GAM Runs 09-011, 09-012, and 09-24

by Ali H. Chowdhury, Ph.D., P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-0834
September 14, 2010

The seal on this document is authorized by Ali H. Chowdhury, P.G. 468 on September 14, 2010

EXECUTIVE SUMMARY

Three baseline predictive model simulations were run to assess the effects of pumping and drought on water levels and groundwater flow in the Edwards Group and Trinity aquifers located within Groundwater Management Area 9. In order to evaluate the sensitivity of changes in pumping to drawdown and groundwater flow, pumping was also increased and decreased (a spread analysis). The spread analysis of pumping included eighteen additional model simulations by increasing and decreasing the pumping amounts from the baseline by 10, 20, and 30 percent. Run 1 shows the effects of drought, run 2 shows the effects of average recharge, and run 3 shows the effects of increased pumping under average recharge.

Run 1 model simulation results show maximum impact to water levels, baseflow, and flow across the Balcones Fault Zone under drought conditions and reduced pumping. For example, water levels across the Groundwater Management Area 9 declined on an average by about 33 feet, baseflow reduced to 98,000 acre feet per year, and flow across the Balcones Fault Zone reduced to about 66,000 acre feet per year due to drought. Run 2 model simulation results show the least impact on water levels, baseflow, and flow across the Balcones Fault Zone under average recharge and reduced pumping. For example, water levels across the Groundwater Management Area 9 declined only by less than 1 foot, baseflow maintained at about 171,000 acre feet per year, and flow across the Balcones Fault Zone continued at 91,000 acre feet per year under average recharge conditions. Run 3 simulation results under increased pumping and average recharge conditions show less impact on water levels, baseflow, and flow across the Balcones Fault Zone than during drought conditions. For example, water levels across the Groundwater Management Area 9 declined on an average by about 15 feet, baseflow reduced to about 162,000 acre feet per year, and flow across the Balcones Fault Zone reduced to about 79,000 acre feet per year due to increased pumping.

Therefore, the model results suggest that even with implementing a reduction in pumping to 2008 pumping volumes during a repeat of a drought of record recharge event, reduced water levels in the aquifer and a decrease in flow from the aquifer to surface water and across the Balcones Fault Zone will occur. As to be expected, a reduction in pumping under average recharge conditions after a period of increased pumping results in a return to previous aquifer conditions. And finally increasing pumping from 2008 volumes results in a decline in water levels and flow to surface water and across the Balcones Fault Zone, yet these reductions to flow are not as severe under average recharge conditions as they would be if a drought of record recharge event occurred.

REQUESTOR:

Mr. Ron Fieseler, General Manager of the Blanco-Pedernales Groundwater Conservation District, on behalf of the groundwater conservation districts in Groundwater Management Area 9.

DESCRIPTION OF REQUEST:

Mr. Ron Fieseler on behalf of the Groundwater Management Area 9 requested that we do model runs to assess the effects of pumping and drought on water levels and groundwater flows in the Edwards Group (Plateau), and Upper-, Middle-, and Lower Trinity aquifers in 2060. He also requested us determine pumpage conditions that would allow water level declines of up to 45 feet in the Lower Trinity Aquifer.

METHODS:

Three baseline predictive model simulations using the Hill Country portion of the Trinity Aquifer model were run to assess the effects of drought and increased pumping on water levels, baseflow, and flow across the Balcones Fault Zone. In order to evaluate the sensitivity of changes in pumping to drawdown and groundwater flow, pumping was also increased and decreased (a spread analysis). The spread analyses consisted of eighteen additional model simulations by increasing and decreasing the pumping amounts from the baseline runs by 10, 20, and 30 percent. Run 1 shows the effects of drought and 2008 pumping volumes in all layers of the model, run 2 shows the effects of average recharge and 2008 pumping volumes in all layers of the model, and run 3 shows the effects of increased pumping in the Middle and Lower Trinity aquifers while maintaining 2008 pumping in the Edwards Group (Plateau) and Upper Trinity aquifers under average recharge conditions (Table 1). In model run 1, 1.5 times 2008 pumping in the Middle and Lower Trinity aquifers from 2009 to 2053 was assumed, and reduced pumping to 2008 levels from 2054 to 2060 was assumed. Average recharge from 2008 to 2053 and drought-of-record recharge from 2054 to 2060 was assumed. In model run 2, average recharge from 2008 to 2060 was assumed, and pumping was assumed the same as in Run 1. In model run 3, 1.5 times 2008 pumping in the Middle and Lower Trinity aquifers throughout the simulation from 2009 to 2060 under average recharge conditions was assumed (Table 1). Note that pumping amounts in the Edwards Group and the Upper Trinity aquifers were fixed to 2008 levels per the directive of Groundwater Management Area 9.

Table 1. Recharge and pumping assignment in model runs 1, 2, and 3.

Run	**Recharge**		**Pumping in Middle and Lower Trinity aquifers**	
	2008-2053 (stress period 1-46)	2054-2060 (stress period 47-53)	2009-2053 (stress period 2-46)	2054-2060 (stress period 47-53)
Run-1	Average recharge	Drought of record	1.5×2008 pumping	2008 pumping
Run-2	Average recharge	Average recharge	1.5×2008 pumping	2008 pumping
Run-3	Average recharge	Average recharge	1.5×2008 pumping	1.5×2008 pumping

PARAMETERS AND ASSUMPTIONS:

- The recently updated groundwater availability model (version 2.01) for the Hill Country portion of the Trinity Aquifer developed by Jones and others (2009) was used for these simulations.

- See Mace and others (2000) and Jones and others (2009) for details on model construction, recharge, discharge, assumptions, and limitations of the model.

- The model has four layers: layer 1 represents the Edwards Group (Plateau), layer 2 represents the Upper Trinity Aquifer, layer 3 represents the Middle Trinity Aquifer, and layer 4 represents the Lower Trinity Aquifer.

- The rivers, streams, and springs were simulated in the model using MODFLOW's Drain package. MODFLOW's Drain package was also used to simulate spring discharge along bedding contacts of the Edwards Group (Plateau) and the Upper Trinity Aquifer in the northwestern parts of the model area. This resulted in the assignment of numerous drain cells along this outcrop contact.

- Pumpage used for the predictive period was developed as per instruction of the groundwater conservation districts located in Groundwater Management Area 9.

- The predictive model has a total of 53 stress periods (2008 to 2060) with the first stress period representing 2008 conditions.

- Average recharge was developed using annual recharge information for 1980 to 1997 that was used to calibrate historical portions of the model (Jones and others, 2009).

- Drought-of-record recharge refers to climatic conditions that occurred during the historical period of drought of the 1950s. During 1950 to 1956, a 7-year drought period, the mean annual precipitation was about two thirds (22 inches) of the long-term 100-year mean annual precipitation of 33 inches. During the last three years of the drought, the mean annual precipitation was less than half (13.9 inches) of the long-term 100-year mean annual precipitation (Mace and others, 2000). Drought-of-record recharge was developed using rainfall data for years 1950 through 1956 for the Hill Country area, percentages of rainfall used for estimating recharge, and proportional amount of streamflow loss through the Cibolo Creek watershed and Cibolo Creek (Jones and others, 2009). More details on recharge estimation through the Cibolo Creek watershed and the Cibolo Creek are presented elsewhere (Jones and others, 2009; Ockerman, 2007). Note that within the drought-of-record a few years have higher than average precipitation and therefore, were assigned higher than average recharge.

- The model was run in Processing MODFLOW for Windows (version 5.3; Chiang and Kinzelbach, 1998)

