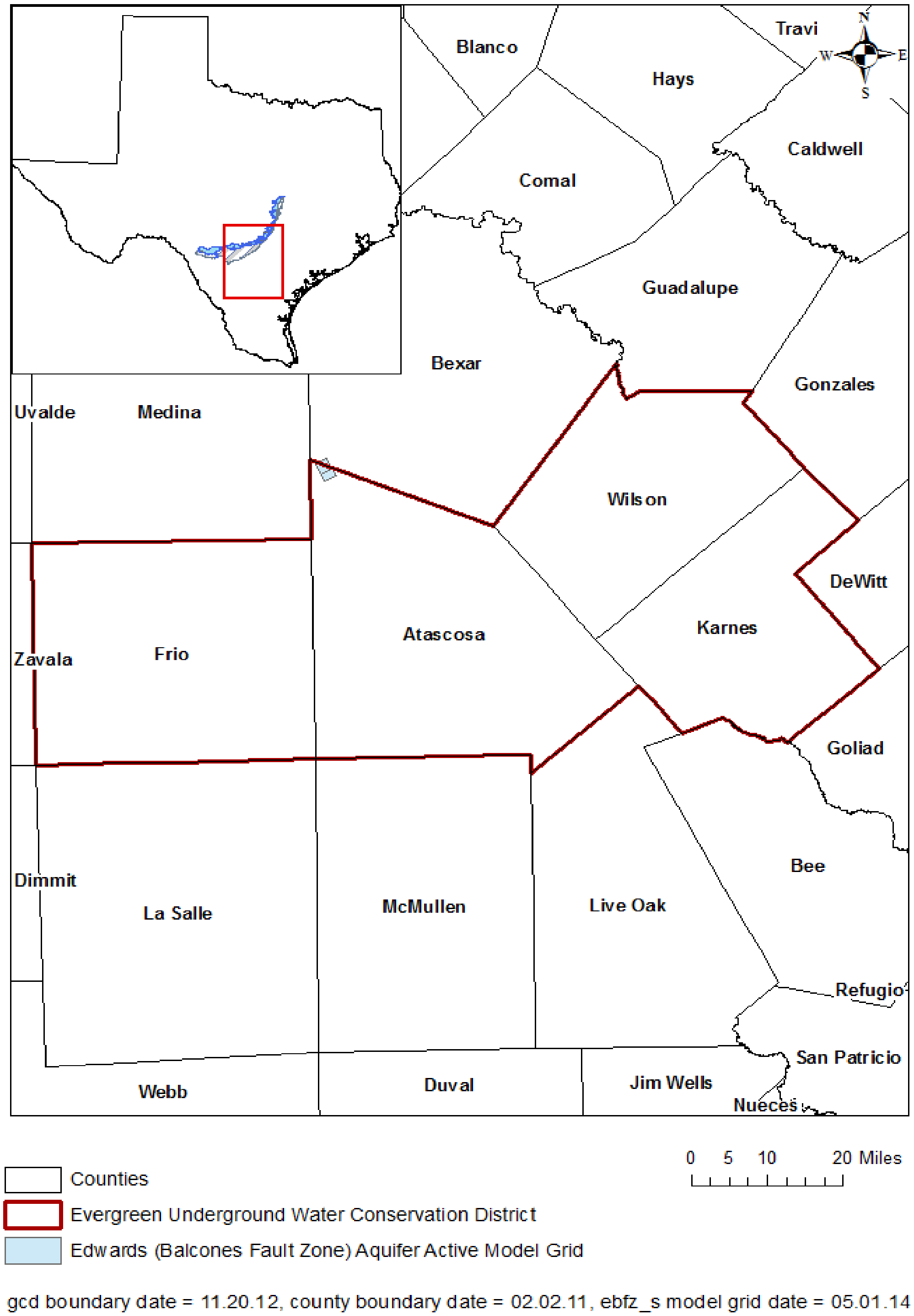

FIGURE 1: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SAN ANTONIO SEGMENT OF THE EDWARDS (BALCONES FAULT ZONE) AQUIFER FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED [THE EDWARDS (BALCONES FAULT ZONE) AQUIFER EXTENT MODELED WITHIN THE DISTRICT BOUNDARY].

