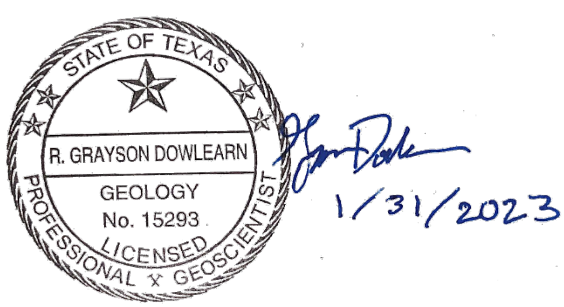
GAM Run 22-016: Sterling County Underground Water Conservation District Management Plan

Tim Cawthon, GIT and Grayson Dowlearn, P.G.
Texas Water Development Board
Groundwater Division
Groundwater Modeling Department
512-463-5076

January 31, 2023



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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.

The TWDB provides data and information to the Sterling County Underground Water 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. 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.

The groundwater management plan for the Sterling County Underground Water Conservation District should be adopted by the district on or before March 29, 2023 and submitted to the executive administrator of the TWDB on or before April 28, 2023. The current management plan for the Sterling County Underground Water Conservation District expires on June 27, 2023.

This analysis used version 1.01 of the groundwater availability model for the High Plains Aquifer System (Deeds and Jigmond, 2015), version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) Aquifer (Anaya and Jones, 2009), and version 1.01 of the groundwater availability model for the Lipan Aquifer (Beach and others, 2004), to estimate the management plan information for the aquifers within the Sterling County Underground Water Conservation District.

This report replaces the results of GAM Run 17-012 (Jones, 2017). Values may differ from the previous report as a result of routine updates to the spatial grid files 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, and 3 summarize the groundwater availability model data required by statute. Figures 1, 3, and 5 show the areas of the models from which the values in Tables 1, 2, and 3 were extracted. Figures 2, 4, and 6 provide generalized diagrams of the groundwater flow components provided in Tables 1, 2, and 3. Full water budgets for each aquifer within the district are provided in Appendix A. These budgets are included to assist the Sterling County Underground Water Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district. If, after review of the figures, the Sterling County 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 mentioned above were used to estimate information for the Sterling County Underground Water Conservation District management plan. Water budgets were extracted for the historical model periods for the Dockum Aquifer (1980 through 2012), Edwards-Trinity (Plateau) Aquifer (1981 through 2000), and Lipan Aquifer (1980 through 1998) using ZONEBUDGET Version 3.01 (Harbaugh, 2009). The average annual water budget values for recharge, surface-water outflow, groundwater inflow to the district, groundwater outflow from the district, and the groundwater flow between aquifers within the district are summarized in this report.

PARAMETERS AND ASSUMPTIONS:

Dockum Aquifer

- We used version 1.01 of the groundwater availability model for the High Plains Aquifer System to analyze the Dockum Aquifer. See Deeds and others (2015) and Deeds and Jigmond (2015) for assumptions and limitations of the model.
- The groundwater availability model for the High Plains Aquifer System contains the following four layers:
    - Layer 1 represents the Ogallala Aquifer,
    - Layer 2 represents the Rita Blanca, Edwards-Trinity (High Plains), and Edwards-Trinity (Plateau) aquifers where present,
    - Layer 3 represents the upper portion of the Dockum Aquifer and equivalent units, and
    - Layer 4 represents the lower portion of the Dockum Aquifer and equivalent units.
- Water budget values for the district were determined only for the Dockum Aquifer (Layers 3 and 4).
- The MODFLOW-NWT River (RIV) package was used to simulate rivers and general head boundaries within the district.
- Water budget terms were averaged for the historical calibration period 1980 to 2012 (stress periods 52 through 84).
- The model was run with MODFLOW-NWT (Niswonger and others, 2011).

Edwards-Trinity (Plateau) Aquifer

- We used version 1.01 of the groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers to analyze the Edwards-Trinity (Plateau) Aquifer. See Anaya and Jones (2009) for assumptions and limitations of the model.

- The groundwater availability model for the Edwards-Trinity (Plateau) and Pecos Valley aquifers contains the following two layers within the Sterling County Underground Water Conservation District:

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

    - Layer 2 represents the undifferentiated Trinity Group hydrostratigraphic units or equivalent units of the Edwards-Trinity (Plateau) Aquifer.

- An individual water budget for the district was determined for the Edwards-Trinity (Plateau) Aquifer (Layers 1 and 2, combined). The Pecos Valley Aquifer does not occur within the Sterling County Underground Water Conservation District and therefore no groundwater budget values are included for it in this report.

- Seeps and springs were simulated with the MODFLOW Drain (DRN) package and streams were simulated with the MODFLOW Streamflow-Routing (SFR) package.

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

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

Lipan Aquifer

- We used version 1.01 of the groundwater availability model for the Lipan Aquifer to analyze the Lipan Aquifer. See Beach and others (2004) for assumptions and limitations of the model.

- The groundwater availability model contains one layer with a constant thickness of 400 feet. The layer represents portions of the Quaternary Leona Formation, underlying Permian units, adjacent Permian units, and the Edwards-Trinity (Plateau) Aquifer.

- Water budget terms were averaged for the period of 1980 through 1998 (stress periods 2 through 20). The last stress period representing the year 1999 was not included because of incorrect pumping values.

- The model does not cover the entire Lipan Aquifer (Figure 5). Consequently, please contact Mr. Stephen Allen with the TWDB at (512) 463-7317 or stephen.allen@twdb.texas.gov for additional information on the aquifer in areas not covered by the groundwater availability model in the Sterling County Underground Water Conservation District.

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

RESULTS:

A groundwater budget summarizes the amount of water entering and leaving the aquifer according to the groundwater availability model. Selected groundwater budget components listed below were extracted from the groundwater availability model results for the Dockum, Edwards-Trinity (Plateau), and Lipan aquifers located within the Sterling County Underground Water Conservation District and averaged over the historical calibration period, as shown in Tables 1, 2, and 3.

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, and 3. Figures 2, 4, and 6 provide generalized diagrams of the groundwater flow components provided in Tables 1, 2, and 3. Full water budgets for each aquifer within the district are provided in Appendix A. These budgets are included to assist the Sterling County Underground Water Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district.

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 DOCKUM AQUIFER THAT IS NEEDED FOR THE STERLING COUNTY 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	Dockum Aquifer	457
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Dockum Aquifer	382
Estimated annual volume of flow into the district within each aquifer in the district	Dockum Aquifer	124
Estimated annual volume of flow out of the district within each aquifer in the district	Dockum Aquifer	634
Estimated net annual volume of flow between each aquifer in the district	To the Dockum Aquifer from the Edwards-Trinity (Plateau) Aquifer	556