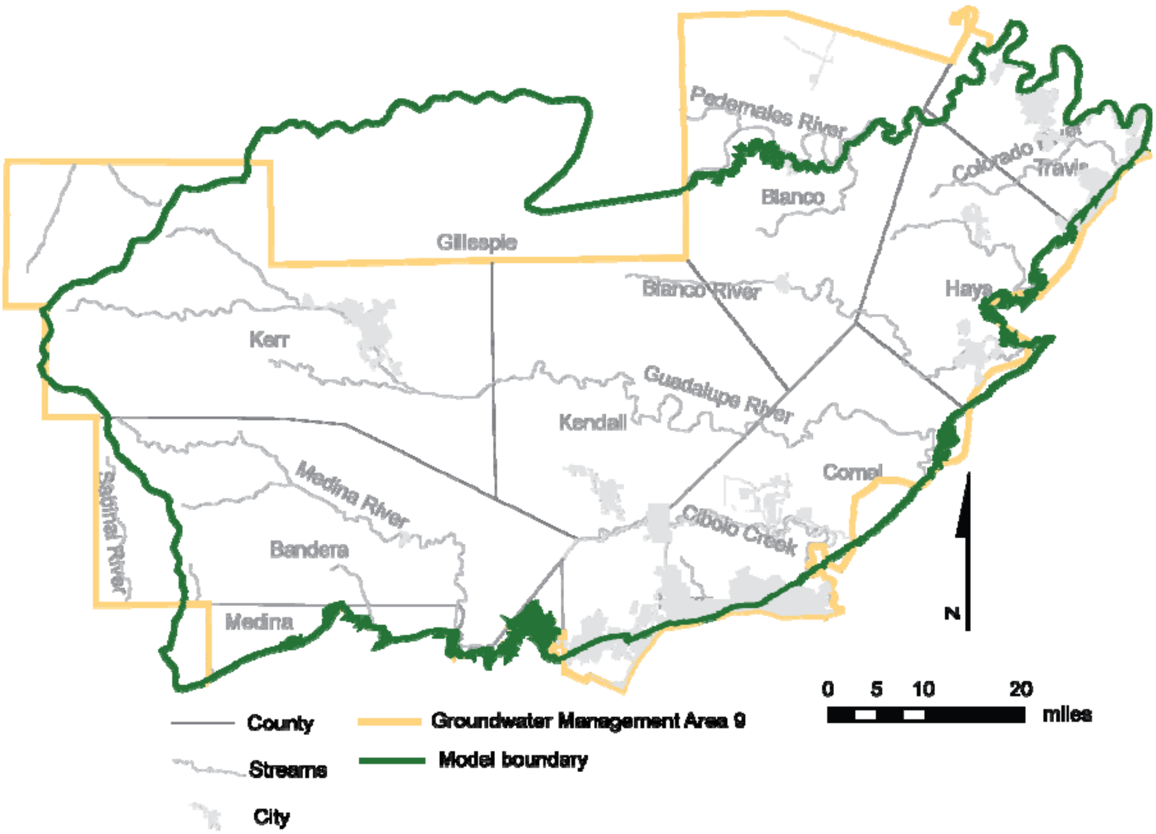

Figure 1. Map showing parts and full county areas and major streams in Groundwater Management Area 9. Outlines of Groundwater Management Area 9 and the model boundary are also shown. Note the groundwater model boundary also includes areas outside Groundwater Management Area 9.

RESULTS:

Among the three predictive model runs, the drought has the most severe impact on water levels, baseflow, and flow across the Balcones Fault Zone. Under drought conditions, water levels, baseflow, and flow across the Balcones Fault Zone are reduced much greater than increased pumping condition under average recharge.

In the run 1 model simulation under drought recharge and 2008 pumping, water levels across Groundwater Management Area 9 declined on average 33 feet, baseflow reduced to 98,000 acre feet per year, and flow across the Balcones Fault Zone reduced to about 66,000 acre feet per year. In the run 2 model simulation under average recharge and 2008 pumping, water levels across Groundwater Management Area 9 declined only by less than 1 foot, baseflow remained at about 171,000 acre feet per year, and flow across the Balcones Fault Zone continued at 91,000 acre feet per year. In the run 3 model simulation under average recharge and increased pumping, water levels across Groundwater Management Area 9 declined on average 15 feet, baseflow reduced to about 162,000 acre feet per year, and flow across the Balcones Fault Zone reduced to about 79,000 acre feet per year (Table 2). Table 3 lists the average water level declines calculated by county for each of the 3 baseline model simulations.

Table 2. Model simulation results for runs 1, 2 and 3 for Groundwater Management Area 9.

Run number (pumpage multiplier)	[1]Pumping in 2060 (acre feet per year)	[2]Pumping in 2060 (acre feet per year)	Edwards Group of the Edwards-Trinity (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	[3]Overall average
Average water level decline (feet)							
1 (1.0)	64,798	61,248	15	40	33	33	33
2 (1.0)	64,798	61,893	0	0	1	1	1
3 (1.0)	94,277	89,921	0	0	22	22	15
Baseflow to rivers and springs (acre feet per year)							
1 (1.0)	64,798	61,248	33,258	43,034	22,016	0	98,309
2 (1.0)	64,798	61,893	51,766	71,872	47,344	0	170,982
3 (1.0)	94,277	89,921	51,764	71,687	38,820	0	162,270
Flow to the Edwards (Balcones Fault Zone) Aquifer (acre feet per year)							
1 (1.0)	64,798	61,248	0	31,382	34,849	0	66,230
2 (1.0)	64,798	61,893	0	38,236	52,292	0	90,528
3 (1.0)	94,277	89,921	0	37,939	40,939	0	78,878

[1]Pumping values as assigned in the input MODFLOW well file.

[2]Pumping values reported are derived from MODFLOW output data. Note that pumping in the output files are reduced due to the presence of dry cells over small areas mainly in Bexar, Kerr, Kendall, and Comal counties.

[3]Overall average water level decline values were calculated for the entire Groundwater Management Area 9 by considering all active cells in all the aquifers within the model domain.

Table 3. Average water level declines by county for runs 1, 2 and 3 under baseline conditions. As noted in Figure 1, not all counties are fully represented in the model. Blanks denote the aquifer is not modeled or does not extend to the corresponding county. A negative value indicates a rise in average water levels. Note that the average water level decline by aquifer reported here may not exactly match with those reported in Table 2 and in the appendix because different methods were applied in determining the average.

Run number	Counties	Water level decline (feet)				
		Edwards Group	Upper Trinity	Middle Trinity	Lower Trinity	Average
Run 1	Bandera	14	41	28	28	28
	Bexar		21	70	71	41
	Blanco		43	38	37	29
	Comal		-4	28	29	13
	Hays		19	16	16	13
	Kendall	8	94	45	46	48
	Kerr	16	28	28	27	25
	Medina		19	15	15	12
	Travis		49	17	17	21
	Average	13	34	32	32	26
Run 2	Bandera	0	0	5	5	2
	Bexar		0	0	0	0
	Blanco		0	0	0	0
	Comal		0	0	0	0
	Hays		0	0	0	0
	Kendall	0	0	-1	-1	0
	Kerr	0	0	1	0	0
	Medina		0	2	2	1
	Travis		0	0	0	0
	Average	0	0	1	1	0
Run 3	Bandera	0	0	25	25	12
	Bexar		0	34	34	17
	Blanco		0	7	7	4
	Comal		0	11	11	6
	Hays		0	10	10	5
	Kendall	0	0	13	13	7
	Kerr	0	0	42	43	21
	Medina		0	13	13	7
	Travis		0	15	15	8
	Average	0	0	19	19	10

To further quantify the differences between the runs, we plotted differences in water levels between the runs. For example, runs 1 and 2 have different recharge (drought versus average) while pumping remains the same in both runs. Therefore, water level declines between the two runs could be attributed solely to changes in recharge (Figure 2). Differences in average water levels of up to about 13 feet occur in the Edwards Group, about 38 feet for the Upper Trinity, and about 30 feet for the Middle and Lower Trinity aquifers, respectively. Water levels recover in the Middle and Lower Trinity aquifers by up to about 5 feet at 30 percent less pumping relative to pumping equivalent to 2008 volumes and show smaller changes at increased pumping by up 30 percent from the 2008 baseline pumping volumes (Figure 2). Smaller changes at higher pumping may be due to the occurrence of an increased number of dry cells and may be an artifact of the method used to calculate average water levels since we excluded dry cells in our process.

We also compared water level declines due to differences in pumping (Figure 3). When we compare water level declines between runs 2 and 3 (2008 baseline versus increased pumping in the Middle and Lower Trinity aquifers), we note linear water level changes due to differences in pumping with about 15 feet at the lowest pumping and 25 feet at the maximum pumping (Figure 3).