TABLE 1: SUMMARIZED INFORMATION FOR THE EDWARDS (BALCONES FAULT ZONE) AQUIFER THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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 (Balcones Fault Zone) Aquifer	0
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards (Balcones Fault Zone) Aquifer	0
Estimated annual volume of flow into the district within each aquifer in the district	Edwards (Balcones Fault Zone) Aquifer	70
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards (Balcones Fault Zone) Aquifer	0
Estimated net annual volume of flow between each aquifer in the district	Not applicable[1]	Not applicable

[1] The groundwater availability model for the San Antonio portion of the Edwards (Balcones Fault Zone) Aquifer assumes no interaction with other aquifers.

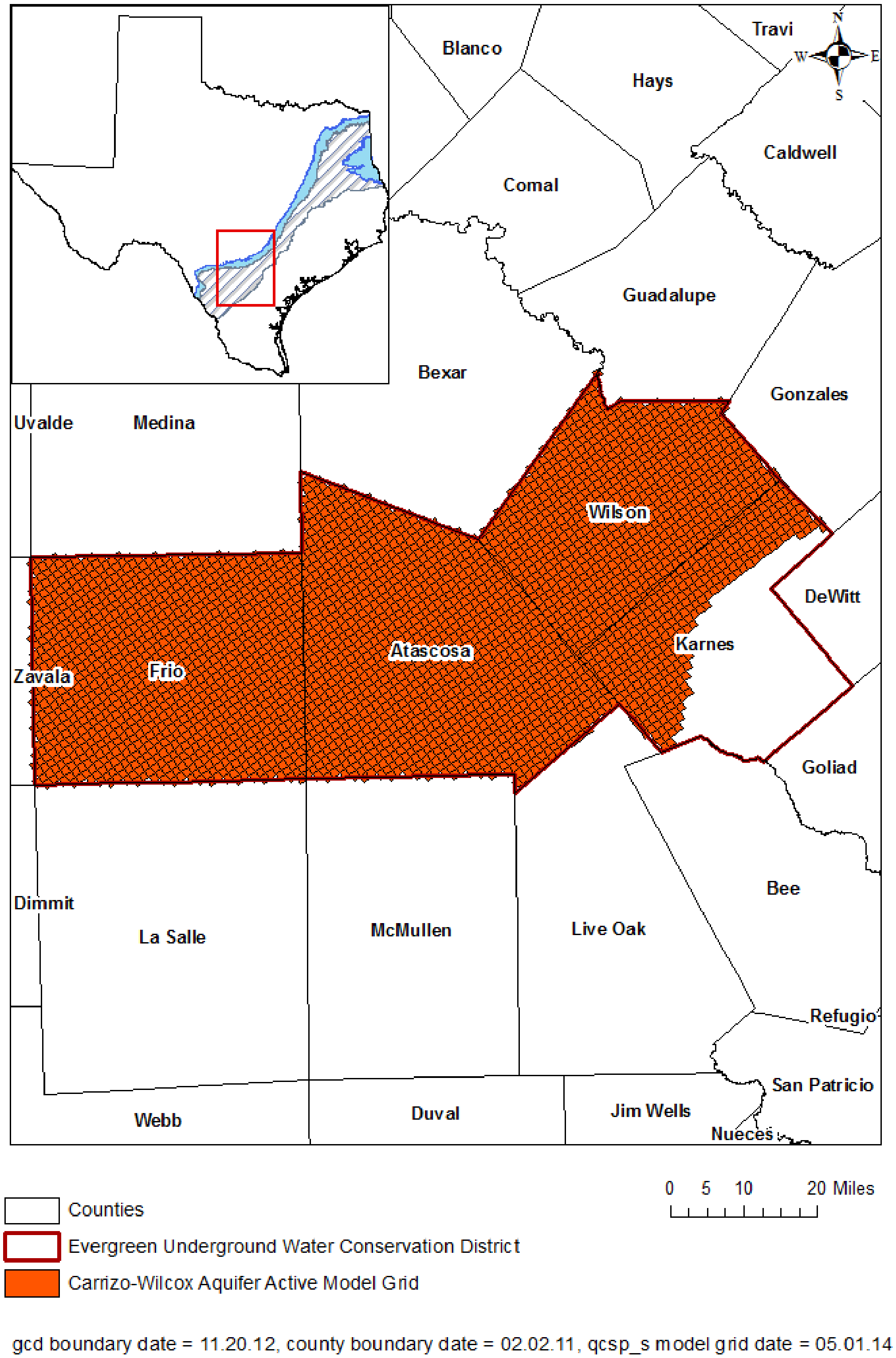

FIGURE 2: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE CARRIZO-WILCOX AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 2: SUMMARIZED INFORMATION FOR THE CARRIZO-WILCOX AQUIFER THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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	20,850
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	3,621
Estimated annual volume of flow into the district within each aquifer in the district	Carrizo-Wilcox Aquifer	72,095
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	15,083
Estimated net annual volume of flow between each aquifer in the district	From the Reklaw Confining Unit into the Carrizo-Wilcox Aquifer	18,695
	From the Carrizo-Wilcox Aquifer into brackish parts of the same geologic unit	2,312