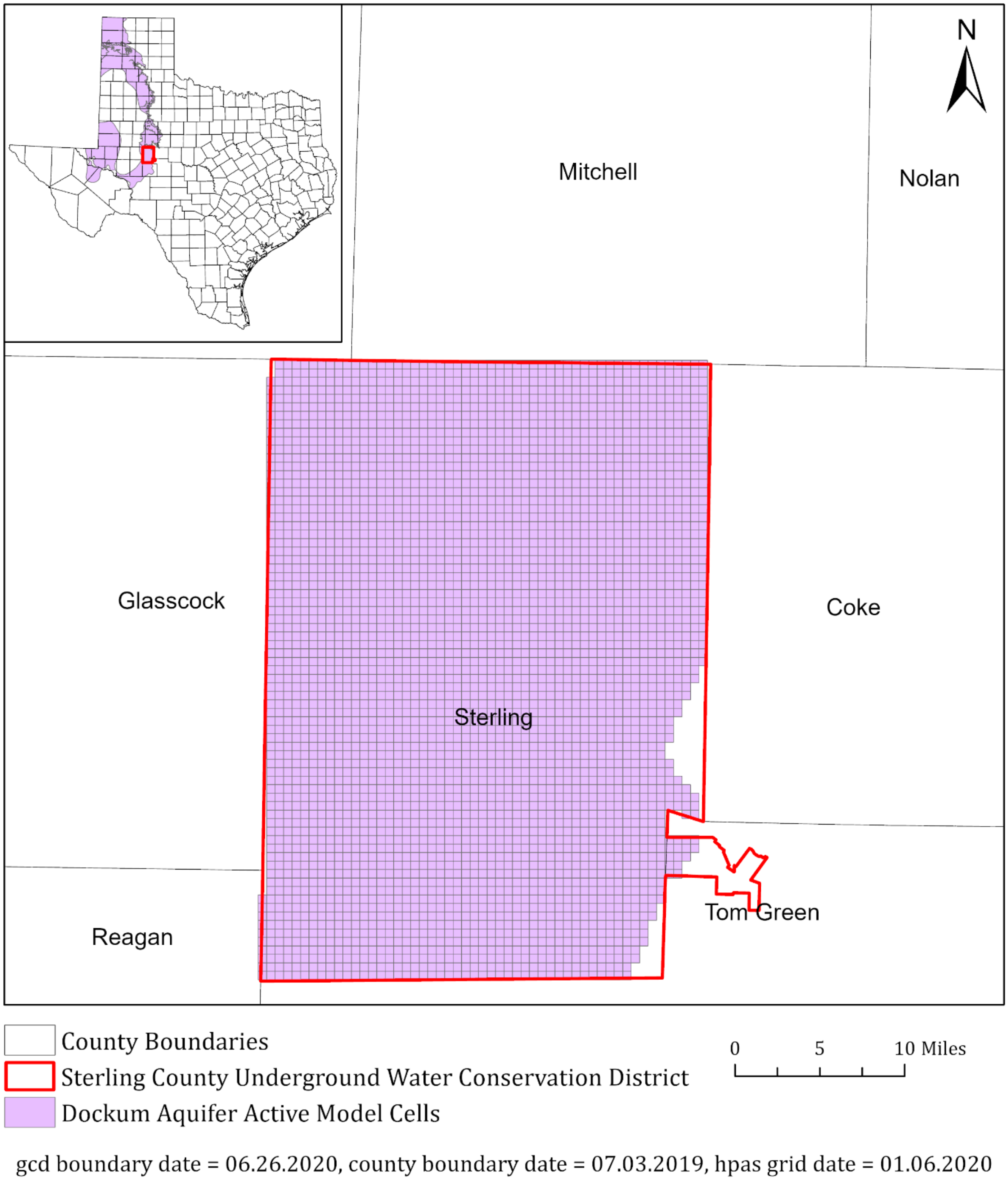
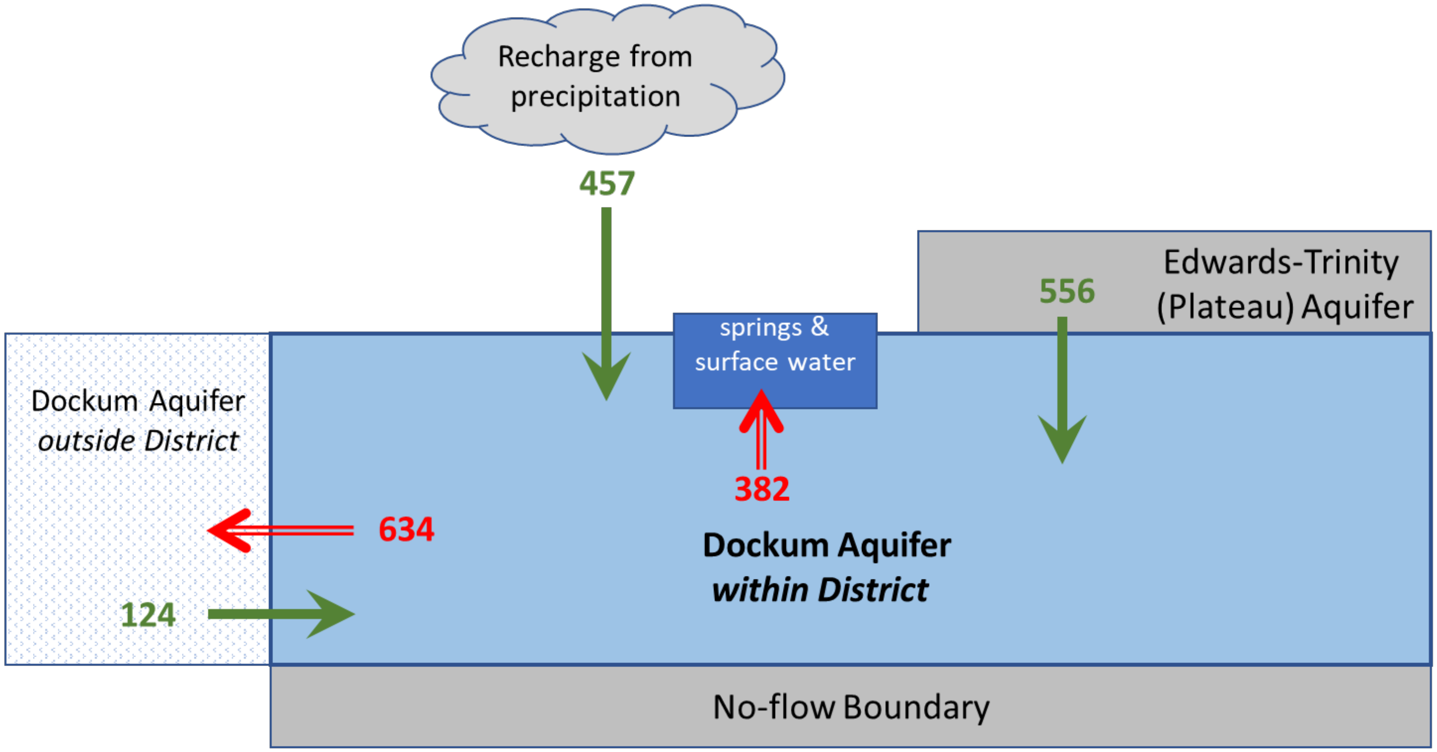


FIGURE 1: AREA OF THE HIGH PLAINS AQUIFER SYSTEM GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 1 WAS EXTRACTED (THE DOCKUM AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



Caveat: This diagram only includes the water budget items provided in Table 1. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 2: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 1, REPRESENTING DIRECTIONS OF FLOW FOR THE DOCKUM AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

TABLE 2: SUMMARIZED INFORMATION FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER THAT IS NEEDED FOR THE STERLING COUNTY 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-Trinity (Plateau) Aquifer	10,202
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Edwards-Trinity (Plateau) Aquifer	6,077
Estimated annual volume of flow into the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	1,709
Estimated annual volume of flow out of the district within each aquifer in the district	Edwards-Trinity (Plateau) Aquifer	4,472
Estimated net annual volume of flow between each aquifer in the district	From the Edwards-Trinity (Plateau) to the Dockum Aquifer	556*
*Flow from the Edwards-Trinity (Plateau) Aquifer to the Dockum Aquifer is provided by the High Plains Aquifer System groundwater availability model.		

