PRELIMINARY APPRAISAL OF THE HYDROLOGY OF THE ROCK ISLAND AREA, LE FLORE COUNTY, OKLAHOMA

By Melvin V. Marcher, DeRoy L. Bergman, Jerry D. Stoner,
and Stephen P. Blumer

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ABSTRACT

Bedrock in the Rock Island area of northeastern Le Flore County in southeastern Oklahoma consists of shale, siltstone, and sandstone of the McAlester, Hartshorne, and Atoka Formations of Pennsylvanian age. The area is on the south flank of the Backbone anticline; the rocks dip to the south at 5°-45°. Alluvium along James Fork consists of sandy and clayey silt and may be as much as 30 feet thick.

Water in bedrock is under artesian conditions. The depth to water in most wells is less than 20 feet below the surface; a few wells flow. Yields of most wells probably are less than 5 gallons per minute. Water from nine wells was a sodium carbonate or sodium mixed anion type; dissolved-solids concentrations ranged from 294 to 1,250 milligrams per liter. No relationship between variations in chemistry of ground water and well depth, geographic distribution, or geologic formation is apparent.

James Fork has flow most of the time and discharge exceeds 25 cubic feet per second about one-half the time. The mean dissolved-solids concentration in James Fork water ranged from 224 milligrams per liter near Williams, Oklahoma, to 322 milligrams per liter near Hackett, Arkansas. Water in James Fork is a calcium magnesium sulfate type about 75 percent of the time. Maximum suspended sediment discharge was 2,720 tons per day. Silt-clay particles (diameters less than 0.062 millimeter) are the dominant sediment size.

Potential hydrologic effects of surface mining for coal include: (1) Creation of additional water storage in surface-mine ponds, (2) changes in rock permeability and ground-water storage, (3) changes in runoff and streamflow characteristics, (4) changes in drainage patterns, and (5) changes in the chemical quality and sediment load of James Fork. Although mining may increase the quantities of sediment and dissolved minerals added to James Fork, detection of these increases would be difficult because the potentially mineable area is very small in proportion to the total area of the basin.

INTRODUCTION

Purpose and Scope

The U.S. Bureau of Land Management has the responsibility of assessing the probable water-resources impacts and reclamation capabilities of any area under Federal jurisdiction where coal might be mined by surface methods. To meet this responsibility, the EMRIA (Energy Minerals Rehabilitation Inventory and Analysis) program was developed and, as part of this program, the U.S. Geological Survey was requested to collect and analyze hydrologic data for selected areas in eastern Oklahoma that have potential for surface mining of coal. The prupose of this report is to describe the hydrology and potential impacts of mining in the vicinity of the town of Rock Island in northeastern Le Flore County (fig. 1) where the upper and lower Hartshorne coals are at or near the surface and amenable to surface mining. Other areas described in reports prepared under the EMRIA program include Blocker in notheastern Pittsburg County (Marcher and others, 1981) and Stigler in north-central Haskell County (Marcher and others, 1983).

Except for long-term records of streamflow and water quality of James Fork near Hackett, Arkansas, data used in preparing this report were collected since 1976. The data include: (1) Partial-record discharge data and analyses of periodic samples for chemical quality and sediment for James Fork near Williams, Oklahoma, (2) continuous record of the water level in two wells completed in bedrock, (3) records of 45 wells including onsite determinations of specific conductance and pH, (4) detailed chemical analyses of water from 9 wells and partial chemical analyses of water from 5 wells, (5) profiles of temperature, specific conductance, pH, and dissolved oxygen and parital chemical analyses of water from 2 surface-mine ponds, and (6) continuous record of precipitation.

Information on the geology of the area, as related to the hydrology, is taken from a report by Knechtel (1949) supplemented with onsite observations and interpretations of logs of test holes drilled in 1979 by the U.S. Bureau of Reclamation under contract to the U.S. Bureau of Land Management. Information on soils is taken from a report by the U.S. Department of Agriculture (1966) and climatic data are provided in a report by the Oklahoma Water Resources Board (1970).

Acknowledgments

Appreciation is extended to the residents of the area who provided information on their wells and permitted measurements of water levels and collection of water samples.

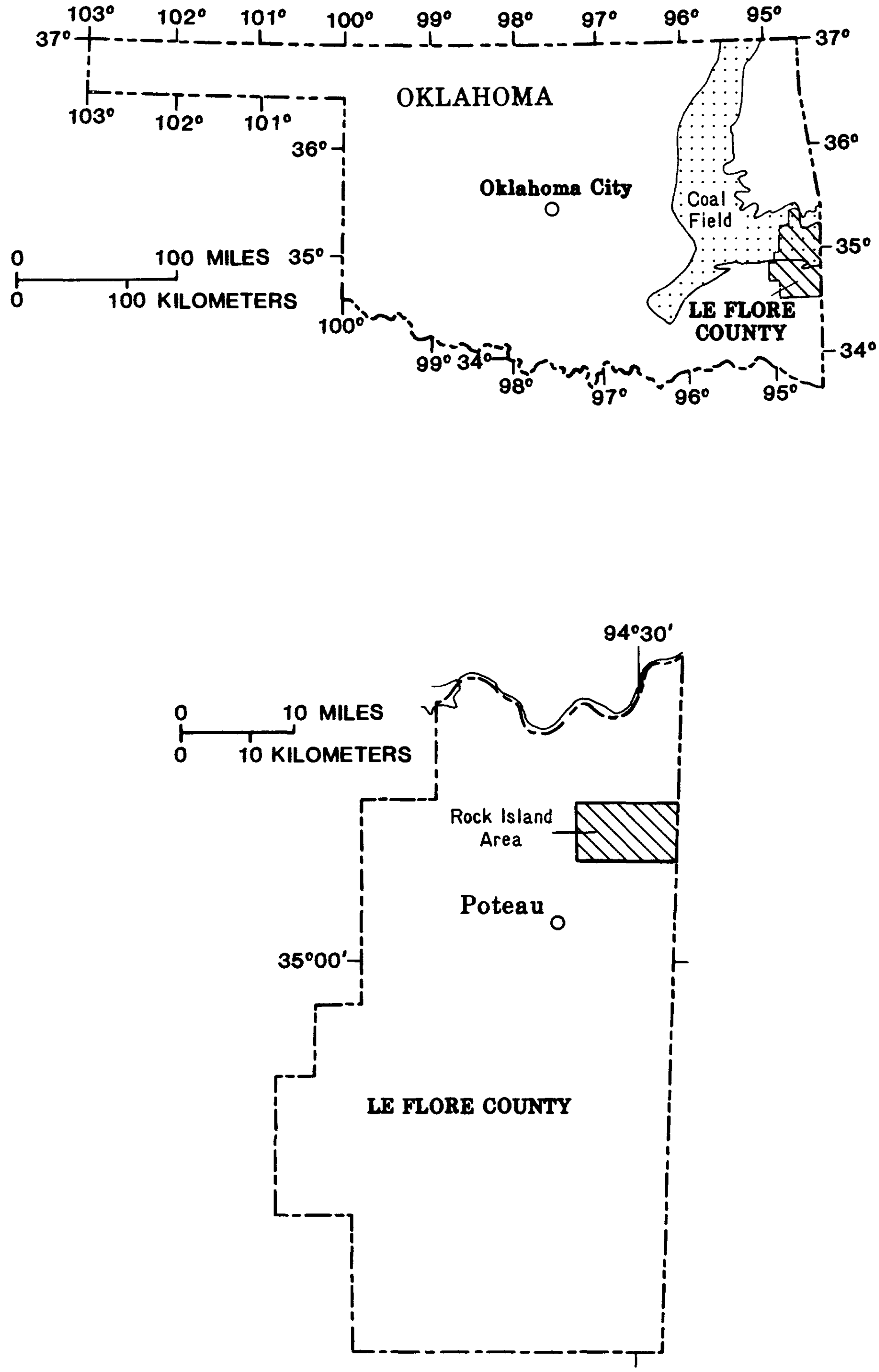
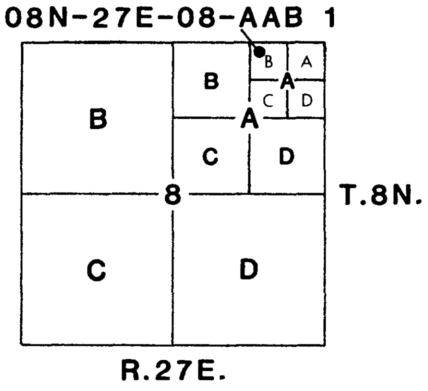


Figure 1.--Location of Le Flore County and the Rock Island area.

Site-Numbering System

The standard method of describing the location of wells or other data-collection sites by fractional section, section, township, and range is replaced by the system illustrated in the diagram below. The location of the site indicated by the dot commonly would be described as NW 1/4, NE 1/4, NE 1/4, sec.16, T.8 N., R.27 E. By the system used in this report, quarter subdivisions of the section are indicated by letters and the location of the site is given as 08N-27E-16 AAB 1. The final digit is the sequential number of a well within the smallest fractional subdivision.



Geographic Setting

The Rock Island area is in the McAlester Marginal Hills Geomorphic Province (Johnson and others, 1972) and is in the Arkoma geologic basin. In this province, the rocks have been folded to form east-trending anticlines and synclines; the crests of some of the anticlines have been broken by thrust faults. The landscape is characterized by ridges and irregular hills generally capped by erosion-resistant sandstones and covered with trees and brush. The intervening broad valleys have been formed by weathering and erosion of thick, weakly resistant shales and are vegetated with native grasses, shrubs, wildflowers, and weeds. Much of the valley areas consists of pasture land used for livestock grazing.

Climate

The area has a warm, temperate climate. Spring and autumn usually are mild and summers are long and hot. Winters are comparatively mild, although an occasional influx of cold air keeps the temperature below freezing several days each year. Based on records at Poteau, the nearest weather station, the average annual precipitation is estimated at 43 in. On the average, about 32 percent of the annual precipitation falls during spring, 27 percent during summer, 22 percent during autumn, and 19 percent during winter. Much of the rainfall results from short-duration thunderstorms of varying intensity which are most common in April, May, and June but can occur any month of the year. The average date of the last freeze in the spring is about the end of March and the first frost usually occurs about the first of November. Snowfall averages 4-6 in. per year with most falling in January and February. Average annual lake evaporation is about 48 in.

GROUND WATER

Occurrence, Movement, and Storage

The occurrence, movement, and storage of ground water in the Rock Island area is controlled largely by the lateral and vertical distribution of rock units and their physical characteristics, especially permeability, and by the geologic structure.

Bedrock consists of shale and sandstone units (in order of increasing age) of the McAlester, Hartshorne, and Atoka Formation of Pennsylvanian age. Test-hole data and onsite observations show that much of the shale is laminated rather than blocky and includes beds of silty and shaly sandstone. These rocks have been weathered to a depth of about 15 ft in some parts of the area. Sandstone units, which comprise about 30 percent of the total thickness of exposed rocks, consist of interbedded sandstone, siltstone, and shale. The sandstone is fine-grained, well cemented with silica and iron oxide, and contains beds of shale a few inches to several feet thick.

Structurally, the area is the south flank of the east-trending Backbone anticline which is broken along its axis by the Backbone fault (pl. 1). Rock layers dip toward the south; the dip steepens from 5°-10° near James Fork to 35°-45° along the crest of Backbone Mountain. Because of the geologic structure, the rock layers are tilted at the surface exposing bedding-plane openings between layers of sandstone and partings between laminae of shale; these openings are in the main avenues of water entry and movement. Other openings for water movement are fractures and joints developed during folding and faulting of the brittle rocks. Faults also may be water conduits but if the rocks are greatly crushed so the openings are sealed, faults may be water barriers.

