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Effects of Proposed Additional Ground-Water Withdrawals from the Mississippi River Valley Alluvial Aquifer on Water Levels in Lonoke County, Arkansas

Scientific Investigations Report 2006-5275

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors and Vertical Datum

Multiply	By	To obtain
foot (ft)	0.3048	meter (m)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
mile (mi)	1.609	kilometer (km)
gallon (gal)	3.785	liter (L)
square mile (mi^2)	2.590	square kilometer (km^2)

Altitude, as used in this report, refers to distance above the vertical datum, and is referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929).

Effects of Proposed Additional Ground-Water Withdrawals from the Mississippi River Valley Alluvial Aquifer on Water Levels in Lonoke County, Arkansas

By John B. Czarnecki

Abstract

The Grand Prairie Water Users Association, located in Lonoke County, Arkansas, plans to increase ground-water withdrawals from the Mississippi River Valley alluvial aquifer from their current (2005) rate of about 400 gallons per minute to 1,400 gallons per minute (2,016,000 gallons per day). The effect of pumping from a proposed well was simulated using a digital model of ground-water flow. The proposed additional withdrawals were added to an existing pumping cell specified in the model, with increased pumping beginning in 2005, and specified to pump at a total combined rate of 2,016,000 gallons per day for a period of 46 years. In addition, pumping from wells owned by Cabot Water Works, located about 2 miles from the proposed pumping, was added to the model beginning in 2001 and continuing through to the end of 2049.

Simulated pumping causes a cone of depression to occur in the alluvial aquifer with a maximum decline in water level of about 8.5 feet in 46 years in the model cell of the proposed well compared to 1998 withdrawals. However, three new dry model cells occur south of the withdrawal well after 46 years. This total water-level decline takes into account the cumulative effect of all wells pumping in the vicinity, although the specified pumping rate from all other model cells in 2005 is less than for actual conditions in 2005. After 46 years with the additional pumping, the water-level altitude in the pumped model cell was about 177.4 feet, which is 41.7 feet higher than 135.7 feet, the altitude corresponding to half of the original saturated thickness of the alluvial aquifer (a metric used to determine if the aquifer should be designated as a Critical Ground-Water Area (Arkansas Natural Resources Commission, 2006)).

Introduction

The Mississippi River Valley alluvial aquifer (hereafter referred to as the alluvial aquifer) is a water-bearing assemblage of gravels and sands that underlies most of eastern Arkansas and several adjacent States. Ground-water withdrawals have caused cones of depression to develop in the aquifer water-level surface, some as much as 100 feet (ft) deep. Recharge to the alluvial aquifer from rivers becomes induced as ground-water levels decline. Long-term water-level measurements in the alluvial aquifer show an average annual decline of 1 foot per year (ft/yr) in some areas. The expansion of the cones of depression and the consistent water-level declines indicate that ground-water withdrawals are occurring at a rate that is greater than the sustainable yield of the aquifer.

For many years, the Arkansas Natural Resources Commission (ANRC) has worked with the U.S. Geological Survey (USGS) and other agencies in the development of ground-water flow models to be used as management tools to determine the sustainability of the water resource. Ground-water flow models of the alluvial aquifer (north alluvial and south alluvial models—divided by the Arkansas River) were developed for eastern Arkansas and parts of northern Louisiana, southeastern Missouri, and adjacent states (Reed, 2003; Stanton and Clark, 2003). The flow models showed that continued ground-water withdrawals at 1997 rates for the alluvial aquifer could not be sustained indefinitely without causing water levels to decline below half of the original saturated thickness of the alluvial aquifer (a metric that is associated with Critical Ground-Water Area designation by the ANRC for certain counties in Arkansas).

The Grand Prairie Water Users Association (GPWUA) has applied to the ANRC for permission to withdraw ground water from the alluvial aquifer at the rate of 2,016,000 gallons per day (gal/d) (1,400 gallons per minute (gal/min)), which is 3.5 times the current (2005) withdrawal rate of 400 gal/min. The ANRC needed an analysis of the effects of withdrawals to be performed prior to the issuance of a well permit. To address this need, the USGS in cooperation with the ANRC used the north alluvial model of Reed (2003) to simulate ground-water flow and water-level changes for the period 1918-2049.

