GAM Run 05-40

by Andrew C. A. Donnelly, P.G.
Texas Water Development Board
Groundwater Availability Modeling Section
(512) 463-3132
February 7, 2006

REQUESTOR:

Ms. Janet Adams on behalf of the Jeff Davis County Underground Water Conservation District (UWCD) and the Presidio County UWCD.

DESCRIPTION OF REQUEST:

Ms. Adams requested a Groundwater Availability Model (GAM) run using the GAM for the Igneous and parts of the West Texas Bolsons aquifers. Ms. Adams requested that we evaluate the impact of pumpage on water levels in both the Igneous and parts of West Texas Bolsons aquifer.

METHODS:

To determine the impacts of pumping on water levels in Jeff Davis and Presidio counties, we used the GAM for the Igneous and parts of the West Texas Bolsons aquifers and increased pumpage to these two aquifers incrementally, essentially providing a "sensitivity analysis" of water levels to pumpage. The portions of the West Texas Bolsons aquifer included the GAM are Wildhorse Flat, Michigan Flat, Ryan Flat, and Lobo Flat and are locally referred to as being part of the Salt Basin Bolson aquifer. To avoid confusion with other parts of the West Texas Bolsons aquifer, we refer to the West Texas Bolsons aquifer in this GAM as the Salt Basin Bolson aquifer in this report.

The baseline pumpage that we used in the predictive runs was the year 2000 estimated historic pumpage from the transient calibration/verification run. This year was the last of the historic pumpage estimates and therefore was considered to be the most accurate recent pumpage estimate for the model area. The year 2000 baseline pumpage was repeated for each year in the predictive model runs. We added an additional zero to two acre-feet per acre per year in both Jeff Davis and Presidio counties to this baseline pumpage for our predictive model runs.

It is important to note that many model cells in both the Igneous and Salt Basin Bolson aquifers contained significant pumpage in the 2000 historic pumpage estimate. When creating uniform pumpage rates for the predictive runs, we only changed the pumpage in a model cell if the existing pumpage was less than the desired uniform pumpage rate. For those cells with higher rates of pumping in the baseline 2000 pumpage data set than what was desired in the model run, the existing pumpage was used. In addition, some active model cells in the Igneous aquifer were assumed to contain no pumpage in 2000, primarily beneath the Salt Basin Bolson aquifer and in the topographically high portions of the Davis Mountains. Pumpage was not added to these areas for our predictive model runs.

PARAMETERS AND ASSUMPTIONS:

- See Beach and others (2004) for assumptions and limitations of the GAM for the Igneous and West Texas Bolsons aquifers.

- The mean absolute error (a measure of the difference between simulated and actual water levels during model calibration) in the entire GAM for the period of 1990 to 2000 is 64 feet, or four percent of the range of measured water levels (Beach and others, 2004).

- The model includes three layers, representing the Salt Basin Bolson aquifer (Layer 1), the Igneous aquifer (Layer 2), and the underlying Cretaceous and Permian units (Layer 3).

- We simulated a 50-year time period for the predictive model runs.

- We used an average annual recharge based on recharge determined through the calibration of the transient model covering the years 1950 to 2000.

- We used the year 2000 historic pumpage estimate as the baseline pumpage. Pumpage is included in the model for all three layers, although pumpage in Layer 3, representing the underlying Cretaceous and Permian units, is minimal, and only occurs in Jeff Davis County on the northeastern margins of the aquifer. No pumpage is present in Presidio County from Layer 3 in the model.

- We added an additional zero to two acre-feet per acre per year to the baseline year 2000 historic estimated pumpage for both the Salt basin Bolson aquifer and the Igneous aquifer.

- The GAM uses drains to simulate discharge to streams. Drains are included in both the Salt Basin Bolson aquifer and Igneous aquifer layers of the model. Drain parameters were held at conditions representing the 2000 stress period for the predictive simulations.

- The GAM uses general-head boundaries (GHB) to simulate cross-formational flow into and out of layer 3, which represents the Cretaceous and Permian units underlying the Igneous aquifer. GHB parameters were held at conditions representing the 2000 stress period for the predictive simulations.

- The GAM uses the MODFLOW evapotranspiration package (ET) to simulate discharge of water to evaporation and transpiration. ET parameters were held at conditions representing the 2000 stress period for the predictive simulations.

- The GAM includes pumpage representing rural domestic, municipal, industrial, irrigation, and livestock uses.

RESULTS:

Both the Salt Basin Bolson and Igneous aquifers were evaluated independently with model runs, and we will discuss the results for each aquifer separately in this report. Presently, the amount of pumpage permitted by the Jeff Davis County UWCD and the Presidio County UWCD is two acre-feet per acre per year. We modeled this amount of pumpage assuming that all of the pumpage was from each aquifer and was in the same location as pumpage in 2000 in Jeff Davis and Presidio Counties.

Salt Basin Bolson Aquifer

The Salt Basin Bolson aquifer is present in limited extent in both Jeff Davis and Presidio counties (Figure 1). Initial (2000) water levels range from approximately 4,500 feet above mean sea level at the southern end of Ryan Flat to less than 3,900 feet above mean sea level where Ryan Flat crosses the Jeff Davis-Culberson county line (Figure 2). Initial (2000) saturated thicknesses range from zero at the bolson margins to more than 1,000 feet in portions of the center of the bolson (Figure 3). As shown in these figures, portions of the aquifer were dry at the start of all of the predictive model runs (black cells are dry areas). Based on the model-derived specific yield of the Salt Basin Bolson aquifer of six percent, the total groundwater in storage in the aquifer at the start of the predictive model runs is approximately 3,860,000 acre-feet in Jeff Davis County and 2,350,000 acre-feet in Presidio County.

Table 1 summarizes the pumping rates for the Salt Basin Bolson aquifer with these GAM runs for the entire county. As can be seen in this table, the annual amount of groundwater pumped from the aquifer from the two-county area in the model runs ranges from nearly 20,000 acre-feet per year to the nearly 400,000 acre-feet per year that is currently permitted.

Table 1. Summary of annual pumpage from the Salt Basin Bolson aquifer in the GAM runs from Jeff Davis and Presidio counties (in acre-feet per year)

Pumpage Rate (acre-feet per acre per year)	Jeff Davis County	Presidio County	Total
0.10	10,144	9,824	19,968
0.25	25,360	24,560	49,920
0.50	50,720	49,120	99,840
1.0	101,440	98,240	199,680
2.0	202,880	196,480	399,360

It is important to note that the volumes in Table 1 are based on the initial (2000) active area in the Salt Basin Bolson aquifer in the predictive runs. This active area decreases (and therefore annual pumpage also decreases) as parts of the aquifer dry up during the model runs. Figure 4 shows the impact of the currently permitted two acre-feet per acre per year of pumpage from the Salt Basin Bolson aquifer over a fifty year predictive modeling period. This figure shows that water levels can be observed decreasing significantly after just ten years, with additional areas of the aquifer drying over time. After twenty years, approximately half of the aquifer in Jeff Davis and Presidio counties is dry, and after thirty years nearly all of the aquifer in these two counties has dried up.

In MODFLOW, when the water level in a model cell falls below the bottom of the cell, the cell goes dry. Because the cell no longer has water in it, MODFLOW turns the cell off. When a cell goes dry, the model is indicating that there is not enough water flowing into the cell (for example, recharge) or there is too much water being removed from the cell (for example, pumping) to keep water in the cell. If pumping is the primary factor, the model is saying that the pumping may be too great for the aquifer in this area. When MODFLOW shuts a cell off, that cell is off for the rest of the simulation. In reality, the aquifer will probably not go dry because pumping will become uneconomical before the aquifer goes dry in any particular area. However, the GAM is suggesting that these areas may experience water supply problems sometime in the next 50 years.

Figure 4 indicates that a permitted rate of two acre-feet per acre per year will cause the Salt Basin Bolson aquifer to dry up in Jeff Davis and Presidio counties in a short period of time. We ran additional model runs to evaluate the impact of lower rates of pumpage on this aquifer.

The impact of 0.10, 0.25, 0.50, and 1.0 acre-feet per acre per year on water levels in the Salt Basin Bolson aquifer after fifty years are shown in Figures 5, 6, 7, and 8, respectively. These figures show the same trend in water level declines as Figure 4, that as more water is pumped from the aquifer, water levels steadily decline and the aquifer dries up. In Figure 4 this is shown with a constant rate of pumpage as time increases, and in Figures 5 to 8 this is shown after a specified amount of time as pumpage increases. The GAM assumes that no recharge occurs to the Salt Basin Bolson aquifer, with the exception of a small amount of recharge through alluvial fan or streambed in limited locations (Beach and others, 2004). Therefore, nearly all of the groundwater being pumped from the Salt Basin Bolson aquifer is being removed from storage. The net inflow of water from the underlying Igneous aquifer is approximately 5,000 acre-feet per year during the transient run for the entire extent of the Salt Basin Bolson aquifer, of which Jeff Davis and Presidio Counties comprise approximately half of the active portion in the year 2000 (Beach and others, 2004). As shown in Table 1, the amount of pumpage in most of the model runs is far greater than the amount of water entering the aquifer from the Igneous aquifer, even when taking into account that the net flux of water entering the Salt Basin Bolson aquifer from the underlying Igneous aquifer will increase as water levels decline.

Igneous Aquifer

The Igneous aquifer is present in much of Jeff Davis and Presidio counties (Figure 9). Initial (2000) water levels range from nearly 6,000 feet above mean sea level in the Davis Mountains to less than 3,000 feet above mean sea level in southern Presidio County (Figure 10). Initial (2000) saturated thicknesses range from zero at the aquifer margins to more than 6,000 feet (Figure 11). As shown in these figures, portions of the aquifer were dry at the start of all of the predictive model runs (black cells are dry areas). Based on the model-derived aquifer characteristics of the Igneous aquifer (which has a specific yield of 0.01), it is estimated that 24,100,000 acre-feet of groundwater is in storage in this aquifer in Jeff Davis County, and 28,750,000 acre-feet in Presidio County.

Table 2 summarizes the pumping rates for the Igneous aquifer with these GAM runs for the entire county. As can be seen in this table, the annual amount of groundwater pumped from the aquifer from the two-county area ranges from approximately 133,000 acre-feet per year to over 5,325,000 acre-feet per year that is currently permitted.

It is important to note that the volumes in Table 2 are based on the initial (2000) active area in the Igneous aquifer in the predictive runs. This active area decreases (and therefore annual pumpage also decreases) as parts of the aquifer dry up during the model runs.

Table 2. Summary of annual pumpage from the Igneous aquifer in the GAM runs from Jeff Davis and Presidio counties (in acre-feet per year)

Pumpage Rate (acre-feet per acre per year)	Jeff Davis County	Presidio County	Total
0.05	57,064	76,096	133,160
0.10	114,128	152,192	266,320
0.25	285,320	380,480	665,800
0.50	570,640	760,960	1,331,600
1.0	1,141,280	1,521,920	2,663,200
2.0	2,282,560	3,043,840	5,326,400

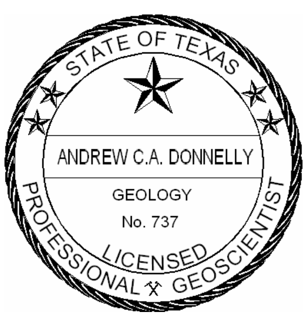
As noted above, the amount of pumpage permitted by the Jeff Davis County UWCD and the Presidio County UWCD is two acre-feet per acre per year. This rate was not assumed to be uniform across the entire extent of the aquifer in the two-county area, rather the distribution of pumpage in the year 2000 pumpage data set was used (in other words, areas or cells with no pumpage in 2000 did not receive any pumpage in the uniform distribution pumpage data sets). The distribution of pumpage in the year 2000 did not include pumpage from the Igneous aquifer over the Salt Basin Bolson aquifer or in the topographically high portions of the Davis Mountains.

Figure 12 shows the impact of the currently permitted two acre-feet per acre per year of pumpage from the Igneous aquifer over a fifty-year predictive modeling period. Because the specific yield for the Igneous aquifer that was determined during the calibration of the model is much lower (0.01) than in the Salt Basin Bolson aquifer, water-level declines are much larger with the same amount of pumpage. Figure 12 shows that with two acre-feet per acre per year, water levels decline dramatically after only ten years, with large portions of the aquifer in Jeff Davis and Presidio counties going dry. Within twenty years most of the aquifer had gone dry; with the only parts of the aquifer not dry being those areas where pumpage was not applied. This figure indicates that the current permitted amount of two acre-feet per acre per year causes large drawdowns in the Igneous aquifer and large portions of the aquifer go dry during the predictive modeling period. We ran additional model runs to evaluate the impact of lower rates of pumpage on the Igneous aquifer.

