PRELIMINARY APPRAISAL OF THE HYDROLOGY OF THE RED OAK AREA, LATIMER COUNTY, OKLAHOMA

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

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U.S. Geological Survey

Water-Resources Investigations Report 83-4166

Prepared in cooperation with the

U.S. Bureau of Land Management

under the

Energy Minerals Rehabilitation Inventory and Analysis Program

Oklahoma City, Oklahoma

1983

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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PRELIMINARY APPRAISAL OF THE HYDROLOGY OF THE RED OAK AREA, LATIMER COUNTY, OKLAHOMA

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ABSTRACT

Bedrock in the Red Oak area consists of shale, siltstone, and sandstone of the McAlester and Savanna Formations of Pennsylvanian age. Water in bedrock occurs in bedding planes, joints, and fractures and is confined. The potentiometric surface generally is less than 20 feet below the land surface. Wells yield enough water for domestic and stock use, but larger amounts of ground water are not available. Ground water commonly is a sodium or mixed cation carbonate/bicarbonate type with dissolved-solids concentrations ranging from 321 to 714 milligrams per liter. Although variable in quality, ground water generally is suitable for domestic use. No relationship between water chemistry and well depth or location is apparent.

Brazil Creek, the principal stream in the area, has no flow 15 percent of the time, and flow is less than 1 cubic foot per second about 25 percent of the time. Water in Brazil Creek is a mixed cation carbonate/bicarbonate type. Dissolved-solids concentrations in Brazil Creek upstream from areas of old and recent mining ranged from 31 to 99 milligrams per liter with a mean of 58 milligrams per liter, whereas concentrations downstream from the mine areas ranged from 49 to 596 milligrams per liter with a mean of 132 milligrams per liter. Water in Brazil and Rock Creeks had concentrations of cadmium, chromium, lead, and mercury that exceeded maximum contaminant levels established by the U.S. Environmental Protection Agency at least once during the 1979-81 water years. Maximum suspended-sediment discharge, in tons per day, was 2,500 for Brazil Creek and 3,318 for Rock Creek. Silt-clay particles (diameters less than 0.062 millimeter) were the dominant sediment size.

A significant hydrologic effect of surface mining is creation of additional water storage in mine ponds; one such pond supplies water for the town of Red Oak. Other effects or potential effects of surface mining include changes in rock permeability and ground-water storage, changes in drainage patterns, and changes in the chemical quality and sediment loads of streams.

INTRODUCTION

In order to make lease decisions and lease stipulations, the U.S. Bureau of Land Management is charged with evaluating the rehabilitation potential and assessing the probable water-resources impacts on 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. 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. One such area is in the vicinity of Red Oak in northeastern Latimer County (fig. 1) where coals in the McAlester Formation (McAlester and upper McAlester coals of Friedman and Woods, 1982) are potentially strippable. Other areas described in reports prepared under the EMRIA program include Blocker in northeastern Pittsburg County (Marcher and others, 1981), Stigler in north-central Haskell County (Marcher and others, 1983a), and Rock Island in northeastern Le Flore County (Marcher and others, 1983b).

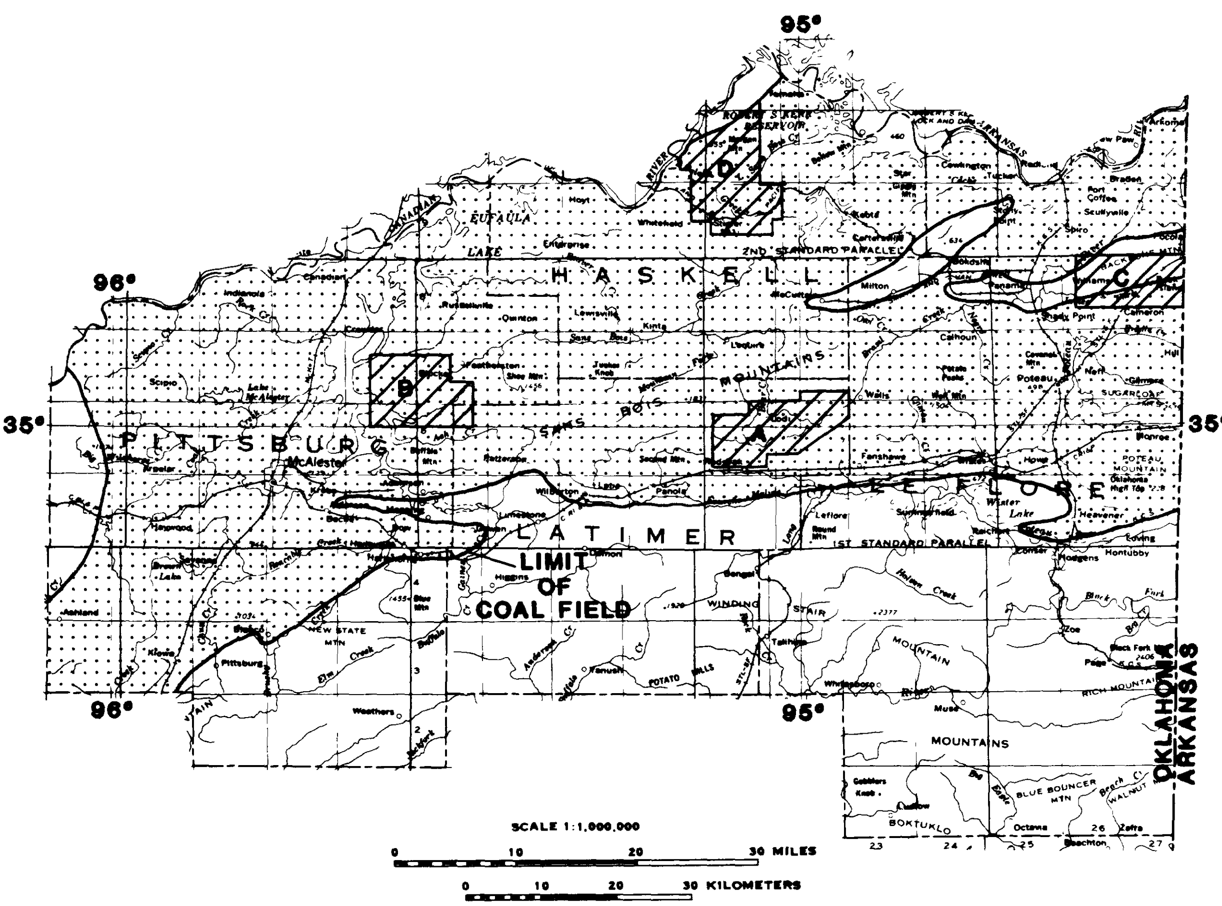


Figure 1. - Location of the Red Oak area and other areas studied under the EMRIA program: A, Red Oak area; B, Blocker area; C, Rock Island area; and D, Stigler area

Purpose and Scope

The purpose of this report is to describe the hydrology of Brazil Creek basin in the vicinity of Red Oak and to assess the potential hydrologic effects of surface mining based on data collected between October 1978 and September 1981. These data include: (1) Continuous or periodic measurement of stream discharge and analysis of periodic samples of water for chemical quality and sediment, (2) records of 103 wells including onsite determination of specific conductance and pH and laboratory determinations of chloride, iron, manganese, and sulfate in water from 51 wells, (3) detailed chemical analysis of water from 7 wells, (4) record of water level in one well completed in bedrock, and (5) record of precipitation at one site.

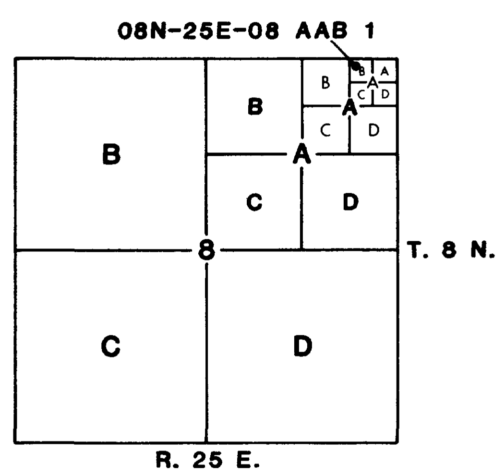
Information on the geology of the area, as related to the hydrology, is taken from a report by Hendricks (1939) supplemented by onsite observations and interpretation of logs of test holes drilled in 1979 by the U.S. Bureau of Reclamation under contract to the U.S. Bureau of Land Management.

Acknowledgments

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

Data-Site Numbering System

The standard method of describing the location of data-collection sites, such as wells, by fractional section, section, township, and range is replaced by the method 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. 8, T.8 N., R.25 E. By the method used in this report, quarter subdivisions are indicated by letters and the location of the site is given as 08N-25E-08 AAB 1. The final digit (1) is the sequential number of a well or site within the smallest fractional subdivision.



Geographic Setting and Climate

The Red Oak area is in the McAlester Marginal Hills Geomorphic Province (Johnson and others, 1972) and is in the Arkoma geologic basin. In this area, the rocks have been moderately folded to form east-trending anticlines and synclines. The landscape is characterized by irregular hills and ridges which generally are capped by erosion-resistant sandstone and covered with brush and trees. The intervening broad valleys have been formed by weathering and erosion of thick, weakly-resistant shale and are vegetated with grasses, shrubs, weeds, and wildflowers. Much of the valley areas are pasture for livestock.

The area has a temperate, continental climate. Spring and autumn usually are mild and summer is hot. Winter is comparatively mild with an average temperature of about 43°F. Much of the rainfall results from short-duration thunderstorms of varying intensity, which are most common in spring and summer but can occur any month of the year. Based on records at Wilburton, the nearest long-term climatic station, the average annual precipitation is about 46 in. which is distributed as follows, in inches:

Jan.	1.9	May	5.5	Sept.	5.0
Feb.	2.6	Jun.	3.8	Oct.	3.9
Mar.	4.0	Jul.	4.4	Nov.	3.6
Apr.	5.3	Aug.	3.3	Dec.	3.0

GROUND WATER

Occurrence, Movement, and Storage

The occurrence, movement, and storage of ground water in the Red Oak area is controlled largely by the lateral and vertical distribution of rock units and their physical characteristics, especially permeability. Bedrock consists of shale, siltstone, and sandstone of the McAlester and Savanna Formations (pl. 1). Onsite observation, auger holes, and core-drill holes (table 1) show that much of the shale is thinly laminated to blocky, silty, and contains beds of silty sandstone a few inches to a few feet thick. These rocks are weathered to a depth of about 20 ft in some parts of the area. Sandstone units, which comprise about 25 percent of the total thickness of exposed rocks, actually consist of interbedded sandstone, siltstone, and shale. The sandstone layers are very fine to fine grained, are poorly to well cemented with silica and iron oxides, and contain thin layers or laminae of shale and siltstone.