The purpose of this report is to compare simulated water levels derived from the north alluvial model (Reed, 2003) with and without an additional 1,000 gal/min ground-water withdrawal rate from a single one-square-mile model cell pumped for a period of 46 years simulated to begin in 2005. Drawdown and resulting saturated thickness of the alluvial aquifer after 46 years of pumping are presented for a radial distance of about 20 miles from the pumped model cell located in eastern Lonoke County. The study area includes Lonoke, Prairie, Arkansas, White, and Jefferson Counties, all of which have been designated as Critical Ground-Water Areas by the ANRC (fig. 1).

Information in this report can be used by water managers to evaluate estimated effects of additional ground-water withdrawals on the ground-water resource. Because alluvial aquifers commonly provide sources of water for municipal, industrial, and agricultural use, it is important to improve understanding of ground-water flow in this type of aquifer.

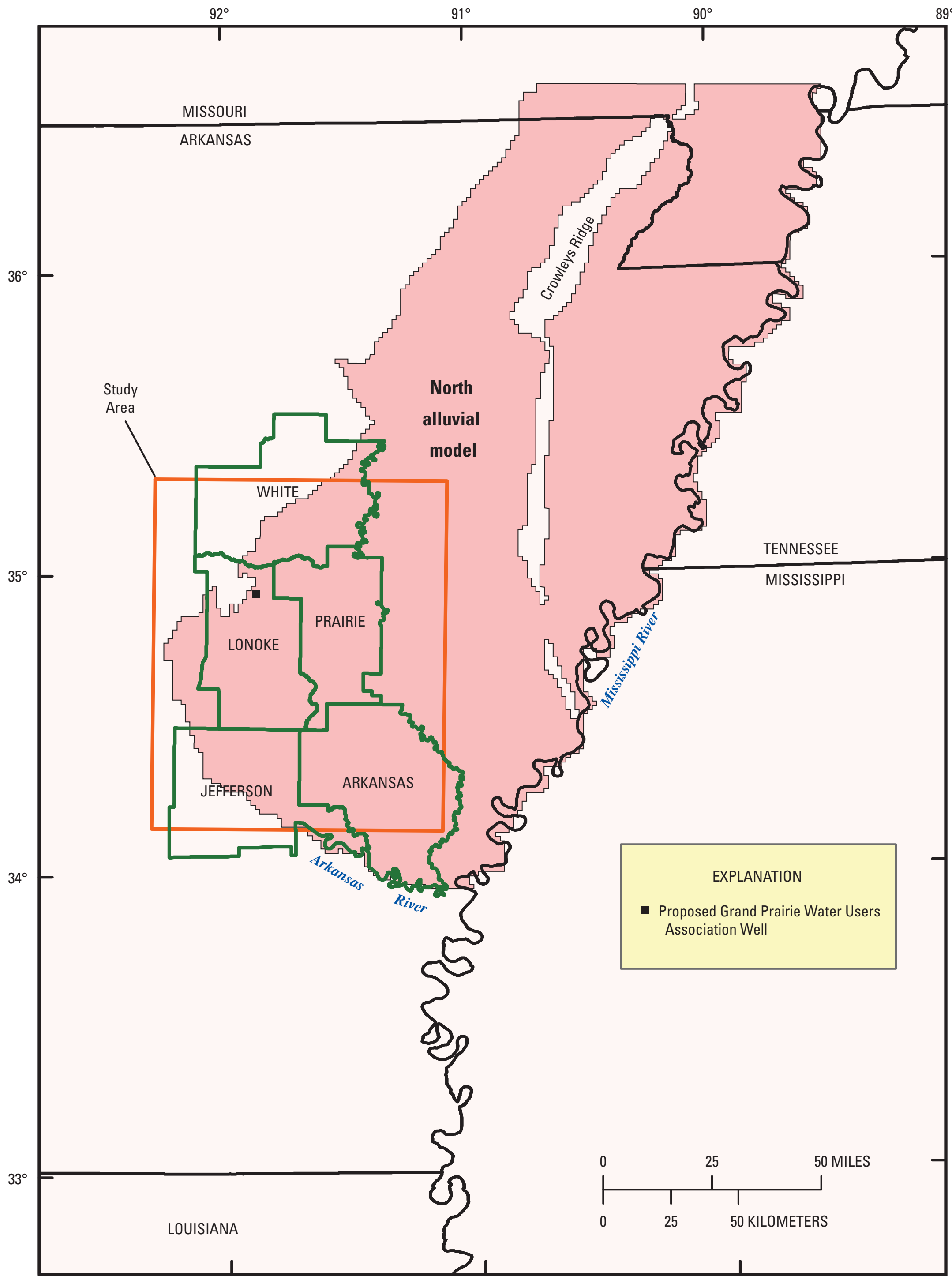

Figure 1. Location of study area, north alluvial model area, and proposed Grand Prairie Water Users Association well.