The impact of 0.05, 0.10, 0.25, 0.50, and 1.0 acre-feet per acre per year on water levels in the Igneous aquifer after fifty years are shown in Figures 13, 14, 15, 16, and 17, respectively. These figures show the same trend in water level declines as Figure 12, that as more water is pumped from the aquifer, water levels steadily decline and the aquifer dries up. In Figure 12 this is shown with a constant rate of pumpage as time increases, in Figures 13 to 17 this is after a specified amount of time as pumpage increases. As noted above, water levels in the Igneous aquifer decline dramatically because the specific yield in the Igneous aquifer is much lower than in the Salt Basin Bolson aquifer.

REFERENCES:

James A. Beach, John B. Ashworth, Steven T. Finch, Jr., Andrew Chastain-Howley, Kenny Calhoun, Kevin M. Urbanczyk, John M. Sharp, and John Olson, 2004, Groundwater Availability Model for the Igneous and parts of the West Texas Bolsons (Wild Horse Flat, Michigan Flat, Ryan Flat and Lobo Flat) Aquifers: Texas Water Development Board, GAM Report, 208 p.



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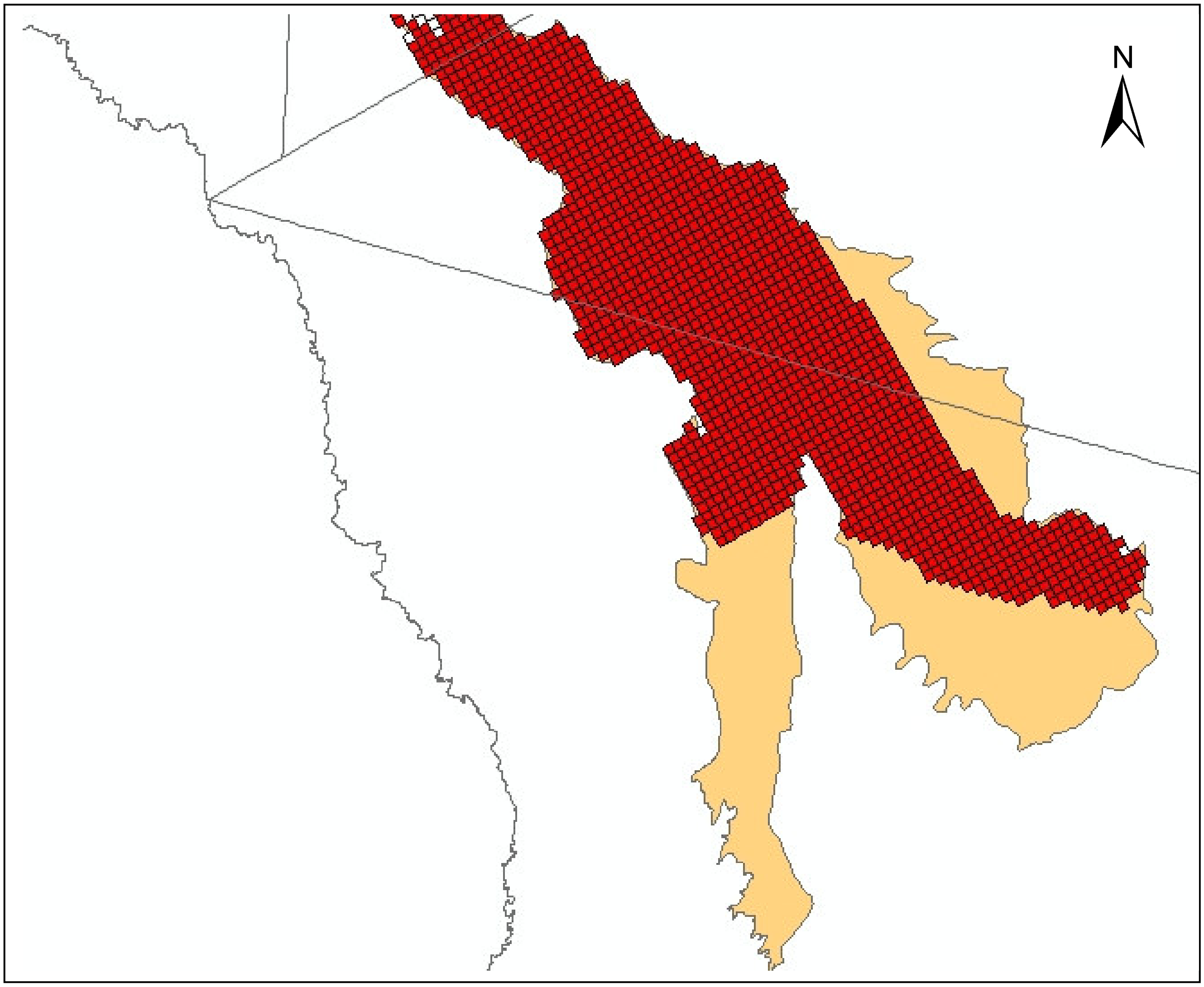


Figure 1. Extent of the Salt Basin Bolson aquifer in the GAM. Model cells in red are active cells that contain pumpage in 2000. Model cells in white are active cells without pumpage. The actual extent of the Salt Basin Bolson aquifer is shown in tan.

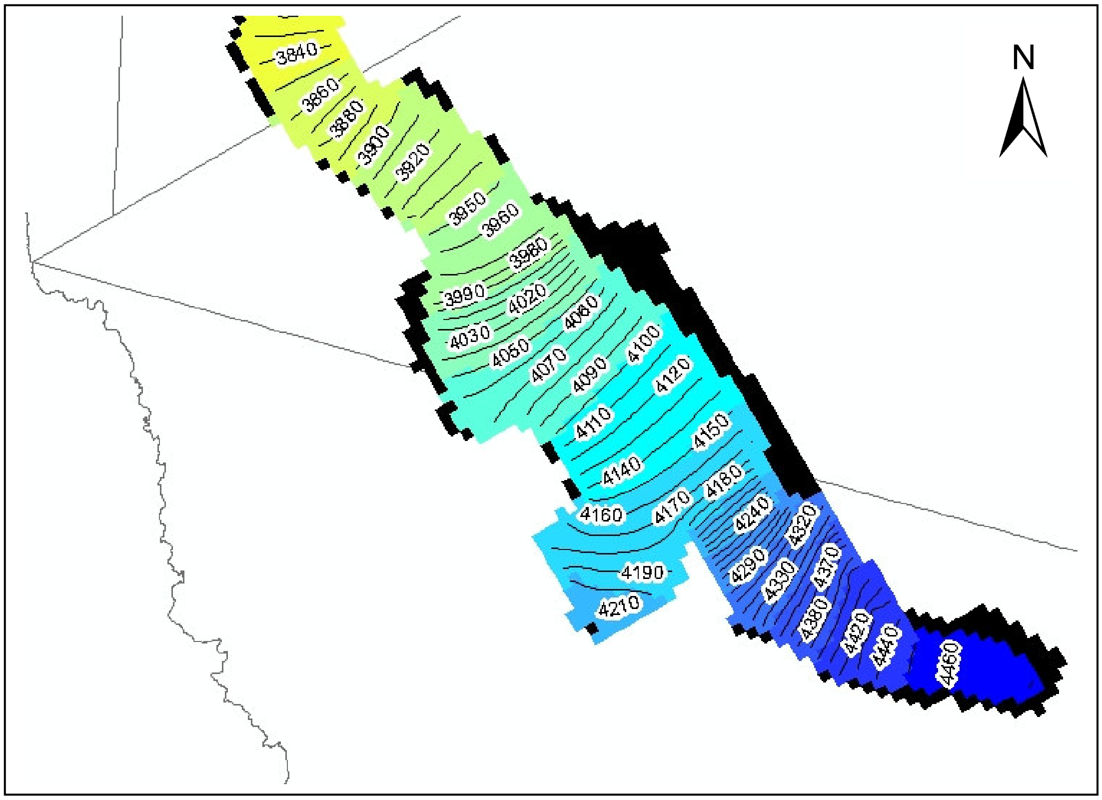


Figure 2. Initial water levels in the Salt Basin Bolson aquifer in the year 2000. Contour interval is 10 feet. Black areas are where the aquifer is dry.

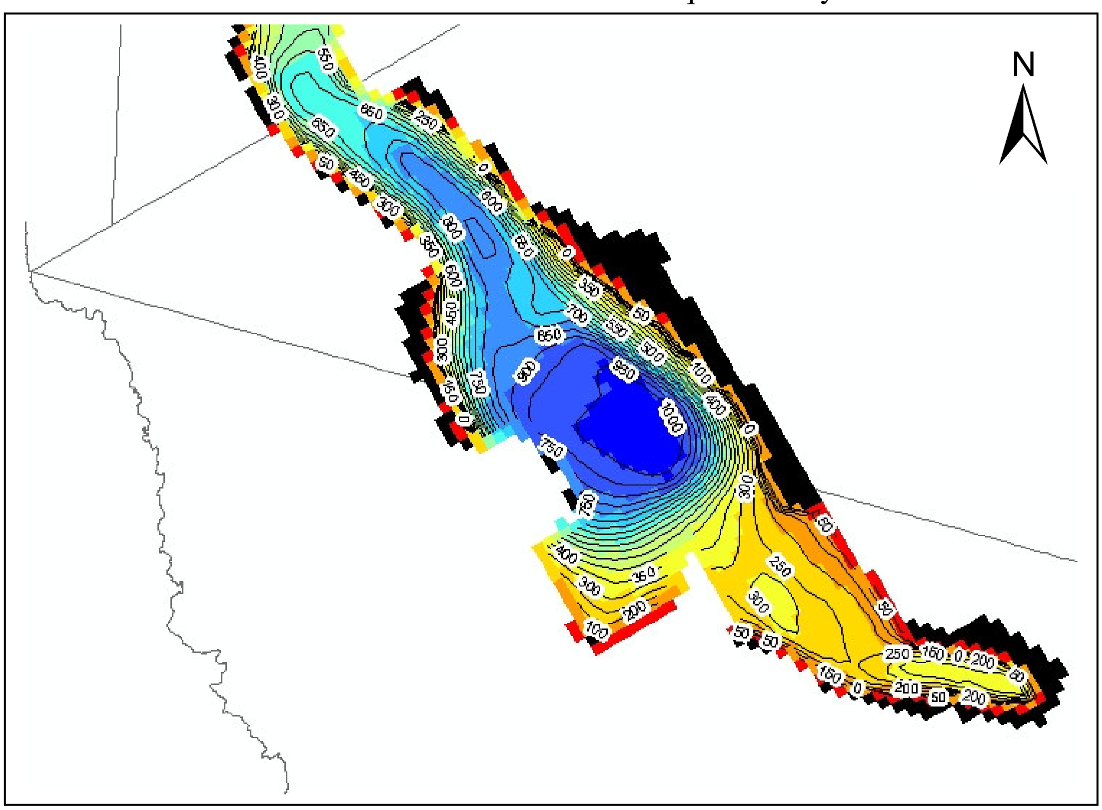


Figure 3. Initial saturated thicknesses in the Salt Basin Bolson aquifer in the year 2000. Contour interval is 50 feet. Black areas are where the aquifer is dry.

