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Simulated Ground-Water Withdrawals by Cabot WaterWorks from the Mississippi River Valley Alluvial Aquifer, Lonoke County, Arkansas

Scientific Investigations Report 2007–5030

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

Cover photograph: Cabot production well, Lonoke County, Arkansas (photograph courtesy of David A. Freiwald, 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 per minute (gal/min)	0.06308	liter per second (L/s)
million gallons per day (Mgal/d)	3.7853	million liter per day (ML/d)
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).

Simulated Ground-Water Withdrawals by Cabot WaterWorks from the Mississippi River Valley Alluvial Aquifer, Lonoke County, Arkansas

By John B. Czarnecki

Abstract

Cabot WaterWorks, located in Lonoke County, Arkansas, plans to increase ground-water withdrawals from the Mississippi River Valley alluvial aquifer from a 2004 rate of approximately 2.24 million gallons per day to between 4.8 and 8 million gallons per day by the end of 2049. The effects of increased pumping from several wells were simulated using a digital model of ground-water flow. The proposed additional withdrawals by Cabot WaterWorks were specified in three 1-square-mile model cells with increased pumping beginning in 2007. Increased pumping was specified at various combined rates for a period of 44 years. In addition, augmented pumping from wells owned by Grand Prairie Water Users Association, located about 2 miles from the nearest Cabot WaterWorks wells, was added to the model beginning in 2007 and continuing through to the end of 2049 in 10 of the 16 scenarios analyzed. Eight of the scenarios included reductions in pumping rates in model cells corresponding to either the Grand Prairie Water Users Association wells or to wells contained within the Grand Prairie Area Demonstration Project.

Drawdown at the end of 44 years of pumping at 4.8 million gallons per day from the Cabot WaterWorks wells ranged from 15 to 25 feet in the three model cells; pumping at 8 million gallons per day resulted in water-level drawdown ranging from about 15 to 40 feet. Water levels in those cells showed no indication of leveling out at the end of the simulation period, indicating non-steady-state conditions after 44 years of pumping. From one to four new dry cells occurred in each of the scenarios by the end of 2049 when compared to a baseline scenario in which pumping was maintained at 2004 rates, even in scenarios with reduced pumping in the Grand Prairie Area Demonstration Project; however, reduced pumping produced cells that were no longer dry when compared to the baseline scenario at the end of 2049. Saturated thickness at the end of 2049 in the three Cabot WaterWorks wells ranged from about 52 to 68.5 feet for pumping rates of 4.8 million gallons per day, and from about 38 to 64 feet for pumping rates of 8 million gallons per day, the latter causing water levels to fall below half the aquifer thickness in the most heavily pumped of the three cells.

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) deeper than the surrounding water-level surface. 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 (Czarnecki and others, 2002).

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 (termed "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 (Arkansas Natural Resources Commission, 2006)). More focused, site-specific analyses of pumping from the alluvial aquifer were performed for pumping centers located near Pine Bluff, Arkansas (Czarnecki, 2006a) and in Lonoke County, Arkansas (Czarnecki, 2006b).

Cabot WaterWorks (CWW) has applied to the ANRC for permission to withdraw ground water from the alluvial aquifer at a rate of between 4.8 to 8 Mgal/d. The ANRC needed an analysis of the effects of withdrawals to be performed prior to the issuance of a water-withdrawal permit. To address this need and to improve the understanding of the effect of municipal users on ground-water flow in this type of aquifer, the USGS in cooperation with CWW used the north alluvial model of Reed (2003) to simulate ground-water flow and water-level changes for the period 1918-2049 for various ground-water pumping scenarios.

The purpose of this report is to compare simulated water levels derived from the north alluvial model (Reed, 2003) with and without several additional ground-water withdrawal rates from several 1-square-mile model cells pumped for a period of 44 years simulated to begin in 2007 (table 1). These cells include pumping from the Grand Prairie Water Users Association (GPWUA), the Grand Prairie Area Demonstration project (GPADP), as well as CWW. GPWUA plans to increase pumping and has proposed the construction of an additional well near its current well field. The GPADP is a project, under the management of the ANRC and U.S. Army Corps of Engineers, designed to route water from the White River to water users in Arkansas, Monroe, Prairie, and eastern Lonoke counties to supplement ground-water demand. By supplying this supplemental water, it is anticipated that water-use pressure on the alluvial aquifer will decrease. Drawdown and resulting saturated thickness of the alluvial aquifer after 44 years of pumping are presented for a radial distance of about 20 miles from the pumped model cells 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 simulated 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 the understanding of ground-water flow in this type of aquifer. Additionally, the types of scenarios analyzed using the ground-water flow model in this report demonstrate the utility of the approach for assessing complex ground-water flow systems and pumping distributions.

Methods

CWW plans to increase ground-water withdrawals from the alluvial aquifer from its 2004 rate of approximately 2.24 Mgal/d to between 4.8 and 8 Mgal/d. The 2.24 Mgal/d withdrawal rate, when applied to a 1-square-mile model cell, makes that rate the 63rd largest among the 10,132 1-square-mile model cells in which withdrawals were 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 wells in northeastern Lonoke County was simulated using the north alluvial model (Reed, 2003) (fig. 1). To assess the various pumping distributions, total pumping from CWW wells was added to the pumping distribution for 1997 used in Reed (2003). CWW pumping was 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 2006 as 2,244,754 gal/d. Pumping rates for wells were variable from 2007 to the end of 2049 depending on the scenario simulated. In addition, planned withdrawals by GPWUA, located about 2 miles from the nearest CWW wells, were added to the existing 1998 withdrawals specified in the model beginning in 2007 and applied to the end of 2049. The 16 scenarios in table 1 are listed such that scenario 1 is the baseline scenario from which water-level altitude differences were computed using water levels from the other 15 scenarios. Ground-water withdrawals from the CWW and GPWUA in scenario 1 are representative of 2006 rates, although all other ground-water withdrawal rates are based on 1997 rates. The variability in ground-water withdrawal rates in table 1 reflects proposed or hypothetical withdrawal-rate distributions. For example, scenarios 7 through 10 and 12 through 16 use reduced withdrawal rates in GPADP from between 0 to 100 percent of rates in 1997, although no specific plans by water managers for that rate reduction exist. These reduced withdrawal rates were simulated to assess potential changes in water levels in the CWW wells and for the ground-water system as a whole.

Pumping from six CWW wells (fig. 2; table 2) was assigned to three 1-square-mile model cells. Model grid spacing is specified uniformly as 1 mile for both rows and columns in the Reed (2003) model. Pumping from the Fraser well was assigned to one model cell located at row 118, column 26, with a 2004 pumping rate of 402,782 gal/d or 18 percent of the total 2004 CWW pumping. Pumping from Hooker 1 and Hooker 2 wells was assigned to one model cell located at row 119, column 26, with a 2004 pumping rate of 557,059 gal/d or 25 percent of the total CWW pumping. Pumping from the McCall well, and from Taylor 1 and Taylor 2 wells was assigned to one model cell located at row 120, column 27, with a 2004 pumping rate of 1,284,893 gal/d, or 57 percent of the total CWW pumping. These percentages were maintained when distributing increased pumping rates for various scenarios shown in table 1. Pumping from all GPWUA wells (fig. 2) was combined and assigned to one model cell located at row 117, column 25. The baseline 1998-2006 rate for all of the GPWUA wells was specified as 340,239 gal/d. Scenarios also were simulated by doubling the GPWUA rate to 680,479 gal/d and up to a proposed rate of 2.016 Mgal/d, a rate proposed by GPWUA (Czarnecki, 2006b). Model cells inside and outside the Grand Prairie Area Demonstration Project (GPADP) (fig. 3) were identified using geographical information system software for purposes of modifying pumping rates for those model cells inside the GPADP per scenarios shown in table 1. To

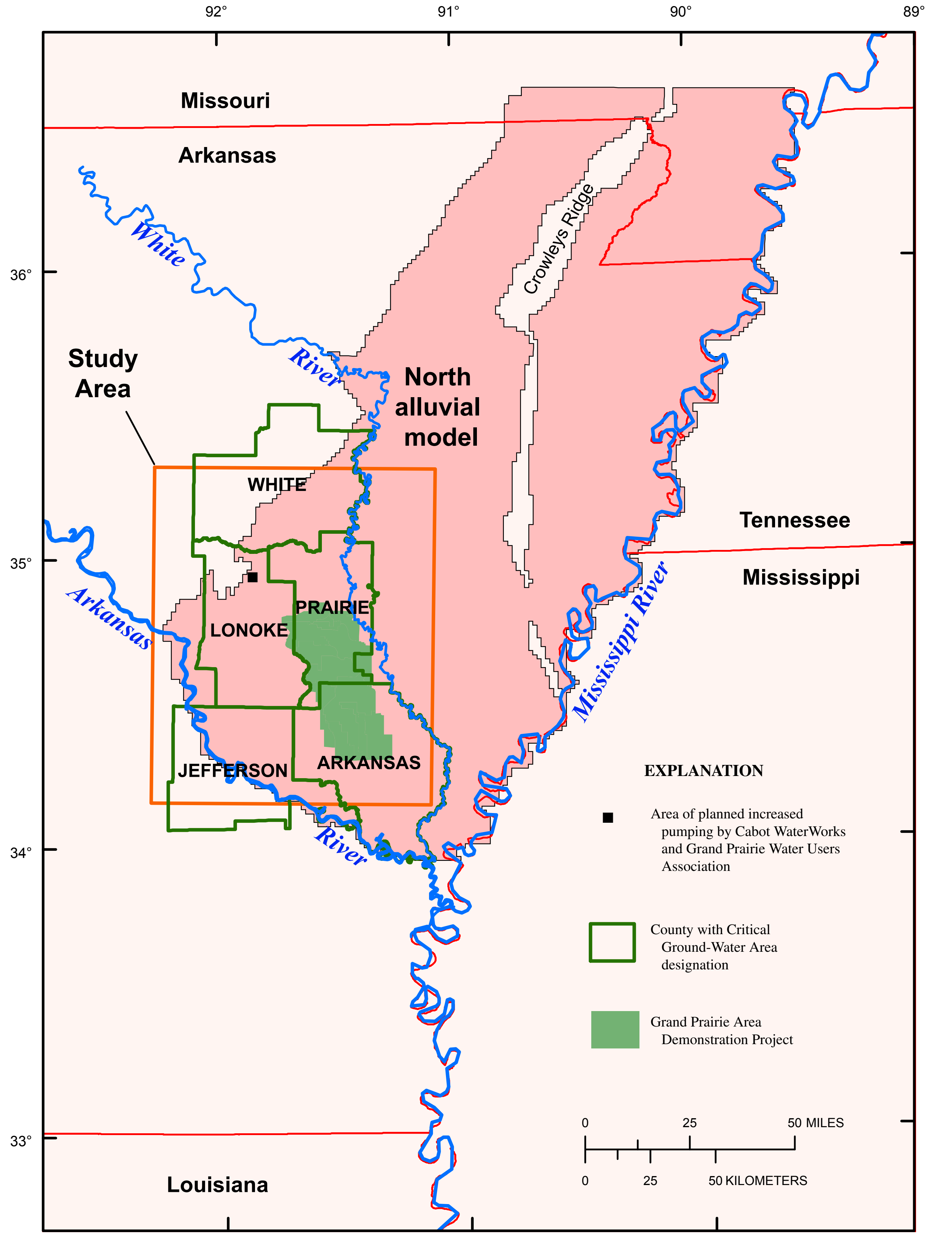

Figure 1. Location of study area, north alluvial model area, and location of planned increased pumping by Cabot WaterWorks.

Table 1. Pumping rates and durations specified for each model scenario.

[Mgal/d, million gallons per day; gal/d, gallons per day; CWW, Cabot WaterWorks; GPWUA, Grand Prairie Water Users Association; GPADP, Grand Prairie Area Demonstration Project]

Model scenario number	Condition											
	CWW maintains pumping at 2.24 Mgal/d from 2004 through 2049	GPWUA maintains pumping at 340,239 gal/d from 1998 through 2049	GPWUA maintains pumping at 680,479 gal/d from 2007 through 2049	GPWUA increases pumping in 2007 to 2.016 Mgal/d and pumps at that rate through 2049	CWW increases pumping in 2007 instantaneously to a rate of 4.8 Mgal/d and pumps at that rate through 2049	CWW increases pumping in 2007 incrementally to maximum rate of 4.8 Mgal/d through 2049	CWW increases pumping in 2007 incrementally to maximum rate of 8.0 Mgal/d through 2049	All wells in the GPADP pumping at the following multiple of 1997 rate:				
								1.00	**0.75**	**0.50**	**0.25**	**0.0**
1	x	x						x				
2				x	x			x				
3	x							x				
4		x			x			x				
5		x				x		x				
6		x					x	x				
7			x				x		x			
8			x				x			x		
9			x				x				x	
10			x				x					x
11				x		x		x				
12				x			x	x				
13				x			x		x			
14				x			x			x		
15				x			x				x	
16				x			x					x

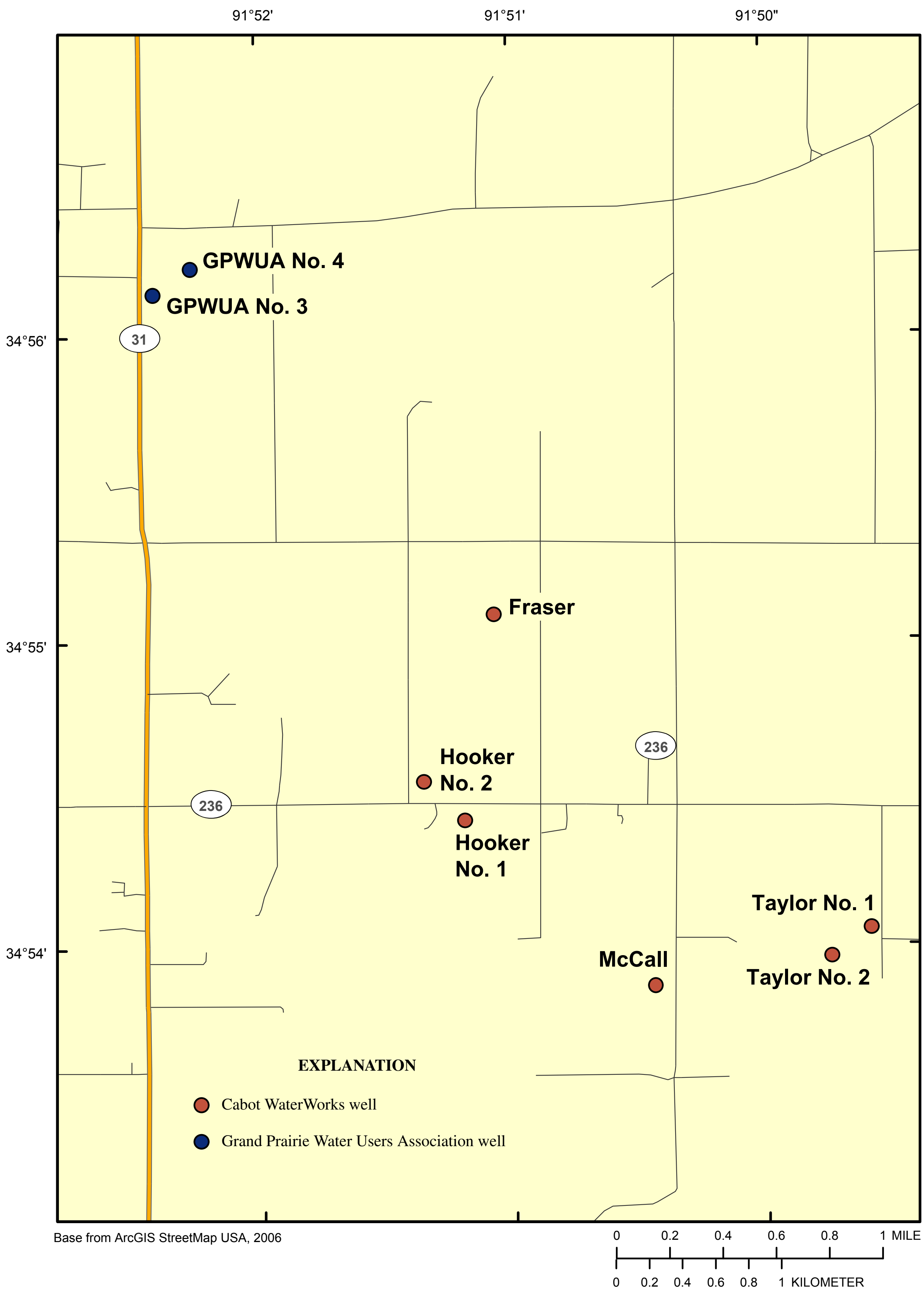

Figure 2. Location of Cabot WaterWorks and Grand Prairie Water Users Association (GPWUA) wells.

Table 2. Cabot WaterWorks well-construction information.

