Final Report

Aqua WSC Permit Applications Review: Pumping Simulations

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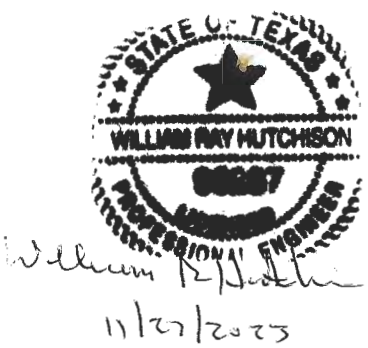

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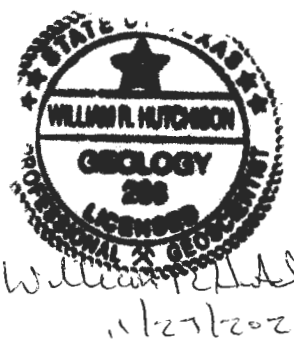

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1.0 Introduction

1.1 Background

In October 2022, Aqua Water Supply Corporation (Aqua WSC) submitted four operating permit applications as follows:

- Foster Well (October 26, 2022)
- Tiner Well (October 21, 2022)
- Waterson Well #1 (October 25, 2022)
- Waterson Well #2 (October 25, 2022)

On February 13, 2023, Aqua WSC submitted results of a 36-hour pumping test as a Response to Request for Additional Information from LPGCD.

This report documents the results of groundwater model simulations that were completed as part of the LPGCD review of the permit application. Each well was included in a simulation with proposed pumping added to the DFC run of the GAM (Run S-19). The wells were treated individually, and the report is organized around the simulations and analyses associated with each well. A fifth simulation was also completed that included proposed pumping of all four wells added to the DFC run of the GAM.

All files associated with this report have been uploaded to a Google Drive folder that can be accessed with this link:

https://drive.google.com/drive/folders/1_5RehgpYFbTAsudmvBd2MLjGEHHB3E3Z?usp=sharing

1.2 Summary of Proposed Wells

Well data from the applications are summarized in Table 1. The permit applications included latitude and longitude coordinates. These were converted to GAM coordinates using Surfer, a commercial gridding program.

Table 1. Summary of Aqua WSC Well Information

Well	Foster	Tiner	Waterson 1	Waterson 2
Latitude	29.8137	29.88838	30.008022	29.994137
Longitude	-97.3179	-97.26742	-97.357345	-97.367376
X-Coordinate (GAM - ft)	5770258.418	5785562.752	5756084.293	5753036.354
Y-Coorindate (GAM - ft)	19171826.73	19199418.11	19242307.61	19237174.26
Depth (ft)	1,170	1,250	1,000	1,000
Screen Interval (ft)	800 to 1,094	777.5 to 1.010	690 to 1,000	745 to 1,000
Well Capacity (gpm)	500	3,000	2,000	2,000
Volume (AF/yr)	807	4,839	3,226	3,226

The applications listed the Carrizo Aquifer as the production formation. However, the comparison of the Waterson wells screen interval, GAM information, and independent geologic information suggests that the Waterson wells, as proposed, will be completed in the Wilcox Aquifer.

1.3 Summary of Results and Conclusions

Key findings and conclusions of this analysis are:

Foster Well

- Proposed pumping volume = 807 AF/yr
- Drawdown from 2011 to 2070 at Foster Well location = 18 ft
- Significant sources of the proposed pumping:
    - Captured outflow that would have gone to Caldwell and Fayette counties.
    - Vertical inflow from the overlying Reklaw formation
    - Storage reduction in the Carrizo Aquifer.

Tiner Well

- Proposed pumping volume = 4,839 AF/yr
- Drawdown from 2011 to 2070 at Tiner Well location = 102 ft
- Significant sources of the proposed pumping:
    - Induced inflow from the shallow flow system.
    - Induced vertical inflow from the overlying Reklaw formation.
    - Storage reduction in the Carrizo Aquifer.
    - Captured outflow components from Fayette County
    - Captured vertical outflow to the underlying Calvert Bluff Aquifer
    - Storage decline in the Carrizo Aquifer.

Waterson 1 Well

- Proposed pumping volume = 3,226 AF/yr
- Drawdown from 2011 to 2070 at Waterson 1 well location = 119 ft
- Significant sources of the proposed pumping:
    - Over half of the proposed pumping would be sourced as induced inflow from the shallow flow system.
    - Induced inflow from the overlying Carrizo Aquifer.
    - Storage decline supplies less than ten percent of the increased pumping.

Waterson 2 Well

- Proposed pumping volume = 3,226 AF/yr
- Drawdown from 2011 to 2070 at Waterson 2 well location = 163 ft
- Significant sources of the proposed pumping:
    - Over half of the proposed pumping would be sourced as induced inflow from the shallow flow system.
    - Induced inflow from the overlying Carrizo Aquifer.
    - Storage decline supplies less than ten percent of the increased pumping.

All Wells Pumping

- Proposed pumping volume:
  - 5,646 AF/yr from Carrizo Aquifer (Layer 7)
  - 6,452 AF/yr from Wilcox Aquifer (Layer 9)
- Drawdown from 2011 to 2070:
  - Foster: 40 ft
  - Tiner: 109 ft
  - Waterson 1: 166 ft
  - Waterson 2: 211 ft
- Significant sources of the proposed pumping (over 10 percent):
  - Over half of the proposed pumping would be sourced as induced inflow from the shallow flow system and alluvium.
  - Induced inflow from overlying Reklaw formation
  - Induced inflow from Caldwell County
  - Captured outflow from Fayette County
  - Storage decline in Carrizo-Wilcox supplies about 16 percent of the increased pumping.

2.0 Summary of Well Completions and GAM Data

2.1 Proposed Aqua WSC Production Well Completions

The Fortran program *getcellnum.exe* was written to locate the proposed production wells and the monitoring wells in the GAM grid. The reported screen intervals were used to assign the aquifer completion. Table 2 summarizes the well completion data, and Figure 1 presents a map with well locations and the monitoring wells are color coded to designate the completion interval.

Table 2. Summary of Aquifer Completion Results for Proposed Aqua Wells

Well	Foster	Tiner	Waterson 1	Waterson 2
Depth (ft)	1,170	1,250	1,000	1,000
Screen Interval (ft)	800 to 1,094	777.5 to 1,010	690 to 1,000	745 to 1,000
GAM Node	105111	105124	160184	160180
GAM Layer	7	7	9	9
Surface Elevation (ft MSL)	509	496	435	471
Layer Top Elevation (ft MSL)	-168	-135	-316	-299
Layer Bottom Elevation (ft MSL)	-629	-582	-538	-490
Depth to Layer Top (ft)	677	631	751	770
Depth to Layer Bottom (ft)	1138	1078	973	961

South of the Colorado River, the Wilcox is commonly treated as undifferentiated (i.e. the Calvert Bluff, Simsboro, and Hooper designations are not used). The GAM still defines the subunits of the Wilcox Aquifer as individual layers. For purposes of these simulations, pumping in the Waterson 1 and 2 wells was specified in layer 9, but the analysis of the water budget results treated the Wilcox Aquifer as a single unit.

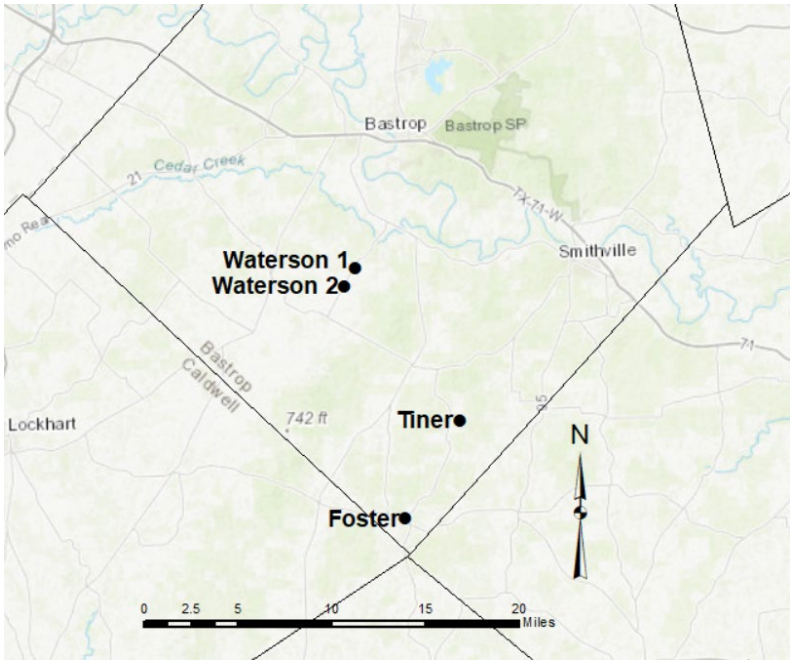

Figure 1. Location Map of Proposed Production Wells

2.3 GAM Parameters at Proposed Aqua WSC Well Locations

Data from the GAM at the locations of the four Aqua WSC wells are presented in Table 3.

For comparison to the transmissivity at the Foster and Tiner well locations (26,276 gpd/ft and 45,038 gpd/ft, respectively), the average transmissivity of all Carrizo Aquifer cells in LPGCD is 22,112 gpd/ft. No pumping test results for the Carrizo Aquifer were submitted with the permit application.

For comparison to the transmissivity at the Waterson 1 and 2 well locations (12,969 gpd/ft and 9,072 gpd/ft, respectively), the average transmissivity for layer 9 is 26,770 gpd/ft. The single pumping test provided in the Aqua WSC application is from "Jacob's Well" completed in the Simsboro Aquifer. Calculated transmissivity ranged between 14,000 and 22,000 gpd/ft.

Table 3. GAM Parameters at Aqua WSC Well Locations

GAM Data or Calculation from GAM Parameters		Aqua WSC Well			
		Foster	Tiner	Waterson 1	Waterson 2
GAM Cell Number		105111	105124	160184	160180
GAM Aquifer Code		7	7	9	9
Official Aquifer Cell (1=yes)		1	1	1	1
GAM Layer		7	7	9	9
Outcrop (0=no)		0	0	0	0
Cell Area (acres)		640	40	160	160
Top (ft)		-168	-135	-316	-299
Bottom (ft)		-629	-582	-538	-490
Thickness (ft)		461	447	222	191
K (ft/day)		7.62	13.47	7.81	6.35
T (gpd/ft)		26,276	45,038	12,969	9,072
Storativity (dimensionless)		1.78E-04	1.77E-04	8.79E-05	7.49E-05
Specific Storage (dimensionless)		1.50E-01	1.50E-01	1.50E-01	1.50E-01
GWE 2010 (ft)		381.83	376.05	360.43	370.01
GWE 2070 (ft)		236.87	283.46	328.17	340.15
DFC Drawdown (ft)		144.96	92.59	32.26	29.86
Artesian Head 2010 (ft)		549.83	511.05	676.43	669.01
Pumping Test (36 hours) Drawdown (ft)	Q=100 gpm	8.46	5.07	17.14	24.25
	Q=300 gpm	25.38	15.22	51.42	72.76
	Q=500gpm	42.30	25.37	85.71	121.27
	Q=700gpm	59.22	35.52	119.99	169.78
	Q=900gpm	76.14	45.67	154.27	218.29

2.4 Nearby Registered Wells Locations and Completions

In an email on November 8, 2023, James Totten provided a list of 16 registered wells near the four proposed wells to be used as monitoring points for the simulations. The Fortran program *getcellnum.exe* was written to locate the 16 "nearby" wells in the GAM grid. The reported well depths were used to assign the aquifer completion. Table 4 summarizes the locations of the wells, and Figure 2 presents the locations of the wells.

