EFFECTS OF FLUCTUATING RIVER-POOL STAGES ON GROUND-WATER LEVELS IN THE ADJACENT ALLUVIAL AQUIFER IN THE LOWER ARKANSAS RIVER, ARKANSAS

By David A. Freiwald and Gerald D. Grosz

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ERRATA SHEET

for

EFFECTS OF FLUCTUATING RIVER-POOL STAGES ON GROUND-WATER LEVELS IN THE ADJACENT ALLUVIAL AQUIFER IN THE LOWER ARKANSAS RIVER, ARKANSAS

Shown below are the explanations for figures 4 and 5 (pages 11 and 12).

Figure 4

EXPLANATION

LAND SURFACE WATER TABLE

SEPTEMBER 30, 1986

OCTOBER 17 AND 20, 1986

DECEMBER 31, 1986

FALL 1959

Figure 5

EXPLANATION

LAND SURFACE WATER TABLE

SEPTEMBER 30, 1986

OCTOBER 20 AND 21, 1986

JANUARY 5, 1987

FALL 1959

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CONVERSION FACTORS

For use of readers who prefer to use metric (International System) units, rather than the inch-pound units used in this report, the following conversion factors may be used.

Multiply inch-pound unit	By	To obtain metric unit
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
gallons per minute (gal/min)	0.0630	liter per second (L/s)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Mean Sea Level of 1929."

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ABSTRACT

The U.S. Geological Survey conducted a study in cooperation with the U.S. Army Corps of Engineers to determine the effect of fluctuating river-pool stages on ground-water levels in the alluvial aquifer on the lower Arkansas River.

A network of 41 wells was used to delineate 4 cross sections adjacent to river pools 2 and 5 of the McClellan-Kerr Arkansas River Navigation System to examine ground-water levels at various distances from the river. The hydraulic gradient of water levels in the alluvial aquifer along these cross sections indicates that the river is losing water to the adjacent aquifer.

The effect on ground-water levels in the alluvial aquifer caused by pool-stage fluctuations was most pronounced at distances less than about 2 miles from the Arkansas River. At distances greater than about 2 miles, the changes in ground-water levels probably were the result of water levels rising in the aquifer since the heavy summer irrigation withdrawals have ceased.

An equation useful for estimating the distribution of head change in an aquifer in response to river-pool-stage changes, was applied to the study area to estimate the effect of a 1-foot rise in pool stage on water levels in the adjacent alluvial aquifer after equilibrium conditions have been established. The theoretical head change (rise) in the aquifer was estimated to range from 1-foot at the Arkansas River to 0.57 foot at a distance of 5 miles away from the river.

INTRODUCTION

The lower Arkansas River, from the mouth at the Mississippi River to Little Rock, flows across the Gulf Coastal Plain where large quantities of freshwater are available from underground sources. The alluvial deposits that lie along the lower Arkansas River are part of the Mississippi River Valley alluvial aquifer, herein referred to as the alluvial aquifer. This aquifer is the major ground-water source for much of eastern Arkansas.

The McClellan-Kerr Arkansas River Navigation System was constructed (beginning in 1957) to provide for navigation, flood control, and hydroelectric power generation on the Arkansas River. It was recognized that the natural ground-water flow system in the alluvial aquifer would be altered by the navigation system.

In the early 1960's, the U.S. Geological Survey monitored ground-water levels in the alluvial aquifer along the lower Arkansas River in cooperation with the U.S. Army Corps of Engineers (Bedinger and Jeffery, 1964). These data, together with an electrical analog model of the alluvial aquifer, were used to project the effect of constructing locks and dams for the Arkansas River Navigation System on ground-water levels (Bedinger and others, 1970).

At present (1987), the Corps of Engineers is proposing to raise the river-pool stages at lock and dam 2 and 5 on the lower Arkansas River by 1 foot during the summer months. The purpose of raising the pools is to allow backwater to flow into the tributaries along the pools to enable more surface water to be used as a source for irrigation of adjacent farmland. The Corps is interested in knowing if maintaining these higher pool stages would adversely effect the water levels in the alluvial aquifer.

This study was conducted in cooperation with the U.S. Army Corps of Engineers.

Purpose and Scope

The purpose of this report is to describe the effects of fluctuating river-pool stages on water levels in the adjacent alluvial aquifer along the Arkansas River. The report also provides a method for estimating the effect of a rise in pool stage on water levels in the adjacent alluvial aquifer if equilibrium conditions are established between the river and the aquifer.

A series of cross sections were constructed from the water-level information obtained from a network of observation wells and pool-stage data in pools 2 and 5 along the lower Arkansas River. Ground-water-level data were collected September 30, 1986; October 17, 20, 21, 1986; December 31, 1986; and January 5, 1987. Continuous water-level data also were collected from September 1986 through January 1987. These data and additional ground-water-level data collected in 1959 prior to the completion of the navigational system were compared with concurrent pool-stage data to define the water-level response in the alluvial aquifer to changes in pool stages. A method useful for estimating aquifer water-level changes in response to a rise in pool stage after the river-aquifer flow system is in equilibrium is described. This method is applied to estimate the effect of a 1-foot rise in pool stage on water levels in the alluvial aquifer in the study area.