[gal/min, gallons per minute; ft, feet; --, not available; all depth measurements in feet below land surface]

Well name	Pumping rate capacity (gal/min)	Top of pump (ft)	Top of sand (ft)	Bottom of sand (ft)	Sand thickness (ft)	Bottom of screen (ft)	Top of screen (ft)	Length of screen (ft)	Depth to water	
									Spring 2001	Spring 2006
Hooker 1	800	140	56	154	98	156	126	30	93	102
Hooker 2	800	140	43	163	120	165	135	30	95	--
Fraser	820	140	75	158	83	160	130	30	86	96
McCall	828	140	58	202	144	184	134	50	84	90
Taylor 1	850	140	57	200	143	177	132	45	91	101
Taylor 2	825	140	57	195	138	182	132	50	85	--

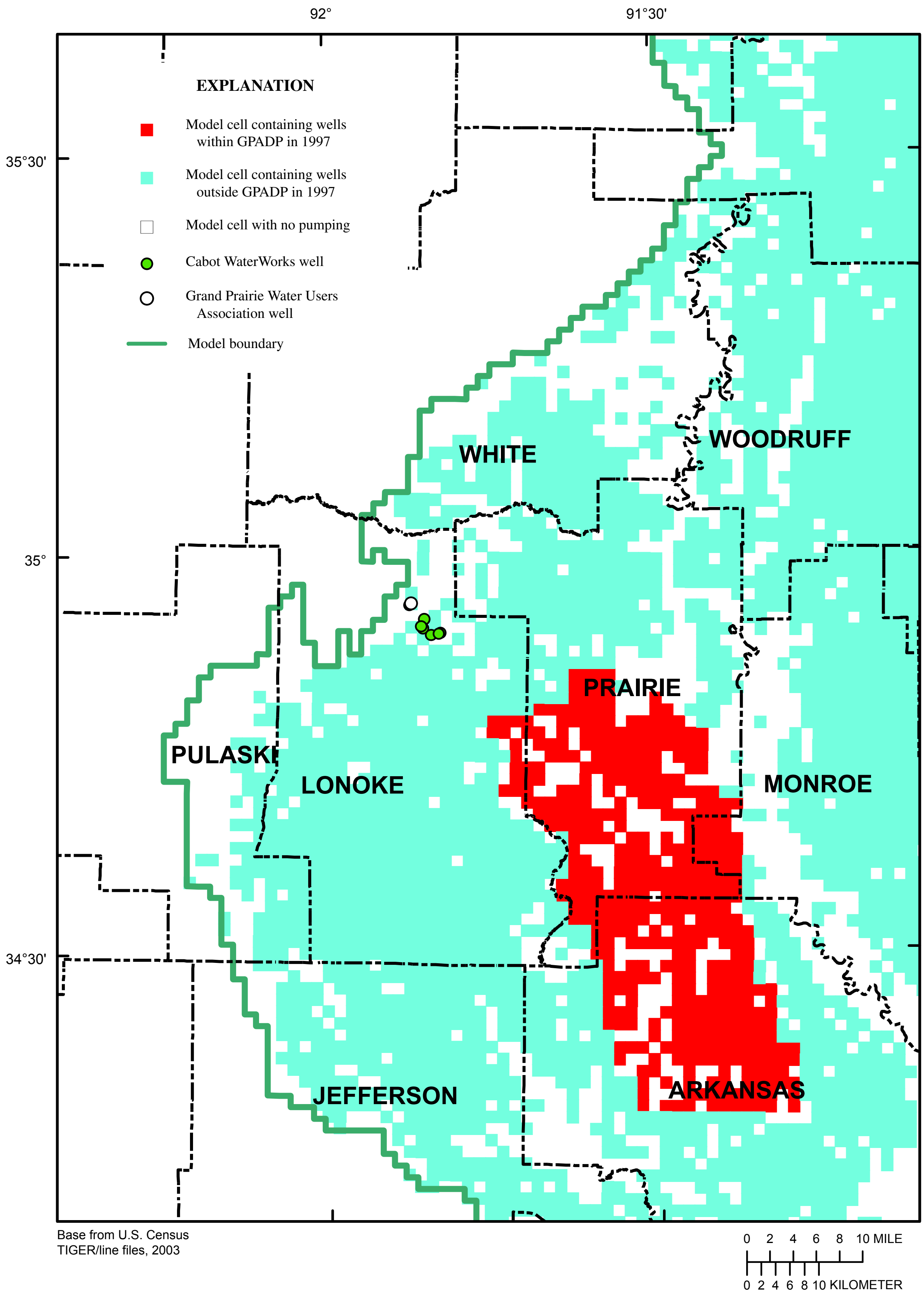

Figure 3. Distribution of 1-square-mile pumping cells inside and outside the Grand Prairie Area Demonstration Project (GPADP).

To analyze incremental increases in CWW pumping with time (scenarios 5 through 16), the time period from the beginning of 2007 to the end of 2049 (44 years) was divided evenly into ten 4.4-year long stress periods with uniform pumping increases of 10 percent specified for each subsequent step until a maximum rate of either 4.8 or 8 Mgal/d was reached for the last time step.

Simulation of Ground-Water Withdrawals

Simulation of ground-water withdrawals using the model scenarios listed in table 1 was done with the north alluvial model of Reed (2003). Model stress periods were added to those used in Reed (2003) to accommodate specification of variable pumping rates from 1998 through 2049 as listed in table 1.

Analysis of the effects of different pumping rates and distributions requires the establishment of a baseline condition from which to make comparisons. In this analysis, water-level altitudes from the last stress period (ending December 31, 2049) from scenario 1 were selected as the baseline, from which cell-by-cell water-level differences were calculated using simulation results from the other scenarios. Baseline pumping conditions specified for scenario 1 yield the distribution of water-level altitudes shown in figure 4. Scenario comparisons include the identification of new dry cells and cells that were dry in scenario 1, but never went dry in the scenario being compared.

CWW wells are located away from major agricultural pumping centers and cones of depression, which are indicated by the areas of dry cells and lower water levels (fig. 4). The simulation of pumping in scenario 1 indicates that despite continued pumping at 2004 rates by CWW wells, no cone of depression in the vicinity of these wells is present when plotted at a regional scale. Aquifer saturated thickness (fig. 5) in the vicinity of the CWW wells is between 50 and 75 ft at the end of 2049 for scenario 1, which is more than half of the thickness of the aquifer (table 3). Aquifer saturated thickness is largest (blue areas on fig. 5) in the vicinity of rivers that recharge the alluvial aquifer, maintaining water levels throughout the period of simulation.

When compared to baseline conditions, changes in simulated water-level altitudes in 2049 in the vicinity of the CWW wells are affected most by changes in pumping rates at the CWW wells (figs. 6A-6O). This can be seen by the distribution of simulated change in water-level altitude in figures 6F through GI and 6L through 6O. In these figures, water-level declines in the vicinity of the CWW wells are consistently between 10 to 20 ft, even as pumping is reduced in the GPADP, where water levels rebound. However, most of the simulated change in water levels from the pumping of the CWW wells occurs within 2 miles of those wells, with only minor changes occurring out to a distance of about 10 miles from the wells.

Another way to examine water-level change under different pumping scenarios is to plot drawdown against time. This was done beginning in 2007 for all scenarios (figs. 7A-7P) for each of the three model cells containing CWW wells. As CWW pumping rates increase, so does the rate and magnitude of drawdown despite decreases in systemwide pumping rates throughout the study area. Drawdown at the end of 44 years of pumping at 4.8 Mgal/d from the CWW wells ranged from 15 to 25 ft in the three model cells (figs. 7B and 7K); pumping at 8 Mgal/d resulted in water-level drawdown ranging from about 15 to 40 ft (figs. 7F-7J and 7L-7O). Water levels in those cells show no indication of leveling out at the end of the simulation period, indicating nonsteady-state conditions after 44 years of pumping.

Remaining simulated saturated thickness through 2049 in model cells containing CWW wells generally is greater than half the thickness of the aquifer (table 3). Major exceptions to this occur at the cell containing the McCall and Taylor 1 and 2 wells, which coincidentally have the largest percentage (57 percent) of pumping of the three CWW pumping cells. Reduction of pumping in that cell would result in a larger saturated thickness. Saturated thickness through 2049 in the three CWW pumping cells ranged from about 51.9 to 68.5 ft for pumping rates of 4.8 Mgal/d (scenarios 2, 4, 5, and 11), and from about 37.5 to 62.8 ft for pumping rates of 8 Mgal/d (scenarios 6-10 and 12-16), the latter causing water level to fall below half the aquifer thickness in the most heavily pumped of the three cells. Actual water levels at the individual wells would be lower than those simulated because the simulated water level applies to the entire 1-square-mile cell in which they are specified.

If simulated water levels reach the bottom of a model cell, the cell goes dry and remains dry from that point in time forward in the simulation. Once a model cell goes dry, it becomes inactive, and any pumping that was specified in that cell is turned off. From one to four new dry cells occurred in each of the scenarios by the end of 2049 when compared to a baseline scenario (scenario 1) in which pumping was maintained at 2004 rates, even in scenarios with reduced pumping in the GPADP; however, reduced pumping produced cells that were no longer dry when compared to the baseline scenario through 2049 (table 4).

Simulated water-level altitudes for most of the scenarios generally are higher than the half-thickness altitude of the aquifer for all of the model cells containing either GPWUA or CWW wells (figs. 8A-D). Because of the presence of a clay-cap confining unit above the alluvial aquifer (Reed, 2003), conditions in the model cell in 2007 containing the GPWUA well (fig. 8A) are confined and remain that way through most of the scenarios, causing simulated water-level altitudes to be higher than the top of the aquifer. Conditions in the model cells in 2007 containing the CWW wells (fig. 8B-D) are unconfined from that point forward until the end of each simulation. Water-level altitude declines past the half-thickness of

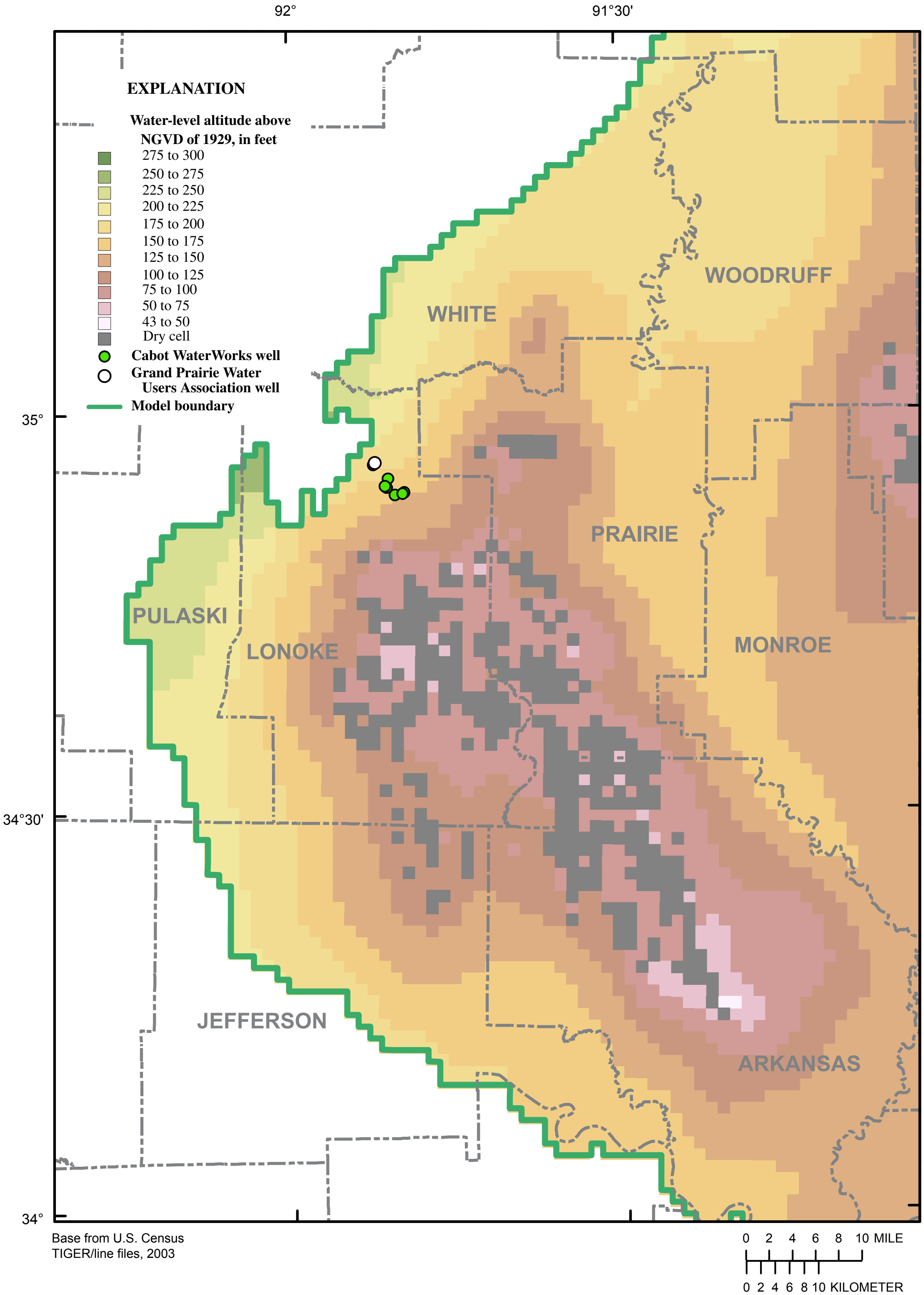

Figure 4. Water-level altitudes at the end of 2049 for scenario 1.

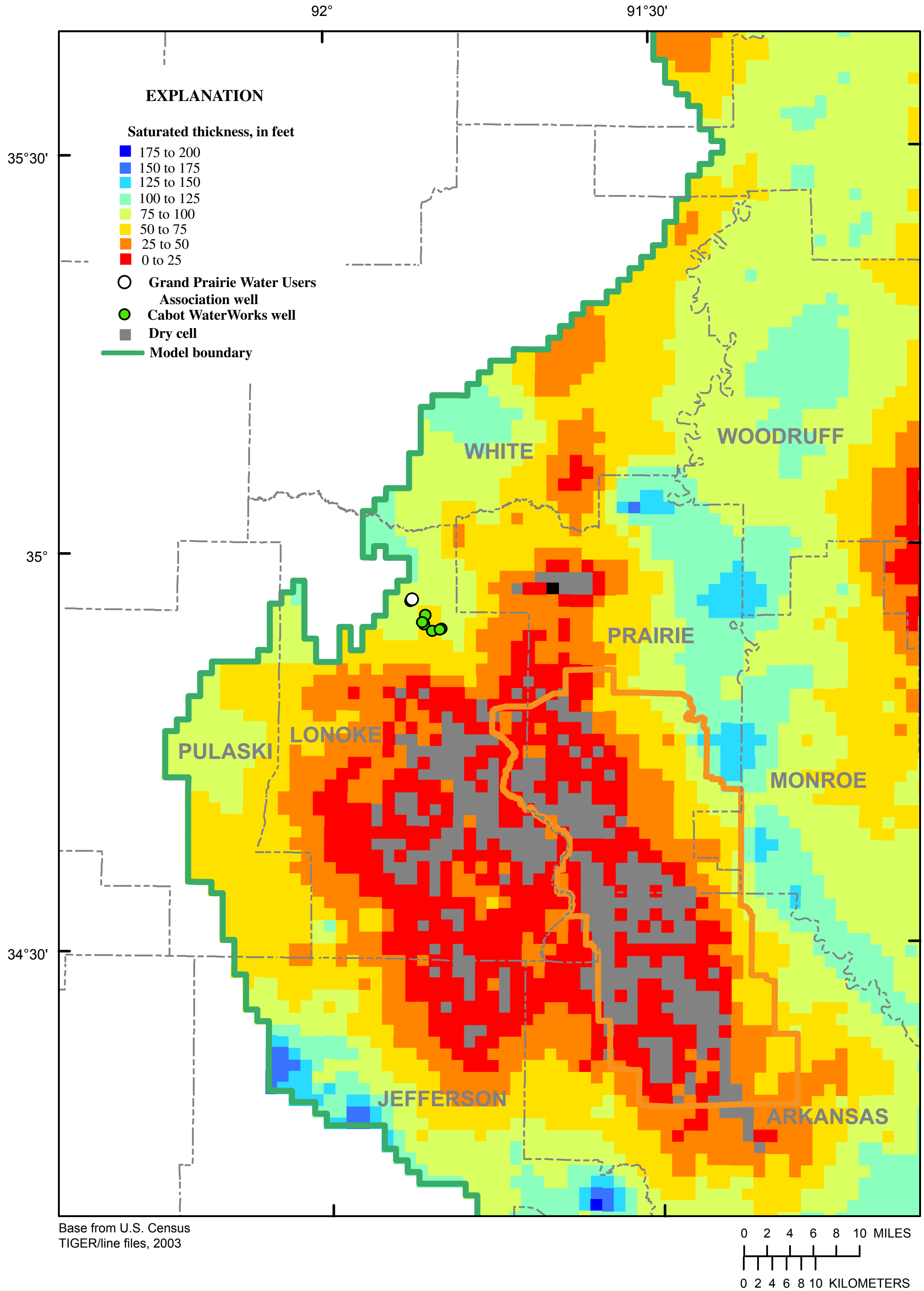

Figure 5. Aquifer saturated thickness at end of 2049 for scenario 1.

Table 3. Remaining saturated thickness in 2049 in model cells containing Cabot WaterWorks wells for each of the scenarios simulated.