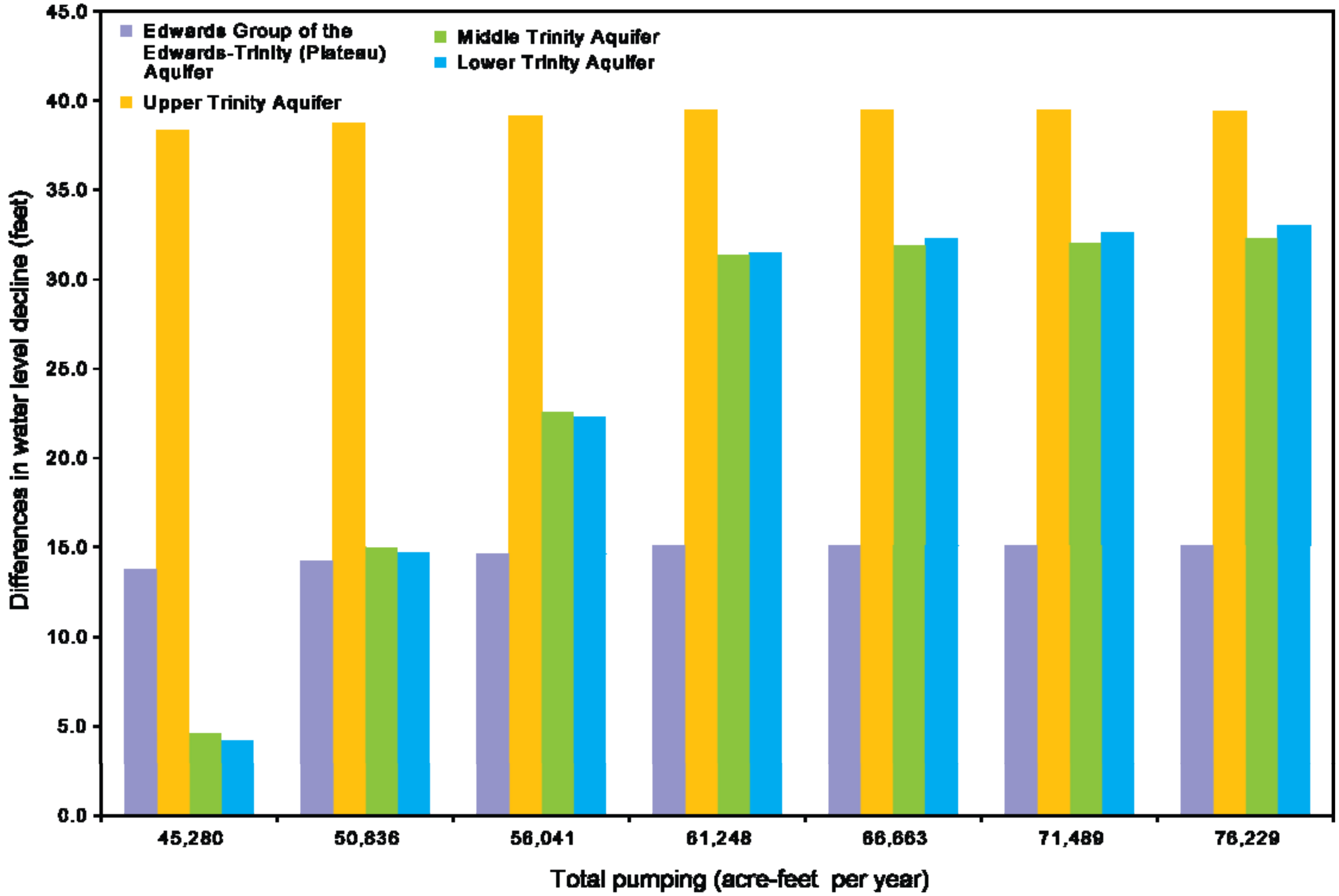

Figure 2. Plot of differences in average water level declines for 2060 between runs 1 and 2.

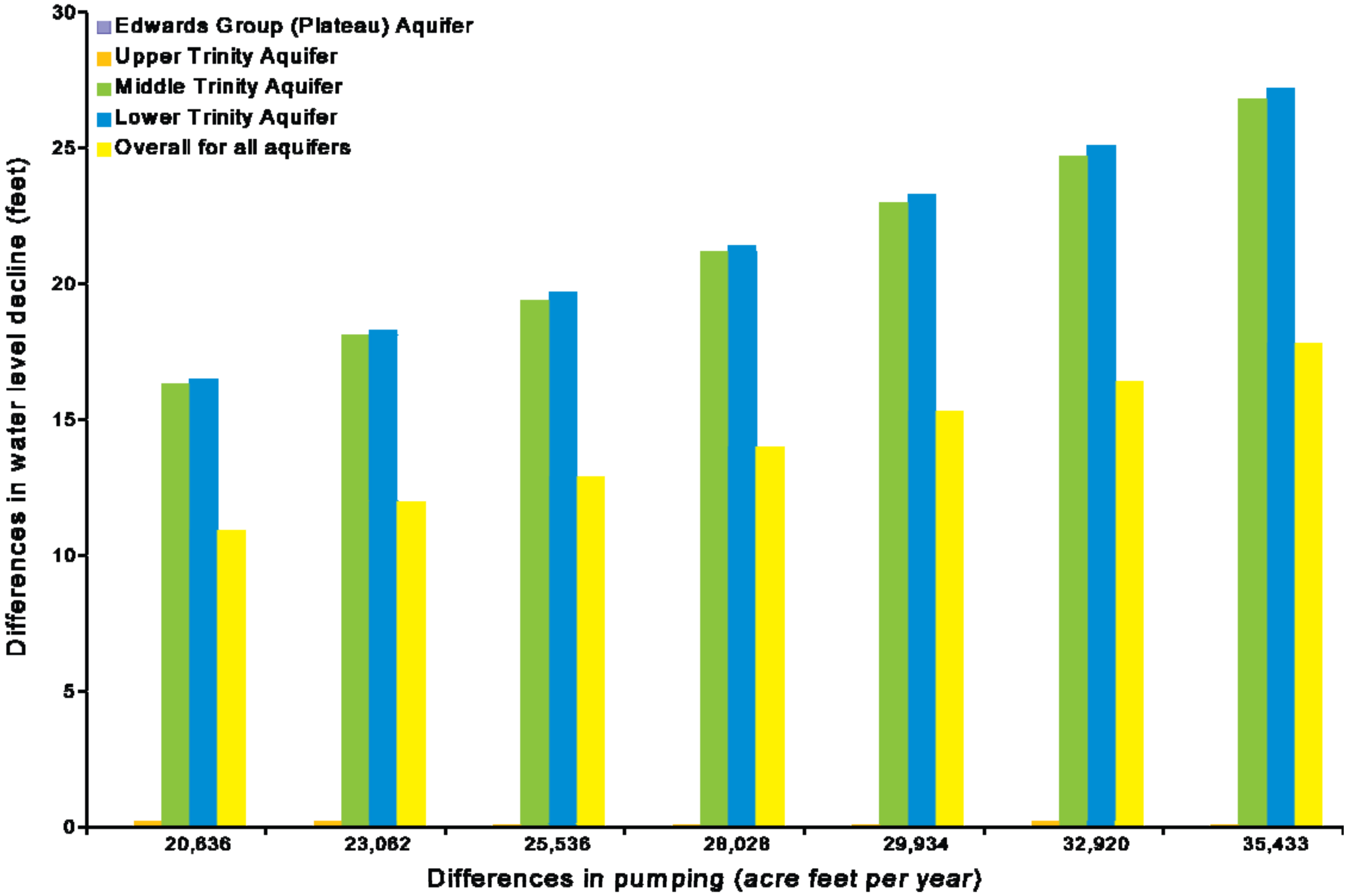

Figure 3. Plot of differences in total pumping versus average water level declines in 2060 between runs 2 and 3.

RFERENCES:

Chiang, W.H. and Kinzelbach, W., 1998, Processing Modflow: A simulation system for modeling groundwater flow and pollution: Hamburgh, Zurich, variously paginated.

Jones, I.C., Anaya, R., and Wade, S., 2009, Groundwater Availability Model for the Hill Country portion of the Trinity Aquifer System, Texas, Texas Water Development Board unpublished report,193 p.

Mace, R.E., Chowdhury, A.H., Anaya, R., and Way, S-C., 2000, Groundwater availability of the Trinity Aquifer, Hill Country Area, Texas—Numerical simulations through 2050: Texas Water Development Board Report 353, 119 p.

Ockerman, D. J., 2007, Simulation of streamflow and estimation of groundwater recharge in the Upper Cibolo Creek watershed, south central Texas, U.S. Geological Survey Scientific Investigations Report 2007-5202, 31

Appendix
Spread Analyses

Table 1. Pumping distribution by aquifers and counties for 2008 within Groundwater Management Area 9. Pumping amount and their distribution into the aquifers were provided by Groundwater Management Area 9.

County	Edwards Group of the Edwards-Trinity (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	Total pumping (county)
Bandera	592	270	3,349	483	**4,693**
Bexar	0	842	17,146	240	**18,228**
Blanco	0	77	1,477	0	**1,554**
Comal	0	398	5,788	0	**6,186**
Hays	0	416	4,412	449	**5,278**
Kendall	313	314	5,704	325	**6,657**
Kerr	1,035	213	6,263	5,534	**13,045**
Medina	0	43	361	733	**1,136**
Travis	0	551	4,967	0	**5,519**
Total pumping (aquifer)	**1,940**	**3,123**	**49,467**	**7,765**	**62,295**

Table 2. Model simulation results for Run 1. Average water level decline, baseflow to rivers and springs, and flow to the Edwards (Balcones Fault Zone) Aquifer in 2060 for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer, and the Upper-, Middle-, and Lower Trinity aquifers under a 10, 20, and 30 percent reduction and 10, 20, and 30 percent increase in pumping from the desired baseline pumping condition as provided by the groundwater conservation districts located in Groundwater Management Area 9. Water level decline values were calculated with respect to simulated water levels in 2008 under baseline pumping condition. Pumping is reported in acre-feet per year.