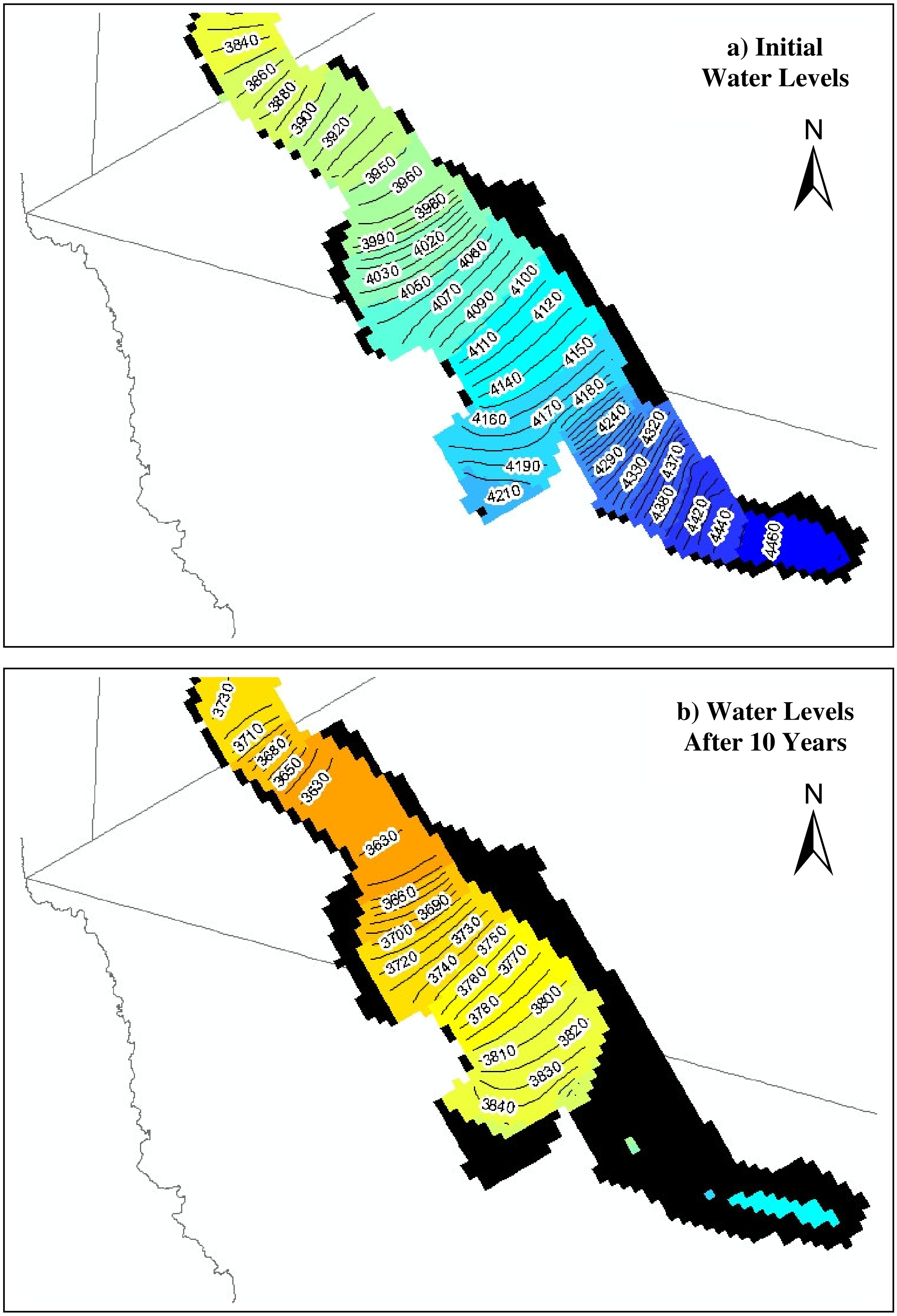
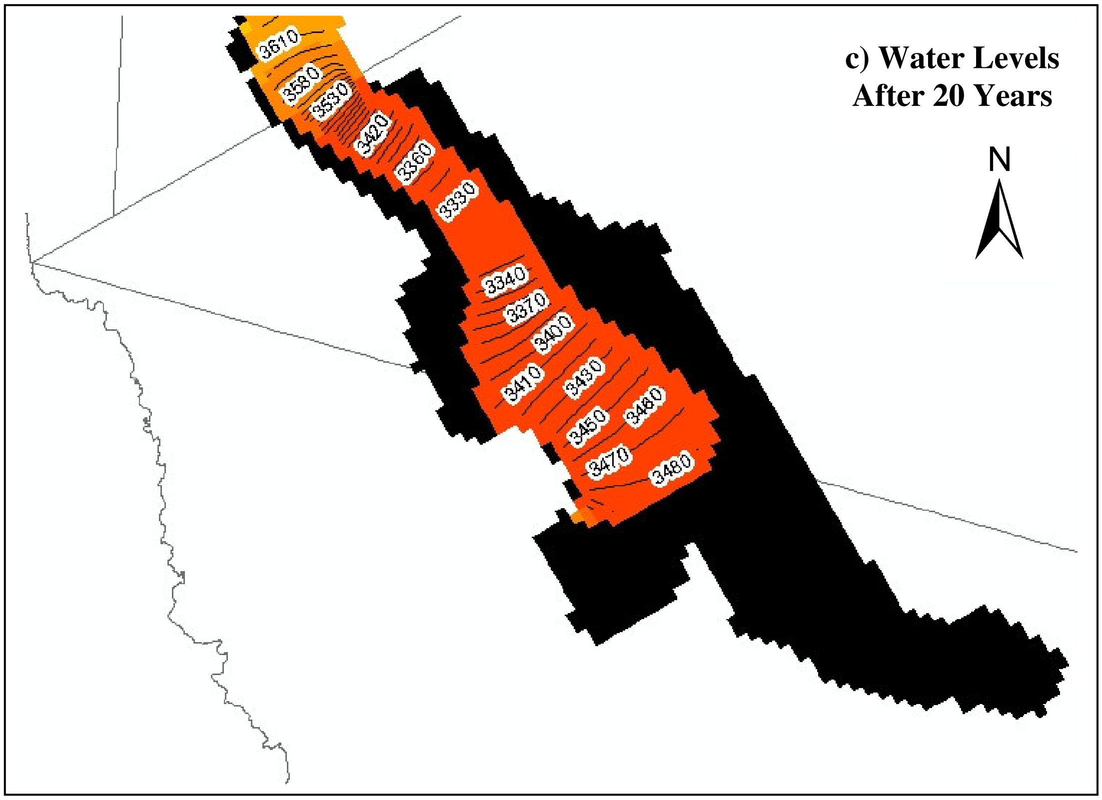


Figure 4. Water levels in the Salt Basin Bolson aquifer with a uniform pumpage rate of two acre-feet per acre per year after (a) 0 years, (b) 10 years, (c) 20 years, (d) 30 years, (e) 40 years, and (f) 50 years of pumpage. Dry model cells are shown in black.



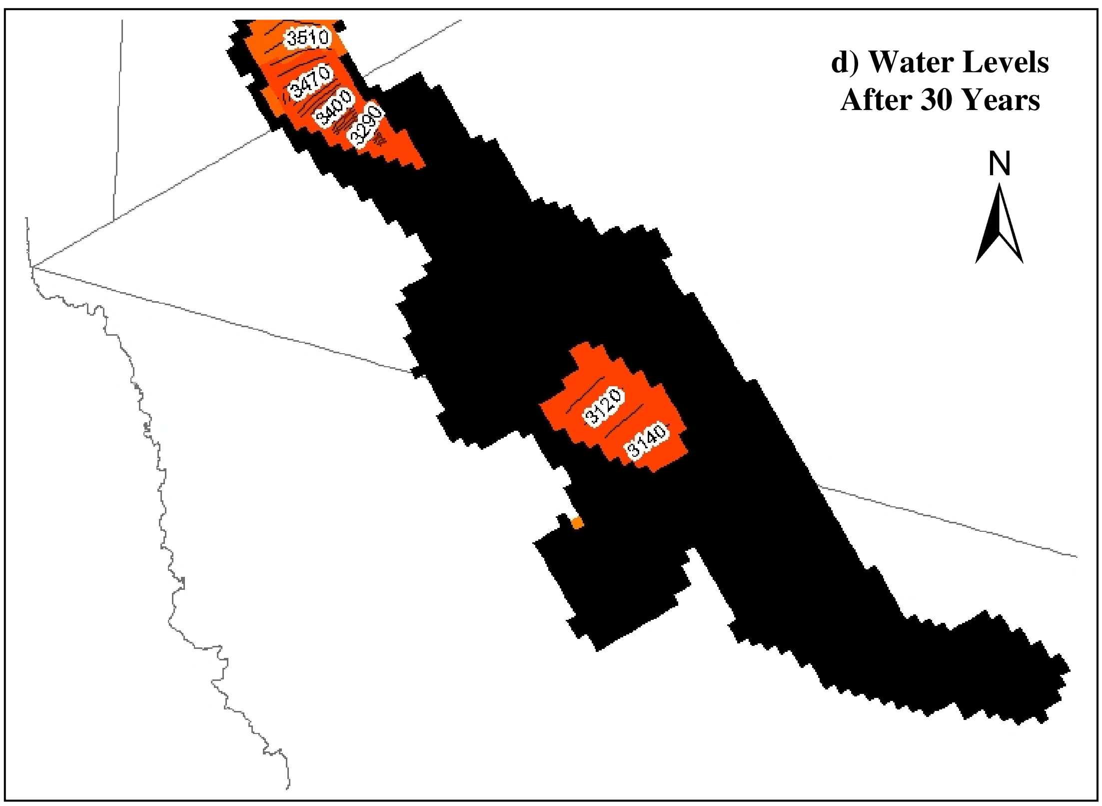
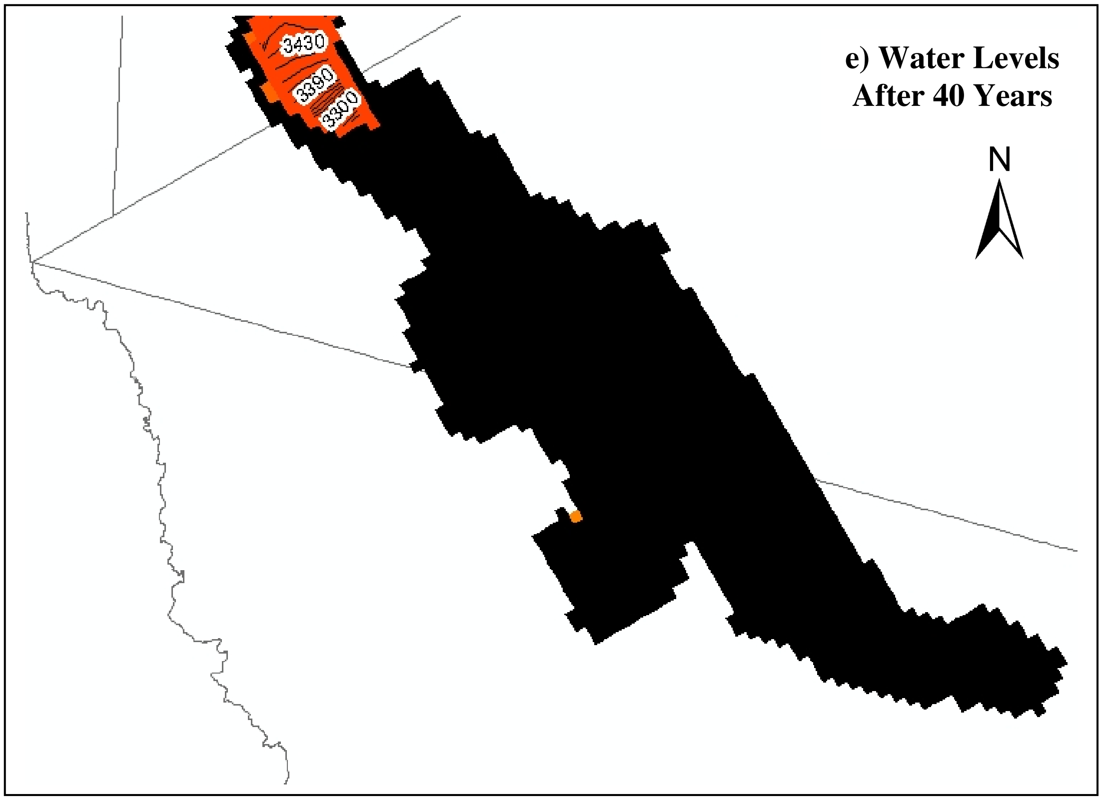
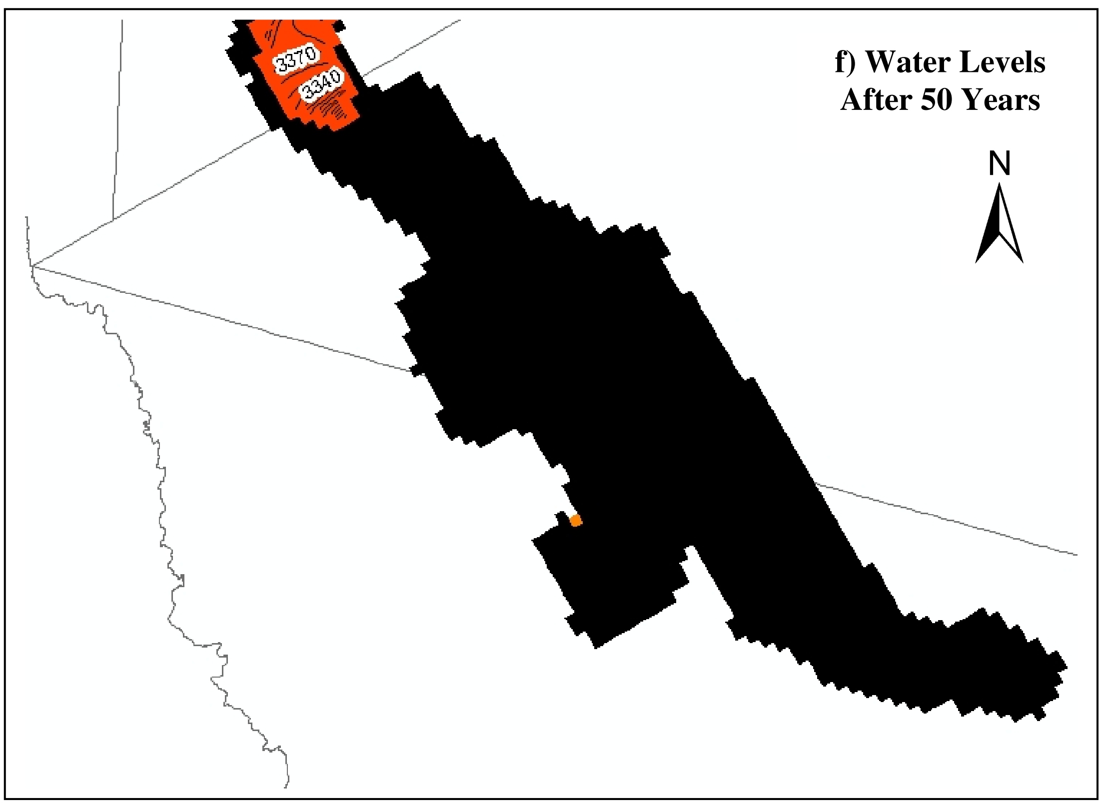


