GAM Run 06-12

by Shirley Wade, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
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July 31, 2006

REQUESTOR:

Mr. Dave Hamilton on behalf of the Saratoga Underground Water Conservation District (the District) in Lampasas County.

EXECUTIVE SUMMARY:

We used the groundwater availability model (GAM) for the northern part of the Trinity aquifer to estimate drawdowns in Lampasas County and surrounding counties resulting from incrementally increased pumping rates. We estimated drawdowns after fifty years of pumping for both average and drought-of-record recharge conditions. We noted the following observations based on the results.

- Maintaining 1999 pumpage patterns for a 50-year simulation leads to zero to twenty feet of water-level drawdowns in Lampasas County by 2050.
- Increasing pumping in only Lampasas County leads to approximately one foot of additional drawdown per 10 percent additional pumping (when the pumping is increased up to 200 percent).
- Increasing pumping model-wide leads to approximately one foot of additional drawdown per one percent additional pumping (when the pumping is increased up to 50 percent).
- About 50 percent of the additional water for increased pumping in (only) Lampasas County is derived from storage, about 35 percent from reduced evapotranspiration, and the remainder from changes in lateral flow.

DESCRIPTION OF REQUEST:

Mr. Hamilton requested a GAM run to help the District make decisions about their desired future conditions for the Trinity aquifer. Mr. Hamilton requested that we incrementally increase pumping in Lampasas County and plot the changes in water levels as a function of the increased pumping under average and drought-of-record conditions. He also requested that we adjust pumping in other counties to show effects of regional changes in pumping.

METHODS:

To determine an appropriate year for the baseline pumping we plotted water levels in several wells in Lampasas County. These plots demonstrated that water levels were reasonably stable through the late 1990s so we based pumping on 1999, the latest year of the model calibration period. The locations of three of the wells are shown in Figure 1 and the hydrographs are shown in Figure 2.

We used the GAM for the northern part of the Trinity aquifer (Bené and others, 2004) and ran the model for a 50-year predictive simulation (2000 through 2049). First we increased pumping in only Lampasas County by approximately 50, 100, and 200 percent of the 1999 pumpage and plotted maps of increased drawdown compared with the baseline 2050 pumping distribution. We then increased model-wide pumping by 10, 20, and 50 percent of the 1999 pumpage and plotted maps of increased drawdown compared against the 2050 baseline results. The model runs were made using both average and drought-of-record recharge conditions. The scenarios are summarized in Table 1.

PARAMETERS AND ASSUMPTIONS:

- See Bené and others (2004) for assumptions and limitations of the GAM.

- The model includes seven layers, representing the Woodbine aquifer (Layer 1), the Washita and Fredericksburg Series (Layer 2), the Paluxy aquifer (Layer 3), the Glen Rose Formation (Layer 4), the Hensell aquifer (Layer 5), the Pearsall/Cow Creek/Hammett/Sligo Formation (Layer 6), and the Hosston aquifer (Layer 7). The Woodbine, Paluxy, Hensell, and Hosston layers are the main aquifers used in the region. All layers except the Woodbine are present in Lampasas County.

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) for the four main aquifers in the model (Woodbine, Paluxy, Hensell, and Hosston) for the calibration and verification time periods (1980 to 2000) ranged from approximately 37 to 75 feet. The root mean squared error was less than ten percent of the maximum head drop in the model (Bené and others, 2004).

- The average annual recharge conditions are based on climate data from 1980 to 1999 for each of the simulations. The drought-of-record recharge conditions were based on precipitation that occurred during 1954 though 1956.

- The model uses the MODFLOW stream package to simulate the interaction between the aquifer(s) and major rivers and streams flowing in the region. Flow both from the stream to the aquifer and from the aquifer to the stream is allowed, and the direction of flow is determined by the water levels in the aquifer and stream during each stress period in the simulation. The only stream or river included in the model in Lampasas County is the Lampasas River.

- The increased pumping was uniformly distributed to model cells that contained pumping in 1999. If a model cell did not have pumping in the baseline scenario it would not have pumping in the predictive scenarios. The intent of this approach was to account for the possibility that additional groundwater pumping would not necessarily come from only existing wells, but reasons for excluding areas from distributed pumping in the original pumping distribution would remain valid.

RESULTS:

We summarized the scenarios and simulated pumping amounts in Table 2 including (1) the total pumping amount simulated in just Lampasas County for all of the Trinity aquifer, (2) the total pumping for the entire model for all of the Trinity and Woodbine aquifers, and (3) the maximum increase in drawdown in Lampasas County in addition to the zero to 20 feet drawdown from the baseline scenario using 1999 pumpage patterns and amounts. We included maps only for the Hensell and Hosston aquifers (Layers 5 and 7 respectively) because these are the two aquifers with the most pumping and where significant drawdown occurred in Lampasas County. Water levels for the Hensell and Hosston aquifers in 2050 assuming baseline (1999) pumping and average recharge for 50 years are shown in Figures 3 and 4, respectively. For Scenarios 2 through 4 (Figures 5 through 10) the maximum additional drawdown will be about one foot per 10 percent increase in pumping. For Scenarios 5 through 7 (Figures 11 through 16) the maximum additional drawdown will be about one foot per one percent increase in pumping.

Water levels in 2050 assuming baseline (1999) pumping and drought-of-record recharge conditions from 2047 through 2050 are shown in Figures 17 and 18. Drawdowns for the drought-of-record scenarios were very similar to the drawdowns for the average recharge scenarios so those maps are not shown in this report. However, the results for the drought-of-record scenarios are included in the water budget table (Table 3). The components of the budgets shown in Table 3 include:

- Wells—this component is water pumped from wells in each aquifer.

- Streams—this is the total water entering the aquifer (inflow) through streams, or total water exiting the aquifer (outflow) to streams.

- Recharge—this is the areally distributed recharge due to precipitation falling on the outcrop areas of each aquifer.

- Lateral flow —this component describes lateral flow within each aquifer between Lampasas County and adjacent counties.

- Change in storage—this component is the change of water stored in each aquifer. Negative change in storage is water that is removed from storage in the aquifer (that is, water levels decline). Positive change in storage is water that is added back into storage in the aquifer (that is, water levels increase). Change in storage is the net sum of water both going into and out of the aquifer because water levels will decline in some areas (water is being removed from storage) and will rise in others (water is being added to storage).

- ET (evapotranspiration) – ET is typically water lost due to evaporation and transpiration by plants. However, in the GAM for the northern part of the Trinity aquifer this component also represents groundwater discharge via small seeps and springs and larger spring discharge to streams not specifically modeled by the Stream package (Bené and others, 2004).

The model water budgets in Lampasas County for Scenarios 1 through 4 and 8 through 11 are listed in Table 3. The water budgets for Scenarios 1, 3, and 4 are shown graphically in Figure 19. Scenarios 8, 10, and 11 are shown graphically in Figure 20.

POSSIBLE CONSEQUENCES:

- About 50 percent of the additional water for increased pumping in Lampasas County is derived from storage (water levels decline), about 35 percent from reduced evapotranspiration (ET), and the remainder from changes in lateral flow. This suggests there will be less water available for plants, seeps, springs, and small streams. The change in lateral flow suggests a change in flow between surrounding counties. For example, if the pumpage in the surrounding counties were to remain as they were in 1999 and Lampasas County increased its pumpage, then the flow of groundwater to Bell and Coryell may decrease and more water may flow from Mills, Hamilton, and Burnet into Lampasas County.

- The amount of water going to streams remains virtually unchanged for the pumping scenarios; however, a greater amount of water is discharged to streams during average conditions compared with drought-of-record conditions.

- Slightly less water flows towards Coryell County as pumping in Lampasas is incrementally increased. However, that trend assumes that pumping does not also increase in Coryell County.

REFERENCES:

Bené, J., Harden, B., O'Rourke, D., Donnelly, A., and Yelderman, J., 2004, Northern Trinity/Woodbine Groundwater Availability Model: contract report to the Texas Water Development Board by R.W. Harden and Associates, 391 p.

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Table 1. Summary of modeling scenarios

Scenario Number	Recharge	Pumpage
1	Average	Baseline- 1999 pumpage
2	Average	50 percent increase in Lampasas County
3	Average	100 percent increase in Lampasas County
4	Average	200 percent increase in Lampasas County
5	Average	10 percent increase in entire model
6	Average	20 percent increase in entire model
7	Average	50 percent increase in entire model
8	Drought of record	Baseline- 1999 pumpage
9	Drought of record	50 percent increase in Lampasas County
10	Drought of record	100 percent increase in Lampasas County
11	Drought of record	200 percent increase in Lampasas County
12	Drought of record	10 percent increase in entire model
13	Drought of record	20 percent increase in entire model
14	Drought of record	50 percent increase in entire model

Table 2. Pumping scenarios.

Scenario	Recharge	Lampasas increased pumping (percent)	Model-wide increased pumping (percent)	Total pumping in Lampasas County (acre-feet per year)	Total model-wide pumping (acre-feet per year)	Maximum additional Lampasas drawdown (feet)
1 baseline	Average	0	0	1,139	193,268	0
2	Average	~ 50	0	1,647	193,776	5
3	Average	~ 100	0	2,151	194,280	10
4	Average	~ 200	0	3,164	195,293	19
5	Average	10	10	1,253	212,596	10
6	Average	20	20	1,367	231,843	20
7	Average	50	50	1,709	289,641	40
8 baseline	Drought of record	0	0	1,139	193,268	0
9	Drought of record	~ 50	0	1,647	193,776	5
10	Drought of record	~ 100	0	2,151	194,280	10
11	Drought of record	~ 200	0	3,164	195,293	19
12	Drought of record	10	10	1,253	212,468	10
13	Drought of record	20	20	1,367	231,805	20
14	Drought of record	50	50	1,709	289,641	40

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Table 3. Water budget for scenarios with pumping incrementally increased in Lampasas County. See text for descriptions of water budget terms. Positive water budget terms indicate flow into the aquifer; negative values indicate flow out of the aquifer. All values are reported in acre-feet per year.