Table 4. Summary of Nearby Wells Locations and Completions

Registered Well Number	Nearby Aqua Well	Surface Elevation (ft MSL)	Well Depth (ft)	Latitude	Longitude	GAMx	GAMy	Model Cell	Model Layer
LP-002643	Watterson	399	460	30.020833	-97.35833	5755660.8	19246967	128760	8
LP-003059	Watterson	747	620	29.999722	-97.36611	5753387.5	19239218	129226	8
LP-002472	Watterson	487	485	30.002797	-97.35797	5755933.9	19240400	129229	8
LP-003200	Watterson	589	620	29.983889	-97.37722	5750014.5	19233367	129225	8
LP-001231	Watterson	465	440	30.021944	-97.39611	5743720.8	19247089	158631	9
LP-002074	Watterson	393	373	29.990277	-97.33333	5763824.2	19236026	130229	8
LP-003236	Foster	542	440	29.818889	-97.33194	5765768.1	19173609	80019	6
LP-002326	Foster	347	815	29.809167	-97.31944	5769809.8	19170164	105110	7
LP-002325	Foster	428	340	29.805556	-97.30194	5775380.6	19168983	58211	5
LP-002323	Foster	490	875	29.819444	-97.29917	5776136.4	19174063	105643	7
LP-002315	Foster	503	503	29.825555	-97.33194	5765709.6	19176037	80020	6
LP-002199	Tiner	670	340	29.883889	-97.26556	5786192.6	19197797	57751	5
LP-002194	Tiner	370	605	29.897777	-97.26083	5787561.1	19202892	80553	6
LP-002198	Tiner	515	400	29.87361	-97.25528	5789535.9	19194133	58219	5
LP-002197	Tiner	575	180	29.906111	-97.2825	5780635.6	19205759	57265	5
LP-002196	Tiner	574	697	29.904722	-97.27472	5783107	19205314	104572	7

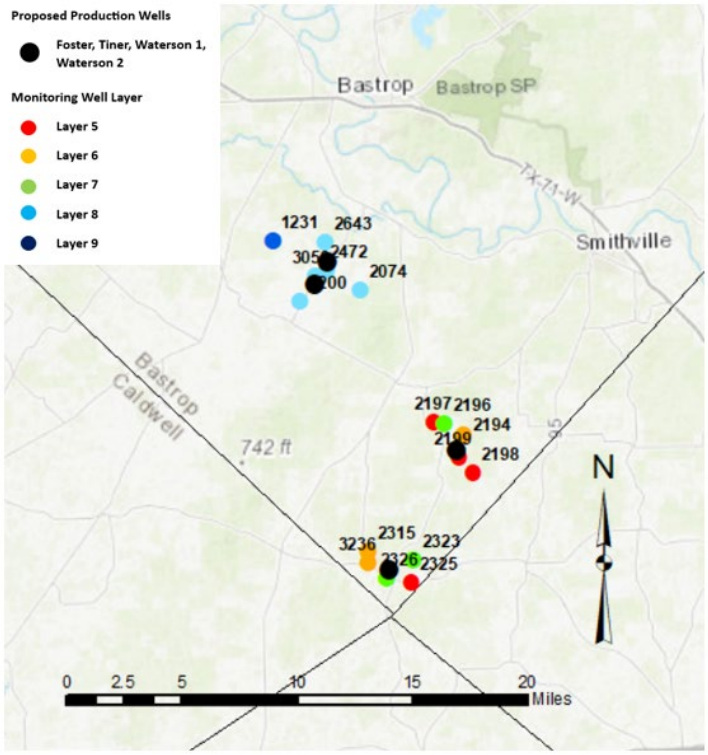

Figure 2. Location Map of Nearby Registered Wells

2.5 GAM Parameters at Nearby Registered Wells

Data from the GAM at the locations of the nearby registered well near the Foster and Tiner wells are presented in Table 5.

Table 5. GAM Parameters for Nearby Registered Wells (Foster and Tiner)

GAM Data or Calculation from GAM Parameters		Nearby Wells (Foster and Tiner)									
		LP-003236	LP-002326	LP-002325	LP-002323	LP-002315	LP-002199	LP-002194	LP-002198	LP-002197	LP-002196
Surface Elevation (ft MSL)		542	347	428	490	503	670	370	515	575	574
Well Depth (ft)		440	815	340	875	503	340	605	400	180	697
GAM Cell Number		80019	105110	58211	105643	80020	57751	80553	58219	57265	104572
GAM Aquifer Code		6	7	5	7	6	5	6	5	5	7
Official Aquifer Cell (1=yes)		0	1	1	1	0	1	0	1	1	1
GAM Layer		6	7	5	7	6	5	6	5	5	7
Outcrop (0=no)		0	0	0	0	0	0	0	0	0	0
Cell Area (acres)		640	640	640	640	640	160	40	160	160	160
Layer Top Elevation (ft MSL)		154	-166	350	-284	144	374	-28	337	392	-80
Layer Bottom Elevation (ft MSL)		-51	-655	-100	-760	-65	-90	-135	-240	66	-490
Layer Thickness (ft)		205	489	450	476	209	464	107	577	326	410
K (ft/day)		0.75	7.12	3.67	8.12	0.68	6.4	0.56	5.76	7.85	15.43
T (gpd/ft)		1150	26043	12353	28911	1063	22213	448	24860	19142	47321
Storativity (dimensionless)		2.68E-04	1.88E-04	7.85E-04	1.76E-04	2.33E-04	6.74E-04	1.09E-04	7.54E-04	5.22E-04	1.68E-04
Specific Storage (dimensionless)		8.00E-02	1.50E-01	1.00E-01	1.50E-01	8.00E-02	1.00E-01	8.00E-02	1.00E-01	1.00E-01	1.50E-01
GWE 2010 (ft)		410.31	382.05	404.84	376.48	410.96	400.77	383.34	386.3	407	377.45
GWE 2070 (ft)		337.22	220.58	362.9	243.24	339.66	356.7	312.4	333.75	367.78	292.75
DFC Drawdown (ft)		73.09	161.47	41.94	133.24	71.3	44.07	70.94	52.55	39.22	84.7
Artesian Head 2010 (ft)		256.31	548.05	54.84	660.48	266.96	26.77	411.34	49.3	15	457.45
Pumping Test (36 hours) Drawdown (ft)	Q=100 gpm	158.05	8.51	15.92	7.73	171.66	9.23	404.57	8.25	10.78	4.85
	Q=300 gpm	474.15	25.53	47.76	23.2	514.98	27.7	1213.7	24.75	32.34	14.56
	Q=500gpm	790.25	42.54	79.6	38.66	858.3	46.17	2022.83	41.26	53.9	24.27
	Q=700gpm	1106.36	59.56	111.43	54.13	1201.62	64.64	2831.97	57.76	75.46	33.98
	Q=900gpm	1422.46	76.58	143.27	69.59	1544.94	83.11	3641.1	74.26	97.02	43.69

Data from the GAM at the locations of the nearby registered well near the Waterson wells are presented in Table 6.

Table 6. GAM Parameters for Nearby Registered Wells (Waterson 1 and Waterson)

GAM Data or Calculation from GAM Parameters		Nearby Registered Wells (Waterson 1 and Waterson 2)					
		LP-002643	LP-003059	LP-002472	LP-003200	LP-001231	LP-002074
Surface Elevation (ft MSL)		399	747	487	589	465	393
Well Depth (ft)		460	620	485	620	440	373
GAM Cell Number		128760	129226	129229	129225	158631	130229
GAM Aquifer Code		8	8	8	8	9	8
Official Aquifer Cell (1=yes)		1	1	1	1	1	1
GAM Layer		8	8	8	8	9	8
Outcrop (0=no)		0	0	0	0	0	0
Cell Area (acres)		40	160	160	640	40	160
Layer Top Elevation (ft)		274	317	317	348	73	325
Layer Bottom Elevation (ft)		-145	-299	-299	-184	-71	-555
Layer Thickness (ft)		419	616	616	532	144	880
K (ft/day)		2.98	2.92	2.84	3.26	9.67	2.47
T (gpd/ft)		9340	13454	13086	12973	10416	16259
Storativity (dimensionless)		6.93E-04	7.23E-04	7.82E-04	7.51E-04	1.08E-04	9.52E-04
Specific Storage (dimensionless)		1.00E-01	1.00E-01	1.00E-01	1.00E-01	1.50E-01	1.00E-01
GWE 2010 (ft)		354.71	377.78	370.79	386.44	373.72	368.65
GWE 2070 (ft)		333.4	356.05	346.75	364.01	357.66	336.34
DFC Drawdown (ft)		21.31	21.73	24.04	22.43	16.06	32.31
Artesian Head 2010 (ft)		80.71	60.78	53.79	38.44	300.72	43.65
Pumping Test (36 hours) Drawdown (ft)	Q=100 gpm	20.86	14.76	15.08	15.24	20.87	12.15
	Q=300 gpm	62.59	44.28	45.25	45.73	62.61	36.46
	Q=500gpm	104.32	73.79	75.41	76.21	104.35	60.77
	Q=700gpm	146.05	103.31	105.58	106.69	146.1	85.07
	Q=900gpm	187.78	132.83	135.74	137.18	187.84	109.38

3.0 GAM Simulations

The simulation used by GMA 12 as the basis for the DFC (Run S-19) is documented in the 2022 GMA 12 Explanatory Report (Daniel B. Stephens & Associated Inc. and others, 2022). The most recent version of the GAM is documented in Young and Kushnereit (2020). Complete documentation of the GAM is available in Young and others (2018). The model files from Run S-19 were used and modified as described below.

3.1 Pumping Scenarios

The Fortran program *makepump.exe* was written to develop the WEL files for each of the pumping simulations. The main input to the program is the cell-by-cell flow file from the calibrated model (*gma12.cbb*) for the DFC GAM run (i.e. Run S-19). Each well proposed in the Aqua WSC permit applications was added individually to the Run S-19 pumping to yield four WEL files. All wells were added to the Run S-19 pumping to yield the fifth WEL file:

- *Foster.wel*
- *Tiner.wel*
- *Waterson1.wel*
- *Waterson2.wel*
- *AquaAll.wel*

3.2 GAM Files for Simulations

The pumping file used in each of the scenarios is documented above. The other input files used to run the simulations are summarized in Table 7. Please note that four of the files were modified from Run S-19 to eliminate echoing of input data to the standard output file (DRN, GNC, HFB, and RIV packages).

The executable for MODFLOW-USG is *mfusg-1.4.exe*, with a file date of 1/27/2021.

Output file names follow the convention of the pumping files by including the name of the scenario (Foster, Tiner, Waterson1, Waterson2, or AquaAll). Output files include:

- Standard output (.lst)
- WEL package flow reduction (.afr)
- Cell by cell flow (.cbb)
- Groundwater elevations or heads (.hds)
- Drawdown (.ddn)

Table 7. Pumping Simulations Input Files (Excluding Pumping)

MODFLOW Package	File Name	File Date	Notes
BAS6	gma12.bas	1/27/2021	
DISU	gma12.dis	1/27/2021	
DRN	gma12.drn	2/24/2023	Added NOPRINT Specfication
EVT (5 files)	gma12.evt	1/27/2023	
	evt.depth.ref	1/27/2023	
	evt.nodes.ref	1/27/2023	
	evt.rate.ref	1/27/2023	
	evt.top.ref	1/27/2023	
GHB	gma12.ghb	1/27/2023	
GNC	gma12.gnc	2/24/2023	Added NOPRINT Specfication
HFB6	gma12.hfb	2/24/2023	Added NOPRINT Specfication
Initial Heads	inititial_2010_heads.hds	1/27/2021	
LPF	gma12.lpf	1/27/2023	
OC	gma12.oc	1/27/2023	
RCH	gma12.rch	1/27/2023	
RIV	gma12.riv	2/24/2023	Added NOPRINT Specfication
SMS	gma12.sms	1/27/2023	

3.3 Groundwater Elevation and Attributable Drawdown

The Fortran program *gethed.exe* was written to extract groundwater elevation and calculate attributable drawdown data from each model simulation (including Run S-19). The output from *gethed.exe* includes one file for each scenario (Run S-19, Foster, Tiner, Waterson 1, Waterson 2, and AquaAll), and includes results from each well site. These files were imported into an Excel file and named *Aqua GWE ADD 4 wells.xlsx*.

Please note that each tab of the spreadsheet file represents a single pumping scenario (Run S-19, Foster, Tiner, Waterson 1, Waterson 2, and AquaAll). In each tab, columns C to F are the annual groundwater elevation estimates for each well location. In each tab, columns G to J are the drawdown attributable to a single Aqua WSC well pumping for the identified scenario (i.e., groundwater elevation from the DFC scenario minus the pumping scenario groundwater elevation). Results of each simulation are presented as follows:

- Section 4 summarizes the Foster simulation.
- Section 5 summarizes the Tiner simulation.
- Section 6 summarizes the Waterson 1 simulation.
- Section 7 summarizes the Waterson 2 simulation.
- Section 8 summarizes the simulation that includes all four wells pumping.

A different version of *gethed.exe* was written to read each of the groundwater elevation results and calculate the attributable drawdown for the nearby registered wells for the five simulations. These results were imported into an Excel file named *Aqua Nearby Wells GWE ADD.xlsx*. These results are presented in Section 9 of this report for all simulations.