Figure 4. (continued)





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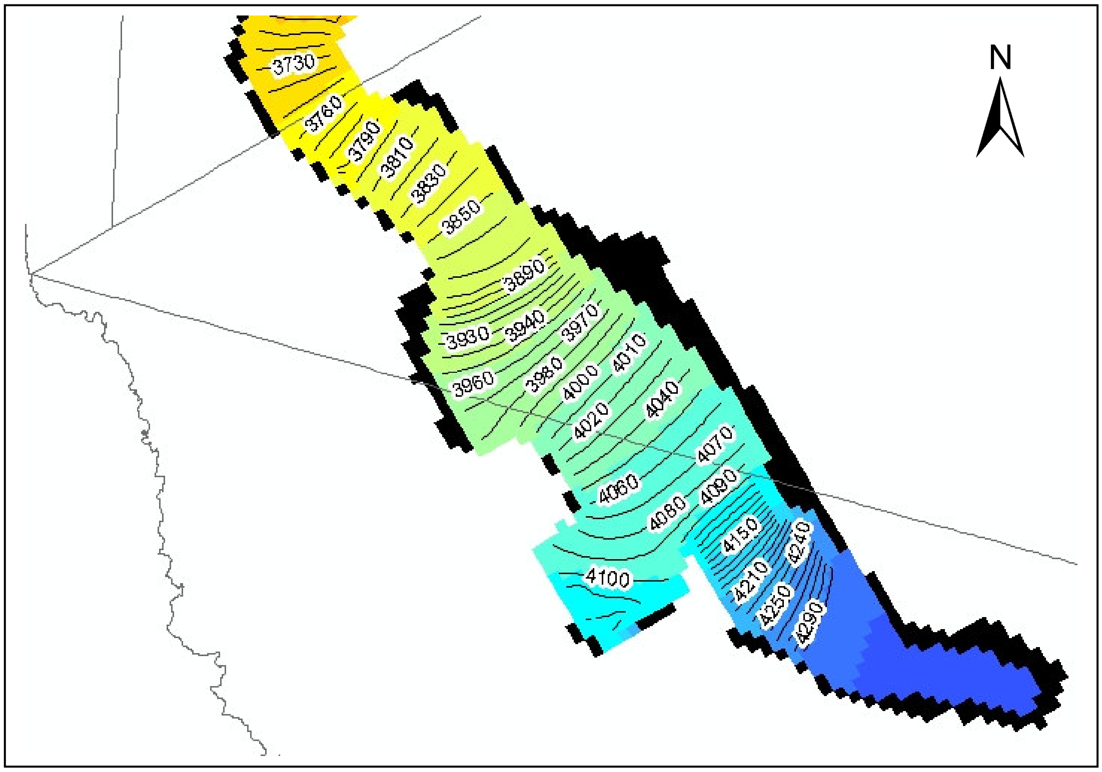


Figure 5. Water levels in the Salt Basin Bolson aquifer after 50 years with a uniform pumping rate of 0.10 acre-feet per acre per year.

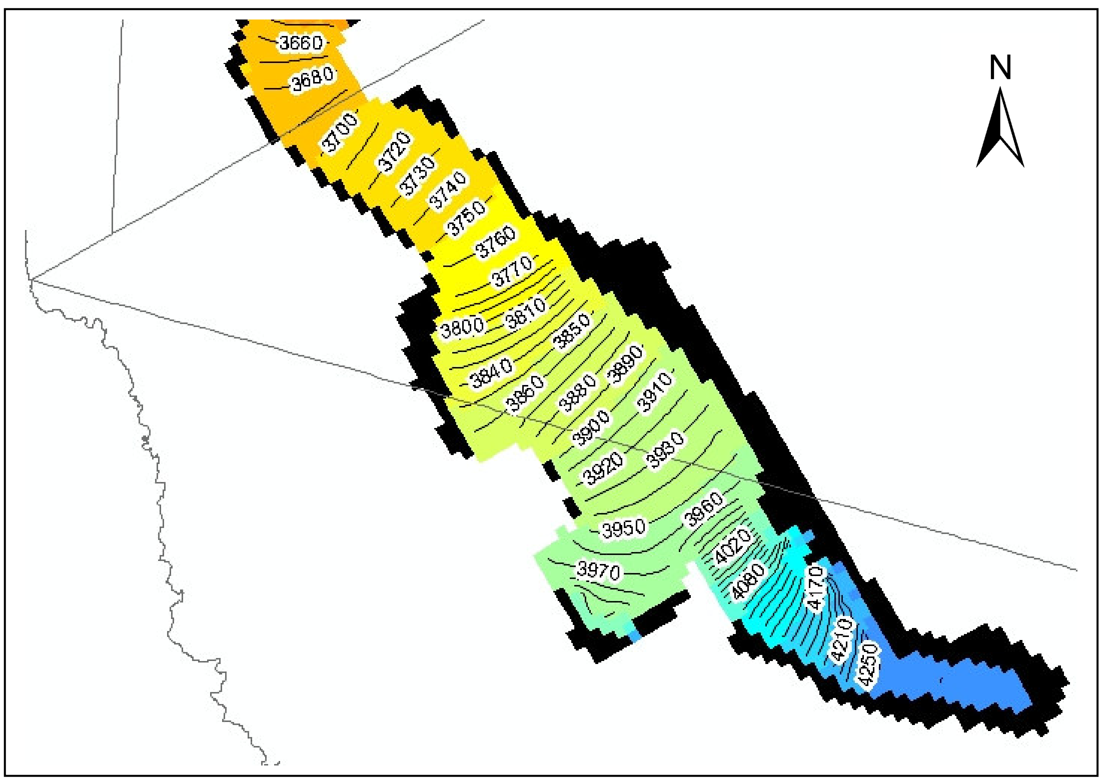


Figure 6. Water levels in the Salt Basin Bolson aquifer after 50 years with a uniform pumping rate of 0.25 acre-feet per acre per year.

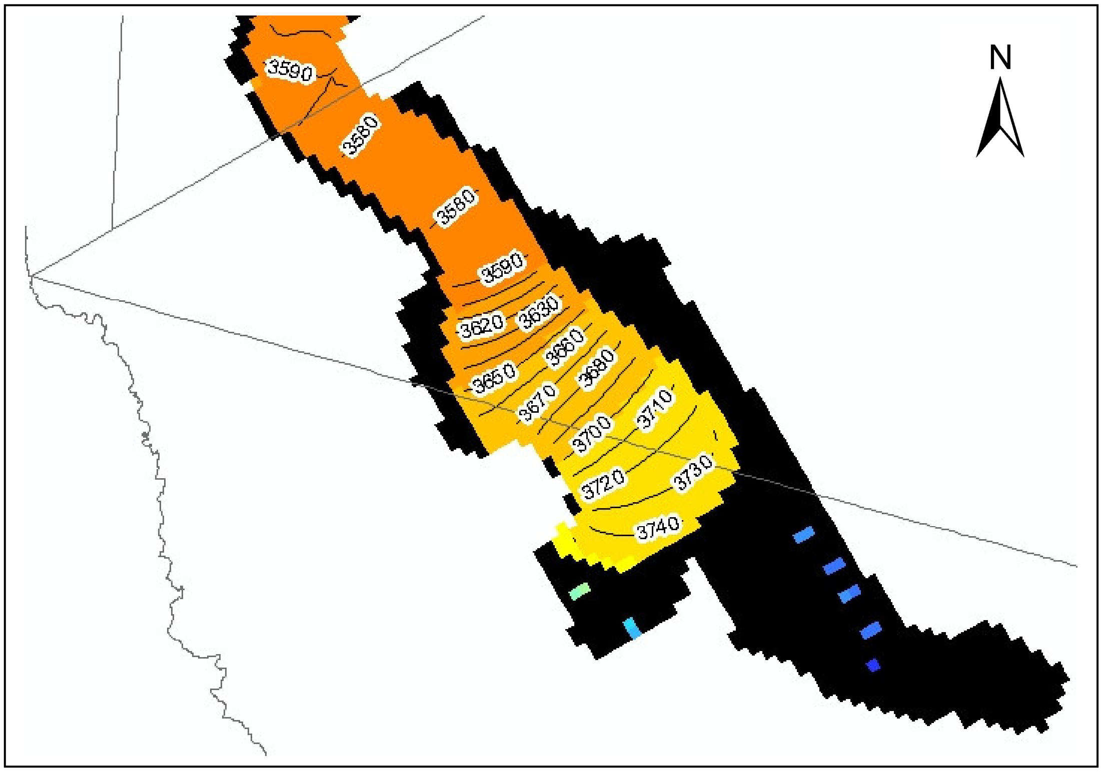


Figure 7. Water levels in the Salt Basin Bolson aquifer after 50 years with a uniform pumping rate of 0.50 acre-feet per acre per year.

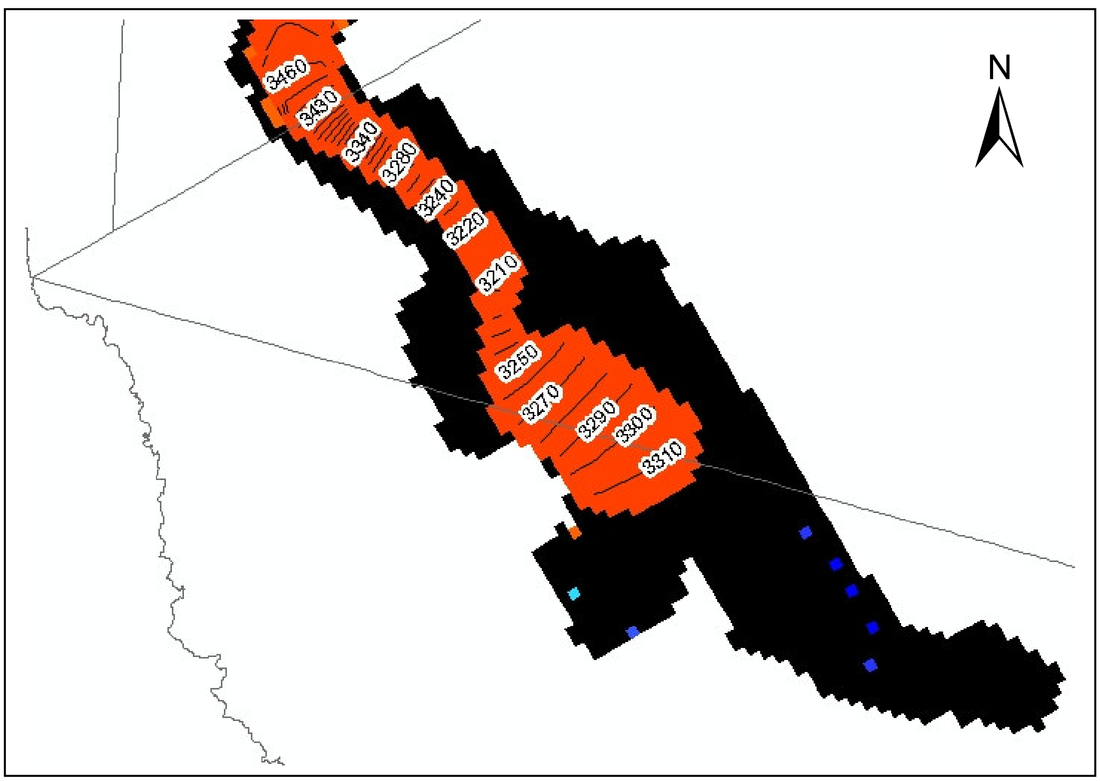


Figure 8. Water levels in the Salt Basin Bolson aquifer after 50 years with a uniform pumping rate of 1.00 acre-feet per acre per year.