Scenario	Well Pumpage	Rivers and Streams	Recharge	ET	Change in Storage	Lateral Flow				
						Bell	Burnet	Coryell	Hamilton	Mills
1	-1,139	-1,915	45,351	-41,222	-1,417	-305	263	-3,363	391	522
2	-1,647	-1,906	45,351	-41,056	-1,660	-303	273	-3,322	405	546
3	-2,151	-1,898	45,351	-40,896	-1,906	-302	282	-3,283	420	571
4	-3,164	-1,881	45,351	-40,579	-2,418	-299	300	-3,210	447	617
8	-1,139	-1,421	18,779	-20,955	-7,236	-306	256	-3,366	391	524
9	-1,647	-1,409	18,779	-20,823	-7,510	-305	266	-3,325	405	547
10	-2,151	-1,397	18,779	-20,694	-7,785	-303	276	-3,286	419	573
11	-3,164	-1,375	18,779	-20,439	-8,352	-300	294	-3,213	447	619

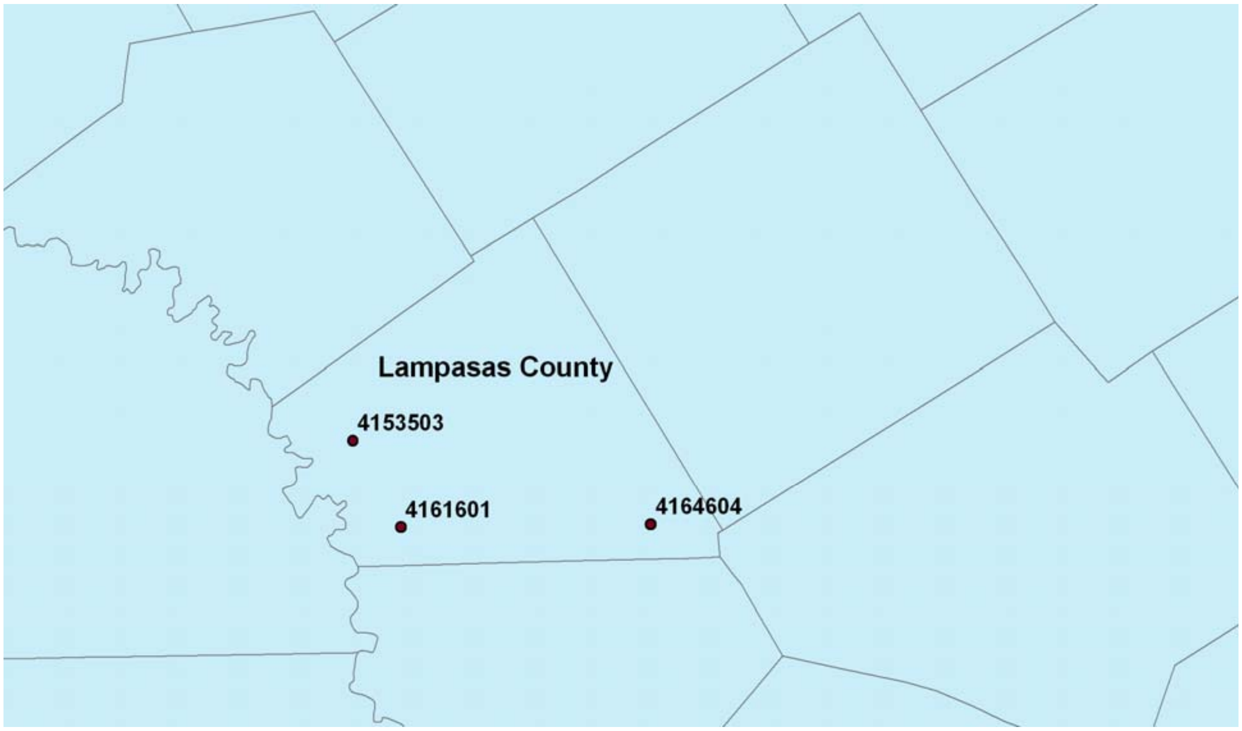

Figure 1. Location of hydrographs shown in Figure 2.

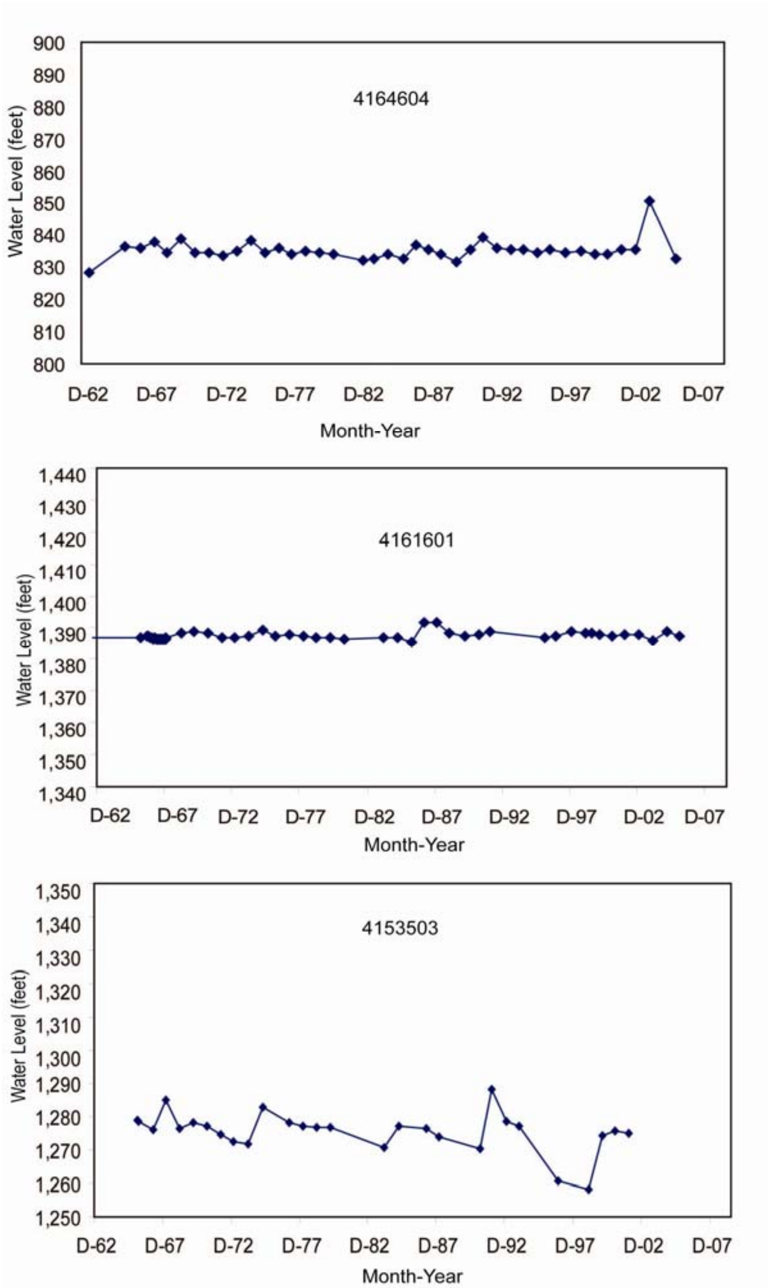

Figure 2. Water levels at select wells through 2002. These hydrographs demonstrate that water levels through the late 1990s were reasonably stable in Lampasas County.