Study Area Description

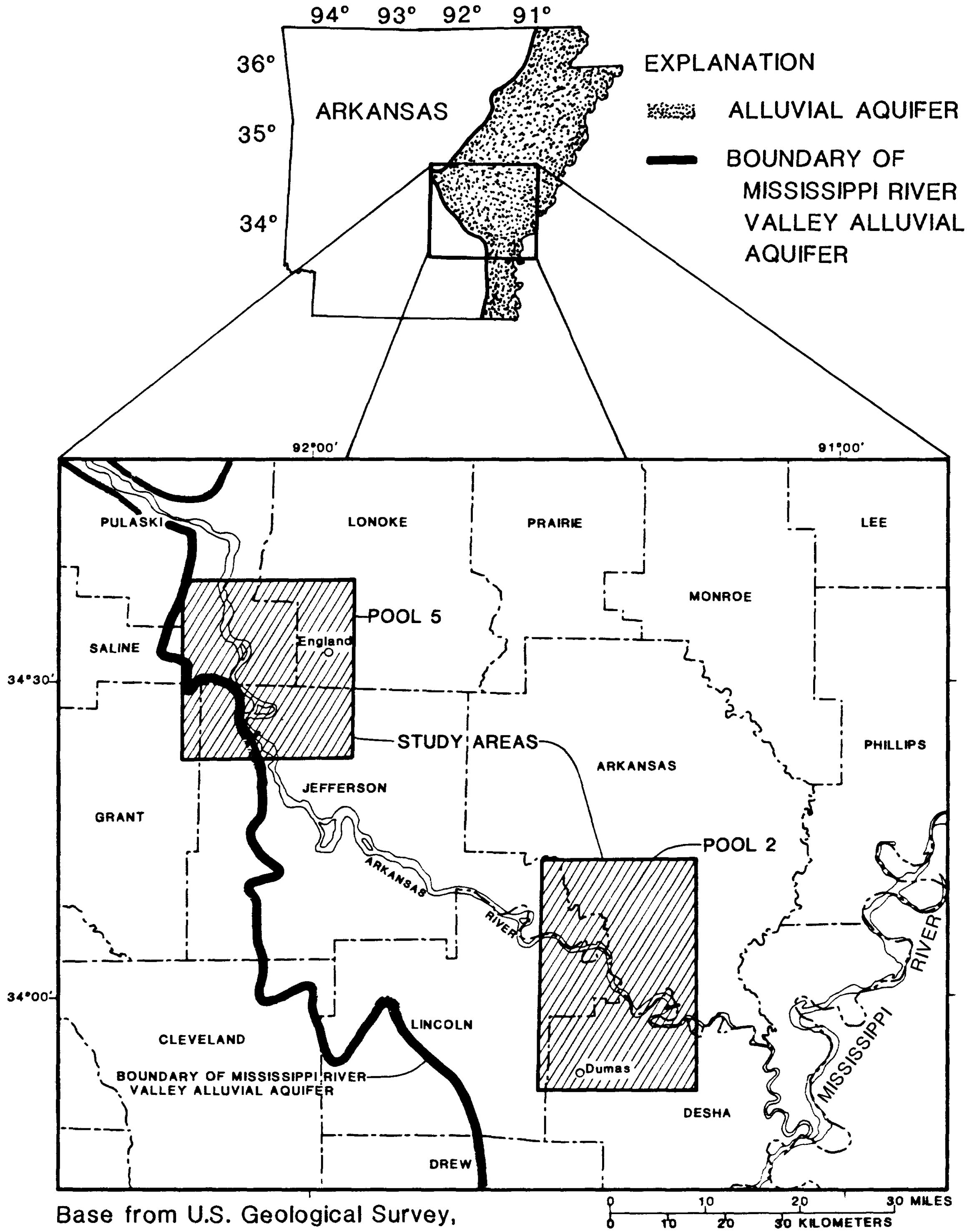
The study was conducted in two areas along the Arkansas River in southeastern Arkansas. The Arkansas River generally flows southeast from Little Rock to its convergence with the Mississippi River (fig. 1). Downstream from Little Rock, the river stage is controlled by a series of six locks and dams. The two study areas are located along navigation pools 2 and 5, which are upstream from dams 2 and 5. Pool 2 is located north of Dumas, whereas pool 5 is southwest of England.

The topography in these areas is relatively flat with land surface altitudes averaging about 155 feet above sea level near Dam 2 and 235 feet near Dam 5. The economy of this region is based primarily on agriculture, especially the production of crops such as cotton, rice, soybeans, and grain sorghum. Much of the cropland in the region is irrigated. Most of the irrigation water is withdrawn from the alluvial aquifer. The area immediately adjacent to the river is swampy and is subject to periodic flooding.