Methods

GPWUA plans to increase ground-water withdrawals from the alluvial aquifer from their current (2005) rate of about 400 gal/min to 1,400 gal/min (2,016,000 gal/d). This withdrawal rate, when applied to the one-square-mile model cell, makes that rate the 106th largest withdrawal rate among the 10,132 model cells in which withdrawals are specified for the year 1998 in the north alluvial model (Reed, 2003) (the last stress period for which water-use data were compiled for that model).

The effect of pumping from the proposed well in northeastern Lonoke County was simulated using the north alluvial model (Reed, 2003) (fig. 1). Planned withdrawals from the proposed well were added to the existing 1998 withdrawals specified in the model beginning in 2005, for a total pumping rate of 2,016,000 gal/d in that model cell, and applied to the end of 2050. In addition, total pumping from Cabot Water Works wells (located about 2 miles to the southeast of the GPWUA proposed well, fig. 2) was revised from pumping in Reed (2003) and specified in 2001 as 1,008,300 gal/d; in 2002 as 1,910,572 gal/d; in 2003 as 2,047,554 gal/d; and from 2004 to 2050 as 2,244,754 gal/d.

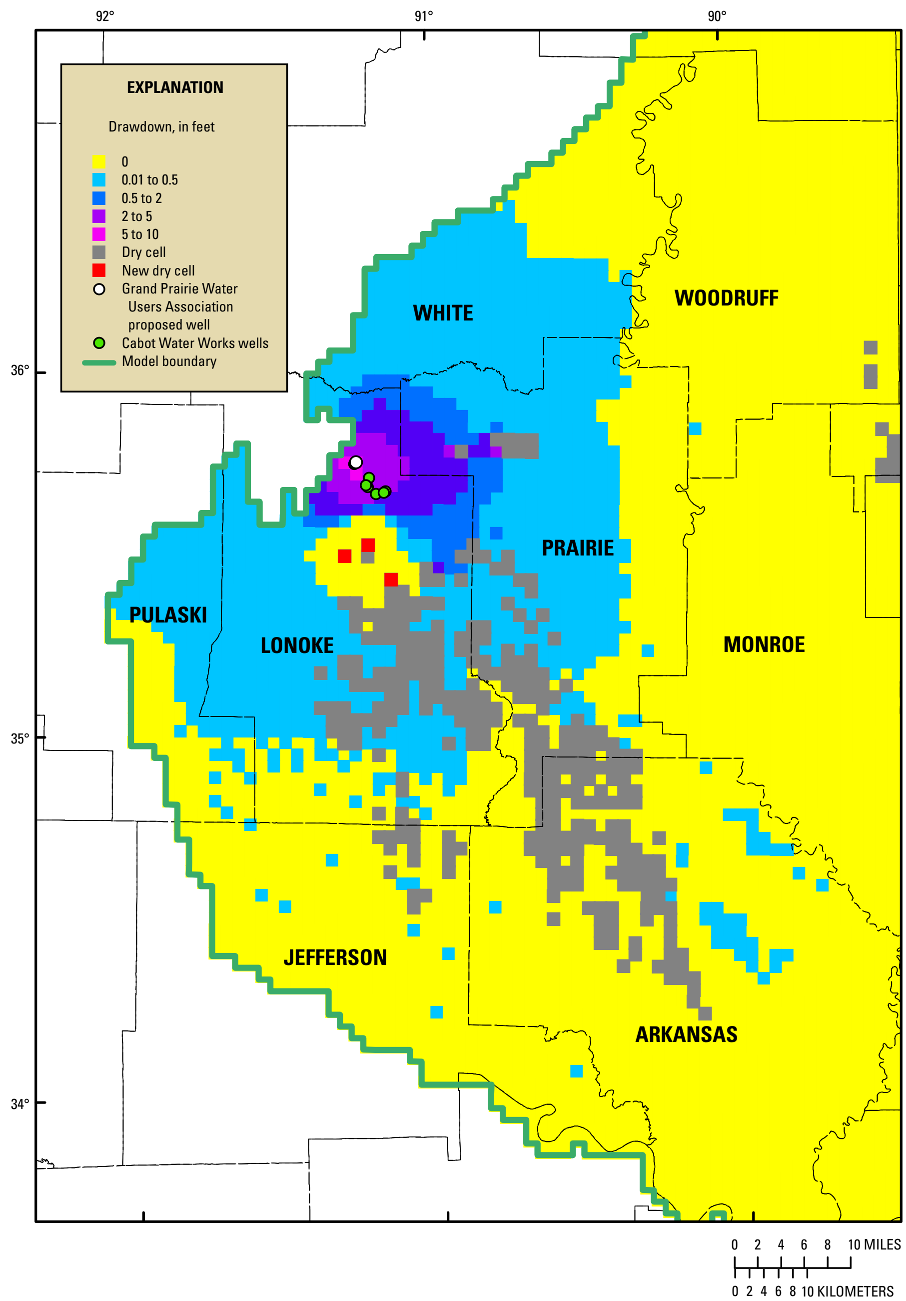

Figure 2. Simulated drawdown in water levels after 46 years of proposed additional pumping by the Grand Prairie Water Users Association.

Effects of Proposed Ground-Water Withdrawals

Analysis of the model results show that pumping at a rate of 2,016,000 gal/d from the GPWUA well and 2,244,754 gal/d from the Cabot Water Works wells from 2005 to the end of 2050 causes a cone of depression to occur in the alluvial aquifer with an additional decline in water level of about 8.5 ft after 46 yrs at the model cell of the proposed well (figs. 2 and 3), when compared to a simulation without any additional pumping, run to the same simulation time. Most of the drawdown (7.2 ft) occurs in the first 6 years of pumping (fig. 3). The additional decline in water level attributed to pumping from the GPWUA well is about 3.3 ft in 2050 (fig. 3). In addition, three new dry cells occur south of the withdrawal well during the last model stress period, which occurs between 2041 and 2050 (fig. 2). This total decline takes into account the cumulative effect of all wells pumping in the model area, although the specified pumping rate in 2005 in Reed (2003) was less than for actual 2005 conditions; therefore, specified pumping rates after 2005 for the entire model area likely will be less than actual conditions.

The altitude at half the thickness of the alluvial aquifer at the proposed well is approximately 135.7 ft. ANRC has designated that more than half of the aquifer needs to remain saturated for an area not to be designated a Critical Ground-Water Area. The altitude of the simulated water level is 177.3 ft, which is 41.6 ft higher than the half-thickness altitude of 135.7 ft. The saturated thickness in the pumped model cell is about 82 ft after 46 years following the increased pumping (fig. 4).