Water-table conditions probably exist in the zone of weathered bedrock. Water in bedrock below the weathered zone is confined. Because of the confining pressure, water rises in wells in most of the area to less than 20 ft below the land surface as shown by the potentiometric contours drawn for that part of the area where adequate water-level data are available pl. 2. A few wells flow at the surface during times of high water level (table 1).

Although the bedrock has minimal permeability and storage capacity, wells ranging in depth from 21 to 166 ft and averaging about 75 ft yield enough water for domestic and livestock supply. No tests to determine well yields have been made in the area, however, tests of wells penetrating similar rocks elsewhere in the coal field generally yield less than 5 gal/min. Wells in the Rock Island area that penetrate thick beds of fractured sandstone might yield as much as 20 gal/min.

Alluvium along James Fork might be as much as 30 ft thick along some reaches of the river. The upper part consists of sandy and clayey silt; the lower part probably includes beds of silty sand. The alluvium probably would yield small quantities of water to wells but such wells would be likely to go dry during periods of no rainfall.

Table 1.--Records of wells and selected ground-water quality data

[Letter following depth to water is accuracy code: A, tape-better than 1 foot; G, reported; aquifer: Pm, McAlester Formation; Ph, Hartshorne Formation; Pa, Atoka Formation; ft, feet; in., inches; mo-yr, month-year, µmho, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L micrograms per liter; 0, chemical analysis in table 2]

Well location	Owner or user	Well depth (ft)	Well diameter (in.)	Depth to water (ft)	Date measured (mo-yr)	Aquifer	Altitude of land surface (ft)	Specific conductance (µmho)	pH (units)	Dissolved chloride (mg/L)	Dissolved sulfate (mg/L)	Dissolved iron (µg/L)	Dissolved manganese (µg/L)	Remarks
08N-26E-01 BDA 1	S. V. Casey	126	6	19 A	06-81	Pa	605	2,420	7.3	---	---	---	---	---
08N-26E-09 CBB 1	A. Hanna	55	6	1 A	06-81	Pa	540	643	6.4	---	---	---	---	---
08N-26E-10 DCB 1	C. Terry	27	24	12 A	06-76	Pa	520	480	6.4	---	---	---	---	---
08N-26E-10 DCB 2	C. Terry	102	6	13 A	06-76	Pa	520	---	---	---	---	---	---	---
08N-26E-11 CAA 1	J. Niblett	56	6	14 A	06-76	Pa	525	430	6.7	---	---	---	---	---
08N-26E-12 BBD 1	J. Morris	80	6	Flowing	06-76	Pa	500	634	8.4	---	---	---	---	0
08N-26E-12 DDA 1	J. Edwards	80	6	16 A	06-76	Ph	495	310	6.2	---	---	---	---	---
08N-26E-13 BAB 1	J. Edwards	---	8	Flowing	06-76	Ph	490	220	6.4	---	---	---	---	---
08N-26E-13 CBB 1	L. Bull	42	---	20 A	07-77	Pm	470	490	5.2	36	19	5,700	190	---
08N-26E-14 ABA 1	Unknown	43	---	4 A	05-76	Pa	490	400	6.3	---	---	---	---	---
08N-26E-14 ACC 1	Test hole	277	6	1 A	09-79	Ph	460	1,350	7.7	44	190	10	20	---
08N-26E-14 BCC 1	N. Shoup	106	6	---	06-76	Ph	475	465	6.9	---	---	---	---	---
08N-26E-14 CBB 1	D. Shoup	106	---	---	07-77	Ph	465	470	7.1	51	53	340	25	---
08N-26E-14 DAA 1	E. Darneal	62	6	7 A	06-76	Pm	465	633	6.8	---	---	---	---	0
08N-26E-15 ABA 1	T. Shoup	89	8	12 A	06-76	Pa	475	1,625	7.0	---	---	---	---	0
08N-26E-15 CAA 1	S. Beam	70	6	8 A	06-76	Pa	460	1,070	7.5	---	---	---	---	---
08N-26E-15 CAC 1	B. Hicks	166	8	16 A	06-76	Ph	465	600	6.5	---	---	---	---	---
08N-26E-15 DAC 1	R. Beggs	125	6	18 A	06-76	Ph	455	155	5.6	---	---	---	---	---
08N-26E-15 DCA 1	P. Eatman	109	6	16 A	06-76	Ph	450	930	8.7	---	---	---	---	0
08N-26E-16 CCD 1	J. Sala	81	6	10 A	06-76	Pa	490	410	6.6	---	---	---	---	---
08N-26E-16 DDA 1	H. Goins	92	6	11 A	06-81	Pa	480	588	6.2	---	---	---	---	---
08N-26E-16 DDD 1	G. Lomon	106	6	15 A	06-76	Ph	465	490	6.9	---	---	---	---	---
08N-26E-17 CBA 1	G. Fox	49	6	13 A	06-81	Pa	505	572	7.8	---	---	---	---	---
08N-26E-21 BBB 1	M. Essery	100	6	22 A	06-76	Ph	510	1,200	6.9	---	---	---	---	0
08N-26E-21 BBB 3	D. Baxter	114	6	12 A	06-76	Ph	490	120	5.7	---	---	---	---	---
08N-26E-22 BBB 1	F. Spicer	78	6	11 A	06-76	Pm	460	460	6.2	---	---	---	---	0
08N-26E-22 BBB 2	F. Spicer	40	8	12 A	06-76	Pm	460	260	5.9	---	---	---	---	---
08N-27E-03 CBC 1	J. Miller	105	6	6 A	06-76	Pa	505	1,900	7.3	---	---	---	---	0
08N-27E-05 ABD 1	S. Sweeten	21	6	8 A	06-76	Pa	515	820	6.8	---	---	---	---	---
08N-27E-05 CDD 1	F. Sweeten	60	6	7 A	06-76	Pa	500	1,100	7.5	---	---	---	---	0
08N-27E-05 DBB 1	R. Sweeten	71	6	5 A	06-76	Pa	505	---	---	---	---	---	---	---
08N-27E-05 DDD 1	D. Cox	70	---	12 A	06-76	Pa	505	960	8.5	---	---	---	---	---
08N-27E-06 CCD 1	D. Emerson	141	6	Flowing	06-76	Pa	500	1,340	8.4	---	---	---	---	---
08N-27E-07 BDD 1	D. Emerson	84	6	8 A	06-76	Pa	485	490	6.7	---	---	---	---	---
08N-27E-07 DBB 1	D. Smith	75	6	12 A	08-77	Ph	495	380	6.3	9	62	8,400	680	---
08N-27E-08 BCD 1	O. Smith	60	6	5 A	06-76	Ph	465	---	---	---	---	---	---	---
08N-27E-09 BBC 1	J. Rhodes	21	18	13 A	06-76	Ph	495	250	6.3	---	---	---	---	---
08N-27E-09 DAA 1	Test hole	150	---	Flowing	09-79	Ph	500	---	---	---	---	---	---	---
08N-27E-10 BBD 1	J. Hamilton	53	6	17 A	06-76	Ph	565	155	5.8	---	---	---	---	---
08N-27E-10 CBD 1	M. Farrar	---	6	32 A	06-79	Pm	520	555	6.9	---	---	---	---	---
08N-27E-10 DBD 1	B. McAfee	63	10	37 A	06-76	Pm	520	1,260	6.9	---	---	---	---	---
08N-27E-15 BCA 1	Unknown	32	36	15 A	06-76	Pm	495	---	---	---	---	---	---	---
08N-27E-16 AAB 1	R. Hamilton	21	---	10 G	06-76	Pm	495	780	8.7	---	---	---	---	0
08N-27E-16 BAB 1	J. Cain	29	6	11 A	06-76	Pm	485	95	5.2	---	6	80	35	---
08N-27E-18 BBB 1	Test hole	200	---	12 A	10-79	Ph	475	---	---	---	---	---	---	---

Recharge and Discharge

Ground-water recharge is derived entirely from precipitation falling directly on or near the area. Measurements of water levels in various parts of the coal field show that most recharge takes place in spring or early summer when evapotranspiration is least. Consequently, the ground-water level, which reflects the volume of water in storage, typically is highest in late spring or early summer and is lowest in late summer or early fall. Intermittent rains of 1-2 in. during summer when evapotranspiration is greatest do not have any significant effect on the water level (fig. 2).

Data available for the Rock Island area are not adequate to make an estimate of the volumes of recharge or evapotranspiration. However, in the Blocker area, which is about 60 mi west and is hydrologically similar to the Rock Island area, recharge has been estimated at 2 acre-ft/mi (Marcher and others, 1981). Recharge in the Rock Island area maybe slightly greater because sandstone beds are thicker and more abundant. Evapotranspiration in the Rock Island area probably is similar to that in the Blocker area which has been estimated at 80 percent of the annual precipitation; the percentage varies from year to year, however, depending on climatic conditions (Marcher and others, 1981).

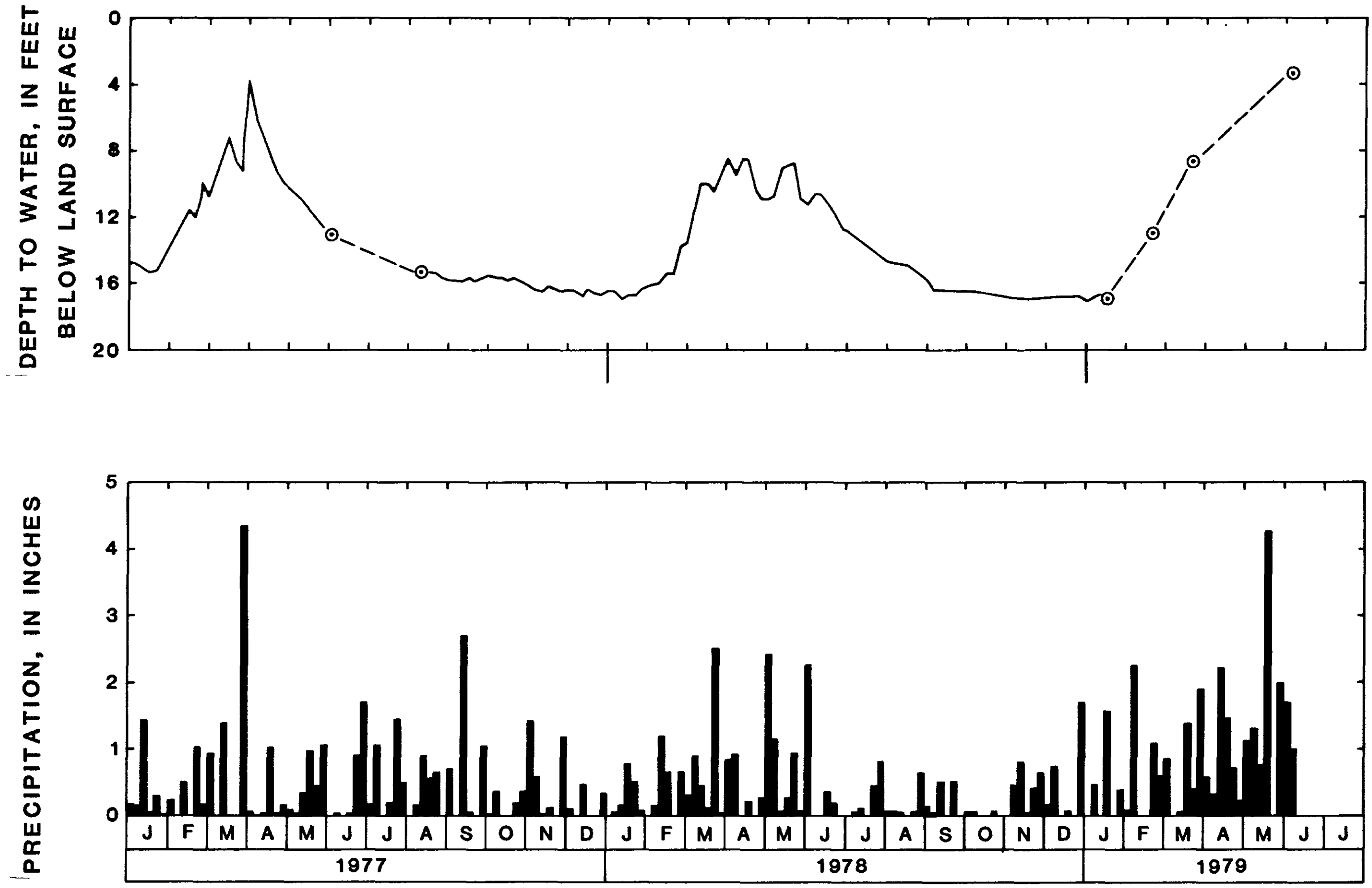


Figure 2.--Water-level hydrograph of well 08N-26E-22 BBB 2 as related to precipitation.