Wells contained in cell	Cell row number	Cell column number	Aquifer thickness, in feet	Remaining saturated thickness, in feet, for scenario:															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fraser Well	118	26	89.6	73.1	63.9	73.8	68.5	68.5	62.8	62.0	62.0	62.1	62.0	63.9	57.4	57.5	57.4	57.4	57.5
Hooker 1 and 2 Wells	119	26	91.7	63.5	53.1	64.1	57.0	57.2	48.6	47.8	47.9	47.9	47.9	53.5	43.3	43.3	43.3	43.3	43.4
McCall and Taylor 1 and 2 Wells	120	27	103.0	65.0	51.9	65.4	55.4	55.9	42.0	41.4	41.4	41.5	41.6	53.2	37.5	37.7	37.6	37.7	37.9

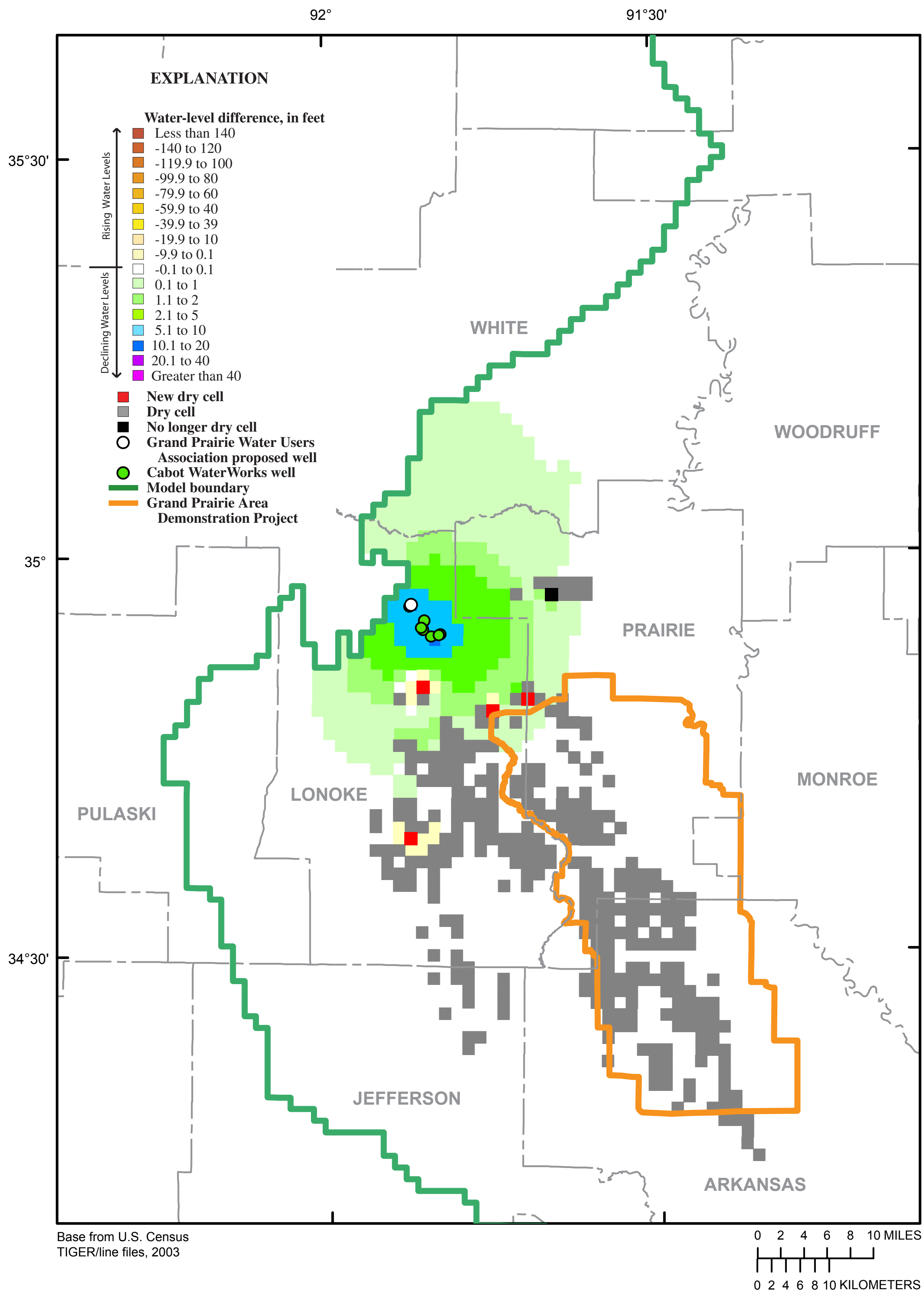

Figure 6A. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 2, table 1.

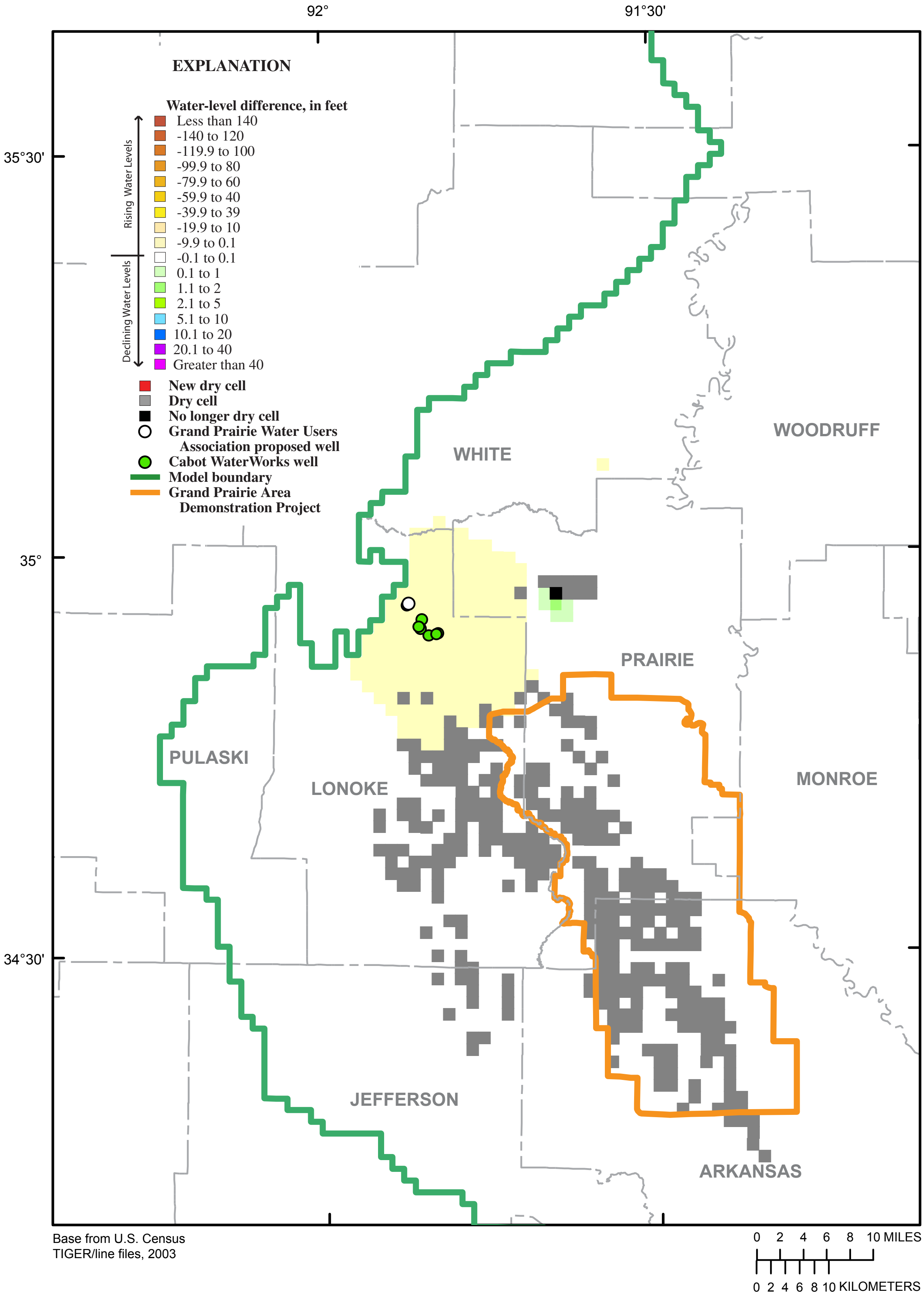

Figure 6B. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 3, table 1.

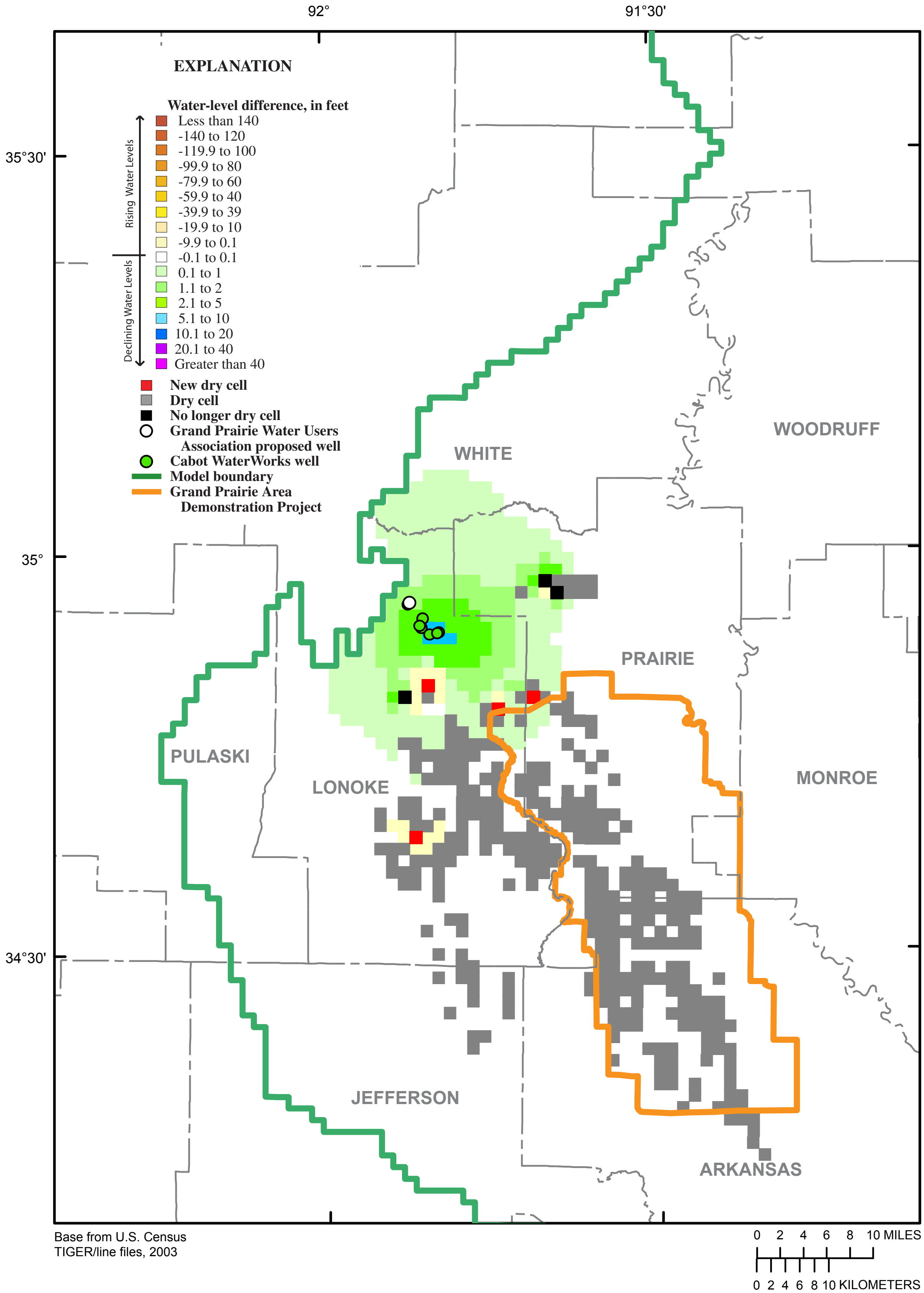

Figure 6C. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scneario 4, table 1.

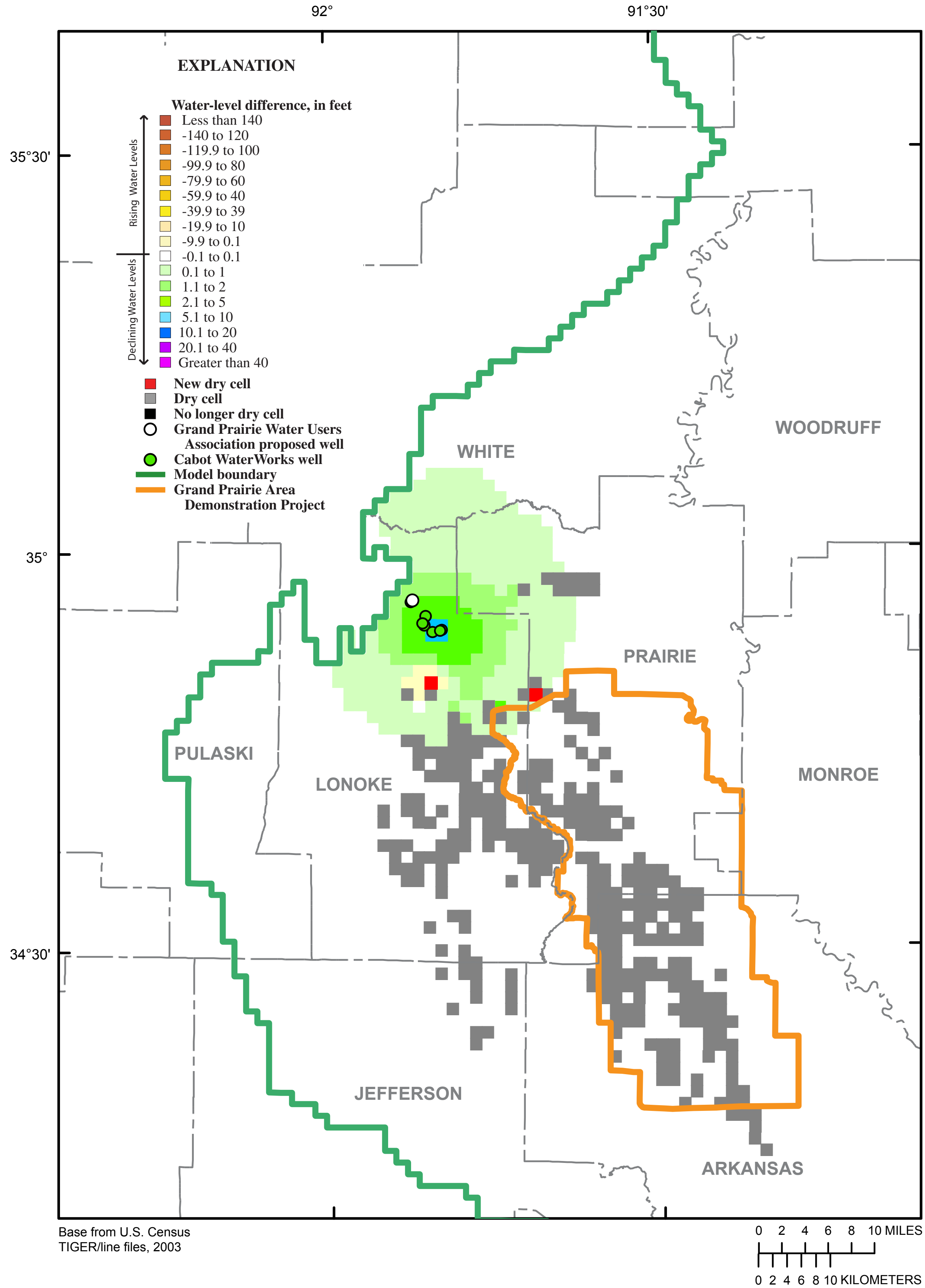

Figure 6D. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 5, table 1.

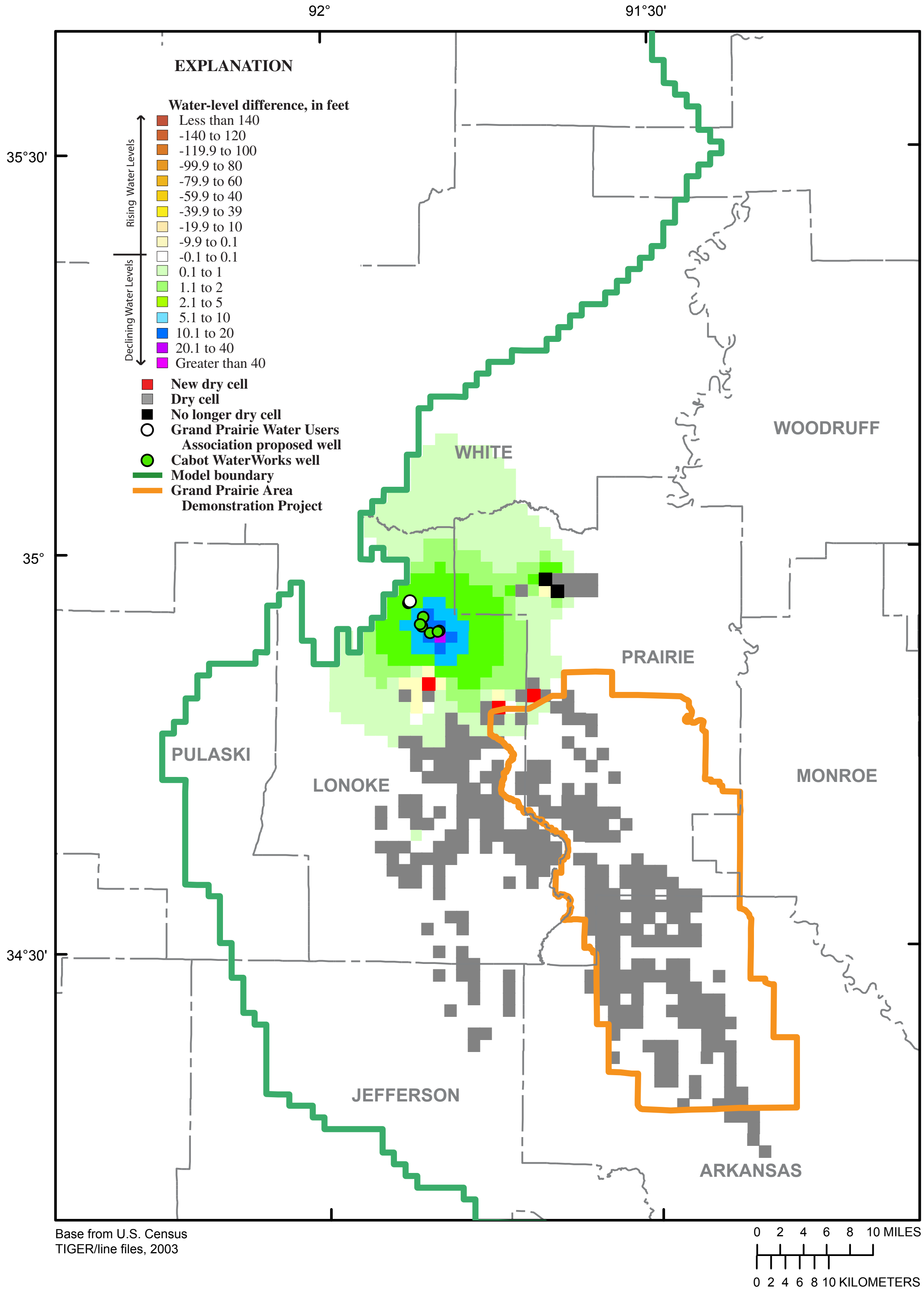

Figure 6E. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 6, table 1.