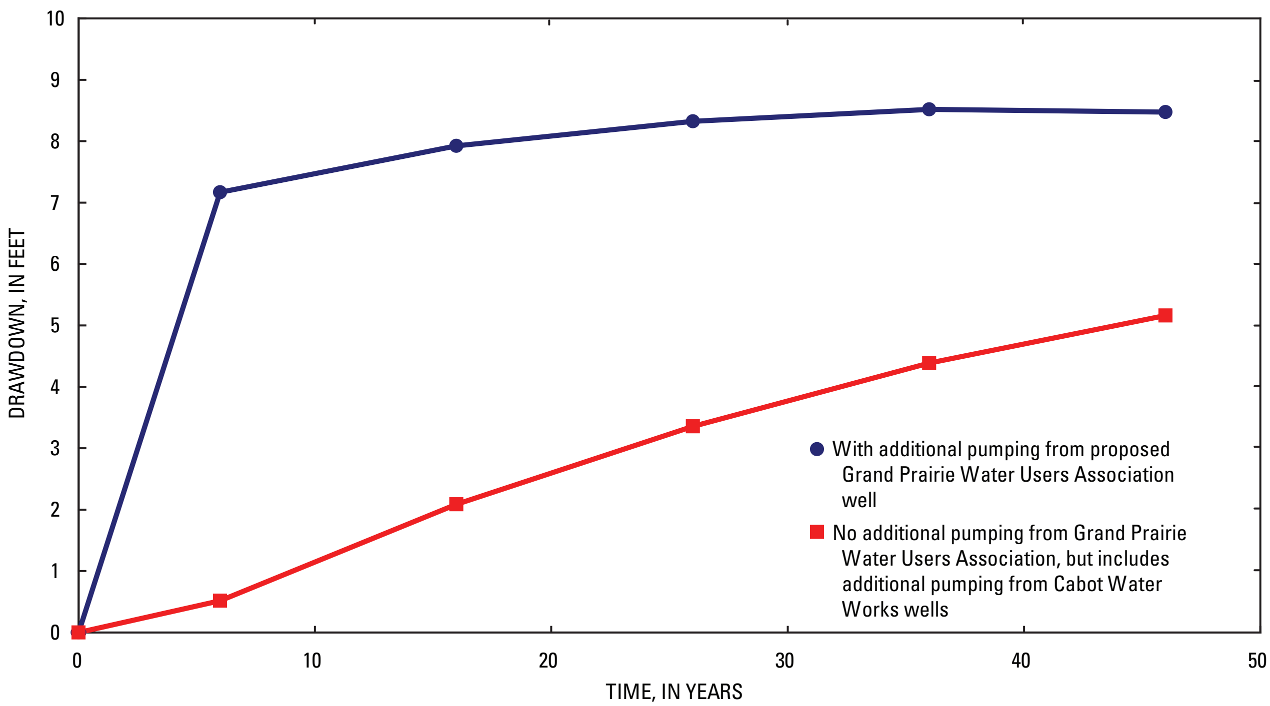

Figure 3. Simulated drawdown with time at model cell with proposed additional pumping by Grand Prairie Water Users Association (GPWUA).