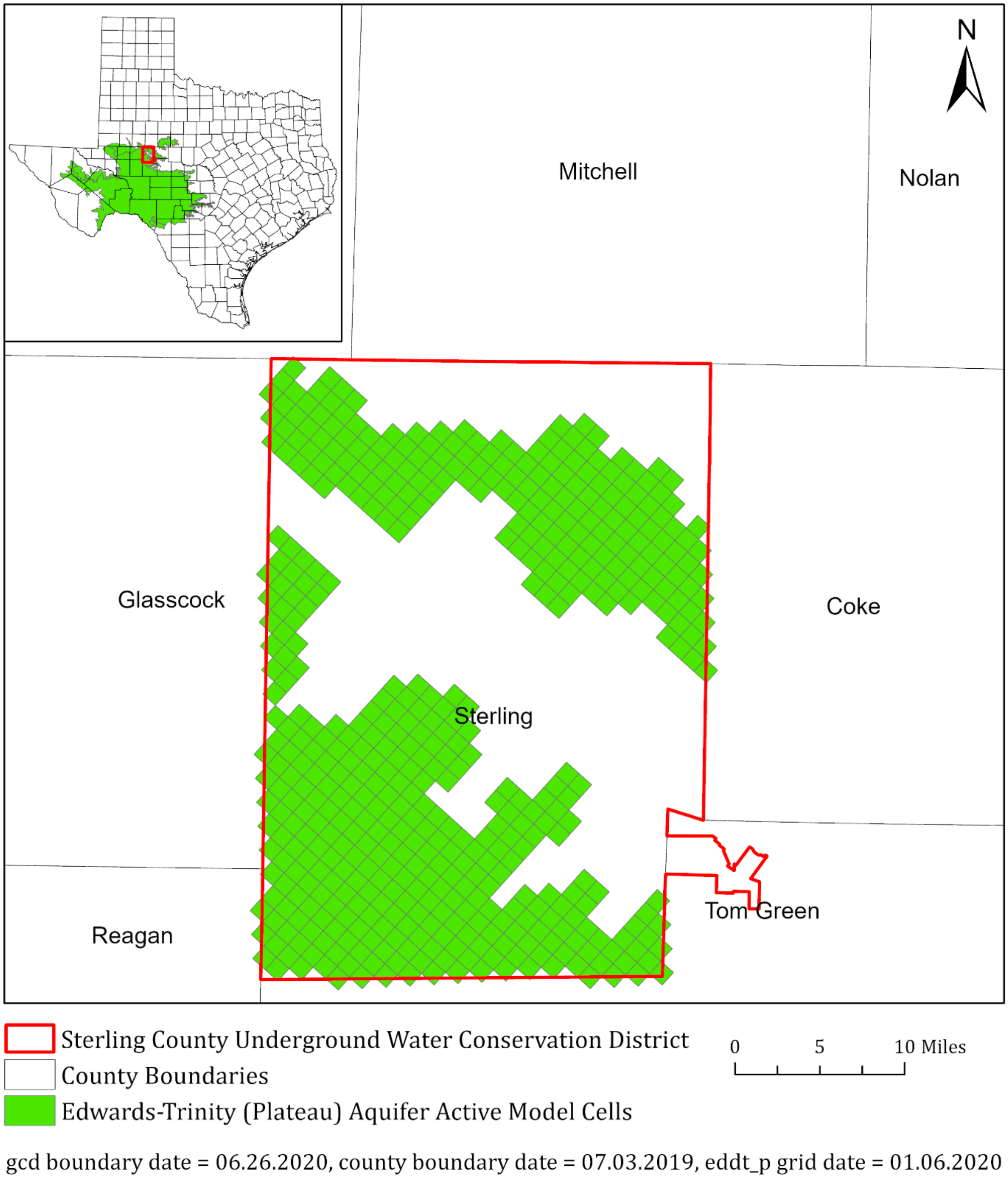
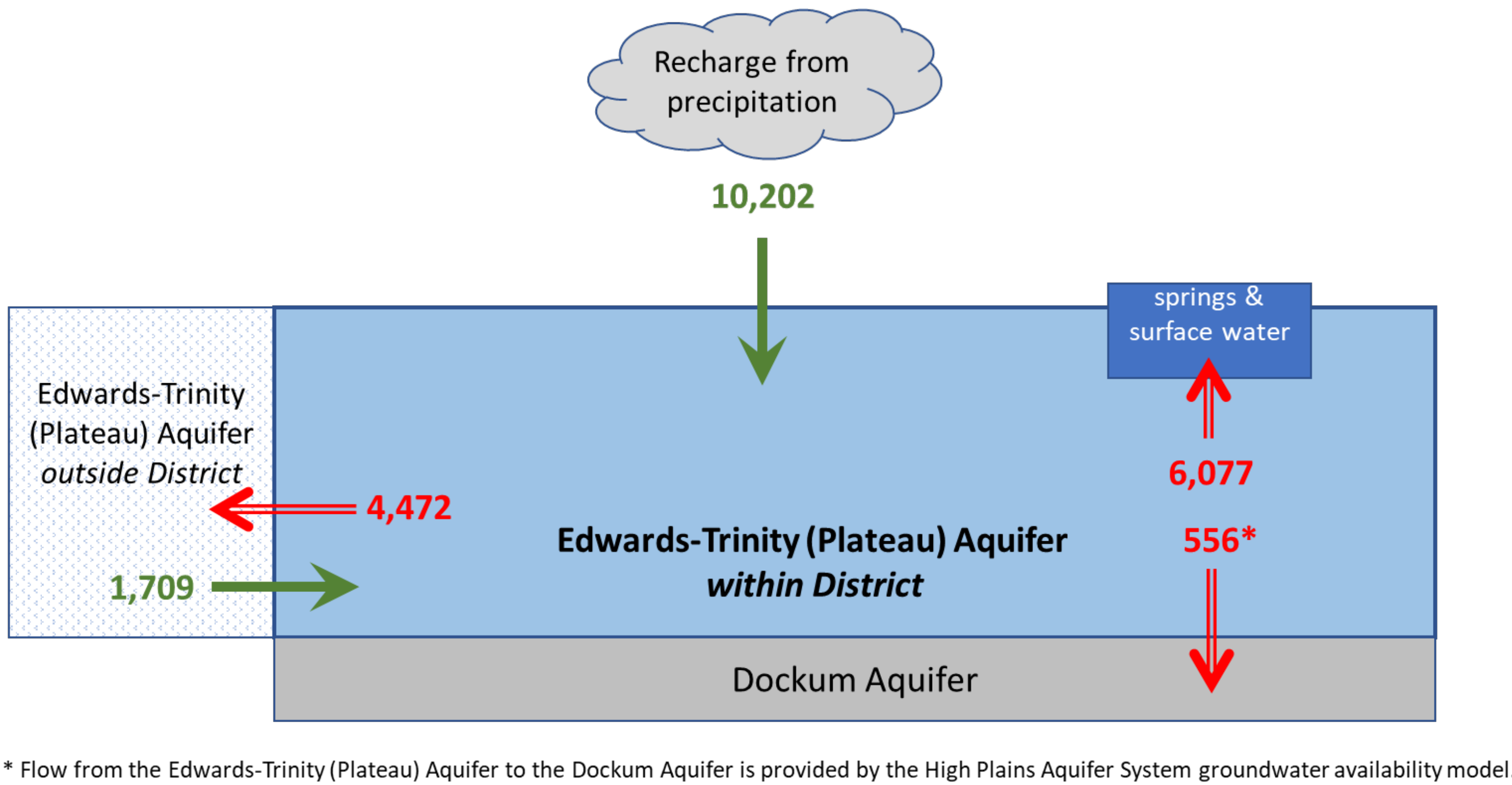


FIGURE 3: AREA OF THE EDWARDS-TRINITY (PLATEAU) AND PECOS VALLEY AQUIFER GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 2 WAS EXTRACTED (THE EDWARDS-TRINITY [PLATEAU] AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



Caveat: This diagram only includes the water budget items provided in Table 2. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 4: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 2, REPRESENTING DIRECTIONS OF FLOW FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT. FLOW VALUES EXPRESSED IN ACRE-FEET PER YEAR.