Multipliers used for pumping adjustments	[1]Pumping in 2060	[2]Pumping in 2060	Edwards Group of the Edwards-Trinity (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	[3]Overall average
Average water level decline (feet)							
0.7	45,358	45,280	14	39	17	17	23
0.8	51,012	50,836	15	39	23	23	26
0.9	58,293	56,041	15	39	27	27	29
1	64,798	61,248	15	40	33	33	33
1.1	71,278	66,663	15	40	40	40	38
1.2	77,757	71,489	15	40	42	43	40
1.3	84,237	76,229	16	40	48	49	44
Baseflow to rivers and springs (acre feet per year)							
0.7	45,358	45,280	33,934	43,468	25,782	0	103,184
0.8	51,012	50,836	33,709	43,223	24,456	0	101,388
0.9	58,293	56,041	33,483	43,137	23,272	0	99,892
1	64,798	61,248	33,258	43,034	22,016	0	98,309
1.1	71,278	66,663	33,035	42,949	20,532	0	96,516
1.2	77,757	71,489	32,813	42,816	19,486	0	95,115
1.3	84,237	76,229	32,590	42,731	18,371	0	93,692
Groundwater Flow to the Edwards (Balcones Fault Zone) Aquifer (acre feet per year)							
0.7	45,358	45,280	0	31,949	42,348	0	74,297
0.8	51,012	50,836	0	31,755	39,852	0	71,607
0.9	58,293	56,041	0	31,570	37,409	0	68,979
1	64,798	61,248	0	31,382	34,849	0	66,230
1.1	71,278	66,663	0	31,204	32,266	0	63,386
1.2	77,757	71,489	0	31,025	29,952	0	60,977
1.3	84,237	76,229	0	30,856	27,575	0	58,431

[1]Pumping values as assigned in the input MODFLOW well file.
[2]Pumping values reported are derived from MODFLOW output data. Note that pumping in the output files are reduced due to the presence of dry cells over small areas mainly in Bexar, Kerr, Kendall, and Comal counties. Note discrepancies between pumpage from MODFLOWs well file and output data increase with increases in pumping values. There are smaller differences between the two pumpage values at decreased pumpage from baseline.
[3]Overall average water level decline values were calculated for the entire Groundwater Management Area 9 by considering all active cells in all the aquifers within the model domain.

Table 3. Model simulation results for Run 2. Average water level decline, baseflow to rivers and springs, and flow to the Edwards (Balcones Fault Zone) Aquifers in 2060 in the Edwards Group (Plateau), and Upper-, Middle-, and Lower Trinity aquifers under a 10,-20, and 30 percent reduction and 10, 20, and 30 percent increase in pumping from the desired baseline pumping condition. Average water level decline values were calculated with respect to simulated water levels in 2008 under baseline pumping condition.

[1]Pumping in 2060 (ac-ft/yr)	[2]Pumping in 2060 (ac-ft/yr)	Multipliers used to adjust input pumping file	Edwards Group (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	[3]Overall average
Average water level decline (feet)							
45,358	45,358	0.7	-1	-1	-13	-13	-9
51,121	51,012	0.8	0	0	-8	-8	-5
58,293	56,327	0.9	0	0	-4	-4	-3
64,798	61,893	1	0	0	1	1	1
71,278	67,841	1.1	0	0	8	8	5
77,757	72,846	1.2	0	0	10	10	7
84,237	78,455	1.3	0	0	16	16	11
Baseflow to rivers and springs (acre-feet per year)							
45,358	45,358	0.7	52,493	72,334	53,253		178,081
51,121	51,012	0.8	52,250	72,169	51,148		175,568
58,293	56,327	0.9	52,008	72,032	49,313		173,353
64,798	61,893	1	51,766	71,872	47,344		170,982
71,278	67,841	1.1	51,524	71,702	45,051		168,278
77,757	72,846	1.2	51,282	71,557	43,563		166,402
84,237	78,455	1.3	51,042	71,425	41,810		164,276
Groundwater flow to the Edwards (Balcones Fault Zone) Aquifer (acre-feet per year)							
45,358	45,358	0.7	0	38,769	59,219	0	97,988
51,121	51,012	0.8	0	38,590	56,888	0	95,478
58,293	56,327	0.9	0	38,415	54,666	0	93,080
64,798	61,893	1	0	38,236	52,292	0	90,528
71,278	67,841	1.1	0	38,054	49,773	0	87,827
77,757	72,846	1.2	0	37,877	47,590	0	85,467
84,237	78,455	1.3	0	37,696	45,073	0	82,769

[1]Pumping values as assigned in the input MODFLOW well file.

[2]Pumping values reported are derived from MODFLOW output data. Note that pumping in the output files are reduced due to the presence of dry cells over small areas mainly in Bexar, Kerr, Kendall, and Comal counties..

[3]Overall average water level decline values were calculated for the entire Groundwater Management Area 9 by considering all active cells in all the aquifers within the model domain

Table 4. Model simulation results for Run 3. Average water level decline, baseflow to rivers and springs, and flow to the Edwards (Balcones Fault Zone) Aquifers in 2060 in the Edwards Group (Plateau), and Upper-, Middle-, and Lower Trinity aquifers under a 10,-20, and 30 percent reduction and 10, 20, and 30 percent increase in pumping from the desired baseline pumping condition. Average water level decline values were calculated with respect to simulated water levels in 2008 under baseline pumping condition.

[1]Pumping in 2060 (ac-ft/yr)	[2]Pumping in 2060 (ac-ft/yr)	Multipliers used to adjust input pumping file	Edwards Group (Plateau) Aquifer	Upper Trinity Aquifer	Middle Trinity Aquifer	Lower Trinity Aquifer	[3]Overall average
Average water level decline (feet)							
65,994	65,994	0.7	-1	0	3	4	2
75,422	74,183	0.8	0	0	10	10	7
84,850	81,863	0.9	0	0	15	15	10
94,277	89,921	1	0	0	22	22	15
103,706	97,775	1.1	0	0	31	31	21
113,133	105,766	1.2	0	0	35	35	23
122,561	113,888	1.3	1	0	43	43	28
Baseflow to rivers and springs (acre feet per year)							
65,994	65,994	0.7	52,489	72,162	46,099	0	170,750
75,422	74,183	0.8	52,246	71,991	43,404	0	167,641
84,850	81,863	0.9	52,005	71,845	41,173	0	165,202
94,277	89,921	1	51,764	71,687	38,820	0	162,270
103,706	97,775	1.1	51,523	71,510	36,218	0	159,252
113,133	105,766	1.2	51,282	71,348	34,328	0	156,959
122,561	113,888	1.3	51,042	71,213	32,210	0	154,456
Groundwater flow to the Edwards (Balcones Fault Zone) Aquifer (acre feet per year)							
65,994	65,994	0.7	0	38,565	51,479	0	90,044
75,422	74,183	0.8	0	38,356	47,977	0	86,332
84,850	81,863	0.9	0	38,148	44,547	0	82,695
94,277	89,921	1	0	37,939	40,939	0	78,878
103,706	97,775	1.1	0	37,727	37,104	0	74,831
113,133	105,766	1.2	0	37,523	33,641	0	71,164
122,561	113,888	1.3	0	37,316	29,814	0	67,130

[1]Pumping values as assigned in the input MODFLOW well file.

[2]Pumping values reported are derived from MODFLOW output data. Note that pumping in the output files are reduced due to the presence of dry cells over small areas mainly in Bexar, Kerr, Kendall, and Comal counties..

[3]Overall average water level decline values were calculated for the entire Groundwater Management Area 9 by considering all active cells in all the aquifers within the model domain