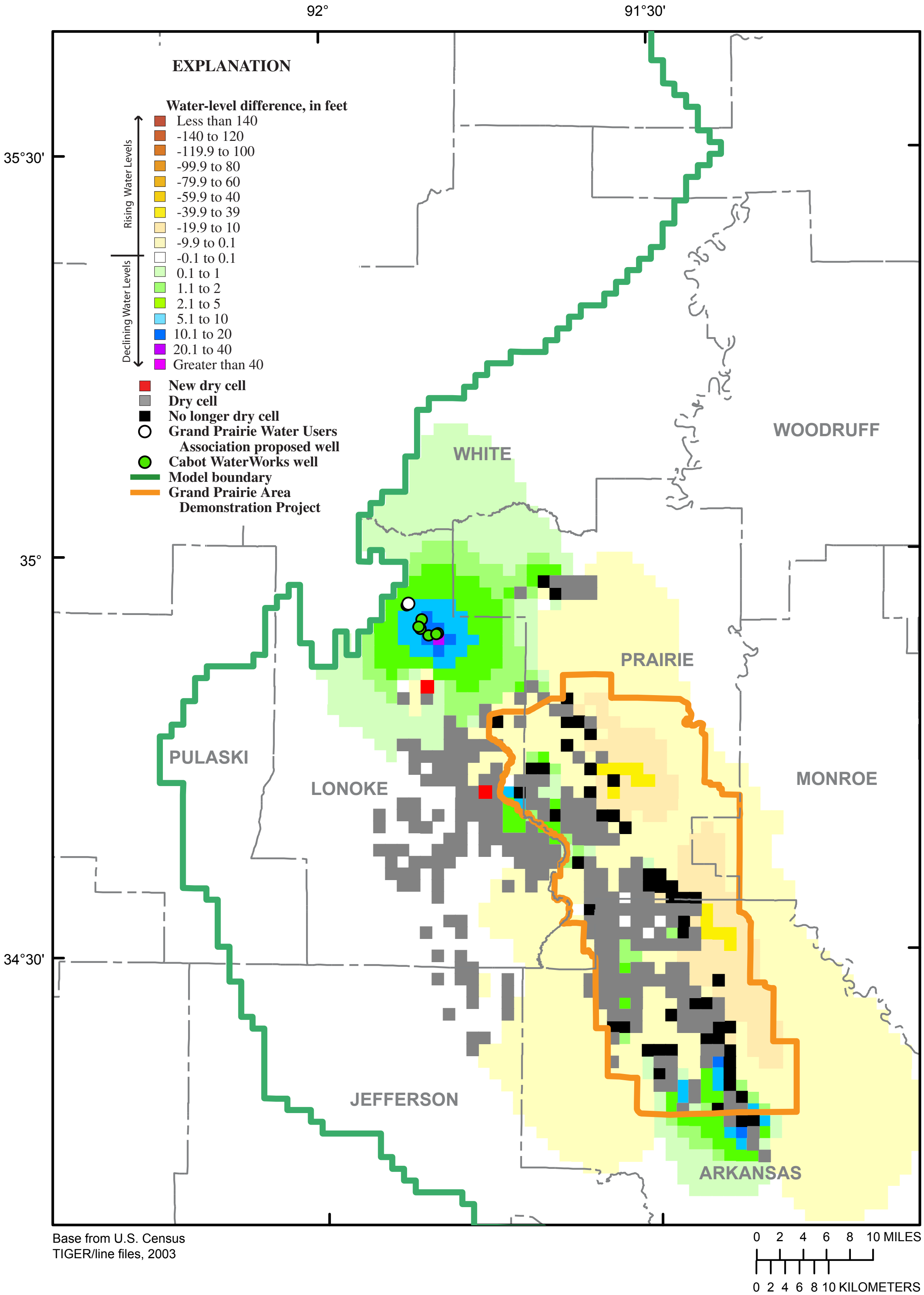

Figure 6F. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 7, table 1.

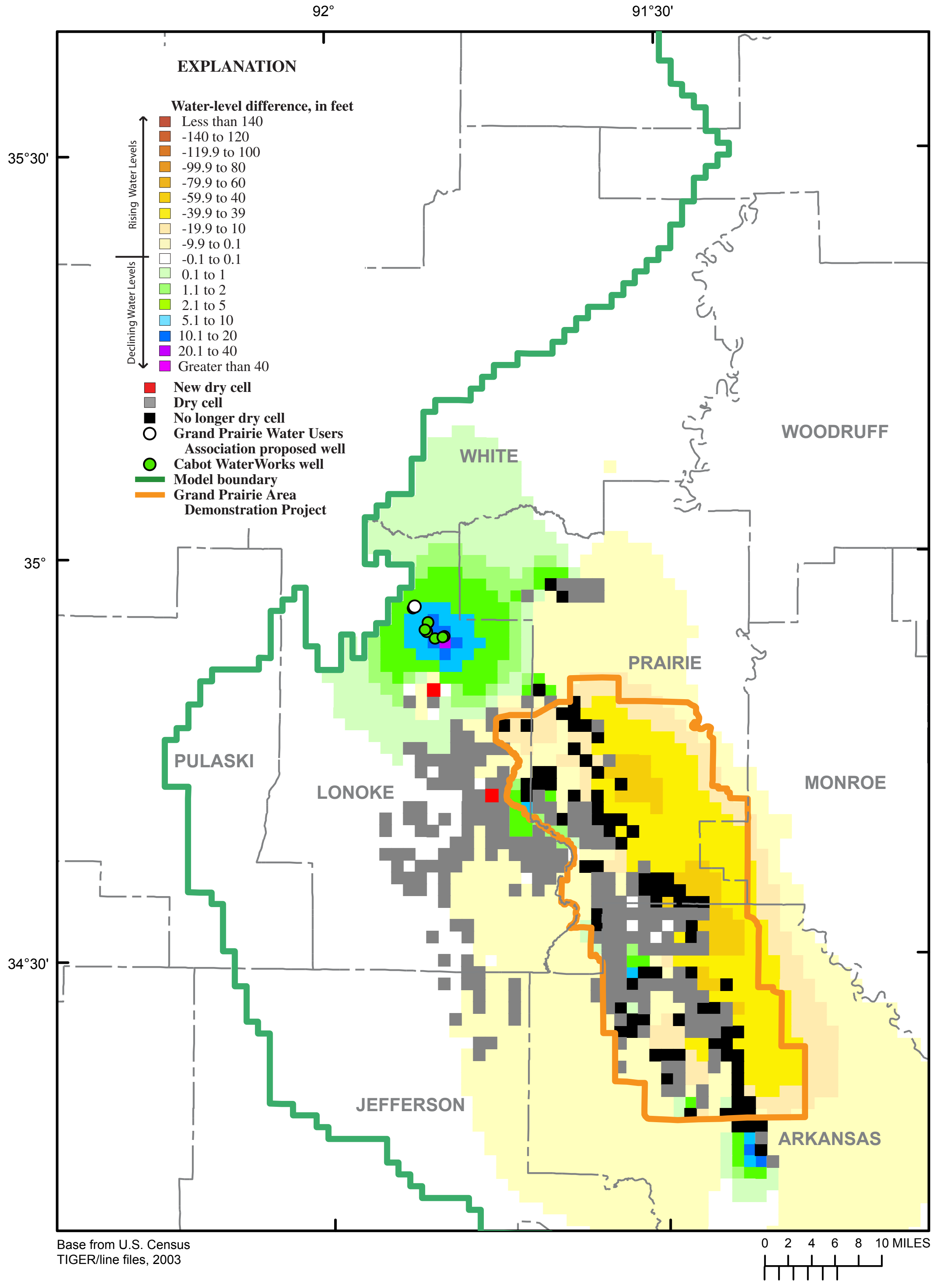

Figure 6G. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 8, table 1.

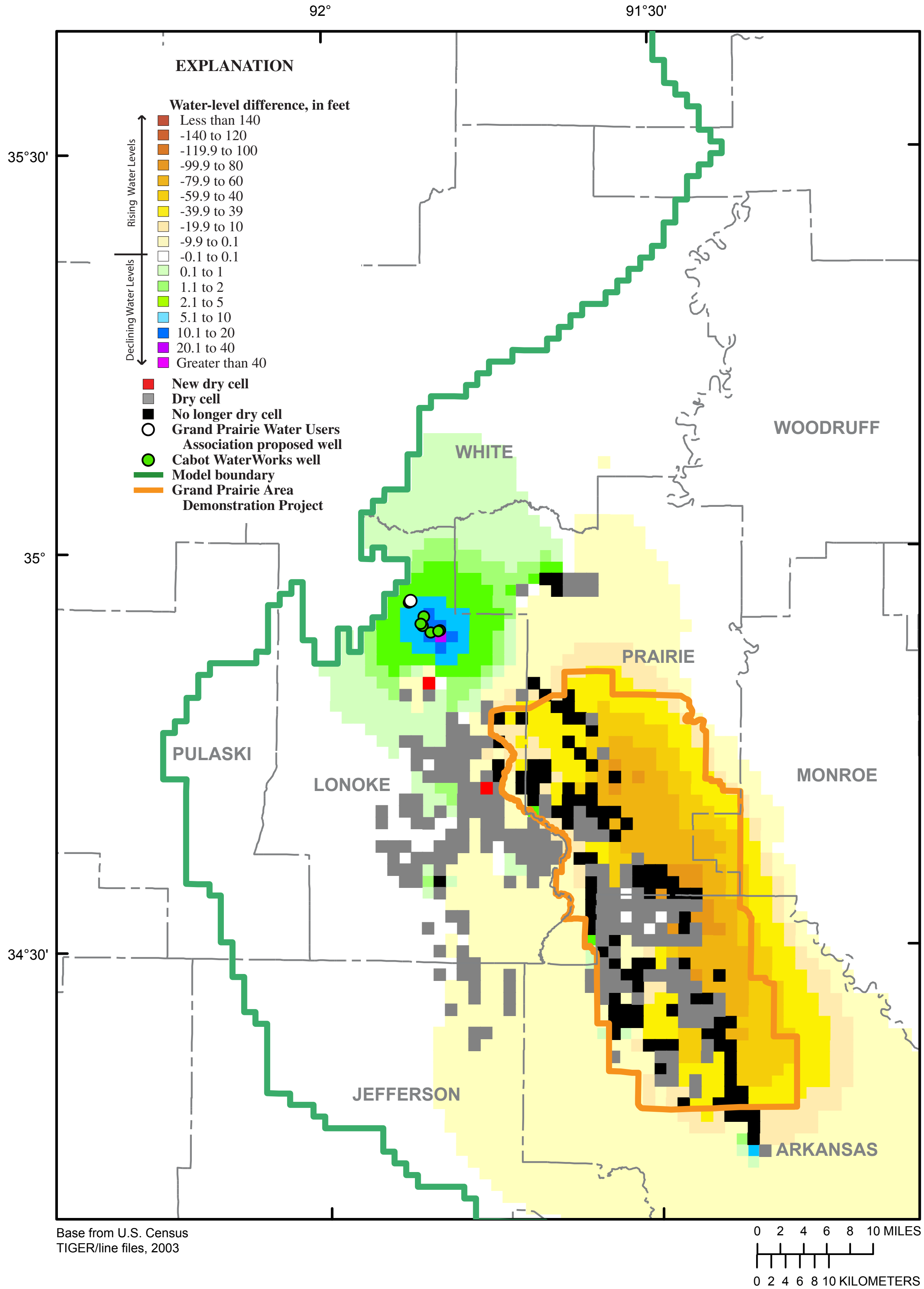

Figure 6H. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 9, table 1.

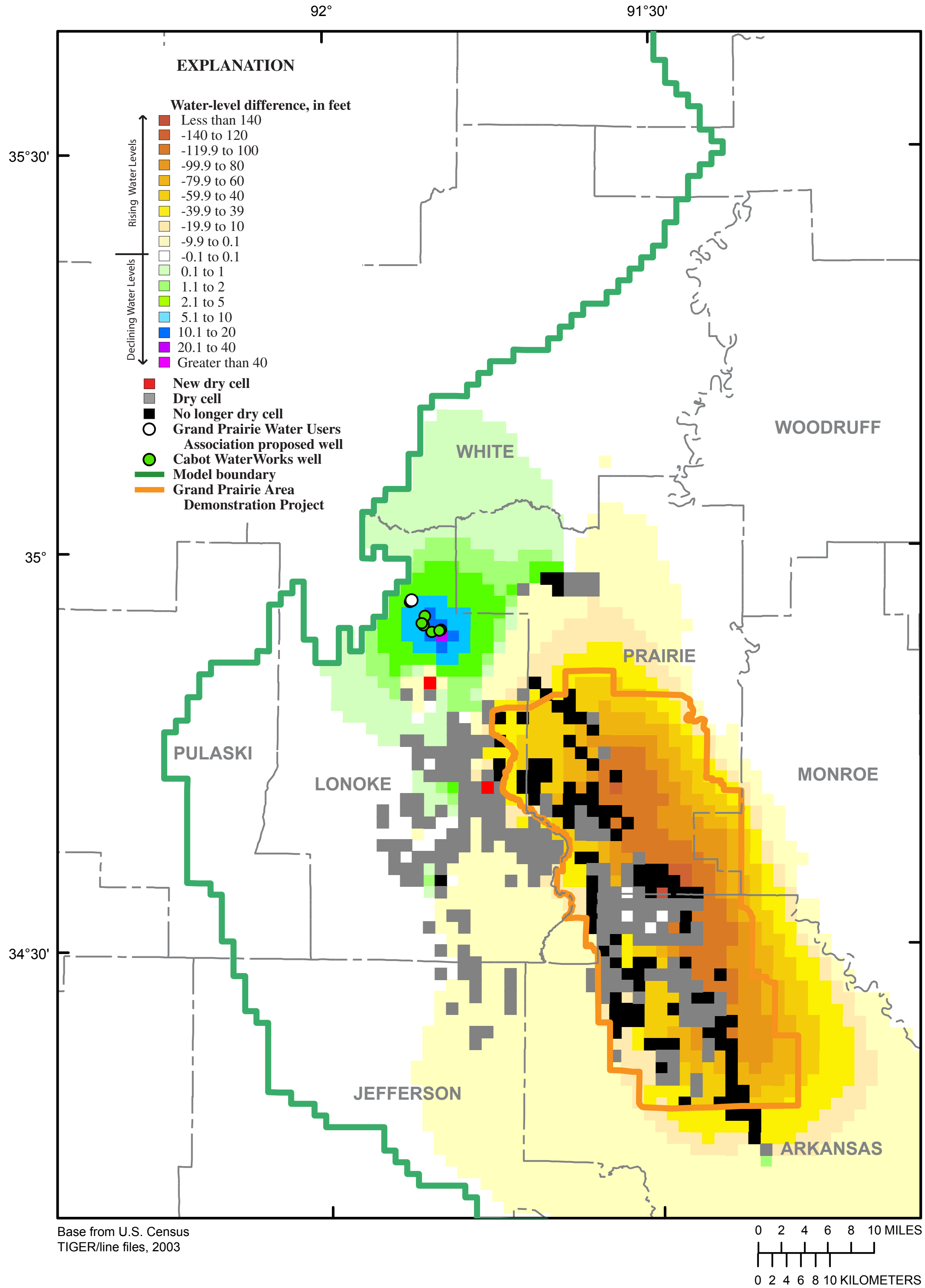

Figure 6I. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 10, table 1.

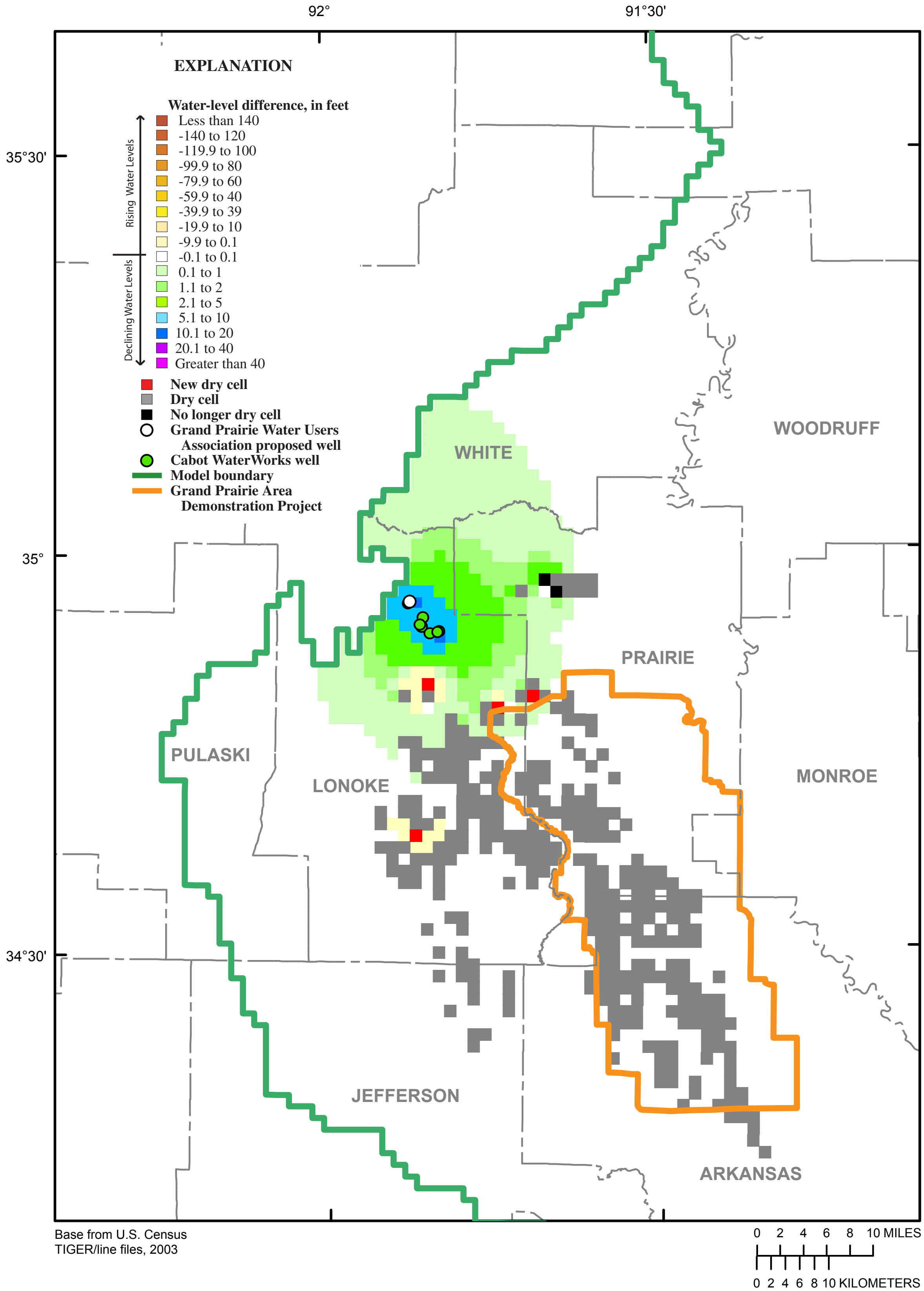

Figure 6J. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 11, table 1.