Structurally, the area is dominated by the Brazil anticline (pl. 1) which trends easterly across the area. Because of the structure, the rocks are tilted at the surface exposing bedding planes between the layers of sandstone and shale; these bedding-plane openings are the main avenues of water entry and movement. Other openings for water movement are fractures and joints developed during folding of the brittle rocks.

Table 1. - Lithologic logs of test holes
(Logged by W. L. Witt, U.S. Bureau of Reclamation)

Lithology	Depth (feet)	Thickness (feet)
06N-21E-16 CCC 1		
Alluvium		
Sand, clayey	1.5	1.5
McAlester Formation		
Shale, decomposed to intensely weathered	12	10.5
Shale, clayey to silty	36.4	24.4
Coal	38.3	1.9
Shale and sandstone, interbedded	45	6.7
Shale, clayey to silty	104	59
Coal	106.8	2.8
Shale, clayey to silty	120	13.2
06N-21E-23 AAB 1		
McAlester Formation		
Shale, decomposed to intensely weathered	13	13
Shale, fissile to thin bedded	47.1	34.1
Coal	47.5	.4
Shale	51	3.5
Coal	51.3	.3
Shale and siltstone, interbedded	138.8	87.5
Coal	140.8	2
Shale with some siltstone	151.5	10.7
06N-22E-18 DCC 1 (completed as a water-level observation well)		
Alluvium		
Clay, sandy	1.5	1.5
McAlester Formation		
Shale, decomposed	9	7.5
Shale, weathered	16	7
Shale, clayey to silty	123.1	107.1
Coal	123.9	.8
Shale, clayey to silty	129.6	5.7
Coal	129.9	.3
Shale, clayey to silty	138.5	8.6

The openings provided by bedding planes, fractures, and joints are limited in size, number, and extent, thus the rocks have limited storage capacity and permeability. Nevertheless, wells ranging in depth from 10 to 299 ft (table 2) and averaging about 77 ft yield enough water for domestic and stock supplies. Wells penetrating bedrock in various parts of the coal field generally yield less than 5 gal/min and many yield only a fraction of that amount (Marcher, 1969); similar yields can be expected in the Red Oak area.

Unconfined conditions probably prevail in the zone of weathered bedrock. Water in bedrock below the weathered zone is confined and, because of the confining pressure, rises in wells so that in most of the area the potentiometric surface is less than 20 ft below the land surface (table 2); a few wells flow at times. Because of differences in pressure in the various water-bearing openings, the altitude of the potentiometric surface in wells only a short distance apart may differ by as much as 10 ft.

Precipitation falling on and infiltrating rocks along the crest of the Brazil anticline tends to move down the flanks of that structure toward the valleys of Brazil and Bear Creeks (fig. 2) where the general direction of movement is downvalley coinciding with the slope of the land surface. The gradient of the potentiometric surface in the valley of Brazil Creek is about 10 ft/mi toward the east (pl. 2). Due to the low gradient and the limited permeability of the rocks, the rate of water movement must be very slow - probably only a few feet per year.

Alluvium along Brazil and Rock Creeks has a maximum thickness of about 15 ft and consists of sandy and clayey silt containing cobbles and boulders of sandstone. If water is present in the alluvium, it probably is unconfined. Wells in the alluvium might yield small volumes of water, but they would be likely to go dry during periods of no rainfall.

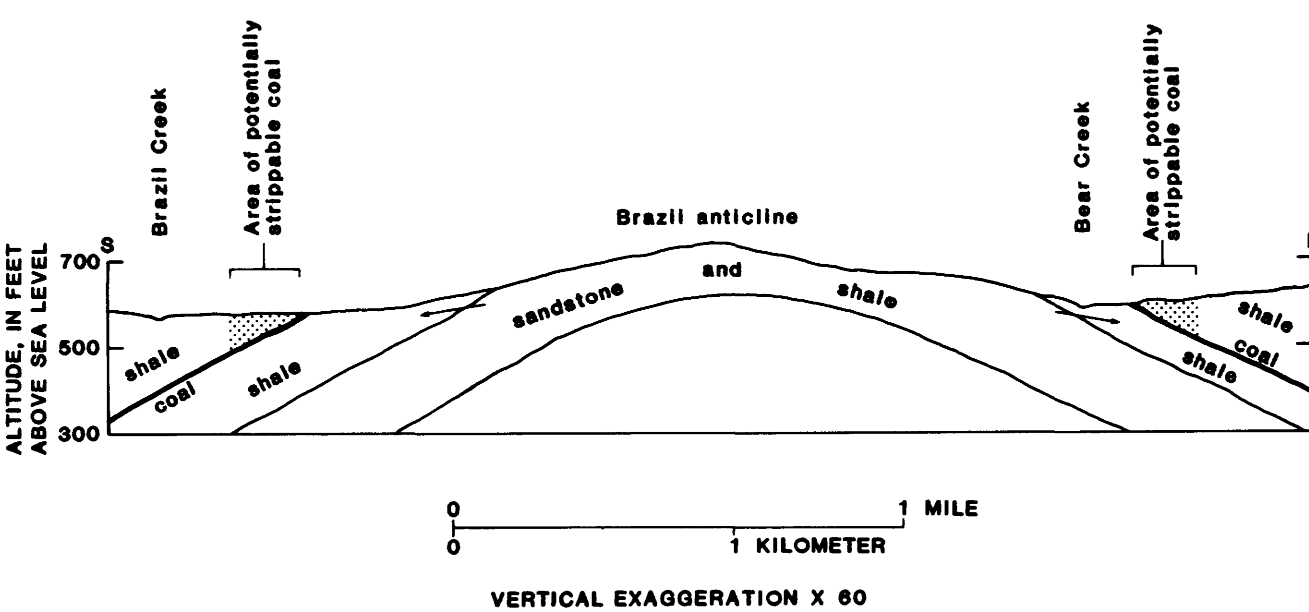


Figure 2. - Generalized geologic section of Brazil anticline, areas of potentially strippable coal, and local direction of ground-water movement (arrows)

Table 2. - Records of wells
(All wells are completed in the McAlester Formation)

Well location	Well depth (feet)	Well diameter (inches)	Depth to water (feet)	Date measured (month-year)	Use of water	Altitude of land surface (feet)
06N-21E-01 ADC 1	150	---	---	---	domestic	650
06N-21E-01 CBA 1	35	6	24	9-79	unused	670
06N-21E-01 CCC 1	---	---	---	---	stock	680
06N-21E-01 DCC 1	90	6	26	11-78	domestic	610
06N-21E-01 DCC 2	15	---	2	2-79	unused	610
06N-21E-02 CAB 1	218	6	23	2-79	domestic	720
06N-21E-02 DBC 1	14	14	8	2-79	domestic	695
06N-21E-08 DDA 1	86	6	14	2-79	domestic	660
06N-21E-09 CAD 1	43	6	19	2-79	unused	665
06N-21E-09 CCC 1	49	6	14	2-79	unused	660
06N-21E-09 DDA 1	82	5	14	2-79	unused	660
06N-21E-09 DDD 1	28	6	1	3-79	stock	645
06N-21E-09 DDD 2	41	5	2	3-79	unused	645
06N-21E-11 BAA 1	96	6	33	11-78	domestic	695
06N-21E-11 CCC 1	45	6	12	3-79	unused	700
06N-21E-12 ACB 1	24	6	2	2-79	unused	645
06N-21E-12 BDD 1	130	8	39	11-78	domestic	660
06N-21E-13 BCC 1	101	6	10	2-79	domestic	640
06N-21E-13 BCC 2	143	6	12	2-79	unused	635
06N-21E-13 BCC 3	54	6	20	2-79	domestic	630
06N-21E-14 AAA 1	81	8	11	2-79	domestic	670
06N-21E-14 BCC 1	39	6	13	3-79	domestic	640
06N-21E-14 BCC 2	70	6	3	3-79	domestic	640
06N-21E-14 BCD 1	38	6	13	3-79	domestic	660
06N-21E-15 BDD 1	233	8	56	2-79	domestic	640
06N-21E-15 CBB 1	14	6	1	3-79	unused	645
06N-21E-15 CBC 1	102	6	5	3-79	unused	625
06N-21E-16 ADC 1	40	6	15	2-79	domestic	640
06N-21E-16 ADD 1	200	6	32	2-79	unused	650
06N-21E-16 BDC 1	160	---	---	---	domestic	640
06N-21E-16 BDC 2	80	6	26	2-79	unused	640
06N-21E-16 BDD 1	118	6	23	2-79	domestic	640
06N-21E-16 BDD 2	71	6	25	2-79	unused	640
06N-21E-16 CAA 1	60	---	---	---	domestic	635
06N-21E-16 CCC 1	120	---	5	8-79	---	605
06N-21E-17 DBB 1	125	---	---	---	domestic	645
06N-21E-21 ABC 1	60	---	10	8-77	domestic	610
06N-21E-21 BAD 1	60	8	11	2-79	unused	600
06N-21E-21 BAD 2	24	6	11	2-79	unused	600
06N-21E-22 AAA 1	109	6	14	3-79	unused	600

Table 2. - Records of wells (continued)

Well location	Well depth (feet)	Well diameter (inches)	Depth to water (feet)	Date measured (month-year)	Use of water	Altitude of land surface (feet)
06N-21E-23 AAB 1	153	---	9	8-79	---	595
06N-21E-23 BAA 1	99	---	---	---	domestic	600
06N-21E-23 DDC 1	60	---	13	2-79	unused	600
06N-21E-24 AAC 1	104	---	24	8-77	domestic	575
06N-21E-24 BBB 1	70	---	4	8-77	domestic	580
06N-21E-24 BBB 2	46	---	2	8-77	domestic	575
06N-21E-24 BBB 3	43	6	5	2-79	domestic	580
06N-21E-24 BDA 1	25	6	17	2-79	unused	585
06N-22E-01 CDD 1	44	6	6	3-79	unused	535
06N-22E-01 CDC 1	38	6	6	3-79	unused	540
06N-22E-01 DAC 1	10	6	2	2-79	unused	560
06N-22E-01 DAD 1	36	6	17	2-79	unused	565
06N-22E-02 BAA 1	84	6	45	2-79	domestic	585
06N-22E-02 BAA 2	299	6	18	3-79	unused	585
06N-22E-02 BAB 1	265	---	---	---	domestic	560
06N-22E-02 BAD 1	65	6	3	3-79	unused	535
06N-22E-02 CBB 1	35	6	2	3-79	unused	545
06N-22E-03 ABA 1	48	6	4	3-79	domestic	550
06N-22E-03 ABA 2	50	8	6	3-79	unused	550
06N-22E-03 CCC 1	50	---	---	---	domestic	560
06N-22E-04 CAD 1	107	6	4	2-79	unused	590
06N-22E-04 DBB 1	44	8	11	11-78	stock	595
06N-22E-04 DCB 1	161	6	32	2-79	domestic	580
06N-22E-04 DCB 2	46	6	19	2-79	unused	580
06N-22E-04 DCC 1	46	6	10	2-79	domestic	570
06N-22E-04 DDC 1	60	8	34	11-78	domestic	560
06N-22E-05 BAC 1	48	6	21	11-78	domestic	640
06N-22E-05 BAC 2	35	6	22	2-79	domestic	645
06N-22E-05 BAD 1	64	6	12	2-79	domestic	645
06N-22E-05 DDB 1	175	6	60	2-79	unused	620
06N-22E-05 DDC 1	79	6	1	2-79	unused	620
06N-22E-07 ACD 1	53	6	3	2-79	domestic	660
06N-22E-07 ACD 2	79	8	18	2-79	unused	660
06N-22E-07 ACD 3	120	---	---	---	domestic	660
06N-22E-07 ADD 1	120	---	---	---	domestic	630
06N-22E-07 BDD 1	103	6	35	3-79	domestic	685
06N-22E-07 CBB 1	72	---	45	7-78	domestic	680
06N-22E-08 ACD 1	17	6	12	11-78	domestic	570
06N-22E-08 ADC 1	29	6	6	2-79	unused	560
06N-22E-09 BBB 1	144	6	25	11-78	domestic	580