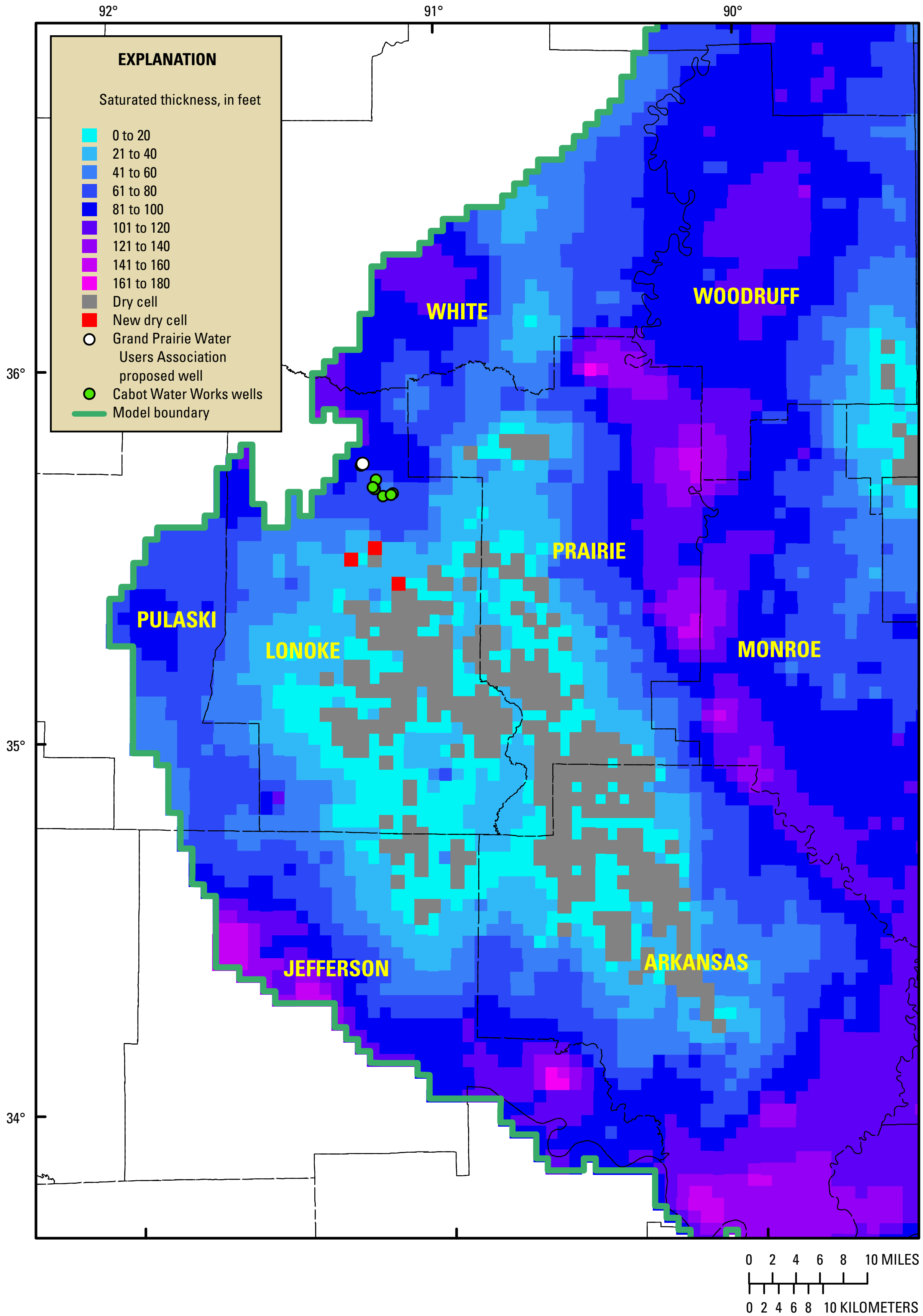

Figure 4. Simulated saturated thickness after 46 years with proposed additional pumping by the Grand Prairie Water Users Association.

Model Limitations

Simulated water levels and estimates of drawdown resulting from the proposed pumping by GPWUA represent average conditions over the one-square-mile grid cells of the model. Drawdown at the actual location of the pumped wells will be greater. The cell with the proposed increased withdrawals is near a general-head boundary (GHB) specified along the western edge of the model (Reed, 2003). The purpose of the GHB is to simulate a source of water some unspecified distance from the model boundary, which may cause drawdown to be less than actual amounts. An examination of the conductance associated with the GHB cell shows it to be small compared to other values used in the model, lessening the effect that the GHB cell would have on simulated water levels interior to the model. The water-level values associated with the nearest GHB cells are set to about 235 ft, which is about 40 to 50 ft higher than the simulated water levels along the western boundary near the pumped well, indicative that the direct effect of the GHB cells on water levels is small. Pumping rates throughout the model, except for those specified for GPWUA and Cabot Water Works, do not reflect 2005 conditions, and likely would be considerably larger than those specified for 1997 in Reed (2003), resulting in greater drawdown. Because the model is a simplification of a complex system, some error in simulated water levels is expected, similar to the mean absolute difference between observed and simulated water levels of about 5 ft obtained by Reed (2003), although the magnitude of the error in the simulated change in water level with time at the proposed pumping well would likely be less than this amount. The nearest water-level observation point used in the model of Reed (2003) to the GPWUA proposed well was simulated to be more than 15 ft higher than was observed in 1998. This difference would cause the estimated saturated thickness in the current analysis to be larger than would actually occur by about that amount. Local variations in hydraulic conductivity and specific storage not accounted for in the model would result in additional differences between simulated and actual water levels.