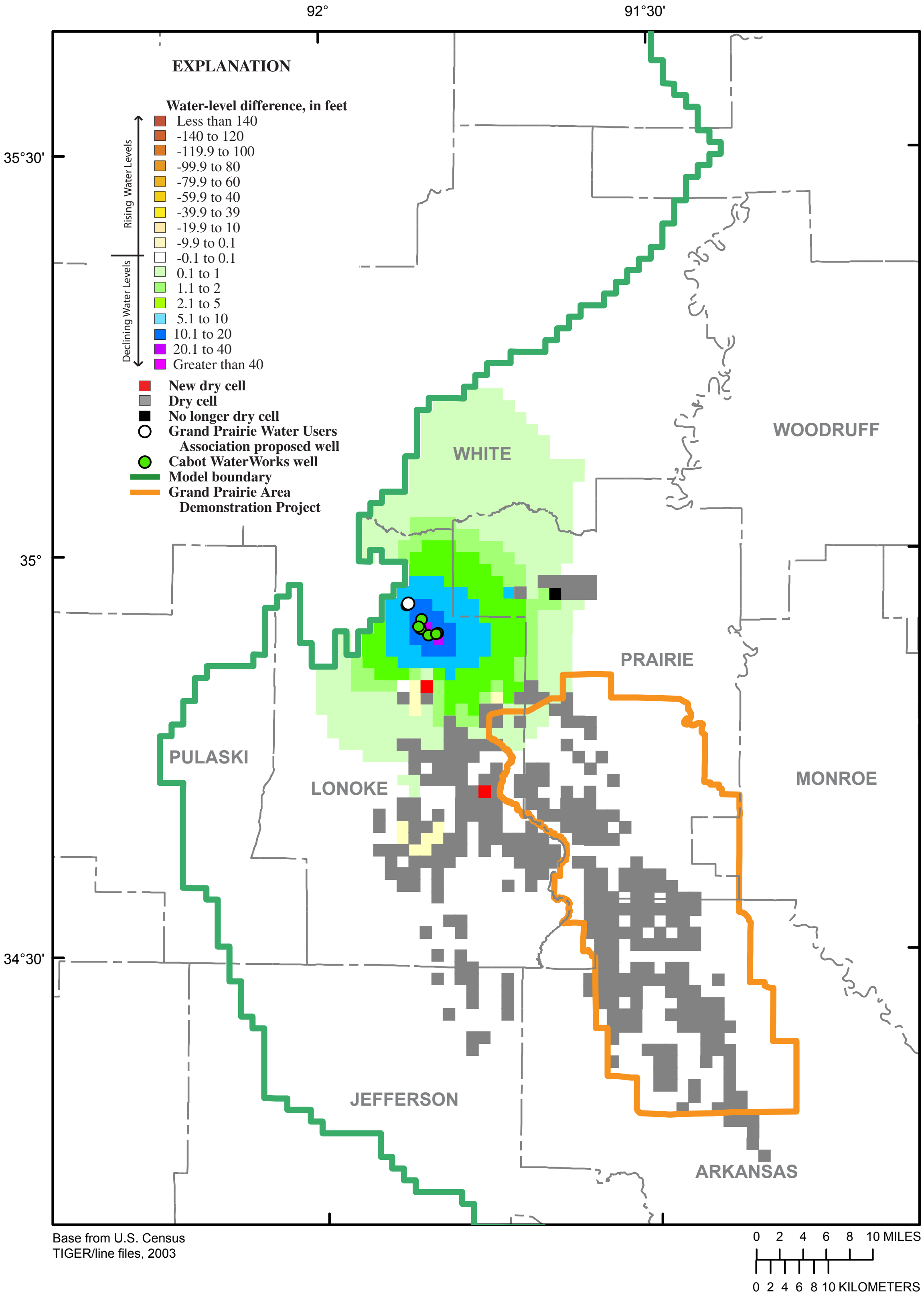

Figure 6K. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 12, table 1.

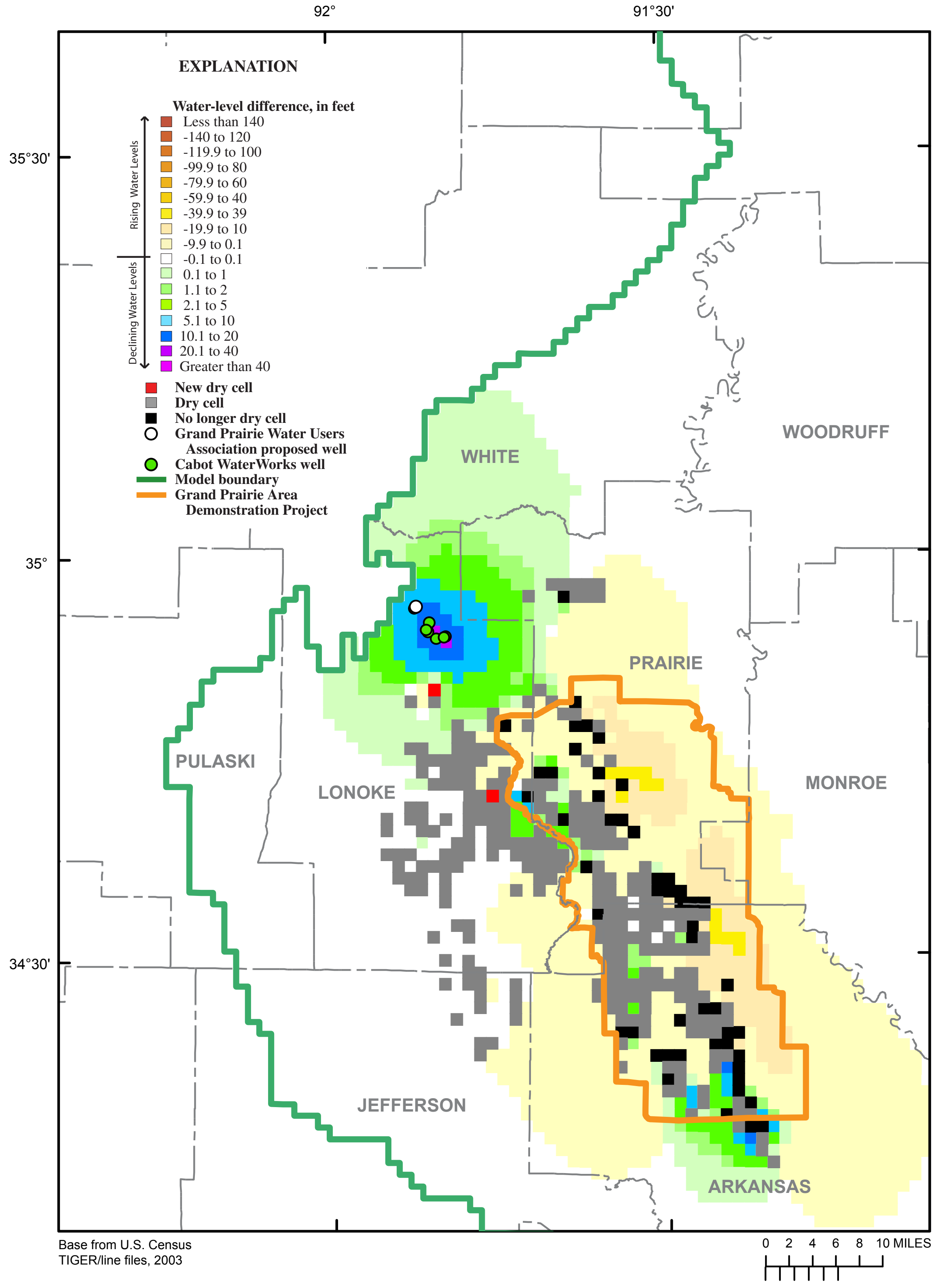

Figure 6L. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 13, table 1.

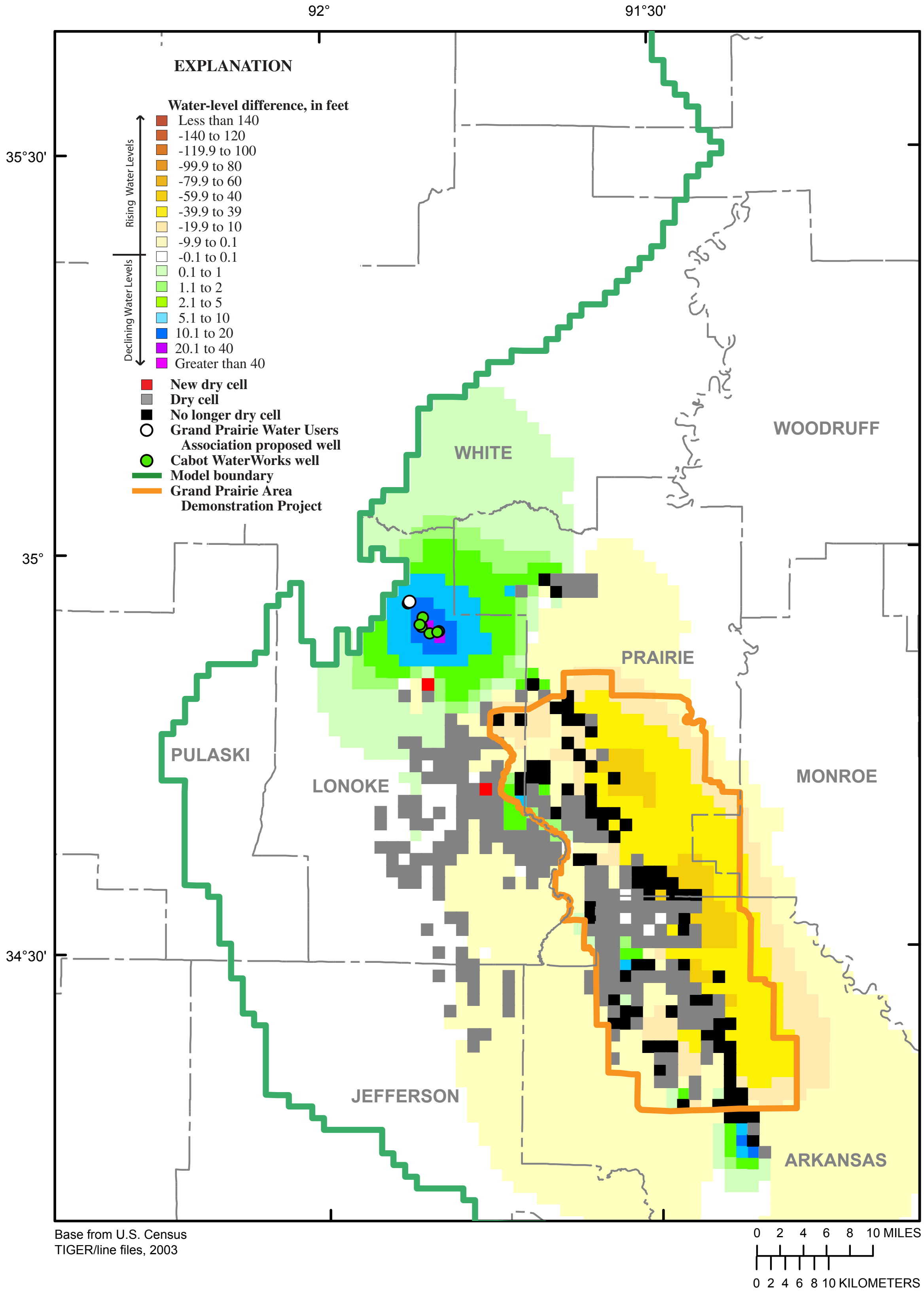

Figure 6M. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 14, table 1.

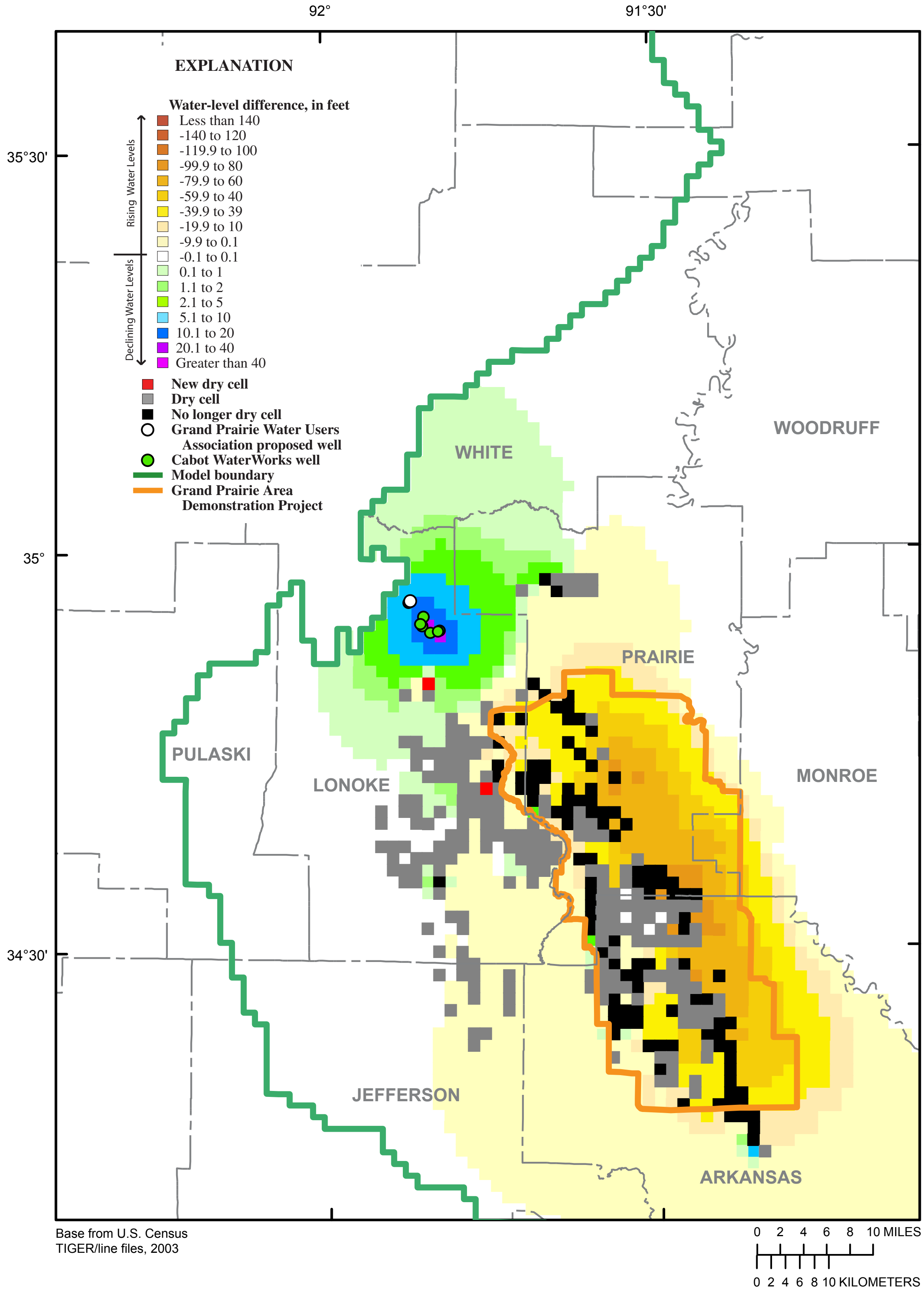

Figure 6N. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 15, table 1.