Table 2. - Records of wells (continued)

Well location	Well depth (feet)	Well diameter (inches)	Depth to water (feet)	Date measured (month-year)	Use of water	Altitude of land surface (feet)
06N-22E-09 BCC 1	26	6	Flowing	2-79	unused	555
06N-22E-11 BDD 1	30	6	3	3-79	unused	545
06N-22E-14 BBB 1	57	6	5	2-79	unused	560
06N-22E-14 BBC 1	92	6	32	11-78	domestic	565
06N-22E-15 AAA 1	95	6	4	2-79	unused	565
06N-22E-15 ABB 1	26	6	12	11-78	domestic	545
06N-22E-15 ABB 2	63	6	13	2-79	domestic	550
06N-22E-15 BAB 1	85	---	---	---	domestic	580
06N-22E-15 BBD 1	90	8	---	---	domestic	580
06N-22E-15 BCD 1	58	6	14	3-79	domestic	570
06N-22E-15 BDB 1	200	6	---	---	domestic	580
06N-22E-15 BDC 1	103	6	55	2-79	domestic	585
06N-22E-15 CBB 1	43	6	3	2-79	unused	565
06N-22E-16 ADA 1	48	6	10	11-78	domestic	555
06N-22E-16 ADD 1	24	6	8	2-79	unused	555
06N-22E-16 CCB 1	50	6	13	2-79	unused	565
06N-22E-16 DBD 1	125	6	15	2-79	domestic	570
06N-22E-16 DCA 1	50	6	20	2-79	unused	590
06N-22E-18 DCC 1	138	6	8	8-79	---	570
06N-22E-20 ABB 1	50	6	1	2-79	unused	580
06N-22E-20 BAA 1	105	6	1	2-79	unused	585
07N-22E-33 DDA 1	56	8	12	11-78	domestic	570
07N-22E-34 DDC 1	54	---	21	11-78	domestic	550

Recharge and Discharge

Ground-water recharge is derived entirely from precipitation falling directly on or near the area. Measurements in various parts of the coal field show that water levels, which reflect the amount of water in storage, typically are highest in spring or early summer indicating that most recharge occurs during that period. Evapotranspiration during the summer growing season removes water from storage and intercepts recharge causing water levels to decline until they reach seasonal lows in late summer or autumn. Intermittent rains of several inches in the summer when evapotranspiration is greatest do not have any significant effect on the general downward trend of the water level. The annual fluctuation of the water level in the Red Oak area generally is less than 10 ft (fig. 3) as it is throughout the coal field.

Virtually all ground-water discharge is by evapotranspiration. Evapotranspiration in the Red Oak area probably is about the same as in the Blocker area, 25 mi northwest of Red Oak, where it has been estimated at 80 percent of the annual precipitation (Marcher and others, 1981). The percentage varies from year to year, however, depending on climatic conditions.

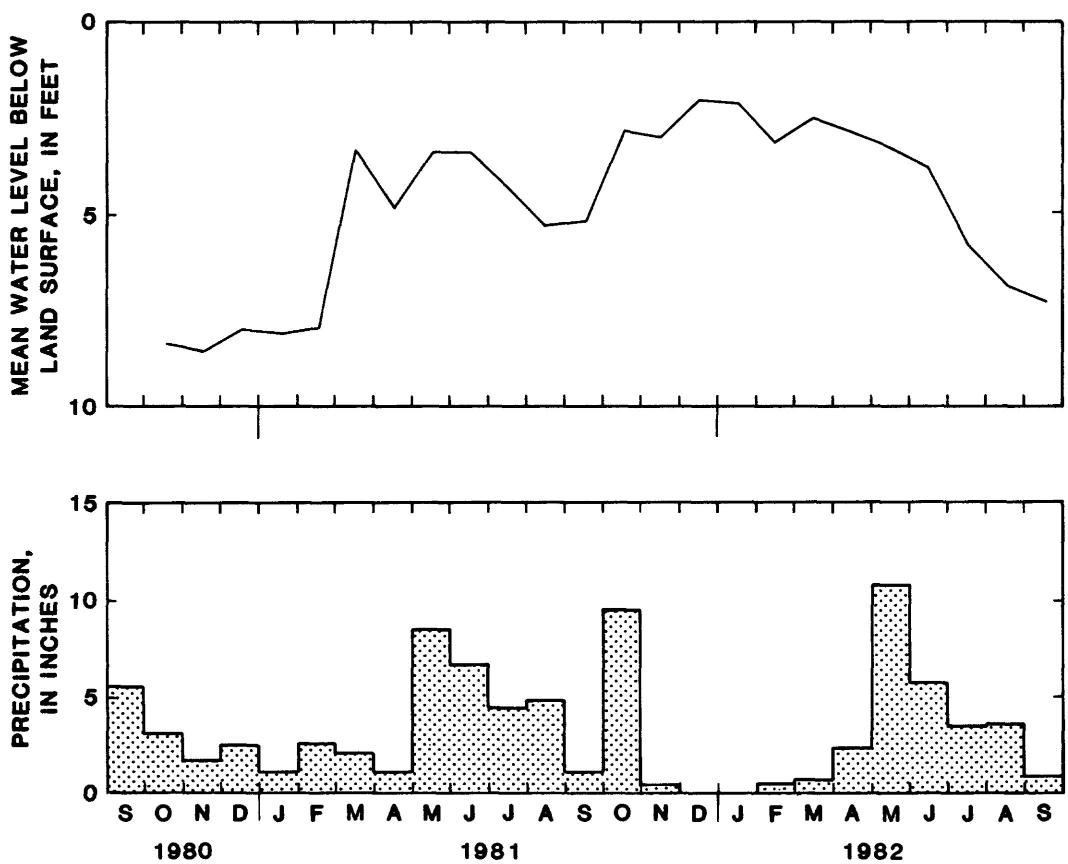


Figure 3. - Water-level hydrograph of well 06N-22E-18 DCC 1 and precipitation at Red Oak

SURFACE WATER

Information regarding surface-water sites in the Red Oak area are summarized below and their locations are shown on plate 2. A continuous recording gage was operated at the station on Brazil Creek near Walls; periodic discharge measurements and observations of no flow were made at the other sites. Streamflow data for all four stations are given in tables 3-6.

Station number	Stream name	Drainage area (square miles)	Period of record
07249080	Brazil Creek near Walls	69.1	1978-81
07249073	Brazil Creek near Lodi	--	1980-81
07249070	Rock Creek near Red Oak	12.0	1978-81
07249060	Brazil Creek near Red Oak	2.74	1978-81

Streamflow Characteristics

Most streamflow in the Red Oak area results from direct storm runoff and return flow from temporary bank storage. The hydrograph of Brazil Creek near Walls (fig. 4), which shows the distribution of runoff for the 1979 water year, is typical of most small streams in the Oklahoma coal field. Maximum discharge normally occurs in spring and early summer when thunderstorms are more common and before evapotranspiration reaches the high levels of summer. Minimum streamflow normally occurs in late summer and early autumn when rainfall is at minimum and evapotranspiration is greatest.

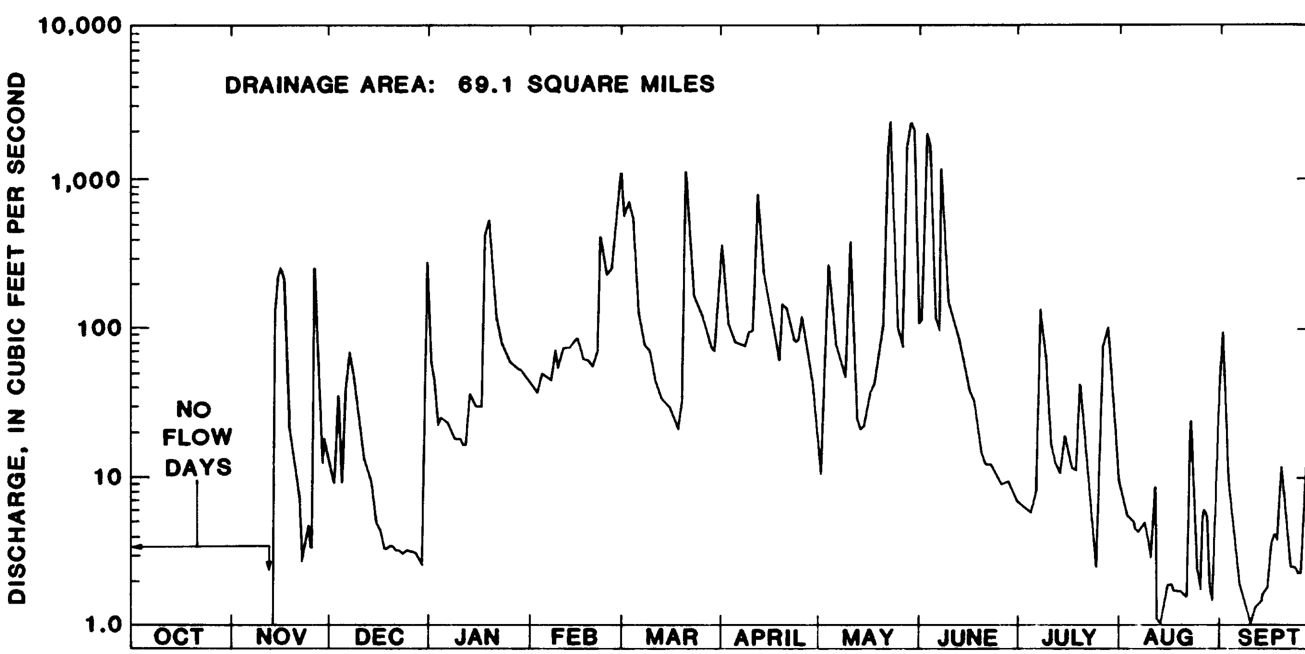


Figure 4. - Hydrograph of mean daily discharge of Brazil Creek near Walls (station 07249080)

Table 3. - Discharge of Brazil Creek near Walls (station 07249080)

LOCATION.--Lat 35°01'21", long 94°56'39", in SW 1/4, NW 1/4, sec. 1, T.6 N., R.22 E., Latimer County, Hydrologic Unit 11110105, at county road bridge, 2.2 mile southwest of Walls and at mile 32.2.

