GAM Run 10-015

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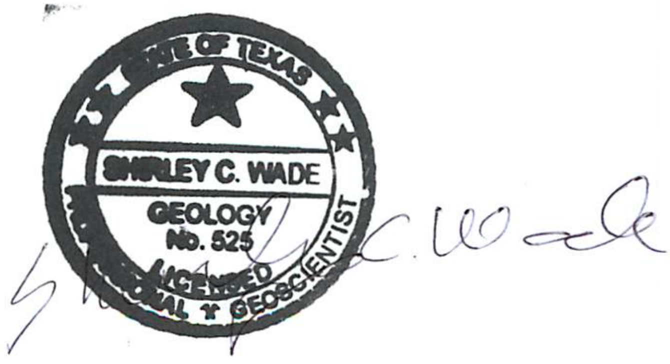

EXECUTIVE SUMMARY:

Texas State Water Code, Section 36.1071, Subsection (h), states that, in developing its groundwater management plan, groundwater conservation districts shall use groundwater availability modeling information provided by the Executive Administrator of the Texas Water Development Board 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:

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

This report supersedes GAM Run 08-62 dated September 3, 2008. The purpose of this model run is to provide information to the Evergreen Underground Water Conservation District for its groundwater management plan. A groundwater availability model was not previously completed for the Yegua-Jackson Aquifer, but a model that includes the Evergreen Underground Water Conservation District was released in May 2010. In addition, the GWSIM-IV model for the Edwards (Balcones Fault Zone) Aquifer in the San Antonio Region was modified so that it could be applied on a subregional basis. This model has been compared to the previously used model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer developed for the Edwards Aquifer Authority (EAA). The groundwater management plan for the Evergreen Underground Water Conservation District was due for approval by the Executive Administrator of the Texas Water Development Board before May 3, 2009.

This report discusses the methods, assumptions, and results from model runs using the groundwater availability models for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer (both the model initially developed for the Edwards Aquifer Authority and the GWSIM-IV model); the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers; the central part of the Gulf Coast Aquifer; and the Yegua-Jackson Aquifer. Tables 1 to 6 summarize the groundwater availability model data required by the statute, and figures 1 to 6 show the area of each model from which the values in the respective tables were extracted.

METHODS:

We ran the groundwater availability models for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer (1980 through 2000) developed for the Edwards Aquifer Authority (EAA); the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer (1980 through 1989) using GWSIM-IV; the southern portion of the Carrizo-Wilcox, Queen City, and Sparta aquifers (1980 through 1999); the central part of the Gulf Coast Aquifer (1981 through 1999); and the Yegua-Jackson Aquifer (1980 through 1997) and (1) extracted water budgets for each year of the transient model period and (2) averaged the 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 portions of the aquifers located within the district.

PARAMETERS AND ASSUMPTIONS:

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

- We used version 1.01 of the groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer. 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 associated limestones.

- The root mean square error (a measure of the difference between simulated and actual water levels during model calibration) for the model between 1947 and 2000 ranged from 4.1 to 23.2 feet (Lindgren and others, 2004).

- 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 an inflation of the values for lateral inflow and outflow as discussed in the Results section.

- We used Groundwater Vistas Version 5 (Environmental Simulations, Inc. 2007) as the interface to process model output.

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

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

- 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 more important 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 is based on estimates of historical pumping.

- For the GWSIM-IV water budget terms, recharge and pumping volumes are from the model input files and 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

- We used Version 2.01 of the groundwater availability model for the southern part of the Carrizo-Wilcox, Queen City, and Sparta aquifers. 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, representing (from top to bottom):

  1. the Sparta Aquifer,
  2. the Weches Confining Unit,
  3. the Queen City Aquifer,
  4. the Reklaw Confining Unit,
  5. the Carrizo Aquifer,
  6. the Upper Wilcox Aquifer and top of the Middle Wilcox Aquifer where the Upper Wilcox is missing,
  7. the Middle Wilcox Aquifer, and
  8. the Lower Wilcox Aquifer.