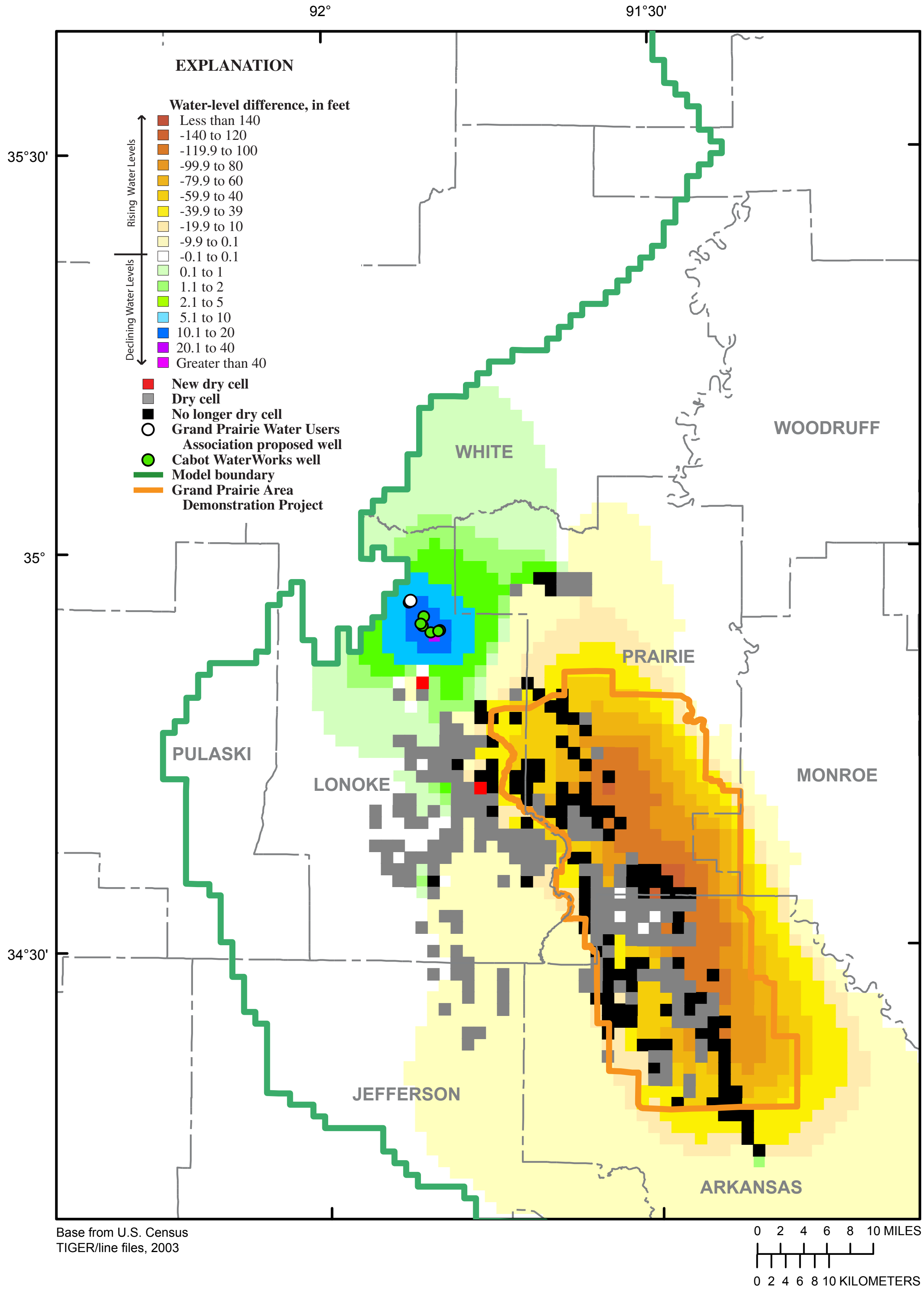

Figure 60. Simulated change in water-level altitude after 44 years of pumping compared to scenario 1 baseline conditions using rates specified in scenario 16, table 1.

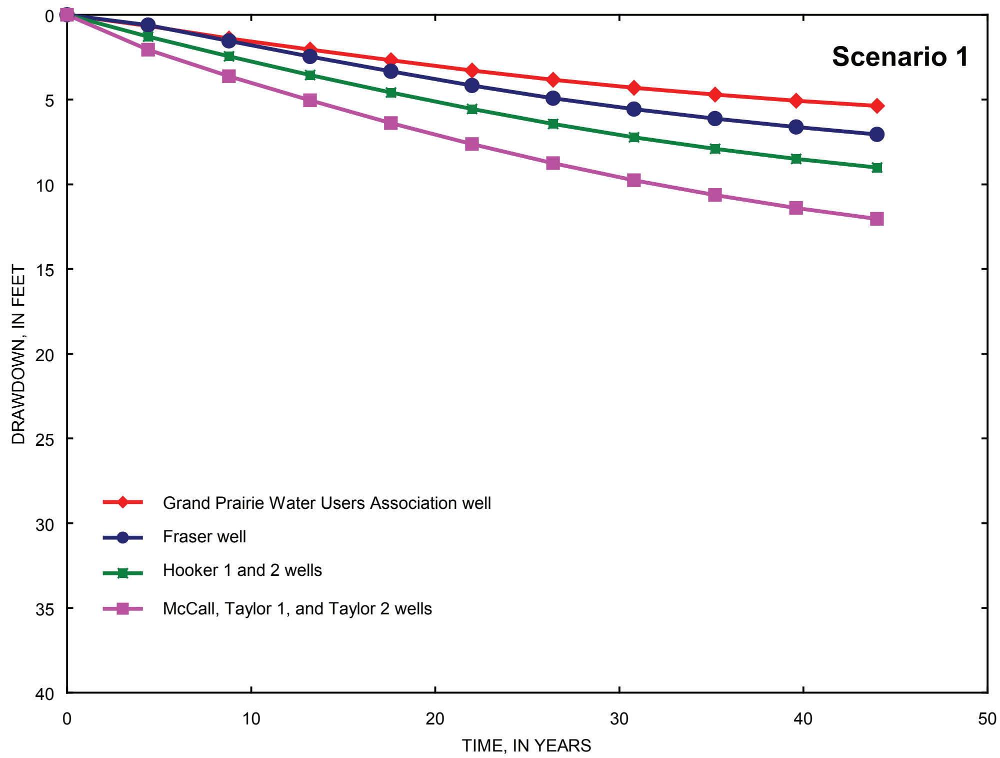

Figure 7A. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 1.

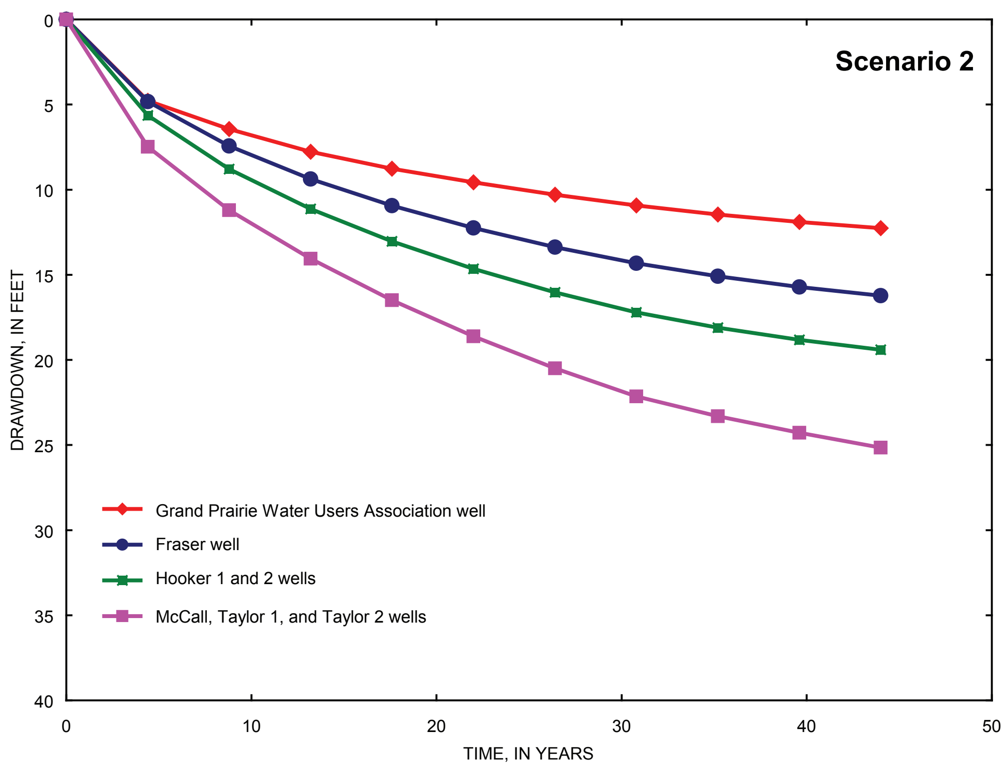

Figure 7B. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 2.

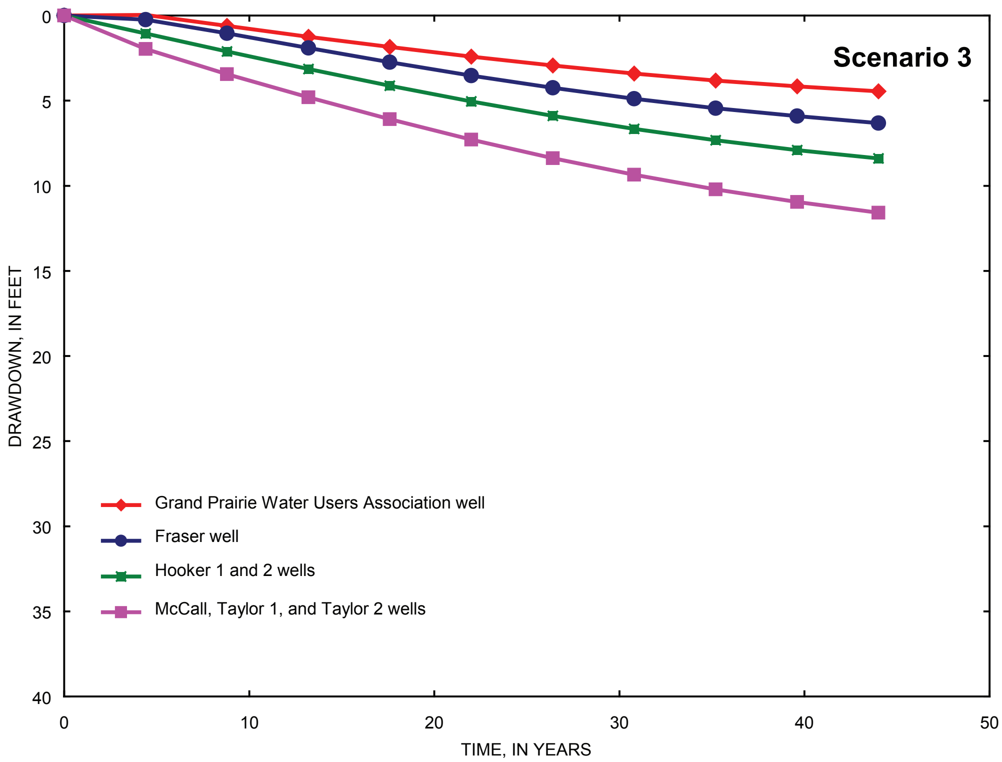

Figure 7C. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 3.

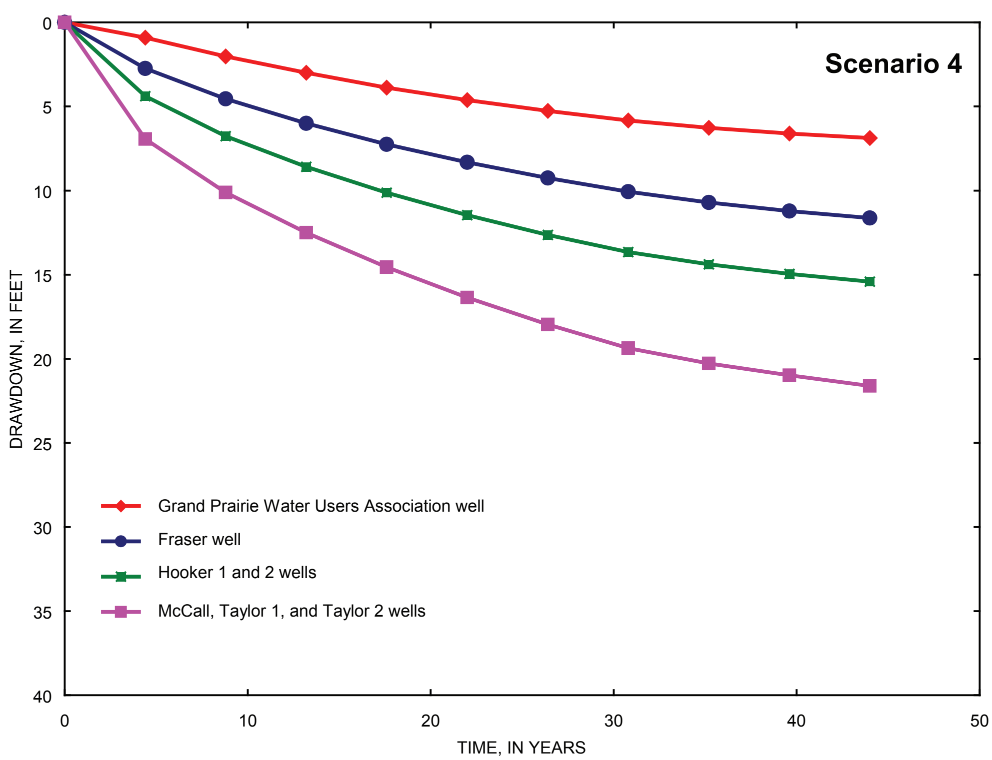

Figure 7D. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 4.

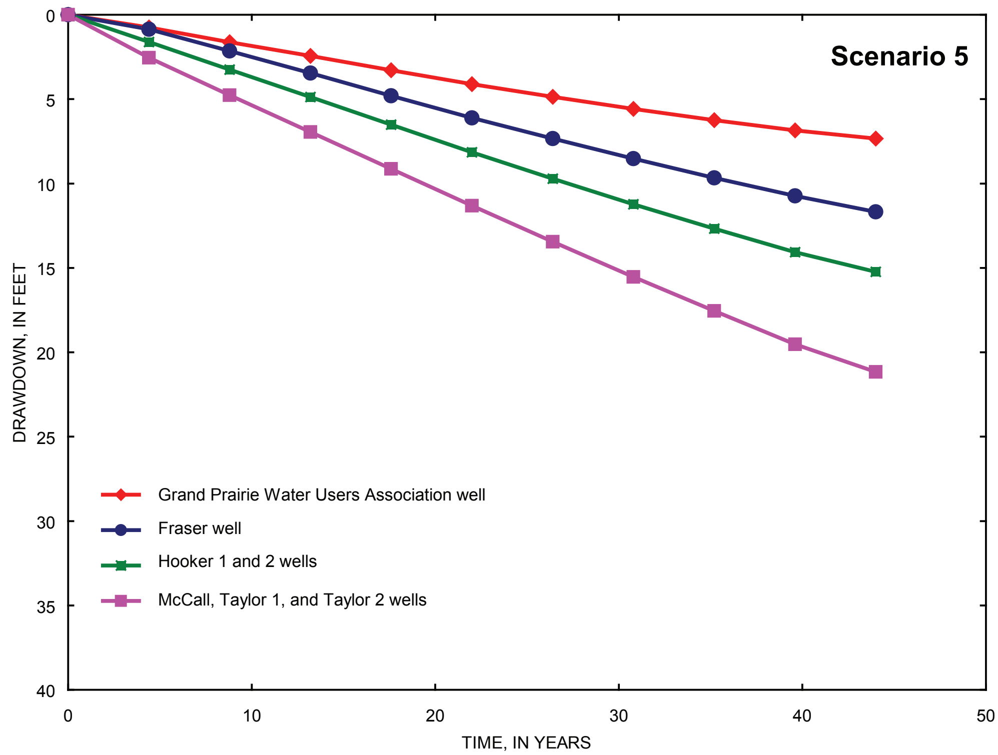

Figure 7E. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 5.

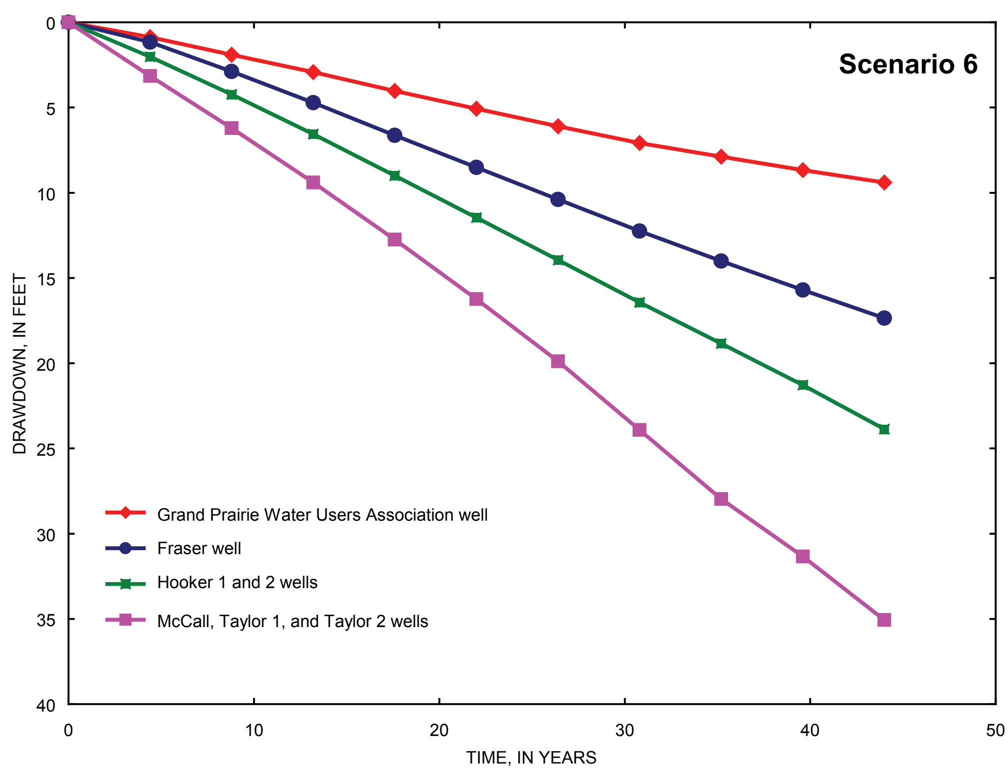

Figure 7F. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 6.