Aquifer Description

The Mississippi River Valley alluvial aquifer includes the Quaternary terrace and alluvial deposits of the Mississippi Alluvial Plain, which covers much of eastern Arkansas (fig. 1) and adjacent States. The alluvial deposits that predominate along the lower Arkansas River in the study area may be divided into two parts. The lower part consists of gravel, sand, and small amounts of silt and clay; the upper part consists of silt and clay and small amounts of sand. The alluvium ranges in thickness from 50 to 200 feet and averages 100 feet.

The silt and clay of the upper part, where present, acts as a confining layer to the coarser material in the lower part. The confining layer varies in thickness from a few feet to more than 75 feet in eastern Arkansas but commonly is a clay or silt lense of small areal extent along the lower Arkansas River. Substantial ground-water withdrawals during the growing season result in the decline of water levels below the bottom of the confining layer at times. These large fluctuations in ground-water levels cause semiartesian conditions in the alluvial aquifer to exist in the study area.



Base from U.S. Geological Survey, State base map, 1967

Figure 1.--Location of study area.

Depth to ground water in the study area ranges from 5 to 50 feet. The saturated thickness in the alluvial aquifer ranges from 60 to greater than 120 feet (Plafcan and Edds, 1986). Well yields as much as 3,000 gallons per minute (gal/min) can be expected but generally average about 1,500 gal/min in the study area. Water use from the aquifer is extensive, primarily for agriculture use with lesser amounts for industrial and domestic use. A large cone of depression centered in Arkansas County has developed as a result of irrigation withdrawals.