TABLE 3: SUMMARIZED INFORMATION FOR THE LIPAN AQUIFER THAT IS NEEDED FOR THE STERLING COUNTY 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	Lipan Aquifer	105*
Estimated annual volume of water that discharges from the aquifer to springs and any surface water body including lakes, streams, and rivers	Lipan Aquifer	0*
Estimated annual volume of flow into the district within each aquifer in the district	Lipan Aquifer	277*
Estimated annual volume of flow out of the district within each aquifer in the district	Lipan Aquifer	354*
Estimated net annual volume of flow between each aquifer in the district		Not applicable*
*The model was developed prior to the extension of the Lipan Aquifer along the North Concho River. The model does not cover the entire Lipan Aquifer as shown in Figure 5. Please contact Mr. Stephen Allen with the TWDB at 512-463-7317 or stephen.allen@twdb.texas.gov for additional information on the aquifer in areas not covered by the groundwater availability model in the Sterling County Underground Water Conservation District.		

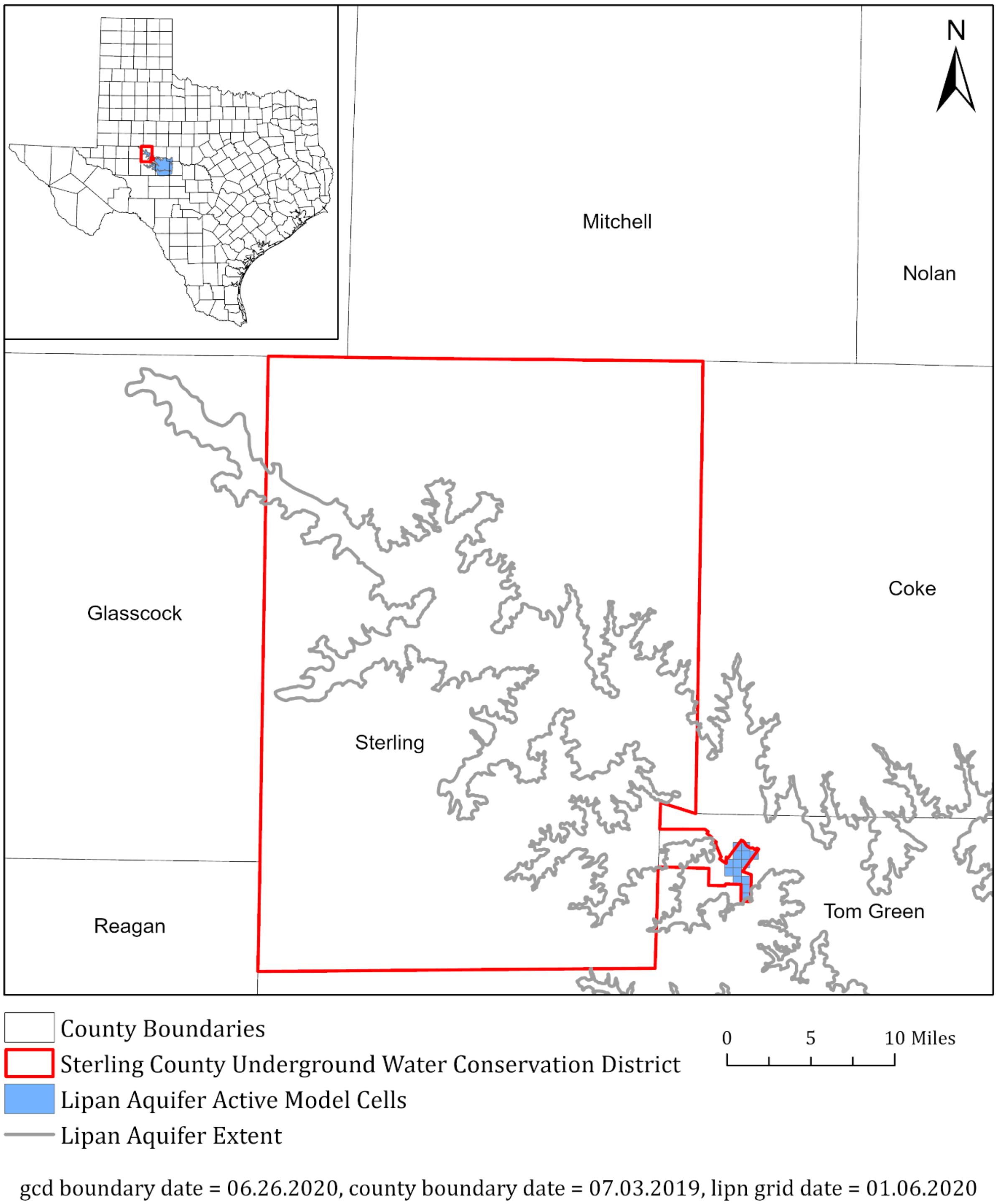
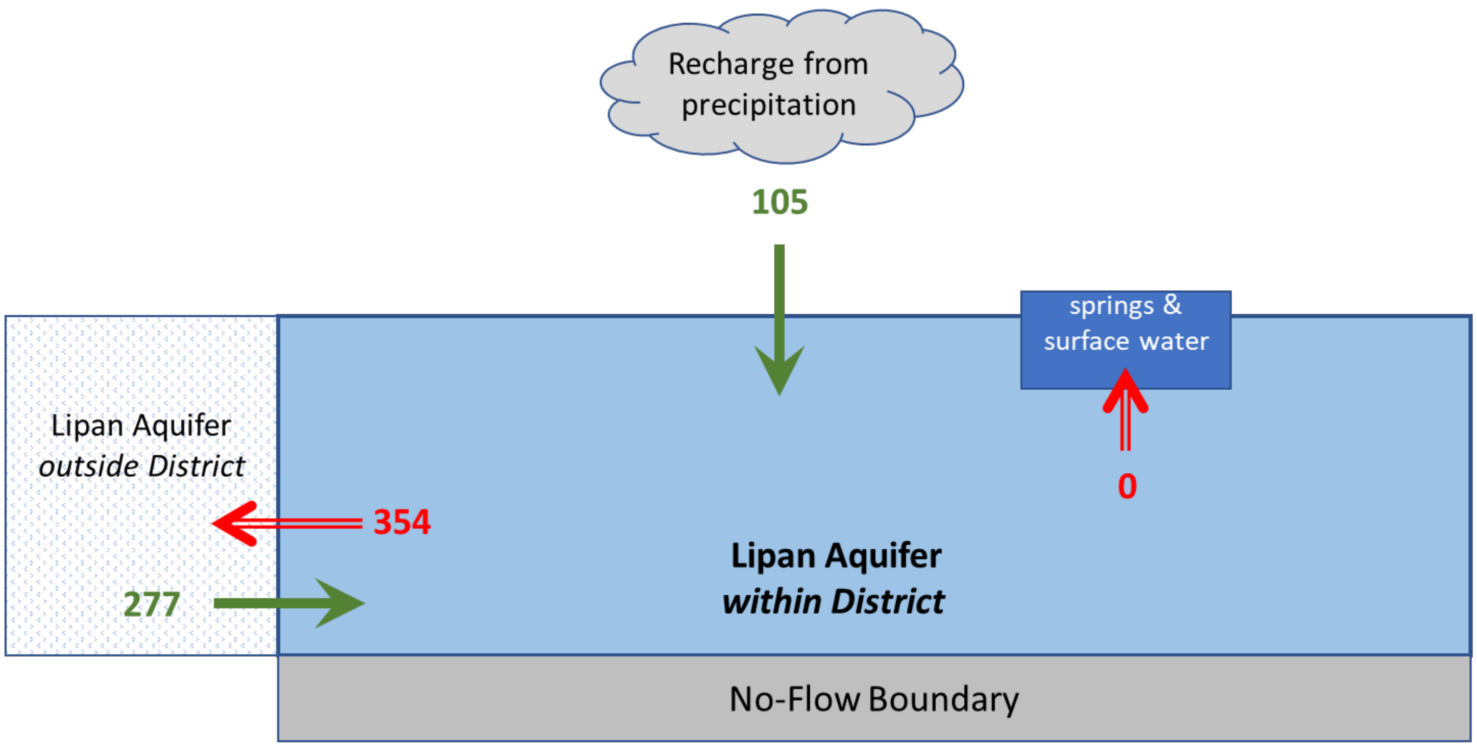


