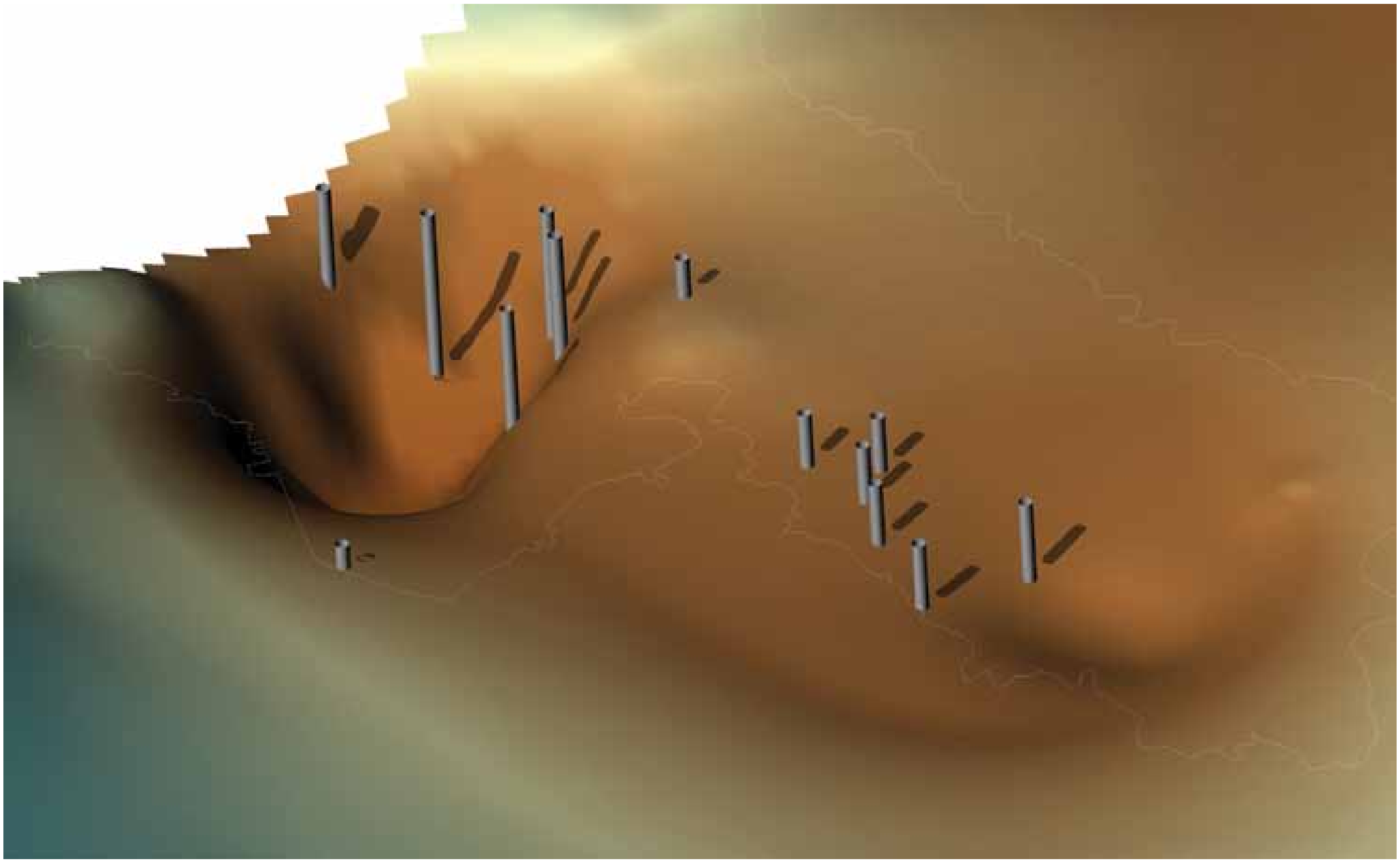
Prepared in cooperation with the Arkansas Natural Resources Commission

Simulation of the Effects of Groundwater Withdrawals on Water-Level Altitudes in the Sparta Aquifer in the Bayou Meto-Grand Prairie Area of Eastern Arkansas, 2007–37



Scientific Investigations Report 2011–5215

U.S. Department of the Interior
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Cover: Oblique view of simulated water levels and selected wells in the Bayou Meto-Grand Prairie study area in eastern Arkansas.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Vertical coordinate information is referenced to National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Simulation of the Effects of Groundwater Withdrawals on Water-Level Altitudes in the Sparta Aquifer in the Bayou Meto-Grand Prairie Area of Eastern Arkansas, 2007–37

By Brian R. Clark[1], Drew A. Westerman[1], and D. Todd Fugitt[2]

