Ground-Water Models of the Alluvial and Sparta Aquifers: Management Tools for a Sustainable Resource

Introduction

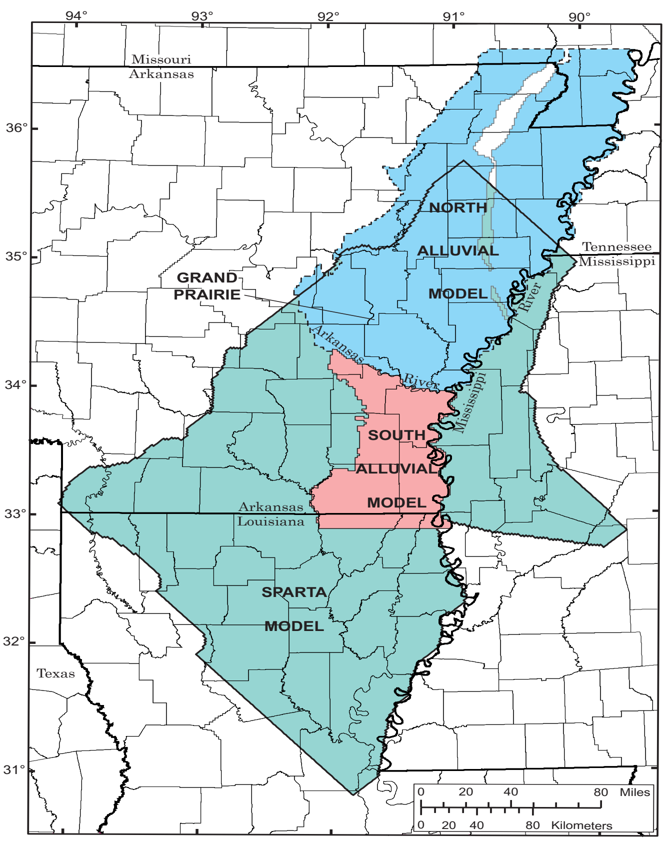
Arkansas is the fourth largest user of ground water in the United States. The Mississippi River Valley alluvial aquifer (alluvial aquifer) is a water-bearing assemblage of gravels and sands that underlies most of eastern Arkansas and several adjacent States. Ground-water withdrawals have caused cones of depression to develop in the alluvial aquifer water-level surface, some as much as 100 feet deep. Long-term water-level measurements show an average annual decline of 1 foot per year in some areas. The Sparta aquifer is largely a confined aquifer of regional importance that comprises a sequence of unconsolidated sand, silt, and clay units. Several large cones of depression have developed in the Sparta aquifer, causing hydraulic heads to drop below the top of the formation in parts of central and southern Arkansas and several areas in north-central Louisiana.

Several counties in the Grand Prairie area and south Arkansas have been designated Critical Ground-Water Areas (areas where alluvial aquifer water levels dropped below 50 percent of the original saturated thickness or below the top of the Sparta Sand formation) by the Arkansas Soil and Water Conservation Commission (ASWCC). 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.

Ground-Water Models

For many years, the ASWCC 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 two areas of the alluvial aquifer (north alluvial and south alluvial—divided by the Arkansas River) and the Sparta aquifer were developed for eastern Arkansas and parts of northern Louisiana and adjacent States (Reed, 2003; Stanton and Clark, 2003; McKee and Clark, 2003).

The flow models showed that continued ground-water withdrawals at 1997 rates for the alluvial aquifer and 1990-97 rates for the Sparta aquifer could not be sustained indefinitely without causing water levels to decline below 50 percent of the original saturated thickness of the alluvial aquifer or below the top of the Sparta Sand formation. To develop estimates of withdrawal rates that could be sustained relative to the constraints of critical ground-water area designation, conjunctive-use optimization modeling was applied to the flow models (Czarnecki and others, 2003a,b; McKee and others, 2004). An optimization model calculates the maximum sustainable yield from wells and rivers, while maintaining simulated water levels and streamflows at or above minimum specified limits or constraints.