3.4 Groundwater Budgets

Cell by cell output from the simulations were used to develop groundwater budgets using Zone Budget (a post processor developed by the USGS):

- Because the Foster and Tiner wells are completed in the Carrizo Aquifer, the groundwater budgets for these wells are based on defining zones based on model layer. Each model layer in LPGCD was assigned a unique zone number. Outside of LPGCD, each county was assigned a unique zone number. For the purposes of this analysis, the Carrizo Aquifer is the unit of interest.
- Because the Waterson 1 and Waterson 2 wells are completed in the undifferentiated Wilcox Aquifer, the groundwater budgets for these wells are based on lumping model layers 8, 9, and 10 together in Bastrop and Lee counties. All other layers retained their unique zone number. Outside LPGCD, each county was assigned a unique zone number. For the purposes of this analysis, the undifferentiated Wilcox Aquifer is the unit of interest (Calvert Bluff, Simsboro, and Hooper in GAM layer nomenclature).
- Because the pumping for the simulations with all four wells involved both the Carrizo and undifferentiated Wilcox, the groundwater budget for this simulation lumped all layers of the Carrizo and Wilcox aquifers (layers 7 to 10) into a single zone for Bastrop and Lee counties. All other layers retained their unique zone number. Outside LPGCD, each county was assigned a unique zone number.

Table 8 summarizes the file names associated with the groundwater budget analysis.

Table 8. Summary of Filenames - Groundwater Budget Analysis

Scenario	DIS file	Zone file	cbb file	Raw Budget file	Processed Budget file
Run S-19 (Carrizo)	gma12.dis	zbzones.dat	RunS-19.cbb	base.2.csv	ZB Base.xlsx
Foster (Carrizo)	gma12.dis	zbzones.dat	Foster.cbb	Foster.2.csv	wbFoster.xlsx
Tiner (Carrizo)	gma12.dis	zbzones.dat	Tiner.cbb	Tiner.2.csv	wbTiner.xlsx
Run S-19 (Wilcox)	gma12.dis	zbzonesWilcox.dat	RunS-19.cbb	S-19Wilcox.2.csv	wbS-19Wilcox.xlsx
Waterson 1 (Wilcox)	gma12.dis	zbzonesWilcox.dat	Waterson1.cbb	Waterson 1Wilcox.2.csv	wbWaterson 1Wilcox.xlsx
Waterson 2 (Wilcox)	gma12.dis	zbzonesWilcox.dat	Waterson2.cbb	Waterson 2Wilcox.2.csv	wbWaterson 2Wilcox.xlsx
Run S-19 (Carrizo-Wilcox)	gma12.dis	zbzonesCW.dat	RunS-19.cbb	S19CW.2.csv	wbS19 CW.xlsx
All Wells Pumping (Carrizo-Wilcox)	gma12.dis	zbzonesCW.dat	AquaAll.cbb	AllPumpCW.2.csv	wbAllPump CW.xlsx

The water budget analyses are presented in Sections 4 to 8 for each simulation below.

4.0 Foster Well Simulation Results

4.1 Groundwater Elevation and Drawdown Results

Groundwater elevation and attributable drawdown results are summarized in the following:

- Figure 3 presents the comparison of groundwater elevation in the Foster well for the DFC run (Run S-19) and the Foster pumping simulation.
- Figure 4 presents the groundwater elevation results of the Foster pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Figure 5 presents the attributable drawdown of the Foster pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Table 9 presents the attributable drawdown (from 2011 conditions) in 2070 for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).

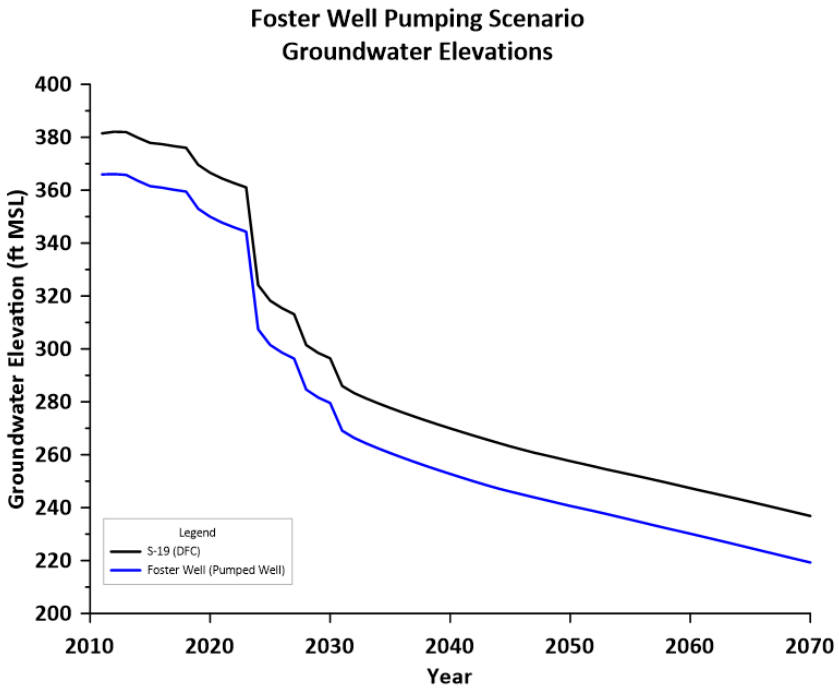

Figure 3. Groundwater Elevation Hydrograph (DFC and Foster Scenarios)

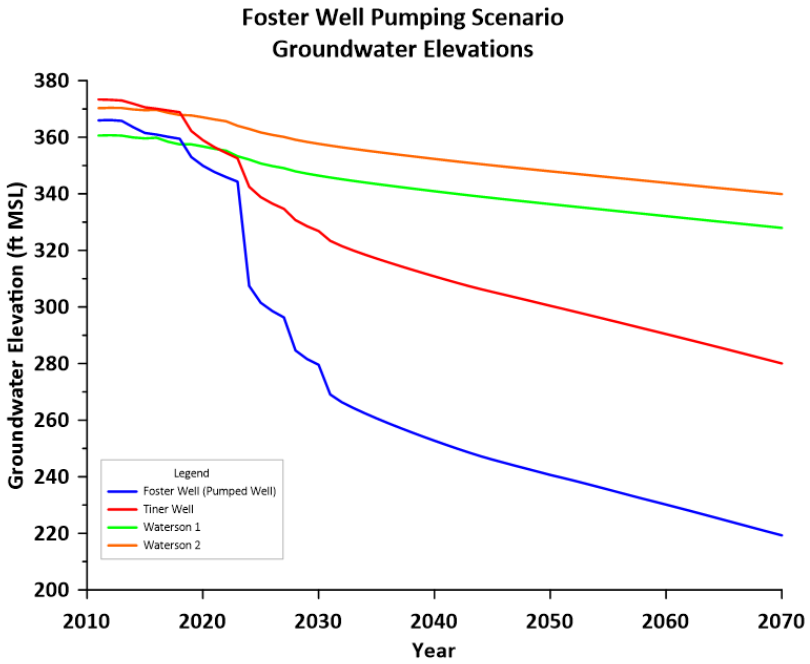

Figure 4. Groundwater Elevation Hydrograph (Foster Scenario, All Locations)

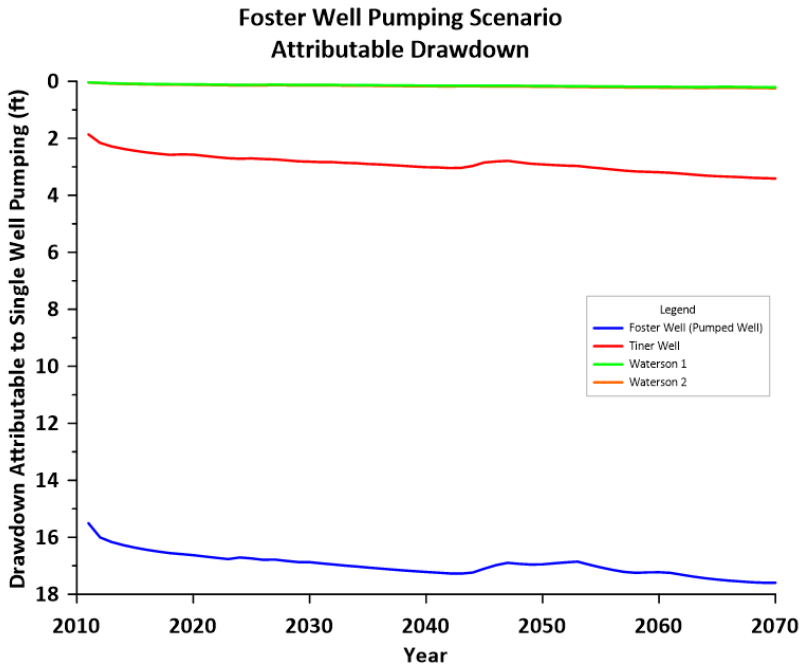

Figure 5. Attributable Drawdown Hydrograph (Foster Scenario)

Table 9. Attributable Drawdown in 2070 - Foster Scenario

Location	Attributable Drawdown in 2070 (ft) (2011 Starting Conditions)
Foster (Pumping Well)	18
Tiner	3
Waterson 1	0
Waterson 2	0

4.2 Groundwater Budget Results

Table 10 presents the groundwater budget of the LPGCD portion of the Carrizo Aquifer for the DFC simulation and the simulation when the Foster well is pumped at a constant rate of 807 AF/yr. The difference between each water budget component is presented in AF/yr and as a percentage of the pumping increase associated with adding Foster well pumping to the DFC simulation.

Please note that most of the pumping is sourced from captured outflow that would have gone to Caldwell and Fayette counties. Other significant sources of water to supply the Foster well are vertical inflow from the overlying Reklaw formation and storage reduction in the Carrizo Aquifer.

Table 10. Groundwater Budget Comparison - Foster Well Pumping Scenario

LPGCD Groundwater Budget Layered, Carrizo Aquifer	DFC/Run S-19 (2011 to 2070) (AF/yr)	Foster Well (2011 to 2070) (AF/yr)	Difference (AF/yr)	Difference (% of Pumping Increase)
Inflows				
From Shallow Flow System (Layer 2)	10,471	10,533	62	7.69
From Reklaw (Layer 6)	10,262	10,370	108	13.37
From Washington County	521	518	-2	-0.29
Total Inflow	21,254	21,422		
Outflows				
Pumping	7,448	8,255	807	100.00
To Burleson County	7,130	7,125	5	0.60
To Caldwell County	2,131	1,865	266	32.97
To Fayette County	4,081	3,913	168	20.80
To Calvert Bluff (Layer 8)	5,545	5,465	80	9.92
Total Outflow	26,336	26,624		
Storage				
Inflow minus Outflow	-5,081	-5,202	121	14.95
Model Storage Change	-5,081	-5,202		
Water Balance Error	0	0		

5.0 Tiner Well Simulation Results

5.1 Groundwater Elevation and Drawdown Results

Groundwater elevation and attributable drawdown results are summarized in the following:

- Figure 6 presents the comparison of groundwater elevation in the Tiner well for the DFC run (Run S-19) and the Tiner pumping simulation.
- Figure 7 presents the groundwater elevation results of the Tiner pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Figure 8 presents the attributable drawdown of the Tiner pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Table 11 presents the attributable drawdown (from 2011 conditions) in 2070 for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).