  Out of the eight layers listed above, 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).

- The root mean squared error (a measure of the difference between simulated and actual water levels during model calibration) in the groundwater availability model is 23 feet for the Sparta Aquifer, 18 feet for the Queen City Aquifer, and 33 feet for the Carrizo Aquifer for the calibration period (1980 to 1989) and 19, 22, and 48 feet for the same aquifers, respectively, in the verification period (1990 to 1999) (Kelley others, 2004). These root mean squared errors are between seven and ten percent of the range of measured water levels (Kelley others, 2004).

- 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.

- We used Groundwater Vistas Version 5 (Environmental Simulations, Inc. 2007) as the interface to process model output.

Yegua-Jackson Aquifer

- We used version 1.01 of the groundwater availability model for the Yegua-Jackson Aquifer. See Deeds and others (2010) for assumptions and limitations of the groundwater availability model.

- This groundwater availability model includes five layers, representing (from top to bottom):

  1. outcrop section for the Yegua-Jackson Aquifer and younger overlying units,
  2. the upper portion of the Jackson Group,
  3. the lower portion of the Jackson Group,
  4. the upper portion of the Yegua Group, and
  5. the lower portion of the Yegua Group.

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).

- As reported in Deeds and others (2010), the mean absolute errors (a measure of the difference between simulated and measured water levels during model calibration) for the Jackson Group (combined upper and lower Jackson units), Upper Yegua, and Lower Yegua portions of the Yegua-Jackson Aquifer for the historical-calibration period of the model are 31.1, 23.9, and 24.5 feet, respectively. These represent 10.3, 5.7 and 6.3 percent of the hydraulic head drop across each model area, respectively.

- We used Groundwater Vistas Version 5 (Environmental Simulations, Inc. 2007) as the interface to process model output.

Gulf Coast Aquifer

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

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

  1. the Chicot Aquifer,
  2. the Evangeline Aquifer,
  3. the Burkeville Confining Unit, and
  4. the Jasper Aquifer (including portions of the Catahoula Formation).

  An overall water budget for the district was determined for the central Gulf Coast Aquifer (Layer 1 to Layer 4 collectively). It should be noted that Layer 1 is not present in the district.

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the entire model for 1999 is 26 feet. This mean absolute error is 4.6 percent of the hydraulic head drop across the model area (Chowdhury and others, 2004).

- The transient portion of the model has a total of 85 stress periods. Of these, monthly stress periods were assigned for 1987 through 1989 and 1996 through 1998. Monthly stress periods were assigned to better simulate possible effects of drought on the groundwater flow system. The remaining stress periods are annual.

- We used Groundwater Vistas Version 5 (Environmental Simulations, Inc. 2007) as the interface to process model output.

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected components were extracted from the groundwater budget for the aquifers located within the district and averaged over the duration of the respective calibration and verification portion of each model run, as shown in tables 1 to 6. The components of the modified budgets shown in the tables include:

- Precipitation recharge—This is 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—This is the total water exiting the aquifer (outflow) to surface water features such as streams, reservoirs, and drains (springs).

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

- Flow between aquifers—This describes the vertical flow, or leakage, between 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. "Inflow" to an aquifer from an overlying or underlying aquifer will always equal the "Outflow" from the other aquifer.

The information needed for the district's management plan is summarized in tables 1 to 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 district or county boundaries, 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 (see figures 1 to 6).

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

The EAA 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 EAA 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 EAA 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 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 (i.e. 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.

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 EAA model is 274,826 acre-feet per year. This breaks down to approximately 156,651 acre-feet per year into Atascosa County and 118,175 acre-feet per year into Frio County. 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 EAA model is 274,832 acre-feet per year. This breaks down to approximately 153,906 acre-feet per year out of Atascosa County and 120,926 acre-feet per year out of Frio County. The estimated annual volume of flow out of the district for the GWSIM-IV model is zero.