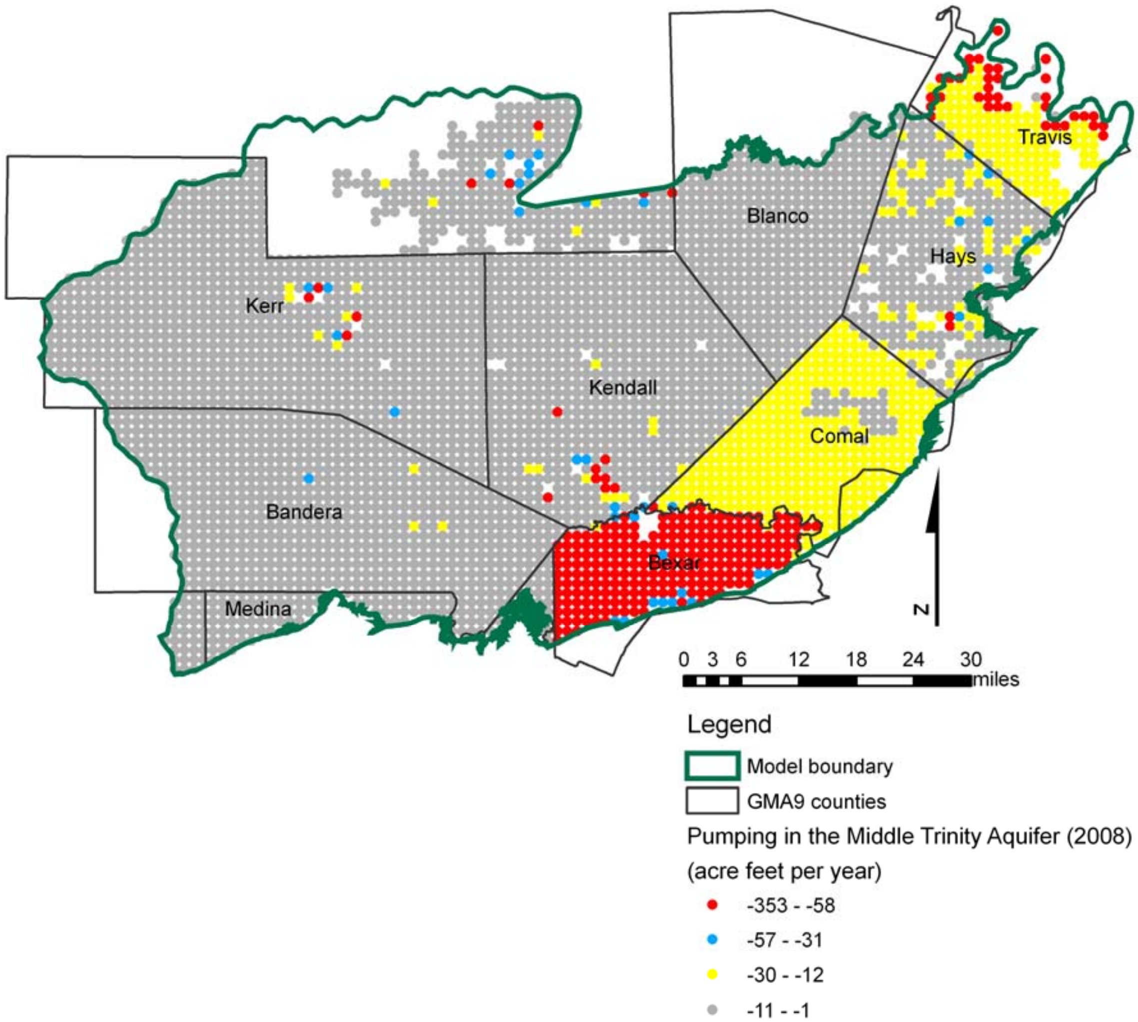

Figure 1. Map showing pumping distribution in the Middle Trinity Aquifer for 2008. Estimated pumping and their distribution in the aquifer are based on information provided by the Groundwater Management Area 9. Note that pumping is generally higher in the east along the Balcones Fault Zone in Bexar, Comal and Travis counties. Higher pumping also occurs locally in Kerr and Kendall counties. Note that the red color areas show pumping over a broad range, from 58 to 353 acre-feet per year.

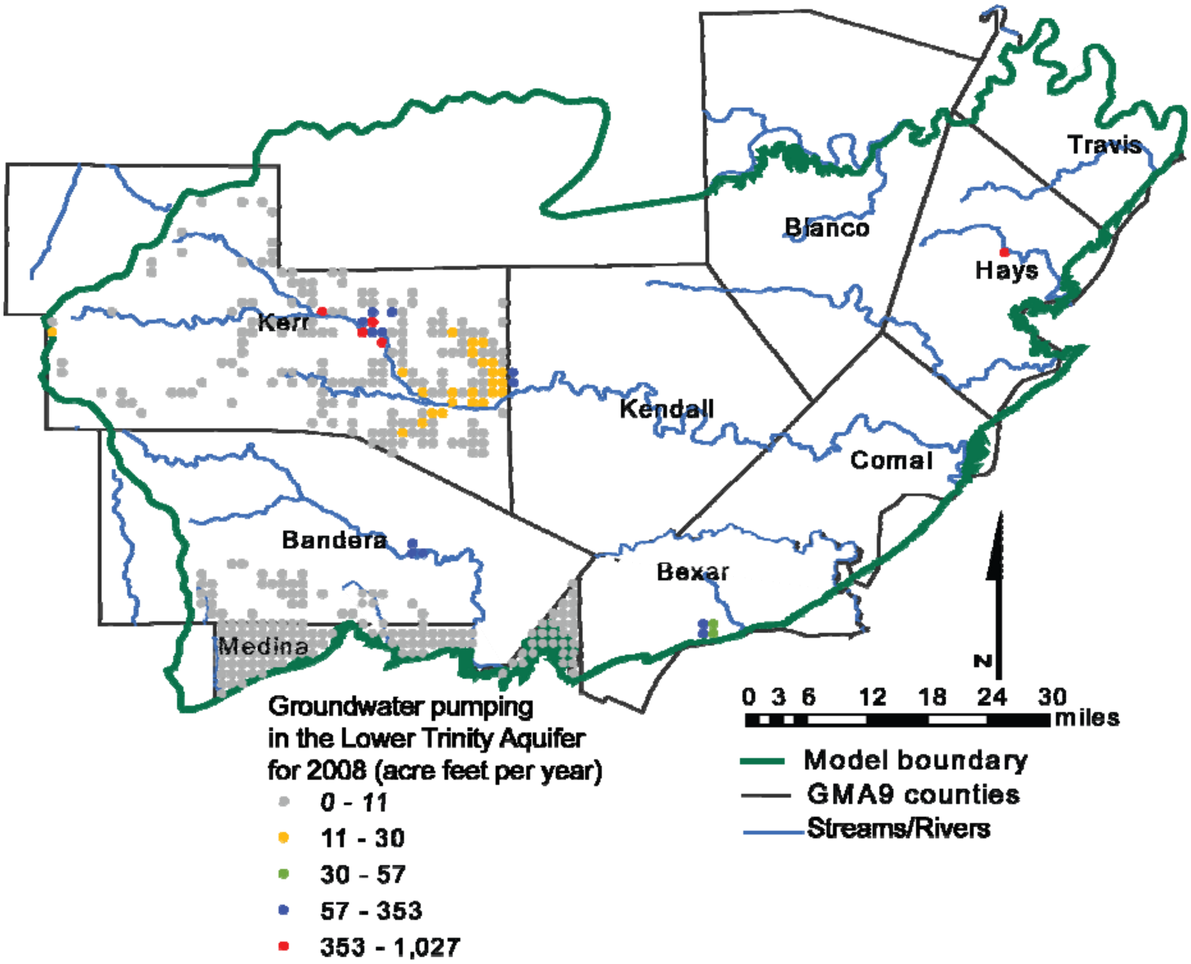

Figure 2. Map of groundwater pumping distribution in the Lower Trinity Aquifer for 2008. Note that most of the pumping in the Lower Trinity Aquifer occurs to the west of the model area in Kerr, Bandera and Medina counties with local high pumping in Hays and Bexar counties

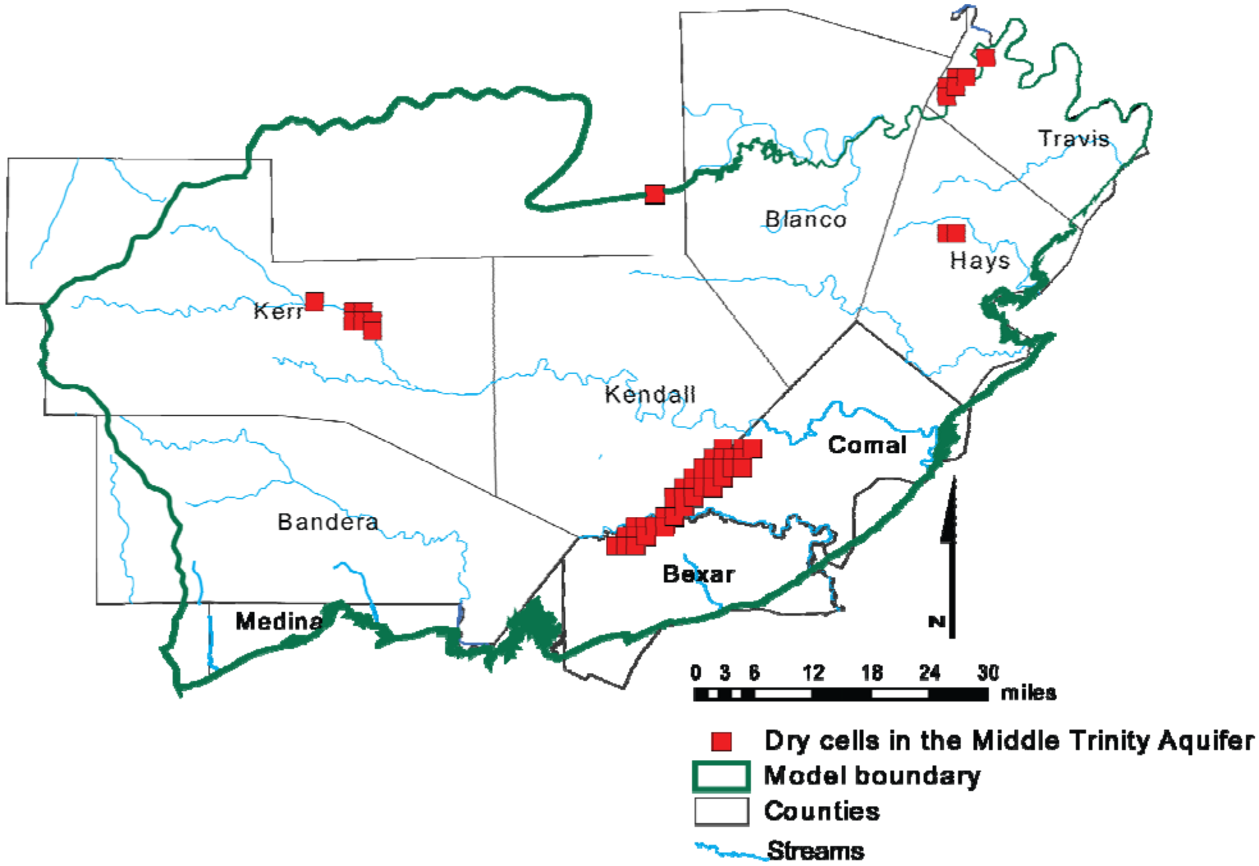

Figure 3. Map showing dry cells in the Middle Trinity Aquifer in 2060 under drought-of-record recharge and 30 percent additional pumping from baseline pumping. Note baseline pumping refers to 2008 pumping for the Edwards Group of the Edwards-Trinity (Plateau) Aquifer and the Upper Trinity aquifers, and 50 percent additional pumping in the Middle and Lower Trinity aquifers from 2008 pumping. Dry cells occur along county lines of Bexar, Comal, and Kendall counties and locally in Kerr, Hays and Travis counties.