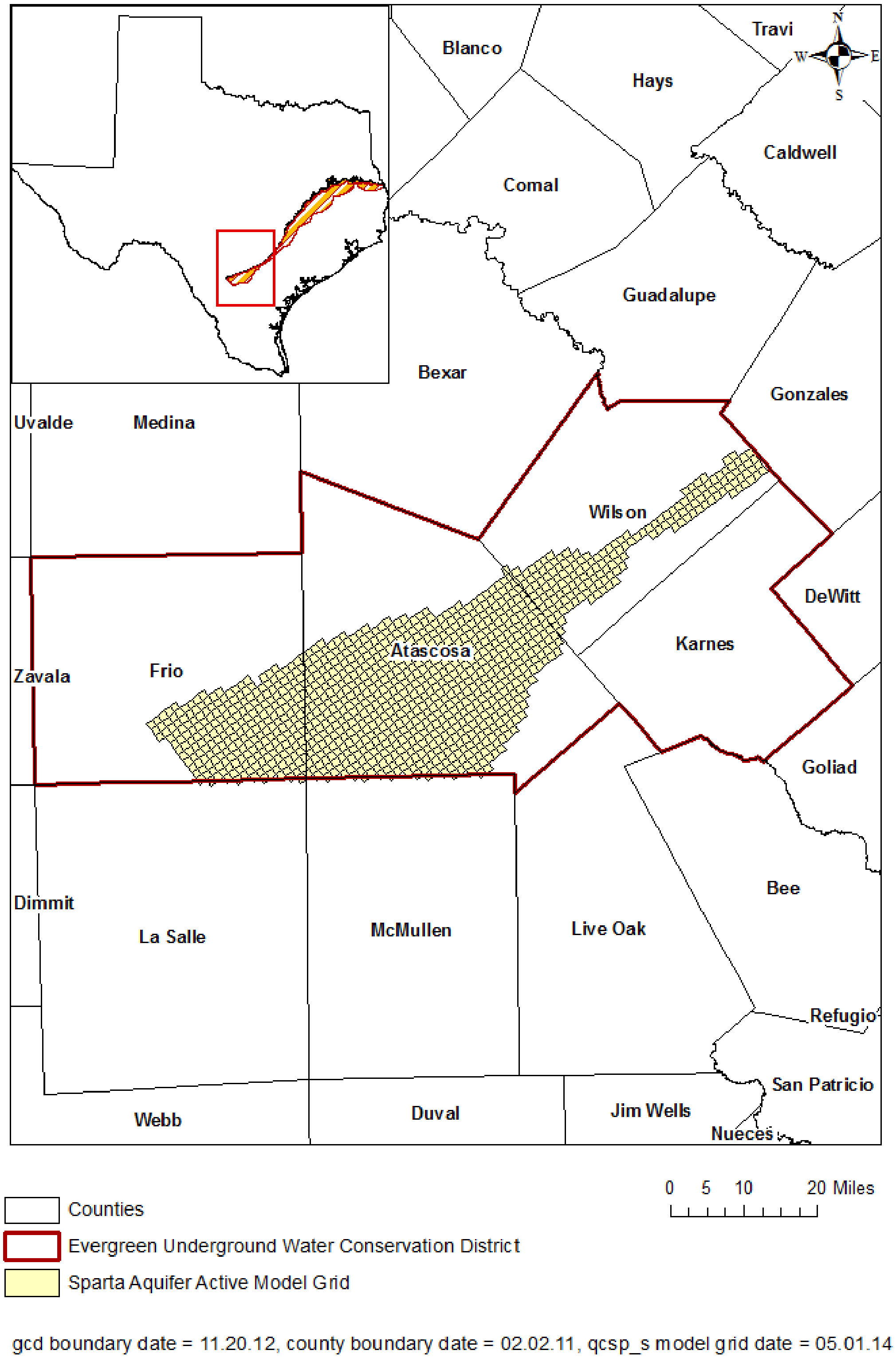

FIGURE 3: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE SPARTA AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 3: SUMMARIZED INFORMATION FOR THE SPARTA AQUIFER THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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	6,150
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Sparta Aquifer	4,407
Estimated annual volume of flow into the district within each aquifer in the district	Sparta Aquifer	73
Estimated annual volume of flow out of the district within each aquifer in the district	Sparta Aquifer	865
Estimated net annual volume of flow between each aquifer in the district	From the Sparta Aquifer into overlying younger units	970
	From the Sparta Aquifer into the underlying Weches Confining Unit	4,486
	From the Sparta Aquifer into brackish parts of the same geologic unit	1,095