The EAA model simulates flow between the Trinity Aquifer using the MODFLOW Well Package. However, the Trinity Aquifer is not in or adjacent to the Evergreen Underground Water Conservation District, 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 EAA 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 EAA model. Therefore, the GWSIM-IV model is believed to be more appropriate than the EAA model and should be used to meet the management plan requirements (see Table 1).

Table 1: Summarized information for the Edwards (Balcones Fault Zone) Aquifer that is needed for 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	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	Not applicable

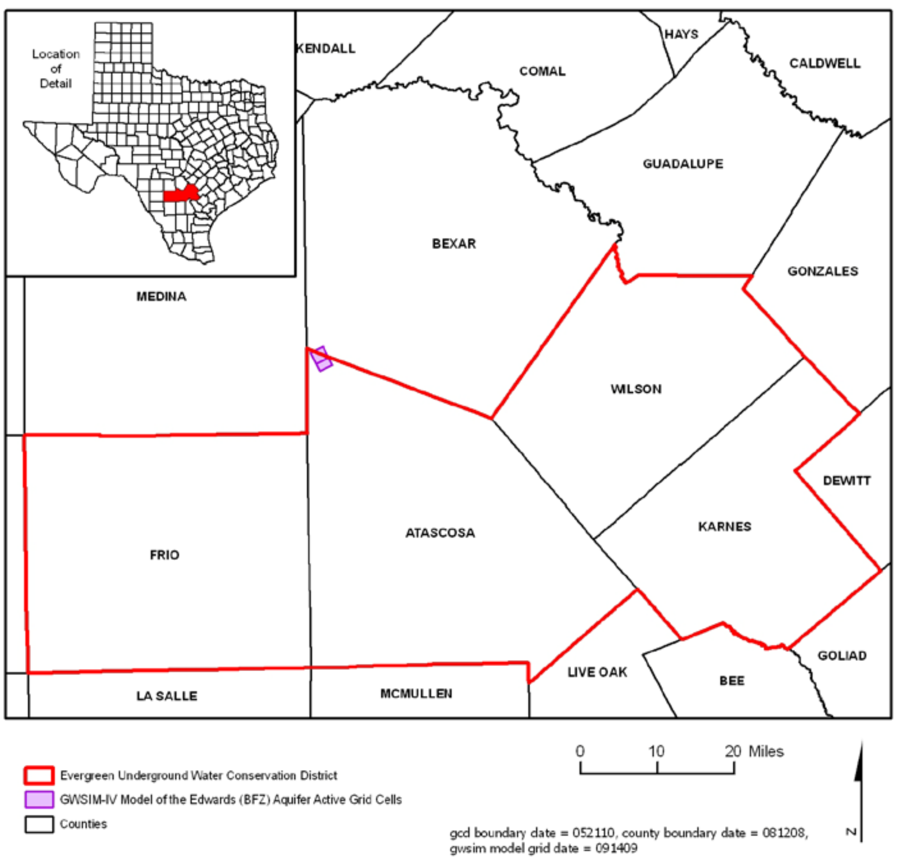

Figure 1: Area of the groundwater availability model for the San Antonio segment of the Edwards (Balcones Fault Zone) Aquifer from which the information in Table 1 was extracted (the aquifer extent within the district boundary).