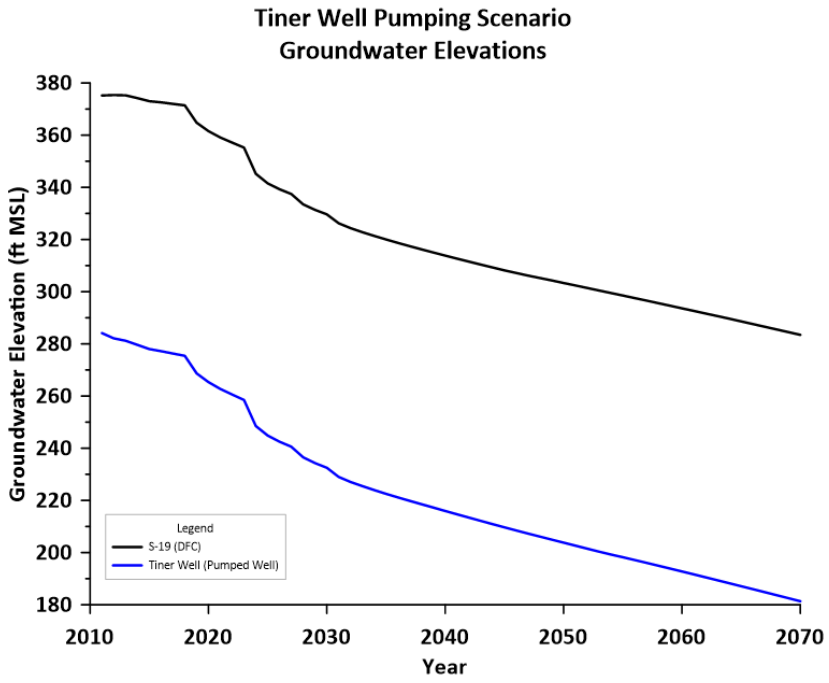

Figure 6. Groundwater Elevation Hydrograph (DFC and Tiner Scenarios)

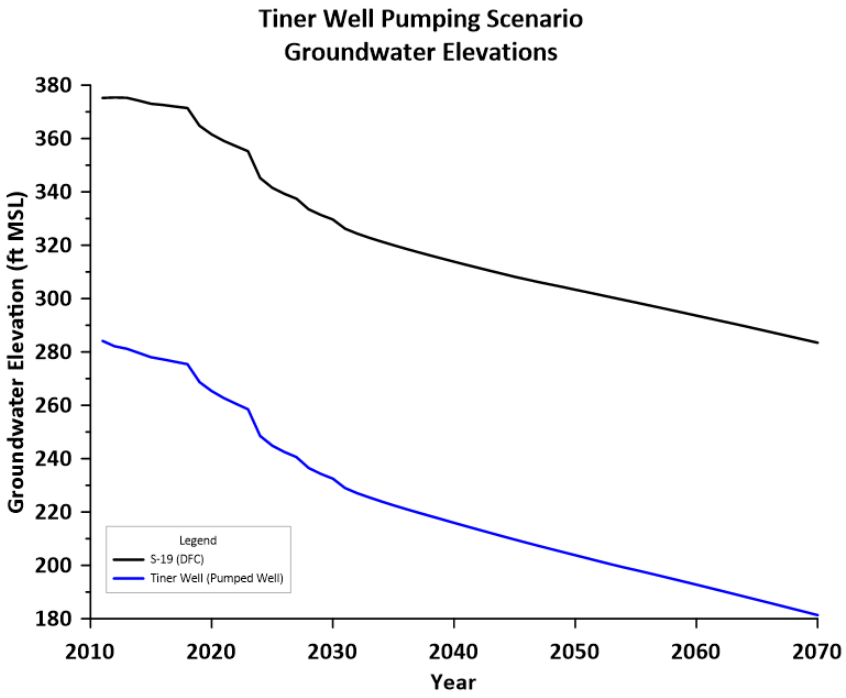

Figure 7. Groundwater Elevation Hydrograph (Tiner Scenario, All Locations)

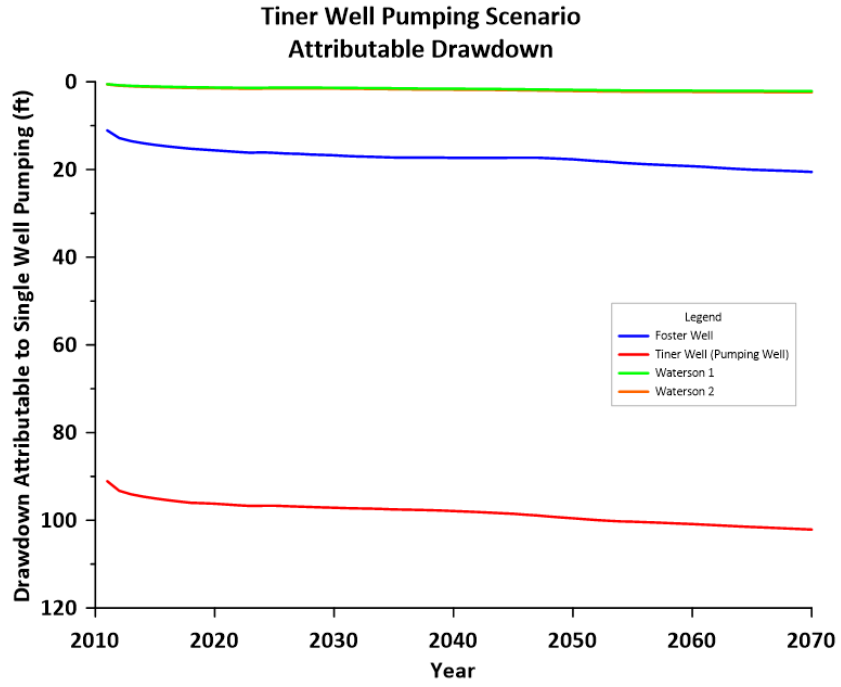

Figure 8. Attributable Drawdown Hydrograph (Tiner Scenario)

Table 11. Attributable Drawdown in 2070 - Tiner Scenario

Location	Attributable Drawdown in 2070 (ft) (2011 Starting Conditions)
Foster	21
Tiner (Pumping Well)	102
Waterson 1	2
Waterson 2	2

5.2 Groundwater Budget Results

Table 12 presents the groundwater budget of the LPGCD portion of the Carrizo Aquifer for the DFC simulation and the simulation when the Tiner well is pumped at a constant rate of 4,839 AF/yr. The difference between each water budget component is presented in AF/yr and as a percentage of the pumping increase associated with adding Tiner well pumping to the DFC simulation.

Please note that significant sources of the pumping are induced inflow from the shallow flow system and induced vertical inflow from the overlying Reklaw formation. Significant captured outflow components include flow to Fayette County and captured vertical outflow to the underlying Calvert Bluff Aquifer. Storage decline is also a relatively large source of the pumping.

Table 12. Groundwater Budget Comparison - Tiner Well Pumping Scenario

LPGCD Groundwater Budget Layered, Carrizo Aquifer	DFC/Run S-19 (2011 to 2070) (AF/yr)	Tiner Well (2011 to 2070) (AF/yr)	Difference (AF/yr)	Difference (% of Pumping Increase)
Inflows				
From Shallow Flow System (Layer 2)	10,471	11,098	626	12.95
From Reklaw (Layer 6)	10,262	11,489	1,227	25.36
From Washington County	521	508	-13	-0.26
Total Inflow	21,254	23,095		
Outflows				
Pumping	7,448	12,287	4,839	100.00
To Burleson County	7,130	7,096	34	0.71
To Caldwell County	2,131	1,698	433	8.96
To Fayette County	4,081	3,237	844	17.44
To Calvert Bluff (Layer 8)	5,545	4,723	822	16.99
Total Outflow	26,336	29,041		
Storage				
Inflow minus Outflow	-5,081	-5,946	864	17.87
Model Storage Change	-5,081	-5,946		
Water Balance Error	0	0		

6.0 Waterson 1 Well Simulation Results

6.1 Groundwater Elevation and Drawdown Results

Groundwater elevation and attributable drawdown results are summarized in the following:

- Figure 9 presents the comparison of groundwater elevation in the Waterson 1 well for the DFC run (Run S-19) and the Waterson 1 pumping simulation.
- Figure 10 presents the groundwater elevation results of the Waterson 1 pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Figure 11 presents the attributable drawdown of the Waterson 1 pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Table 13 presents the attributable drawdown (from 2011 conditions) in 2070 for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).

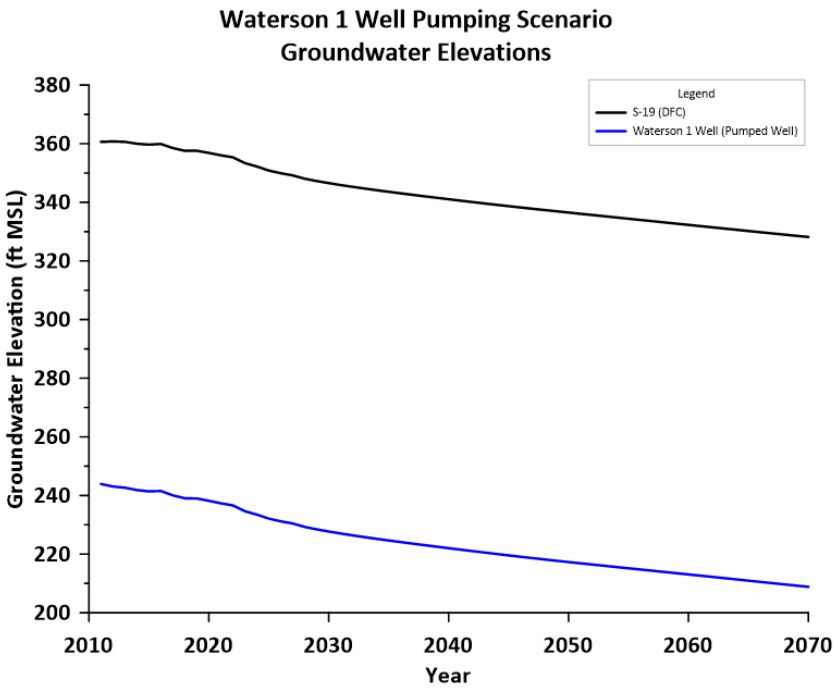

Figure 9. Groundwater Elevation Hydrograph (DFC and Waterson 1 Scenarios)

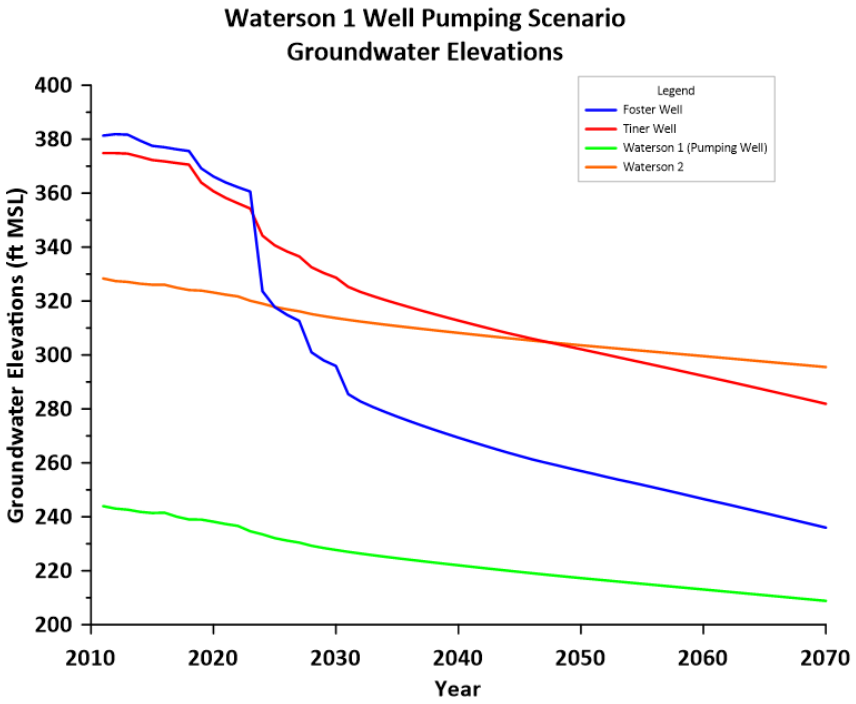

Figure 10. Groundwater Elevation Hydrograph (Waterson 1 Scenario, All Locations)

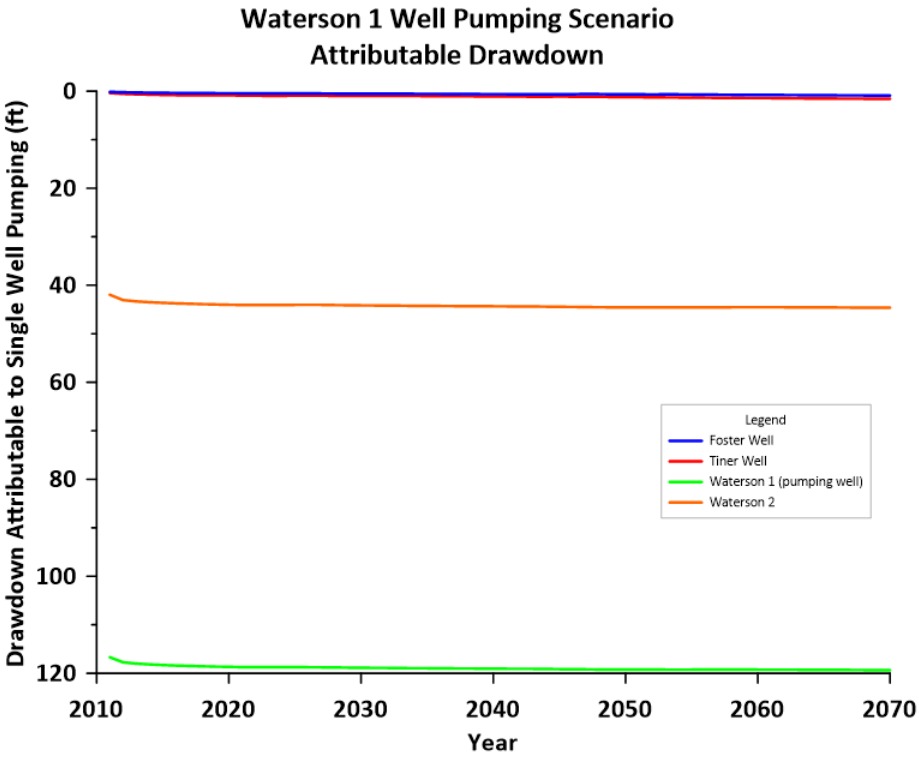

Figure 11. Attributable Drawdown Hydrograph (Waterson 1 Scenario)

Table 13. Attributable Drawdown in 2070 – Waterson 1 Scenario

Location	Attributable Drawdown in 2070 (ft) (2011 Starting Conditions)
Foster	1
Tiner	2
Waterson 1 (Pumping Well)	119
Waterson 2	45

6.2 Groundwater Budget Results

Table 14 presents the groundwater budget of the LPGCD portion of the Wilcox Aquifer for the DFC simulation and the simulation when the Waterson 1 well is pumped at a constant rate of 3,226 AF/yr. The difference between each water budget component is presented in AF/yr and as a percentage of the pumping increase associated with adding Waterson 1 well pumping to the DFC simulation.