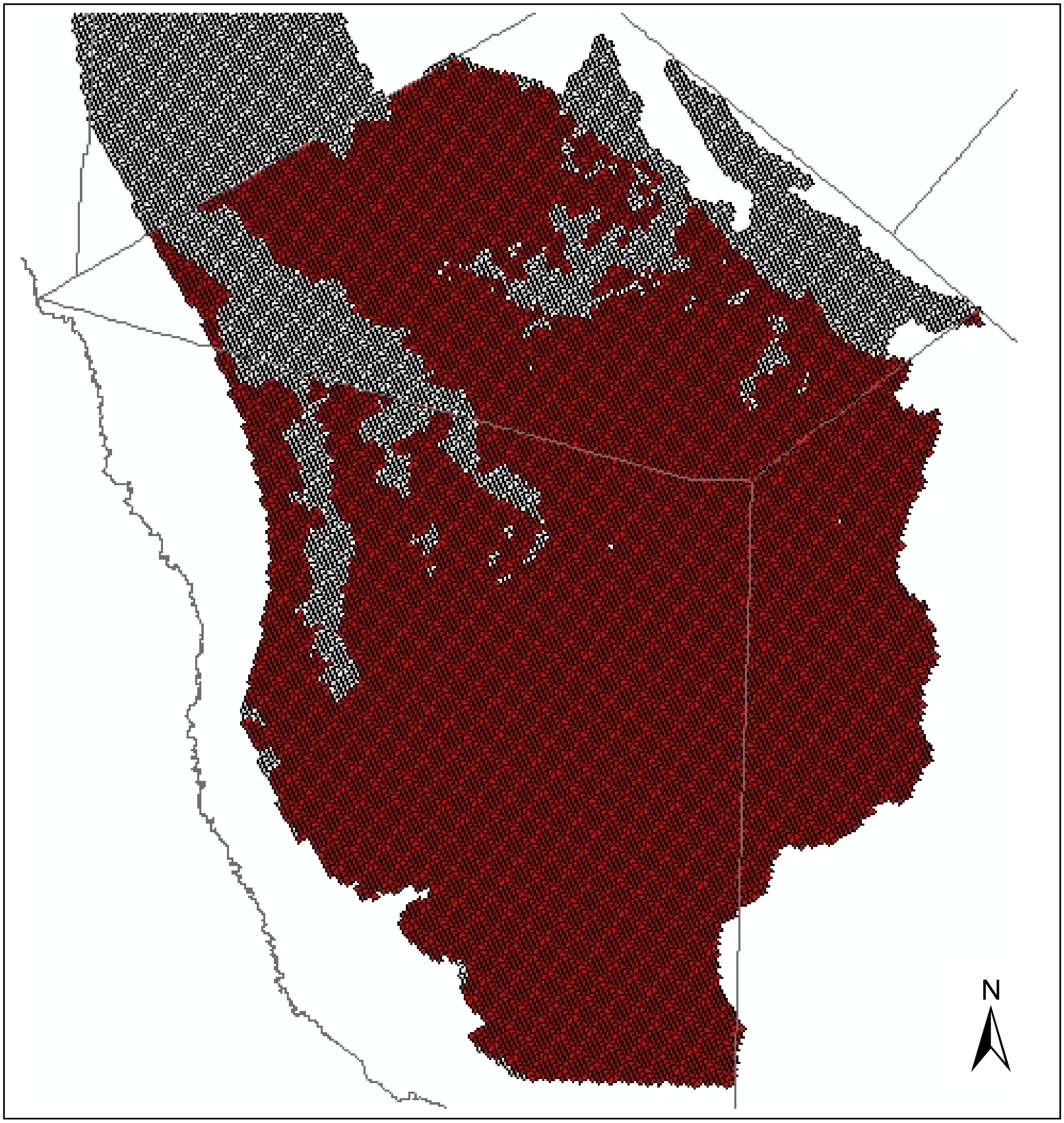


Figure 9. Extent of the Igneous aquifer in the GAM. Model cells in red are active cells that contain pumpage in 2000. Model cells in white are active cells without pumpage. The scale of this figure makes it difficult to see individual model cells.

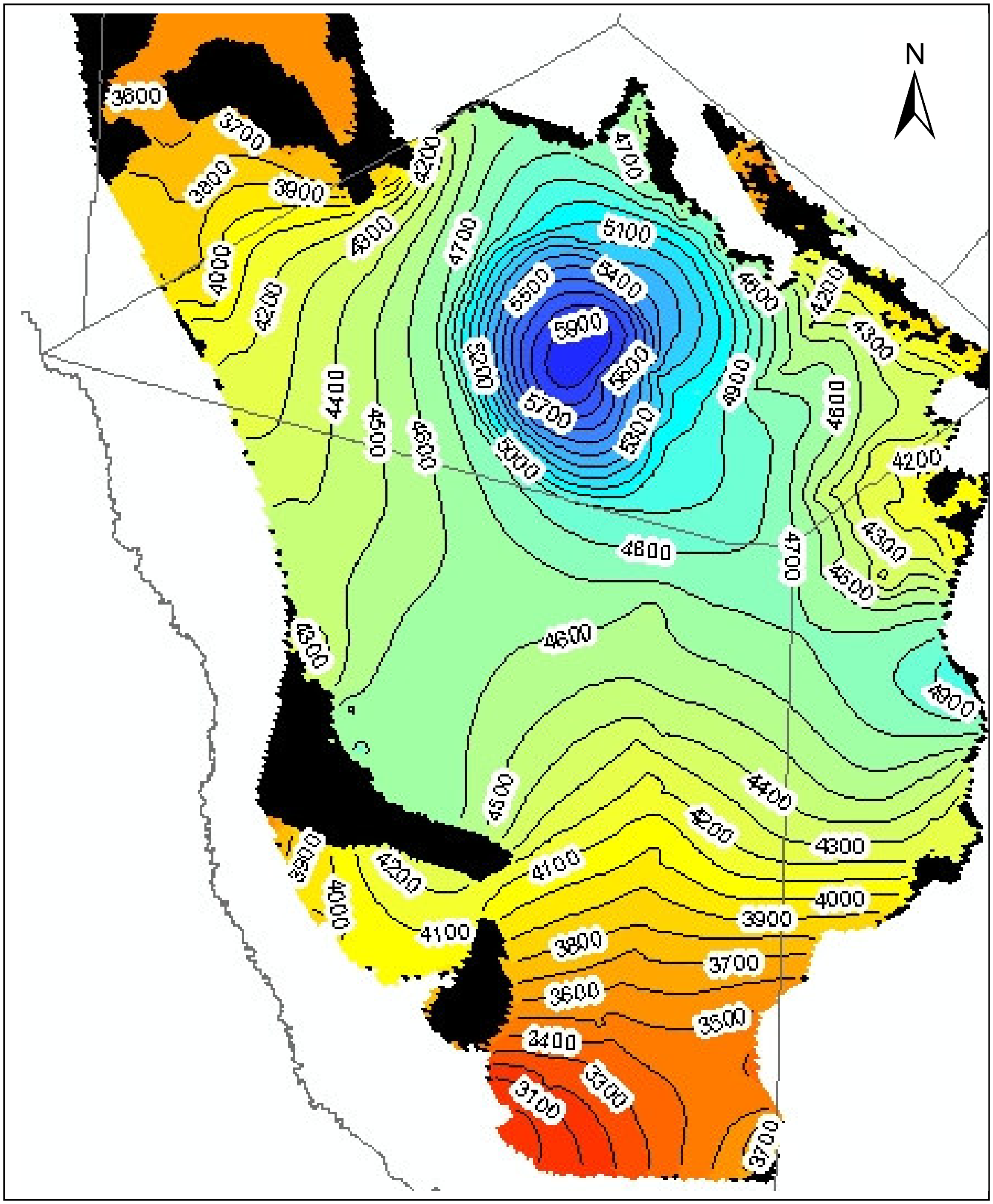


Figure 10. Initial water levels in the Igneous aquifer in the year 2000. Contour interval is 100 feet. Black areas are where the aquifer is dry.

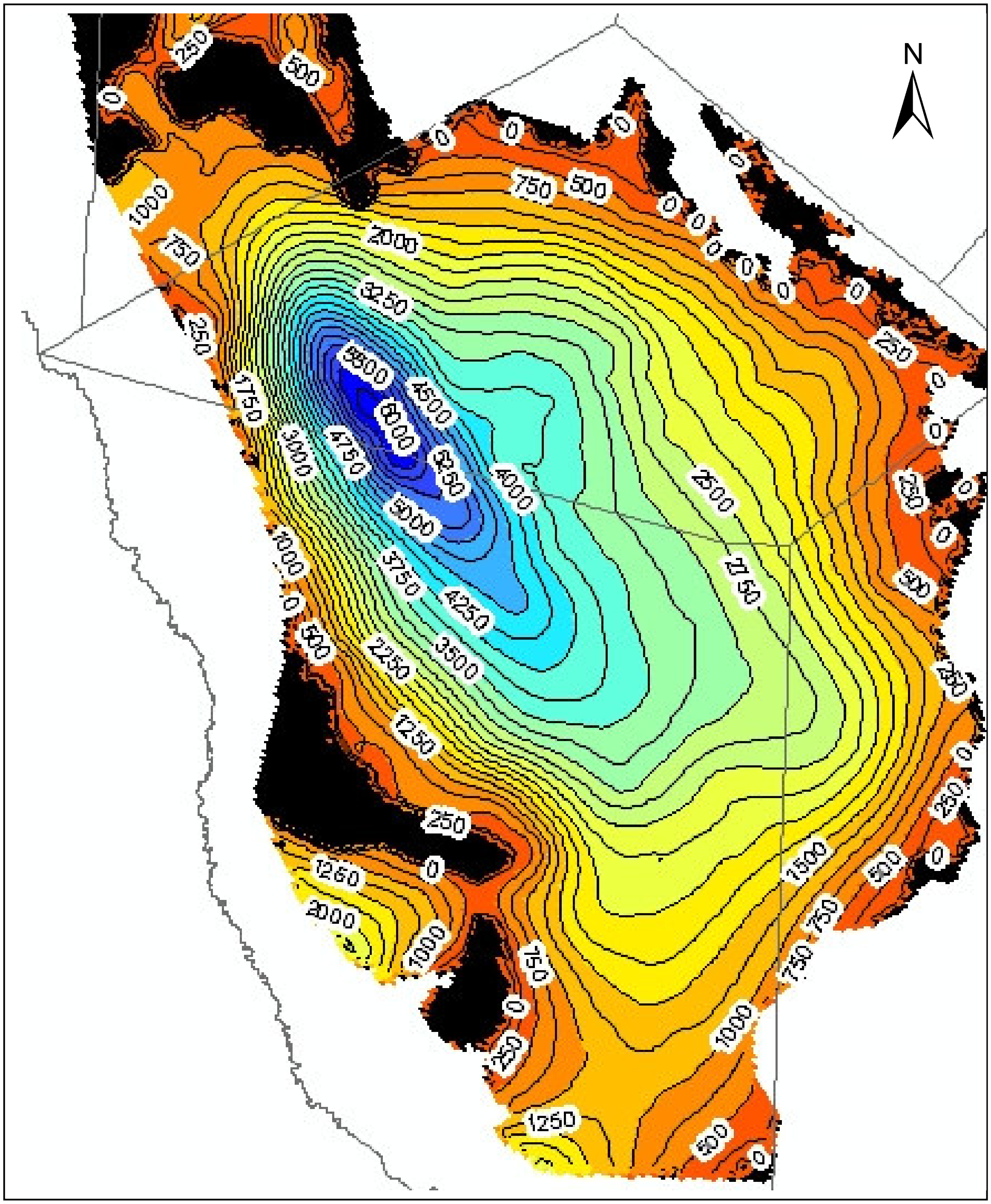


Figure 11. Initial saturated thicknesses of the Igneous aquifer in the year 2000. Contour interval is 500 feet. Black areas are where the aquifer is dry.