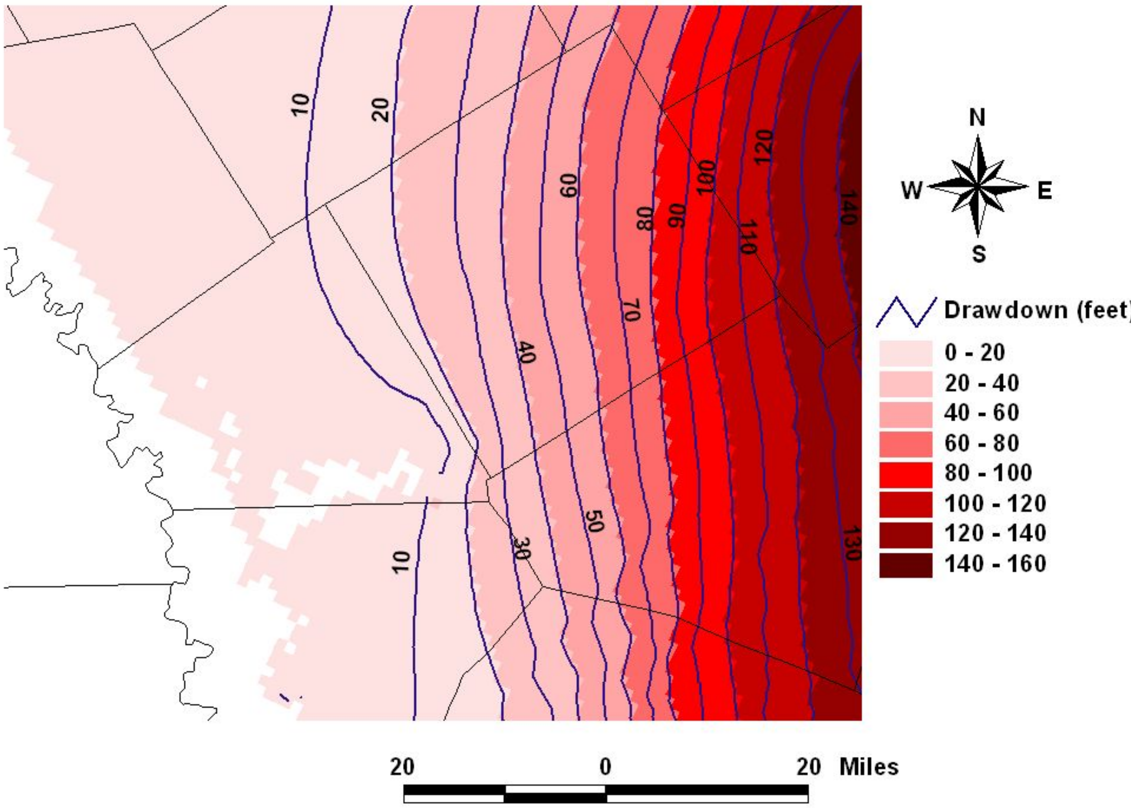

Figure 3. Water level drawdowns for the Hensell aquifer in Lampasas County assuming 1999 pumpage amounts and distribution after 50 years. Contour interval in 10 feet.

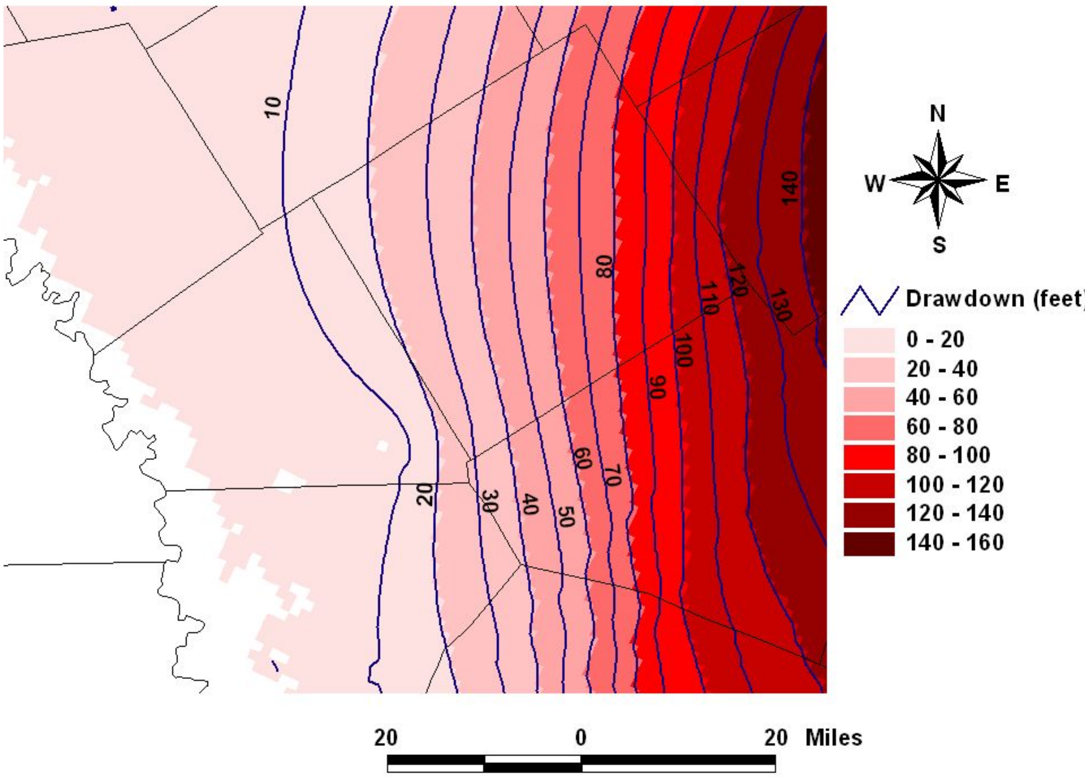

Figure 4. Water level drawdowns for the Hosston aquifer in Lampasas County assuming 1999 pumpage amounts and distribution after 50 years. Contour interval in 10 feet.

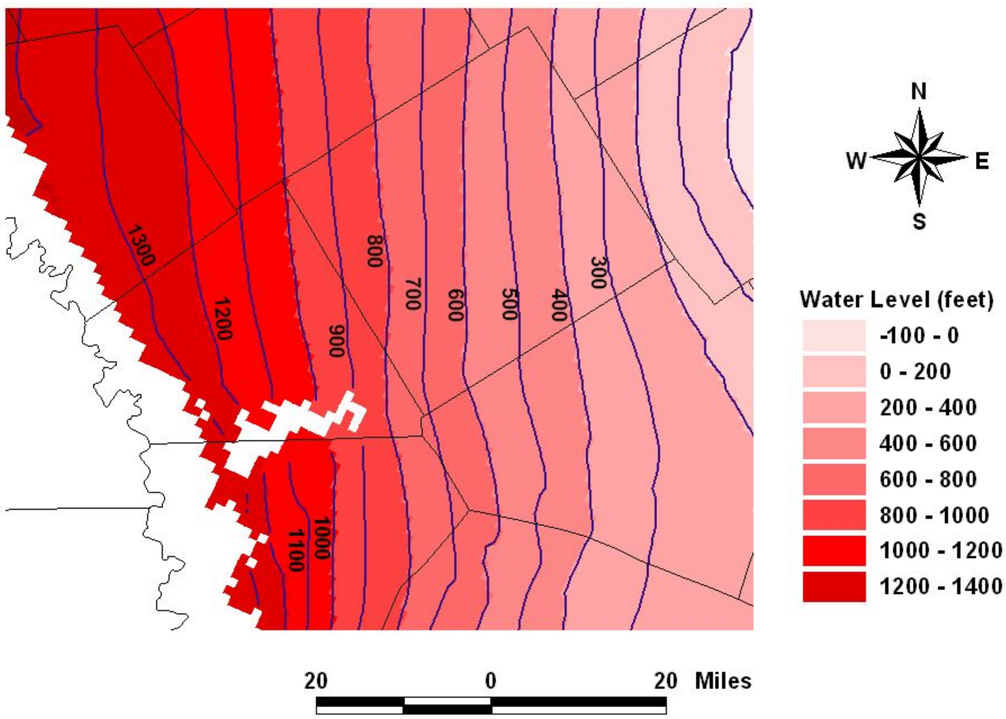

Figure 5. 2050 simulated water elevations in the Hensell (Layer 5) aquifer using 1999 pumpage for the 50-year predictive simulation and average precipitation. The contour interval is 100 feet.

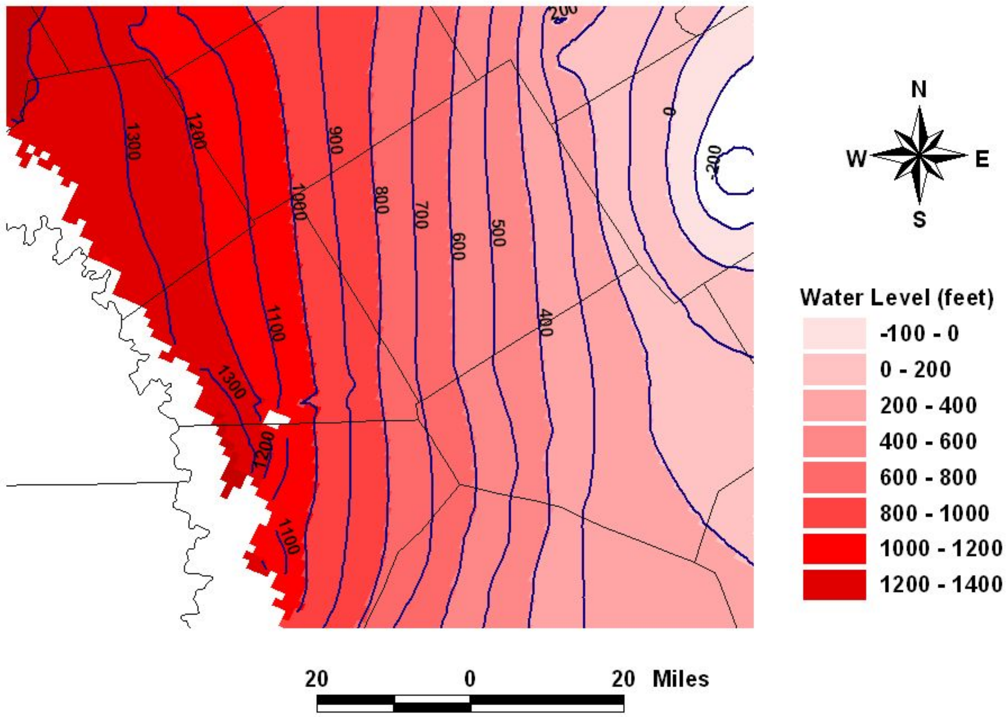

Figure 6. 2050 simulated water elevations in the Hosston (Layer 7) aquifer using 1999 pumpage for the 50-year predictive simulation and average precipitation. The contour interval is 100 feet.