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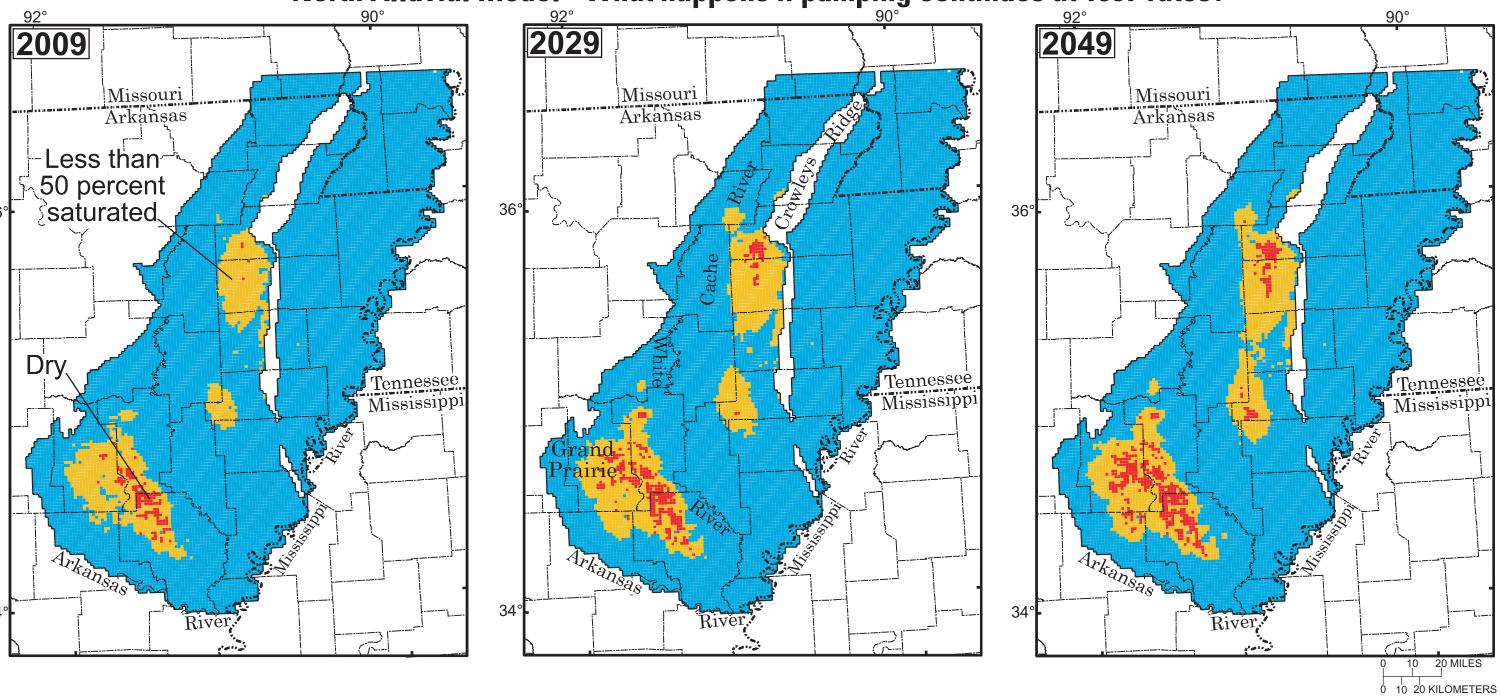
Sustainable yield is the rate at which water can be withdrawn indefinitely from ground- and surface-water sources without violating specified constraints. This rate is calculated through the use of a **conjunctive-use optimization model**. Sustainable yield is dependent on upper limits of specified withdrawal rates for wells and rivers and can vary given various imposed constraints. **Demand** is the amount of ground water used or withdrawn during the period. Unmet demand is the difference between a desired withdrawal rate (demand) and the sustainable yield. **Sustainable yield from rivers** represents a potential source of water that could supplement ground water.

North Alluvial Model - What happens if pumping continues at 1997 rates?