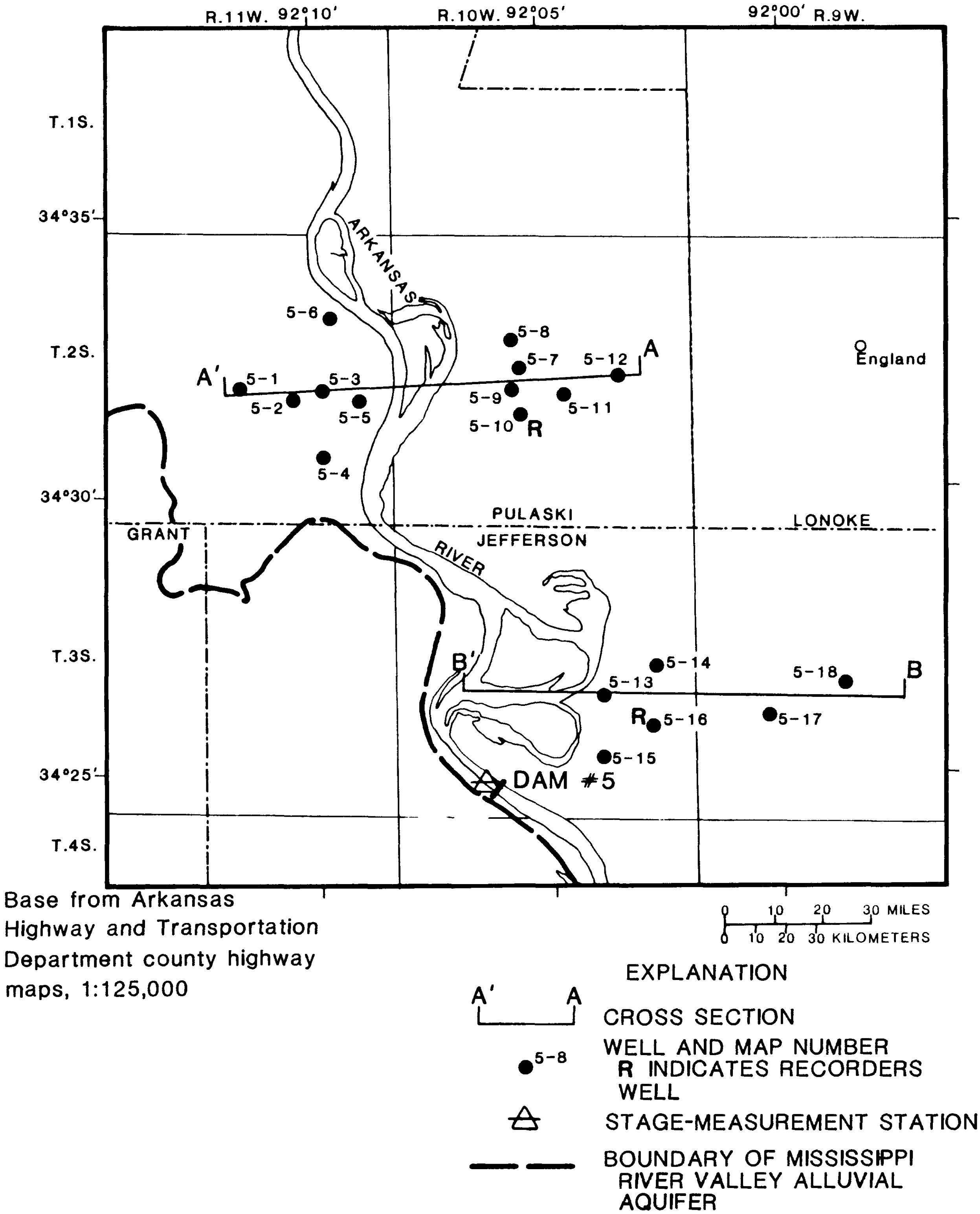
DESCRIPTION OF WELL NETWORK

Existing wells in the study area were used to establish a well network for monitoring ground-water levels adjacent to the Arkansas River. The network consisted of 41 wells that were located at various distances from the river to form 4 cross sections (figs. 2 and 3). Two cross sections were located at pool 2 and two at pool 5. Most of the wells were reactivated wells from previous Survey work in connection with the navigation study (Bedinger and Jeffrey, 1964). Where wells had been destroyed, private irrigation wells were used to provide adequate water-level control. All wells were slug tested and, if necessary, redeveloped to insure interchange of water between the well and the aquifer. All wells were screened in the alluvial aquifer and ranged in depth from 38 to 158 feet.

Eighteen wells (well 5-1 through 5-18) at pool 5 formed cross-sections A-A' and B-B' (fig. 2). Cross-section A-A', which intersects the Arkansas River at river mile 95.7, consists of 12 wells. Cross-section B-B', located at river mile 87.7, consists of six wells and extends only east of the river because of the absence of the alluvial aquifer west of the river in this area. Twenty-three wells (well 2-1 through 2-23) at pool 2 formed cross-sections C-C' and D-D' (fig. 3). Cross-section C-C', located at river mile 30.4, consists of 12 wells. Cross-section D-D', located at river mile 22.9, consists of 11 wells.

DATA COLLECTION

Three sets of water-level measurements were made at most observation wells during the study. Water levels in all wells were first measured on September 30, 1986. This was the final day that pool stages were maintained at a level 1 foot above normal pool stage. Beginning October 1, 1986, pool stages were lowered to their normal level. A flood event crested the Arkansas River in the study areas between October 10 and 15 and produced pool stages that were about 3.5 to 11 feet higher than previously measured during the study. The second set of water-level measurements was made from October 17 to 21, while the river stage was high. A third set of measurements was made December 31, 1986 and January 5, 1987. Tables 1 and 2 present the water-level data for the wells that formed the network.



Base from Arkansas Highway and Transportation Department county highway maps, 1:125,000

Figure 2.--Location of cross sections, wells, and stage-measurement station for pool 5.