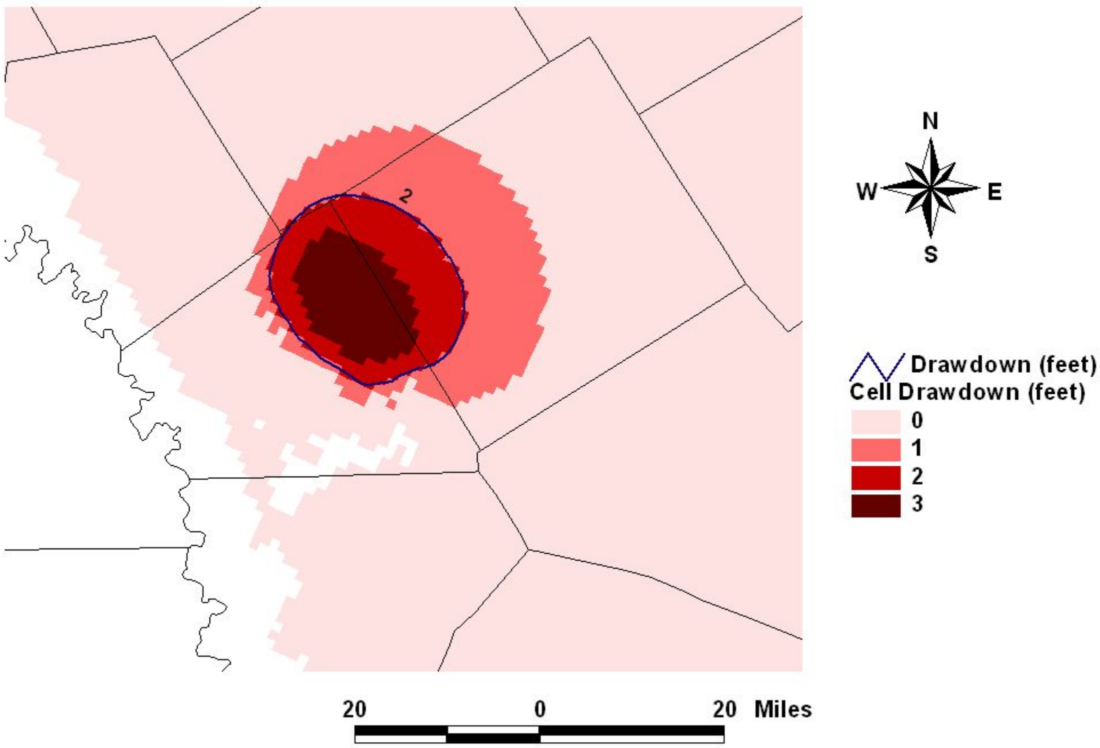

Figure 7. Additional drawdown in the Hensell (Layer 5) aquifer in 2050 due to 50 percent increase in pumping in Lampasas County with average recharge. The contour interval is two feet.

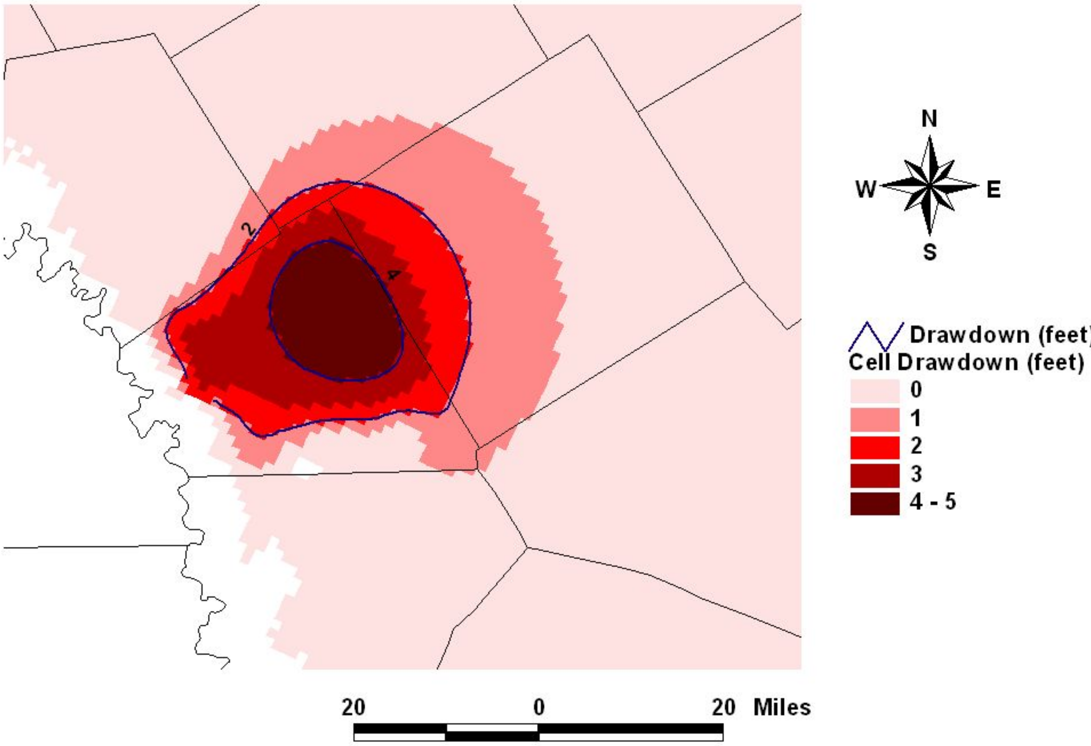

Figure 8. Additional drawdown in 2050 in the Hosston (Layer 7) aquifer due to 50 percent increase in pumping in Lampasas County. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 50 percent additional pumping. Recharge is based on average precipitation. The contour interval is two feet.

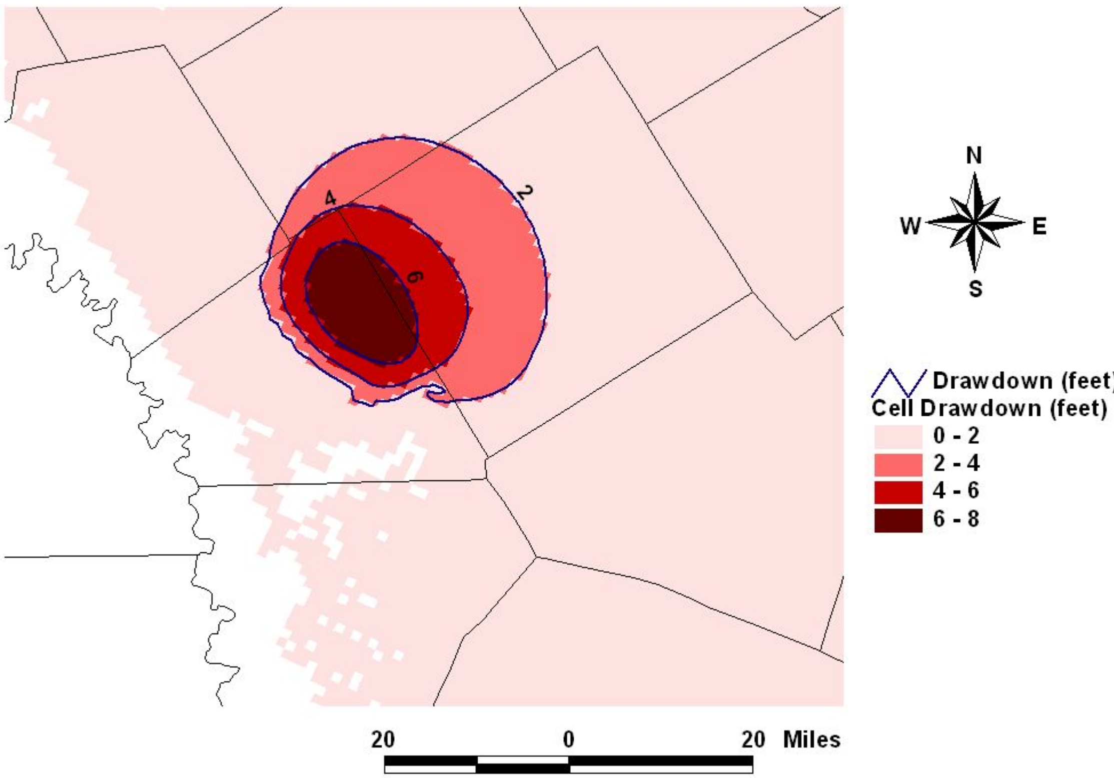

Figure 9. Additional drawdown in the Hensell (Layer 5) aquifer in 2050 due to 100 percent increase in pumping in Lampasas County. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 100 percent additional pumping. Recharge is based on average precipitation. The contour interval is two feet.

