The Mississippi River Valley Alluvial Aquifer in Arkansas: A Sustainable Water Resource?

Introduction

The Mississippi River Valley alluvial aquifer, often termed simply the "alluvial aquifer," is a water-bearing assemblage of gravels and sands that underlies about 32,000 square miles of Missouri, Kentucky, Tennessee, Mississippi, Louisiana, and Arkansas. In Arkansas, the alluvial aquifer occurs in an area generally 50 to 125 miles wide by about 250 miles long adjacent to the Mississippi River (fig. 1). The alluvial aquifer is the uppermost aquifer in this area. Water derived from the alluvial aquifer is primarily used for irrigation of rice (fig. 2) and other agricultural crops, and for fish farming (fig. 3).

Hydrologic Characteristics

The alluvial aquifer is an excellent source of water because of its favorable hydrologic characteristics. Total thickness of the alluvial aquifer in Arkansas ranges from about 50 to 150 feet (ft), thus providing a limited but still considerable amount of stored ground water. Throughout much of Arkansas, the alluvial aquifer is overlain by a silt and clay unit that is generally 10 to 50 ft thick. Individual wells completed in the aquifer typically produce between 300 to 2,000 gallons per minute (gal/min), and average about 800 gal/min.

Water Use

Water from the alluvial aquifer is used for public supply only where an adequate supply of water of better quality is not available from deeper aquifers. Characteristics that limit its usefulness as a public water source are excessive hardness, high concentrations of iron and manganese, and high salinity. In most areas, however, ground water from the alluvial aquifer is very well suited for agricultural supply.

Withdrawal of ground water from the alluvial aquifer for agriculture started in the early 1900's in the Grand Prairie for irrigation of rice, and to a lesser extent, soybeans. Water-level declines in the alluvial aquifer were first documented in 1927 (Engler and others, 1963, p. 21). Water use from the alluvial aquifer in Arkansas County in east-central Arkansas (fig. 4) increased from 113 million gallons per day (Mgal/d) in 1965 (Halberg and Stephens, 1966) to 560 Mgal/d in 2000 (T.W. Holland, U.S. Geological Survey, written commun., 2002)—an increase of 396 percent. In 2000, 85 percent of the ground water obtained in Arkansas County came from wells completed in the alluvial aquifer; the remainder came from wells completed in the underlying Sparta aquifer.

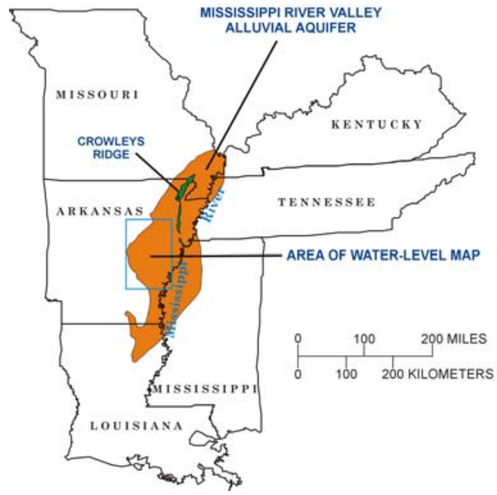

Figure 1. Location of the Mississippi River Valley alluvial aquifer (Ackerman, 1996).

Figure 2. Rice farming represents the primary use of water from the alluvial aquifer (Photos courtesy of U.S. Department of Agriculture Natural Resources Conservation Service).

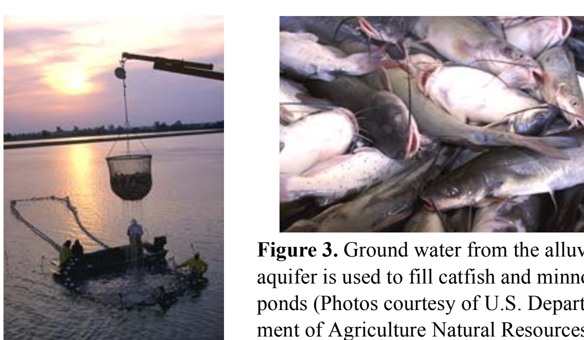

Figure 3. Ground water from the alluvial aquifer is used to fill catfish and minnow ponds (Photos courtesy of U.S. Department of Agriculture Natural Resources Conservation Service).