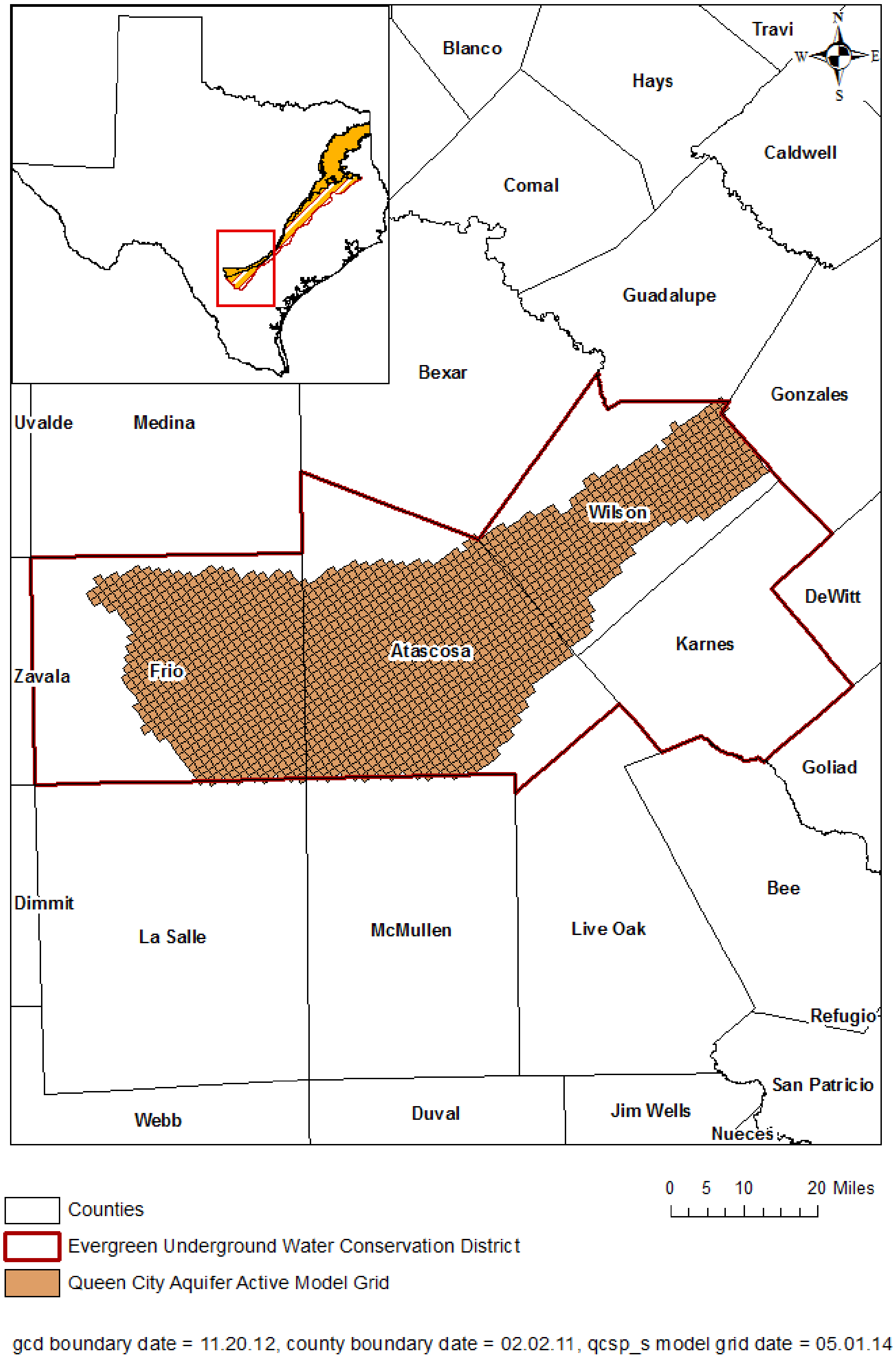

FIGURE 4: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE SOUTHERN PORTION OF THE CARRIZO-WILCOX, QUEEN CITY, AND SPARTA AQUIFERS FROM WHICH THE INFORMATION IN TABLE 4 WAS EXTRACTED (THE QUEEN CITY AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 4: SUMMARIZED INFORMATION FOR THE QUEEN CITY AQUIFER THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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	23,084
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	7,097
Estimated annual volume of flow into the district within each aquifer in the district	Queen City Aquifer	80
Estimated annual volume of flow out of the district within each aquifer in the district	Queen City Aquifer	1,717
Estimated net annual volume of flow between each aquifer in the district	From the Weches Confining Unit into the Queen City Aquifer	6,259
	From Queen City Aquifer into the Reklaw Confining Unit	7,282
	From the Queen City Aquifer into brackish parts of the same geologic unit	527