Please note that over half of the proposed pumping would be sourced from the shallow flow system. The only other significant source is induced inflow from the overlying Carrizo Aquifer. Storage decline supplies less than ten percent of the increased pumping.

Table 14. Groundwater Budget Comparison – Waterson 1 Well Pumping Scenario

LPGCD Groundwater Budget Layered, Undifferentiated Wilcox	DFC/Run S-19 (2011 to 2070) (AF/yr)	Waterson 1 Well (2011 to 2070) (AF/yr)	Difference (AF/yr)	Difference (% of Pumping Increase)
Inflows				
From Alluvium (Layer 1)	126	132	6	0.20
From Shallow Flow System (Layer 2)	45,998	48,177	2,179	67.62
From Carrizo (Layer 7)	5,545	6,165	620	19.23
From Caldwell County	1,493	1,618	125	3.89
From Milam County	9,226	9,233	7	0.22
From Washington County	1,939	1,936	-2	-0.07
From Williamson County	2,447	2,448	1	0.04
Total Inflow	66,774	69,710		
Outflows				
Pumping	63,367	66,589	3,222	100.00
To Burleson County	19,581	19,558	23	0.71
To Fayette County	537	487	50	1.54
Total Outflow	83,485	86,634		
Storage				
Inflow minus Outflow	-16,711	-16,925	213	6.62
Model Storage Change	-16,711	-16,925		
Water Balance Error	0	0		

7.0 Waterson 2 Well Simulation Results

7.1 Groundwater Elevation and Drawdown Results

Groundwater elevation and attributable drawdown results are summarized in the following:

- Figure 12 presents the comparison of groundwater elevation in the Waterson 2 well for the DFC run (Run S-19) and the Waterson 2 pumping simulation.
- Figure 13 presents the groundwater elevation results of the Waterson 2 pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Figure 14 presents the attributable drawdown of the Waterson 2 pumping simulation for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Table 15 presents the attributable drawdown (from 2011 conditions) in 2070 for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).

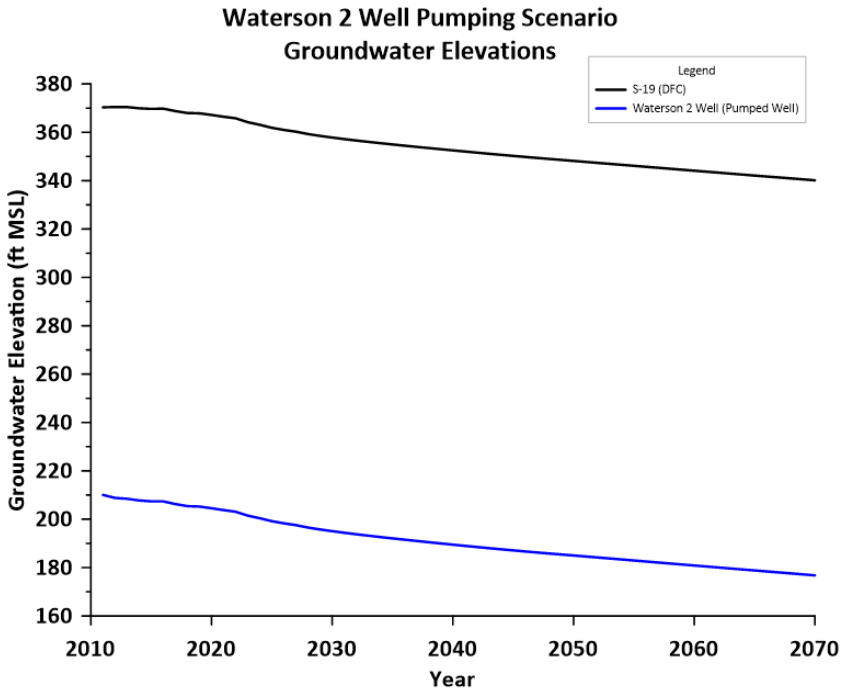

Figure 12. Groundwater Elevation Hydrograph (DFC and Waterson 2 Scenarios)

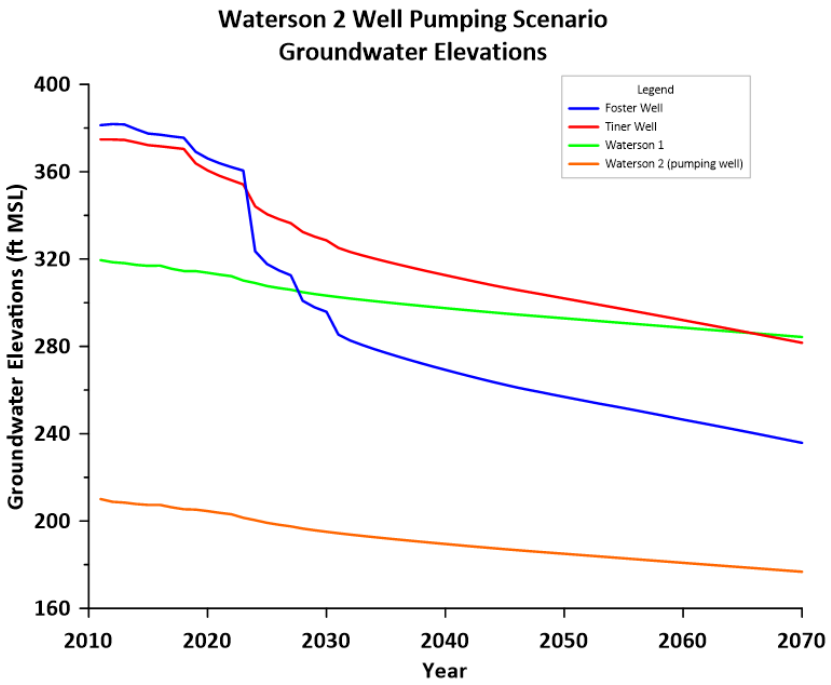

Figure 13. Groundwater Elevation Hydrograph (Waterson 2 Scenario, All Locations)

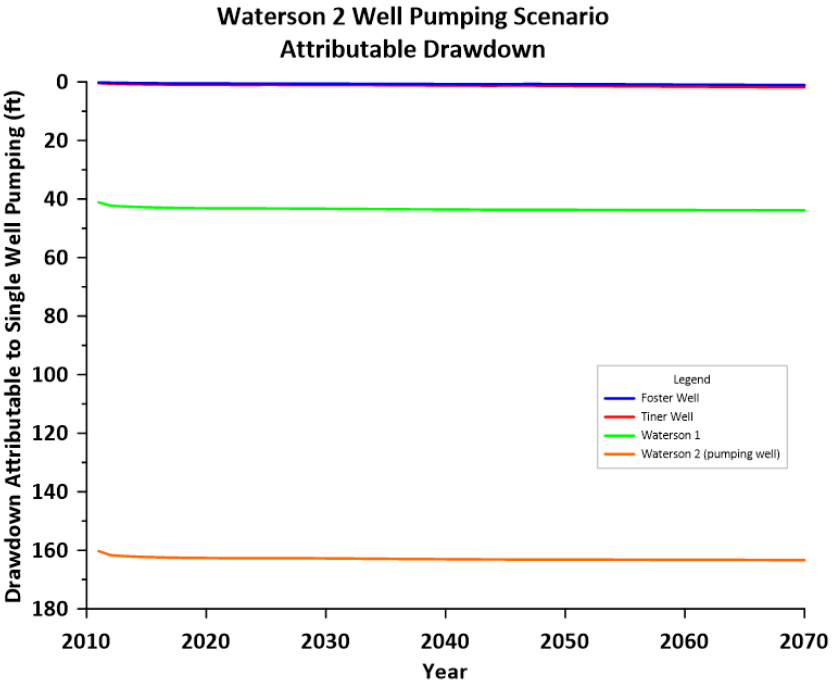

Figure 14. Attributable Drawdown Hydrograph (Waterson 2 Scenario)

Table 15. Attributable Drawdown in 2070 – Waterson 2 Scenario

Location	Attributable Drawdown in 2070 (ft) (2011 Starting Conditions)
Foster	1
Tiner	2
Waterson 1	44
Waterson 2 (Pumping Well)	163

7.2 Groundwater Budget Results

Table 16 presents the groundwater budget of the LPGCD portion of the Wilcox Aquifer for the DFC simulation and the simulation when the Waterson 2 well is pumped at a constant rate of 3,226 AF/yr. The difference between each water budget component is presented in AF/yr and as a percentage of the pumping increase associated with adding Waterson 2 well pumping to the DFC simulation.

Please note that over half of the proposed pumping would be sourced from the shallow flow system. The only other significant source is induced inflow from the overlying Carrizo Aquifer. Storage decline supplies less than ten percent of the increased pumping.

Table 16. Groundwater Budget Comparison – Waterson 2 Well Pumping Scenario

LPGCD Groundwater Budget Layered, Undifferentiated Wilcox	DFC/Run S-19 (2011 to 2070) (AF/yr)	Waterson 2 Well (2011 to 2070) (AF/yr)	Difference (AF/yr)	Difference (% of Pumping Increase)
Inflows				
From Alluvium (Layer 1)	126	131	5	0.15
From Shallow Flow System (Layer 2)	45,998	48,121	2,122	65.87
From Carrizo (Layer 7)	5,545	6,122	576	17.89
From Caldwell County	1,493	1,680	187	5.79
From Milam County	9,226	9,233	7	0.22
From Washington County	1,939	1,936	-3	-0.09
From Williamson County	2,447	2,448	1	0.04
Total Inflow	66,774	69,669		
Outflows				
Pumping	63,367	66,589	3,222	100.00
To Burleson County	19,581	19,559	23	0.70
To Fayette County	537	480	57	1.78
Total Outflow	83,485	86,627		
Storage				
Inflow minus Outflow	-16,711	-16,958	246	7.65
Model Storage Change	-16,711	-16,958		
Water Balance Error	0	0		

8.0 All Wells Pumping Simulation Results

8.1 Groundwater Elevation and Drawdown Results

Groundwater elevation and attributable drawdown results are summarized in the following:

- Figure 15 presents the groundwater elevation results of simulation that included all four proposed wells pumping for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Figure 16 presents the attributable drawdown results of simulation that included all four proposed wells pumping for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).
- Table 17 presents the attributable drawdown (from 2011 conditions) in 2070 for all four well sites (Foster, Tiner, Waterson 1, and Waterson 2).