Abstract

A groundwater-flow model of the Mississippi embayment was used to evaluate changes in water-level altitudes before (scenario 1) and after (scenario 2) the addition of wells that simulate potential future pumping from the Sparta aquifer in the Bayou Meto-Grand Prairie area of eastern Arkansas for the 30-year period from 2007 through 2037. Water-level altitudes at six model cell locations from the two different scenarios were compared for the period 2007 through 2037. Potential future pumping wells were added to the Mississippi Embayment Regional Aquifer Study model at a rate of 13 wells per year within areas of potential future pumping. Change maps for the Bayou Meto-Grand Prairie area were constructed for each scenario and water-level hydrographs were constructed for each scenario for each of the six model cell locations. The additional pumping from wells in the Sparta aquifer created greater water-level declines in the Bayou Meto-Grand Prairie area. In scenario 1, simulated water-level altitude declines range from 20 to 40 feet from 2007 through 2037. In scenario 2, the cone of depression in Lonoke County is the deepest, with a maximum water-level decline of approximately 102 feet. Water-level altitude declines range from 40 to 50 feet over most of the remainder of the Bayou Meto-Grand Prairie area in scenario 2. Simulated water-level altitudes across the Bayou Meto-Grand Prairie area and at all six model cell locations indicate substantial declines when additional wells pumping from the Sparta aquifer are introduced into the model from 2007 through 2037.

Introduction

The Sparta aquifer, known regionally as the middle Claiborne aquifer, is a confined aquifer of regional importance within the Mississippi embayment aquifer system. It consists of varying amounts of unconsolidated sand, interstratified with silt and clay lenses within the Sparta Sand of the Claiborne Group. In 2005, about 170 million gallons per day (Mgal/d) was pumped from the Sparta aquifer in Arkansas. The Bayou Meto-Grand Prairie area (BMGP) (fig. 1), consisting dominantly of Arkansas, Lonoke, and Prairie Counties, with parts of White and Jefferson Counties (Clark and others, 2011, U.S. Army Corps of Engineers, 2011), had the largest amount of pumping (over 51 Mgal/d) in Arkansas (Holland, 2007). Groundwater-level declines over 100 feet (ft) in some areas in the BMGP of eastern Arkansas have caused cones of depression to develop in the water-level surface of the aquifer (Clark and others, 2011). Pumping from the Sparta aquifer is one to two orders of magnitude less than pumping from the Mississippi River Valley alluvial aquifer (hereafter referred to as the alluvial aquifer). The large difference in pumping is attributed to fewer wells, lower aquifer permeability, and lower storage than the alluvial aquifer. However, because the Sparta aquifer is confined, the volumes of groundwater pumped produce much larger water-level declines. Because of the water-level declines, water users and managers question the ability of the aquifer to supply water for the long term.

For the analysis contained in this report, the groundwater-flow model of the Mississippi Embayment Regional Aquifer Study of Clark and others (2011) (hereafter referred to as the MERAS model) was used to simulate groundwater flow and water-level altitudes for the period 2007 through 2037. The study area includes the BMGP area, which was designated as a Critical Groundwater Area by the Arkansas Natural Resource Commission (ANRC) in 1998 (Arkansas Natural Resources Conservation Commission, 2009). Increases in the number of wells constructed in the Sparta aquifer in the BMGP area in response to a projected increase in demand on the Sparta aquifer because of declining water levels in the alluvial aquifer are of concern to the ANRC.

The purpose of this report (prepared in cooperation with ANRC) is to present an analysis of the effects of groundwater withdrawals on water-level altitudes within the Sparta aquifer from 2007 through 2037. The report shows comparisons between simulated water-level altitudes derived from the MERAS model for pumping rates from 2005 (scenario 1) and pumping rates from 2005 with potential future pumping from additional Sparta aquifer wells in the BMGP area (scenario 2).