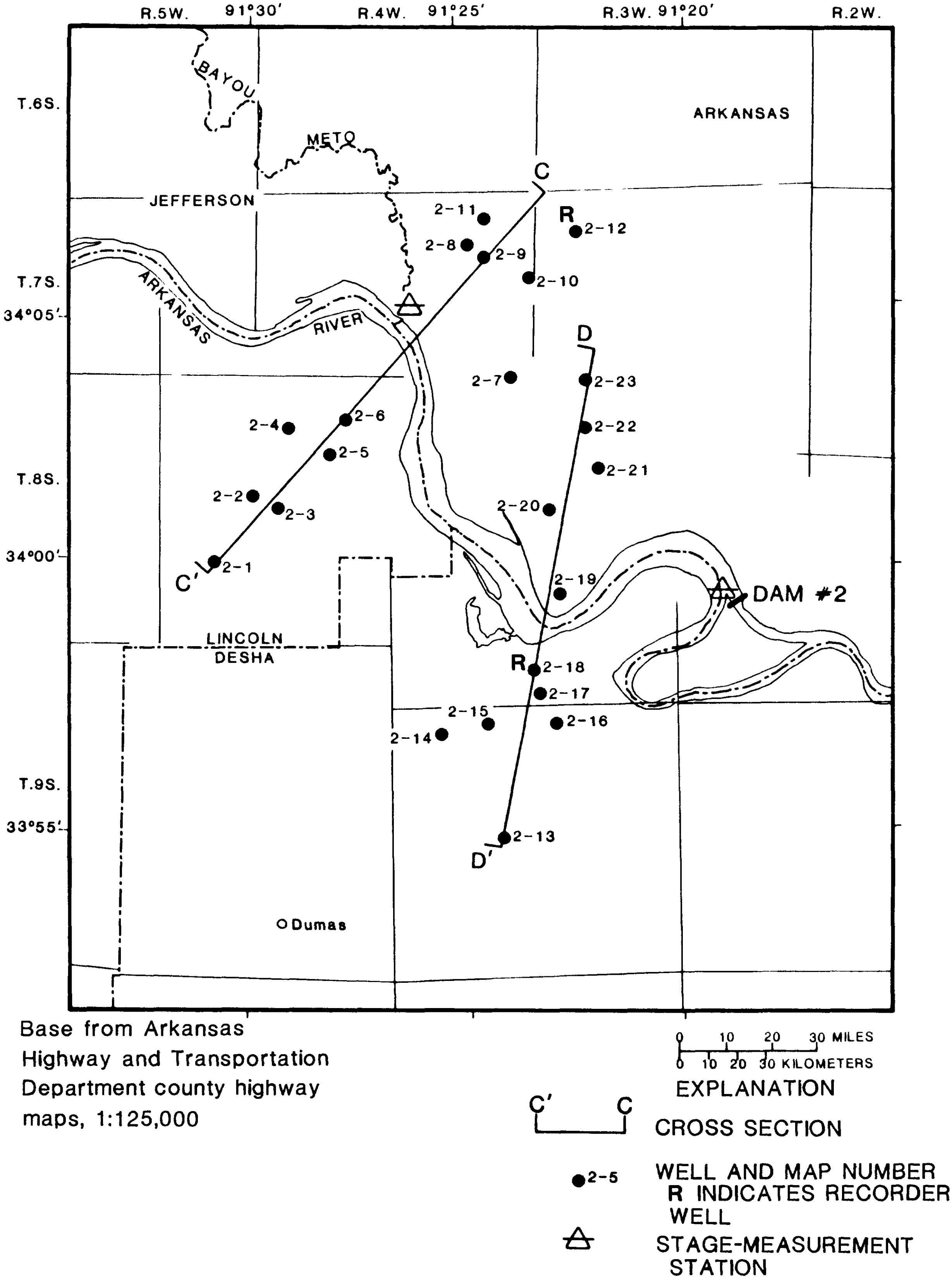


Figure 3.--Location of cross sections, wells, and stage-measurement stations for pool 2.

Table 1.--Location and altitude of water levels in wells along cross-section A-A' and B-B'

[Altitude in feet above sea level; USGS, U.S. Geological Survey]

Well number	USGS well number	Effective position (in miles)	Altitude of land surface	Altitude of water level Sept. 30	Oct. 17	Oct. 20	Dec. 31
			Cross-Section A-A'				
5-1	2S11W21AAC1	3.54	231.37	212.79		212.58	213.44
5-2	2S11W23BCB1	2.64	236.76	213.56		210.83	214.13
5-3	2S11W23BAA1	2.40	230.0 *	210.42		210.13	211.16
5-4	2S11W26DBB1	1.73	233.40	214.56		214.55	215.24
5-5	2S11W24BDB1	1.57	227.0 *	214.18		215.89	--
5-6	2S11W11DCA1	1.23	220.0 *	213.57		215.20	--
5-7	2S10W16CCA1	1.19	230.76	205.88	207.15		210.43
5-8	2S10W16BAA1	1.31	234.0 *	205.86	207.62		209.96
5-9	2S10W21BBA1	1.38	230.0 *	205.89	207.43		210.83
5-10	2S10W21CAC1	1.59	227.0 *	207.51	208.95		212.95
5-11	2S10W22BAD1	2.52	226.0 *	200.51	201.04		204.25
5-12	2S10W14CDD1	3.40	225.0 *	201.67	202.19		203.00
			Cross-Section B-B'				
5-13	3S10W23BCC1	2.90	223.65	208.57	213.55		210.70
5-14	3S10W13CCA1	3.74	217.76	200.93	202.57		203.34
5-15	3S10W26CBC1	3.93	218.94	200.54	205.61		206.36
5-16	3S10W25BBB1	4.02	216.37	197.91	199.82		201.62
5-17	3S09W20CCD1	6.15	217.94	192.90	192.42		194.18
5-18	3S09W21ADB1	7.51	223.38	192.20	192.14		192.25

* Land surface altitude estimated from topographic map.

Table 2.--Location and altitude of water levels in wells along cross-section C-C' and D-D'

[Altitude in feet above sea level; Tr., tract; USGS = U.S. Geological Survey]

Well number	USGS well number	Effective position (in miles)	Altitude of land surface	Altitude of water level Sept. 30	Oct. 20	Oct. 21	Jan. 5
			Cross-Section C-C'				
2-1	8S04W29BAA1	4.78	164.98	140.48	--	141.89	147.46
2-2	8S04W16CBB1	3.35	165.69	146.84	--	149.58	156.04
2-3	8S04W21ABB1	3.22	166.41	146.19	--	148.37	154.76
2-4	8S04W09AAB1	1.96	173.0 *	157.05	--	162.87	166.29
2-5	8S04W10DCC1	1.81	168.46	156.13	--	156.97	161.86
2-6	8S04W02CCD1	1.43	174.0 *	160.78	--	164.43	166.91
2-7	7S04WTr.2293	2.01	181.09	155.97	--	155.84	156.68
2-8	7S04W11ABB1	2.42	177.0 *	147.97	--	148.07	148.55
2-9	7S04W11ADD2	2.45	181.0 *	145.23	--	145.77	146.80
2-10	7S04W12DDC1	2.86	185.43	143.30	--	143.45	144.19
2-11	7S04W02DAA1	3.07	183.34	145.08	--	145.08	145.54
2-12	7S03W06DDD1	4.37	180.84	133.35	--	133.80	134.96
2-13	9S03W16CCB1	4.72	154.0 *	130.14	130.54	--	132.10
2-14	9S03W06DAB1	2.61	160.77	141.68	141.96	--	143.04
2-15	9S03W05ADC2	2.42	160.0 *	143.32	143.52	--	145.01
2-16	9S03W03BDB1	2.29	163.0 *	146.05	145.78	--	150.98
2-17	8S03W33DAC1	1.62	163.0 *	148.88	149.19	--	153.82
2-18	8S03W33ABD1	1.00	166.74	159.10	160.97	--	162.22
2-19	8S03W18CDB1	.52	169.07	160.39	161.86	--	164.79
2-20	8S03WTr.2286	1.29	170.97	160.41	160.69	--	162.98
2-21	8S03WTr.2299(3)	1.92	178.28	156.64	156.56	--	157.90
2-22	7S03W32BBC1	2.62	176.92	152.66	152.69	--	153.11
2-23	7S03W29BBB1	3.41	181.14	148.81	149.10	--	149.67