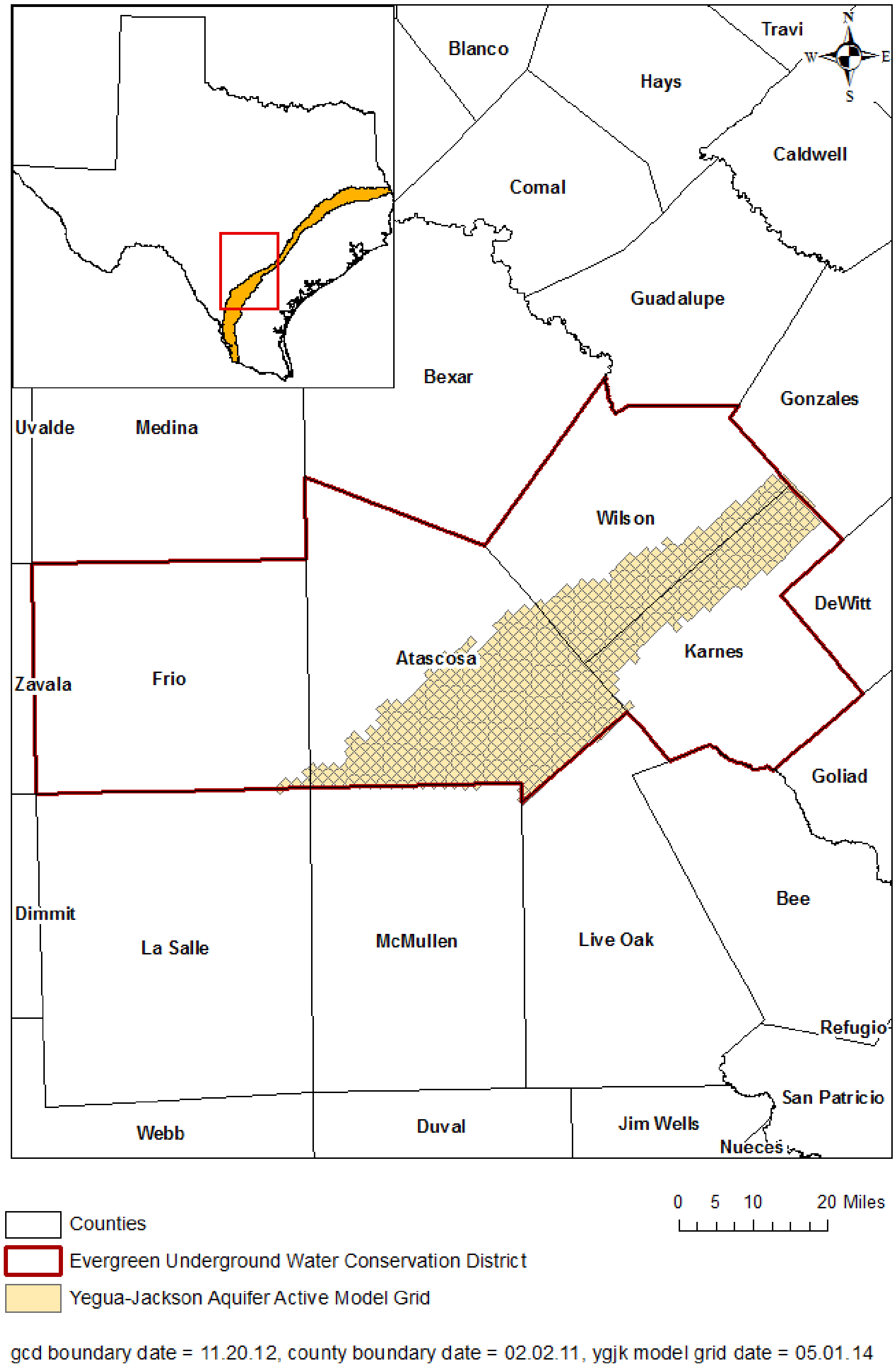

FIGURE 5: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE YEGUA-JACKSON AQUIFER FROM WHICH THE INFORMATION IN TABLE 5 WAS EXTRACTED (THE YEGUA-JACKSON AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 5: SUMMARIZED INFORMATION FOR THE YEGUA-JACKSON AQUIFER THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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	42,086
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	46,062
Estimated annual volume of flow into the district within each aquifer in the district	Yegua-Jackson Aquifer	2,680
Estimated annual volume of flow out of the district within each aquifer in the district	Yegua-Jackson Aquifer	4,580
Estimated net annual volume of flow between each aquifer in the district	Flow into the brackish portion of the Yegua-Jackson units	269