FIGURE 5: AREA OF THE LIPAN AQUIFER GROUNDWATER AVAILABILITY MODEL FROM WHICH THE INFORMATION IN TABLE 3 WAS EXTRACTED (THE LIPAN AQUIFER EXTENT WITHIN THE DISTRICT BOUNDARY).



Caveat: This diagram only includes the water budget items provided in Table 3. A complete water budget would include additional inflows and outflows. Please see Appendix A for a full water budget.

FIGURE 6: GENERALIZED DIAGRAM OF THE SUMMARIZED BUDGET INFORMATION FROM TABLE 3, REPRESENTING DIRECTIONS OF FLOW FOR THE LIPAN AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT. FLOW VALUES 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:

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Texas Water Code, 2011, http://www.statutes.legis.state.tx.us/docs/WA/pdf/WA.36.pdf

Appendix A – Full Groundwater Budget Diagrams

Full water budget diagrams presented in Figures A-1 through A-6 are included to assist the Sterling County Underground Water Conservation District in analyzing the effects of pumping and recharge on the aquifers within the district. These diagrams are intended to provide additional insight for groundwater conservation districts to better understand their aquifers and to provide more detailed information to inform groundwater management.

Figures A-1, A-3, and A-5 show the full water budgets for the years of minimum and maximum pumping within each aquifer in the district during the historical calibration periods described in the Parameters and Assumptions section. Figure A-2 shows the full water budget for the first and last years of the historical calibration period for the High Plains Aquifer System groundwater availability model. Years of minimum and maximum recharge are not included because the model keeps recharge constant for each stress period within the district during the historical calibration period. Figures A-4 and A-6 show the full water budgets for the years of minimum and maximum recharge of the historical calibration period for the Edwards-Trinity (Plateau) Aquifer and Lipan Aquifer groundwater availability models. Table A-1 lists each component and provides an explanation of each component contained in the full water budget diagrams.

TABLE A-1: EXPLANATION OF EACH BUDGET COMPONENT INCLUDED IN THE FULL WATER BUDGETS FOR THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT.

Full water budget component	Explanation
Recharge	Representative of recharge to the aquifer from areally distributed rainfall that reaches the water table of the aquifer.
Pumping	The amount of water pumped out of the aquifer through water wells located within the aquifer.
Natural Discharge	Represents the combination of water leaving the aquifer through ephemeral streams, evapotranspiration, springs, and free flowing wells. - Ephemeral streams are streams that do not flow year-round - Springs are locations where groundwater is directly connected to the ground surface and water leaves the aquifer

TABLE A-1: EXPLANATION OF EACH BUDGET COMPONENT INCLUDED IN THE FULL WATER BUDGETS FOR THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT.

Full water budget component	Explanation
	- Free flowing wells are wells which connect to the aquifer where the water level is above ground surface and water will flow without the need of pumping
River Leakage	Only representative of the net exchange of water between the rivers/reservoirs and the aquifer in the model
Evapotranspiration	Only represents the amount of water removed from the water table by vegetation or direct evaporation from the water table. This does not include total evapotranspiration for all plants or water features covering the modeled area
Groundwater Exchanges	The sum of the net exchange of groundwater between the aquifer of interest within the district and all geologic units within and outside of the district boundaries
Storage	Represents the difference from the previous year in the amount of water contained within the aquifer and indicates a relative water level rise (negative Storage value) or water level decline (positive Storage value). Change in storage (dS) is the difference between inflows and outflows (Equation 1). To solve the zero-sum budget over the volume of the aquifer within the district, the term dS must be subtracted from both sides of Equation 1 (Equation 2). If total inflows are greater than outflow, Storage will be negative. If total outflows are greater than total inflows, Storage will be positive. $dS = Inflows - Outflows$ **Equation 1** $0 = Inflows - Outflows - dS$ **Equation 2**