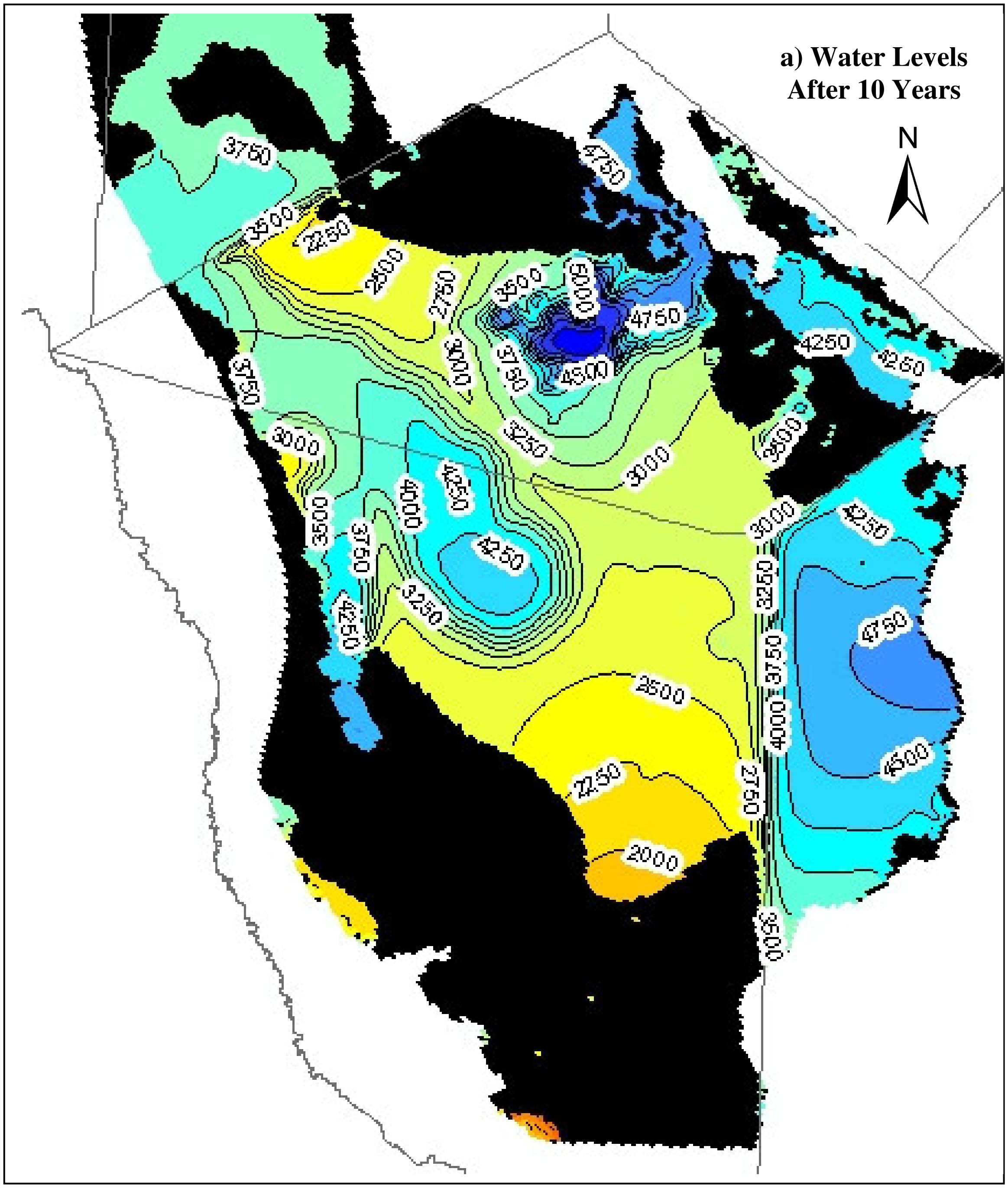


Figure 12. Water levels in Igneous aquifer with a uniform pumpage rate of two acre-feet per acre per year after (a) 10 years, (b) 20 years, (c) 30 years, (d) 40 years, and (e) 50 years of pumpage. Dry model cells are shown in black.

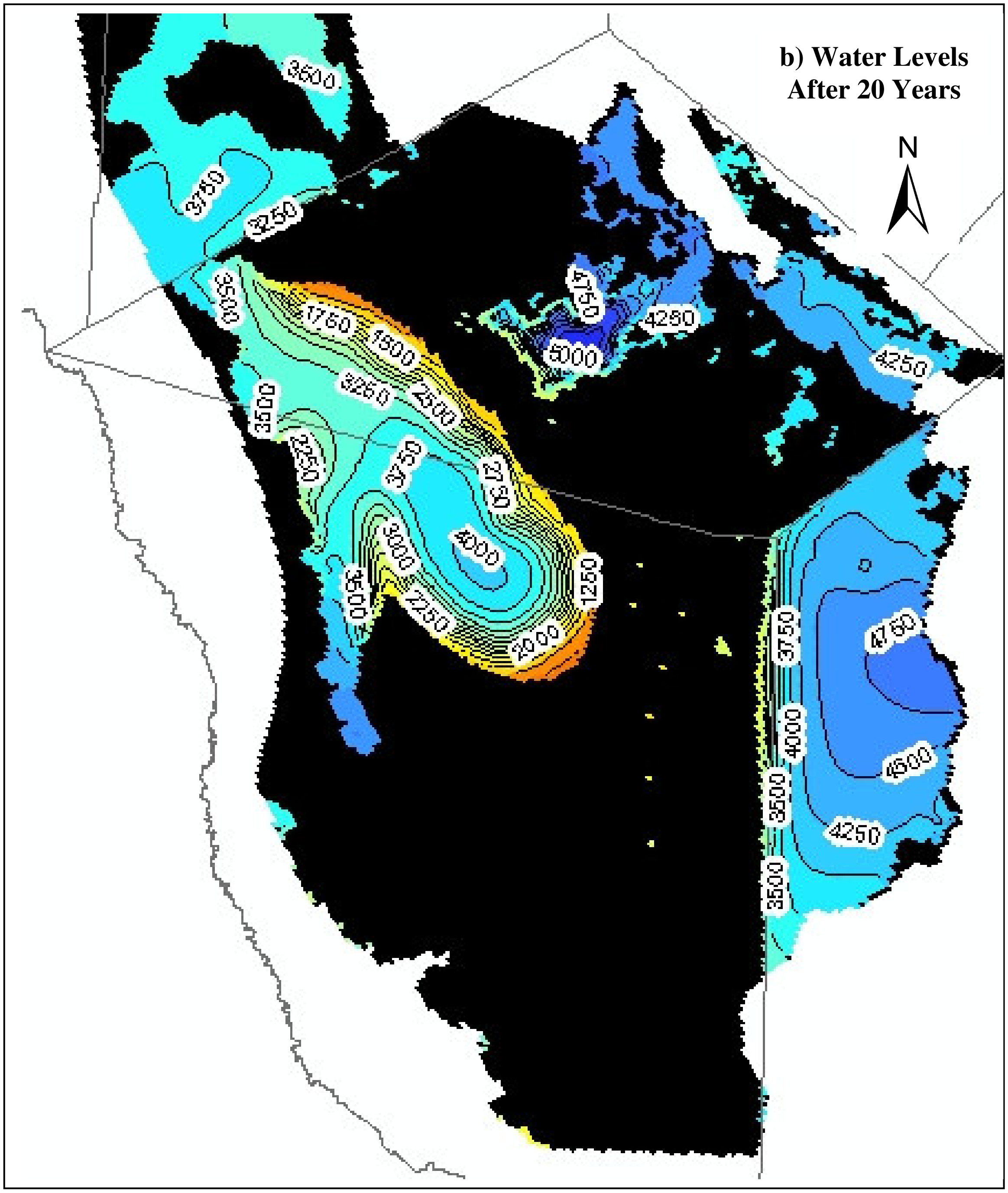


Figure 12. (continued)

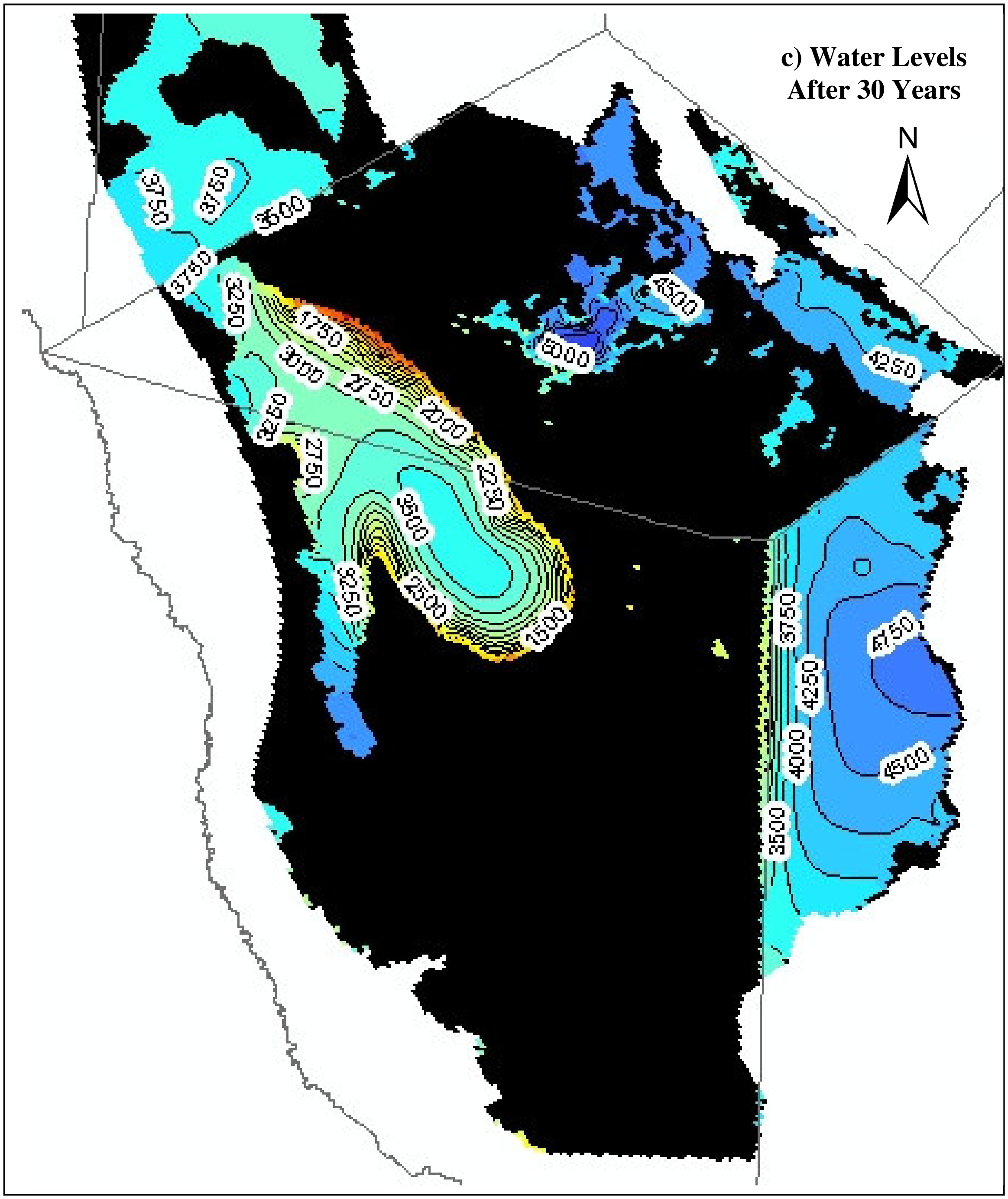
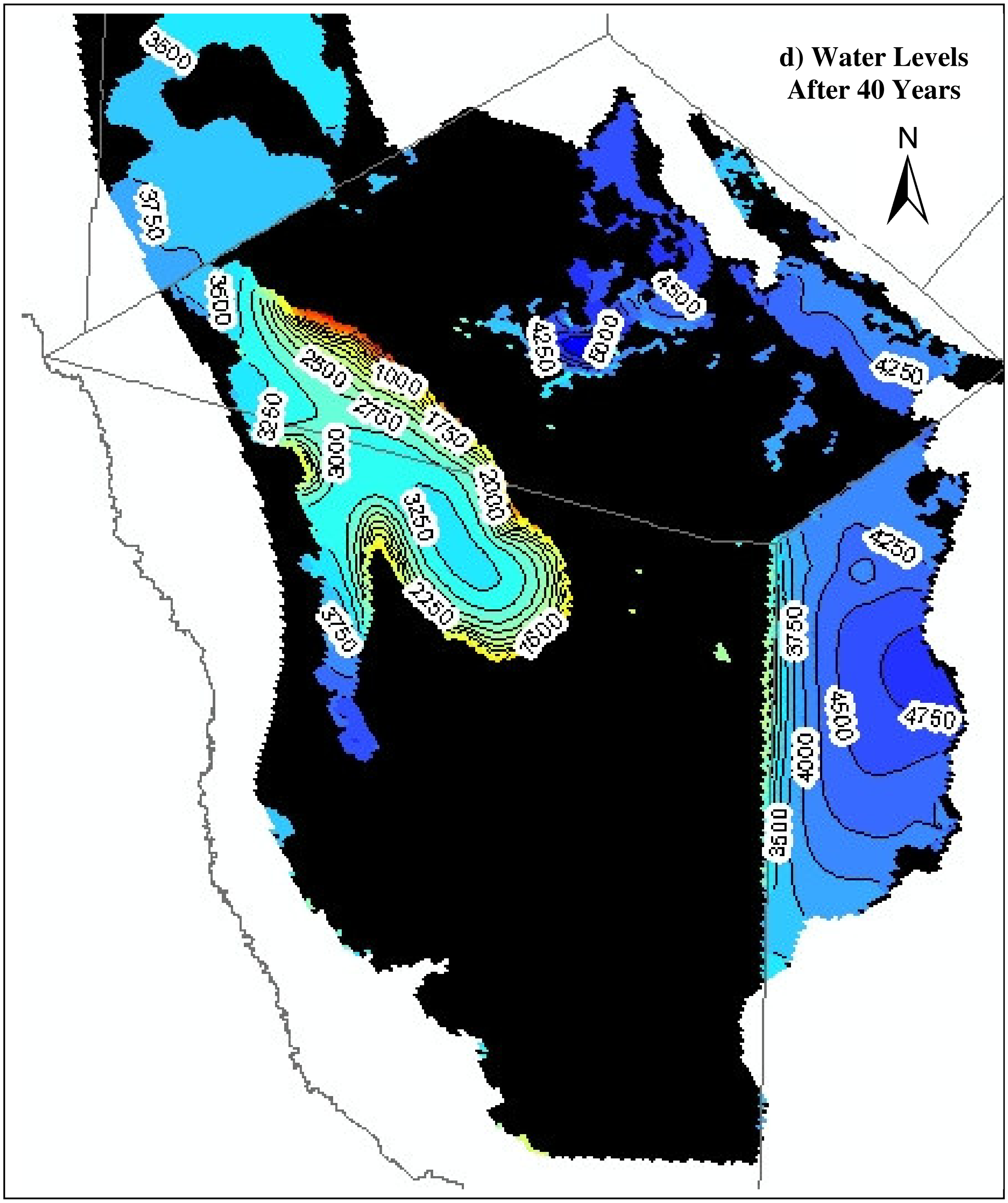