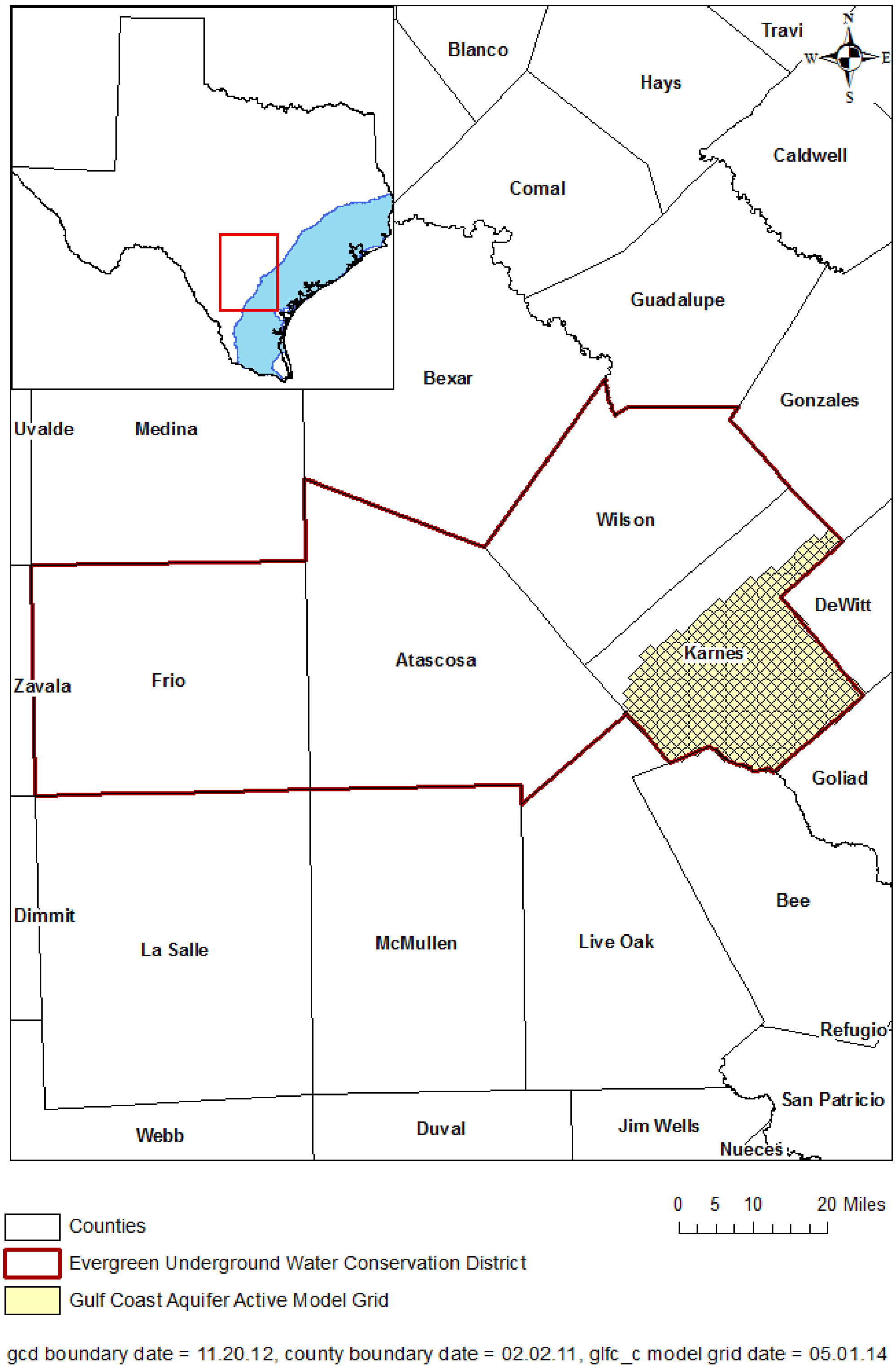

FIGURE 6: AREA OF THE GROUNDWATER AVAILABILITY MODEL FOR THE CENTRAL PORTION OF THE GULF COAST AQUIFER SYSTEM FROM WHICH THE INFORMATION IN TABLE 6 WAS EXTRACTED (THE GULF COAST AQUIFER SYSTEM EXTENT WITHIN THE DISTRICT BOUNDARY).

TABLE 6: SUMMARIZED INFORMATION FOR THE GULF COAST AQUIFER SYSTEM THAT IS NEEDED FOR THE EVERGREEN UNDERGROUND WATER CONSERVATION DISTRICT'S 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	1,196
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	1,496
Estimated annual volume of flow into the district within each aquifer in the district	Gulf Coast Aquifer System	746
Estimated annual volume of flow out of the district within each aquifer in the district	Gulf Coast Aquifer System	1,198
Estimated net annual volume of flow between each aquifer in the district	Not applicable[2]	Not applicable

[2] The groundwater availability model for the central portion of the Gulf Coast Aquifer System assumes no-flow conditions at the base of the aquifer.

LIMITATIONS:

The groundwater model(s) used in completing this analysis is the best available scientific tool that can be used to meet the stated objective(s). 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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