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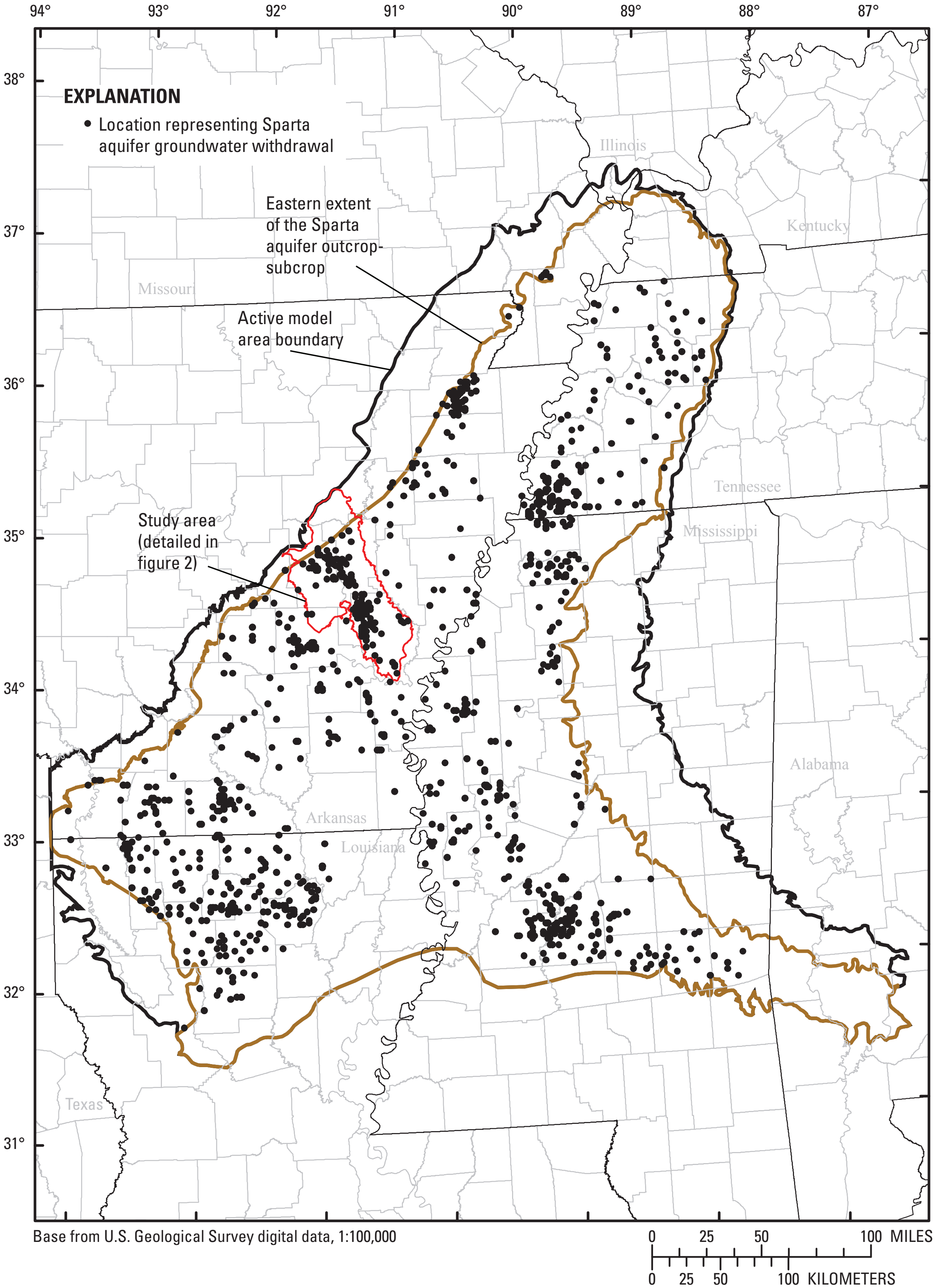

Figure 1. Location of study area, active model area, and model cell locations with Sparta (middle Claiborne) aquifer groundwater withdrawals.

The number and location of wells added for scenario 2 are described in the following methods section.

Methods

The MERAS model was used to simulate water-level altitudes before and after the addition of wells that simulate potential future pumping from the Sparta aquifer for approximately a 30-year period from 2007 through 2037. The simulation period was divided into 16 transient stress periods (Clark and others, 2011). The pumping rate for each additional well was determined from the average pumping rate of Sparta aquifer wells in the BMGP area during 2005 (381 acre-feet/year [acre-ft/yr]). The number of wells added to the simulation was determined from the number of Sparta aquifer wells constructed in the BMGP area from 1998 to 2011 (an average of approximately 13 wells per year). The new wells were added to the simulation beginning in 2008, and 26 wells were added each stress period, which represents a 2-year period, and an increase in pumping of approximately 20 percent over 2005 pumping rates each stress period. Additional wells were located within areas where depressions in the alluvial aquifer potentiometric surface existed (Schrader, 2008, 2010) to simulate potential future pumping from the Sparta aquifer (fig. 2). The area of potential future pumping was weighted more heavily to Lonoke and Prairie Counties, meaning that new wells would be added sooner to these areas rather than the area in Arkansas County (fig. 2). The reason for this weighting is that the Sparta aquifer is closer to land surface in Lonoke and Prairie Counties, making it more economically feasible to drill wells in that area, rather than in Arkansas County where the Sparta aquifer is deeper.