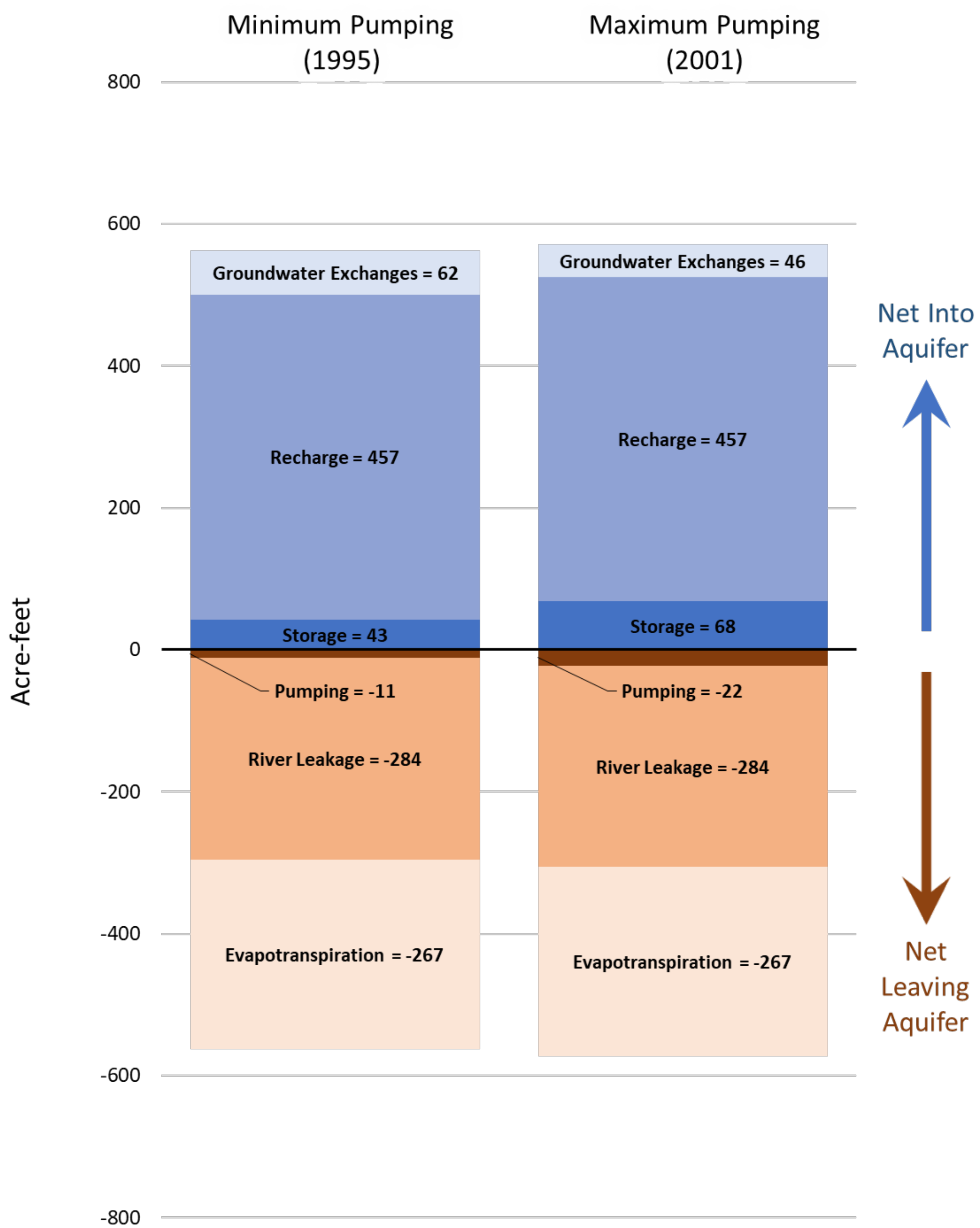

FIGURE A-1: FULL WATER BUDGETS FOR THE DOCKUM AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1980 AND 2012.

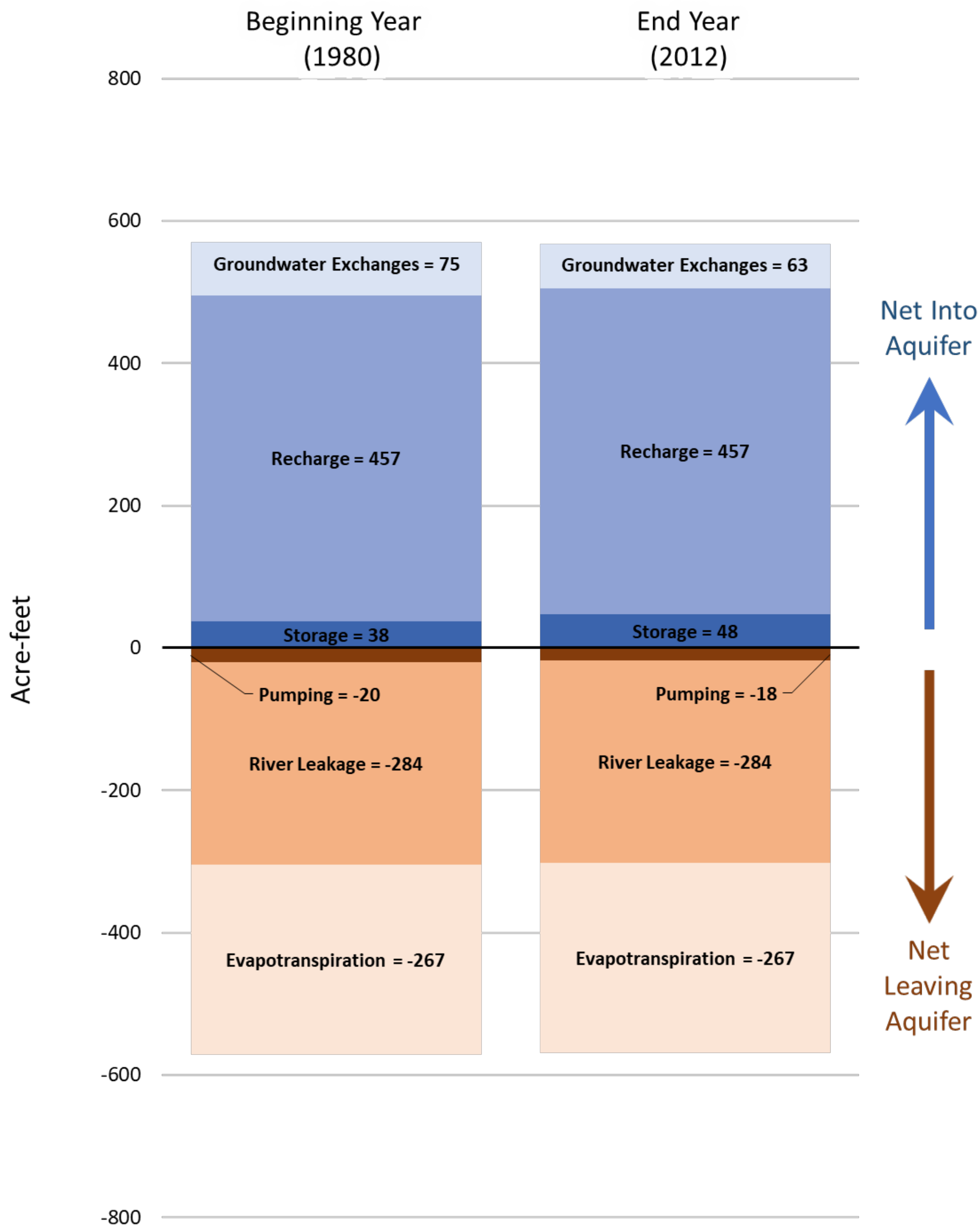

FIGURE A-2: FULL WATER BUDGETS FOR THE DOCKUM AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE FIRST AND LAST YEAR OF THE HISTORICAL TRANSIENT PERIOD BETWEEN 1980 AND 2012.