SURFACE WATER

Stream Discharge Characteristics

The Rock Island area is drained by James Fork. Daily streamflow records have been collected on James Fork near Hackett, Arkansas (station 07249400) since 1958. Miscellaneous measurements made on James Fork at Williams, Oklahoma (station 07249410), about 7 mi downstream from Hackett, indicate that streamflow characteristics at the two sites are not significantly different.

Seasonal changes in the streamflow of James Fork reflect the quantity and frequency of rainfall, and evapotranspiration in the drainage basin. The seasonal distributation of streamflow characteristic to James Fork is shown by a hydrograph of mean daily discharge (fig. 3). James Fork does not flow at times of deficient rainfall in late summer and early fall during some years. Peak discharge for the period of record was 30,000 ft^3/s on May 14, 1968. Mean daily discharge for the same period of record was 126 ft^3/s (91,200 acre-ft per year). The flow duration curve for the James Fork at gaging station near Hackett, Ark. shows that mean daily discharges have equaled or exceded 0.9 ft^3/s 90 percent of the time; 27 ft^3/s 50 percent of the time; and 250 ft^3/s 10 percent of the time from October 1, 1957 to September 30, 1979 (fig. 4).

The results of statistical analysis of high flows are shown in figure 5. The annual peak-flow exceedance probability is plotted versus discharge using the Log Pearson Type III distribution (U.S. Water Resources Council, 1977). High-flow exceedance probability curves were developed using the Weibul plotting position for the annual peak and for durations of 1, 7, 15, 30, and 90 days. Non-exceedance probability curves using the Weibul plotting position for durations of 1, 7, 14, and 30 days are shown in figure 6.

Flood-Prone Areas

Large storms generate high streamflows that inundate floodplains adjacent to stream channels. Approximate boundaries of flood-prone areas can be delineated when water-surface profiles are known or can be computed or when regional equations are available for computation of flood depths for various recurrence intervals. Regional equations (Thomas, 1976) were used to compute the 100-year flood depth along James Fork (pl. 3). Approximate boundaries of the 100-year, flood-prone areas were delineated on the topographic map as indicated by the computed flood depths. The approximate 100-year, flood-prone area corresponds to the area where there is a 1-in-100 chance of flooding during any year.

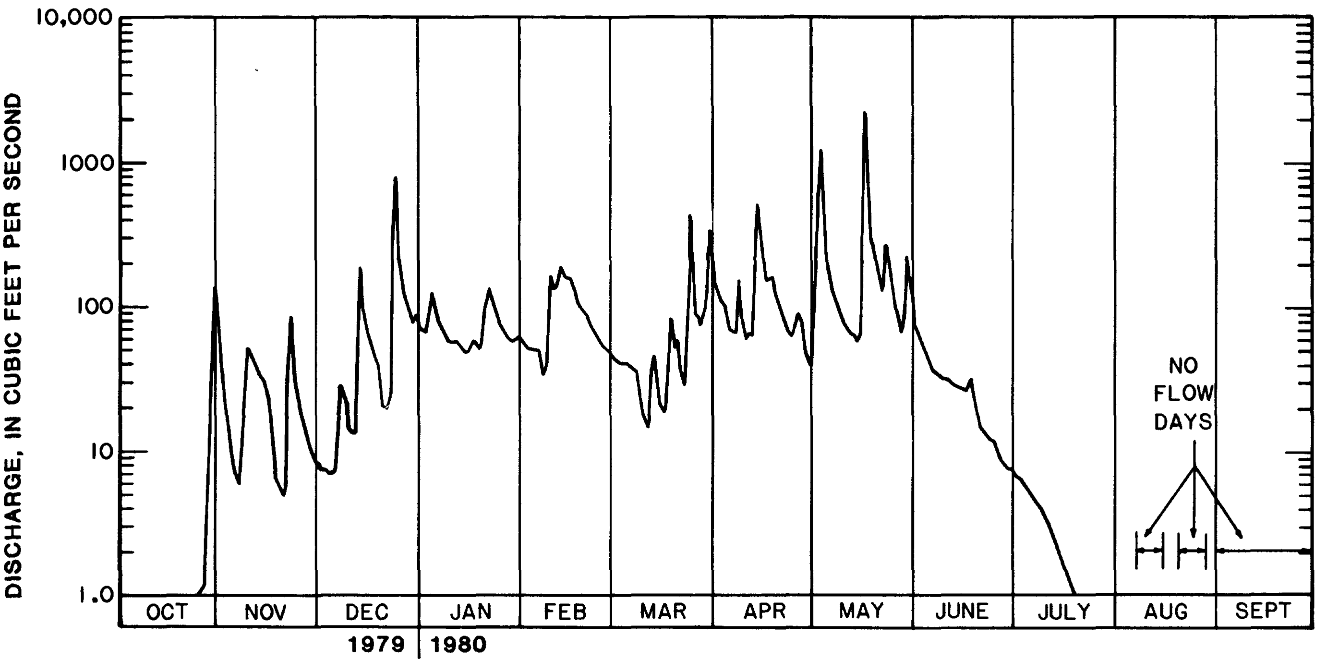


Figure 3.—Hydrograph of mean daily discharge, 1980 water year, for James Fork near Hackett, Arkansas (station 07249400).

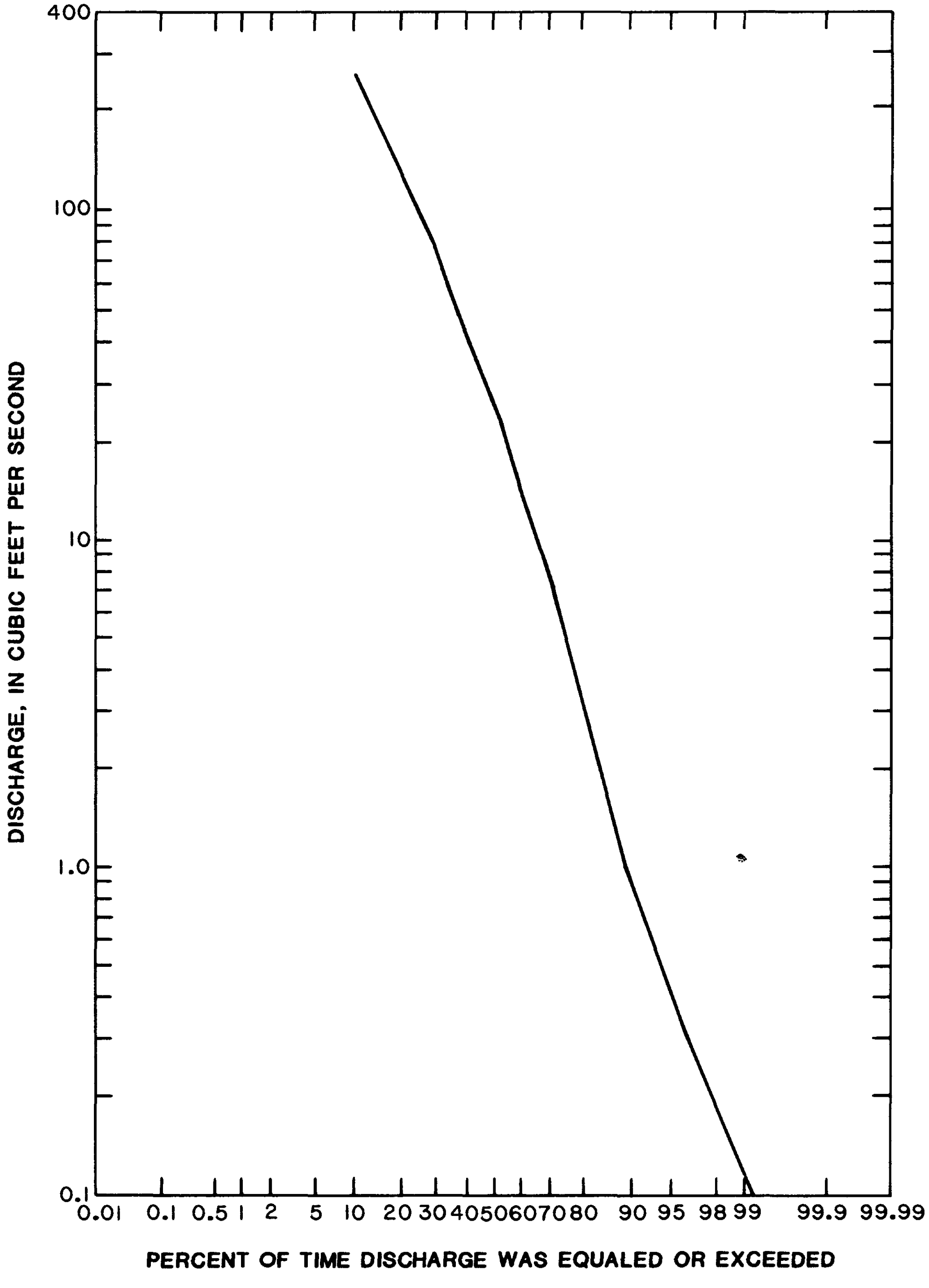


Figure 4.--Partial flow-duration curve, 1958-79 water years, for James Fork near Hackett, Arkansas (station 07249400).