Effects of Groundwater Withdrawals on Water-Level Altitudes

Simulated water-level altitudes vary between scenario 1 and the addition of Sparta aquifer pumping wells specified in scenario 2. Hydrographs for each scenario at six model cell locations near production wells of concern are plotted in figure 3. The general shape of the different hydrographs are similar for each of the hydrograph sets (fig. 3), although water-level declines are greater in scenario 2. Water-level declines simulated by scenario 1 between 2007 and 2037 in the Sparta aquifer range from 22.7 ft at model cell 6 to 29.1 ft at model cell 4 (table 1 and fig. 3). After the addition of pumping wells in scenario 2, water levels declined an additional 21.2 ft (43.9 ft total decline from 2007) at model cell 6 and 30.3 ft (59.4 ft total decline from 2007) at model cell 4 (table 2). The greatest water-level decline (61.5 ft) in scenario 2 occurred at model cell 2, which lies within a part of the BMGP area with the highest density of pumping from the Sparta aquifer. The second greatest water-level decline (59.4 ft) in scenario 2 occurred at model cell 4 (table 2), which lies in the center of the cone of depression of the alluvial aquifer in Arkansas County. Water-level altitudes at model cells 2, 5, and 6 declined to a point below the top of the Sparta aquifer (as defined in Hart and others, 2008) by the end of the simulation in both scenarios (table 1 and 2). Because the Sparta aquifer in the BMGP area is currently under confined conditions, water-level declines below the top of the aquifer could result in irreparable loss in aquifer storage because of compaction (Galloway and others, 1999).

The effect of additional wells in the Sparta aquifer is greater water-level declines for scenario 2 compared to scenario 1 (fig. 4). Scenario 1 simulated a water-level altitude decline ranging from 30 to 40 ft from 2007 through 2037 in northern Lonoke and Arkansas Counties (fig. 4). Water-level altitude declines range from 20 to 30 feet over most of the remainder of the BMGP area in scenario 1. The additional pumping wells in scenario 2 produce two distinct cones of depression in the Sparta aquifer by 2037. The cone of depression in Lonoke County is the deepest, with a maximum water-level decline of approximately 102 ft (fig. 4). Water-level altitude declines range from 40 to 50 ft over most of the remainder of the BMGP area in scenario 2. Simulated water-level altitudes across the BMGP area and at all six model cell locations indicate substantial declines when additional Sparta aquifer pumping wells are introduced into the model from 2007 through 2037. These water-level altitude declines may adversely affect production wells in the study area by increasing the energy required to lift the water to land surface.

Model Limitations

An understanding of model limitations is essential to effectively use simulation results. Limitations of analysis using the MERAS model are documented in Clark and Hart (2009). A summary of limitations that need to be considered when interpreting model results is restated here. Because the model is a simplification of a complex system (for example, local variations in hydraulic conductivity and specific storage are not reflected in the model), some error in simulated water-level altitude is expected, similar to the mean absolute difference between observed and simulated water-level altitudes of about 35 ft obtained by Clark and others (2011); however, the magnitude of the error in the simulated change in water-level altitude with time at the BMGP area likely would be less than this amount because this simulation spans a 30-year period compared to the 137-year period simulated by the MERAS model. The Sparta aquifer is simulated as a confined aquifer in the MERAS model. In areas of large water-level decline, such as the cone of depression noted in Lonoke County from scenario 2 and model cells indicated in tables 1 and 2, the assumption of a confined aquifer may be incorrect where the water-level declines below the top of the aquifer.