Table 2: Summarized information for the Sparta Aquifer that is needed for 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. Flows may include fresh and brackish waters.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Sparta Aquifer	9,286
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Sparta Aquifer	4,912
Estimated annual volume of flow into the district within each aquifer in the district	Sparta Aquifer	438
Estimated annual volume of flow out of the district within each aquifer in the district	Sparta Aquifer	2,380
Estimated net annual volume of flow between each aquifer in the district	Sparta Aquifer into the Weches Confining Unit	6,081

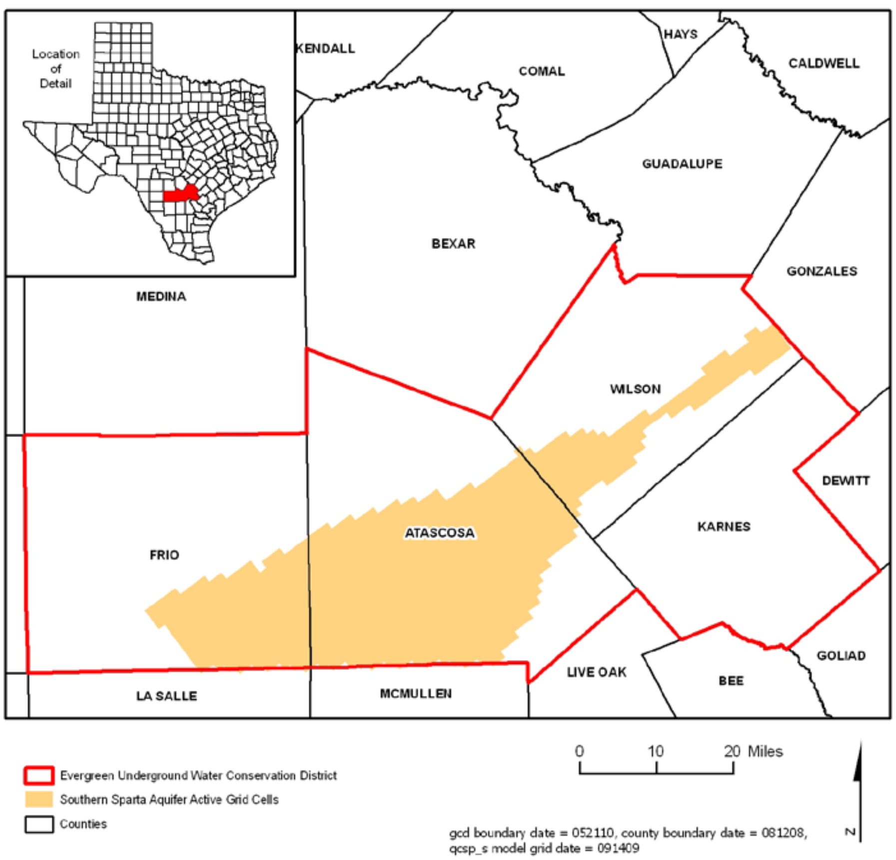

Figure 2: Area of the groundwater availability model for the southern part of the Sparta Aquifer from which the information in Table 2 was extracted (the aquifer extent within the district boundary).

Table 3: Summarized information for the Queen City Aquifer that is needed for 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. Flows may include fresh and brackish waters.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Queen City Aquifer	27,417
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	7,095
Estimated annual volume of flow into the district within each aquifer in the district	Queen City Aquifer	736
Estimated annual volume of flow out of the district within each aquifer in the district	Queen City Aquifer	2,911
Estimated net annual volume of flow between each aquifer in the district	Weches Confining Unit into the Queen City Aquifer	8,714
	Queen City Aquifer into the Reklaw Confining Unit	11,935