118 square miles of dry aquifer
1,481 square miles less than 50 percent saturated

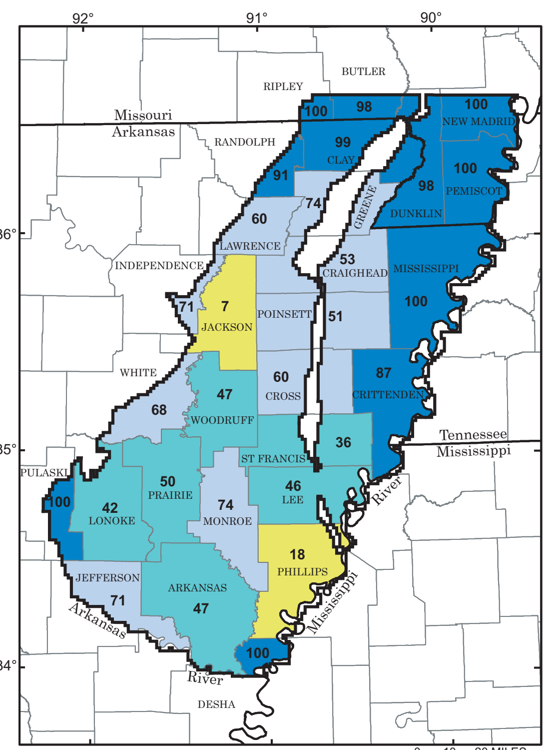
273 square miles of dry aquifer
1,971 square miles les than 50 percent saturated

401 square miles of dry aquifer
2,195 square miles less than 50 percent saturated

North Alluvial Model

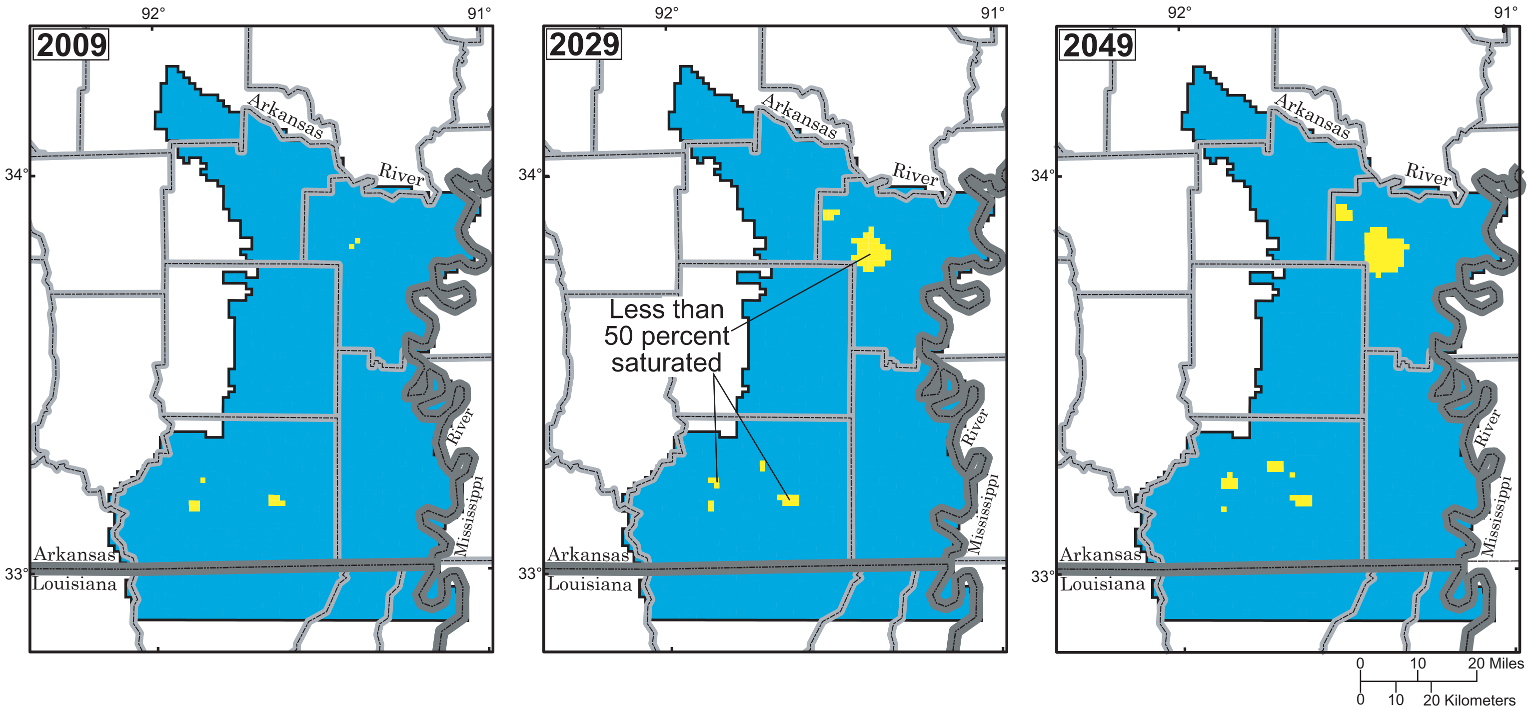
The alluvial flow model in northeastern Arkansas was used to predict ground-water flow for a 50-year period from 1998-2049 with different hypothetical pumping scenarios. If pumping remains at 1997 rates (635.7 million cubic feet per day (Mft^3/d), large simulated water-level declines occur in two areas of the aquifer, one in the Grand Prairie area between the Arkansas and White Rivers and the other west of Crowleys Ridge along the Cache River. Simulations show that by 2009 over 100 square miles (mi^2) of the alluvial aquifer could be dry (demand exceeding sustainable yield) with about 400 mi^2 of the aquifer going dry by 2049. Given imposed constraints, ground-water sustainable yield is 360.3 Mft^3/d—57 percent of the 635.7 Mft^3/d demand in 1997. This unmet demand of 275.5 Mft^3/d of ground water could be obtained from large sustainable surface-water withdrawals. Total sustainable yield from all rivers combined was 12,806 Mft^3/d, which represents a substantial source for supplementing ground water to meet the total water demand.