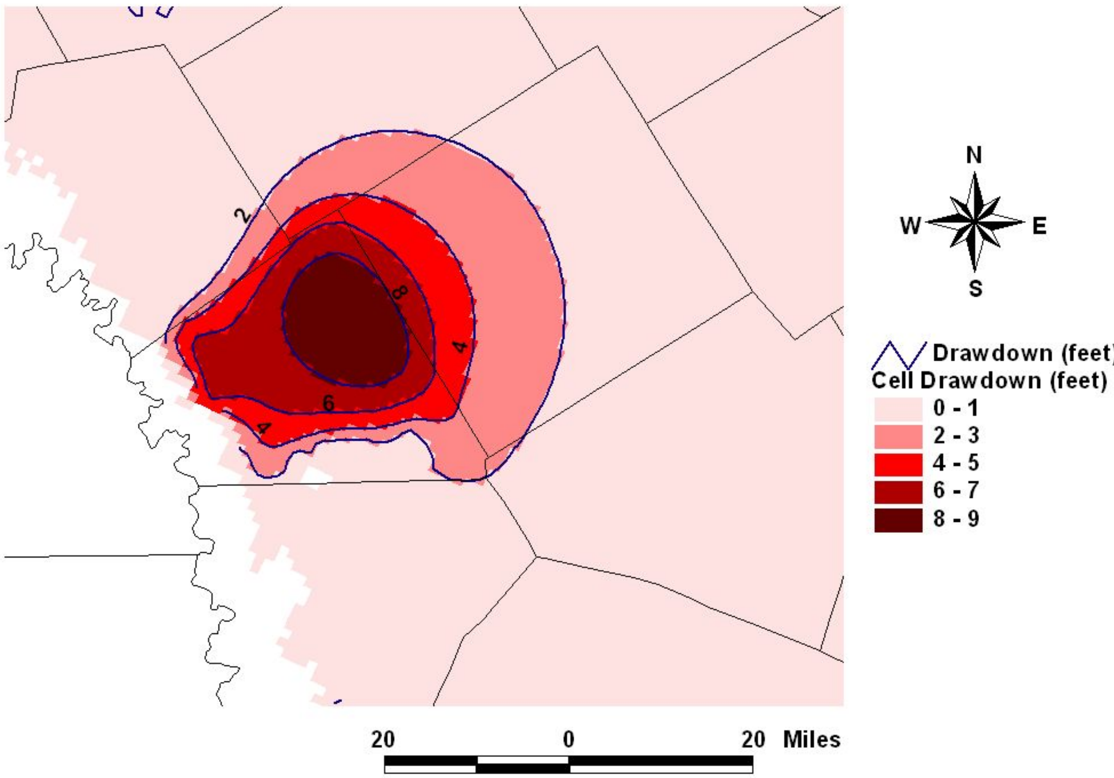

Figure 10. Additional drawdown in 2050 in the Hosston (Layer 7) aquifer due to 100 percent increase in pumping in Lampasas County. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 100 percent additional pumping. Recharge is based on average precipitation. The contour interval is two feet.

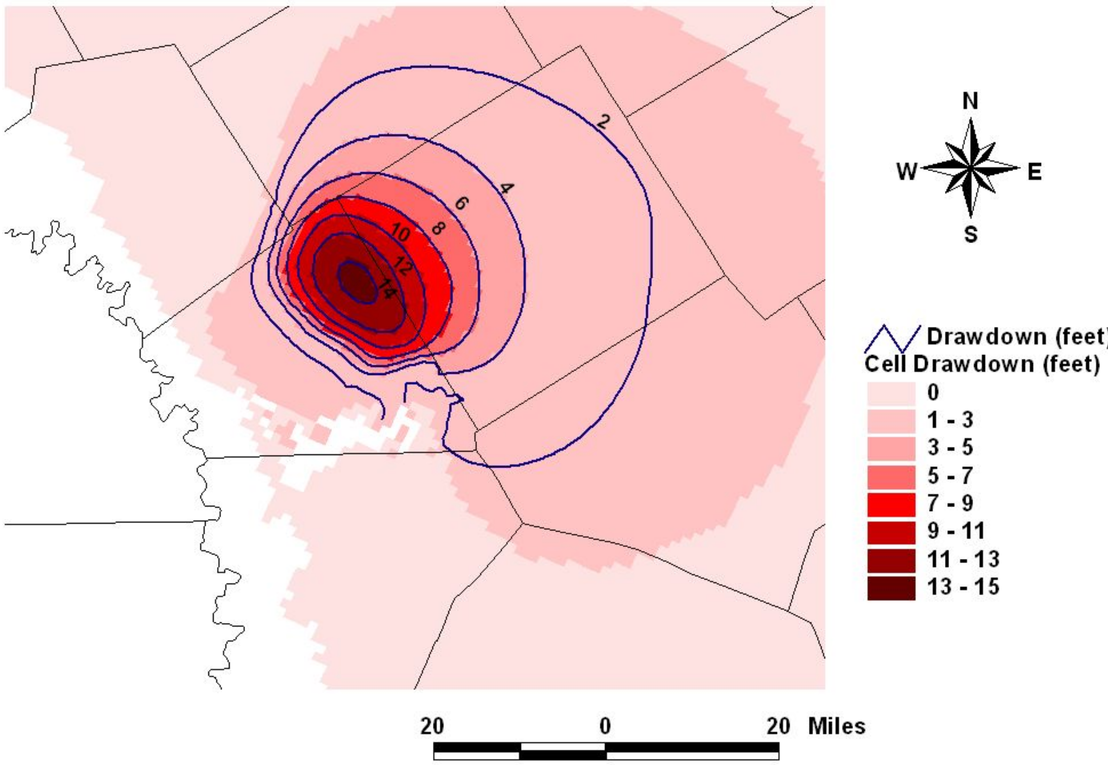

Figure 11. Additional drawdown in the Hensell (Layer 5) aquifer in 2050 due to 200 percent increase in pumping in Lampasas County. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 200 percent additional pumping. Recharge is based on average precipitation. The contour interval is two feet.

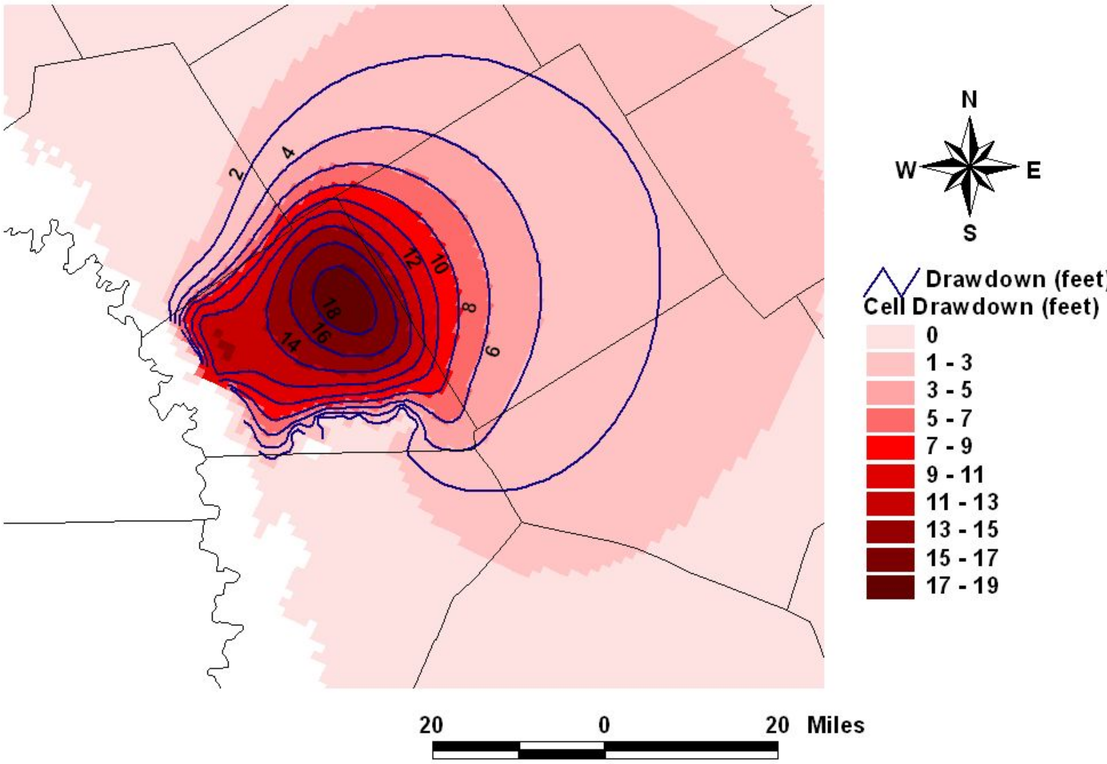

Figure 12. Additional drawdown in 2050 in the Hosston (Layer 7) aquifer due to 200 percent increase in pumping in Lampasas County. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 200 percent additional pumping. Recharge is based on average precipitation. The contour interval is two feet.