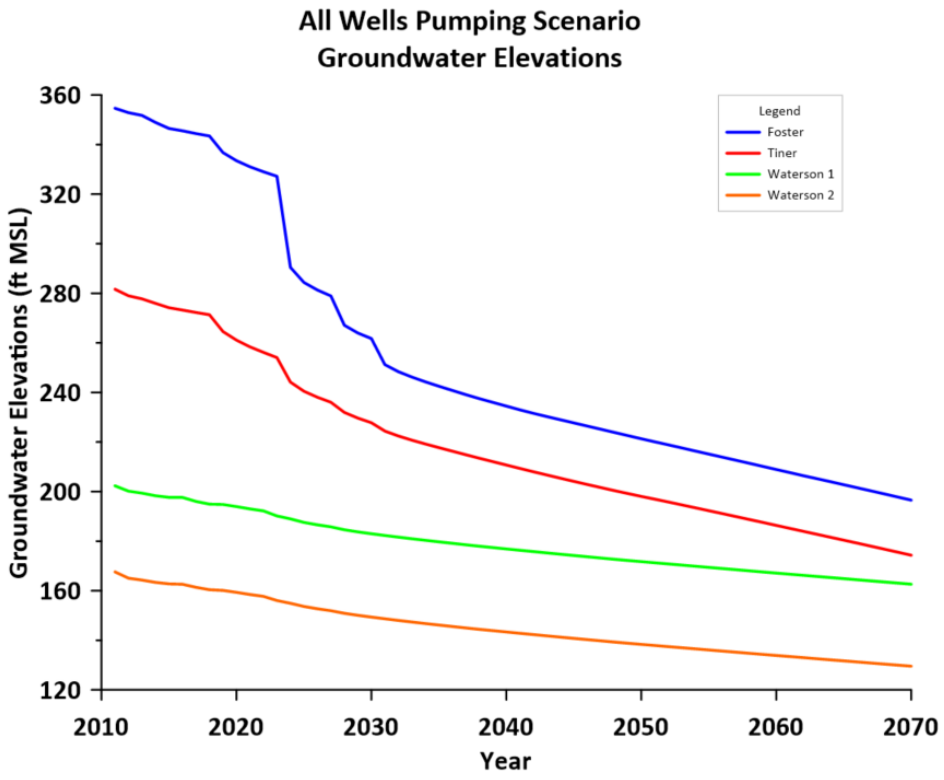

Figure 15. Groundwater Elevation Hydrograph (All Wells Pumping Scenario)

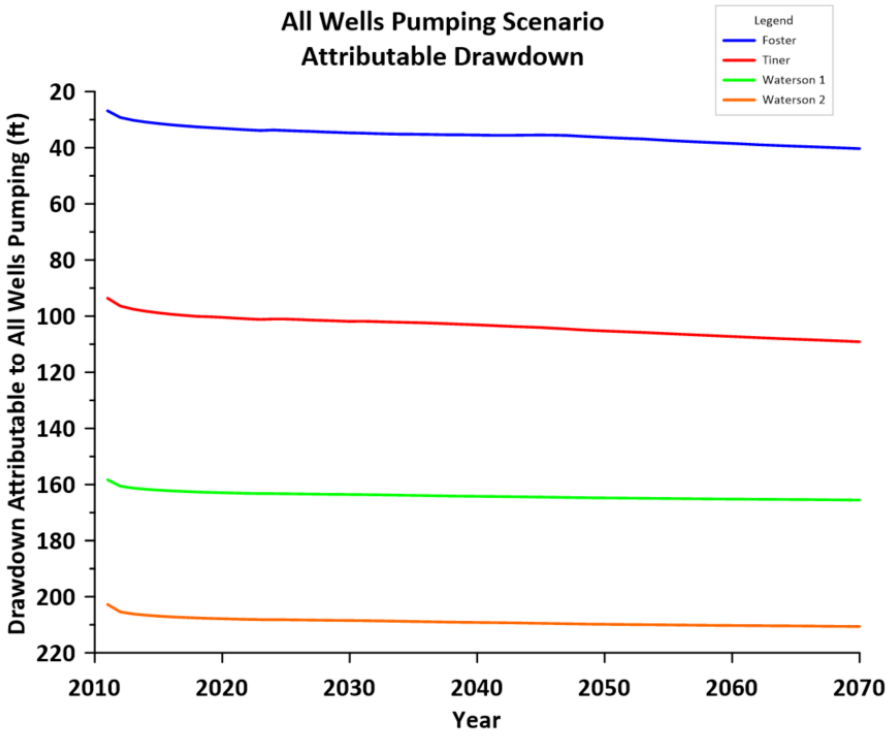

Figure 16. Attributable Drawdown Hydrograph (All Wells Pumping Scenario)

Table 17. Attributable Drawdown in 2070 – All Wells Pumping Scenario

Location	Attributable Drawdown in 2070 (ft) (2011 Starting Conditions)
Foster	40
Tiner	109
Waterson 1	166
Waterson 2	211

8.2 Groundwater Budget Results

Table 18 presents the groundwater budget of the LPGCD portion of the lumped Carrizo-Wilcox Aquifer for the DFC simulation and the simulation with all four proposed wells pumping at the following rates: 5,646 AF/yr from Carrizo Aquifer (Layer 7) and 6,452 AF/yr from Wilcox Aquifer (Layer 9). The difference between each water budget component is presented in AF/yr and as a percentage of the pumping increase associated with adding all four proposed wells pumping to the DFC simulation.

Table 18. Groundwater Budget Comparison – Waterson 2 Well Pumping Scenario

LPGCD Groundwater Budget Layered, Carrizo-Wilcox	DFC/Run S-19 (2011 to 2070) (AF/yr)	Aqua All Pump (2011 to 2070) (AF/yr)	Difference (AF/yr)	Difference (% of Pumping Increase)
Inflows				
From Alluvium (Layer 1)	126	139	13	0.11
From Shallow Flow System (Layer 2)	56,470	62,453	5,983	49.48
From Reklaw (Layer 6)	10,262	11,795	1,533	12.68
From Caldwell County	NA	559	1,197	9.90
From Milam County	9,226	9,254	29	0.24
From Washington County	2,459	2,429	-30	-0.25
From Williamson County	2,447	2,451	4	0.03
Total Inflow	80,990	89,080		
Outflows				
Pumping	70,815	82,907	12,092	100.00
To Burleson County	26,711	26,572	139	1.15
To Caldwell County	638	NA	NA	
To Fayette County	4,618	3,355	1,263	10.44
Total Outflow	102,782	112,834		
Storage				
Inflow minus Outflow	-21,793	-23,754	1,961	16.22
Model Storage Change	-21,793	-23,754		
Water Balance Error	0	0		

Please note that over half of the proposed pumping would be sourced from the alluvium and shallow flow system. Other significant sources are induced inflow from the overlying Reklaw Formation, induced inflow from Caldwell County, and captured outflow from Fayette County. Storage decline supplies about 16 percent of the increased pumping.

9.0 Attributable Drawdown at Nearby Wells

As noted above, the simulation output was processed to obtain groundwater elevation results at the 16 nearby registered well sites that are close to the four proposed production wells. Groundwater elevation, attributable drawdown, and distance results are in the Excel file named *Aqua Nearby Wells GWE ADD.xlsx*. A summary of attributable drawdown in the 16 nearby wells for each of the simulations is summarized in Table 19.

Table 19. Summary of Drawdown in Nearby Wells for All Simulations

Well Number	Well Depth (ft)	Model Layer	Attributable Drawdown Due to Simulated Pumping Well from 2011 to 2070 in feet									
			Foster (807 AF/yr from Layer 7)		Tiner (4,839 AF/yr from Layer 7)		Waterson 1 (3,226 AF/yr from Layer 9)		Waterson 2 (3,226 AF/yr from Layer 9)		All Wells (5,646 AF/yr from Layer 7 and 6,452 AF/yr from Layer 9)	
			Drawdown (ft)	Distance to Foster (mi)	Drawdown (ft)	Distance to Tiner (mi)	Drawdown (ft)	Distance to Waterson 1 (mi)	Drawdown (ft)	Distance to Waterson 2 (mi)	Simulated Drawdown with All Wells Pumping(ft)	Sum of Drawdowns for Individual Well Simulations (ft)
LP-002643	460	8	0.15	14.50	1.57	10.64	15.47	0.89	12.11	1.92	29.34	29.31
LP-003059	620	8	0.26	13.16	2.44	9.69	13.86	0.78	17.99	0.39	34.44	34.55
LP-002472	485	8	0.28	13.27	2.77	9.58	14.89	0.36	16.03	0.82	33.61	33.96
LP-003200	620	8	0.31	12.27	2.76	9.31	10.78	2.05	15.45	0.92	28.97	29.30
LP-001231	440	9	0.09	15.11	0.89	12.01	11.20	2.51	12.83	2.58	25.02	25.01
LP-002074	373	8	0.44	12.22	4.68	8.06	10.18	1.89	11.22	2.05	26.12	26.52
LP-003236	440	6	2.49	0.91	8.24	6.16	0.34	13.14	0.40	12.28	11.62	11.47
LP-002326	815	7	10.88	0.33	17.46	6.29	0.78	13.91	0.93	13.08	30.27	30.05
LP-002325	340	5	0.83	1.11	4.48	6.08	0.20	14.36	0.22	13.59	5.59	5.72
LP-002323	875	7	8.91	1.19	23.34	5.12	0.96	13.47	1.13	12.73	34.54	34.33
LP-002315	503	6	2.70	1.17	9.93	5.81	0.40	12.68	0.47	11.83	13.68	13.49
LP-002199	340	5	0.85	5.77	8.67	0.33	0.37	10.18	0.41	9.75	10.35	10.30
LP-002194	605	6	2.11	6.73	34.98	0.76	1.12	9.55	1.27	9.21	39.66	39.48
LP-002198	400	5	0.89	5.58	7.85	1.25	0.36	11.11	0.40	10.69	9.55	9.50
LP-002197	180	5	0.82	6.72	10.00	1.52	0.42	8.34	0.48	7.92	11.93	11.72
LP-002196	697	7	2.93	6.79	46.57	1.21	1.73	8.68	1.99	8.30	53.49	53.23

9.1 Distance Drawdown Summaries

Please note that the distance between each proposed production well and each nearby well is listed in Table 19 above. The distance drawdown data for each simulation is presented as follows:

- Figure 17: Foster Simulation
- Figure 18: Tiner Simulation
- Figure 19: Waterson 1 Simulation
- Figure 20: Waterson 2 Simulation

Each point represents the attributable drawdown for a specific nearby well. The number above each data point represents the completion layer for that nearby well based on its depth. In general, as distance increases from the proposed production well, the simulated drawdown decreases. A best fit line is presented in each figure that includes all data. Because the data represent different model layers, the best fit line is presented as a visual aid rather than as an aid for interpretation or interpolation of data. For example, it can be seen in the Foster simulation (Figure 17) three points that are about 7 miles from the Foster well with the most drawdown in Layer 7 (the layer with the pumped well. The points for layer 5 and layer 6 have lower drawdowns because these wells are completed in overlying formations.