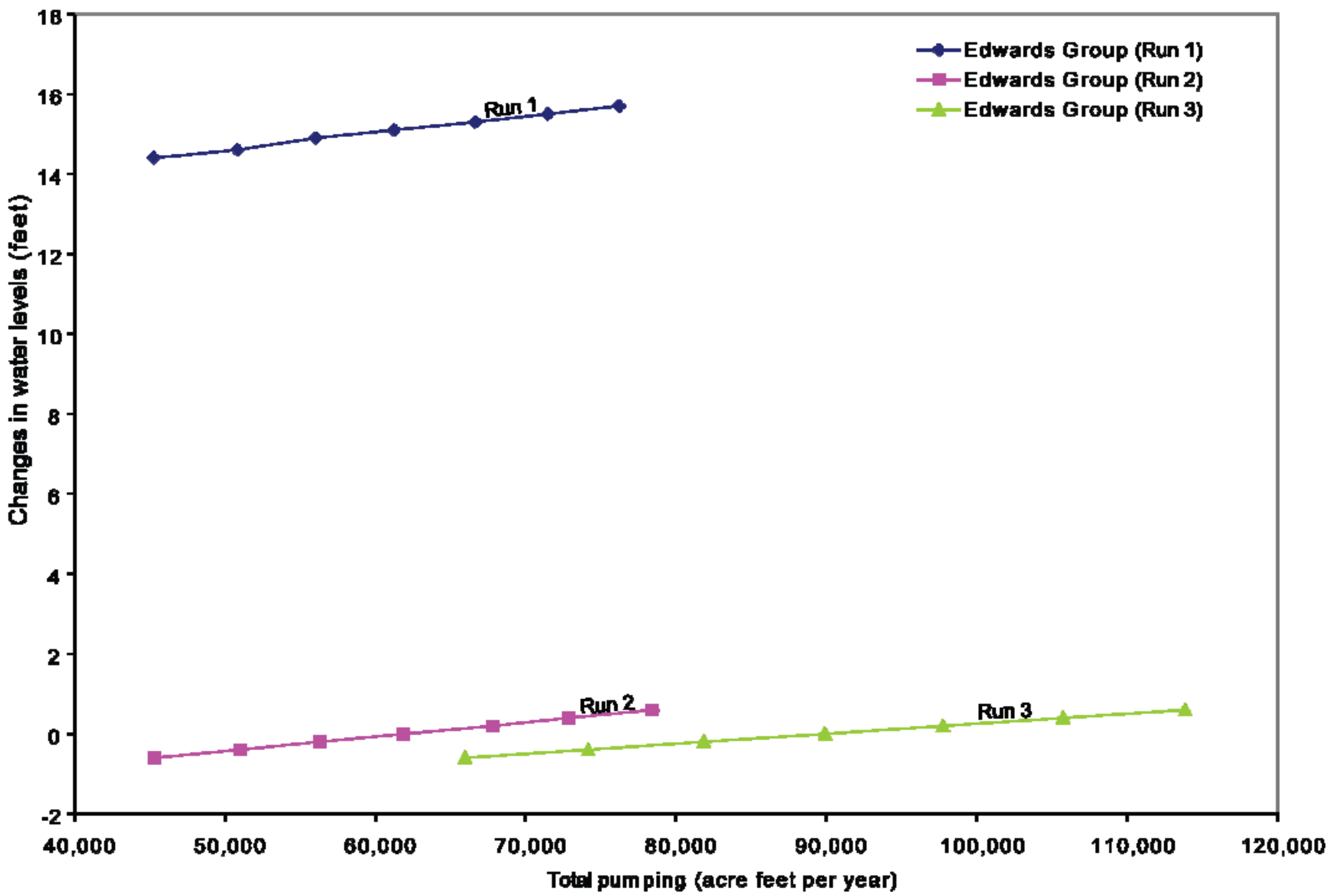

Figure 4. Model simulation results from runs 1, 2, and 3. Average water level decline in the Edwards Group of the Edwards-Trinity (Plateau) Aquifer plotted against total pumping for the portions of Groundwater Management Area 9 located within the active model domain. Total pumping refers to the sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau) Aquifer, and the Upper-, Middle-, and Lower Trinity aquifers. Note positive water level changes are water level decline and negative water level changes are water level recovery in the aquifer. Note maximum water level decline in the aquifer occur under drought conditions (run 1).

.

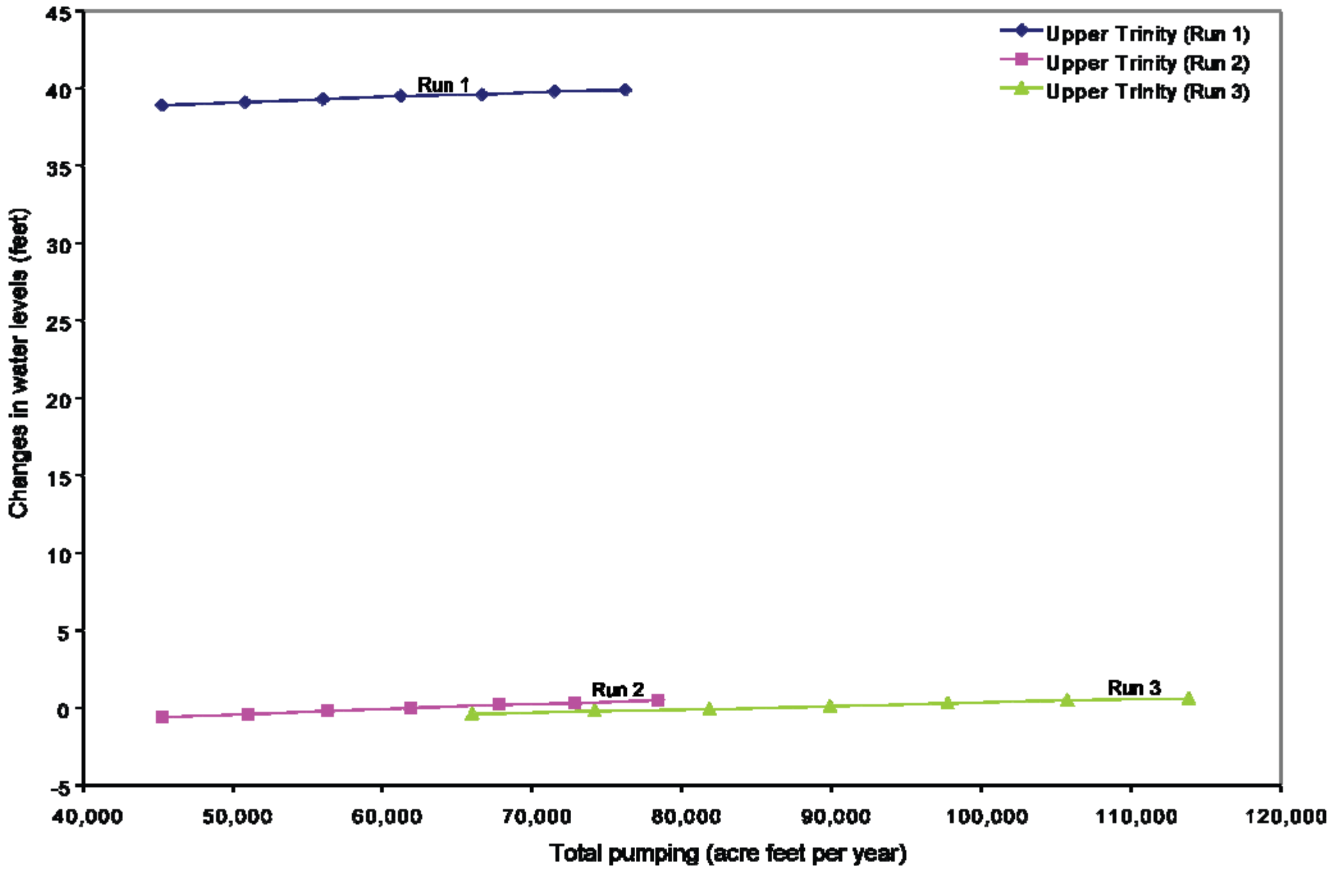

Figure 5. Model simulation results from runs 1, 2, and 3. Average water level decline in the Upper Trinity Aquifer plotted against total pumping in the model for Groundwater Management Area 9. Total pumping refers to sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau), and Upper-, Middle-, and Lower Trinity aquifers. Note positive water level changes are water level decline and negative water level changes are water level recovery in the aquifer. Note maximum water level decline in the aquifer occur under drought conditions (run 1).