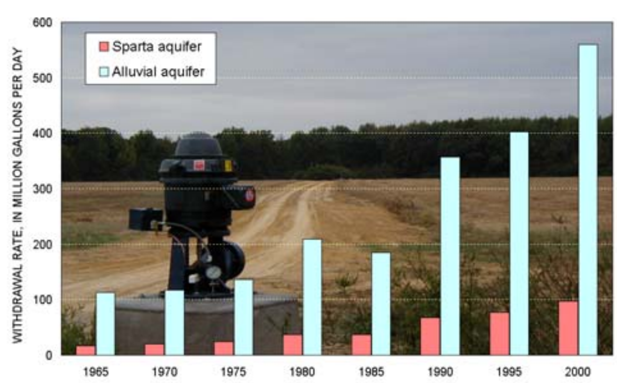

Figure 4. Ground-water use in Arkansas County.

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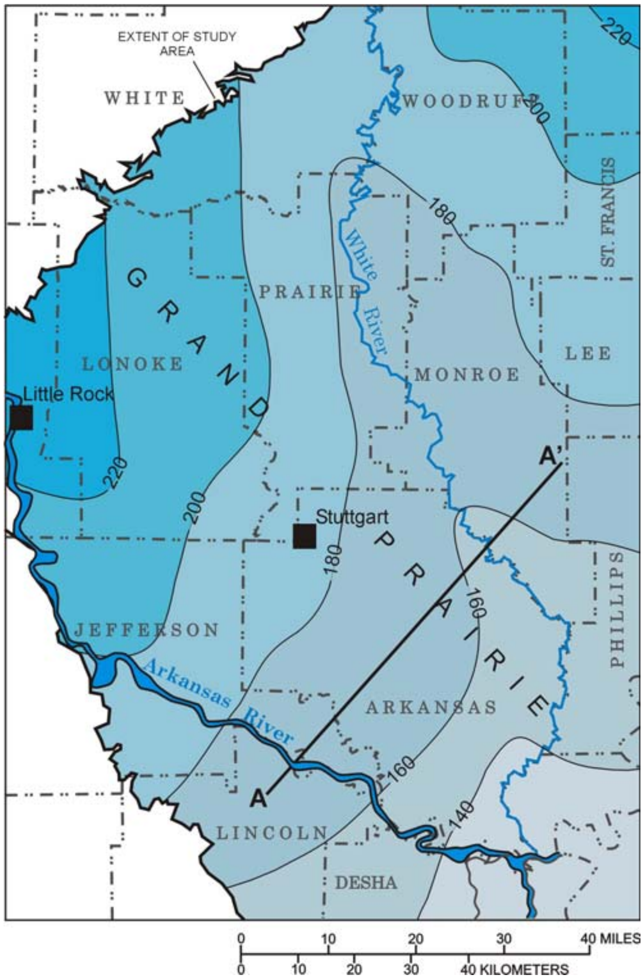
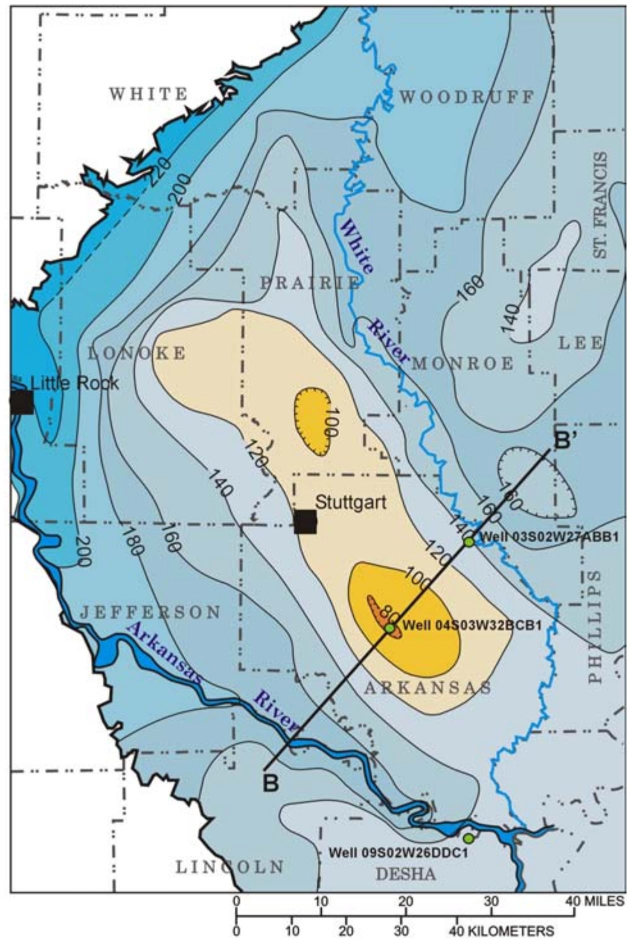