* Land surface altitude estimated from topographic map.

One well in each cross section was equipped with a digital recorder to monitor hourly fluctuations in ground-water levels. (See wells 5-10, 5-16, 2-12, and 2-18 in figures 2 and 3.)

Pool-stage data were obtained from gages of the Corps of Engineers located at dams 2 and 5 and Bayou Meto. Pool stages for cross-sections A-A' and B-B' were calculated by using a rating curve corrected for actual headwater altitude at dam 5. Pool stage at cross-section C-C' was assumed to be the same as that at the Bayou Meto gage. Pool stage was assumed to change linearly between Bayou Meto and dam 2 for cross-section D-D'. Table 3 presents the pool stages for the three measuring periods at each cross section.

Table 3.—Arkansas River pool stages

[Altitude in feet above sea level]

Cross section	Altitude of pool stage		
	Sept. 10	Oct. 17-21	Dec. 31-Jan. 5
A-A'	213.93	225.00	213.93
B-B'	213.55	220.63	213.26
C-C'	163.07	171.57	163.07
D-D'	163.05	164.41	162.59

To establish an axis for referencing the wells along cross-sections A-A' through D-D', the centerline of the navigation channel was labeled zero (figs. 4 and 5). The effective position of each well is defined as the shortest distance from each well to the river's edge plus the distance from the river's edge to the zero point as measured along the cross-section line. For example, on cross-section D-D' on figure 5, the zero point is 0.22 mile from the left bank. The distance from well 2-19 to the closest location of the left river bank is 0.30 mile. Thus, the effective position (distance) of well 2-19 is 0.52 mile from the zero point.

EFFECTS OF FLUCTUATING RIVER-POOL STAGES ON GROUND-WATER LEVELS

Figures 4 and 5 show the altitude of the water table in the alluvial aquifer and the pool stages in the navigation channel along cross-sections A-A' through D-D'. Also shown are the water-level altitudes measured in the fall of 1959, which are included to compare present (1986) water-level conditions to the precompletion water-level conditions of the navigation system in 1959. The 1959 data were estimated from a potentiometric map contained in a report by Bedinger and Jeffrey (1964).

The land-surface profiles shown in figures 4 and 5 were estimated from topographic maps. The profiles represent general topography and are only to be used as a reference and not actual depth to water.

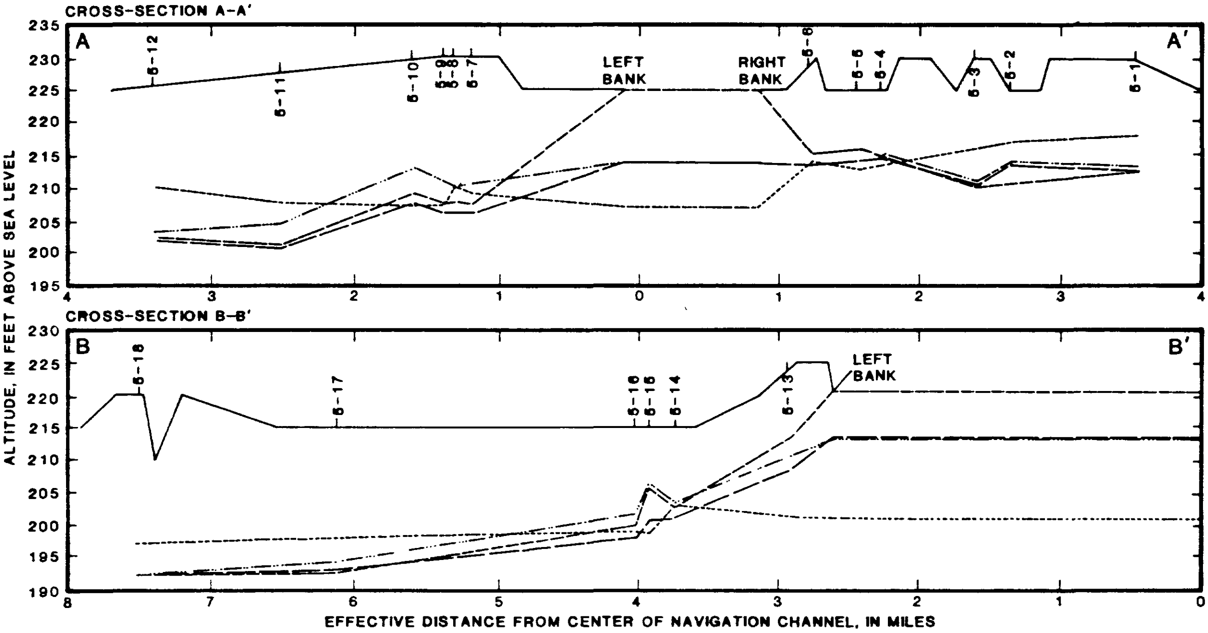


Figure 4.--Water table and river-pool stage along cross sections at pool 5.