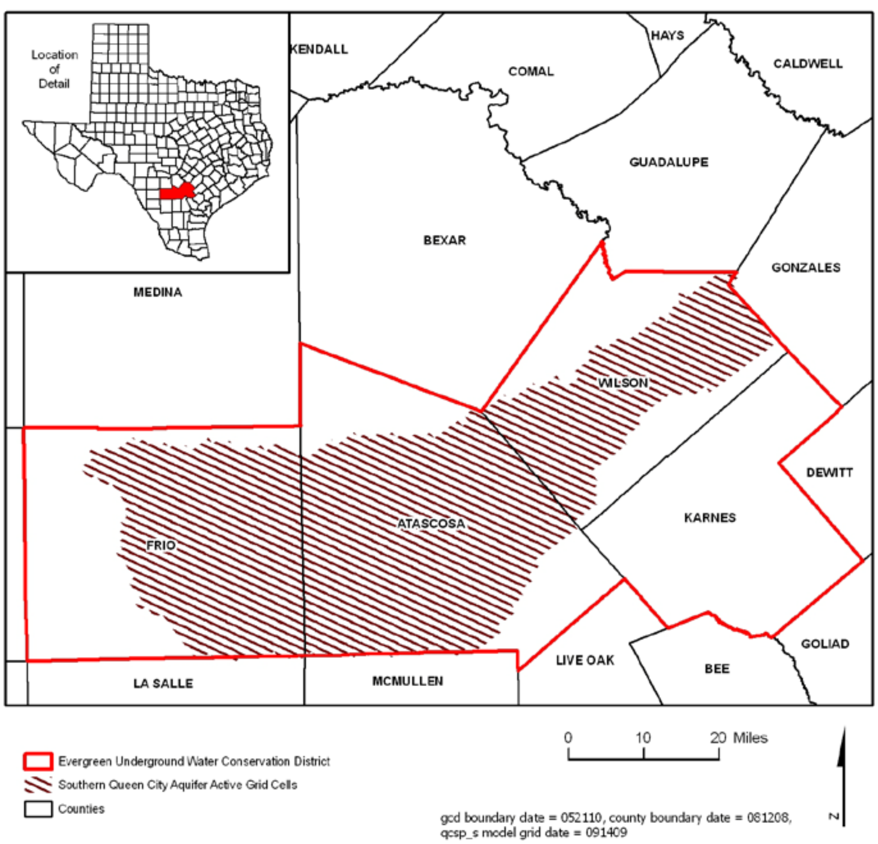

Figure 3: Area of the groundwater availability model for the southern part of the Queen City Aquifer from which the information in Table 3 was extracted (the aquifer extent within the district boundary).

Table 4: Summarized information for the Carrizo-Wilcox Aquifer that is needed for 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. Flows may include fresh and brackish waters.

Management Plan requirement	Aquifer or confining unit	Results
Estimated annual amount of recharge from precipitation to the district	Carrizo-Wilcox Aquifer	21,025
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	3,624
Estimated annual volume of flow into the district within each aquifer in the district	Carrizo-Wilcox Aquifer	72,459
Estimated annual volume of flow out of the district within each aquifer in the district	Carrizo-Wilcox Aquifer	17,935
Estimated net annual volume of flow between each aquifer in the district	Reklaw Confining Unit into the Carrizo-Wilcox Aquifer	18,691