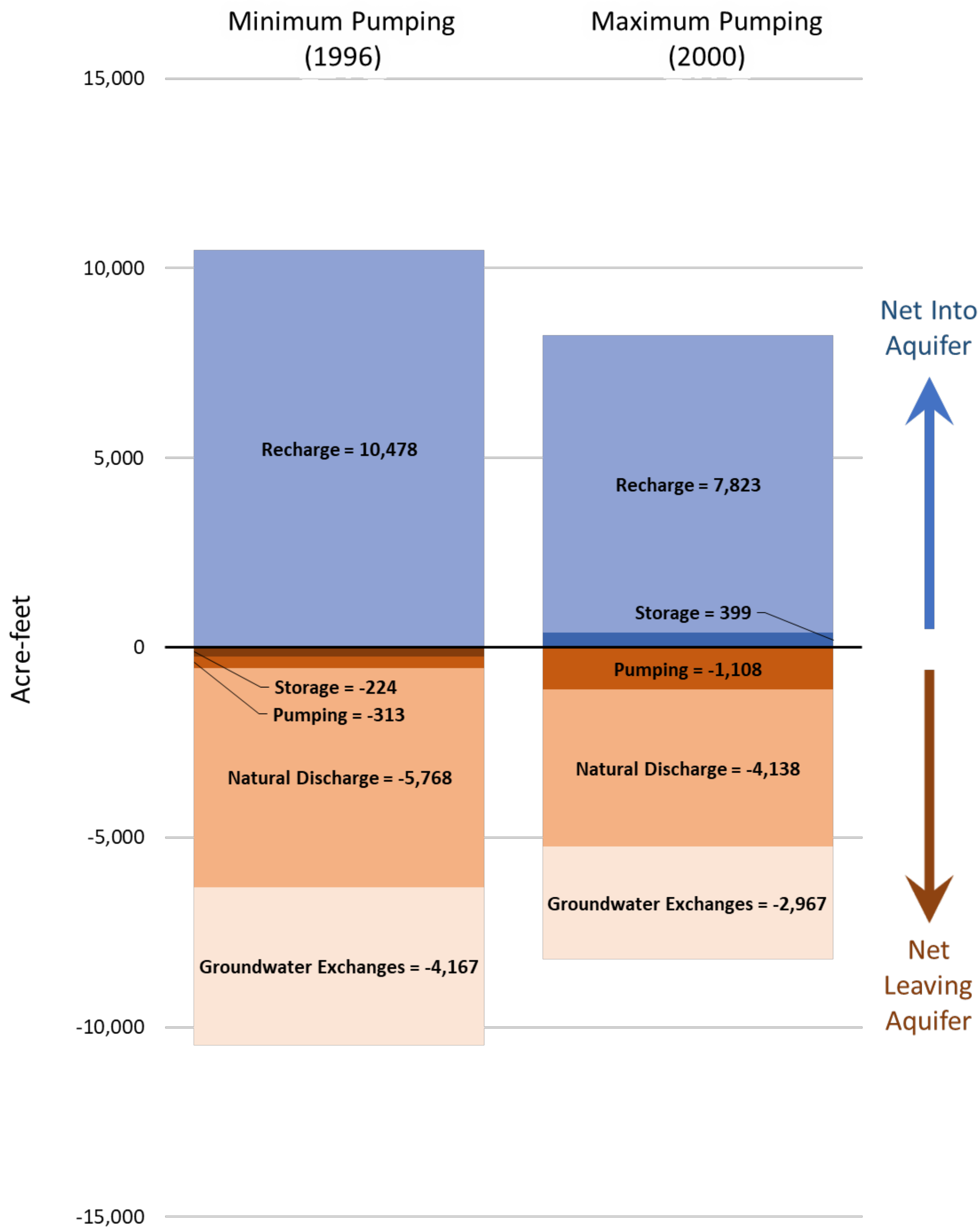

FIGURE A-3: FULL WATER BUDGETS FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1981 AND 2000.

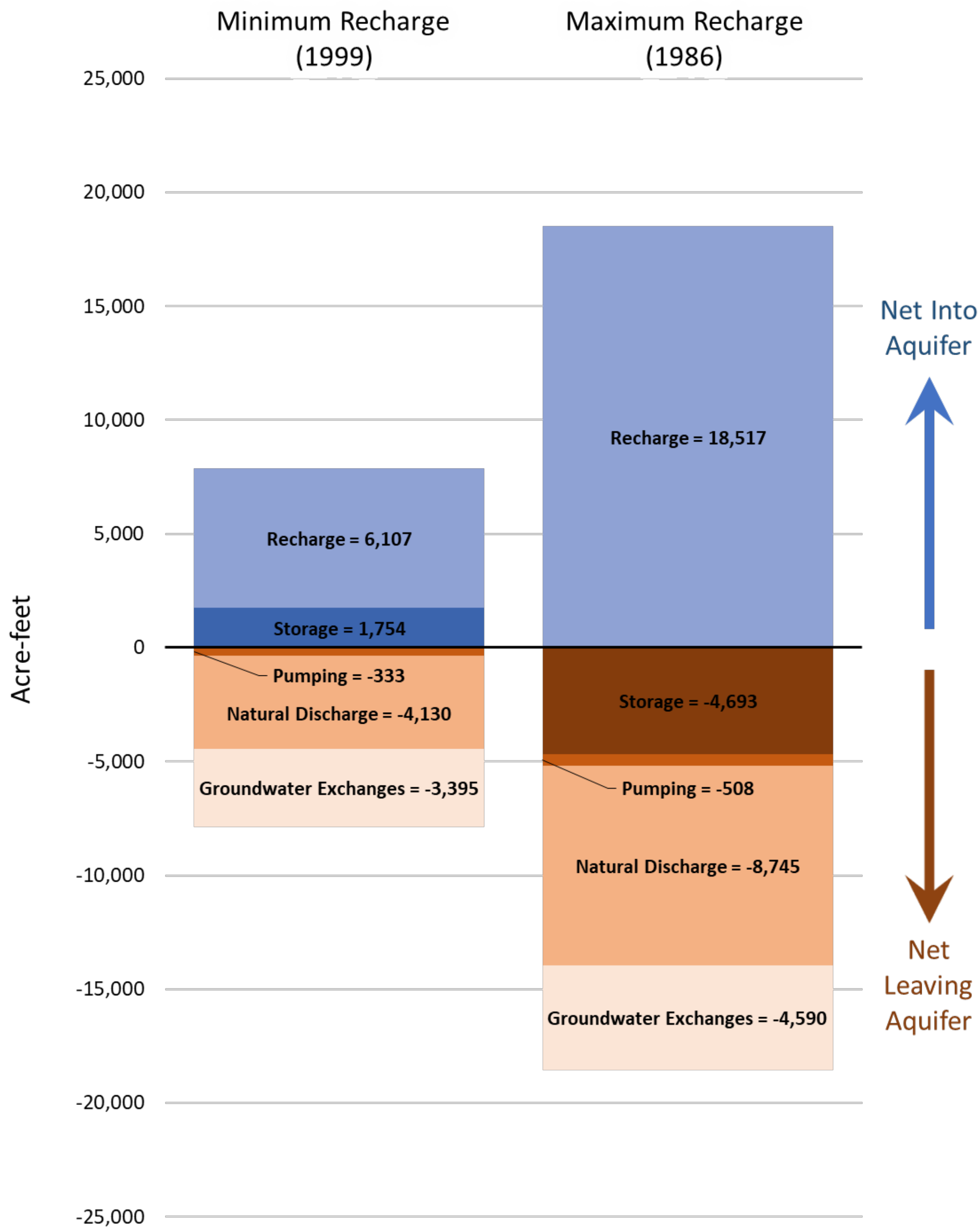

FIGURE A-4: FULL WATER BUDGETS FOR THE EDWARDS-TRINITY (PLATEAU) AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM RECHARGE AND THE YEAR OF MAXIMUM RECHARGE BETWEEN 1981 AND 2000.