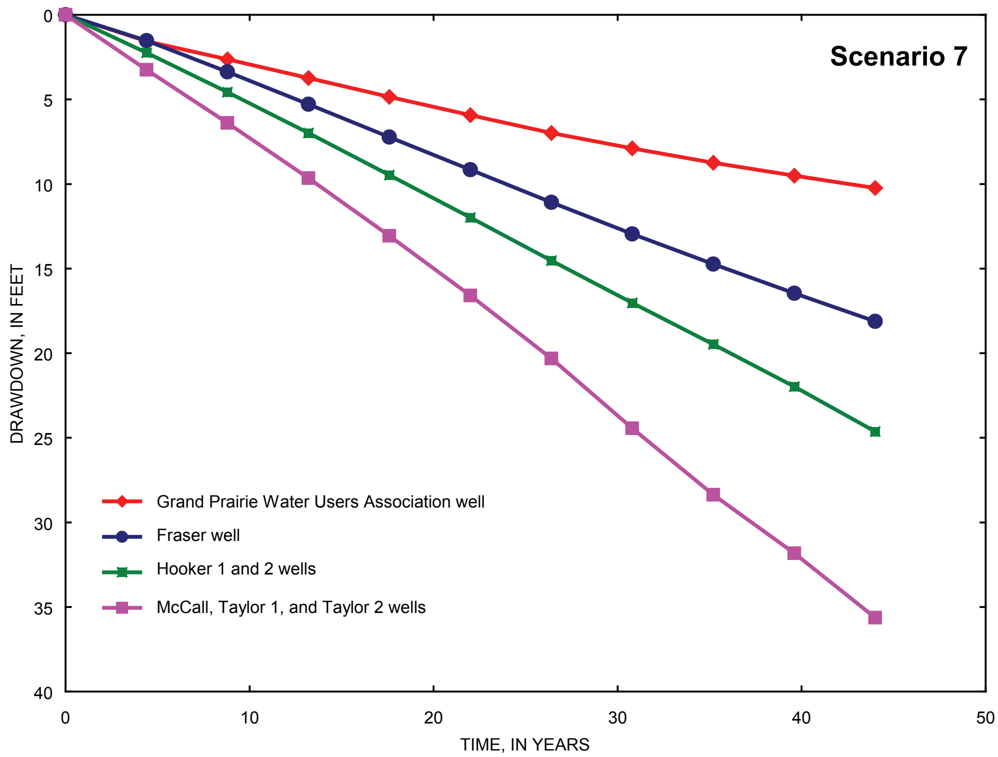

Figure 7G. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 7.

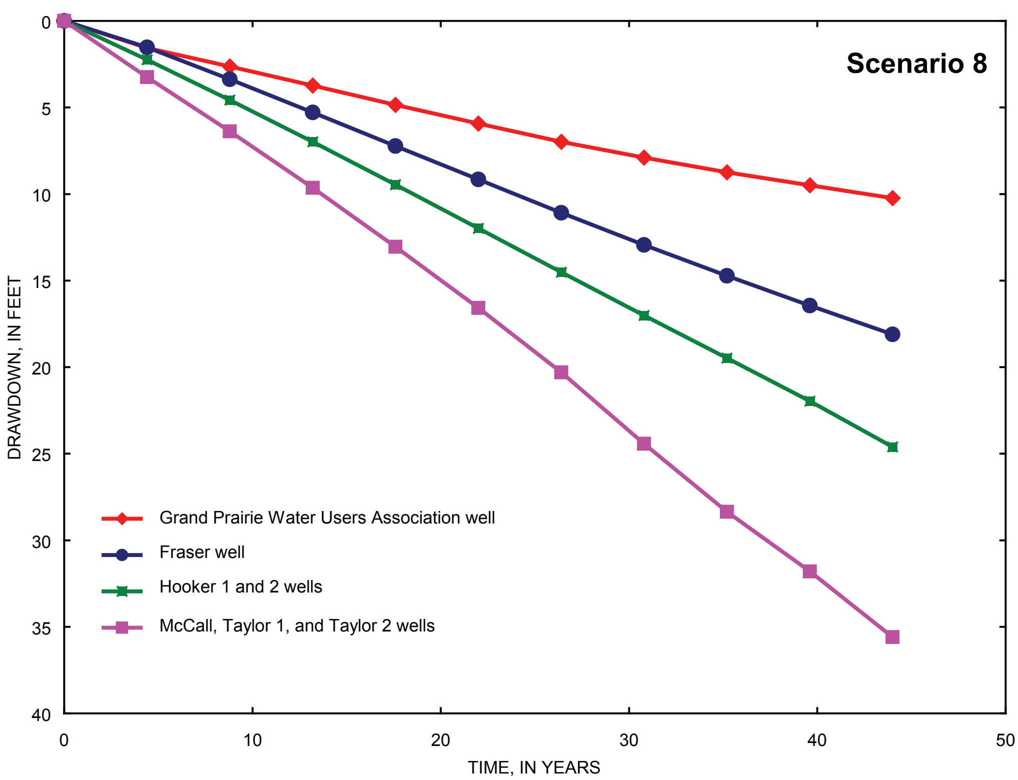

Figure 7H. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 8

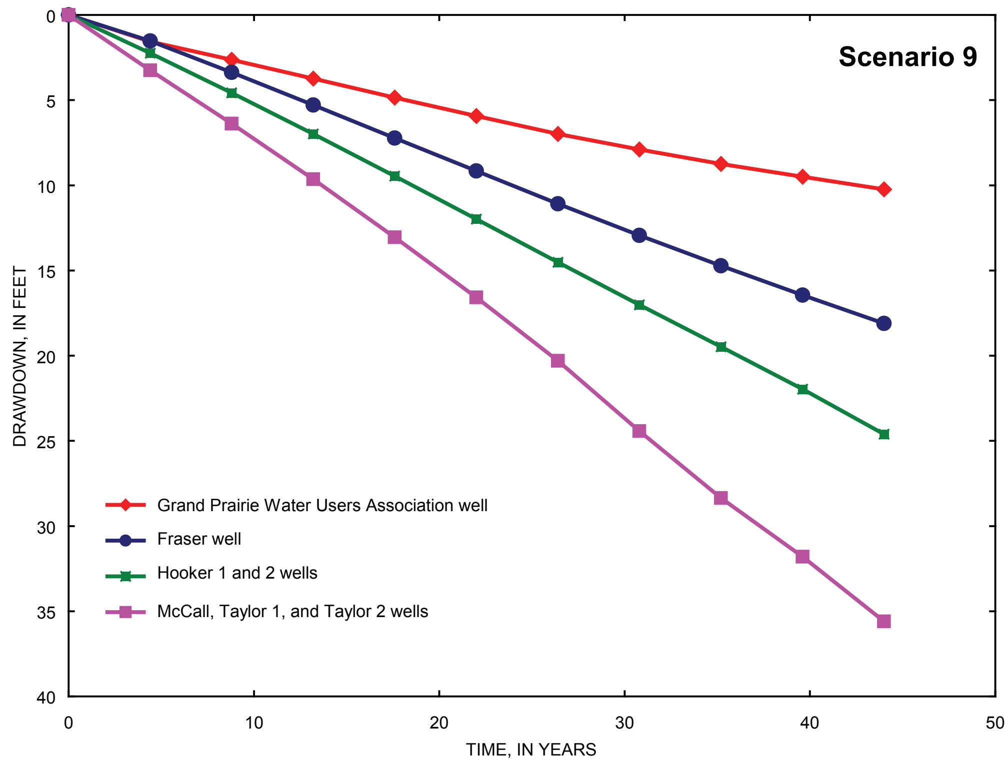

Figure 7I. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 9.

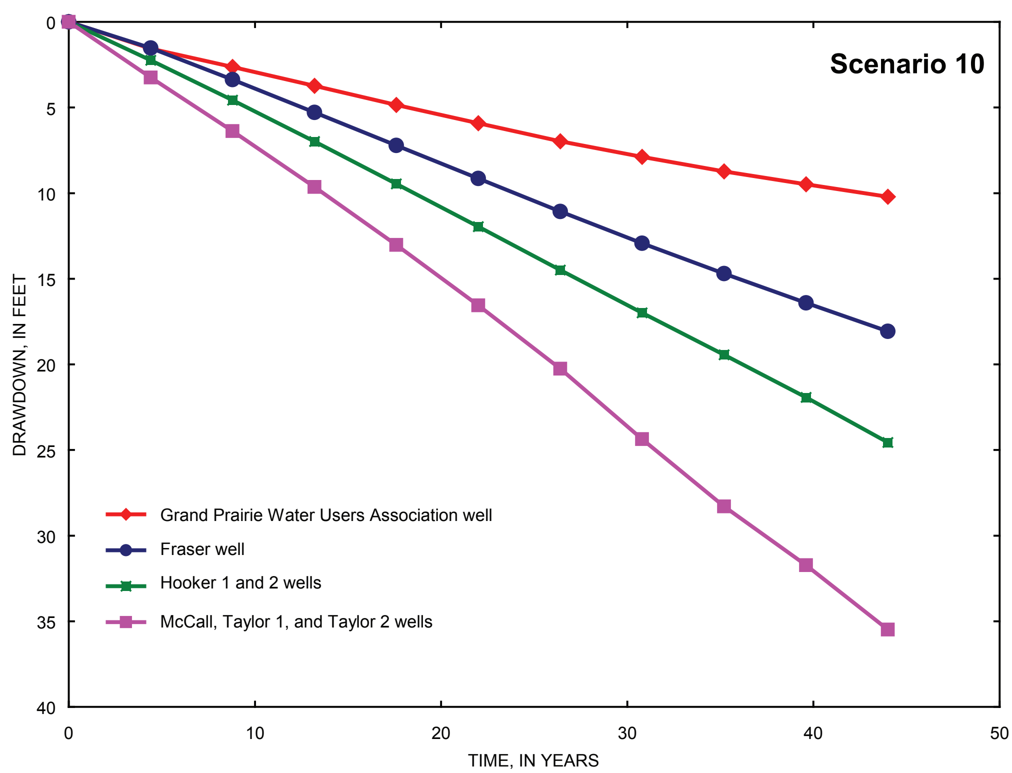

Figure 7J. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 10.

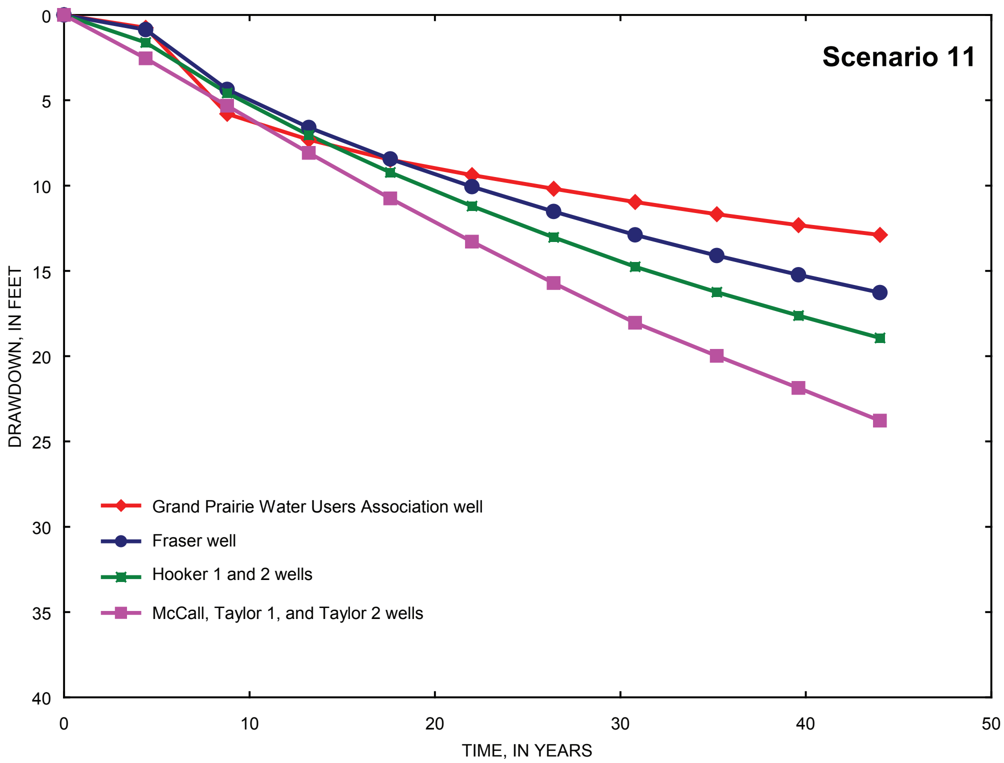

Figure 7K. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 11.

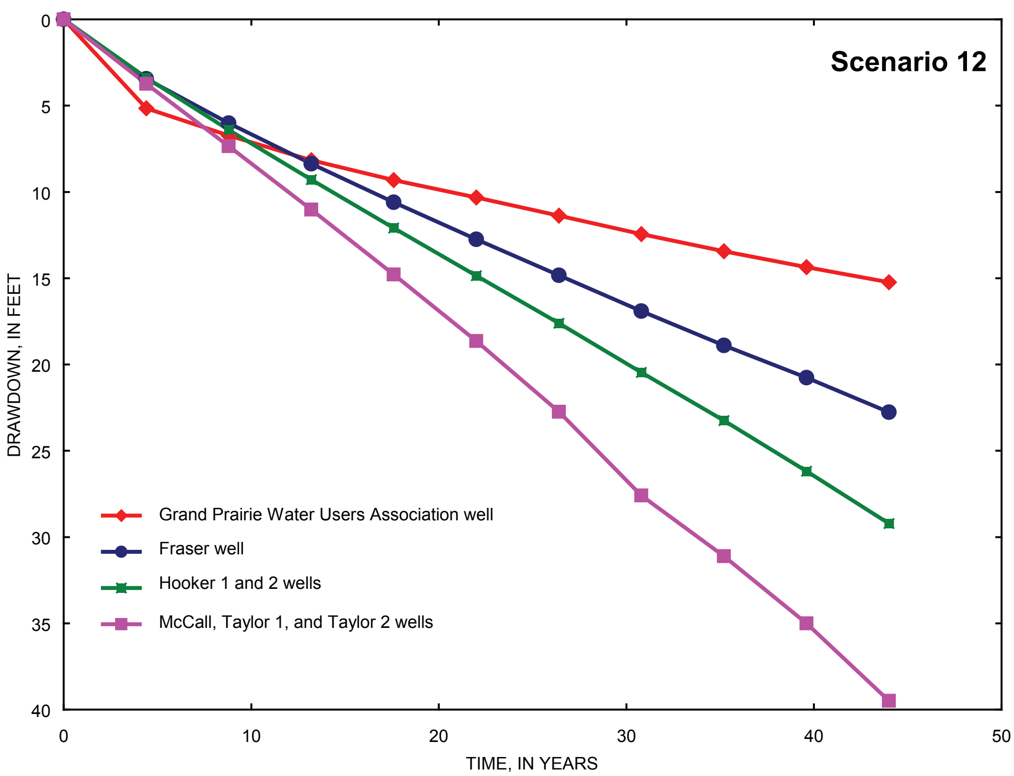

Figure 7L. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 12.

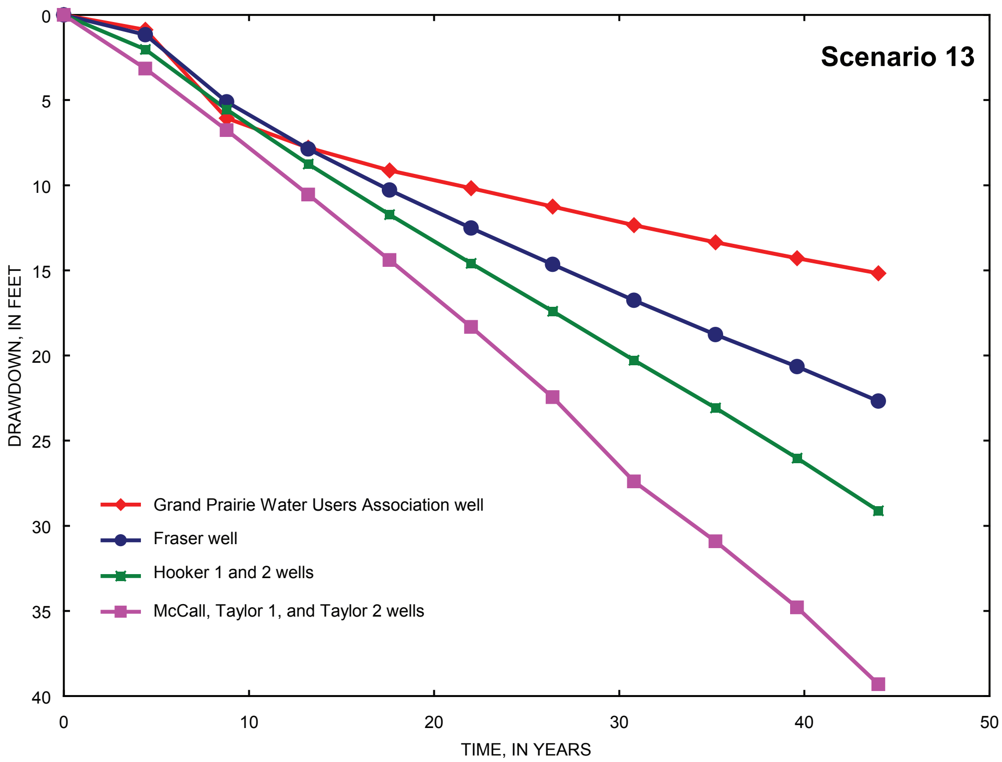

Figure 7M. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 13.