DRAINAGE AREA.--69.1 square miles.

PERIOD OF RECORD.--October 1978 to September 1981.

GAGE.--Water-stage recorder. Altitude of gage is 642 feet above National Geodetic Vertical Datum of 1929, from topographic map.

Water Year October 1978 to September 1979
Mean discharge, in cubic feet per second

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.00	0.00	11	80	40	530	266	10	116	6.6	8.7	93
2	.00	.00	8.9	44	38	658	118	40	1,940	6.3	6.0	18
3	.00	.00	36.9	22	36	681	93	262	1,590	6.0	5.1	8.3
4	.00	.00	9.6	25	50	526	82	182	322	5.5	5.1	5.1
5	.00	.00	37	24	48	255	77	86	114	5.3	4.4	3.3
6	.00	.00	41	23	46	123	76	69	95	7.7	4.2	2.2
7	.00	.00	68	20	43	84	75	54	1,160	129	4.4	1.7
8	.00	.00	49	18	70	73	73	45	286	88	4.9	1.5
9	.00	.00	28	18	52	70	95	46	151	56	3.3	1.2
10	.00	.00	19	18	67	60	94	360	124	18	2.8	1.1
11	.00	.00	13	16	73	46	776	69	96	13	8.7	1.3
12	.00	.00	12	17	73	36	521	24	84	11	1.2	1.4
13	.00	.00	10	36	73	32	241	20	62	10	1.0	1.4
14	.00	122	6.5	31	80	31	170	21	46	19	1.4	1.7
15	.00	220	4.8	29	87	29	129	26	38	16	1.9	1.7
16	.00	253	4.2	29	67	26	97	36	36	12	1.9	3.5
17	.00	207	3.2	29	60	22	71	39	31	11	1.7	4.2
18	.00	26	3.2	412	61	20	57	53	21	11	1.7	3.5
19	.00	17	3.4	542	56	31	143	71	14	42	1.7	12
20	.00	12	3.4	364	54	1,080	135	111	12	23	1.6	6.6
21	.00	8.0	3.2	120	67	448	107	1,440	12	12	1.5	4.4
22	.00	2.6	3.2	87	400	235	82	2,340	12	6.3	24	2.5
23	.00	3.4	2.9	77	351	162	78	788	11	3.2	8.7	2.2
24	.00	4.8	3.1	67	224	146	81	161	9.7	2.5	2.6	2.2
25	.00	3.4	3.2	60	238	130	117	91	8.7	2.5	1.7	2.3
26	.00	256	3.1	57	358	108	81	73	9.0	54	6.0	5.5
27	.00	96	3.1	54	569	89	60	1,620	9.4	91	5.5	27
28	.00	12	2.8	53	1,040	73	46	2,300	8.7	102	1.8	1.9
29	.00	18	2.5	50	---	69	26	2,030	7.7	33	1.4	2.8
30	.00	14	4.6	47	---	160	16	800	6.8	16	3.9	1.5
31	.00	---	249	43	---	361	---	108	---	13	38	---
TOTAL	.00	1,275.2	651.9	2,512	4,421	6,394	4,083	13,375	6,433	831.9	166.8	225.3
MEAN	.000	42.5	21.0	81.0	158	206	136	431	214	26.8	5.38	7.51
MAXIMUM	.00	256	249	542	1,040	1,080	776	2,340	1,940	129	38	93
MINIMUM	.00	.00	2.5	16	36	20	16	10	6.8	2.5	1.0	1.1
INCHES	.00	.69	.35	1.35	2.38	3.44	2.20	7.20	3.46	.45	.09	.12
ACRE-FEET	.00	2,530	1,290	4,980	8,770	12,680	8,100	26,530	12,760	1,650	331	447

WATER YEAR 1979 TOTAL 40,369.10 MEAN 111 MAXIMUM 2,340 MINIMUM 0.00 INCHES 21.73 ACRE-FEET 80.070

Table 3. - Discharge of Brazil Creek near Walls (station 07249080) (continued)

Water Year October 1979 to September 1980
Mean discharge, in cubic feet per second

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	1.4	31	2.1	5.4	5.2	3.6	35	237	10	0.86	0.04	0.00
2	1.4	12	2.0	5.0	4.9	3.6	26	933	7.2	.60	.04	.00
3	1.5	7.7	2.0	4.2	3.8	3.2	25	662	5.5	.82	.32	.00
4	2.1	7.7	1.9	3.7	3.5	3.0	20	113	4.5	1.3	.25	.00
5	1.9	4.6	1.9	3.1	3.7	2.7	17	62	4.6	.46	.17	.00
6	1.5	1.8	1.7	3.2	3.2	3.0	12	42	3.3	.33	.12	.00
7	1.3	1.7	1.7	3.0	3.4	3.0	11	28	3.0	.25	.09	.00
8	1.1	1.8	1.7	2.6	59	2.5	11	18	2.6	.18	.09	.00
9	1.0	1.8	2.0	2.7	86	2.5	9.8	14	2.3	.19	.05	.00
10	1.0	2.2	2.5	3.0	40	3.1	7.3	11	2.0	.20	.03	.00
11	1.0	1.8	2.3	3.3	37	2.1	7.7	8.4	1.9	.23	.00	.00
12	1.0	1.6	2.2	2.9	32	5.2	6.9	7.0	1.7	.16	.00	.00
13	1.0	1.6	20	3.1	30	5.1	5.5	7.3	1.5	.12	.00	.00
14	1.0	1.6	15	3.1	27	4.3	5.4	6.2	1.5	.11	.00	.00
15	.98	1.6	11	2.7	26	3.2	5.8	53	1.5	.11	.00	.00
16	.96	1.5	9.4	2.8	23	1.9	5.5	638	1.4	.09	.00	.00
17	.92	1.5	8.0	2.9	17	7.1	5.9	99	1.5	.08	.00	.00
18	.90	1.5	6.6	2.6	14	9.6	5.5	56	2.7	.07	.00	.00
19	.88	1.7	5.7	2.4	13	8.3	6.8	81	1,570	.05	.00	.00
20	.86	1.8	4.9	2.9	12	6.6	5.0	52	193	.04	.00	.00
21	.86	7.4	4.1	4.0	11	5.1	3.3	56	82	.04	.00	.00
22	.84	25	3.6	6.1	8.4	5.0	4.5	134	34	.03	.00	.00
23	.84	5.0	6.6	5.4	7.9	53	3.3	82	18	.02	.00	.00
24	.84	3.5	38	6.6	7.3	311	2.6	52	13	.00	.00	.00
25	.84	3.0	30	6.2	6.1	91	3.2	33	7.9	.00	.00	---
26	.84	2.7	19	5.3	5.3	54	5.5	23	5.6	.00	.00	.00
27	.84	2.6	14	4.6	4.6	37	6.2	16	5.1	.04	.00	.00
28	.84	2.5	11	4.2	4.1	35	5.5	12	3.1	.05	.00	.00
29	.84	2.4	8.6	5.6	3.6	60	4.8	12	2.2	.05	.00	.00
30	41	2.2	7.0	5.7	---	91	8.7	13	1.1	.05	.00	.00
31	124	---	5.8	5.6	---	53	---	13	---	.04	.00	---
TOTAL	196.28	144.8	252.3	123.9	502.0	878.7	281.7	3,573.9	1,993.7	6.57	1.20	.00
MEAN	6.33	4.83	8.14	4.00	17.3	28.3	9.39	115	66.5	.21	.039	.000
MAXIMUM	124	31	38	6.6	86	311	35	933	1,570	1.3	.32	.00
MINIMUM	.84	1.5	1.7	2.4	3.2	1.9	2.6	6.2	1.1	.00	.00	.00
INCHES	.11	.08	.14	.07	.27	.47	.15	1.92	1.07	.00	.00	.00
ACRE-FEET	389	287	500	246	996	1,740	559	7,090	3,950	13	2.4	.00

WATER YEAR 1980 TOTAL 7,955.05 MEAN 21.7 MAXIMUM 1,570 MINIMUM 0.00 INCHES 4.28 ACRE-FEET 15,780

Table 3. - Discharge of Brazil Creek near Walls (station 07249080) (continued)

Water Year October 1980 to September 1981
Mean discharge, in cubic feet per second

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	0.00	0.81	0.55	0.76	1.9	209	35	75	116	171	18	2.1
2	.00	.70	.89	.64	2.1	68	26	36	85	62	12	1.9
3	.00	.56	.66	.61	1.5	48	21	17	73	33	6.9	.94
4	.00	.38	.73	.55	1.4	305	22	12	52	17	3.9	.66
5	.00	.29	.87	.48	1.6	104	17	33	217	12	2.3	.49
6	.00	.27	.85	.49	1.6	58	14	33	2,060	12	1.9	.40
7	.00	.38	1.1	.46	1.4	41	13	22	1,400	34	21	.42
8	.00	.35	218	.40	1.4	34	11	39	240	20	5.7	.43
9	.00	.24	143	.39	1.8	30	11	1,150	111	14	4.6	.41
10	.00	.16	43	.42	74	25	10	1,920	67	10	3.7	.37
11	.00	.10	26	.40	49	21	7.8	356	49	7.0	2.7	.29
12	.00	.05	18	.40	26	18	7.1	142	39	5.0	2.0	.29
13	.00	.00	14	.36	18	17	6.0	116	30	4.1	1.5	2.3
14	.00	.00	10	.46	15	15	5.4	382	31	3.7	1.2	92
15	.00	.00	7.4	.51	12	14	5.2	137	25	3.1	1.2	37
16	.00	.01	5.5	.54	11	15	4.2	81	271	2.6	1.0	17
17	.00	.46	4.9	.51	9.2	17	3.9	64	114	2.1	12	5.0
18	.00	1.7	4.0	.52	7.9	18	3.6	50	56	1.5	28	2.2
19	.16	3.0	3.3	.47	6.8	17	5.5	35	37	1.3	7.3	1.4
20	.35	2.1	4.0	.59	5.8	18	4.8	27	26	2.0	2.6	1.1
21	.35	1.4	4.4	.62	5.2	16	3.9	21	18	1.2	1.6	.86
22	.29	.89	4.2	.58	4.7	15	8.0	16	14	.81	1.1	.81
23	.29	.77	3.3	.51	4.3	13	63	14	11	.69	.95	.56
24	.27	.54	3.1	.48	3.6	12	29	281	8.4	.59	.87	.43
25	.27	.39	2.5	.52	3.1	11	15	121	6.5	.60	.77	.38
26	.24	.32	1.8	.58	3.1	9.1	9.8	91	7.0	.65	.70	.75
27	6.6	.29	1.7	.56	4.1	8.2	7.0	54	13	.54	8.9	1.1
28	4.9	.27	1.4	.58	170	7.3	5.9	65	9.5	1.1	6.6	10
29	3.6	.41	1.2	.74	---	135	19	356	11	12	5.1	2.8
30	1.8	.40	1.3	.93	---	100	18	1,030	8.3	21	3.7	1.1
31	1.2	---	.93	1.1	---	54	---	243	---	15	2.9	---
TOTAL	20.32	17.24	532.58	17.16	447.5	1,472.6	412.1	7,019	5,205.7	471.58	172.69	185.49
MEAN	.66	.57	17.2	.55	16.0	47.5	13.7	226	174	15.2	5.57	6.18
MAXIMUM	6.6	3.0	218	1.1	170	305	63	1,920	2,060	171	28	92
MINIMUM	.00	.00	.55	.36	1.4	7.3	3.6	12	6.5	.54	.70	.29
INCHES	.01	.01	.29	.01	.24	.79	.22	3.78	2.80	.25	.09	.10
ACRE-FEET	40	34	1,060	34	888	2,920	817	13,920	10,330	935	343	368