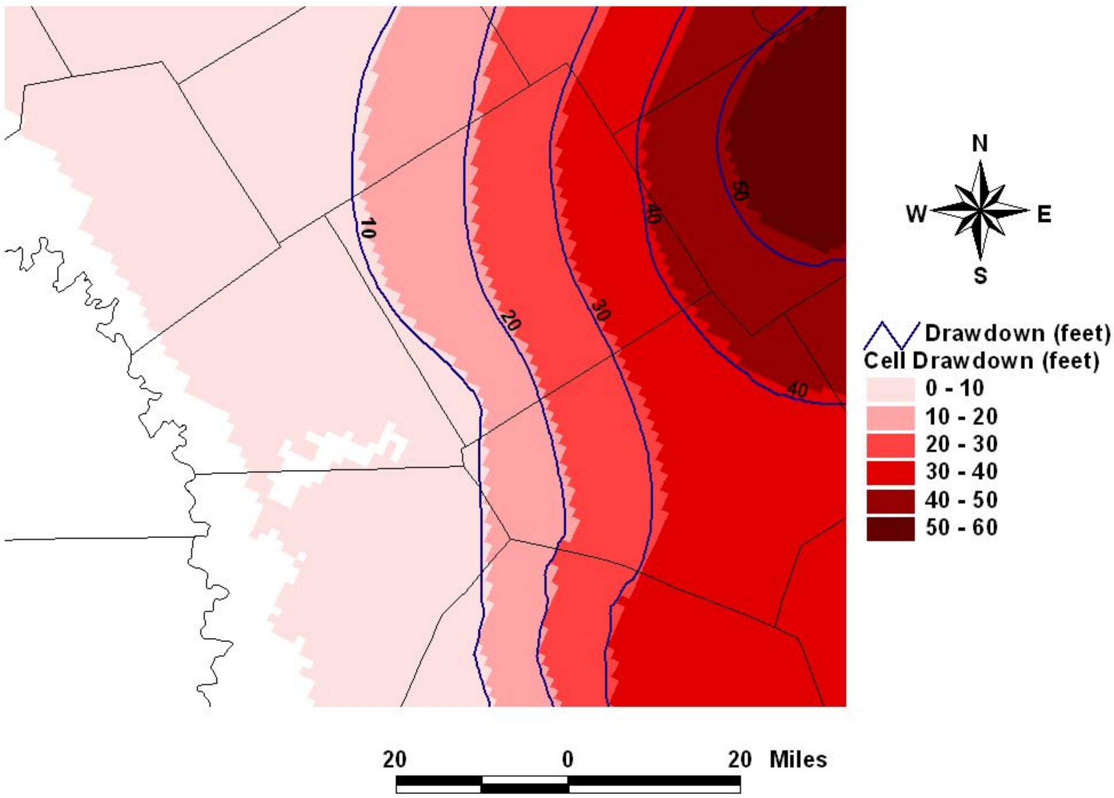

Figure 13. Additional drawdown in the Hensell (Layer 5) aquifer in 2050 due to 10 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 10 percent additional pumping. Recharge is based on average precipitation. The contour interval is ten feet.

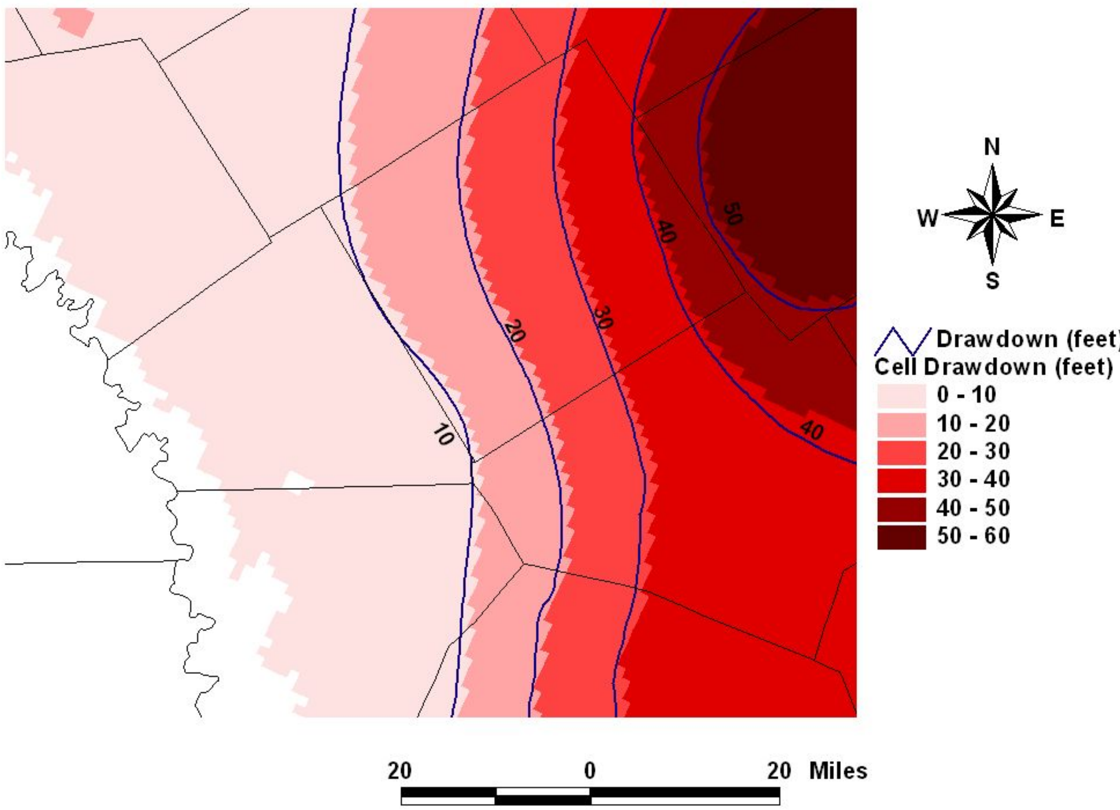

Figure 14. Additional drawdown in the Hosston (Layer 7) aquifer in 2050 due to 10 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 10 percent additional pumping. Recharge is based on average precipitation. The contour interval is ten feet

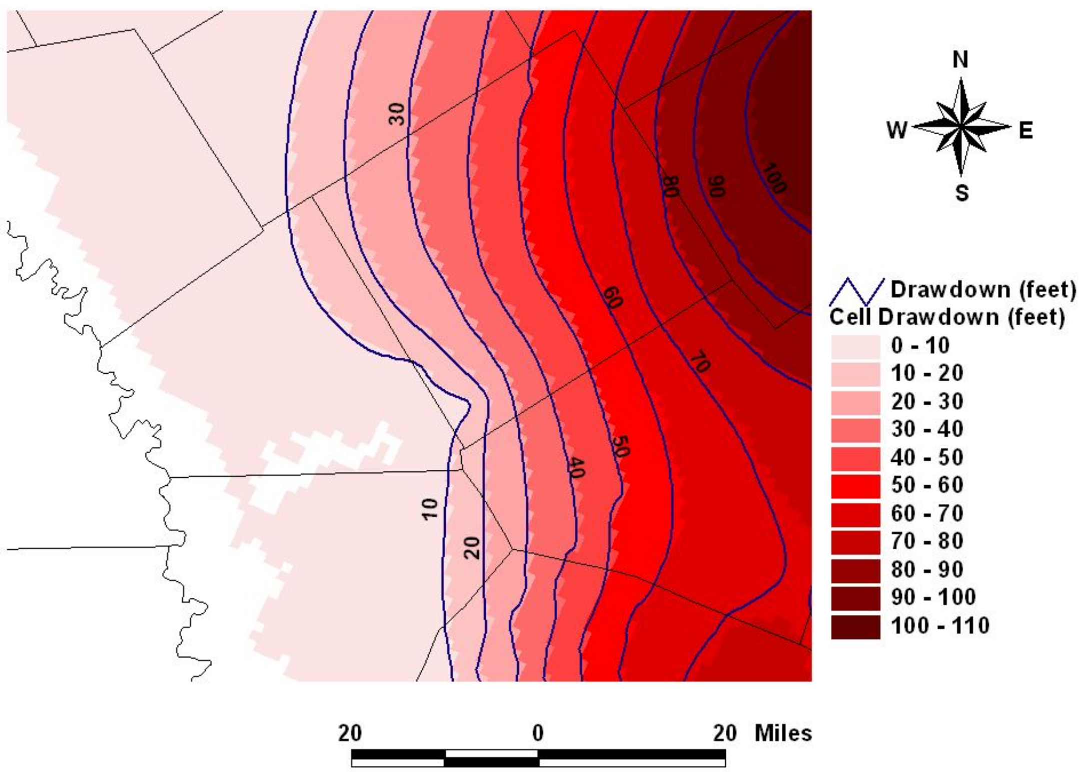

Figure 15. Additional model-wide drawdown in the Hensell (Layer 5) aquifer in 2050 due to 20 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 20 percent additional pumping. Recharge is based on average precipitation. The contour interval is ten feet

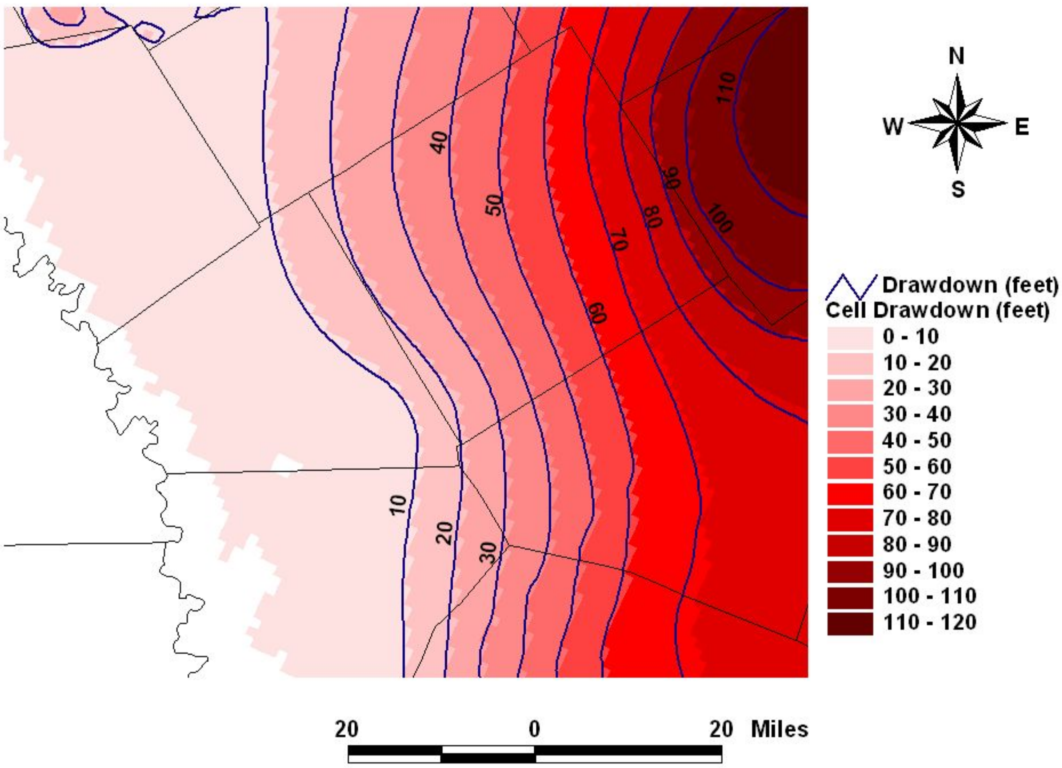

Figure 16. Additional model-wide drawdown in the Hosston (Layer 7) aquifer in 2050 due to 20 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 20 percent additional pumping. Recharge is based on average precipitation. The contour interval is ten feet