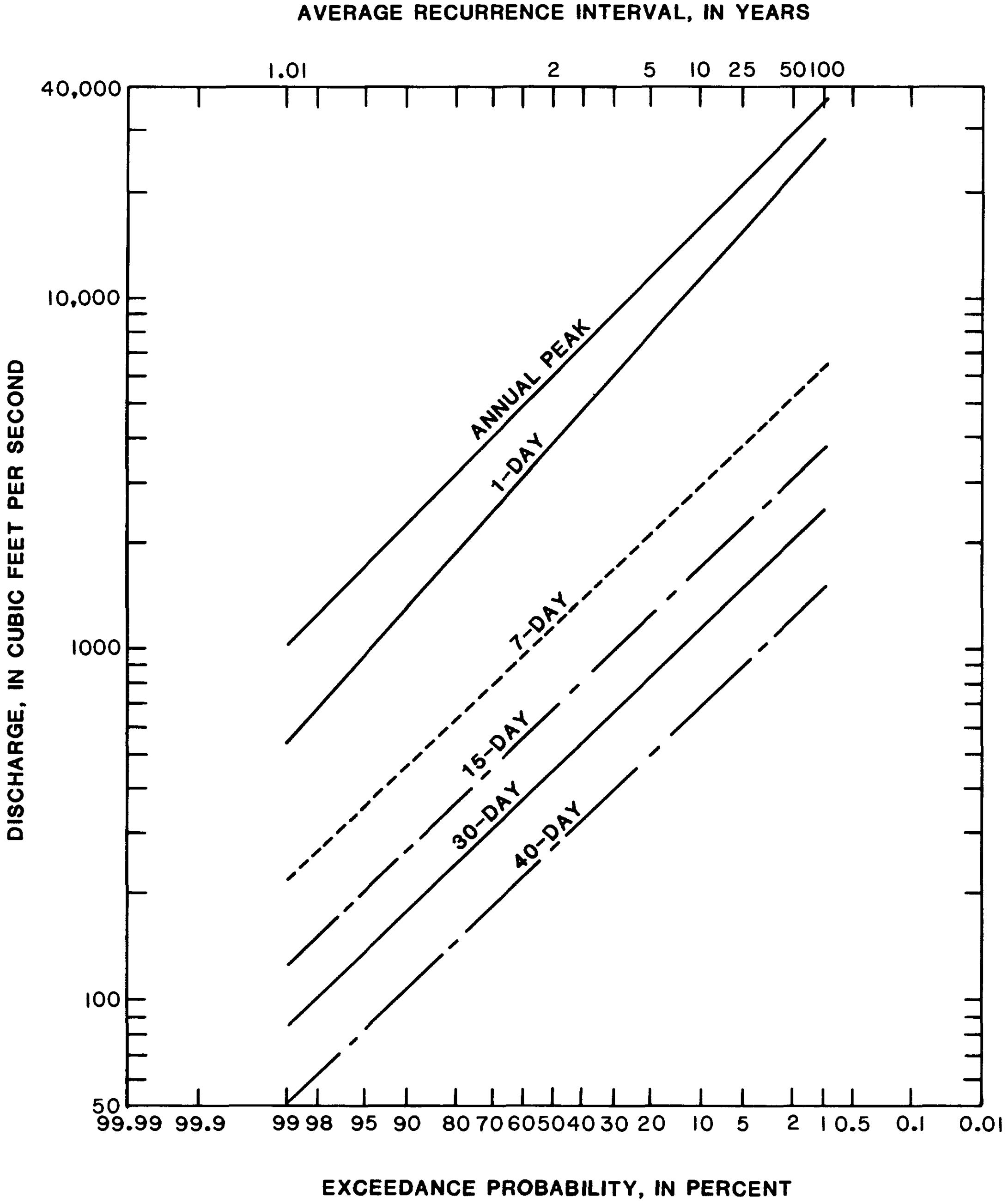


Figure 5.--Annual peak and high-flow probability, 1958-79, for James Fork near Hackett, Arkansas (station 07249400).

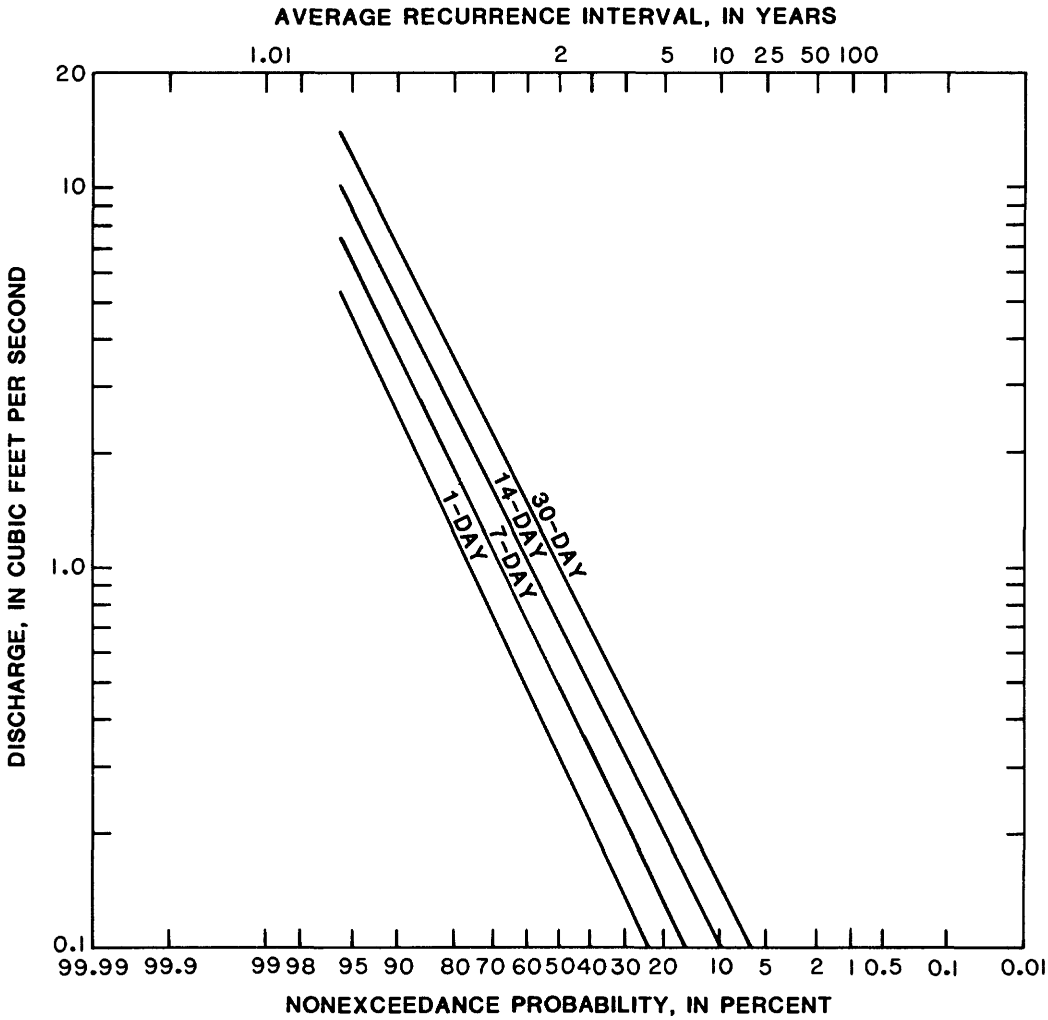


Figure 6.--Low-flow probability, 1958-79 water years, for James Fork near Hackett, Arkansas (station 07249400).

WATER QUALITY

All natural waters contain mineral constituents dissolved from the rock and soil with which it has been in contact. The concentrations of dissolved constituents largely depend on the type of rock or soil, the length of contact time, and pressure and temperature conditions. In addition to these natural conditions, man's activities, such as disposal of wastes, agricultural practices, and activities associated with mineral of fuel production, can have significant effects on the chemical quality of surface and ground waters.

The Rock Island area is rural with no industrial development or municipal waste-disposal systems. Most homes use septic tanks for waste disposal. Agricultural activities include cutting of hay and limited qrowning of small grains. Timber is not used for lumber although cutting of firewood is done on a small scale. Several natural gas wells have been drilled in the area but as far as is known none of them produce salt water. In sum, the impact of man's activities on the quality of water in the Rock Island area did not appear significant as of 1980.

In natural waters, the major cations--calcium, magnesium, and sodium plus potassium--and the major anions--carbonate and bicarbonate, chloride, and sulfate--generally constitute more than 95 percent of the total ions in solution. Water can be typed or classified according to the percentage of each of the major ions. For example, in a calcium sulfate type water, calcium constitutes more than 50 percent of the cations and sulfate constitutes more than 50 of the anions. If none of the cations or anions constitutes more than 50 percent of its respective ion group, the water is described as mixed type.

Ground Water

Water samples for detailed laboratory analysis were collected from nine wells chosen to provide geographic coverage and representative depths ranging from 21 to 109 ft; the results are given in table 2 and the location of the wells are shown in plate 2. Laboratory determinations of concentrations of chloride, sulfate, iron, and manganese were made on water from an additional five wells (table 1).

In addition to the laboratory analyses, specific conductance and pH of water from 39 wells (table 1) were determined at the well sites. Values for specific conductance ranged from 95 to 2,420 μmho (micromhos per centimeter at 25° Celsius); the median was 520 μmho. Specific conductance of water from nine wells, or about one-fourth of those sampled, exceeded 1,000 μmhos. Values for pH ranged from 5.2 to 8.7. Water from 28 wells, or about three-fourths of those sampled, had pH values between 6 and 8.

The concentration of dissolved solids may limit the use of water for some purposes. Specific-conductance measurements provide a means of estimating the dissolved-solids concentration in water where that concentration has not been directly determined. The average ratio of measured dissolved-solids concentration to the specific conductance of ground water in the Rock Island area, as determined from the laboratory analyses, is 0.62. Thus, by multiplying the specific conductance by 0.62 an approximation of the dissolved-solids concentration is obtained.

Table 2.--Quality of water from selected wells

[Aquifer: Pm, McAlester Formation; Ph, Hartshorne Formation; Pa, Atoka Formation; µmhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; ROE, residue on evaporation at 180° Celsius]

Number on trilinear diagram (figure 7)----------------- Well number-----------------	1 08N-26E-12 BBD 1	2 08N-26E-14 DAA 1	3 08N-26E-15 ABA 1	4 08N-26E-15 DCA 1	5 08N-26E-21 BBB 1	6 08N-26E-22 BBB 1	7 08N-27E-03 CBC 1	8 08N-27E-05 CDD 1	9 08N-27E-16 AAB 1
Date sampled (month-day-year)	8-24-76	8-24-76	8-24-76	8-25-76	8-24-76	8-24-76	8-24-76	8-24-76	8-24-76
Depth of well (feet)	80	62	89	109	100	78	105	60	21
Aquifer	Pa	Pm	Pa	Ph	Ph	Pm	Pa	Pa	Pm
Water temperature (°Celsius)	19.5	19.0	23.0	18.5	20.0	21.0	20.0	19.0	23.0
Specific conductance (µmhos)	634	635	1,625	930	1,200	460	1,900	1,100	780
pH	8.4	6.8	7.0	8.7	6.9	6.2	7.3	7.5	8.7
Alkalinity as $CaCO_3$ (mg/L)	340	236	268	342	119	67	408	381	178
Total acidity as $CaCO_3$ (mg/L)	20	20	20	5.0	30	10	10	10	10
Bicarbonate (HCO_3) (mg/L)	414	288	327	417	145	82	498	465	217
Carbonate (CO_3) (mg/L)	0	0	0	0	0	0	0	0	0
Hardness (Ca plus Mg) (mg/L)	160	120	540	24	480	97	350	140	130
Noncarbonate hardness (mg/L)	0	0	270	0	360	29	0	0	0
Calcium (Ca) (mg/L)	32	23	76	5.1	70	14	75	24	19
Magesium (Mg) (mg/L)	20	16	85	2.8	73	15	40	20	19
Sodium (Na) (mg/L)	95	97	180	200	49	59	310	180	120
Potassium (K) (mg/L)	.6	.6	1.0	.4	1.1	.3	1.0	.6	3.1
Chloride (Cl) (mg/ L)	11	26	27	91	27	46	110	37	29
Sulfate (SO_4) (mg/L)	9.8	57	600	4.3	400	88	490	68	160
Fluoride (F) (mg/L)	.5	.4	.3	1.3	.2	.2	.3	1.0	.4
Silica (SiO_2) (mg/L)	30	20	13	13	29	29	15	12	11
Arsenic (As) (µg/L)	<1	<1	<1	<1	<1	<1	<1	<1	1
Barium (Ba) (µg/L)	<100	<100	<100	<100	<100	<100	<100	<100	<100
Boron (B) (µg/L)	160	190	230	360	100	50	240	270	110
Cadmium (Cd) (µg/L)	3	7	3	<20	---	4	3	4	5
Chromium (Cr) (µg/L)	---	---	---	---	---	---	---	---	---
Cobalt (Co) (µg/L)	---	---	---	---	<2	---	---	---	---
Copper (Cu) (µg/L)	---	---	---	---	---	---	---	3	---
Iron (Fe) (µg/L)	490	1,300	80	80	17,000	200	1,300	20	650
Lead (Pb) (µg/L)	15	43	15	60	3	27	18	28	26
Manganese (Mn) (µg/L)	170	160	320	20	930	110	170	50	730
Molybdenum (Mo) (µg/L)	<1	<1	1	<1	<1	<1	<1	<1	<1
Nickel (Ni) (µg/L)	---	---	<2	---	<2	<2	---	---	---
Vanadium (V) (µg/L)	1.1	.0	.1	1.0	.7	.0	2.8	.2	9.0
Zinc (Zn) (µg/L)	<20	---	40	20	20	30	---	20	70
Aluminum (Al) (µg/L)	10	<100	<100	10	<100	<100	10	20	<100
Lithium (Li) (µg/L)	30	20	20	20	50	<10	30	<10	<10
Selenium (Se) (µg/L)	<1	<1	4	<1	<1	<1	<1	1	<1
Dissolved solids (ROE) (mg/L)	393	367	1,170	520	773	294	1,250	597	465
Dissolved solids (sum) (mg/L)	404	384	1,140	524	740	293	1,290	573	470
Mercury (Hg) (µg/L)	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5

The trilinear diagram (fig. 7) shows that sodium is the dominant cation in water from seven of the nine wells sampled. Water from wells 1, 2, 4, and 8 is a sodium bicarbonate type. Water from wells 6, 7, and 9 is a sodium mixed anion type. Water from well 3 is a sodium magnesium sulfate type and water from well 5 is a magnesium bicarbonate type.