WATER YEAR 1981 TOTAL 15,973.96 MEAN 43.8 MAXIMUM 2,060 MINIMUM 0.00 INCHES 8.60 ACRE-FEET 31,680

Table 4. - Discharge of Brazil Creek near Lodi (station 07249073)

LOCATION.--Lat 34°59'28", long 95°00'24", NE 1/4, SW 1/4, sec. 24, T.6 N., R.22 E., Latimer County, Hydrologic Unit 11110105.

PERIOD OF RECORD.--May 1980 to September 1981.

Date	Time	Discharge (cubic feet per second)
	Water Year October 1979 to September 1980	
Jun. 18	1655	0.51
Jun. 20	1255	46.9
Jul. 24	1235	.00
Aug. 23	--	.00
Sept. 17	0950	.00
	Water Year October 1980 to September 1981	
Oct. 1	1350	.09
Oct. 28	1605	1.57
Nov. 13	1420	.01
Dec. 22	1620	1.28
Jan. 26	1640	.35
Feb. 21	1500	3.02
Mar. 19	1630	5.97
Apr. 15	1550	2.11
May 13	1700	23.5
Jun. 18	1200	17.9
Jul. 17	1240	.70
Aug. 20	1450	.49
Sept. 11	1550	.05

Table 5. - Discharge of Rock Creek near Red Oak (station 07249070)

LOCATION.--Lat 34°59'30", long 95°04'56", NE 1/4, SW 1/4, sec. 15, T.6 N., R. 21 E., Latimer County, Hydrologic Unit 11110105.

DRAINAGE AREA.--12.0 square miles.

PERIOD OF RECORD.--October 1978 to September 1981.

Date	Time	Discharge (cubic feet per second)
	Water Year October 1978 to September 1979	
Oct. 17	1530	0.00
Nov. 8	1700	.00
Nov. 21	1155	1.36
Dec. 12	1315	1.48
Jan. 31	1257	5.08
Feb. 28	1258	155
May 21	1725	1,040
May 22	1220	354
Jun. 20	1610	.94
Aug. 29	1145	.01
Sept. 26	1450	.00
	Water Year October 1979 to September 1980	
Oct. 4	1130	.00
Oct. 25	0920	.00
Nov. 27	1720	.57
Dec. 6	1155	.49
Jan. 10	1150	7.24
Feb. 14	0920	6.25
May 22	1450	285
Jul. 24	1320	.00
Aug. 13	0825	.00
Sept. 17	1015	.00
	Water Year October 1980 to September 1981	
Oct. 1	1124	.00
Oct. 23	1700	.08
Dec. 26	1118	.58
Jan. 27	1230	.18
Feb. 19	1020	1.99
Mar. 20	1520	3.56
Mar. 25	1220	2.22
Mar. 26	1240	1.95
Apr. 14	1125	1.15
May 15	1240	25.7
Jun. 11	1225	7.52
Jul. 16	1500	.21
Aug. 20	1032	.12
Sept. 11	1320	.02

Table 6. - Discharge of Brazil Creek near Red Oak (station 07249060)

LOCATION.--Lat 34°59'03", long 95°07'06", on north line SW 1/4, sec. 17, T.6 N., R.21 E., Latimer County, Hydrologic Unit 11110105.

DRAINAGE AREA.--2.74 square miles.

PERIOD OF RECORD.--October 1978 to September 1981.

Date	Time	Discharge (cubic feet per second)
	Water Year October 1978 to September 1979	
Nov. 21	0940	0.23
Dec. 12	1500	.30
Jan. 31	0915	56
Feb. 28	1015	37.4
May 21	1545	270
Aug. 9	1425	.14
Aug. 29	1030	.00
	Water Year October 1979 to September 1980	
Oct. 25	0945	.05
Feb. 14	1440	1.77
May 23	1050	3.81
Jul. 24	1350	.00
Aug. 13	--	.00
	Water Year October 1980 to September 1981	
Oct. 23	1525	.05
Sept. 19	1205	.00
Nov. 12	1310	.01
Dec. 26	1520	.05
Jan. 27	1630	.01
Feb. 19	1245	.24
Mar. 20	1120	.26
Mar. 26	1540	.13
Apr. 14	1330	.11
May 15	1535	1.95
Jun. 11	1525	1.09
Jul. 16	1200	.05
Aug. 20	1230	.02
Sept. 11	1140	.01

The flow-duration curve for Brazil Creek (fig. 5) shows that during the 1979-81 water years, the stream flowed about 85 percent of the time and that discharge exceeded about 8 ft^3/s for 50 percent of the time. The average annual yield of Brazil Creek upstream from the Walls gaging station was 0.85 $(ft^3/s)/mi^2$.

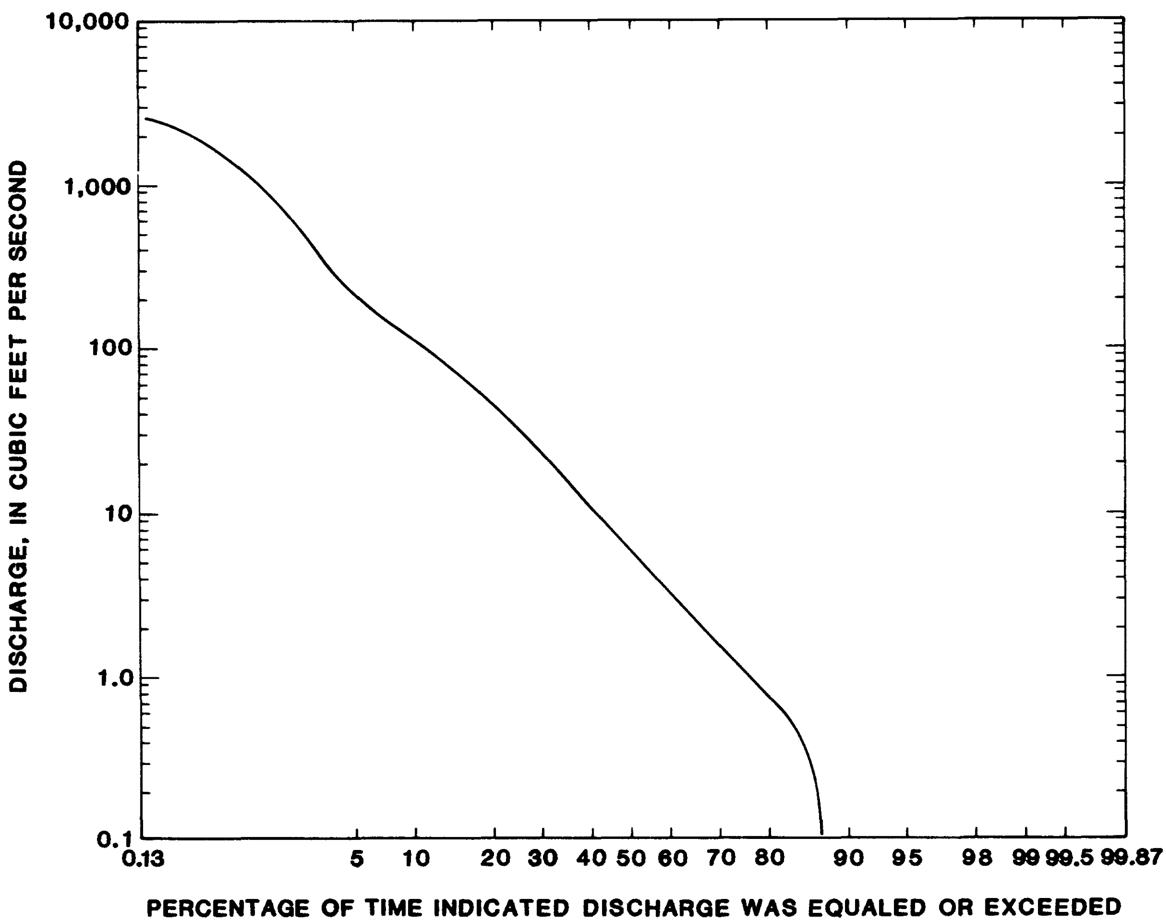


Figure 5. - Flow-duration curve for Brazil Creek near Walls (station 07249080)

For the 1980 water year, cumulative runoff for Brazil Creek (fig. 6) was about 8.5 in./mi^2 or about 24 percent of the rainfall recorded at Red Oak about 8 mi from the stream gage at Walls. The peak flow of Brazil Creek near Walls for the period of record was 3,610 ft^3/s on May 27, 1979.