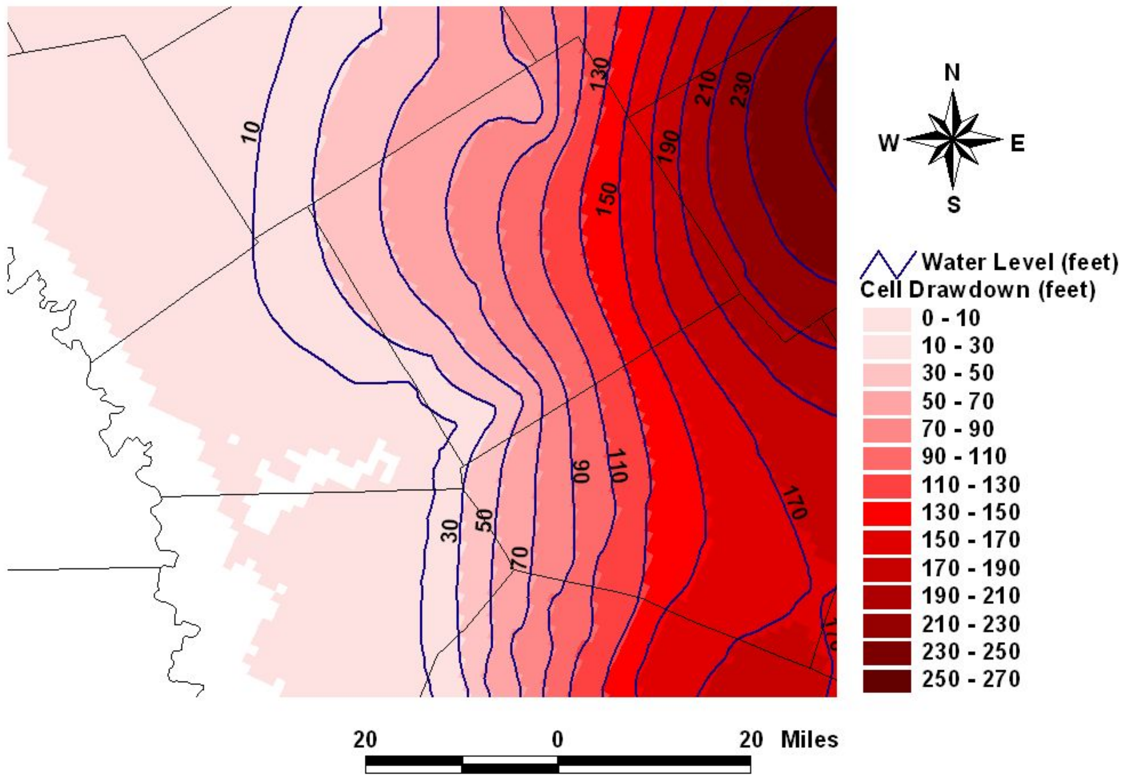

Figure 17. Additional drawdown in the Hensell (Layer 5) aquifer in 2050 due to 50 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 50 percent additional pumping. Recharge is based on average precipitation. The contour interval is twenty feet

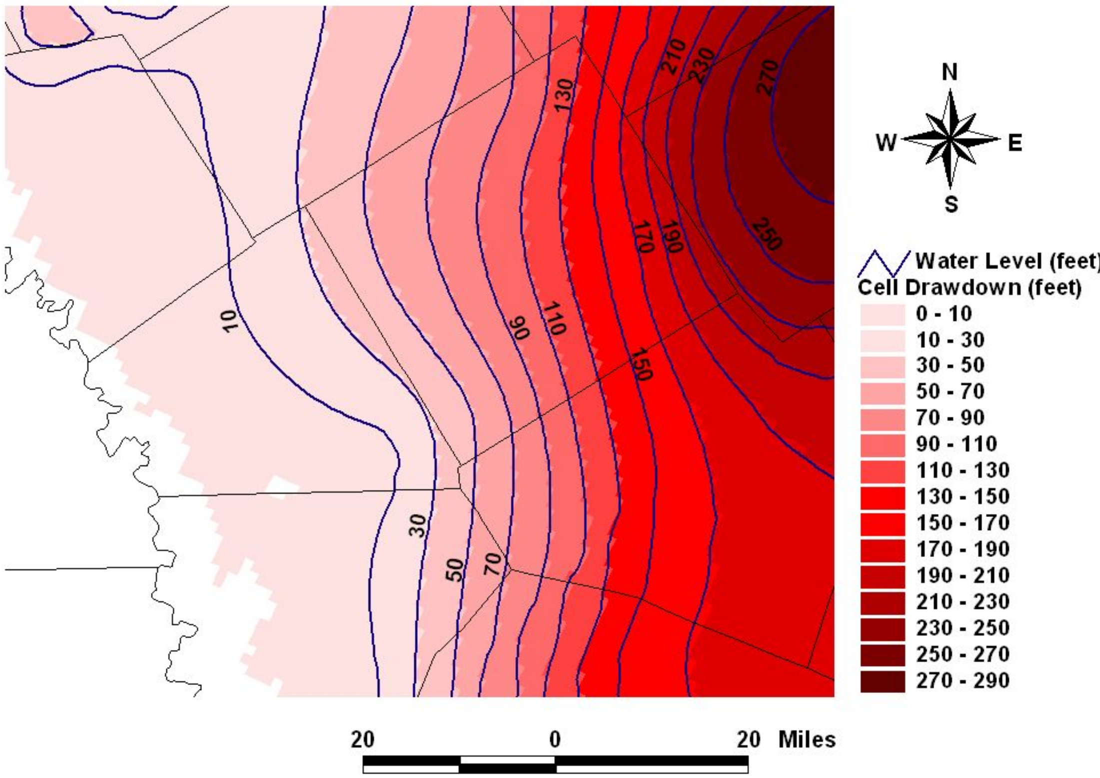

Figure 18. Additional drawdown in the Hosston (Layer 7) aquifer in 2050 due to 50 percent increase in model-wide pumping. Additional drawdown is equal to water levels in 2050 using baseline 1999 pumping minus water levels in 2050 using 50 percent additional pumping. Recharge is based on average precipitation. The contour interval is twenty feet.

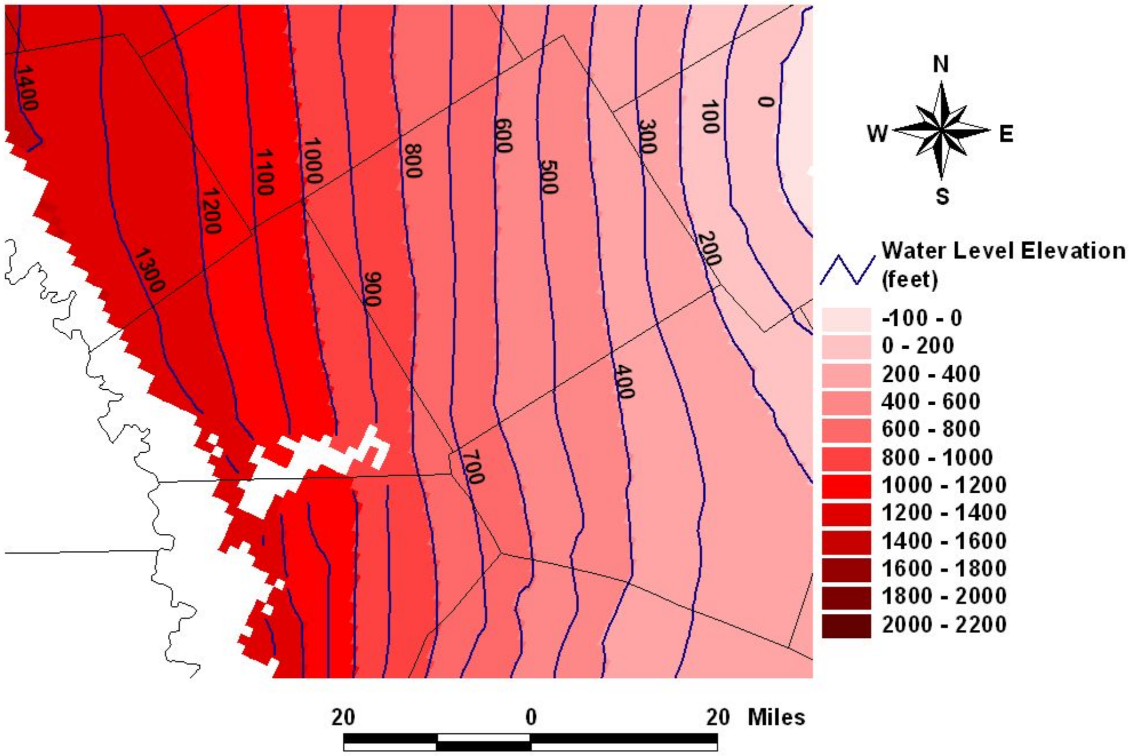

Figure 19. 2050 simulated water elevations from the baseline pumping scenario in feet above mean sea level for the Hensell (Layer 5) aquifer. Recharge is based on drought-of-record precipitation. Drawdowns were very similar between the average recharge and drought-of-record simulations so the drought drawdowns are not shown. The contour interval is 100 feet.