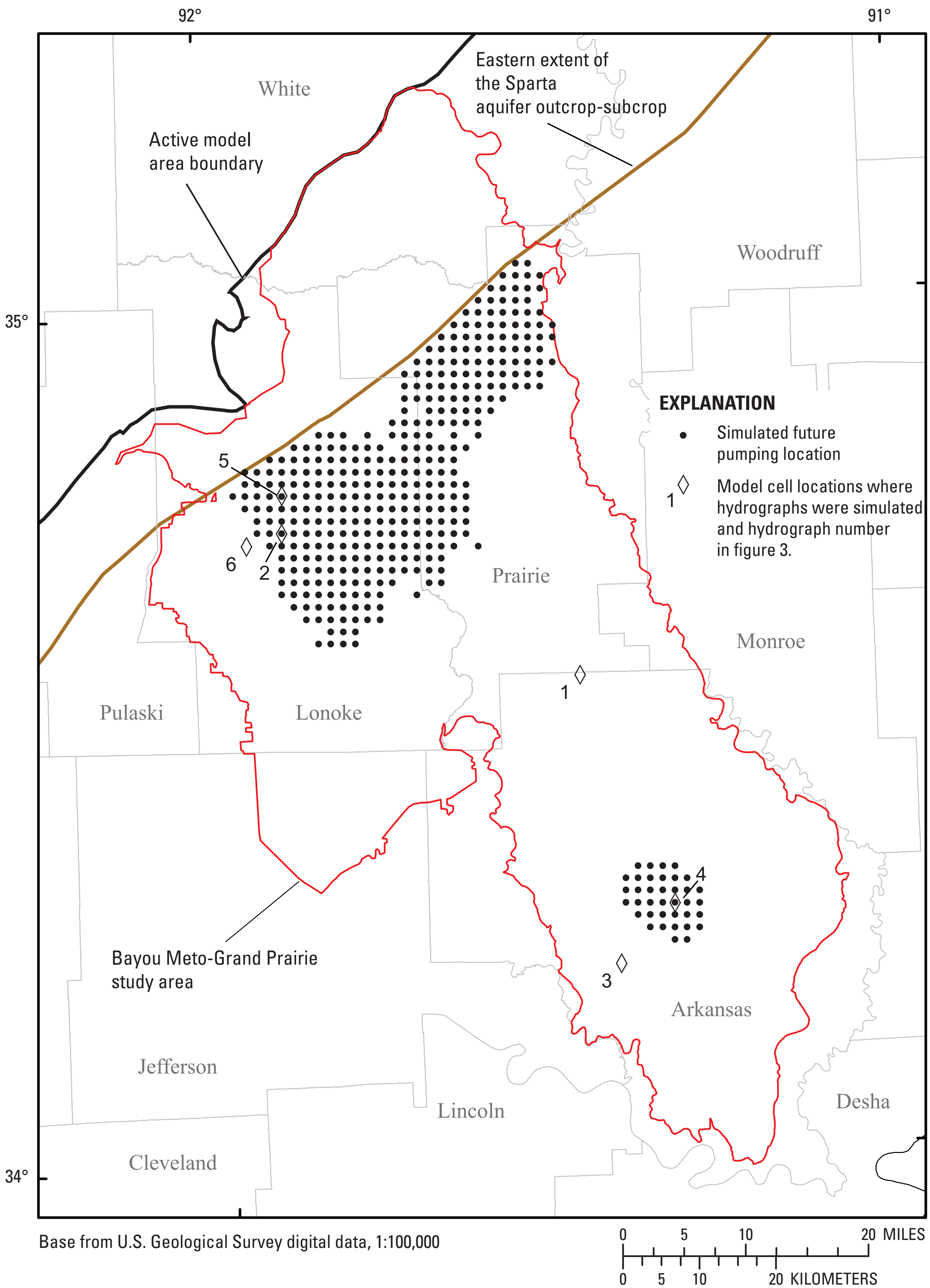

Figure 2. Area of potential future pumping within the study area.