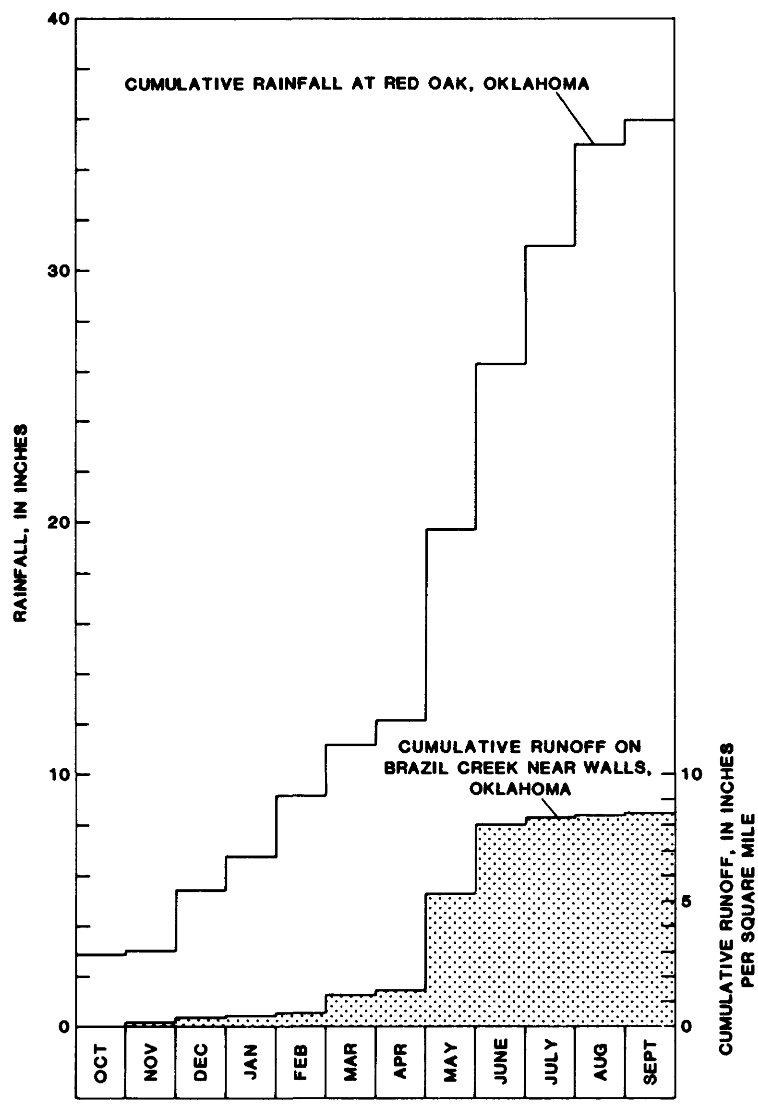


Figure 6. - Comparison of cumulative annual runoff of Brazil Creek near Walls (station 07249080) to cumulative annual rainfall at Red Oak

Flood Frequencies

Data on the magnitude and frequency of floods to be expected in an area are needed for engineering design of safe and economical structures such as culverts, sediment ponds, embankments, and dams. Regulations stemming from the "Surface Mining Control and Regulation Act of 1977" (Public Law 95-87) refer in particular to the 2-year, 24-hour and the 10-year, 24-hour rainfall for the design of temporary and permanent structures, respectively. Although rainfall is the primary cause of floods, no exact correlation exists between the amount of rainfall and the resulting flood discharge.

Flood-frequency estimates for ungaged, unregulated rural basins in Oklahoma can be obtained by use of equations which were developed for this purpose (Sauer, 1974, and Thomas and Corley, 1977). These equations, which were developed by use of flood data from long-term streamflow-gaging stations, utilize annual rainfall, drainage basin area, and stream-channel slope to estimate flood-peak magnitude and probability of occurrence or recurrence interval. Probability of occurrence is the percent chance of a given flood magnitude being exceeded in any 1 year. Recurrence interval is the reciprocal of the probability of occurrence times 100 and is the average number of years between exceedances. For instance, a flood having a probability of occurrence of 1 percent has a recurrence interval of 100 years. This does not mean that each 100 years this flood will be exceeded, but that it will be exceeded on the average once every 100 years; in fact, it may be exceeded in successive years. Flood-frequency estimates for Brazil Creek near Walls and Rock Creek near Red Oak are given in table 7 and illustrated by figure 7.

Table 7. - Flood frequency and magnitude for Brazil Creek near Walls (station 07249080) and Rock Creek near Red Oak (station 07249070)

Flood frequency (years)	Discharge (cubic feet per second)	Basin characteristics
	Brazil Creek near Walls	
2	4,900	Drainage area: 69.1 mi^2
5	8,130	
10	11,000	10/85 channel slope: 9.98 ft/mi 1/
25	14,500	
50	17,000	Annual precipitation: 46.5 in.
100	20,500	
	Rock Creek near Red Oak	
2	2,110	Drainage area: 12.0 mi^2
5	3,600	
10	4,910	10/85 channel slope: 39.5 ft/mi
25	6,570	
50	7,800	Annual precipitation: 46.5 in.
100	9,330	

1/ 10/85 channel slope is the mean slope between elevations at points 10 and 85 percent of the distance along the stream channel from the gaging station to the drainage divide.

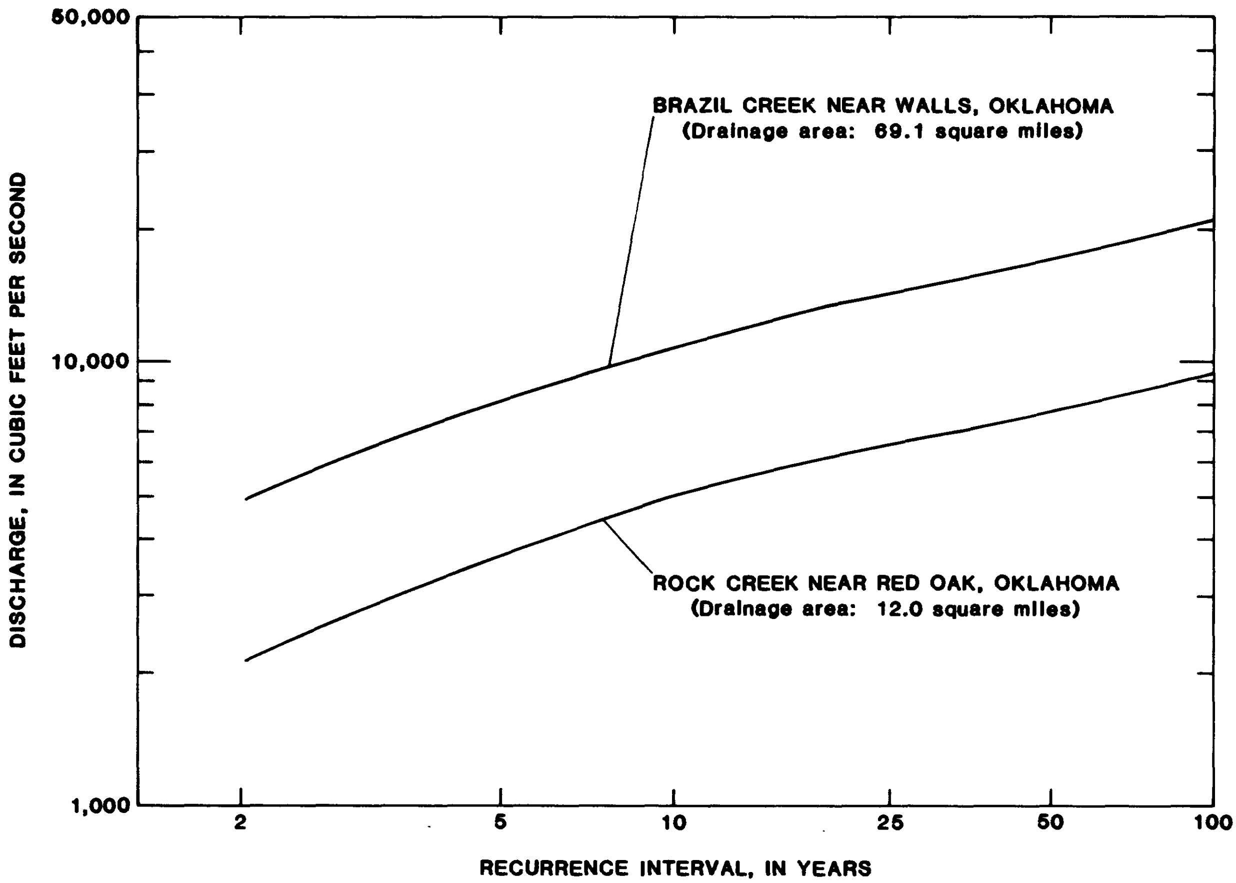


Figure 7. - Flood-frequency curves for Brazil Creek near Walls (station 07249080) and Rock Creek near Red Oak (station 07249070)

Flood-Prone Areas

Heavy rainfall during intense storms results in streamflows that inundate the floodplains adjacent to streams. 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 computations of flood depths for various recurrence intervals. Flood depths for rural, unregulated streams can be estimated by use of equations developed for this purpose (Thomas, 1976). These equations use the contributing drainage area and the 2-year, 24-hour rainfall to estimate flood depths. The approximate 100-year recurrence interval flood depths were computed for Brazil, Jefferson, Bear, and Rock Creeks, and the boundaries were drawn on the topographic map of the Red Oak area (pl. 3).

WATER QUALITY

All natural waters contain mineral constituents dissolved from the rocks and soil with which they have been in contact. The concentrations of dissolved constituents largely depend on the type of rock or soil, 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 or fuel production may have significant effects on the chemical quality of surface and ground waters.

The Red Oak area is rural with no industrial development or waste-disposal systems. Septic tanks commonly are used for domestic waste disposal. Cutting of hay is the principal agricultural activity. Harvesting of trees for lumber or firewood is not significant. Several producing natural gas wells have been drilled in the area, but as far as is known, they do not produce salt water. Coal has been surface mined in the area since the 1930's and as of 1973, approximately 480 acres had been disturbed by mining (Johnson, 1974); mining was active during the period of data collection for this study.

In natural waters, the major cations--calcium, magnesium, and sodium plus potassium--and the major anions--carbonate/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, if calcium constitutes more than 50 percent of the cations and sulfate constitutes more than 50 percent of the anions, the water is classified as calcium sulfate type. If none of the cations or anions constitute more than 50 percent of its respective ion group, the water is classed as a mixed type.

Ground Water

Onsite determination of specific conductance and pH and laboratory determinations of chloride, sulfate, iron, and manganese were made on water from 51 wells (table 8). Water from seven of these wells, ranging in depth from 40 to 233 ft, was analyzed for common constituents and selected trace metals (table 9).

The concentration of dissolved solids may limit the use of water for some purposes. Specific conductance of water from the 51 wells, which ranged from 70 to 3,500 µmho (micromhos per centimeter at 25° Celsius) and had a median of 800 µmho, provides a means of estimating the dissolved-solids concentration. The average ratio of measured dissolved-solids concentration to the specific conductance in the Red Oak area, as determined from laboratory analyses, was 0.60. Thus, an approximation of the dissolved-solids concentration, in milligrams per liter, can be obtained by multiplying the specific conductance by 0.60.

Concentrations of dissolved solids determined in the laboratory ranged from 321 to 714 mg/L (milligrams per liter) and had a median of 475 mg/L. Values for pH, determined at the well sites, ranged from 5.5 to 8.7; water from nine wells, or 16 percent, had a pH of less than 7. Concentrations of chloride exceeded 250 mg/L in water from two wells and concentrations of sulfate exceeded 250 mg/L in water from three wells. None of the ground-water samples had concentrations of the toxic elements arsenic, chromium, lead, or mercury exceeding the maximum contaminant levels established by the U.S. Environmental Protection Agency (1976).