EXPLANATION

—160—	POTENTIOMETRIC CONTOUR--ALTITUDE, IN FEET ABOVE SEA LEVEL TO WHICH WATER IN TIGHTLY CASED WELLS WOULD HAVE RISEN
A — A'	LINE OF SECTION IN FIGURE 8 SHOWN ON OPPOSITE PAGE
B — B'	LINE OF SECTION IN FIGURE 9 SHOWN ON OPPOSITE PAGE
●	WELL FOR WHICH WATER LEVELS ARE SHOWN IN FIGURE 7

Figure 5. Simulated predevelopment potentiometric surface of the alluvial aquifer in the Grand Prairie area (from Ackerman, 1996). The potentiometric surface represents the level to which water in a tightly cased well would have risen. Prior to development, the alluvial aquifer was under confined conditions; that is, water levels in the aquifer would rise higher than the base of the "clay cap" and direction of flow was from northwest to southeast.

Figure 6. Potentiometric surface of the alluvial aquifer in the Grand Prairie area, spring 1998 (Joseph, 1999). Heavy pumpage from the alluvial aquifer has caused the aquifer to become unconfined as water levels have declined below the "clay cap" in many areas. Cones of depression have formed in the potentiometric surface and the primary direction of flow has changed as water flows into the cones.

Effects of Pumping

Because the aquifer is characterized by relatively large values of saturated thickness, specific yields, and hydraulic conductivity, water-level declines during brief periods of heavy pumping may be minimal. However, sustained heavy pumping from multiple wells for extensive periods has lead to substantial, widespread water-level declines in parts of eastern Arkansas. In some areas, declines of water levels (figs. 6 and 9) have resulted in: (1) unconfined conditions (that is, some of the upper parts of the aquifer are now partially air filled); and (2) reductions in hydraulic pressure, saturated thickness, stored water, lateral flow within the alluvial aquifer, and baseflow to streams throughout most of its extent in Arkansas. In some areas, water levels have declined so much that water cannot be pumped at the rates needed to support agriculture. In areas where less than 50 ft of saturated thickness remain in the aquifer due to declining water levels, sustainable well yields have decreased to less than 100 gal/min. Furthermore, excessive dewatering of an aquifer can lead to irreversible compaction of the aquifer (subsidence), reducing its water-yielding capacity or ability to be recharged. Examples of areas that have experienced substantial subsidence include the San Joaquin Valley in California, and Houston, Texas (Galloway and others, 2000).

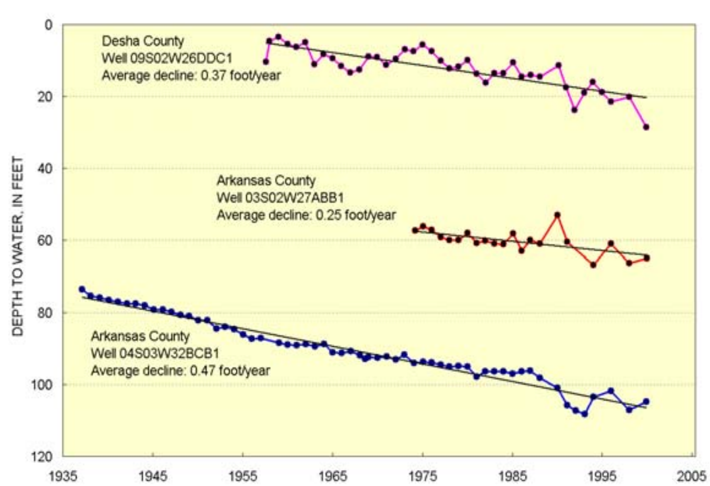


Figure 7. Declining ground-water levels at selected wells. Average decline is computed from the line of best fit through each data set.