The dissolved-solids concentrations in water from the nine wells ranged from 294 to 1,250 mg/L (milligrams per liter) and averaged about 650 mg/L. Water from one well (well 4, table 2) exceeded the maximum contaminant level of 50 µg/L for lead in drinking water established by the U.S. Environmental Protection Agency (1976). The maximum contaminant levels of arsenic, cadmium, and mercury were not exceeded in any of the samples.

Variations in water type and constituent concentrations in the Rock Island area are comparable to those in the Blocker area (Marcher and others, 1981) where water from four of nine wells was a sodium bicarbonate type and dissolved-solids concentrations ranged from 297 to 2,020 mg/L. There is no apparent relationship between the chemistry of ground water and well depth, geologic formation, or geographic distribution in either Rock Island or Blocker areas.

Stream Water

A trilinear diagram (fig. 8) of data provided by samples from James Fork near Hackett, Ark., and near Williams, Okla., shows that no cation was predominant. However, the sum of calcium and magnesium was predominant in all samples. For the anions, sulfate exceeded 50 percent in about three-fourths of the samples. Therefore, water in James Fork is a calcium magnesium sulfate type about 75 percent of the time; the rest of the time it is a calcium magnesium mixed-anion type.

The maximum dissolved-solids concentration in water from James Fork near Hackett was 570 mg/L and the mean was 322 mg/L (table 3). The maximum dissolved-solids concentration near Williams was 406 mg/L and the mean was 224 mg/L (table 4). Although the mean values indicate some dilution between the two sites, an analysis of variance at the 5-percent probability level showed no significant difference in the dissolved-solids concentration.

Statistical analysis of data on major chemical constituents at the Hackett and Williams sites showed no significant difference in concentrations of calcium, mangesium, potassium, chloride, and sulfate. Of the two constituents that were different--sodium and bicarbonate--statistical analysis indicated that concentrations were slightly greater at Hackett but the change is so slight that it does not produce any significant difference in the dissolved-solids concentrations.

None of the toxic metals--arsenic, cadmium, chromium, lead, and mercury--at the Hackett site exceeded the maximum contaminant levels as established by the U.S. Environmental Protection Agency (1976). At the Williams site, however, the maximum concentration of total recoverable lead was 100 µg/L (micrograms per liter) which is twice the maximum established level for this element. The maximum concentration of dissolved lead at the same site was only 33 µg/L. Thus, much of the lead apparently is sorbed to the suspended sediment; the source of the lead is unknown.

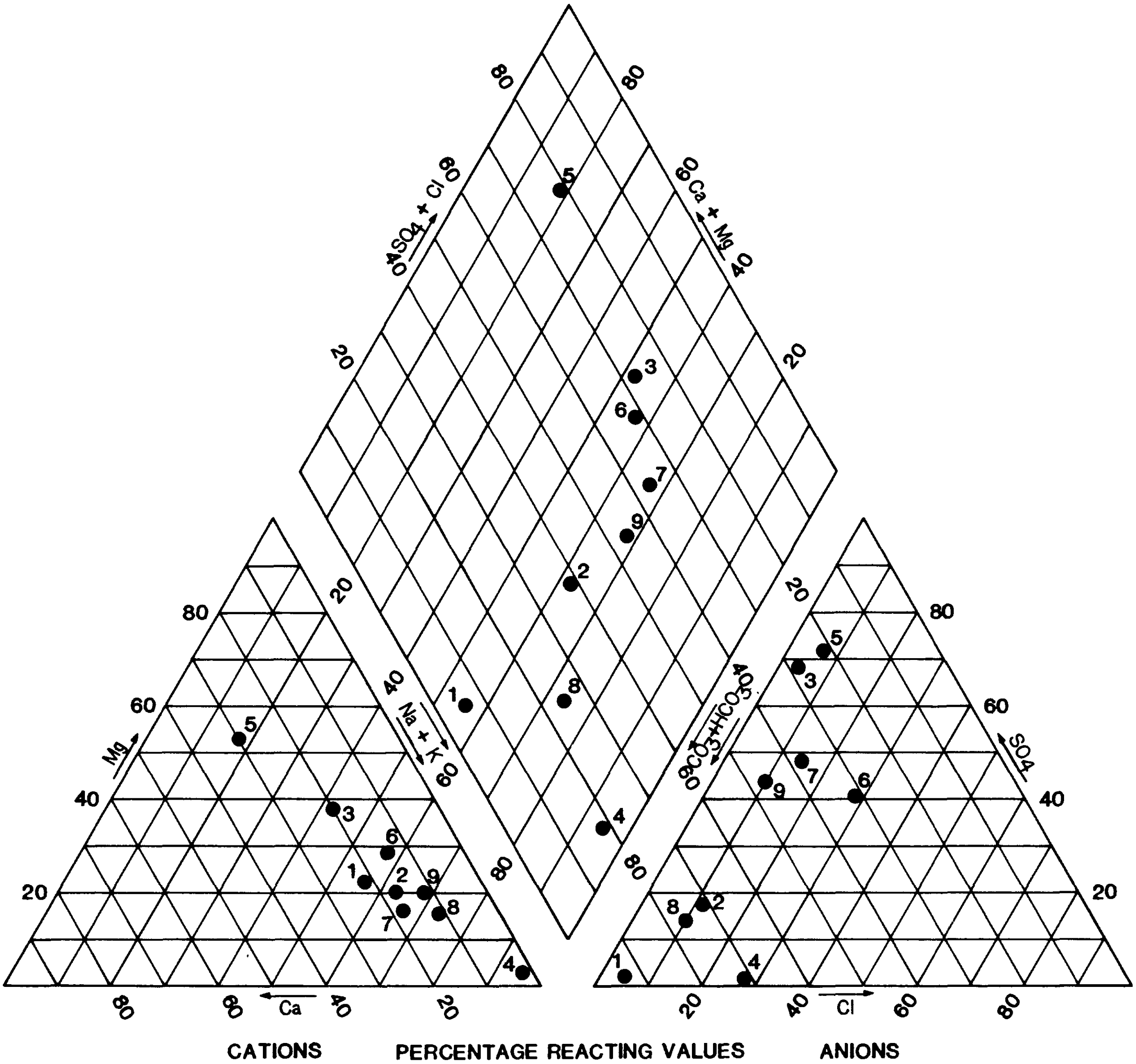


Figure 7.--Trilinear diagram for water from selected wells. Numbers refer to well locations shown on plate 2. and table 2.

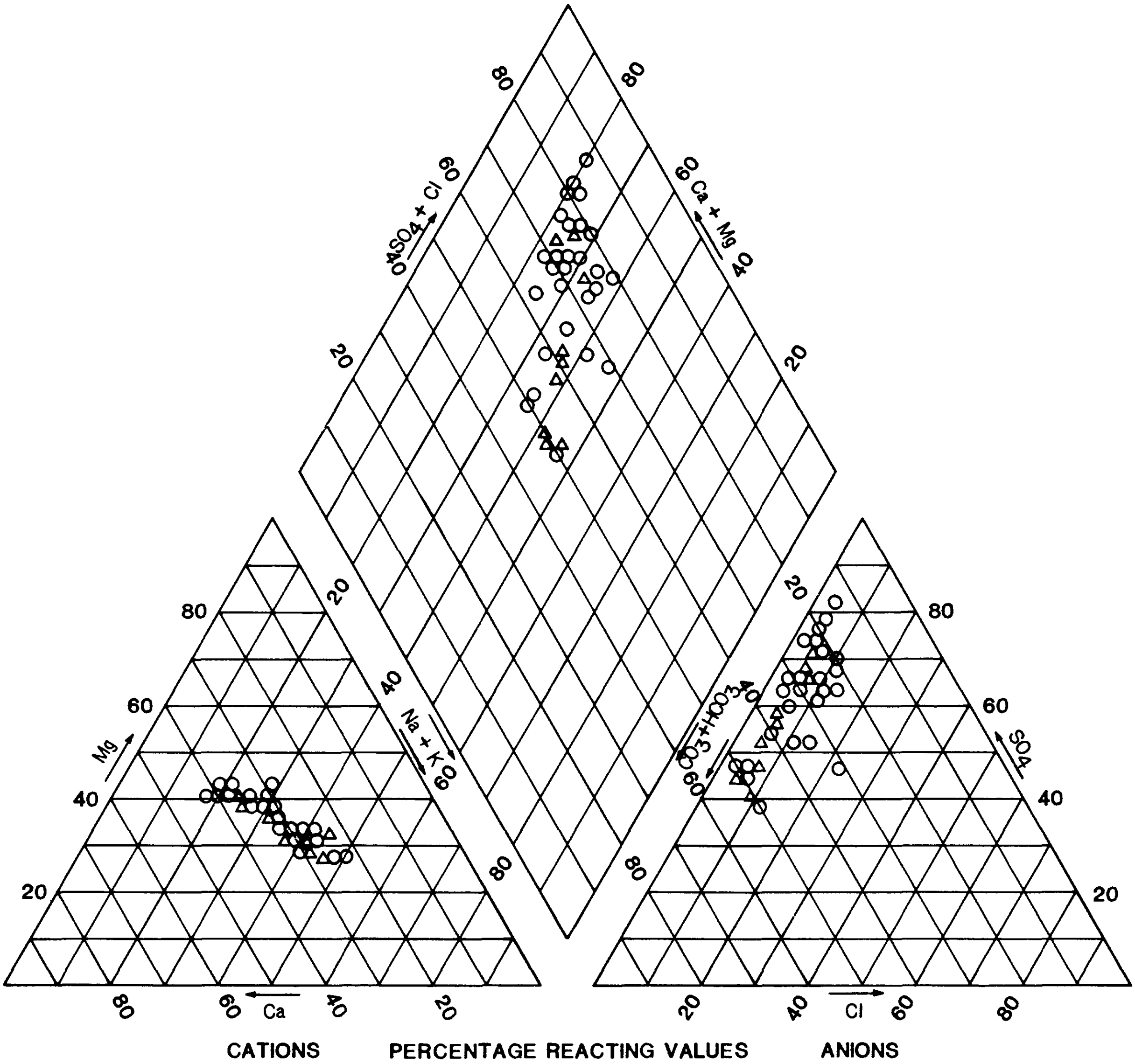


Figure 8.--Trilinear diagram for water from James Fork. Triangles are analyses of samples from James Fork near Hackett, Arkansas (station 07249400); circles are analyses of samples from James Fork near Williams, Oklahoma (station 07249410).