Table 8. - Specific conductance, pH, chloride, sulfate, iron, and manganese in water from wells

[μmho, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; Q, chemical analysis in table 9]

Well location	Well depth (feet)	Specific conductance (μmho)	pH (units)	Dissolved constituents: Chloride (mg/L)	Sulfate (mg/L)	Iron (μg/L)	Manganese (μg/L)	Remarks
06N-21E-01 ADC 1	150	480	7.9	27	18	130	20	
06N-21E-01 CBA 1	35	800	7.2	32	131	30	50	
06N-21E-01 DCC 1	90	340	6.7	3	53	40	60	
06N-21E-01 DCC 2	15	200	6.0	17	26	140	10	
06N-21E-02 CAB 1	218	2,400	8.2	137	1,153	20	110	
06N-21E-02 DBC 1	14	---	5.5	4	16	260	10	
06N-21E-08 DDA 1	86	900	7.2	23	100	680	65	
06N-21E-09 CAD 1	43	650	7.0	92	28	770	615	
06N-21E-09 CCC 1	49	800	7.0	32	92	20	35	
06N-21E-09 DDA 1	82	340	6.7	43	16	30	30	
06N-21E-11 BAA 1	96	550	7.6	24	19	130	30	Q
06N-21E-12 ACB 1	24	440	7.4	12	9	280	200	
06N-21E-12 BDD 1	130	580	7.4	24	2	180	125	
06N-21E-13 BCC 1	101	800	7.1	19	31	700	200	Q
06N-21E-13 BCC 3	54	750	7.0	105	57	560	210	
06N-21E-14 AAA 1	81	700	6.9	36	2	40	110	
06N-21E-14 BCC 1	39	660	7.4	23	60	500	90	
06N-21E-15 BDD 1	233	930	8.6	75	5.3	50	8	Q
06N-21E-16 ADC 1	40	570	7.1	14	15	20	40	Q
06N-21E-16 ADD 1	200	650	7.8	14	22	80	10	
06N-21E-16 BDC 1	160	900	8.2	114	12	50	5	
06N-21E-16 BDD 1	118	850	8.4	43	15	60	20	
06N-21E-16 BDD 2	71	360	6.9	48	38	30	15	
06N-21E-16 CAA 1	60	540	6.9	31	81	30	45	
06N-21E-17 DBB 1	125	1,095	7.8	63	62	110	50	
06N-21E-21 ABC 1	60	150	---	2	13	60	5	
06N-21E-21 BAD 1	60	1,850	7.5	132	277	20	120	
06N-21E-21 BAD 2	24	2,000	7.3	184	684	30	20	
06N-21E-23 BAA 1	99	1,050	7.3	54	187	740	100	
06N-22E-02 BAB 1	265	1,500	8.4	16	5	100	5	
06N-22E-03 ABA 1	48	1,200	7.7	98	130	50	30	Q
06N-22E-03 CCC 1	50	1,250	7.9	72	75	50	50	
06N-22E-04 DCB 1	161	1,600	8.7	75	10	10	10	
06N-22E-04 DCC 1	46	3,500	7.1	262	1,412	50	150	
06N-22E-07 ACD 3	120	590	7.0	44	13	220	110	
06N-22E-07 ADD 1	120	900	7.9	40	16	60	45	
06N-22E-07 BDD 1	103	700	7.2	39	30	880	90	
06N-22E-07 CBB 1	72	820	6.7	48	8	320	605	
06N-22E-08 ACD 1	17	810	8.0	36	4	2,160	100	
06N-22E-14 BBC 1	92	600	7.4	52	87	90	30	
06N-22E-15 ABB 1	26	580	7.2	107	87	1,080	110	
06N-22E-15 ABB 2	63	1,000	7.3	98	98	530	100	Q
06N-22E-15 BAB 1	85	720	8.4	49	27	160	20	
06N-22E-15 BBD 1	90	860	7.4	23	112	100	30	
06N-22E-15 BCD 1	58	800	7.7	19	37	130	30	Q
06N-22E-15 BDB 1	200	700	8.2	23	12	70	10	
06N-22E-15 BDC 1	103	1,000	8.6	96	97	20	20	
06N-22E-16 ADA 1	48	620	8.3	55	10	70	20	
06N-22E-16 DBD 1	125	1,050	8.7	66	2	30	15	
07N-22E-34 DDC 1	54	1,300	8.5	168	0	130	5	

Table 9. - Quality of water from selected wells

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

Number on trilinear diagram (fig. 8)	1	2	3	4
Well number	06N-21E-11 BAA 1	06N-21E-13 BCC 1	06N-21E-15 BDD 1	06N-21E-16 ADC 1
Date sampled (year-month-day)	79-09-11	79-09-12	79-09-12	79-09-11
Depth of well (feet)	96	54	233	40
Water temperature (° Celsius)	22	16.5	18	16.5
Specific conductance (μmho)	550	800	930	570
Solids, dissolved (ROE) (mg/L)	338	396	529	321
Solids, dissolved (sum) (mg/L)	331	472	522	354
pH (units)	7.6	7.1	8.6	7.1
Alkalinity (mg/L as $CaCO_3$)	240	380	360	290
Hardness (mg/L as $CaCO_3$)	13	210	5	210
Hardness, noncarbonate (mg/L)	0	0	0	0
Calcium, dissolved (mg/L)	3.1	43	1.8	43
Magnesium, dissolved (mg/L)	1.2	26	.1	25
Sodium, dissolved (mg/L)	120	100	210	53
Potassium, dissolved (mg/L)	.7	1.5	.6	1.4
Chloride, dissolved (mg/L)	24	19	75	14
Fluoride, dissolved (mg/L)	.5	.3	.6	.3
Sulfate, dissolved (mg/L)	19	31	5.3	15
Silica, dissolved (mg/L)	18	22	12	22
Arsenic, dissolved (μg/L)	1	1	1	1
Chromium, dissolved (μg/L)	0	10	0	0
Copper, dissolved (μg/L)	1	0	1	4
Iron, dissolved (μg/L)	130	700	50	20
Lead, dissolved (μg/L)	0	0	3	5
Manganese, dissolved (μg/L)	30	200	8	40
Mercury, dissolved (μg/L)	.1	.0	.2	.1
Selenium, dissolved (μg/L)	0	0	0	0
Zinc, dissolved (μg/L)	20	4	10	100

Number on trilinear diagram (fig. 8)	5	6	7
Well number	06N-22E-03 ABA 1	06N-22E-15 ABB 2	06N-22E-15 BCD 1
Date sampled (year-month-day)	79-09-12	79-09-12	79-09-12
Depth of well (feet)	48	63	58
Water temperature (° Celsius)	18	18	17
Specific conductance (μmho)	1,200	1,000	800
Solids, dissolved (ROE) (mg/L)	714	684	338
Solids, dissolved (sum) (mg/L)	971	719	331
pH (units)	7.7	7.3	7.7
Alkalinity (mg/L as $CaCO_3$)	460	390	360
Hardness (mg/L as $CaCO_3$)	130	120	14
Hardness, noncarbonate (mg/L)	0	0	0
Calcium, dissolved (mg/L)	24	23	3.4
Magnesium, dissolved (mg/L)	17	16	1.3
Sodium, dissolved (mg/L)	220	230	180
Potassium, dissolved (mg/L)	1.7	1.5	.9
Chloride, dissolved (mg/L)	81	98	19
Fluoride, dissolved (mg/L)	.9	.6	.8
Sulfate, dissolved (mg/L)	130	98	37
Silica, dissolved (mg/L)	22	17	14
Arsenic, dissolved (μg/L)	1	1	1
Chromium, dissolved (μg/L)	10	10	10
Copper, dissolved (μg/L)	1	1	1
Iron, dissolved (μg/L)	50	530	130
Lead, dissolved (μg/L)	0	0	0
Manganese, dissolved (μg/L)	30	100	30
Mercury, dissolved (μg/L)	.1	.0	.1
Selenium, dissolved (μg/L)	0	0	0
Zinc, dissolved (μg/L)	190	3	3

The trilinear diagram (fig. 8) shows that water from five wells (1, 3, 5, 6, and 7) was a sodium carbonate/bicarbonate type. Water from wells 2 and 4 was a mixed cation carbonate/bicarbonate type. Sodium constituted more than 95 percent of the cations in water from wells 1, 3, and 7. This high percentage of sodium has no apparent relationship to well depths, which were 96, 233, and 58 ft, respectively. The low concentrations of chloride in the water preclude natural brine as a potential source of the sodium. Presumably, then, sodium is derived from the rocks with which the water has been in contact, but the geochemical reactions that might account for such sodium enrichment are not known.

In general, ground water in the Red Oak area is suitable for domestic and stock use. Variations in water type and constituent concentrations are comparable to those in the Blocker, Stigler, and Rock Island areas (Marcher and others, 1981, 1983a, and 1983b). No relationship between ground-water chemistry and well depth, geologic unit, or geographic distribution is apparent in any of the four areas.

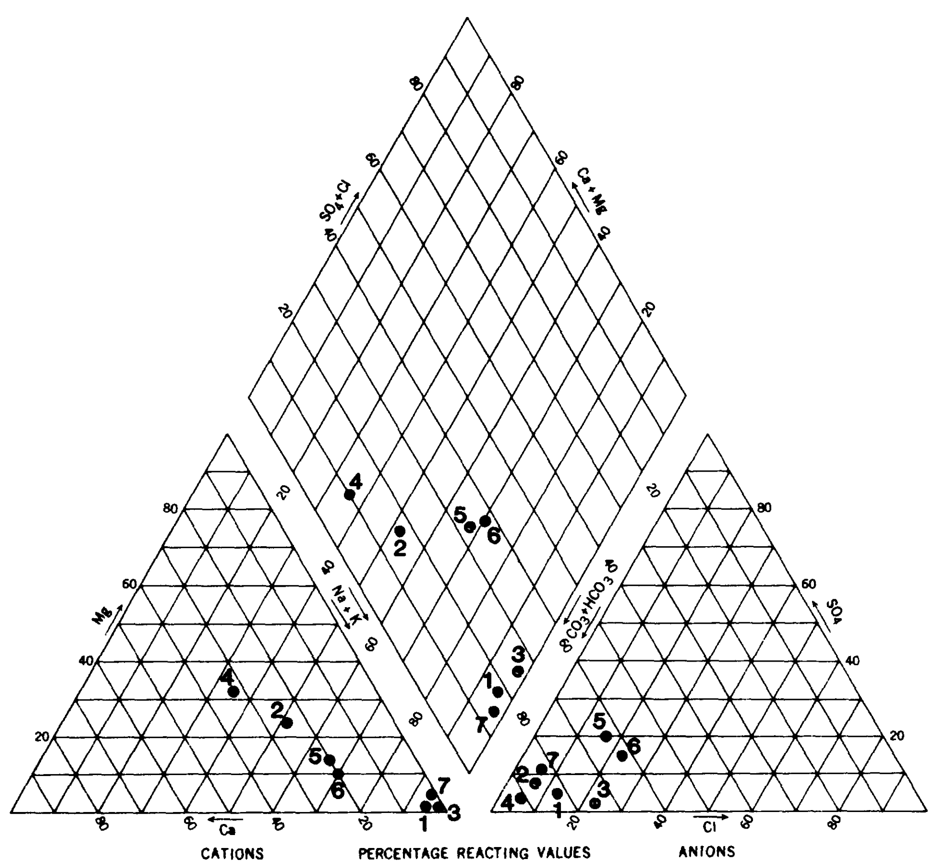


Figure 8. - Trilinear diagram of chemical constituents in water from selected wells. Numbers refer to analyses in table 9

Stream Water

As part of this study, water samples for chemical analysis were collected periodically from Brazil Creek near Red Oak (station 07249060), Rock Creek near Red Oak (station 07249070), and Brazil Creek near Walls (station 07249080). The results of the analyses are summarized in table 10.