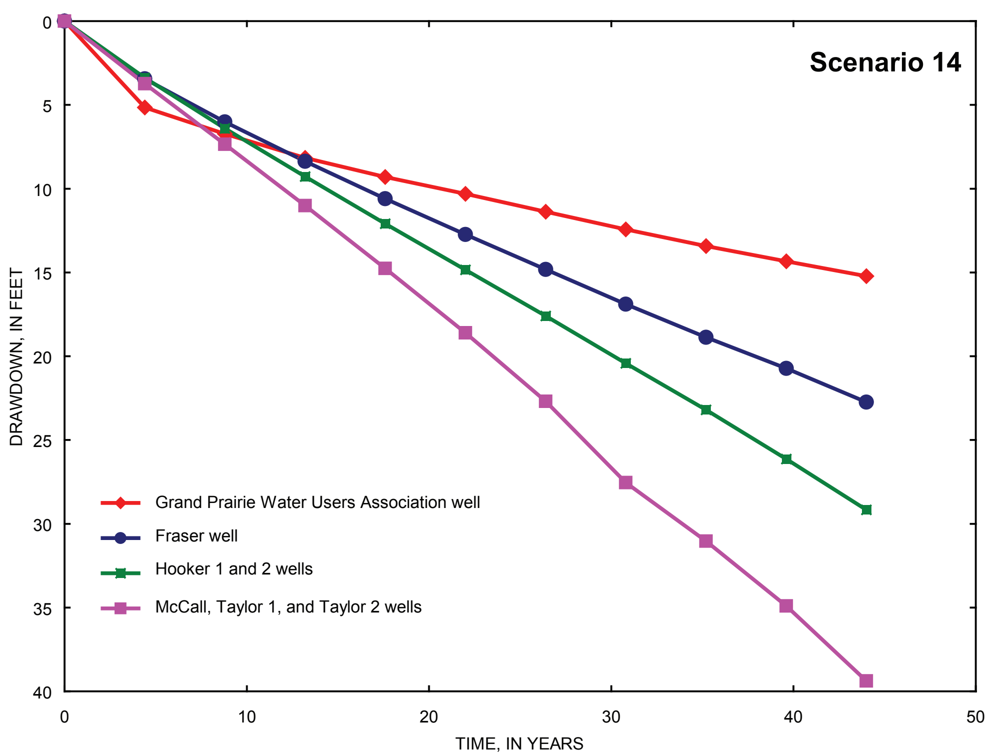

Figure 7N. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 14

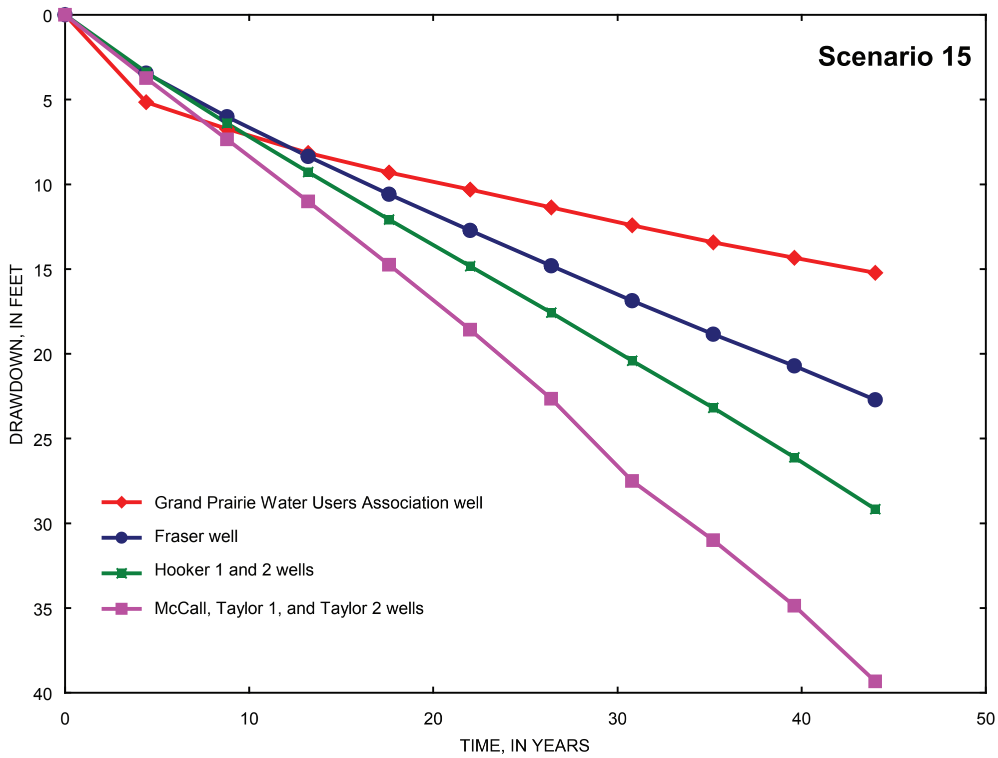

Figure 7O. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 15.

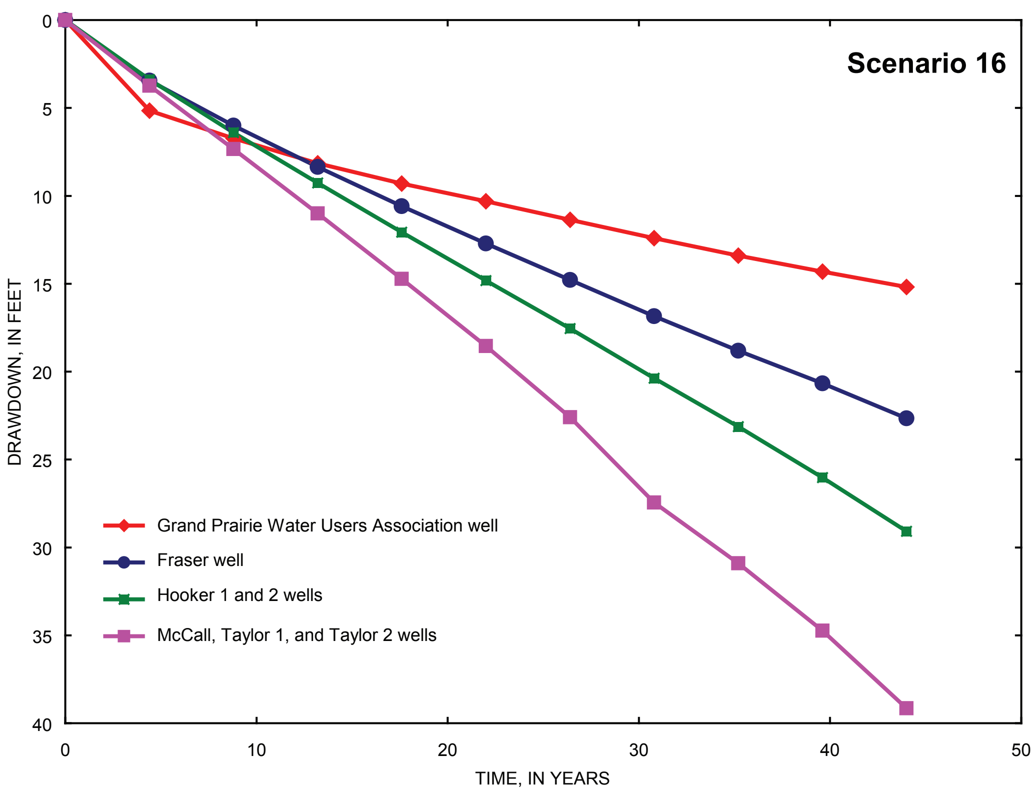

Figure 7P. Drawdown after January 1, 2007, in model cells containing Grand Prairie Water Users Association or Cabot WaterWorks pumping wells for scenario 16.

Table 4. Changes in number of dry cells between scenario 1 and other scenarios through 2049.

Condition	Scenario														
	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Number of new dry cells	4	0	4	2	3	2	2	2	2	4	2	2	2	2	2
Number of cells no longer dry	1	1	3	0	2	52	84	108	120	2	1	51	84	107	121

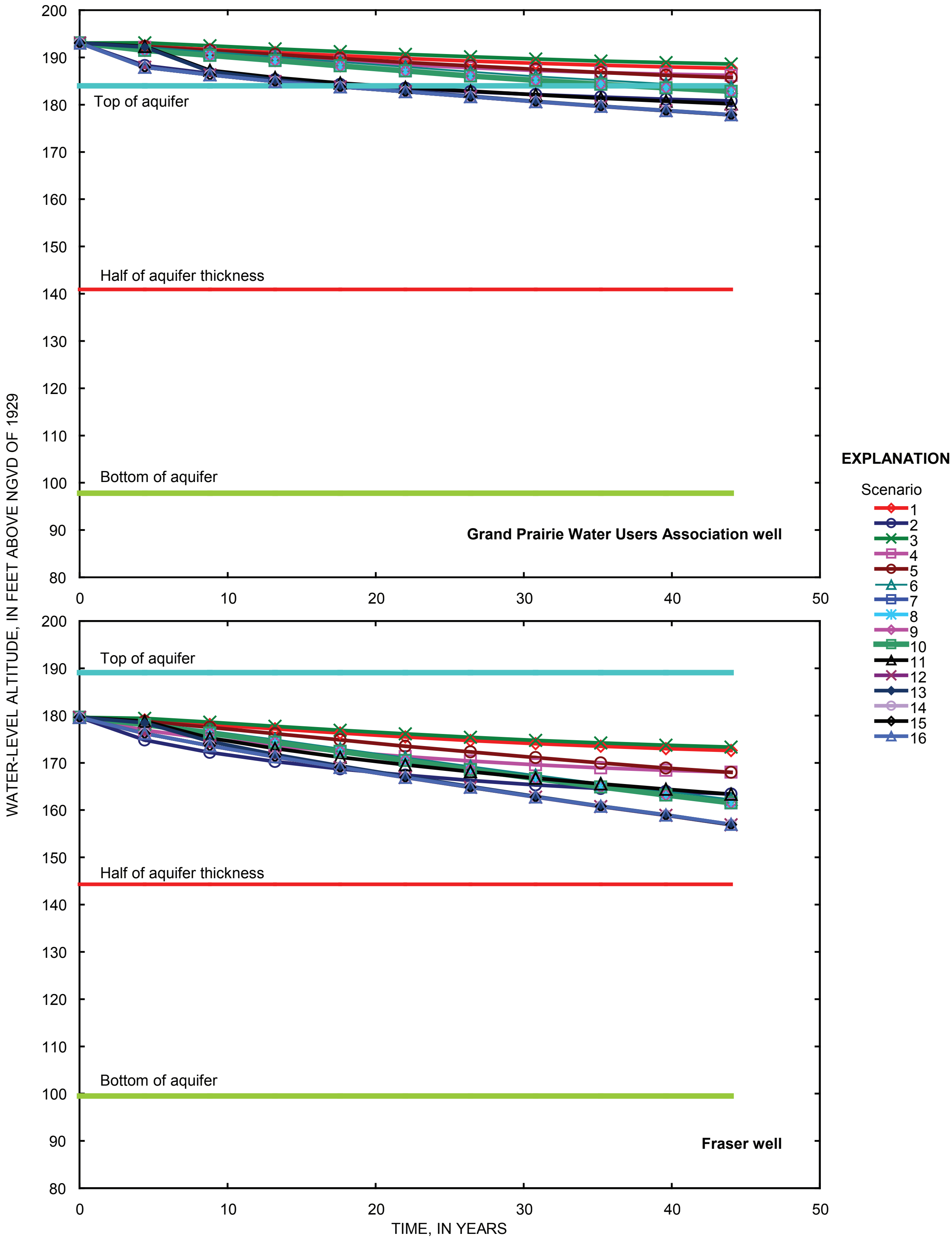

Figure 8. Simulated water-level altitude with time for each model scenario, in relation to the top, half-thickness, and bottom of the aquifer for the model cell containing the wells.

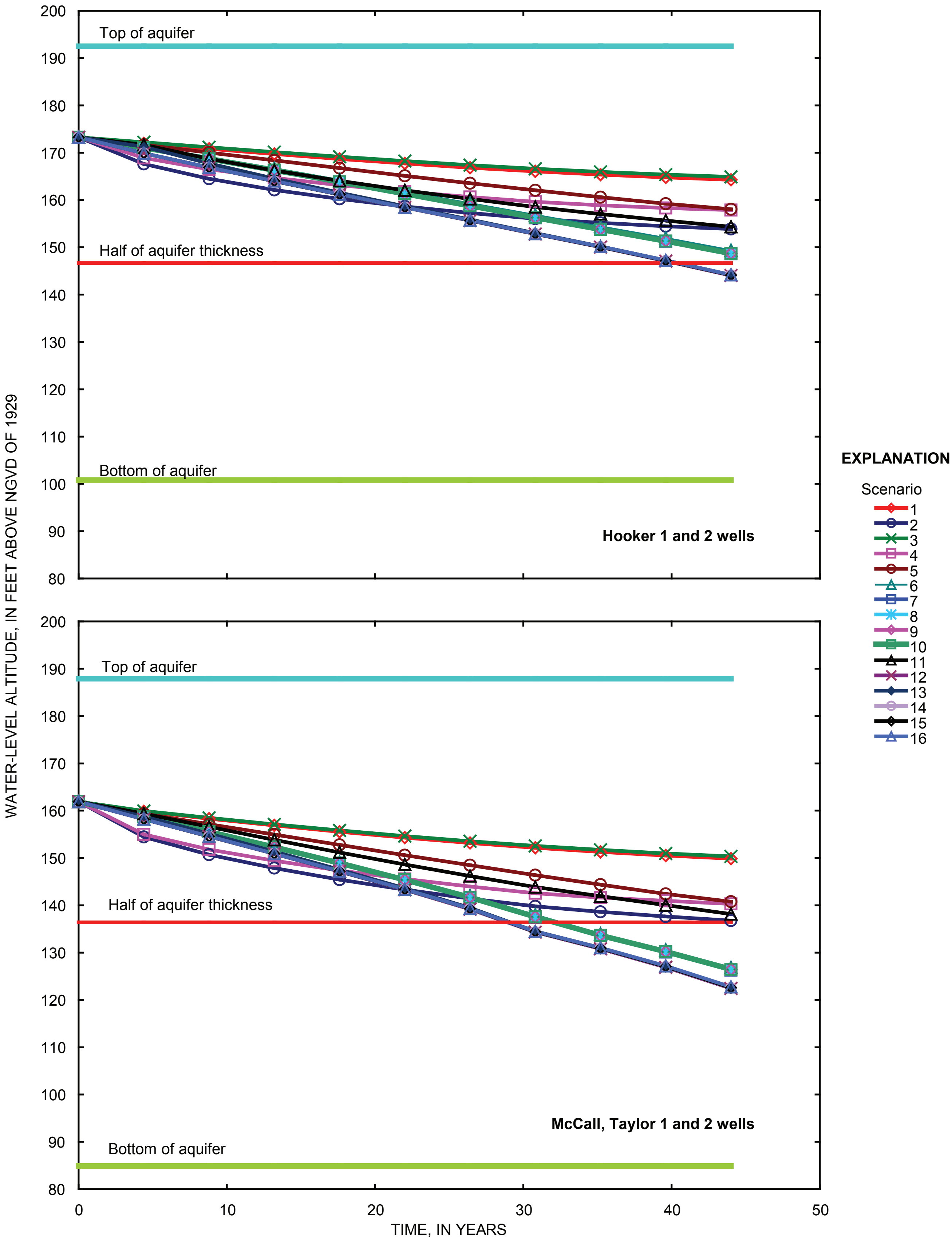

Figure 8. Simulated water-level altitude with time for each model scenario, in relation to the top, half-thickness, and bottom of the aquifer for the model cell containing the wells.—Continued

the aquifer beginning in about 2038 for scenarios 12 through 16, and in about 2042 for scenarios 6 through 10, in the model cell containing the McCall, Taylor 1, and Taylor 2 wells.

Model Limitations

By its very nature, a ground-water model is a simplification of a complex natural system, with inherent limitations. Simulated water levels and estimates of drawdown resulting from the proposed pumping by CWW represent average conditions over the 1-square-mile grid cells of the model. Drawdown at the actual location of the pumped wells will be greater.

Proximity of pumping cells to flux boundaries may result in unrealistic water levels. The model cells with the proposed increased withdrawals are 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. However, this boundary condition 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 are important variables that have a large effect on simulated water levels. Pumping rates throughout the model, except for those specified for GPWUA and CWW, do not reflect current (2006) conditions, and likely would be considerably larger than those specified for 1997 in Reed (2003), resulting in greater drawdown. Pumping rates specified in the model are not representative of current (2006) conditions with a few exceptions. Pumping rates throughout the model, except for those specified for the CWW and GPWUA wells, reflect 1997 conditions, and would be considerably larger today, resulting in greater drawdown and less available ground water.

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 could 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 15 feet. 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.

Model cells that go dry during a simulation remain dry from that point in time until the simulation is finished. Cells that are near the threshold of going dry may respond nonlinearly following abrupt changes in pumping rates, causing numerical inaccuracies to occur within that part of the model. Cells that were no longer dry for some of the simulations likely occur in those cells that were near this threshold; consequently their saturated thickness is small.

Summary

Cabot WaterWorks (CWW), located in Lonoke County, Arkansas, plans to increase ground-water withdrawals from the Mississippi River Valley alluvial aquifer from a 2004 rate of 2.24 Mgal/d to between 4.8 and 8 Mgal/d by 2049. The effects of increased pumping from several wells were simulated using a digital model of ground-water flow. The proposed additional withdrawals by CWW were specified in three 1-square-mile model cells, with increased pumping beginning in 2007. Increased pumping was specified at various combined rates for a period of 44 years. In addition, augmented pumping from wells owned by Grand Prairie Water Users Association (GPWUA), located about 2 miles from the nearest CWW wells, was added to the model beginning in 2007 and continuing through 2049 in 10 of the 16 scenarios analyzed. Eight of the scenarios included reductions in pumping rates in model cells corresponding to wells contained within the Grand Prairie Area Demonstration Project (GPADP).

Drawdown at the end of 44 years of pumping at 4.8 Mgal/d from the CWW wells ranged from between 15 to 25 feet in the three model cells; pumping at 8 Mgal/d resulted in water-level drawdown ranging from about 15 to 40 feet. Water levels in those cells showed no indication of leveling out at the end of the simulation period, indicating nonsteady-state conditions after 44 years of pumping. However, most of the simulated change in water levels from the pumping of the CWW wells occurs within 2 miles of those wells, with only minor changes occurring out to a distance of about 10 miles from the wells. From one to four new dry cells occurred in each of the scenarios by 2049 when compared to the baseline scenario in which pumping was maintained at 2004 rates, even in scenarios with reduced pumping in the GPADP; however, reduced pumping produced cells that were no longer dry when compared to the baseline scenario at the end of 2049. Saturated thickness by 2049 in the three CWW wells ranged from about 51.9 to 68.5 feet for pumping rates of 4.8 million gallons per day, and from about 37.5 to 62.8 feet for pumping rates of 8 million gallons per day, the latter causing water level to fall below half the aquifer thickness in the most heavily pumped of the three cells. Pumping rates throughout the model, except for those specified for the CWW and GPWUA wells, reflect 1997 conditions, and would be considerably larger today, resulting in greater drawdown, and less available ground water.

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