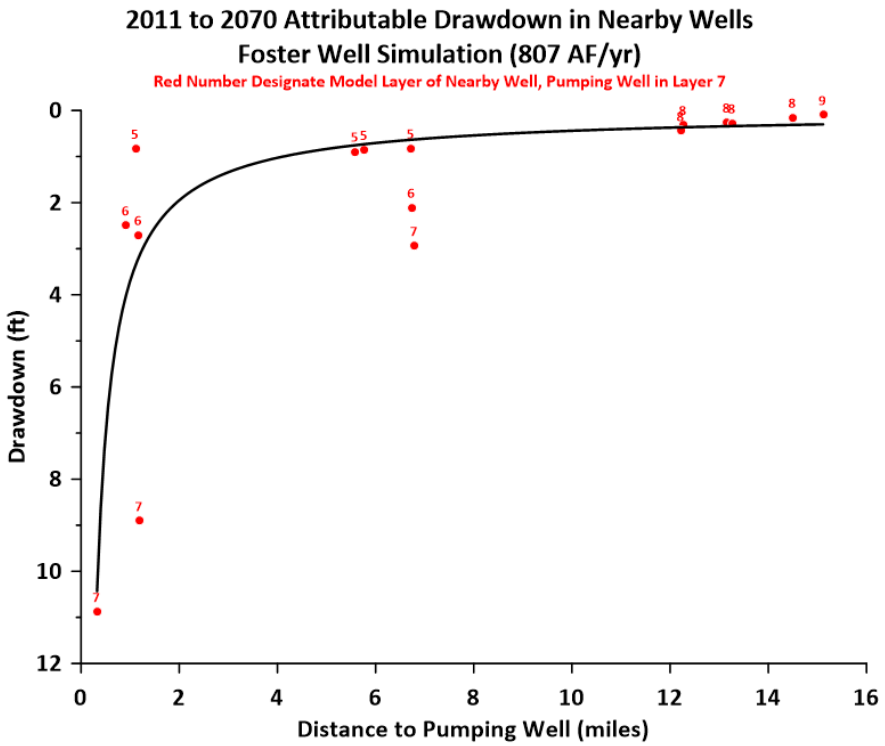

Figure 17. Distance Drawdown in Nearby Wells - Foster Simulation

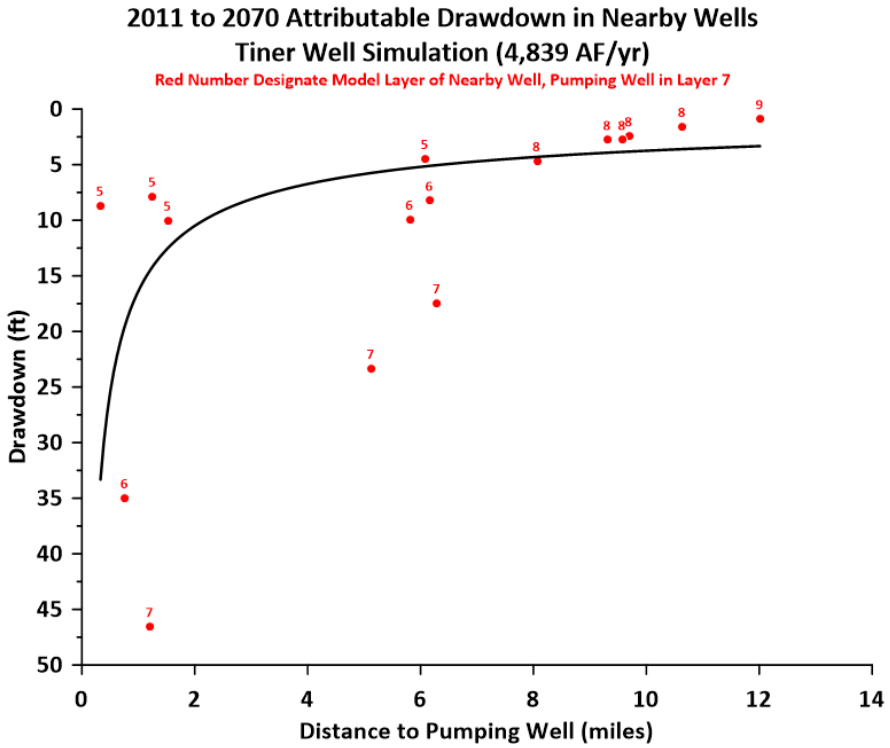

Figure 18. Distance Drawdown in Nearby Wells - Tiner Simulation

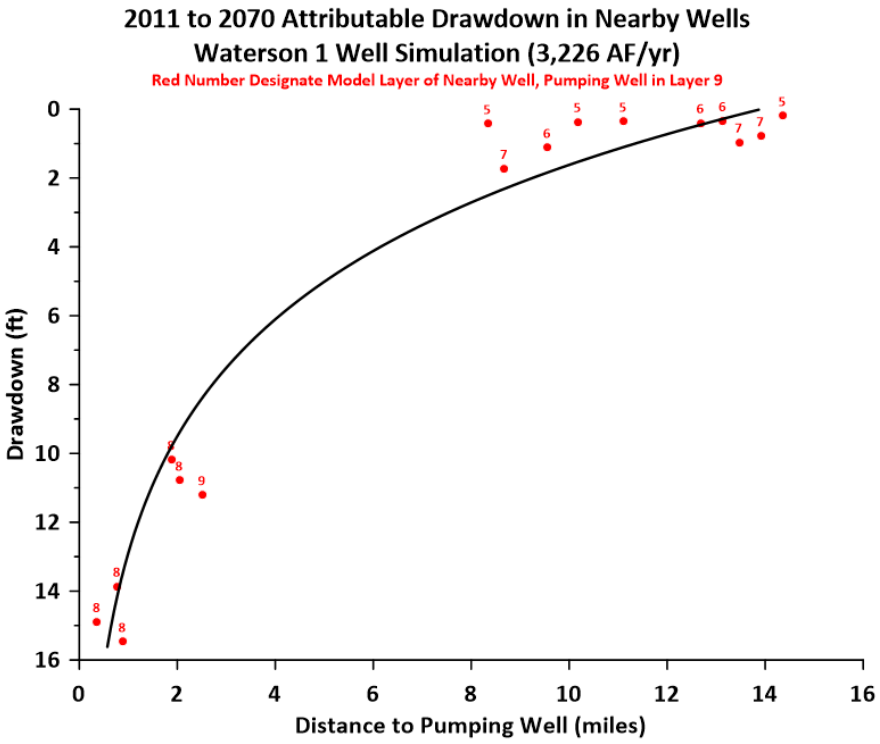

Figure 19. Distance Drawdown in Nearby Wells – Waterson 1 Simulation

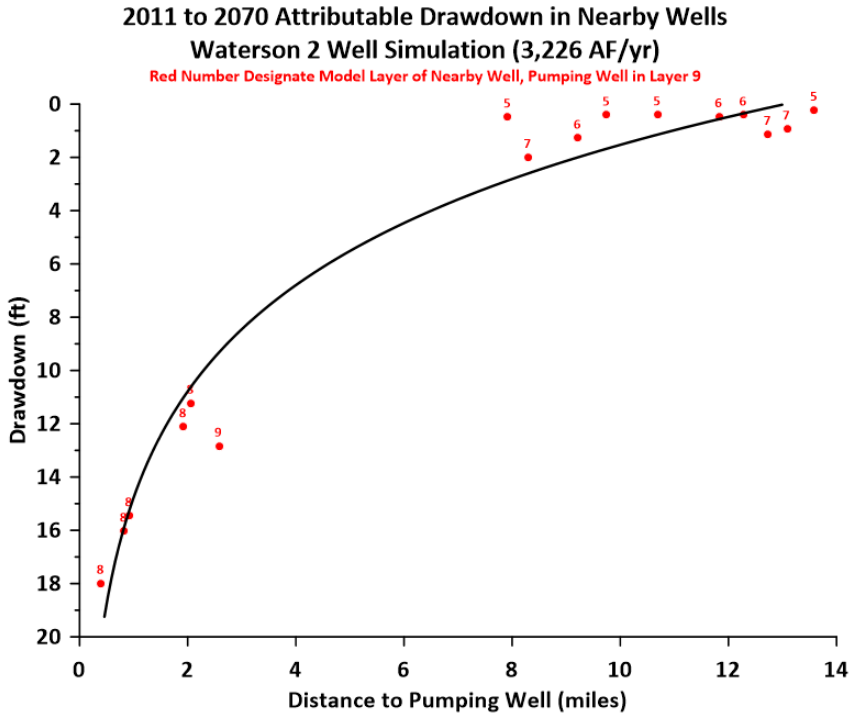

Figure 20. Distance Drawdown in Nearby Wells - Waterson 2 Simulation

11.0 Attributable Drawdown Contour Maps

The distance drawdown graphs in the previous section provide summaries of the attributable drawdown in specific wells in various formations (production, overlying, and underlying). More generally, the attributable drawdown due to pumping is presented as contour maps for each model layer. The results of the scenario with all proposed wells pumping are presented below in two groups:

- Production Well Formations:
  - Layer 7 (Carrizo)
  - Layer 9 (Simsboro)
- Overlying and Underlying Formations:
  - Layer 2 (Shallow Flow System)
  - Layer 5 (Queen City)
  - Layer 6 (Reklaw)
  - Layer 8 (Calvert Bluff)
  - Layer 10 (Hooper)

11.1 Production Well Formations

Figures 21 and 22 present the attributable drawdown contours due to all proposed wells pumping in the Carrizo Aquifer and Simsboro Aquifer from 2011 to 2070, respectively.

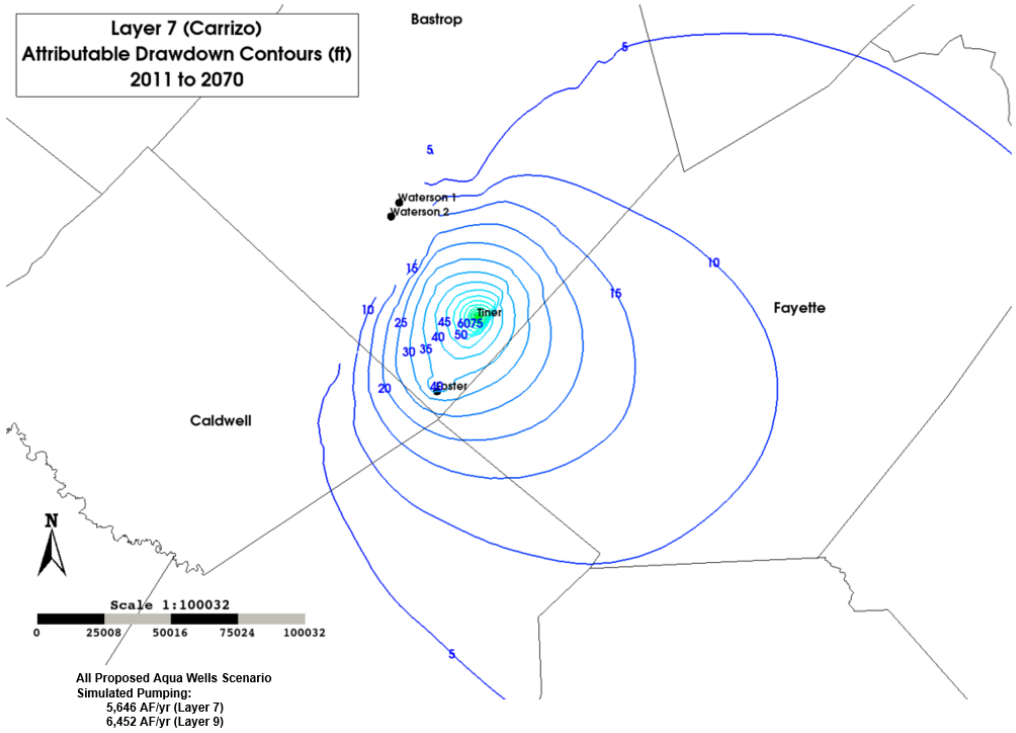

Figure 21. Attributable Drawdown: Carrizo Aquifer

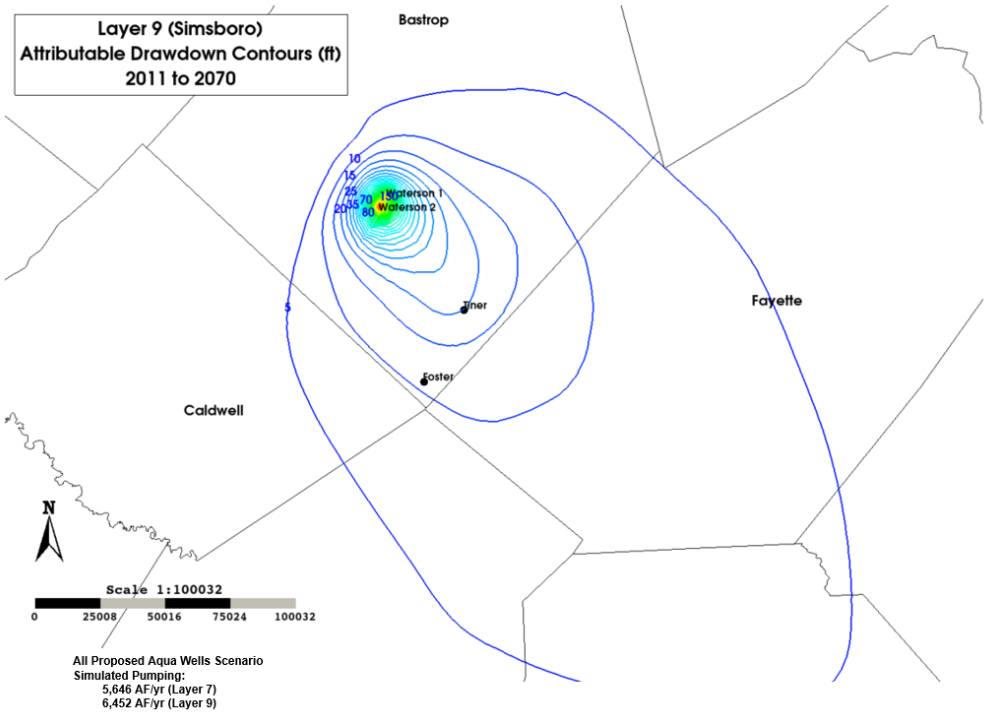

Figure 22. Attributable Drawdown: Simsboro Aquifer

11.2 Overlying and Underlying Formations

Attributable drawdown contours for the overlying and underlying formations due to all proposed wells pumping are presented as follows:

- Figure 23: Layer 2 (Shallow Flow System)
- Figure 24: Layer 5 (Queen City)
- Figure 25: Layer 6 (Reklaw)
- Figure 26: Layer 8 (Calvert Bluff)
- Figure 27: Layer 10 (Hooper)

Please note that the "Shallow Flow System" in the GAM generally represents the outcrop areas of the main formations in the model (i.e. Queen City, Carrizo, and the components of the Wilcox). Drawdowns in the shallow flow system can be used to generally evaluate the impacts of the pumping to surface water impacts.

The Reklaw Formation is not a formally recognized aquifer, but it is simulated in the GAM as a confining layer. It is possible that wells completed in the Reklaw may produce groundwater. The regional nature of the GAM is a limitation in characterizing the Reklaw with respect to its ability to yield groundwater to wells. However, from a regional perspective, the GAM provides insight as to the nature of how pumping in one formation can impact groundwater elevations in overlying and underlying formations.