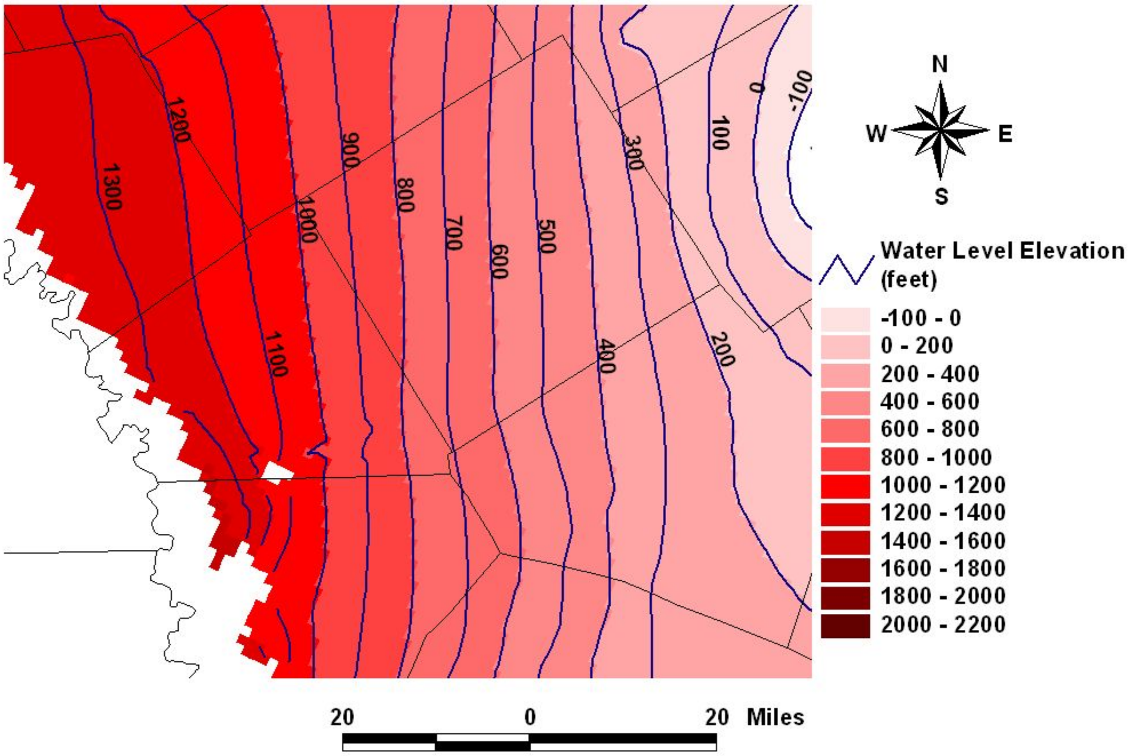

Figure 20. 2050 simulated water elevations from the baseline pumping scenario in feet above mean sea level for the Hosston (Layer 7) aquifer. Recharge is based on drought-of-record precipitation. Drawdowns were very similar between the average recharge and drought-of-record simulations so the drought drawdowns are not shown. The contour interval is 100 feet.

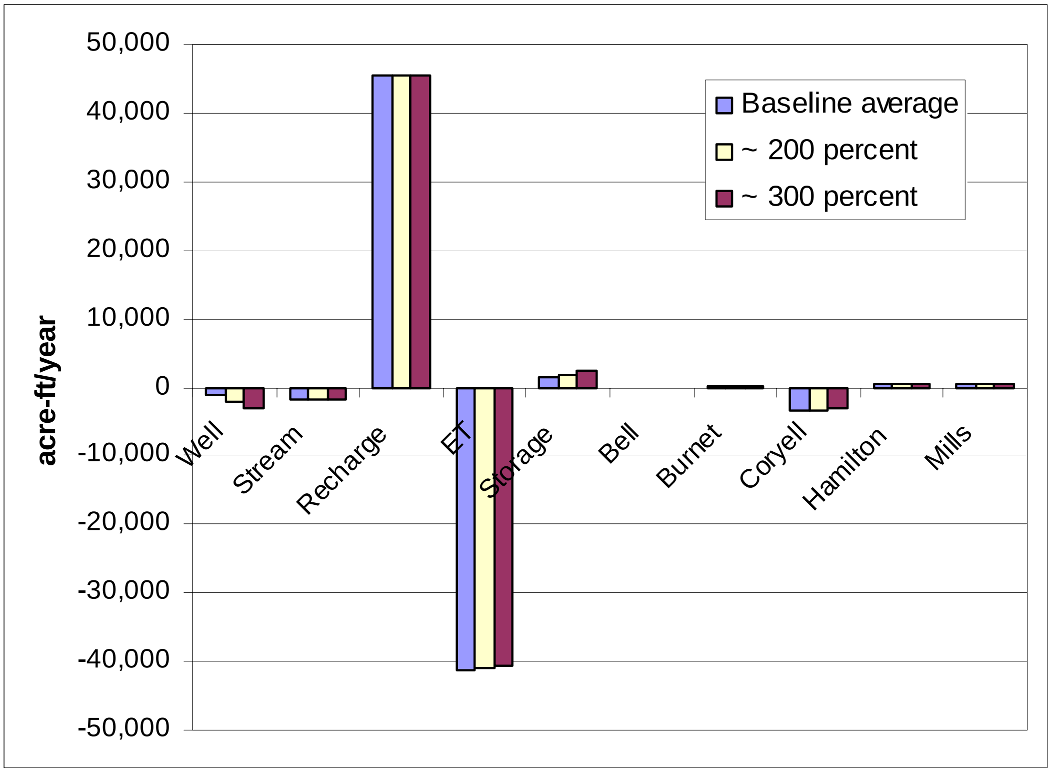

Figure 21. Flow budget in Lampasas for select average recharge scenarios. Negative values represent water leaving the aquifer in the county. Positive values represent water entering the aquifer in the county.

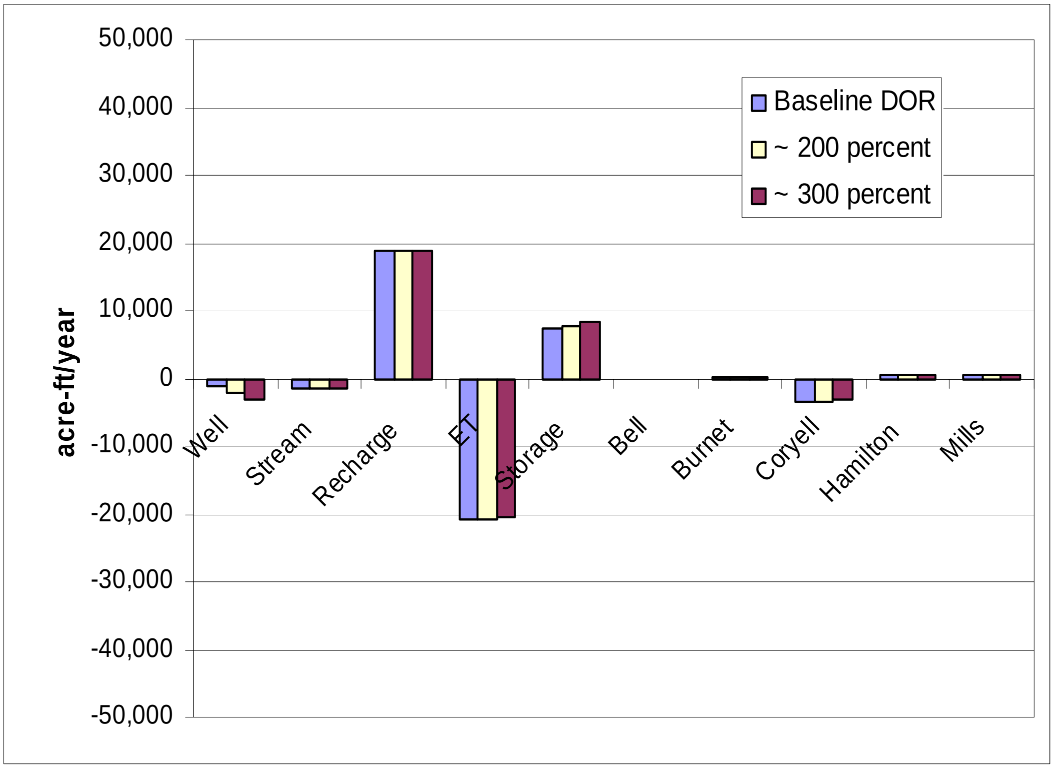

Figure 22. Flow budget in Lampasas for select drought-of-record recharge scenarios. Negative values represent water leaving the aquifer in the county. Positive values represent water entering the aquifer in the county.