Water Levels

Water levels in wells completed in the alluvial aquifer prior to 1900 (defined as predevelopment conditions) were above the base of the clay cap (figs. 5 and 8), caused by confined conditions within the underlying aquifer (that is, all the pore spaces within the aquifer were filled, and the hydraulic pressure was greater than atmospheric pressure). As ground-water use increases, water levels in many parts of the alluvial aquifer have declined (figs. 6 and 7). Water in some areas of eastern Arkansas is being withdrawn from the alluvial aquifer at rates that exceed recharge, and therefore cannot be sustained indefinitely. In some areas, water levels have declined at least 40 ft in a period of 40 years or less (Schrader, 2001). This water-budget imbalance has resulted in regional water-level declines, formation of extensive cones of depression, reduction of the amount of water in storage, and decreases in well yields. Large cones of depression have formed in two areas (the Cache River area west of Crowleys Ridge and the Grand Prairie area) and continue to expand. Water levels will continue to decline unless withdrawals from the alluvial aquifer are reduced.

Interaction of Ground Water with Surface Water

The alluvial aquifer is hydraulically connected to many rivers, streams, lakes, and drains, resulting in considerable volumes of water being contributed to or taken from these surface-water bodies. Prior to the development of the alluvial aquifer (figs. 5 and 8), most rivers and lakes in eastern Arkansas received part of their flow from ground water; this ground-water-derived component of flow constituted a significant part of total river flow during dry summer months. As ground-water pumping from the alluvial aquifer continued and water levels declined, this transfer of water has reversed (figs. 6 and 9). Most rivers now lose water to the aquifer, and minimum observed river flows have decreased, especially during the summer months. Increased pumping from wells induces greater rates of recharge from rivers to the aquifer.

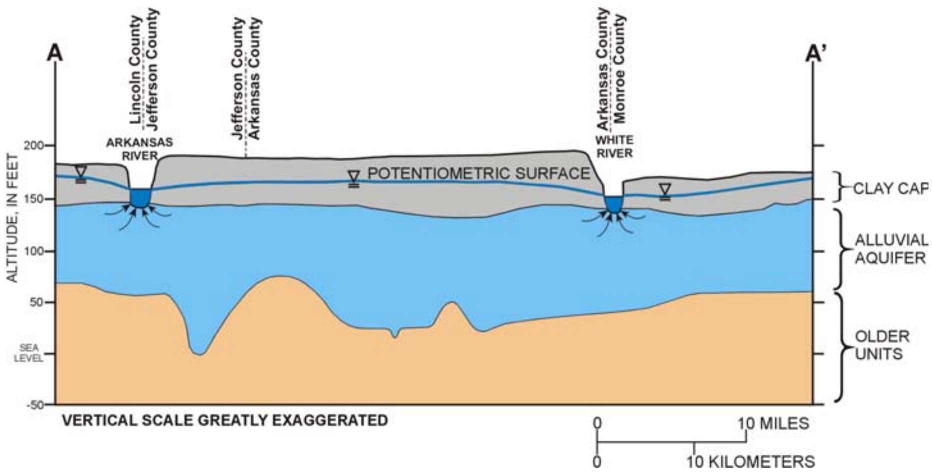


Figure 8. A depiction of the predevelopment potentiometric surface in a southwest to northeast section (see line A-A'; fig. 5) through the alluvial aquifer. The aquifer was confined throughout the area. Geologic unit contacts were derived from borehole cuttings and geophysical logs.