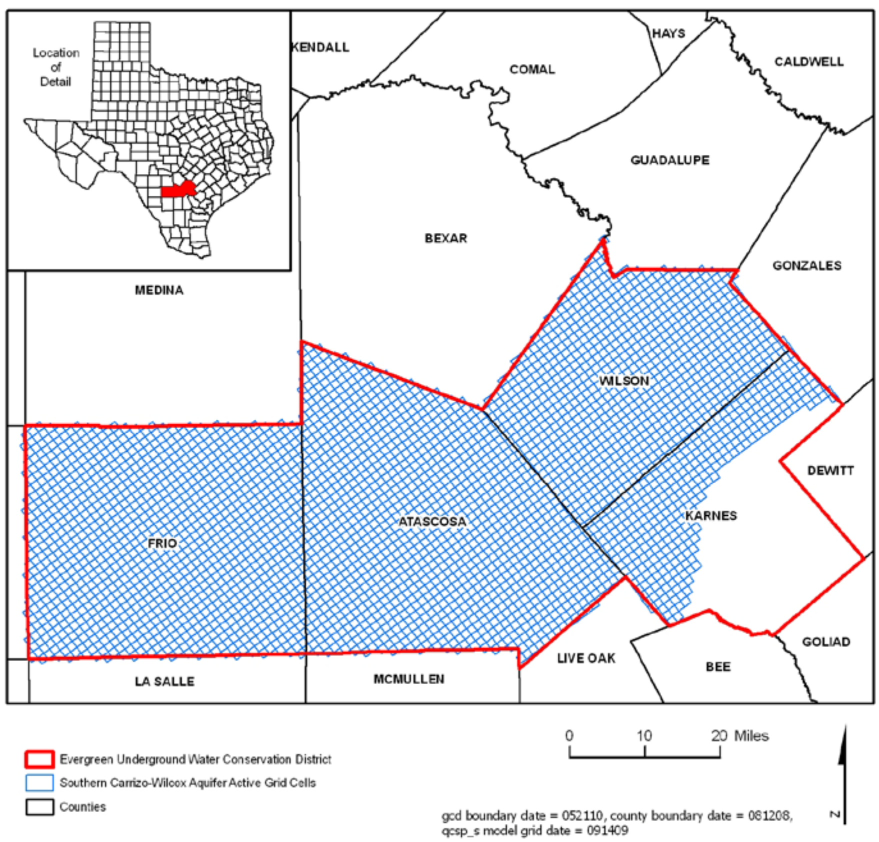

Figure 4: Area of the groundwater availability model for the southern part of the Carrizo-Wilcox Aquifer from which the information in Table 4 was extracted (the aquifer extent within the district boundary).

Table 5: Summarized information for the Yegua-Jackson Aquifer that is needed for 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. Flows may include fresh and brackish waters.

Management Plan requirement	Aquifer	Results
Estimated annual amount of recharge from precipitation to the district	Yegua-Jackson Aquifer	41,827
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	46,061
Estimated annual volume of flow into the district within each aquifer in the district	Yegua-Jackson Aquifer	3,030
Estimated annual volume of flow out of the district within each aquifer in the district	Yegua-Jackson Aquifer	4,942
Estimated net annual volume of flow between each aquifer in the district	Not applicable	Not applicable