Summary

The Grand Prairie Water Users Association, located in Lonoke County, Arkansas, plans to increase ground-water withdrawals from the Mississippi River Valley alluvial aquifer 3.5 times the current (2005) rate of 400 gal/min to 1,400 gal/min (2,016,000 gal/d). The effect of pumping from the proposed well was simulated using an existing digital model of ground-water flow. The proposed well was added to the existing wells specified in the model beginning in 2005, and was specified to pump at a rate of 2,016,000 gal/d for a period of 46 years. In addition, pumping from wells owned by Cabot Water Works, located about 2 miles from the proposed pumping, was added to the model beginning in 2001 and continuing through to the end of 2049.

When compared to a simulation without any additional pumping, pumping at 2,016,000 gal/d and the Cabot Water Works wells pumping at 2,224,754 gal/d causes a cone of depression to occur in the alluvial aquifer with a maximum decline in water level of about 8.5 ft in 46 years in the model cell of the proposed well. About 3.3 ft of the decline can be attributed to the proposed well. However, three new dry cells occur south of the withdrawal well after 50 years. This total water-level decline takes into account the cumulative effect of all wells pumping in the vicinity, although the specified pumping rate for the entire model area in 2005 was less than the actual 2005 rates conditions, because all but GPWUA and Cabot Water Works rates were specified as 1997 pumping rates per Reed (2003). After 46 years with the additional pumping, the water-level altitude in the pumped model cell was about 177.3 ft, which is 41.6 ft higher than the half-thickness altitude of 135.7 ft. Pumping rates throughout the model, except for those specified for the GPWUA and Cabot Water Works, do not reflect current (2005) conditions, and likely would be considerably larger than those specified as 1997 rates, resulting in greater drawdown.

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