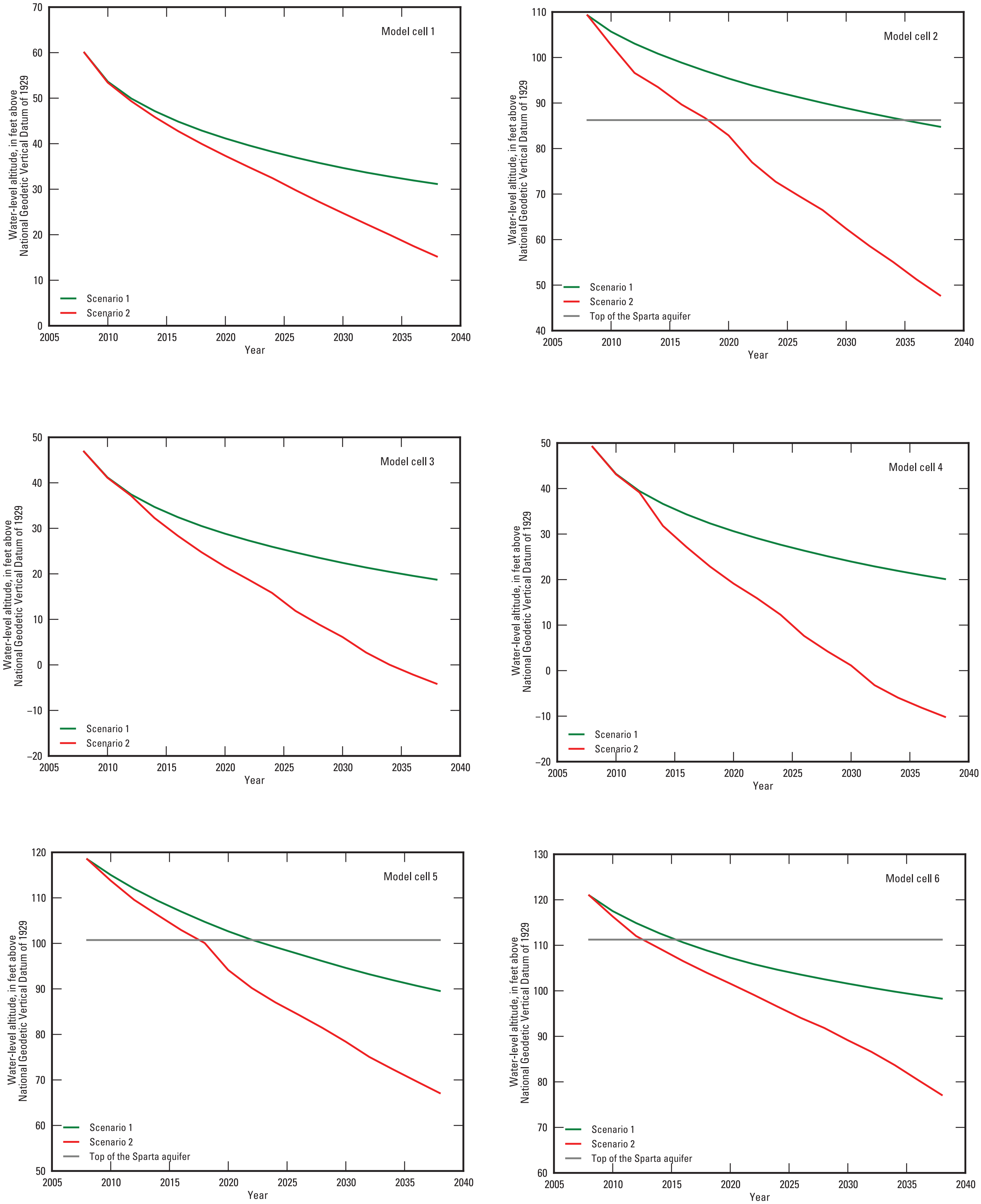

Figure 3. Simulated change in water-level altitude between 2007 and 2037 for scenarios 1 and 2 for each of six model cells.

Table 1. Difference between simulated water-level altitude from 2007 through 2037 for scenario 1 at selected model cells.

[All values in feet; negative values indicate water-level altitudes that are lower than 2007. Scenario 1 extends all pumping at 2005 rates; value enclosed in brackets indicates the water level is below the top of the Sparta aquifer]

Year	Model cell					
	1	2	3	4	5	6
2007	0.0	0.0	0.0	0.0	0.0	0.0
2009	-6.4	-3.6	-5.7	-6.0	-3.5	-3.5
2011	-10.1	-6.2	-9.4	-9.8	-6.5	-6.1
2013	-12.9	-8.4	-12.2	-12.6	-9.1	-8.4
2015	-15.2	-10.4	-14.4	-14.9	-11.5	[-10.3]
2017	-17.1	-12.2	-16.4	-16.8	-13.8	[-12.1]
2019	-18.8	-13.9	-18.0	-18.6	-15.8	[-13.7]
2021	-20.4	-15.4	-19.5	-20.1	-17.7	[-15.1]
2023	-21.8	-16.8	-20.9	-21.5	[-19.3]	[-16.3]
2025	-23.1	-18.0	-22.2	-22.8	[-20.8]	[-17.4]
2027	-24.3	-19.2	-23.3	-24.1	[-22.4]	[-18.4]
2029	-25.3	-20.4	-24.4	-25.2	[-23.9]	[-19.4]
2031	-26.3	-21.5	-25.5	-26.3	[-25.3]	[-20.3]
2033	-27.2	-22.5	-26.4	-27.3	[-26.6]	[-21.1]
2035	-28.1	[-23.5]	-27.3	-28.2	[-27.8]	[-21.9]
2037	-28.9	[-24.5]	-28.1	-29.1	[-28.9]	[-22.7]

Table 2. Difference between simulated water-level altitude from 2007 through 2037 for scenario 2 at selected model cells.

[All values in feet; negative values indicate water-level altitudes that are lower than 2007. Scenario 2 increases the number of wells in the study area; value enclosed in brackets indicates the water level is below the top of the Sparta aquifer]

Year	Model cell					
	1	2	3	4	5	6
2007	0.0	0.0	0.0	0.0	0.0	0.0
2009	-6.6	-6.5	-5.8	-6.1	-4.7	-4.6
2011	-10.7	-12.7	-9.7	-10	-8.9	-8.9
2013	-14.2	-15.8	-14.6	-17.4	-12.3	[-11.7]
2015	-17.3	-19.6	-18.5	-22.0	-15.6	[-14.5]
2017	-20.1	-22.6	-22.1	-26.3	[-18.4]	[-17.0]
2019	-22.7	[-26.4]	-25.3	-30.1	[-24.4]	[-19.4]
2021	-25.2	[-32.3]	-28.1	-33.3	[-28.3]	[-21.9]
2023	-27.6	[-36.5]	-31.0	-36.9	[-31.4]	[-24.4]
2025	-30.3	[-39.7]	-35.0	-41.6	[-34.2]	[-26.9]
2027	-32.8	[-42.8]	-38.0	-45.0	[-37.0]	[-29.1]
2029	-35.3	[-46.9]	-40.7	-48.1	[-40.1]	[-31.8]
2031	-37.7	[-50.7]	-44.1	-52.4	[-43.4]	[-34.4]
2033	-40.0	[-54.2]	-46.8	-55.1	[-46.2]	[-37.3]
2035	-42.5	[-58.0]	-49.0	-57.3	[-48.8]	[-40.6]
2037	-44.8	[-61.5]	-51.0	-59.4	[-51.4]	[-43.9]