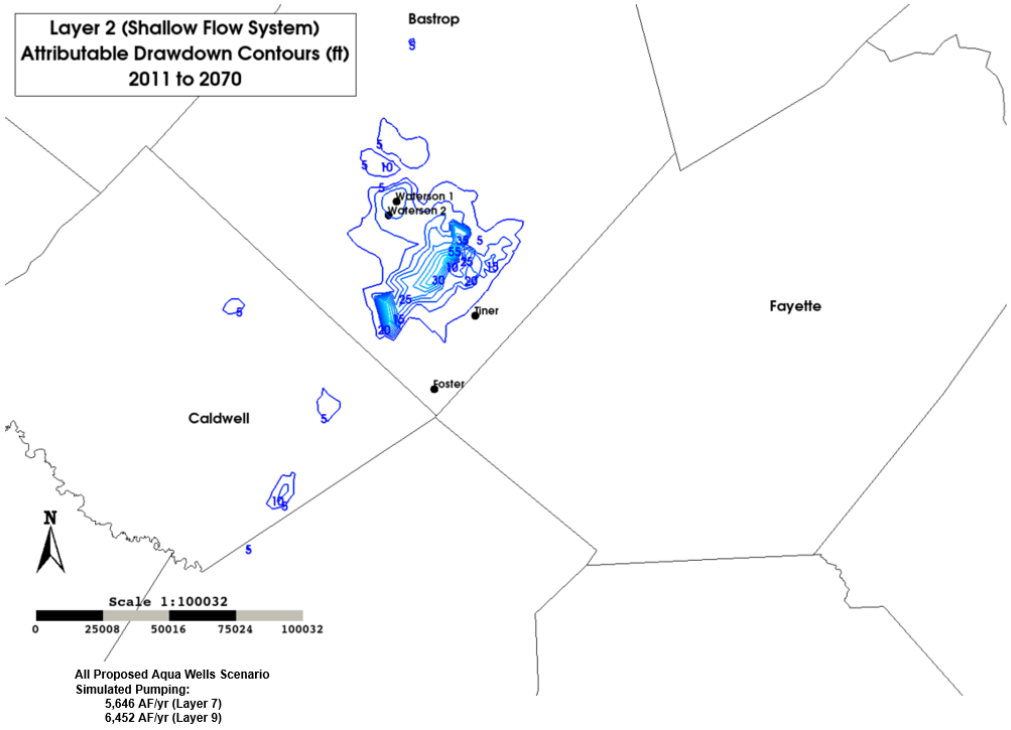

Figure 23. Attributable Drawdown: Shallow flow System

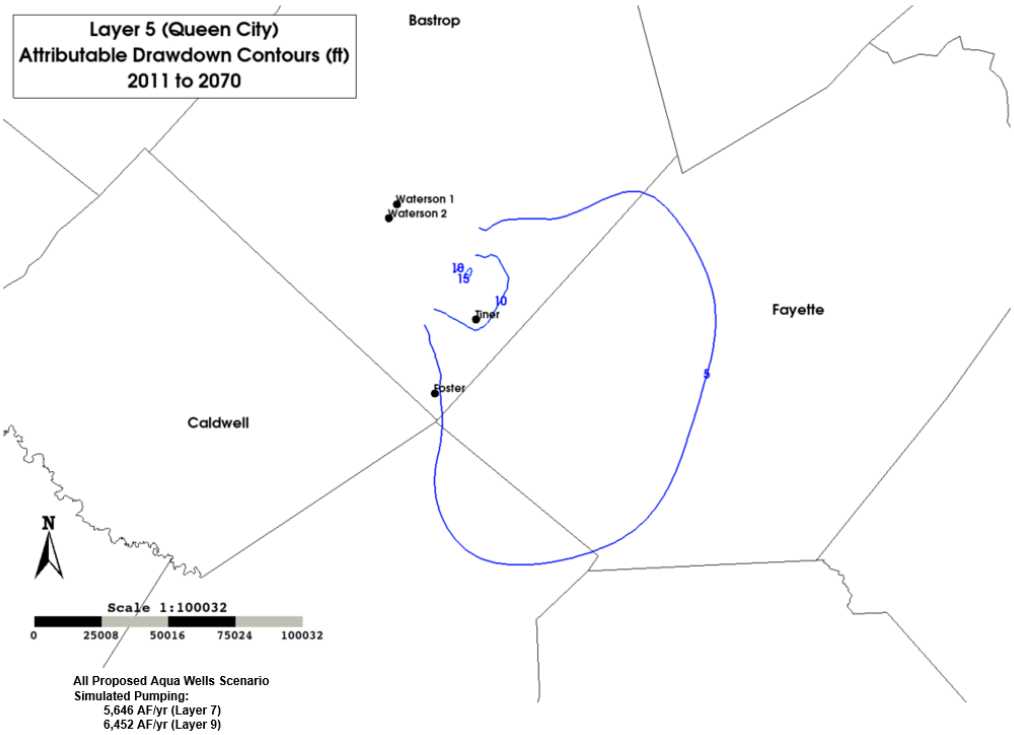

Figure 24. Attributable Drawdown: Queen City Aquifer

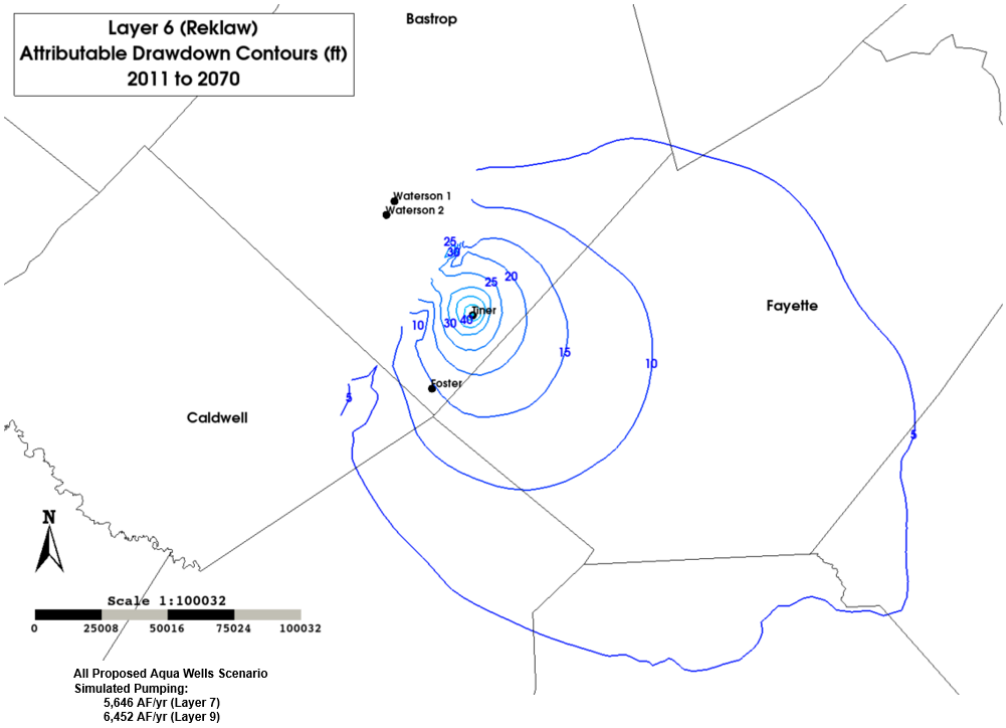

Figure 25. Attributable Drawdown: Reklaw Formation

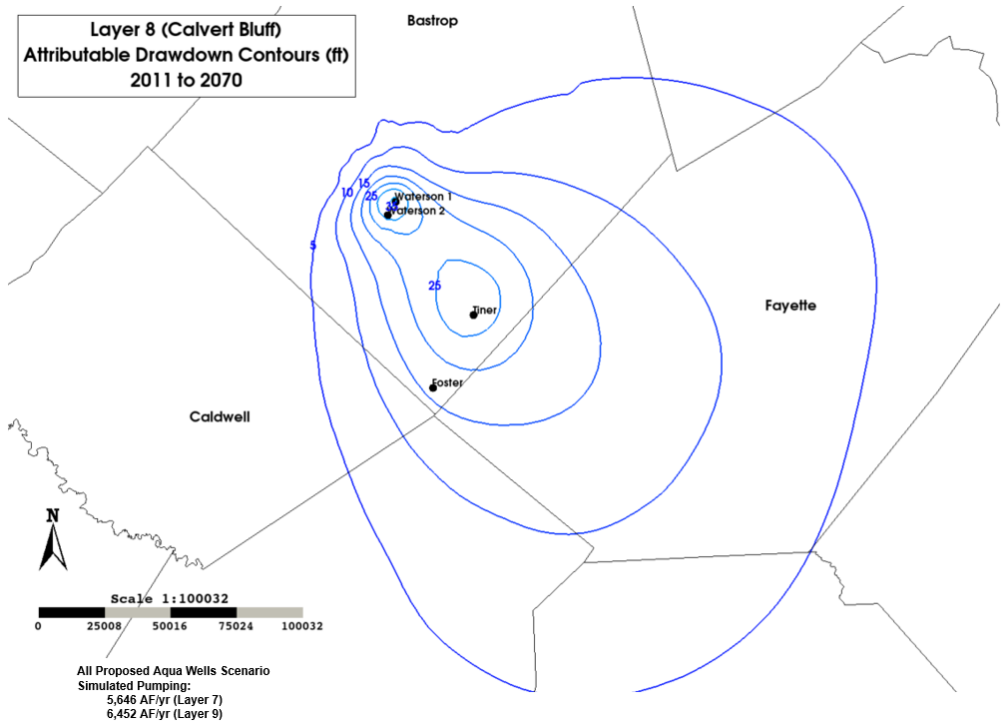

Figure 26. Attributable Drawdown: Calvert Bluff Aquifer

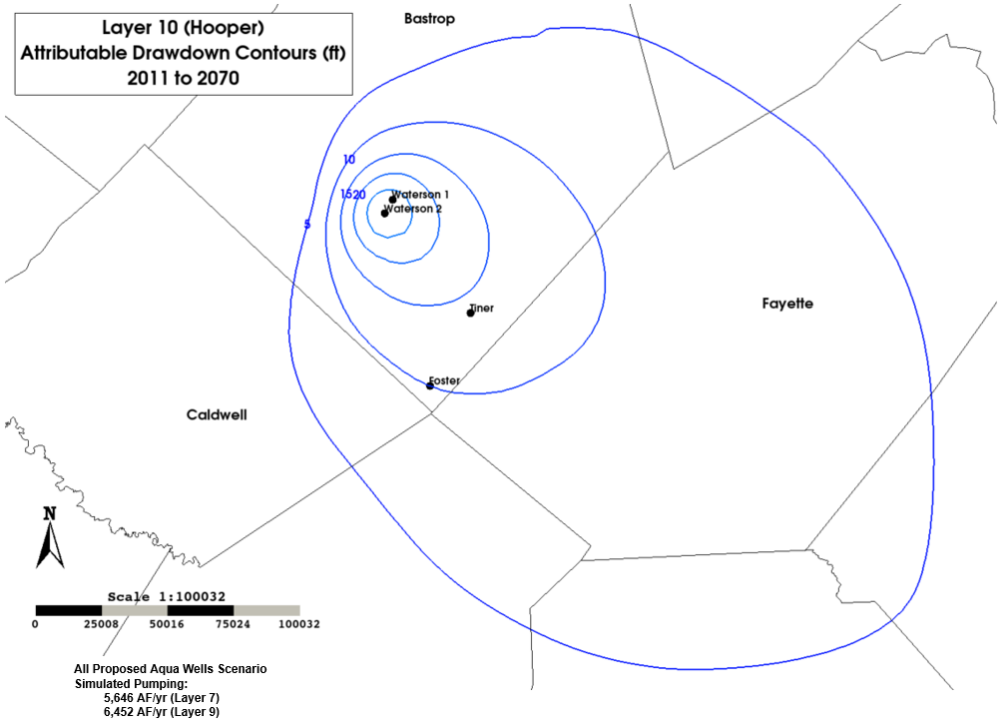

Figure 27. Attributable Drawdown: Hooper Aquifer

12.0 References

Daniel B. Stephens & Associates Inc., INTERA Incorporated, and Groundwater Consultants LLC, 2022. Desired Future Condition Explanatory Report for Groundwater Management Area 12. Considered and approved by the member districts of Groundwater Management Area 12 on January 28, 2022, 859p.

Young, S, Jigmond, M., Jones, T., and Ewing, T., 2018. Final Report: Groundwater Availability Model for the Central Portion of the Sparta, Queen City, and Carrizo-Wilcox Aquifers. Report for the Texas Water Development Board. September 2018, 404p.

Young, S.C., and Kushnereit, R., 2020. GMA 12 Update to the Groundwater Availability Model for the Central Portion of the Sparta, Queen City, and Carrizo-Wilcox Aquifers, Update to Improve Representation of the Transmissive Properties of the Simsboro Aquifer in the Vicinity of the Vista Ridge Well Field. Prepared for Groundwater Management Area 12 Members. October 2020. 30p.