.

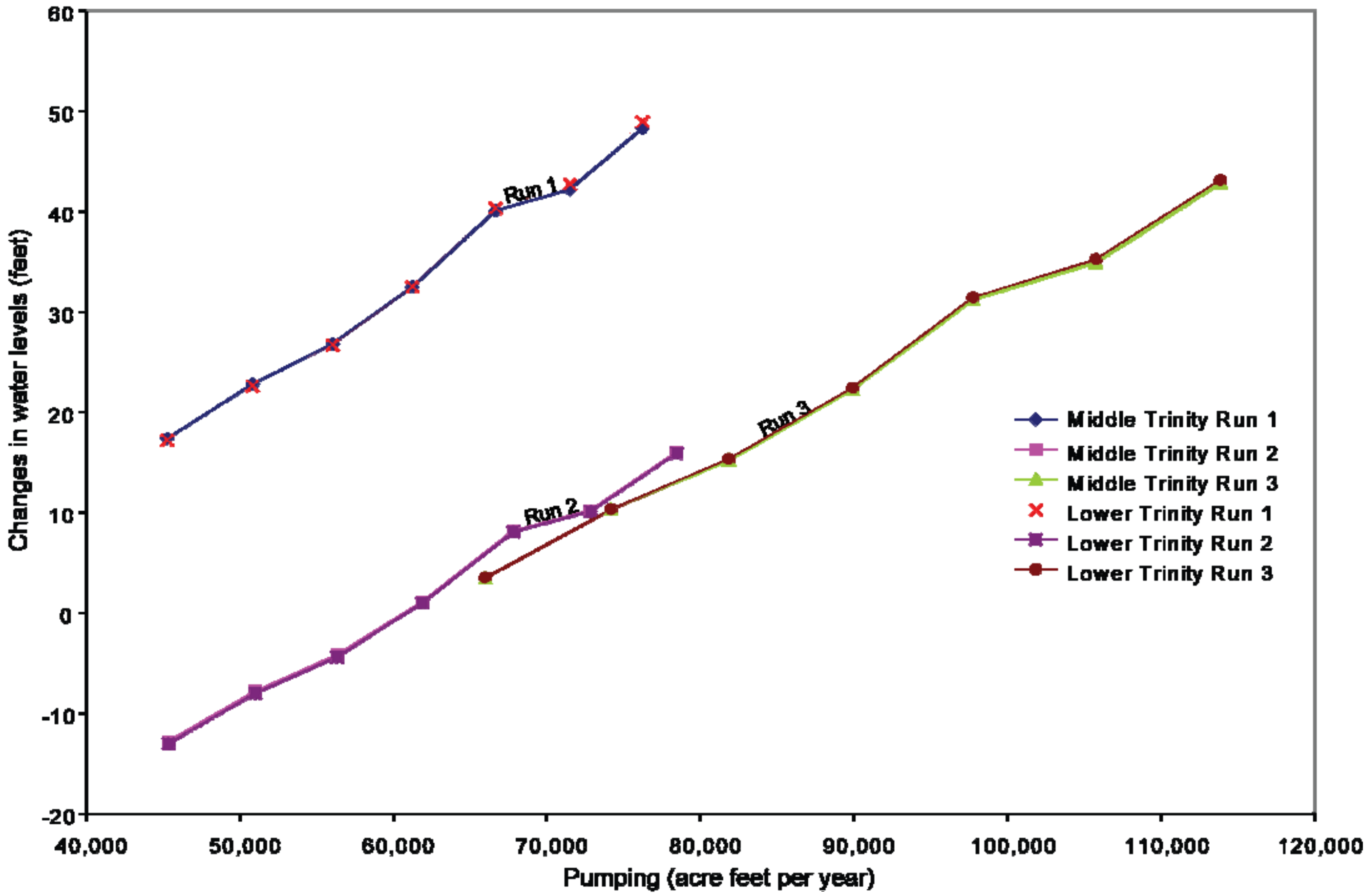

Figure 6. Model simulation results from runs 1, 2, and 3. Average water level declines in the Middle and Lower Trinity aquifers plotted against total pumping in the Groundwater Management Area 9. Total pumping refers to sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau), and Upper-, Middle-, and Lower Trinity aquifers. Note positive water level changes are water level decline and negative water level changes are water level recovery in the aquifer. Note maximum water level decline in the aquifer occur under drought conditions (run 1). Also note no significant differences in water level decline between the Middle and Lower Trinity aquifers.

.

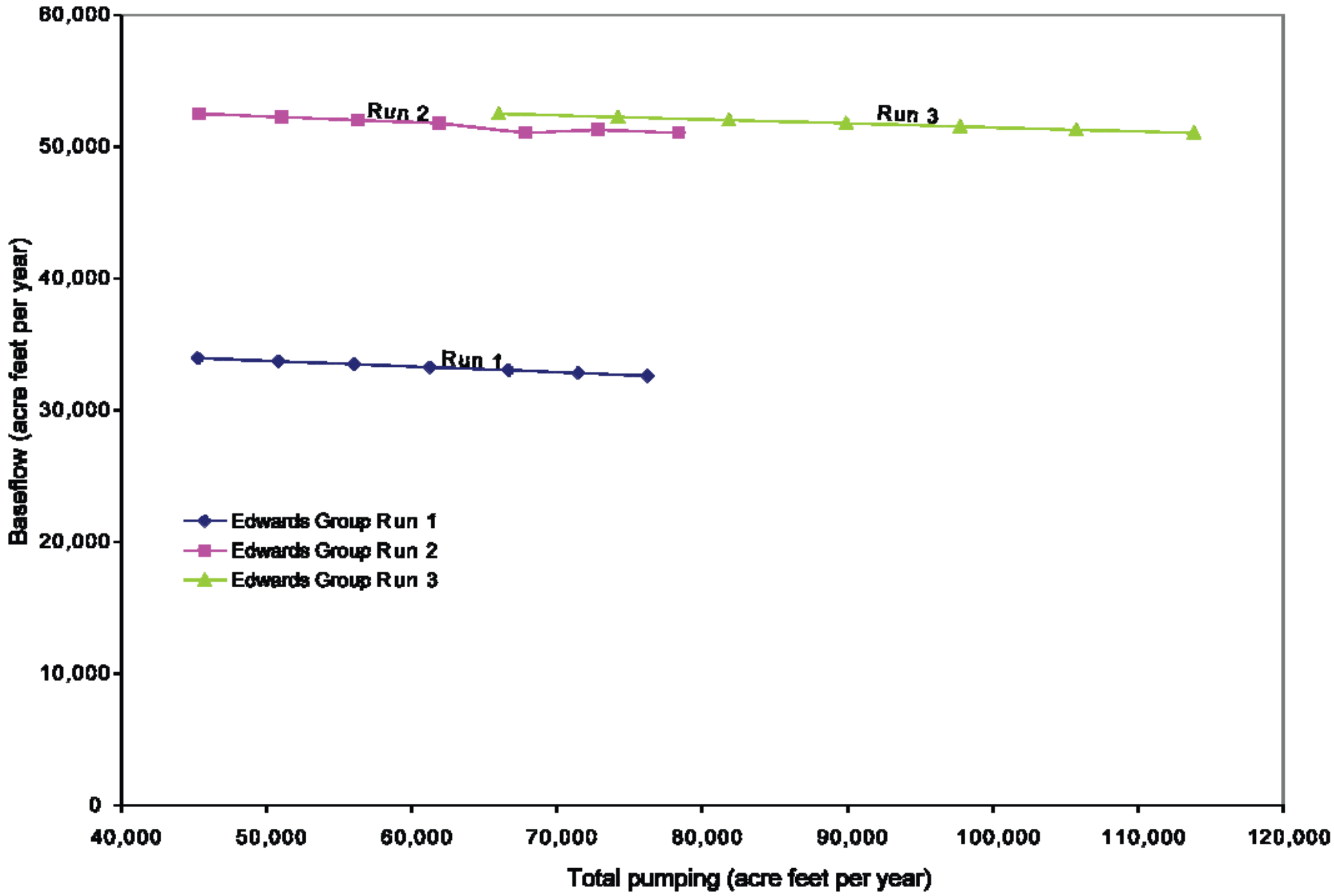

Figure 7. Model simulation results from runs 1, 2 and 3. Average baseflow to the rivers and springs in the Edwards Group of the Edwards-Trinity (Plateau) Aquifer plotted against total pumping for the portions of Groundwater Management Area 9 located within the active model domain. Total pumping refers to the sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau) , and Upper-, Middle-, and Lower Trinity aquifers. Note maximum baseflow reduction under drought conditions (run 1). Baseflow from the rivers and springs also remain steady due to changes in pumping by up to 30 percent from baseline.