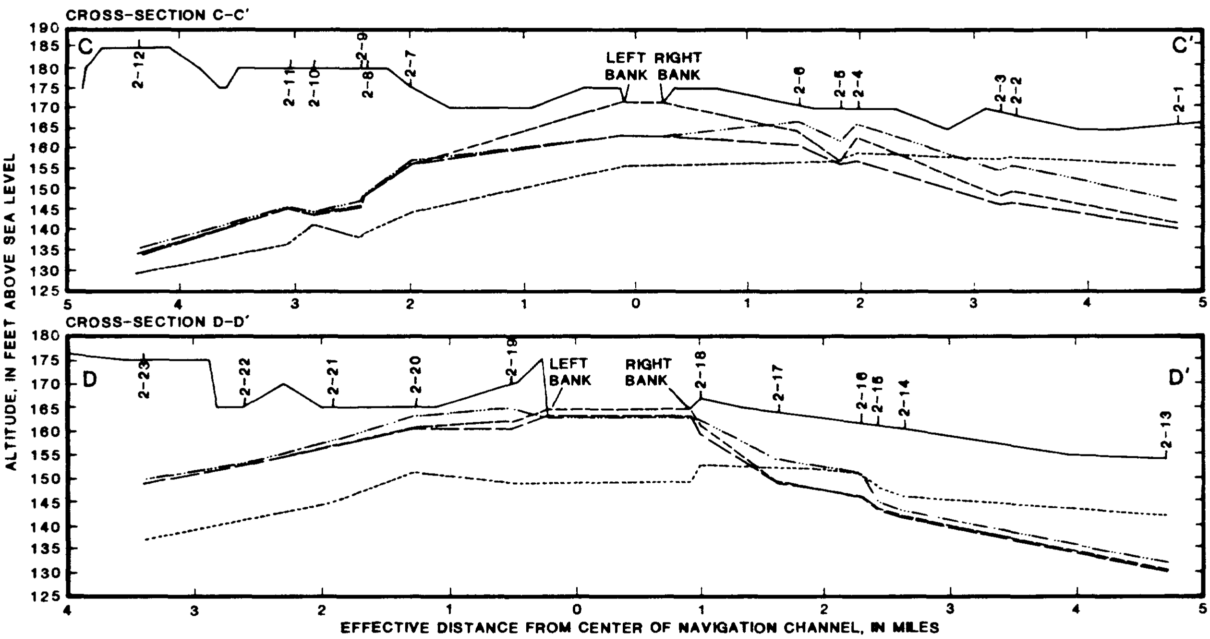


Figure 5.--Water table and river-pool stage along cross sections at pool 2.

The hydraulic gradients of ground-water levels (except for precompletion surface) along the cross sections (fig. 4 and 5) slope away from the river, which indicates that the river was losing water to the adjacent aquifer. The pool stages in the river were maintained at a level that was 1 foot above normal during the summer of 1986 and through the first set of measurements on September 30, 1986. Ground-water-level measurements made during this period indicate that maintenance of high pool stages did not result in any undesirable effects to farmland in areas adjacent to the river and actually increased the recharge to the alluvial aquifer. Ground-water levels measured on September 30, 1986, were the lowest than at any other time during the study and reflected the large ground-water withdrawals during the summer irrigation season.

Measurements from October 17 to 21, 1986, during the highest pool stages, show that the effect on ground-water levels was greatest near the river. During this period, the altitude of the water table, at distances greater than about 1.5 miles from the river's edge, was only slightly higher than on September 30, 1986.

Pool stages during the third measurement period (December 31, 1986, and January 5, 1987), were about the same as those during September 30, 1986, and 2 to 11 feet lower than those during October 17-21, 1986. At distances greater than 1 mile from the river's edge, ground-water levels measured during December 31 and January 5 were generally higher than the two previous periods. Along sections C-C' and D-D', ground-water-level changes exceeded pool-stage changes as much as 1 to 3 feet in places. Some of the rise in the ground-water levels probably was the result of the mid-October flood that occurred in the Arkansas River. The remainder of the rises can be explained in that, by this time, the alluvial aquifer had had about 4 months to recover since the irrigation season ended. Recharge in the alluvial aquifer had occurred vertically through precipitation and horizontally from underflow from adjacent areas. Major ground-water withdrawals had also ceased and evapotranspiration was negligible during this winter measurement period.