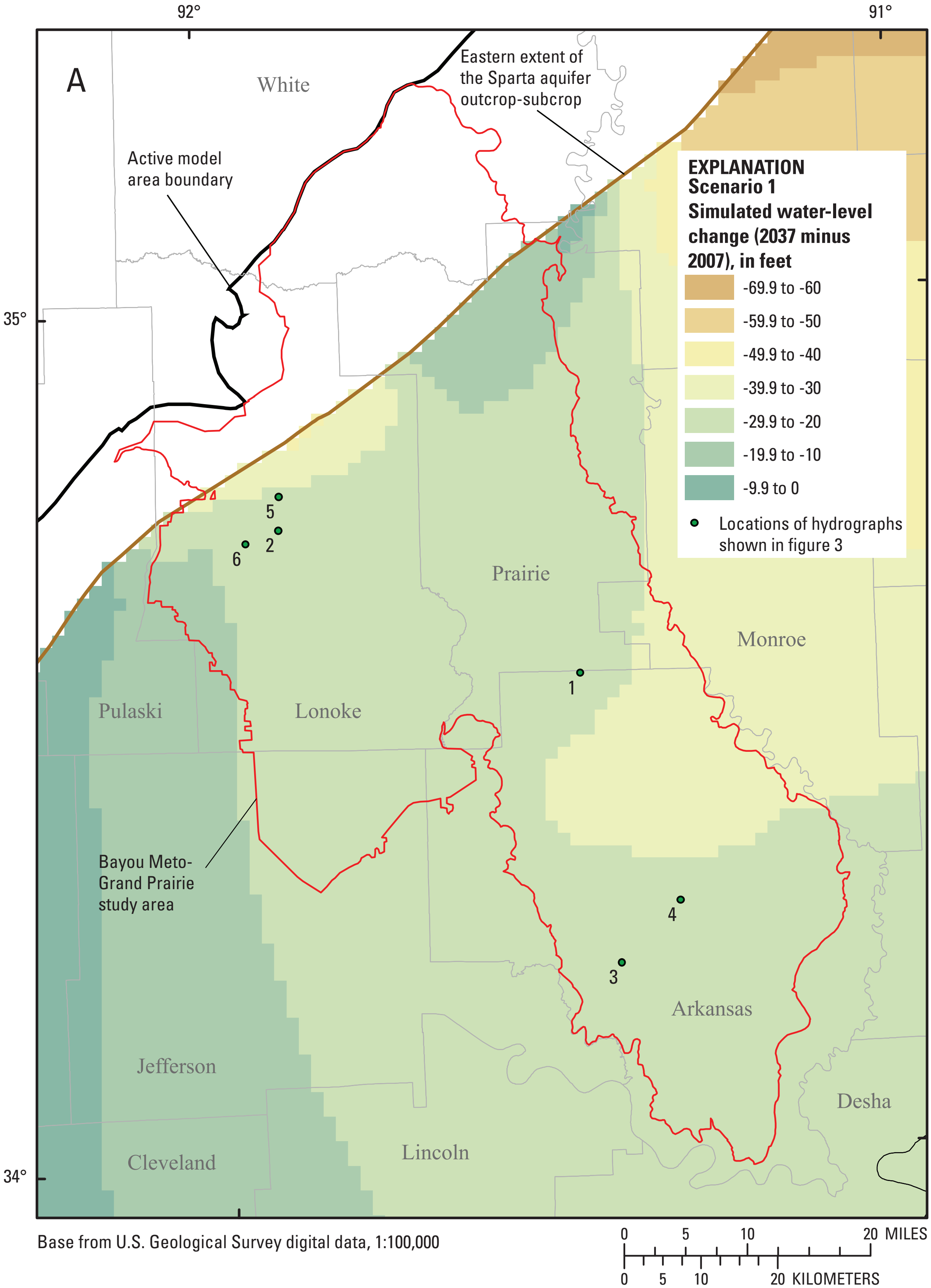

Figure 4. Simulated change in water-level altitude between 2007 and 2037 for (A) scenario 1 and (B) scenario 2 within the study area.