Figure 12. (continued)



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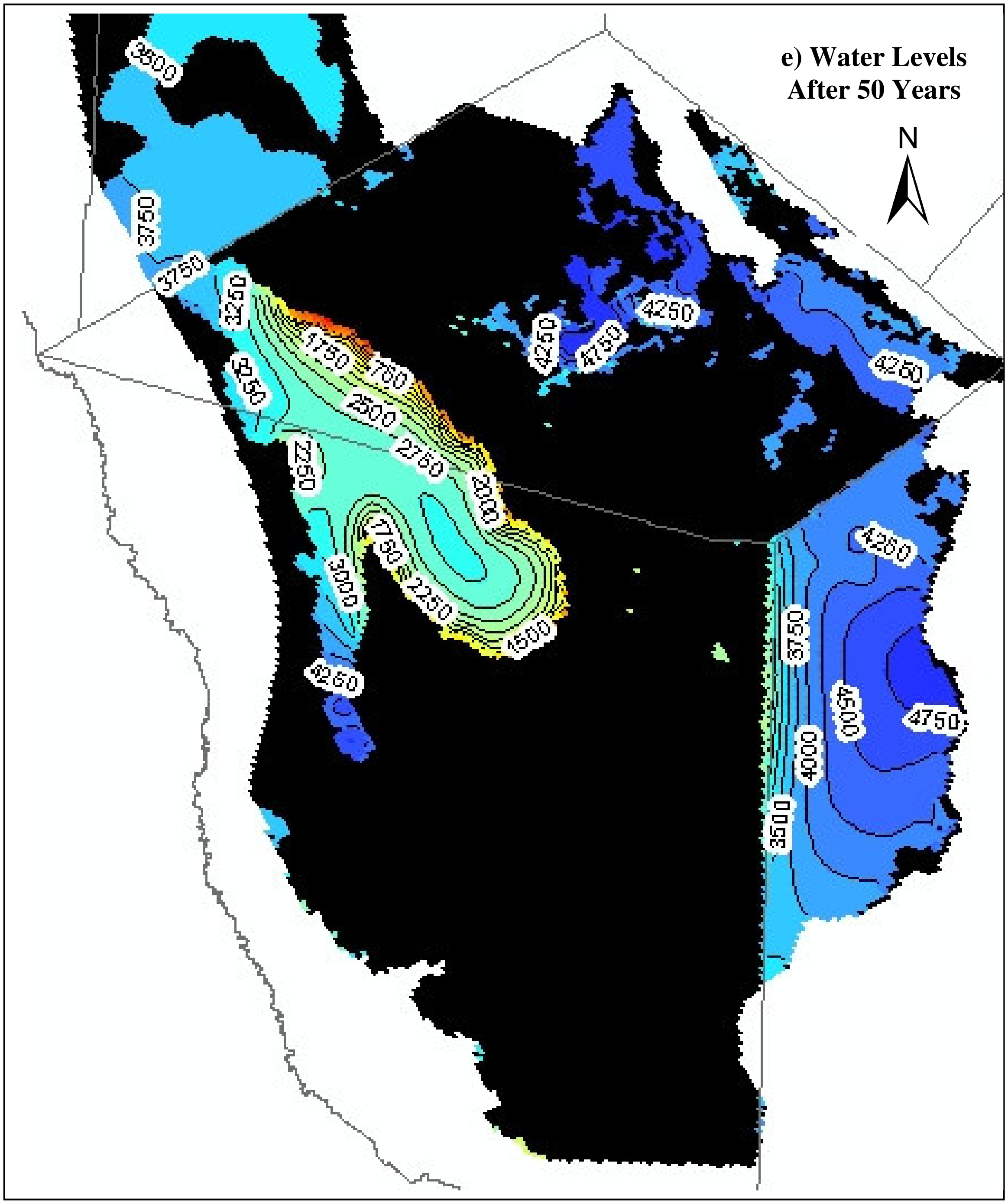

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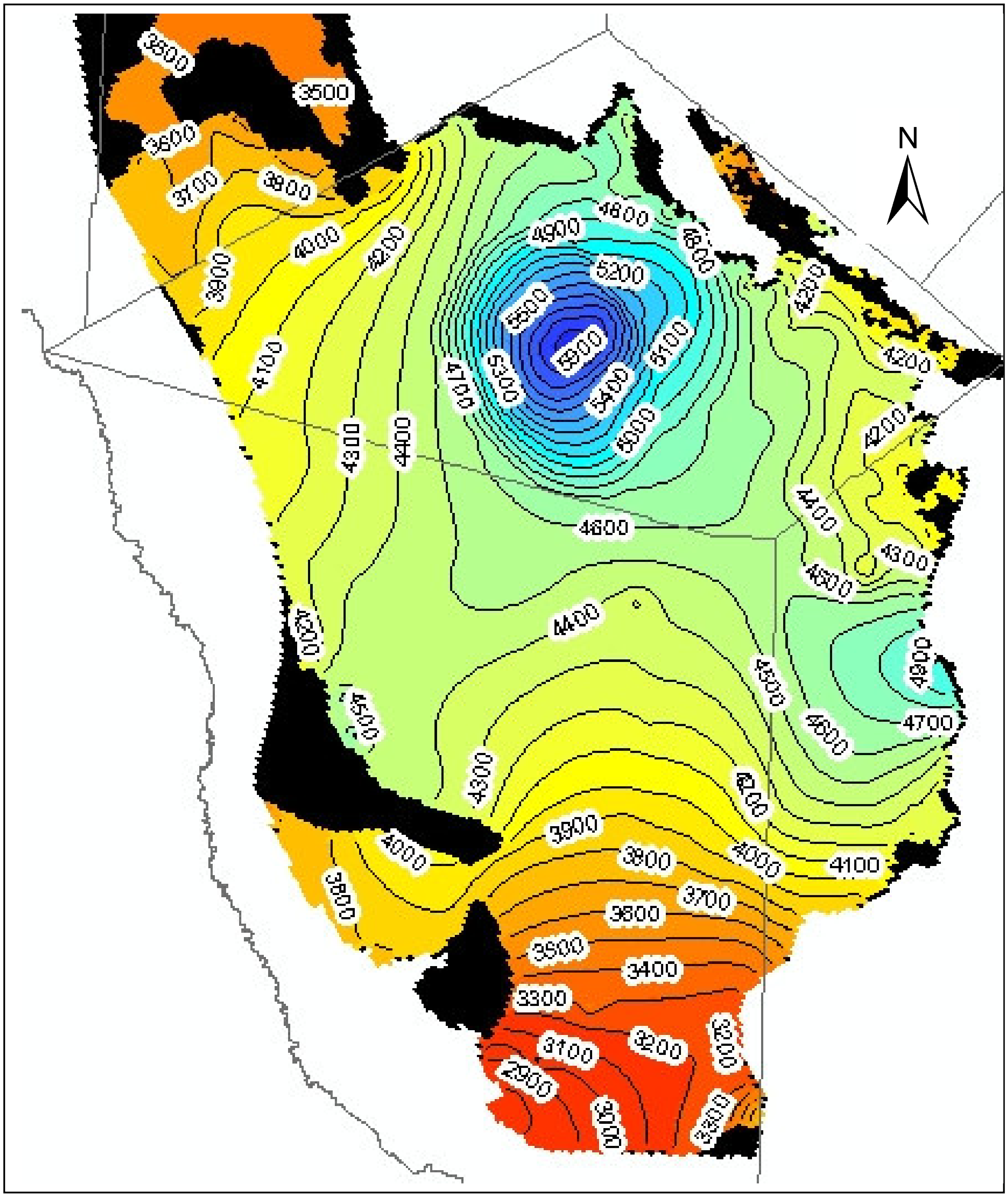

Figure 13. Water levels in the Igneous aquifer after 50 years with a uniform pumping rate of 0.05 acre-feet per acre per year.

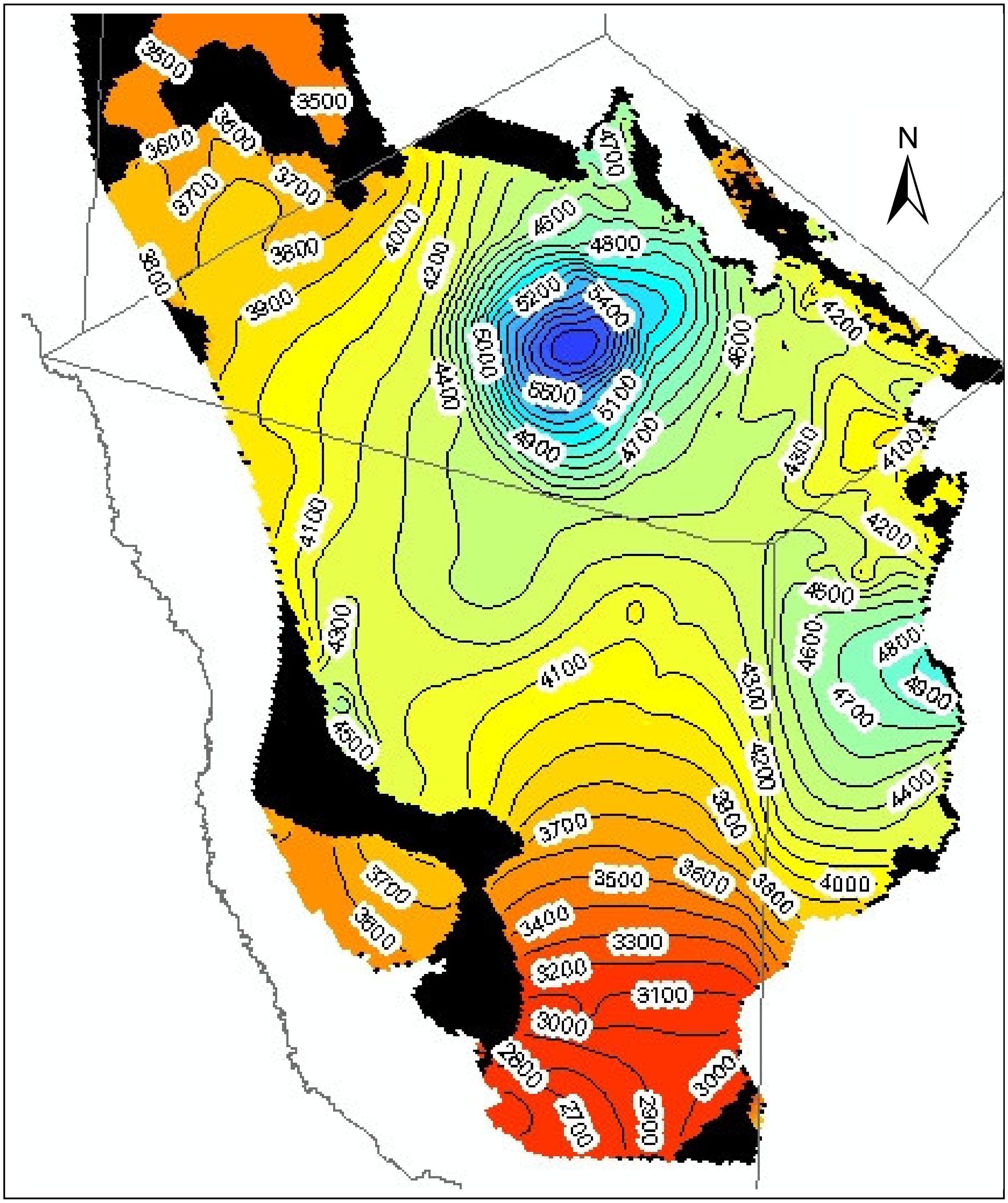

Figure 14. Water levels in the Igneous aquifer after 50 years with a uniform pumping rate of 0.10 acre-feet per acre per year.