In comparison, pool stages during the current study were up to 21 feet above the 1959 precompletion river stages. These higher pool stages should have raised ground-water levels throughout the study area. Water levels in wells within about 2 miles of the river were higher than in 1959; however, water levels in wells further away generally are lower. This indicates that, at distances greater than about 2 miles, the aquifer has been affected more by ground-water withdrawals than by the higher pool stages resulting from construction of the navigation system.

Pool stages and ground-water levels were compared for the period September through December by plotting the continuous water-level-recorder data from wells 5-10, 5-16, 2-12, and 2-18 and the pool stage along the corresponding cross section (figs. 6 and 7). The figures show that all four wells exhibited a general rise in ground-water level. Three of the wells (wells 5-10, 5-16, and 2-18) responded to the large increase in pool stage during October, although all experienced a continuing rise in water level after the pool stage returned to near normal. This continuing rise was most likely caused by the decrease in withdrawals from the aquifer after the summer irrigation season had ended.

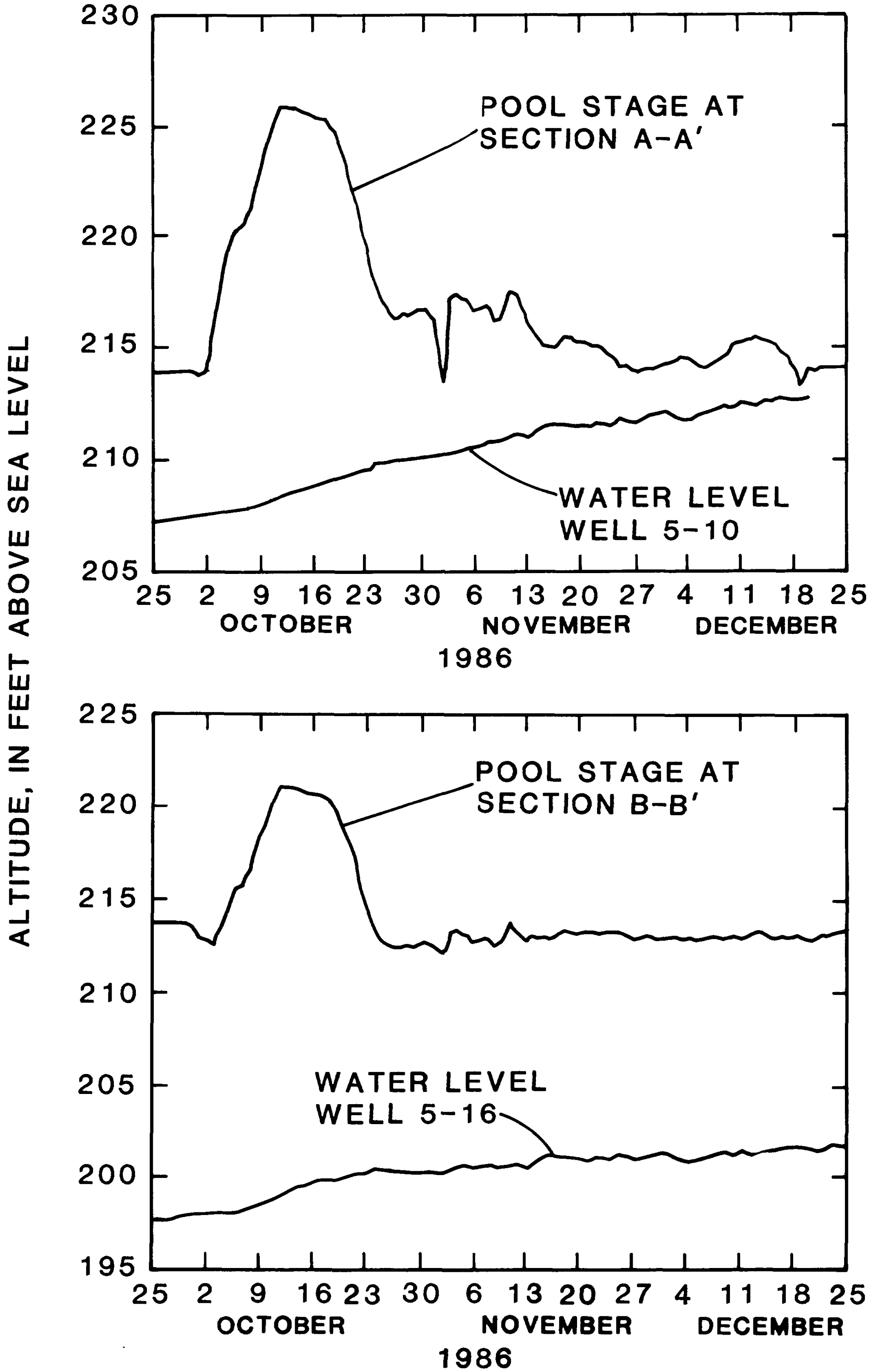


Figure 6.--Fluctuations of stage at pool 5 along cross-sections A-A', B-B', and water levels in wells 5-10 and 5-16.