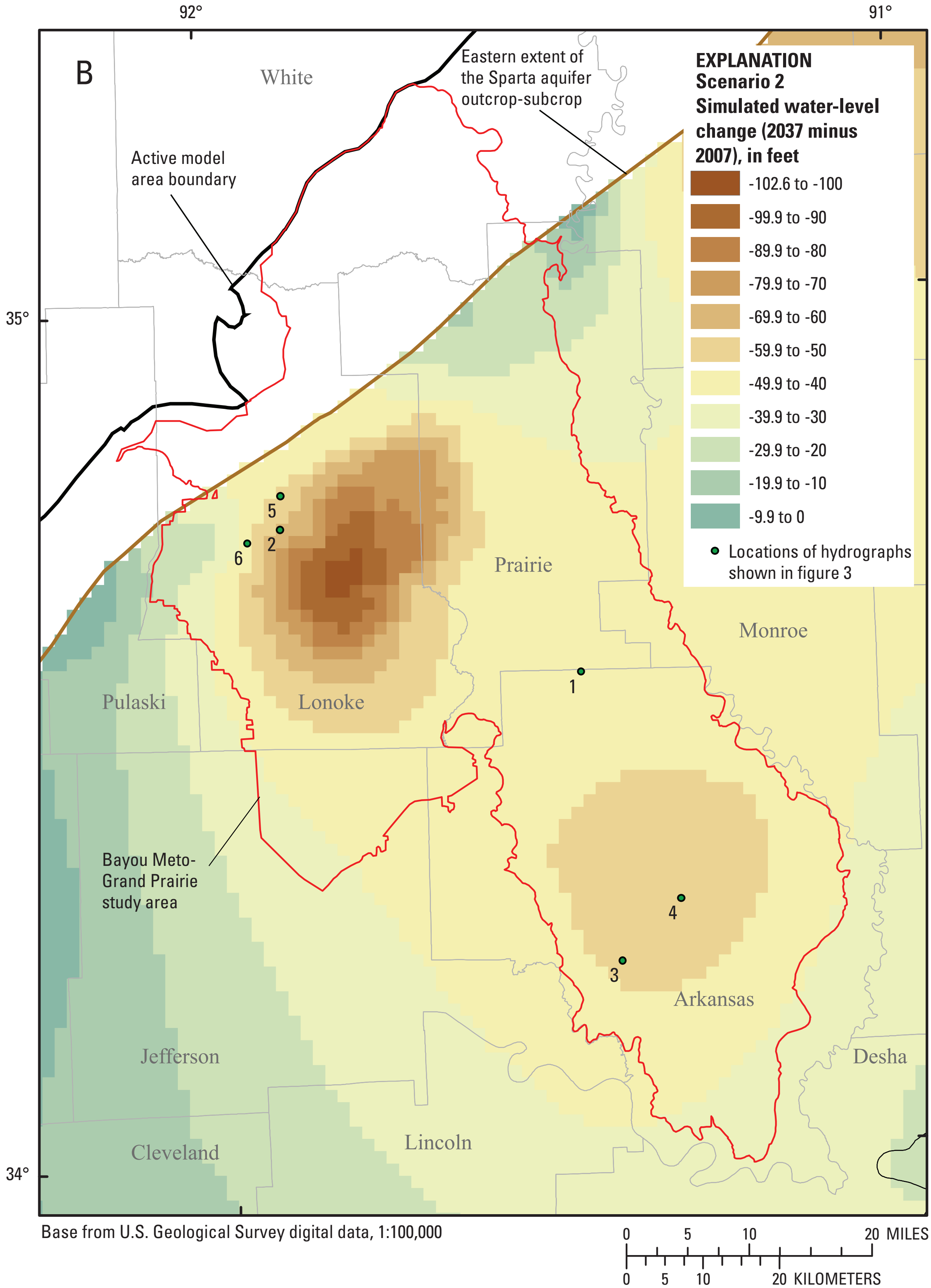

Figure 4. Simulated change in water-level altitude between 2007 and 2037 for (A) scenario 1 and (B) scenario 2 within the study area.—Continued

Summary

A groundwater-flow model of the Mississippi embayment was used to simulate changes in water-level altitudes before (scenario 1) and after (scenario 2) the addition of wells that simulate potential future pumping from the Sparta aquifer in the Bayou Meto-Grand Prairie (BMGP) area of eastern Arkansas for the 30-year period from 2007 through 2037. Water-level altitudes at six model cell locations from the two different scenarios were compared for the period 2007 through 2037. Pumping wells were added to the Mississippi Embayment Regional Aquifer Study (MERAS) model at a rate of 13 wells per year within areas of potential future pumping. Change maps for the Bayou Meto-Grand Prairie area were constructed for each scenario and water-level hydrographs were constructed for each scenario for each of the six model cell locations. Simulated water-level altitudes decrease in response to the addition of Sparta aquifer pumping wells. The general shape of the different hydrographs are similar for each of the hydrograph sets, although water-level declines are greater in scenario 2. Water-level declines simulated by scenario 1 from 2007 through 2037 in the Sparta aquifer range from 22.7 feet (ft) at model cell 6 to 29.1 ft at model cell 4. The greatest water-level decline of 61.5 ft in scenario 2 occurred at model cell 2, which lies within a part of the BMGP area with the highest density of pumping from the Sparta aquifer.

The additional wells in the Sparta aquifer created greater water-level declines in the BMGP area. Simulated water-level altitude declines range from 20 to 40 ft from 2007 through 2037 in scenario 1. The additional pumping wells in scenario 2 produce two distinct cones of depression in the Sparta aquifer by 2037. The cone of depression in Lonoke County is the deepest, with a maximum water-level decline of approximately 102 ft. Water-level altitude declines range from 40 to 50 ft over most of the remainder of the BMGP area in scenario 2. Simulated water-level altitudes across the BMGP area and at all six model cell locations indicate substantial declines when additional Sparta aquifer pumping wells are introduced into the model from 2007 through 2037. These water-level altitude declines may adversely affect production wells in the study area by increasing the energy required to lift the water to land surface.

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