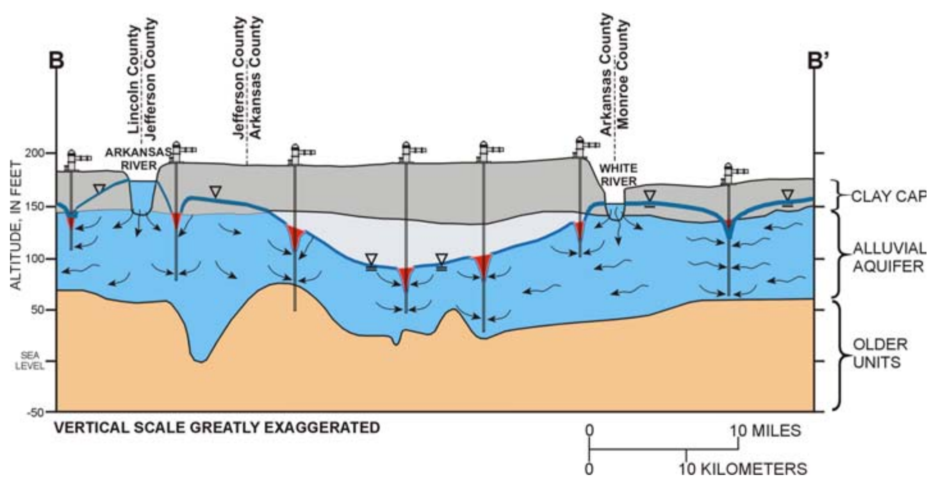
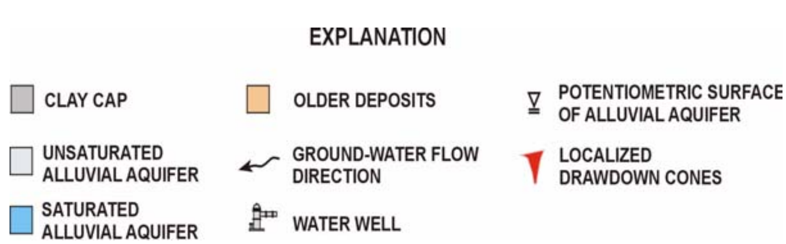


Figure 9. A depiction of the spring 1998 potentiometric surface in a southwest to northeast section (see line B-B'; fig. 6). Decades of heavy pumping have desaturated portions of the upper aquifer and resulted in the aquifer being unconfined throughout much of its occurrence. Geologic unit contacts were derived from borehole cuttings and geophysical logs.



As water levels in the alluvial aquifer decline with increased pumping, river-derived recharge has become a substantial component of water supplied to the alluvial aquifer in several areas. Wells located near rivers show minimal water-level declines because they intercept recharged water before it can flow to areas away from the rivers. Consequently in areas away from the rivers, less river-recharge water is available, causing water levels in wells to decline more rapidly. An example of this condition occurs in the Grand Prairie area located between the Arkansas and White Rivers (figs. 6 and 9). Because the central area between these two rivers receives little recharge from the rivers, continued pumping has resulted in the formation of an extensive cone of depression to the northwest along an axis lying approximately midway between the rivers. Recharge from rainfall probably is much smaller than from the rivers. Recharge to the aquifer of water infiltrating through rice fields and shallow ponds also may occur, but in lesser amounts than from the rivers. However, rates of recharge from these sources are not well quantified.

A Sustainable Water Resource?

The Mississippi River Valley alluvial aquifer supplies large volumes of water for agriculture. Water production from the aquifer is limited, however, by the finite volume of water stored within it, and by the relatively small volume of recharge water being added through time. Recharge rates are exceeded by ground-water pumping rates in many areas, causing ground-water levels to decline. In a few areas, less than 50 ft of saturated thickness of the alluvial aquifer remain; however, those areas will expand if current pumping rates are maintained, resulting in lower water levels and possible compaction of the aquifer. Ground-water pumping from wells located near rivers causes recharge water from the rivers to be intercepted, resulting in less decline in ground-water levels in those wells compared with wells in areas away from the rivers.

Ground water from the Mississippi River Valley alluvial aquifer can be a sustainable resource if managed properly. However, the rate at which ground water is being pumping cannot be sustained indefinitely, as indicated by large water-level declines and areally extensive cones of depression, without some form of management. Management alternatives might include artificial recharge to the aquifer, limits on withdrawals from the aquifer, switching to withdrawals from other aquifers, conjunctive use of ground water and surface water, or a combination of approaches (fig. 10).

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Figure 10. Tail-water recovery system at Lonoke County, Arkansas, constructed to capture surface-water runoff (Photos courtesy of U.S. Department of Agriculture Natural Resources Conservation Service).

For more information on ground-water conditions in the Mississippi River Valley alluvial aquifer, contact the District Chief, U.S. Geological Survey, 401 Hardin Rd., Little Rock, AR 72211; phone: 501-228-3600. Website: http://ar.water.usgs.gov/

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