Table 3.--Mean, minimum, and maximum values for selected physical properties and chemical constituents of water from James Fork near Hackett, Ark. (station 07249400), 1976-78 water years

[µmhos, micromhos per centimeter at 25° Celsius; ROE, residue on evaporation at 180° Celsius; mg/L, milligrams per liter, µg/L, micrograms per liter]

Property or constituent	Number of determinations	Mean	Minimum	Maximum
Specific conductance (µmhos)	64	440	90	868
pH	59	---	6.4	8.2
Dissolved solids (ROE)	22	322	79	570
Hardness ($CaCO_3$) (mg/L)	24	126	23	220
Bicarbonate (HCO_3) (mg/L)	15	98	29	200
Carbonate (CO_3) (mg/L)	14	0	0	0
Calcium, dissolved (Ca) (mg/L)	15	28	5	41
Magnesium, dissolved (Mg) (mg/L)	15	17	4.2	25
Sodium, dissolved (Na) (mg/L)	9	38	9.6	65
Potassium, dissolved (K) (mg/L)	9	2.5	1.8	3.3
Chloride, dissolved (Cl) (mg/L)	46	9.6	3.4	23
Sulfate, dissolved (SO_4) (mg/L)	41	119	6.0	270
Fluoride, dissolved (F) (mg/L)	9	.2	.1	.3
Arsenic, dissolved (As) (µg/L)	29	0	0	2.0
Arsenic, total (As) (µg/L)	15	3	0	10
Cadmium, dissolved (Cd) (µg/L)	27	1	0	5
Cadmium, total (Cd) (µg/L)	24	9	0	10
Chromium, dissolved (Cr) (µg/L)	27	2	0	14
Chromium, total (Cr) (µg/L)	15	5	0	30
Lead, dissolved (Pb) (µg/L)	27	4	0	12
Lead, total ((Pb) (µg/L)	17	16	2	40
Mercury, dissolved (Hg) (µg/L)	29	.1	.0	.8
Mercury, total (Hg) (µg/L)	5	.3	.0	1.0
Boron, dissolved (B)(µg/L)	24	52	0	110
Boron, total (B) (µg/L)	4	355	30	1,200
Iron, dissolved (Fe) (µg/L)	27	128	10	590
Iron, total (Fe) (µg/L)	41	1,099	30	3,500
Manganese, dissolved (Mn) (µg/L)	27	244	40	620
Manganese, total (Mn) (µg/L)	41	419	110	2,500
Aluminum, dissolved (Al) (µg/L)	27	67	0	400
Aluminum, total (Al) (µg/L)	3	160	100	220
Copper, dissolved (Cu) (µg/L)	29	2	0	7
Copper, total (Cu) (µg/L)	37	72	3	200
Nickel, dissolved (Ni) (µg/L)	27	11	0	41
Nickel, total (Ni) (µg/L)	4	10	3	22
Zinc, dissolved (Zn) (µg/L)	27	40	0	790
Zinc, total (Zn) (µg/L)	37	80	10	200
Molybdenum, dissolved (Mo) (µg/L)	27	1	0	3
Molybdenum, total (Mo) (µg/L)	3	2	0	3
Nitrogen, dissolved (nitrate as N) (mg/L)	9	.0	.0	.0
Nitrogen, dissolved (nitrate as N) (mg/L)	9	.4	0.0	1.3

Table 4.--Mean, minimum, and maximum values for selected physical properties and chemical constituents of water from James Fork near Williams, Okla. (station 07249410), 1976-78 water years

[μmhos, micromhos per centimeter at 25° Celsius; ROE, residue on evaporation at 180° Celsius; mg/L, milligrams per liter, μg/L, micrograms per liter]

Property or constituent	Number of determinations	Mean	Minimum	Maximum
Specific conductance (μmhos)	30	356	78	650
pH	30	---	6.5	8.2
Dissolved solids (ROE)	30	224	69	406
Hardness ($CaCO_3$) (mg/L)	30	127	24	250
Bicarbonate (HCO_3) (mg/L)	30	62	19	180
Carbonate (CO_3) (mg/L)	30	0	0	0
Calcium, dissolved (Ca) (mg/L)	30	24	4.9	50
Magnesium, dissolved (Mg) (mg/L)	30	16	2.9	30
Sodium, dissolved (Na) (mg/L)	30	21	4.8	63
Potassium, dissolved (K) (mg/L)	30	2.6	1.4	4.4
Chloride, dissolved (Cl) (mg/L)	30	7	3.6	12
Sulfate, dissolved (SO_4) (mg/L)	30	107	16	220
Fluoride, dissolved (F) (mg/L)	30	.2	.0	.3
Arsenic, dissolved (As) (μg/L)	30	0	0	2
Arsenic, total (As) (μg/L)	14	1	0	3
Cadmium, dissolved (Cd) (μg/L)	28	1	0	5
Cadmium, total (Cd) (μg/L)	14	5	0	10
Chromium, dissolved (Cr) (μg/L)	28	2	0	10
Chromium, total (Cr) (μg/L)	14	4	0	10
Lead, dissolved (Pb) (μg/L)	28	5	0	33
Lead, total ((Pb) (μg/L)	14	29	0	100
Mercury, dissolved (Hg) (μg/L)	30	.1	.0	.5
Mercury, total (Hg) (μg/L)	12	.1	.0	.4
Boron, dissolved (B)(μg/L)	28	44	20	80
Boron, total (B) (μg/L)	15	246	20	2,700
Iron, dissolved (Fe) (μg/L)	28	124	10	490
Iron, total (Fe) (μg/L)	14	1,162	270	3,500
Manganese, dissolved (Mn) (μg/L)	28	613	20	11,000
Manganese, total (Mn) (μg/L)	14	1,119	30	12,000
Aluminum, dissolved (Al) (μg/L)	28	62	0	390
Aluminum, total (Al) (μg/L)	14	527	140	2,600
Copper, dissolved (Cu) (μg/L)	30	2	0	6
Copper, total (Cu) (μg/L)	14	6	1	10
Nickel, dissolved (Ni) (μg/L)	28	6	0	32
Nickel, total (Ni) (μg/L)	14	21	4	50
Zinc, dissolved (Zn) (μg/L)	28	19	0	270
Zinc, total (Zn) (μg/L)	14	17	0	30
Molybdenum, dissolved (Mo) (μg/L)	28	0	0	1
Molybdenum, total (Mo) (μg/L)	14	1	0	5
Nitrogen, dissolved (nitrate as N) (mg/L)	28	0	0	0
Nitrogen, dissolved (nitrate as N) (mg/L)	28	.3	.0	1.1

Water in Surface-Mine Ponds

Water in abandoned surface-mine ponds constitutes a valuable resource in the Oklahoma coal field where the availability of ground water is limited and most streams are dry several months of each year. As part of a regional study of coal-field hydrology, selected water-quality data have been collected at 57 surface-mine ponds; two of those ponds are in the Rock Island area (pl. 2). The data available for these two ponds are comparable to that from other ponds of about the same age elsewhere in the southern part of the coal field. Spoil adjacent to the ponds in the Rock Island area has not been reclaimed in any way but is vegetated to varying degrees with trees, brush, and weeds. Water in the ponds is derived from runoff and direct precipitation although shallow ground-water seepage may contribute at times.

Examination of the data for the ponds in the Rock Island area (table 5) shows that: (1) Specific conductance is 685 umhos or less and increased with water depth, (2) pH decreases with depth but, except for one measurement, is greater than 7.0, (3) chloride is 13 mg/L or less, (4) concentrations of iron and manganese vary with depth, time, and location. The variations in concentrations of iron (10-1,740 µg/L) and manganese (20-405 µg/L), and to some extent sulfate (20-301 mg/L), presumably are related to differences in mineralogy of the spoil.

Table 5.--Selected physical properties and chemical constituents of water from strip-mine ponds

[ft, feet below water surface; °C, degrees Celsius; µmhos, micromhos per centimeter at 25° Celsius; percent, percent saturation; mg/L, milligrams per liter; µg/L micrograms per liter]

Depth (ft)	Temperature (°C)	Specific conductance (µmhos)	pH (units)	Dissolved oxygen (percent)	Dissolved oxygen (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Iron (µg/L)	Manganese (µg/L)
2.5 miles west of Williams, Okla. (08N-26E-20 BDC 1)									
Date sampled: 9-27-77									
1	26.0	385	8.4	90.9	7.0	-	-	-	-
5	24.5	380	8.2	80.5	6.2	11	30	1,740	25
10	22.5	375	7.7	37.7	2.9	-	-	-	-
15	17.5	395	7.4	1.3	0.1	-	-	-	-
20	13.5	425	7.5	0	0	-	-	-	-
25	13.0	425	7.5	0	0	13	22	750	405
30	14.0	415	7.5	0	0	-	-	-	-
Date sampled: 8-15-79									
0.25	27	370	8.0	70.5	5.6	-	-	-	-
2	26	---	---	69.3	5.5	-	-	-	-
4	26	370	7.9	64.2	5.1	8	29	10	20
6	26	---	---	40.3	3.2	-	-	-	-
8	23	370	7.9	3.8	0.3	-	-	-	-
10	20	---	---	1.3	0.1	-	-	-	-
12	17	390	7.8	3.8	0.3	5	28	80	100
15	14	420	7.6	10.1	0.8	-	-	-	-
20	12	450	7.6	6.3	0.5	-	-	-	-
25	12	480	7.6	10.1	0.8	13	20	910	160
30	12	440	7.6	15.1	1.2	-	-	-	-
3 miles east of Williams, Okla. (08N-27E-08 CBB 1)									
Date sampled: 9-28-77									
1	26.5	685	7.4	89	7.3	3.0	301	20	20
3	---	---	7.4	89	7.3	-	-	-	-
6	---	---	7.4	89	7.3	-	-	-	-
9	---	---	7.3	90.2	7.4	-	-	-	-
12	---	---	7.2	85.4	7.0	-	-	-	-
14	---	---	6.7	45.1	3.7	2.0	298	10	140

SUSPENDED SEDIMENT

The quantity and characteristics of suspended sediment transported by a stream are affected by many interrelated environmental conditions. Major conditions affecting sediment transport in the Rock Island area are quantity and intensity of precipitation, land use and cover conditions, length and degree of slope, and soil characteristics. Much of the precipitation falls as thunderstorms of varying intensity during spring and summer; the largest sediment loads can be expected at those times.

Soil associations in the Rock Island area include the Lee-Philo-Pope, the Taloka-Choteau-Bates, and the Hector-Linkers-Enders (U.S. Department of Agriculture, 1966). Soils of the Lee-Philo-Pope association were formed on alluvium and occur on level to gently sloping land used for pasture and crops. Surface layers of Lee and Philo soils are primarily silty loam and subsoils are primarily silty clay loam. Pope soils are primarily sandy loam throughout the profile. The Taloka-Choteau-Bates association is derived from alluvium, sandstone, and shale; the topography is level to gently sloping. All soils have deep profiles with silt loam surface layers. Taloka soils have clayey subsoils. The Hector-Liners-Enders association occupies gently sloping to steeper area and consists of loamy soils under forest cover and pasture. Hector and Linker soils were derived from sandstone; Enders soils were derived from shale. Hector soils have shallow profiles whereas Linker and Ender soils have deep profiles.

Suspended-sediment samples from the Rock Island area represent conditions at the time they were collected. Samples were collected irrespective of stream stage, either rising or falling, and do not necessarily correspond to peak discharge. Concentrations were determined from samples collected using depth-integrating samplers, usually representing several verticals in the cross section. Suspended-sediment concentration is the velocity-weighted concentration of suspended sediment in the sampled zone expressed as milligrams of dry sediment per liter of water-sediment mixture. Each vertically sampled zone extends from the water surface to a point approximately 0.3 ft above the streambed, a limit established by nozzle and sampler configuration.

The relationship between stream discharge and suspended sediment is shown in figure 9. Data for both the Hackett and Williams sites show fairly well defined relationships at discharges less than 300 ft^3/s. Some of the scatter of the points are attributed to plotting both rising-and falling-stage samples. Rising-stage discharge would be expected to transport significantly greater quantities of suspended sediment as has been determined at other sites in the coal field.