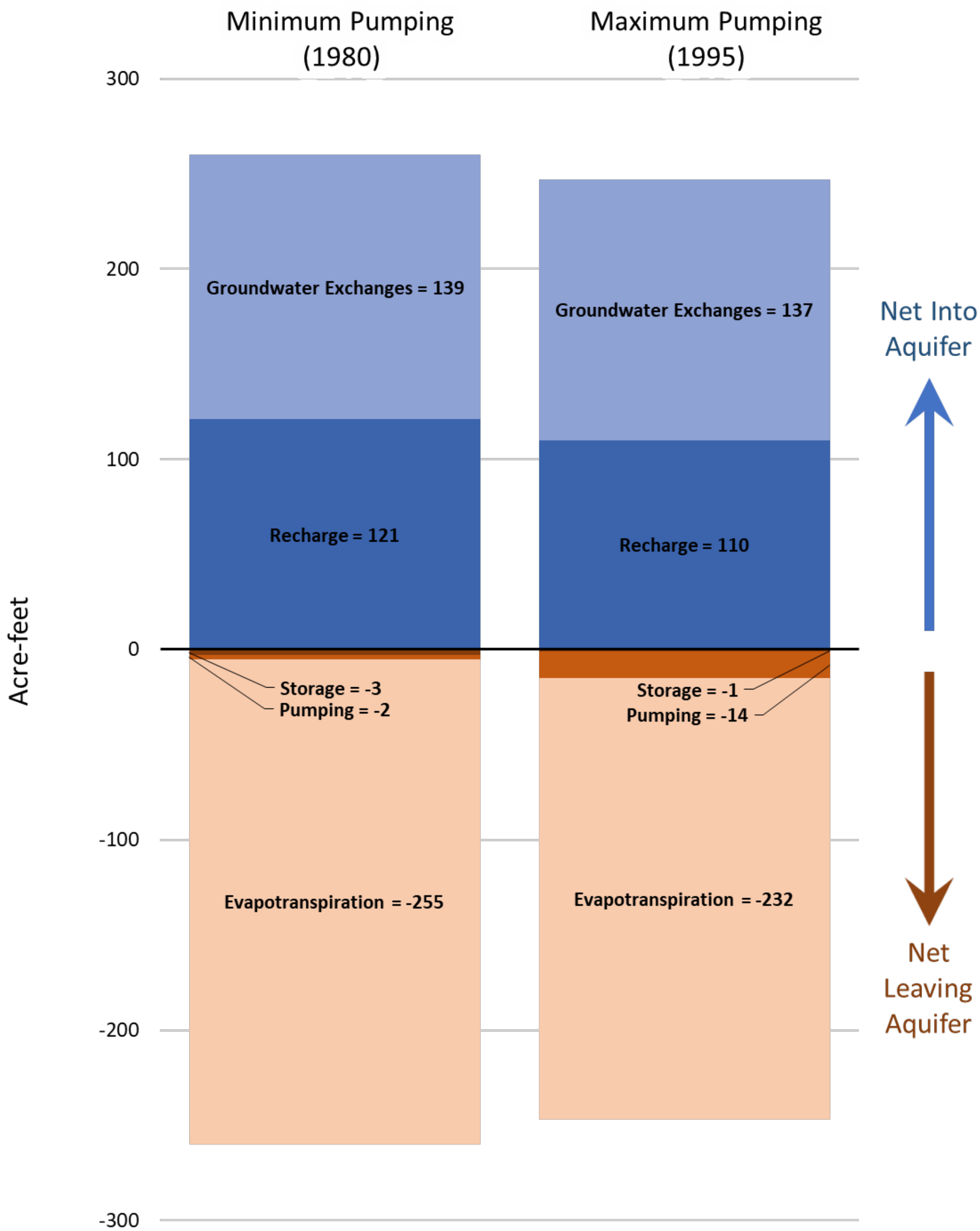

FIGURE A-5: FULL WATER BUDGETS FOR THE LIPAN AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM PUMPING AND THE YEAR OF MAXIMUM PUMPING BETWEEN 1980 AND 1998.

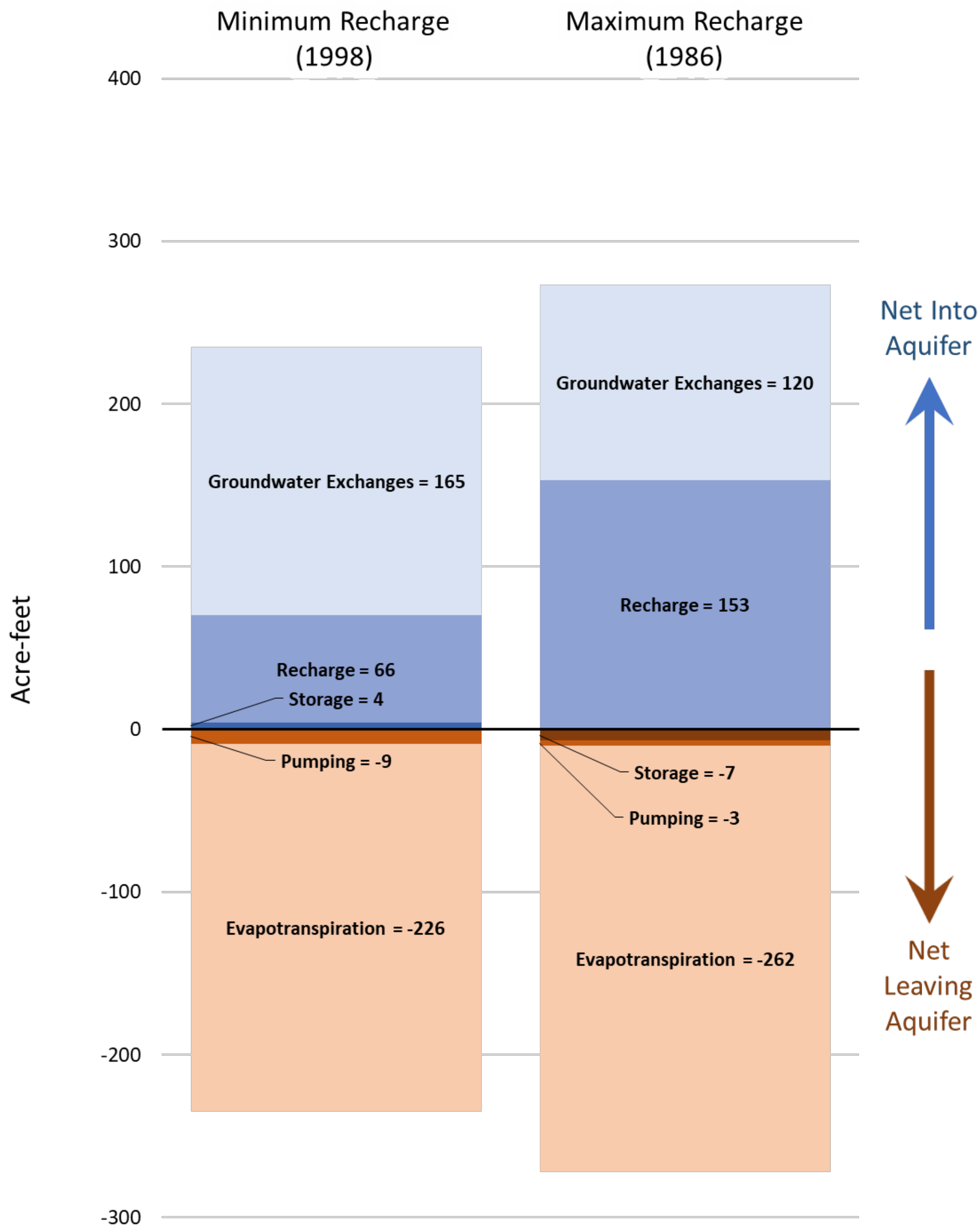

FIGURE A-6: FULL WATER BUDGETS FOR THE LIPAN AQUIFER WITHIN THE STERLING COUNTY UNDERGROUND WATER CONSERVATION DISTRICT SHOWING THE YEAR OF MINIMUM RECHARGE AND THE YEAR OF MAXIMUM RECHARGE BETWEEN 1980 AND 1998.