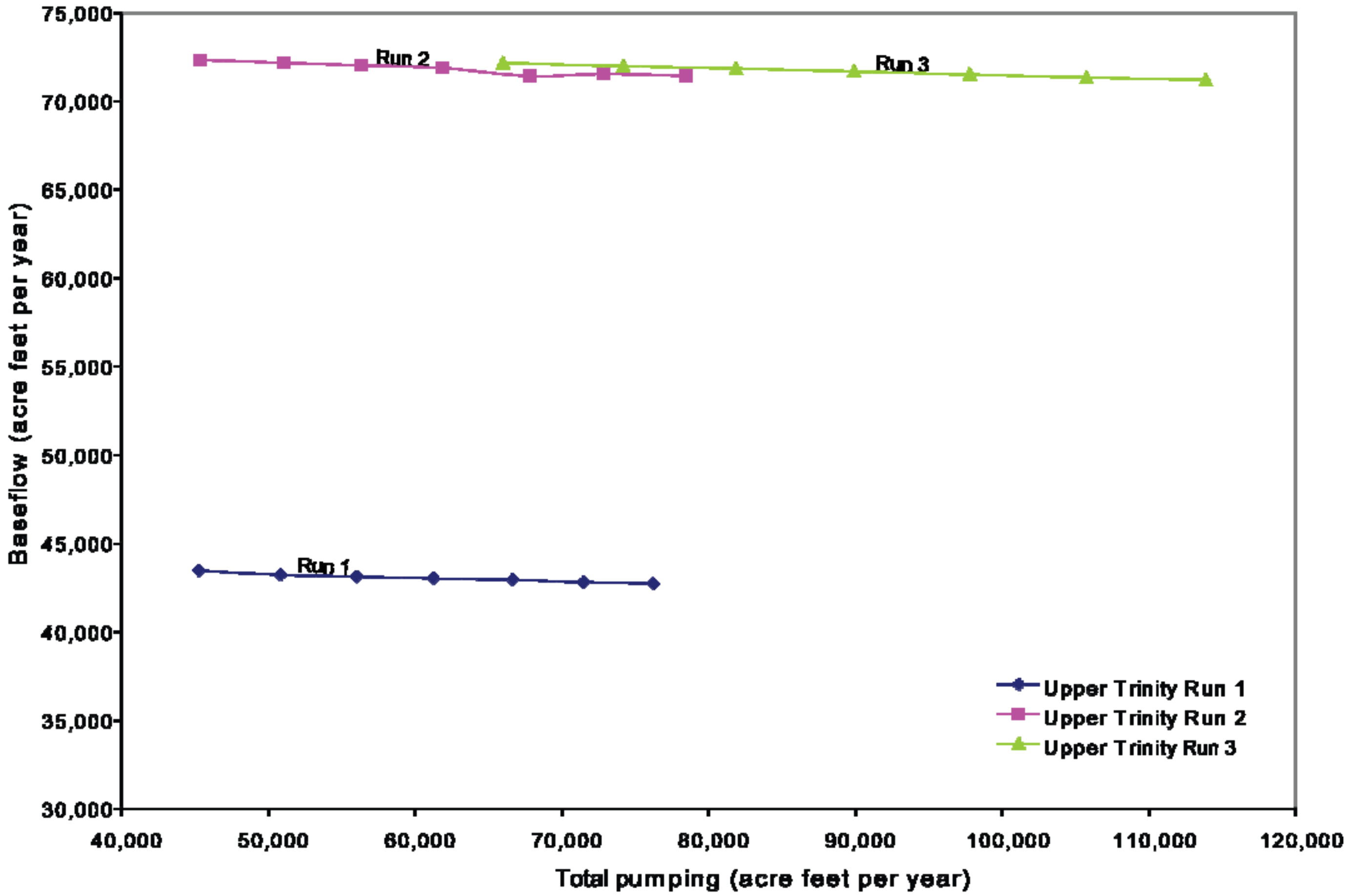

Figure 8. Model simulation results from runs 1, 2 and 3. Average baseflow to the rivers and springs in the Upper Trinity Aquifer plotted against total pumping for the portions of Groundwater Management Area 9 located within the active model domain. Total pumping refers to the sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau) , and Upper-, Middle-, and Lower Trinity aquifers. Note maximum baseflow reduction under drought conditions (run 1). Baseflow from the rivers and springs also remain steady due to changes in pumping by up to 30 percent from baseline.

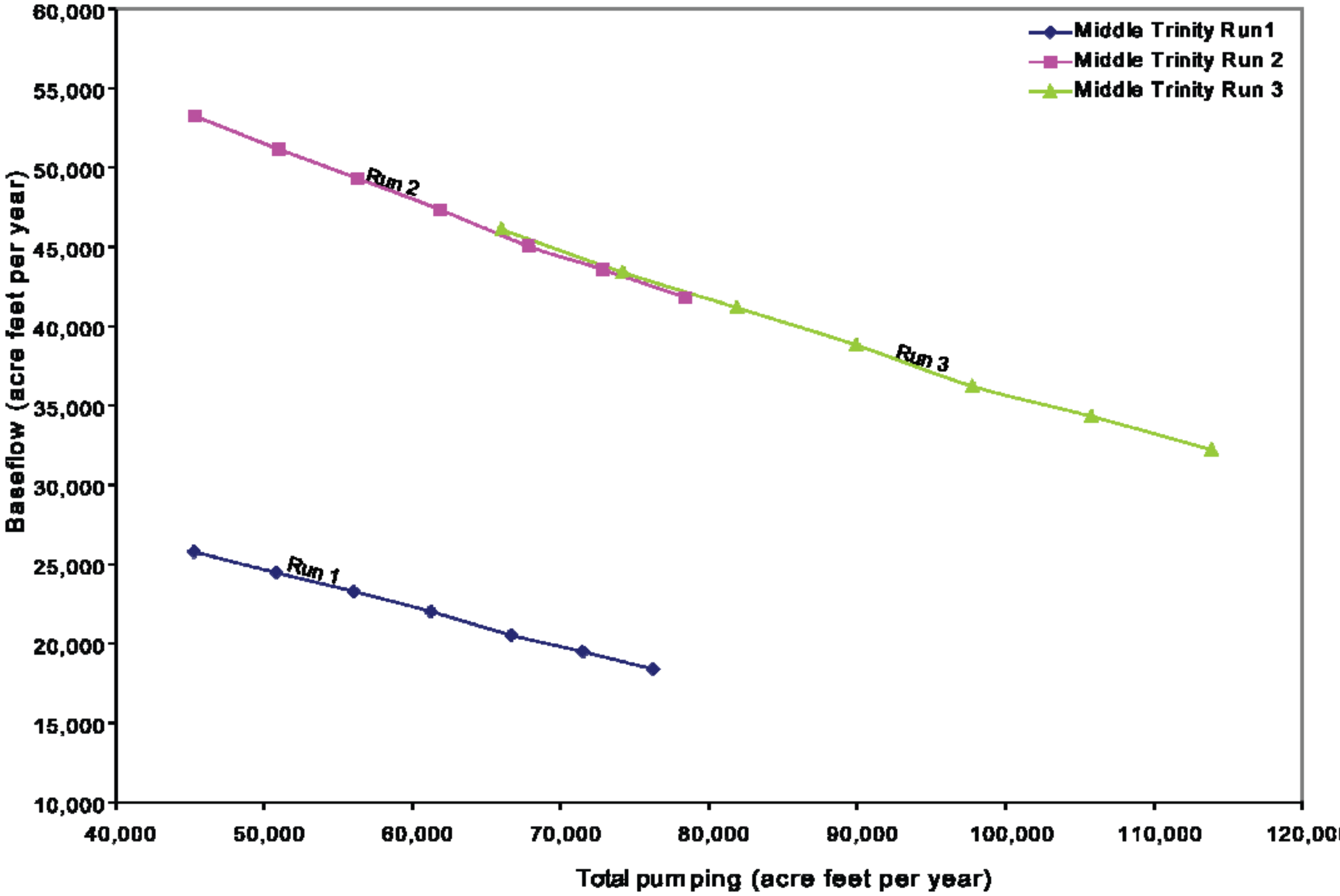

Figure 9. Model simulation results from runs 1, 2 and 3. Average baseflow to the rivers and springs in the Middle Trinity Aquifer plotted against total pumping for the portions of Groundwater Management Area 9 located within the active model domain. Total pumping refers to the sum of pumping in all four model layers representing the Edwards Group of the Edwards-Trinity (Plateau) , and Upper-, Middle-, and Lower Trinity aquifers. Note maximum baseflow reduction under drought conditions (run 1). Baseflow from the rivers and springs proportionately changes in baseflow with changes in pumping by up to 30 percent from baseline.