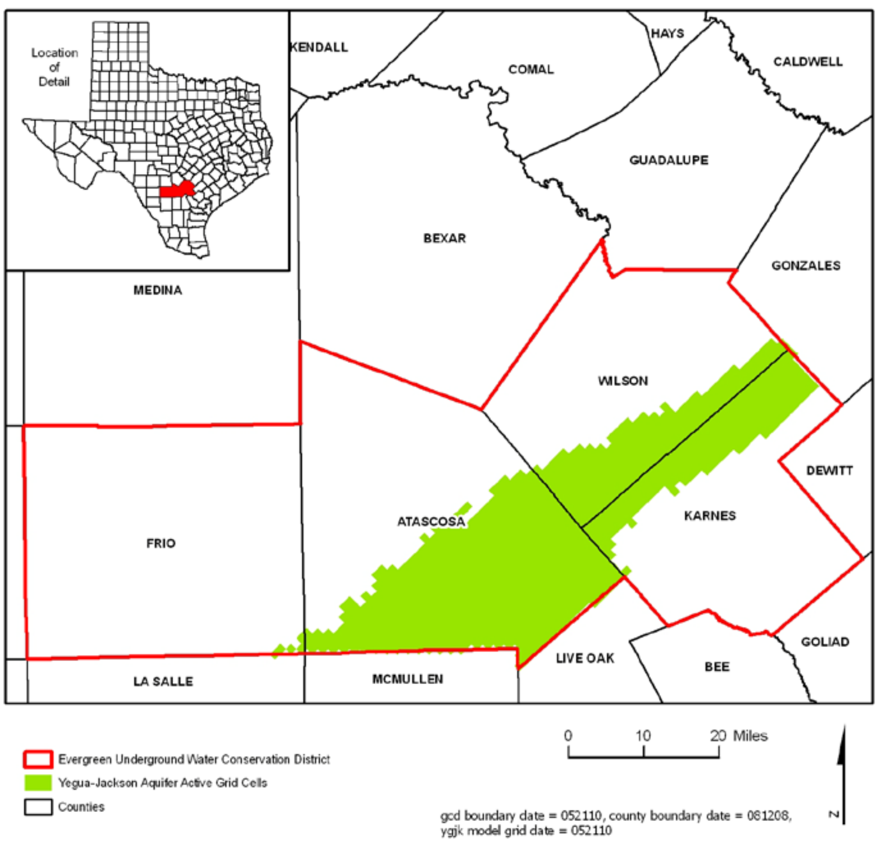

Figure 5: Area of the groundwater availability model for the Yegua-Jackson Aquifer from which the information in Table 5 was extracted (the aquifer extent within the district boundary).

Table 6: Summarized information for the Gulf Coast Aquifer that is needed for 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	Results
Estimated annual amount of recharge from precipitation to the district	Gulf Coast Aquifer	384
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	1,579
Estimated annual volume of flow into the district within each aquifer in the district	Gulf Coast Aquifer	553
Estimated annual volume of flow out of the district within each aquifer in the district	Gulf Coast Aquifer	670
Estimated net annual volume of flow between each aquifer in the district	Not applicable	Not applicable

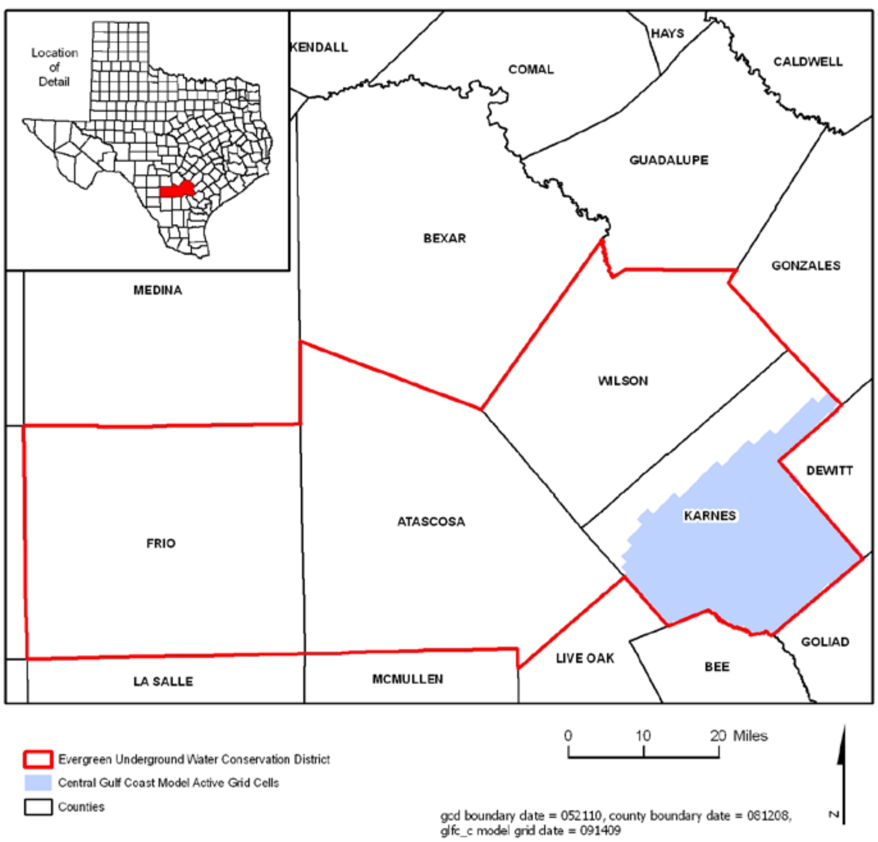

Figure 6: Area of the groundwater availability model for the central part of the Gulf Coast Aquifer from which the information in Table 6 was extracted (the aquifer extent within the district boundary).

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