Sustainable yield from ground water (Mft^3/d)	Ground-water demand (Mft^3/d)	Unmet demand for ground water (Mft^3/d)	Sustainable yield from rivers (Mft^3/d)
360.3	635.7	275.5	12,806



Percentage of 1997 withdrawal from alluvial aquifer that is sustainable by county (north alluvial model)

South Alluvial Model - What happens if pumping continues at 1997 rates?



0 square miles of dry aquifer
12 square miles less than 50 percent saturated

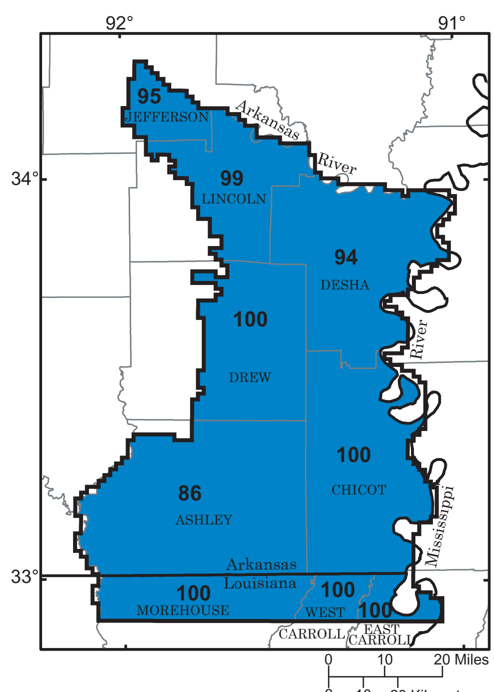
0 square miles of dry aquifer
52 square miles less than 50 percent saturated

0 square miles of dry aquifer
81 square miles less than 50 percent saturated

South Alluvial Model

The flow model for the alluvial aquifer in southeastern Arkansas was used to predict ground-water flow for a 50-year period from 1998-2049 with different hypothetical pumping scenarios. If pumping remains at 1997 rates (73.5 Mft^3/d), an area centered in Desha County and two areas in Ashley County show simulated water levels dropping below 50 percent of the saturated thickness of the alluvial aquifer by 2009. Simulated water levels for 2029 and 2049 indicate enlargement and deepening of these areas and up to 81 mi^2 where the aquifer drops below 50 percent of the saturated thickness, although no areas of the aquifer go dry. Given imposed constraints, ground-water sustainable yield is 70.3 Mft^3/d—96 percent of the demand of 73.5 Mft^3/d. Unmet demand for the model area is 3.3 Mft^3/d. Total sustainable yield from the rivers is about 4,918 Mft^3/d, or about 6,700 percent of the amount of ground water withdrawn in 1997, which represents a substantial source for supplementing ground water to meet the total water demand.