Particle-size determinations separate sediment into two size groups-diameters larger or smaller than 0.062 mm (millimeter). Particles with diameters larger than 0.062 mm are classed as sand; particles with diameters smaller than 0.062 mm are classed as silt-clay. As expected in an area of loamy soils, the median for the silt-clay fraction was 94 percent at the Hackett site and 95 percent at the Williams site (table 6). All available suspended sediment data are given in tables 7 and 8.

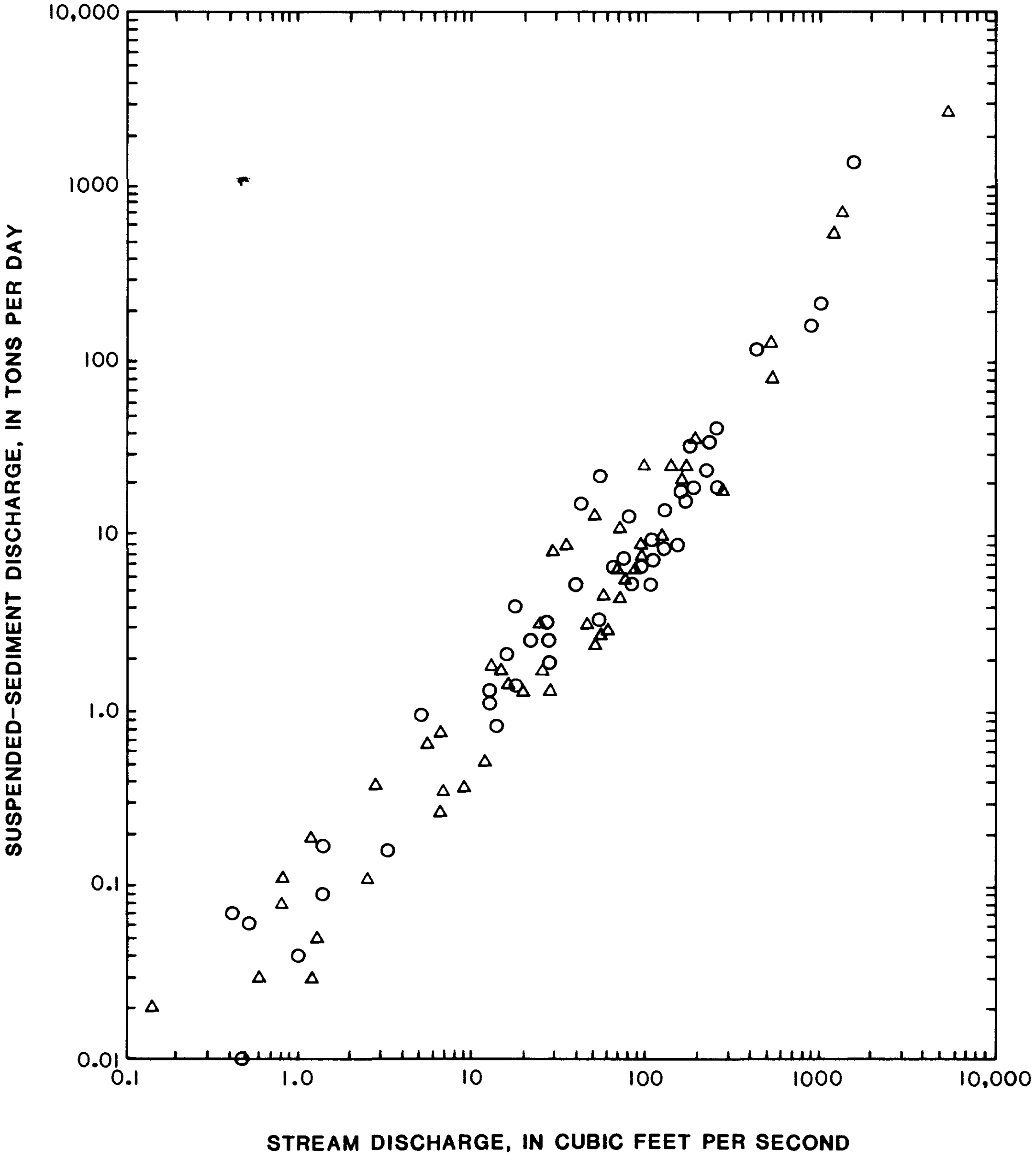


Figure 9.—Relationship between stream discharge and suspended-sediment discharge. Triangles are samples from James Fork near Hackett, Arkansas (station 07249400); circles are samples from James Fork near Williams, Oklahoma (station 07249410).

Table 6.--Summary of suspended-sediment data

[A, James Fork near Hackett, Ark.; B, James Fork near Williams, Okla.; mg/L, milligrams per liter; ton/d, tons per day; mm, millimeter]

Sediment characteristics	Number of determinations		Median		Minimum		Maximum	
	A	B	A	B	A	B	A	B
Suspended-sediment concentration (mg/L)	55	46	34	36	10	4	178	318
Suspended-sediment discharge (ton/d)	55	46	3.1	5.9	0	0	2,720	1,370
Suspended-sediment sieve diameter (percent finer than 0.062 mm)	55	46	94	95	56	51	100	100

Table 7.--Suspended-sediment data for James Fork near Hackett, Arkansas (station 07249400)

Date	Instantaneous streamflow (cubic feet per second)	Suspended-sediment concentration (milligrams per liter)	Suspended-sediment discharge (tons per day)	Percentage of suspended sediment finer than 0.062 millimeter
Water year October 1976 to September 1977				
Jan. 19	97	29	---	95
Feb. 10	60	18	---	86
Mar. 15	196	67	---	98
Apr. 20	71	23	---	96
May 18	20	24	---	94
June 15	2.8	50	---	85
July 20	1.2	10	---	78
Aug. 16	2.5	17	---	87
Water year October 1977 to September 1978				
Oct. 4	.8	37	0.08	96
Oct. 31	26	24	1.7	86
Dec. 6	52	17	2.4	99
Jan. 27	79	26	5.5	94
Feb. 6	56	18	2.7	96
Mar. 6	100	91	25	56
Apr. 4	96	34	8.8	94
May 2	29	17	1.3	96
June 19	6.6	15	.27	90
July 19	9.1	15	.37	76
Aug. 8	.59	18	.03	96
Sept. 3	.01	14	---	97
Water year October 1978 to September 1979				
Oct. 18	.10	17	.00	99
Nov. 8	13	52	1.8	97
Dec. 20	15	41	1.7	92
Jan. 22	163	41	21	81
Feb. 6	69	36	6.4	90
Feb. 21	89	27	6.4	91
Mar. 6	274	24	18	62
Mar. 19	72	39	11	95
Apr. 2	1,230	72	558	97
Apr. 17	172	54	25	94
Apr. 30	125	30	10	98
May 21	5,720	176	2,720	79
May 30	540	57	80	93
June 7	1,360	178	735	88
June 19	51	57	13	95
July 10	30	104	8.1	98
Aug. 8	25	47	3.2	99
Sept. 12	5.6	42	.66	100
Sept. 24	.81	59	.11	97
Water year October 1979 to September 1980				
Oct. 3	1.2	58	.19	95
Oct. 23	36	90	8.7	95
Nov. 5	6.7	42	.76	96
Nov. 27	11	48	1.4	99
Dec. 3	6.9	19	.35	93
Dec. 18	36	88	8.6	95
Jan. 9	58	29	4.5	96
Jan. 22	146	63	25	98
Feb. 11	144	23	8.9	83
Mar. 19	46	25	3.1	95
Apr. 14	521	92	129	90
May 21	118	30	9.6	73
June 24	12	16	.51	90
July 24	.19	10	0	75
Aug. 12	.14	52	.02	72
Sept. 16	1.3	15	.05	82

Table 8.--Suspended-sediment data for James Fork near Williams, Okla. (station 07249410)

Date	Instantaneous streamflow (cubic feet per second)	Suspended-sediment concentration (milligrams per liter)	Suspended-sediment discharge (tons per day)	Percentage of suspended sediment finer than 0.062 millimeter
		Water year October 1976 to September 1977		
Feb. 10	82	67	13	51
Mar. 15	179	50	33	97
Apr. 20	96	29	6.6	91
May 18	16	38	2.1	95
June 15	.42	18	.07	95
July 19	1.4	15	.09	75
Aug. 17	3.3	20	.16	92
		Water year October 1977 to September 1978		
Jan. 27	165	39	17	96
Feb. 6	87	22	5.2	91
Mar. 6	155	21	8.8	93
Apr. 4	133	39	14	95
May 2	29	24	1.9	96
June 19	13	31	1.1	95
July 19	1	16	.04	88
Aug. 7	.23	7	.00	85
Sept. 3	.48	8	.01	97
		Water year October 1978 to September 1979		
Nov. 9	.52	41	.06	99
Dec. 20	13	36	1.3	98
Jan. 23	232	38	24	90
Feb. 7	67	36	6.5	89
Feb. 20	110	32	9.5	83
Mar. 14	130	24	8.4	95
Apr. 3	1,030	78	217	98
Apr. 17	238	54	35	98
May 1	171	34	16	98
May 30	907	67	164	94
June 7	1,590	318	1,370	81
June 19	76	36	7.4	96
July 10	56	144	22	97
Aug. 8	40	48	5.2	83
Aug. 22	43	133	15	97
Sept. 12	27	42	3.1	98
Sept. 25	5.2	68	.95	95
		Water year October 1979 to September 1980		
Oct. 2	1.4	45	.17	97
Oct. 23	18	80	3.9	92
Nov. 7	22	42	2.5	94
Nov. 27	28	33	2.5	99
Dec. 5	14	22	.83	100
Jan. 9	112	24	7.3	96
Jan. 22	262	60	42	97
Feb. 13	268	26	19	95
Mar. 19	109	18	5.3	96
Apr. 15	444	99	119	90
May 22	192	37	19	93
June 24	18	28	1.4	91
July 22	.01	4	0	87
Aug. 12	0			
Sept. 16	0			

STREAMBED MATERIAL

Samples of streambed materials were analyzed for selected trace constituents and nutrients (table 9). The number of sampling points within a cross section or reach depended on the width of flow at the sampling time.

WATER DEVELOPMENT AND USE

Wells are the principal source of water for domestic use in the Rock Island area although part is served by a rural water district (Oklahoma Water Resources Board, 1980). For this study, 42 wells were inventoried, mostly in June, 1976; the number of wells probably has increased since that time. As stated previously, well yields probably are less than 5 gal/min. Greater yields might be obtained from deeper wells that penetrate thick units of fractured sandstone but below a depth of 250-300 ft the water is likely to be too mineralized for domestic use. Total ground water use is estimated at 10,000 gal/d. The quantity of water provided by the rural water district was not determined. Water used for stock is provided mainly by ponds and a few wells; the quantity of water used for stock is estimated as 4,000 gal/d.

James Fork is not used as a source of water supply except for limited watering of livestock. The stream has flow most of the time and therefore provides habitat for fish and wildlife. The U.S. Fish and Wildlife Service (1978) has placed James Fork in Value Class I, Highest-valued fishery resource.