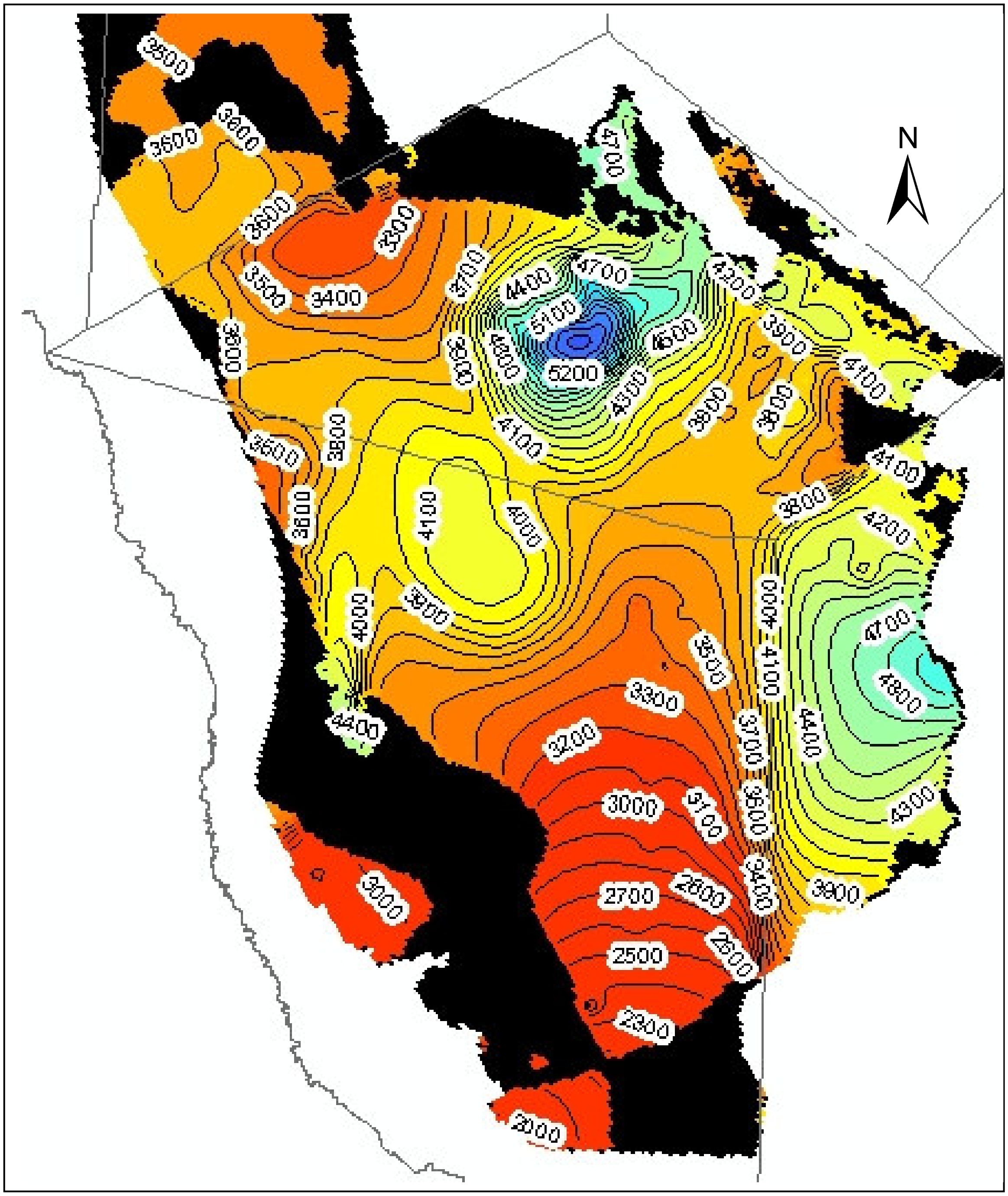

Figure 15. Water levels in the Igneous aquifer after 50 years with a uniform pumping rate of 0.25 acre-feet per acre per year.

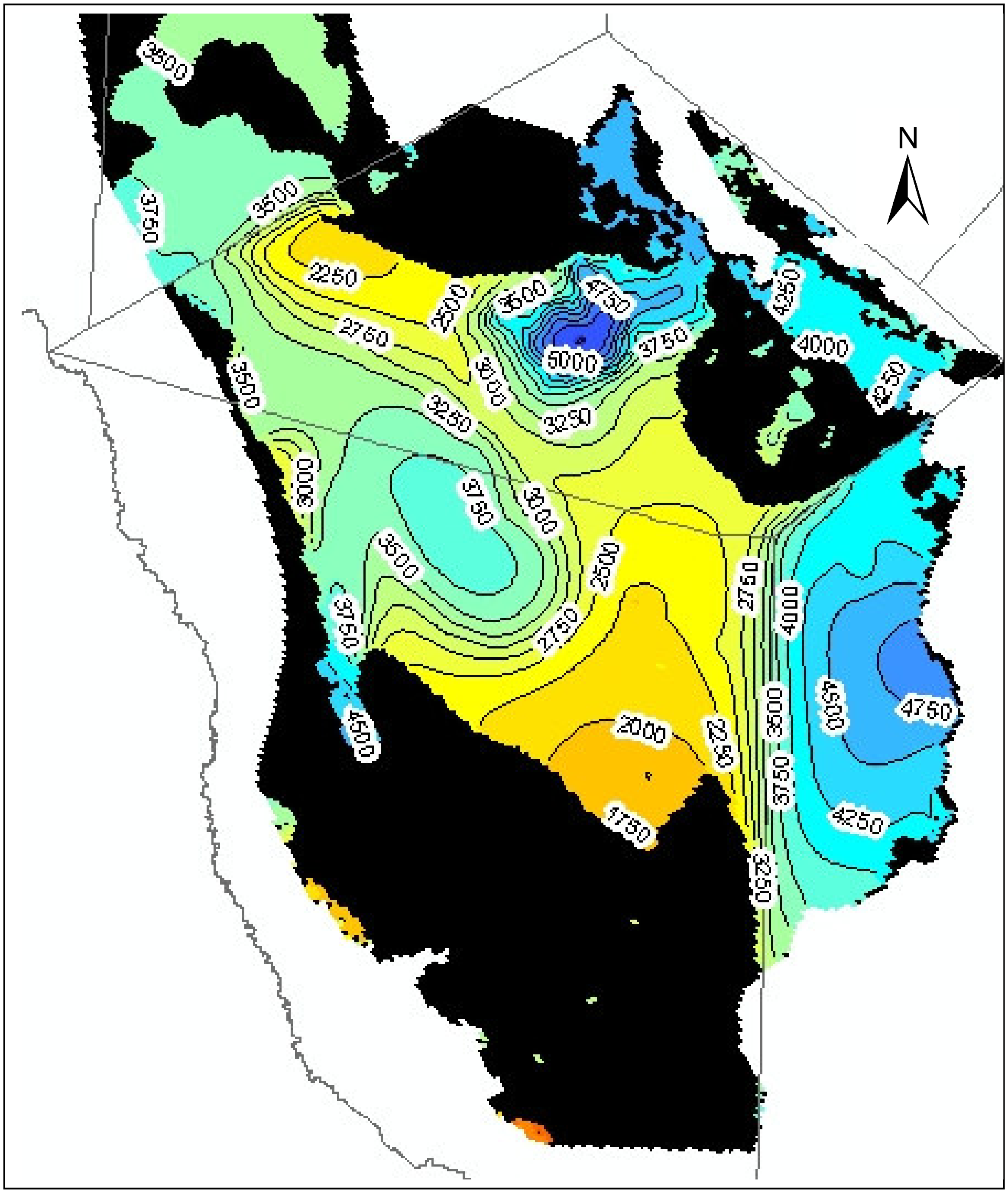

Figure 16. Water levels in the Igneous aquifer after 50 years with a uniform pumping rate of 0.50 acre-feet per acre per year.

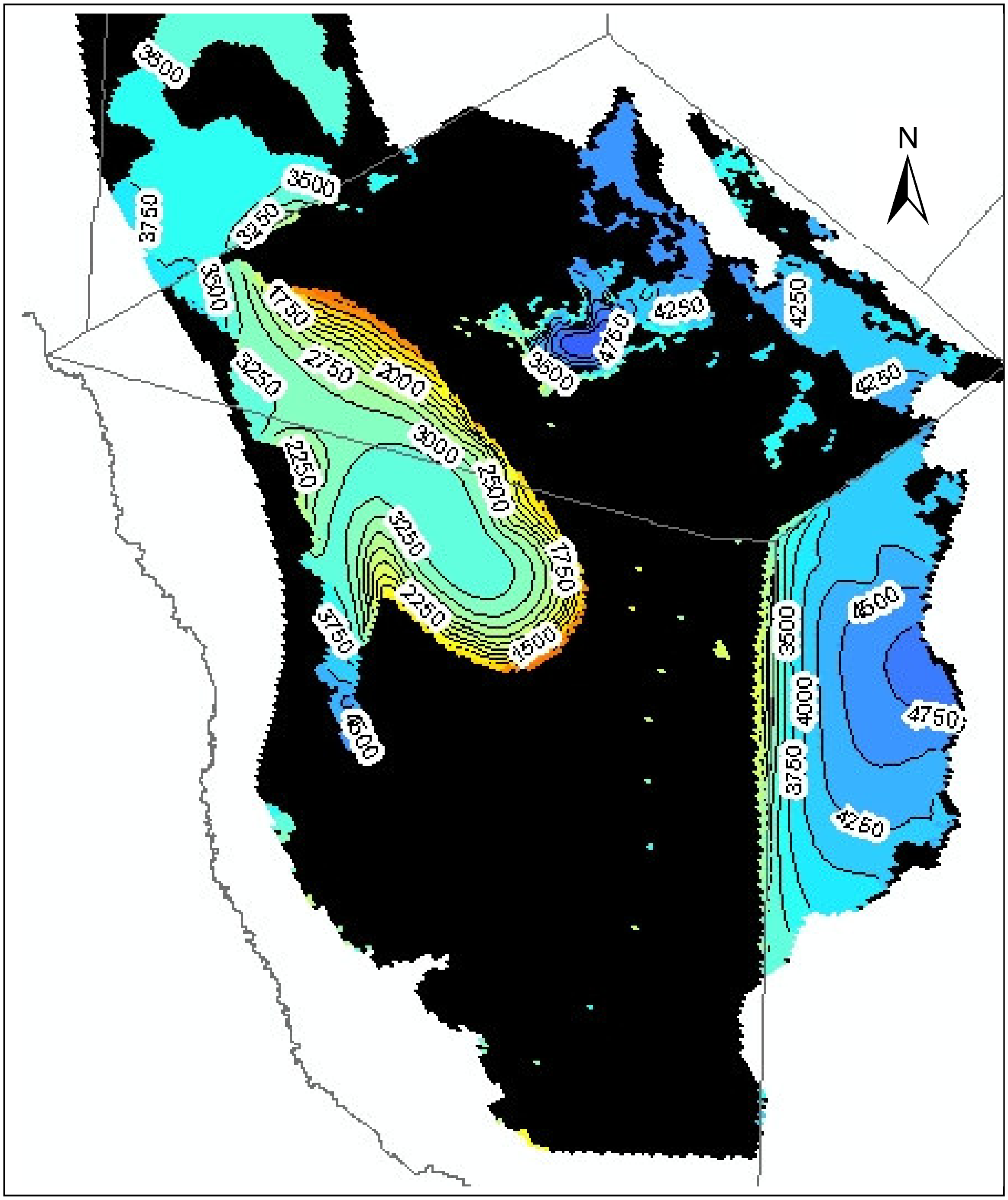

Figure 17. Water levels in the Igneous aquifer after 50 years with a uniform pumping rate of 1.0 acre-feet per acre per year.