Sustainable yield from ground water (Mft^3/d)	Ground-water demand (Mft^3/d)	Unmet demand for ground water (Mft^3/d)	Sustainable yield from rivers (Mft^3/d)
70.3	73.5	3.3	4,918

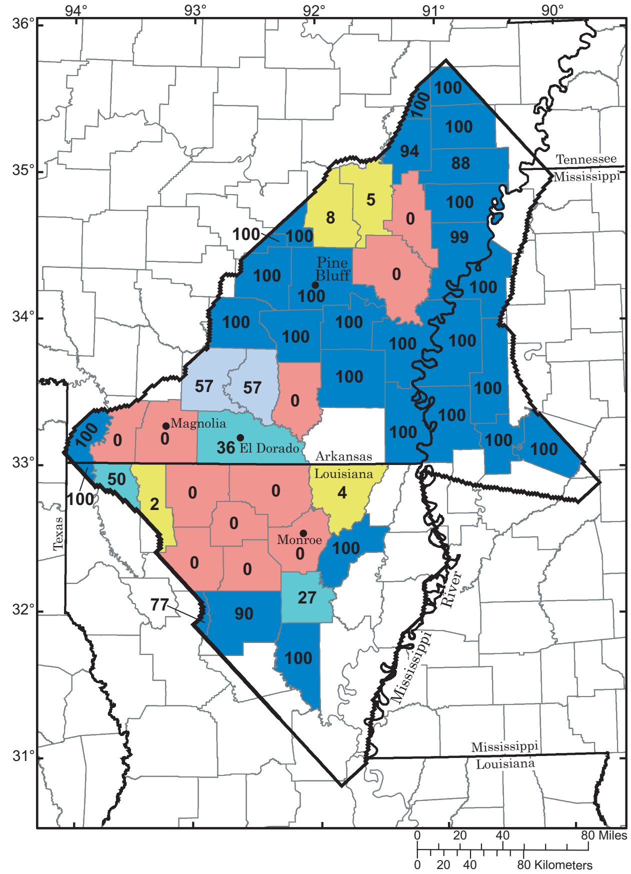


Percentage of 1997 withdrawal from alluvial aquifer that is sustainable by county (south alluvial model)

Sparta Model

The Sparta flow model was used to predict the effects of three hypothetical withdrawal scenarios on water levels over a 30-year period from 1998-2027. In one scenario, withdrawal rates (30.6 Mft^3/d) from 1990-97 were held constant for 30 years from 1998-2027 and simulated water levels decreased by 10 feet in El Dorado and 17 feet in Pine Bluff, Arkansas. Through 2027, simulated water levels continue to decline in the center of cones of depression in areas of El Dorado, Pine Bluff, Magnolia in Arkansas, and in Monroe, Louisiana. Cones of depression continue to deepen and expand, and areas where water levels have dropped below the top of the Sparta Sand formation grow to 1,787 mi^2 in size in Arkansas and 2,821 mi^2 in Louisiana by 2027. Given imposed constraints, ground-water sustainable yield in Arkansas and Louisiana is 11.9 Mft^3/d—39 percent of the total ground-water demand of 30.6 Mft^3/d. The remainder, 18.8 Mft^3/d, is defined as unmet demand that could be obtained from the 5,396 Mft^3/d sustainable yields from rivers.

Sustainable yield from ground water (Mft^3/d)	Ground-water demand (Mft^3/d)	Unmet demand for ground water (Mft^3/d)	Sustainable yield from river (Mft^3/d)
11.9	30.6	18.8	5,396



Percentage of 1990-97 withdrawal from Sparta aquifer that is sustainable by county (Sparta model).

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Information on technical reports and hydrologic data related to this study can be obtained from:

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