Table 9.--Selected trace constituents and nutrients in streambed material

[A, James Fork near Hackett, Ark.; B, James Fork near Williams, Okla. All values are in micrograms per gram except nitrogen and phosphorus which are in milligrams per kilogram

SITE	DATE	Nitrogen (NO_2+NO_3)	Nitrogen (NH_4)	Nitrogen (NH_4+organic)	Phosphorus	Aluminum	Arsenic	Cadmium	Chromium
A	05-02-78	--	--	--	--	2,800	39	0	20
A	07-10-79	0.0	39	830	540	0	15	0	0
A	01-09-80	1.6	7.8	1,480	310	370	40	100	9
A	06-24-80	240	71	1,600	310	840	27	1	16
B	05-02-78	--	--	--	--	2,000	27	0	19
B	07-10-79	5.3	19	335	860	0	20	0	0
B	01-09-80	4.2	19	168	430	370	9	0	10
B	06-24-80	270	27	4,700	120	680	23	1	20

SITE	DATE	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Zinc
A	05-02-78	--	8	10,000	10	--	--	0	72
A	07-10-79	0	1	0	0	400	0.07	0	2
A	01-09-80	30	25,000	14,000	8,000	1,000	.03	14	380
A	06-24-80	30	12	12,000	20	1,400	.04	0	68
B	05-02-78	--	5	12,000	40	2,500	.03	0	65
B	07-10-79	0	0	0	0	110	.04	0	0
B	01-09-80	30	750	19,000	2,000	900	.02	4	52
B	06-24-80	30	15	13,000	20	1,500	.04	0	61

POTENTIAL HYDROLOGIC EFFECTS OF SURFACE MINING COAL

Surface mining for coal and subsequent reclamation in the Oklahoma coal field may cause changes in the hydrologic system; these changes may be either short or long term. The following description of the coal-mining process as practiced in Oklahoma is summarized from Johnson (1974) to show how some of these changes may occur.

A surface-mining operation (fig. 10) involves digging a trench to expose the coal bed which is then removed. As each succeeding cut is made, the overburden or spoil is placed into the cut previously excavated. Successive cuts are mined until the overburden thickness becomes so great that the coal can no longer be mined profitably. The final cut leaves an open trench bounded by the last spoil pile on one side and the undisturbed highwall on the other. The ridges of spoil are graded to a rolling topography and revegetated with pasture grasses. The final cut and other depressions partly fill with water from precipitation and ground-water seepage. The revegetated area usually is not grazed until the grass has become well established.

A readily apparent change in the hydrologic system resulting from surface mining is the creation of additional water storage in the last mine cut shown in figure 10. A mine pond 0.5 mi long, 200 ft wide, and containing 30 ft of water has a volume of about 360 acre-ft, a valuable asset in an area where ground water is limited. Such a pond would provide habitat for aquatic and semiaquatic wildlife and could be stocked with fish as has been done in other parts of the coal field. Also, water from mine ponds may be used for stock, domestic, municipal, and irrigation supply if the quality is suitable.

In addition to increasing the storage of water in mine ponds, other changes in the hydrologic system may include: (1) Changes in permeability and ground water storage, (2) changes in runoff and streamflow characteristics, (3) changes in drainage patterns, (4) changes in the chemical quality of water, and (5) changes in the sediment loads of streams.

1. Changes in permeability and ground-water storage

Overburden in the southern part of the Oklahoma coal field consists mainly of shale with some siltstone and sandstone; these rocks have minimal porsity and permeability. During mining, however, the overburden is broken and shattered to form spoil with many more or less interconnected openings that may facilitate the entry, movement, and storage of water. Water stored in the spoil may (a) move into adjacent bedrock, (b) be slowly discharged to streams, or (c) be used by plants.

The volume of water entering the spoil is controlled partly by the permeability of the surface and near-surface material. Where that material consists of silt and clay, openings in the spoil may be plugged thus preventing or limiting the volume and rate of infiltration. In the Stigler area, for example, an auger test hole adjacent to a small pond and at the same elevation, was drilled to a depth of 37.5 ft in spoil consisting of broken shale with some blocks of sandstone. The upper 11 ft of the spoil was moist but below that depth, it was completely dry indicating that the bottom of the pond was sealed with fine sediment thereby limiting downward movement of water. Other larger and deeper depressions nearby did not contain water indicating that the surface material in these depressions is permeable.

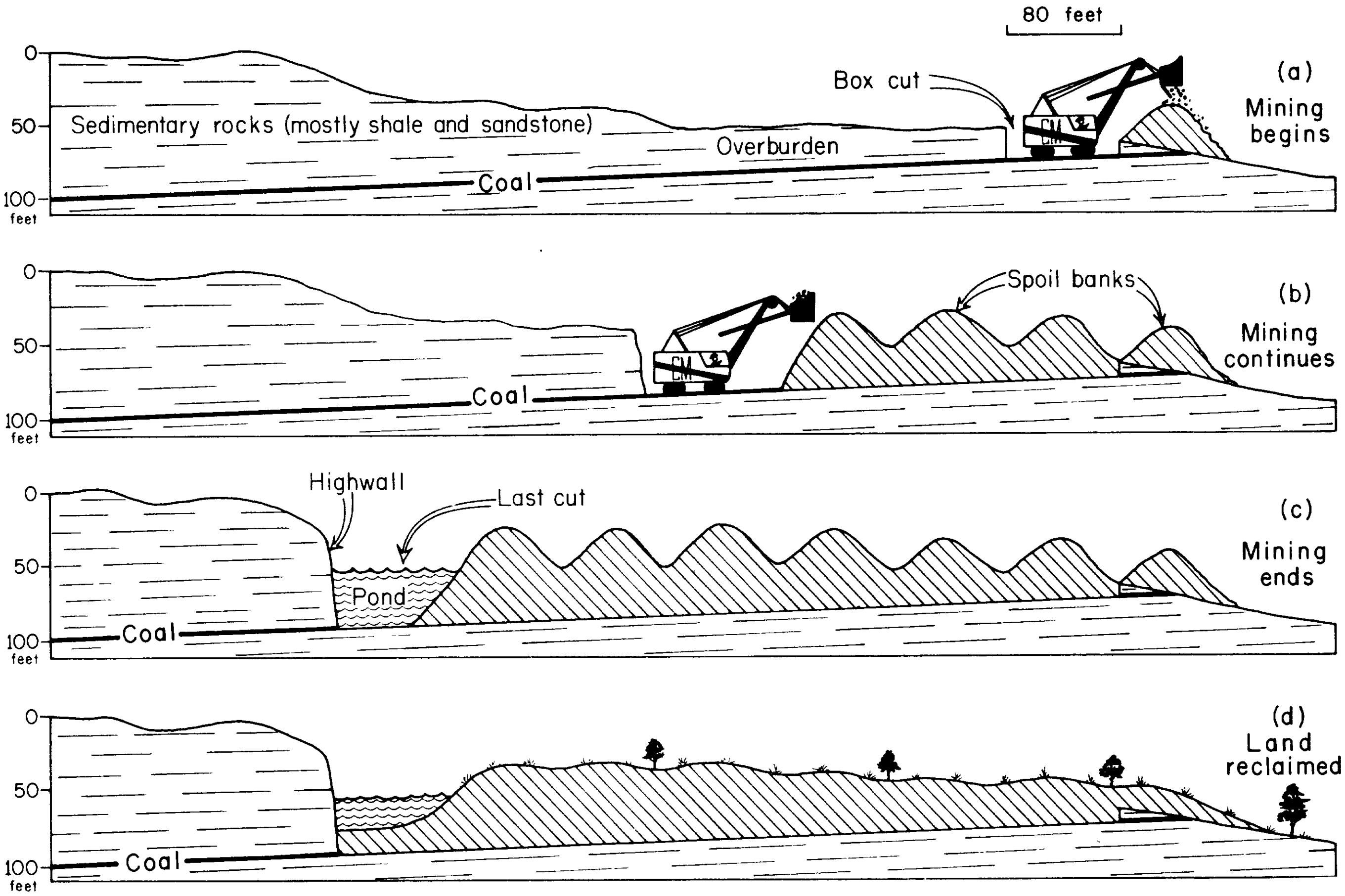


Figure 10.--Schematic cross section showing stages of surface mining for coal (from Johnson, 1974).

2. Changes in runoff and streamflow characteristics

Observations in various parts of the Oklahoma coal field show that if appropriate reclamation procedures are used and climatic conditions are favorable, grasses on reclaimed spoil may be more lush and have denser growth than the original native vegetation. This denser plant growth tends to retard overland storm runoff so that it has more time to soak into the spoil and, as a consequence, less water reaches streams during times of normally high runoff. Conversely, water stored in the spoil may, under some circumstances, be slowly released to streams thereby sustaining streamflow during dry periods. The overall resulting change in streamflow would be to decrease peak discharges and to extend periods of low flow. Streamflow also may be affected to some extent by interception of runoff in mine ponds and other depressions left in the reclaimed areas. In the Rock Island area, the effects of these changes on James Fork probably would not be significant because the mined areas would be only a very small fraction of the total drainage basin.

3. Changes in drainage patterns

To prevent storm runoff from entering surface pits during mining operations and to effectively extract the coal, some diversions of stream channels are commonly necessary. These diversions generally are of limited extent and if appropriately constructed and maintained are not likely to have any great effect on the hydrologic system. Mining across drainageways may cause permanent changes but the significance of these changes would depend largely on the size of the area disrupted.

4. Changes in chemical quality of water

Minerals in the overburden and coal are in equilibrium with their environment as long as that environment is not changed. Mining, however, disturbs that equilibrium and the minerals react with various chemical components of their new environment such as water, oxygen, and plant acids. For example, pyrite, which is commonly associated with coal, reacts with water and oxygen to release iron and sulfate and to increase the acidity of the water. Other reactions may result in the release of various trace elements, such as lead and zinc, that may be present in the coal. As a consequence of these reactions, new and generally undesirable chemicals may be added to the hydrologic system. The kinds and quantities of these chemicals and their overall effect on the hydrologic system in the Rock Island area cannot be determined from the available data.

5. Changes in sediment loads

Disruption of the land surface during mining and before the spoil is fully reclaimed will increase the quantity of sediment available to streams. However, if appropriate mining practices are followed, such as the use of settling ponds, the quantity of sediment added to streams can be decreased. Likewise, if the spoil is revegetated rapidly and effectively, the time available for the addition of sediment can be decreased.

In summary, the principal effect of mining in the Rock Island area probably would be to increase the volume of water stored in mine ponds. Changes in drainage patterns would be of limited extent and not likely to significantly affect the hydrologic system of the area. Increases in sediment loads of James Fork should be of limited quantity and duration if appropriate mining and reclamation practices are followed. Impairment of the chemical quality of ground water, if it occurs at all, would be of limited extent. The kinds of dissolved minerals added to the stream depends largely on the mineralogy of the overburden and the coal; the quantities would, to some extent, depend on mining and reclamation practices.

SUMMARY

Wells in the shale and sandstone bedrock in the Rock Island area obtain water primarily from bedding planes, fractures, and joints. These openings are limited in number, size, and extent; therefore, the availablity of ground water is limited. However, wells in most of the area provide enough water of suitable quality for domestic use. The chemical quality of ground water is extremely variable as it is throughout the Oklahoma coal field; the causes of these variations are not known.

Ponds left when mining is completed would provide additional sources of water for various uses if the quality is suitable and for wildlife habitat. Water from these ponds might provide ground-water recharge locally but, except for iron and manganese, mine-pond water is not highly mineralized.

James Fork has flow most of the time and, therefore, provides habitat for wildlife and could be used as a source of water supply. Data available for James Fork indicate that the chemical quality of its water has not been greatly affected by man. Although surface mining coal may increase the quantities of sediment and dissolved minerals added to James Fork, detection of any such increases would be difficult because the potentially mineable area is very small in proportion to the total area of the basin. Furthermore, if appropriate mining and reclamation practices are followed, the effects of mining should be of limited extent and duration.

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CONVERSION FROM INCH-POUND TO SI UNITS

Inch-pound	Multiply by	To obtain SI units
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
ton per day (ton/d)	0.9072	megagram per day
gallon per minute (gal/min)	0.06309	liter per second
gallon per day (gal/d)	0.003785	cubic meter per day
mile (mi)	1.609	kilometer
micromho per centimeter at 25° Celsius (umho)	1.0	microseimens per centimeter at 25° Celsius
acre-foot per square mile ($acre\text{-}ft/mi^2$)	3,194	cubic meter per square kilometer

The National Geodetic Vertical Datum of 1929 (NGVD of 1929) is used in place of sea level datum of 1929 or mean sea level.