Water Type and Constituent Concentrations

The trilinear diagram (fig. 9) of mean constituent values shows that water at all three stations is a mixed type. However, water from Brazil Creek near Walls tends toward a mixed cation carbonate/bicarbonate type.

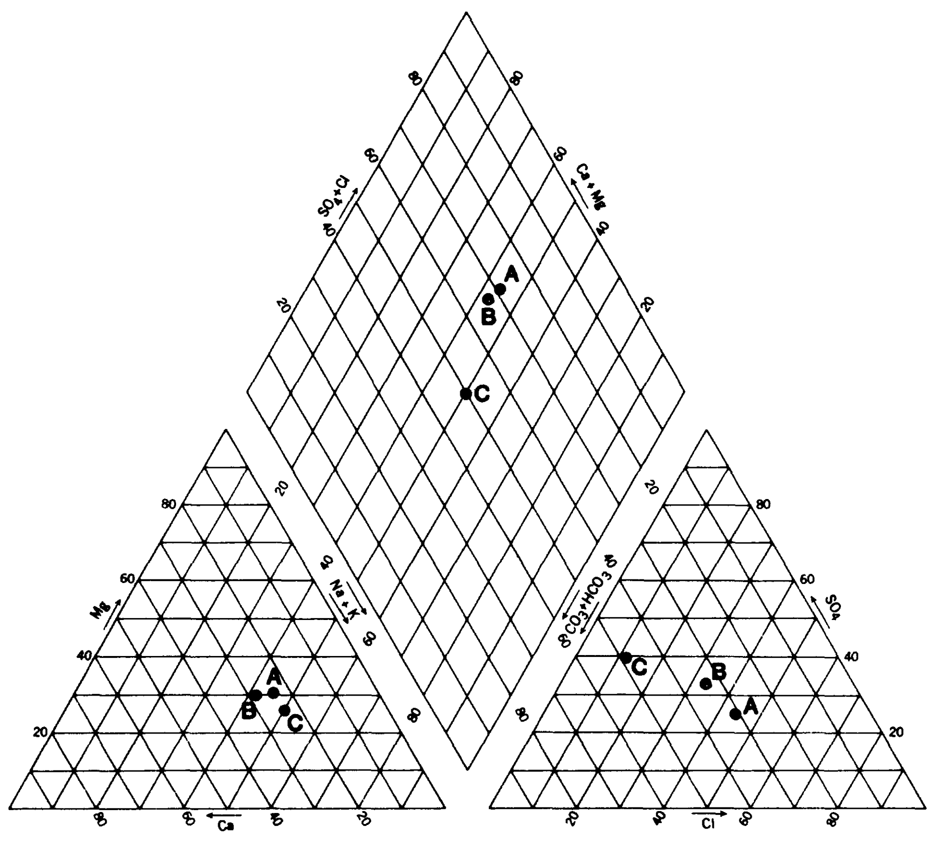


Figure 9. - Trilinear diagram of mean values of chemical constituents in water from Brazil and Rock Creeks; A, Brazil Creek near Red Oak; B, Rock Creek near Red Oak; C, Brazil Creek near Walls

Table 10. - Minimum, mean, and maximum values of selected physical properties and chemical constituents in water from Brazil and Rock Creeks

[A, Brazil Creek near Red Oak (station 07249060); B, Rock Creek near Red Oak (station 07249070); C, Brazil Creek near Walls (station 07249080); µmho, micromhos per centimeter at 25° Celsius; ROE, residue on evaporation at 180° Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter]

Physical characteristic or constituent	Number of analyses			Minimum			Mean			Maximum		
	A	B	C	A	B	C	A	B	C	A	B	C
Temperature (° Celsius)	41	43	48	1.0	2.0	0.0	15.5	15.4	15.6	30.5	35	31.5
Specific conductance (µmho)	40	43	48	23	29	46	79.5	68.9	190	125	120	820
Solids, dissolved (ROE)	26	30	29	31	34	49	58	50	132	99	86	596
Oxygen, dissolved (mg/L)	38	40	46	5	6.5	3.1	9.5	10	8.4	5	15	16
pH (units)	41	42	47	6	6.3	6.7	---	---	---	9.7	8.2	8.5
Alkalinity (mg/L as $CaCO_3$)	29	31	34	3	1	8	13.9	12.2	52	30	24	300
Bicarbonate (mg/L as HCO_3)	12	12	14	11	11	21	19.8	17.1	70	37	29	360
Carbonate (mg/L as CO_3)	12	12	14	0	0	0	0	0	0	0	0	0
Nitrogen, total (mg/L)	18	19	19	.13	.11	.47	.7	.6	1.1	2.4	1.9	2.9
Nitrogen, dissolved (mg/L)	20	20	22	.04	.11	.15	.4	.6	.8	1	1.5	1.7
Phosphate, total (mg/L)	4	5	4	.03	.03	.09	.1	.13	.14	.2	.2	.2
Phosphorus, total (mg/L)	22	22	23	0	.01	.01	.04	.05	.11	.3	.2	.9
Phosphorus, dissolved (mg/L)	21	19	21	.01	0	0	.02	.02	.02	.04	.05	.05
Hardness (mg/L as $CaCO_3$)	28	26	28	7	8	17	21.8	18.2	49.8	35	31	220
Hardness, noncarbonate (mg/L)	28	26	28	0	0	0	8.2	7.3	4.4	21	23	22
Calcium, dissolved (mg/L)	28	27	28	1.4	1.4	3	4.1	3.5	9.6	7	7	45
Magnesium, dissolved (mg/L)	30	29	30	.8	1	2	2.8	2.3	6.1	4.5	3.9	26
Sodium, dissolved (mg/L)	29	31	29	1.7	1.6	5	7.2	5.8	24	13	13	130
Potassium, dissolved (mg/L)	30	31	30	.6	.6	1.1	1.4	1.5	2.2	2	2.9	4.3
Chloride, dissolved (mg/L)	28	29	28	1.4	1.9	2.8	9.8	6.8	8	18	17	23
Sulfate, dissolved (mg/L)	28	27	28	5.2	3.5	7.8	10.7	10.4	35.7	20	23	220
Fluoride, dissolved (mg/L)	25	25	30	0	0	0	.06	.07	.12	.2	.4	.3
Silica, dissolved (mg/L)	30	31	30	5.4	4.6	2.4	9.2	8	7.1	19	12	10
Aluminum, dissolved (µg/L)	33	34	36	20	0	0	148	135	121	1,000	750	500
Aluminum, suspended (µg/L)	25	27	30	0	0	0	825	1,200	1,400	2,500	6,400	8,100
Aluminum, total (µg/L)	33	35	38	70	0	20	915	1,200	1,600	2,700	6,600	8,400
Arsenic, dissolved (µg/L)	23	26	35	0	0	0	.4	.5	1	2	1	3
Arsenic, suspended (µg/L)	27	27	30	0	0	0	.5	.7	.7	2	3	2
Arsenic, total (µg/L)	29	32	42	0	0	1	.7	1	1.4	2	4	3
Beryllium, dissolved (µg/L)	3	2	2	0	0	0	0	0	.5	0	0	1
Beryllium, suspended (µg/L)	4	3	2	0	0	0	0	0	0	0	0	0
Beryllium, total (µg/L)	11	11	10	0	0	0	.9	0	1	10	0	10
Boron, dissolved (µg/L)	30	26	39	0	5	20	31	34.4	78	180	170	370
Boron, suspended (µg/L)	24	24	29	0	0	0	21	21	39	50	50	570
Boron, total (µg/L)	27	27	32	20	0	40	47	44	112	90	80	630
Cadmium, dissolved (µg/L)	6	8	11	0	2	0	5.8	4	4.1	27	11	16
Cadmium, suspended (µg/L)	12	13	20	0	0	0	0	.6	2	0	8	19
Cadmium, total (µg/L)	24	26	27	0	0	0	1.3	1.8	5.6	19	13	60
Chromium, dissolved (µg/L)	24	24	25	0	0	0	2.5	4.6	3.6	20	60	30
Chromium, suspended (µg/L)	30	31	34	0	0	0	4.5	6.3	5	24	30	24
Chromium, total (µg/L)	24	25	28	0	0	0	6.4	9.8	9.3	24	30	24
Copper, dissolved (µg/L)	23	23	26	0	0	0	1.5	2.5	3	5	14	17
Copper, suspended (µg/L)	27	28	31	0	0	0	11.5	19.6	20	90	130	120
Copper, Total (µg/L)	27	25	28	0	0	0	15.7	25.3	26	92	130	120
Iron, dissolved (µg/L)	38	39	42	19	20	20	173	199	216	670	1,700	930
Iron, suspended (µg/L)	28	29	29	150	140	230	1,100	1,600	4,000	2,500	7,500	19,000
Iron, total (µg/L)	38	39	42	310	310	990	1,200	1,700	4,000	2,500	7,700	19,000
Lead, dissolved (µg/L)	24	25	27	0	0	0	13.1	8	7	260	82	95
Lead, suspended (µg/L)	27	28	31	0	0	0	12.2	7.9	14	100	100	100
Lead, total (µg/L)	24	24	27	0	0	0	23.5	13.2	30	200	100	200
Manganese, dissolved (µg/L)	32	32	42	0	7	30	15	21.2	163	70	90	1,000
Manganese, suspended (µg/L)	30	30	34	0	0	10	14.6	34.7	96	30	440	520
Manganese, total (µg/L)	33	39	42	0	0	40	29	48.5	255	90	530	1,300
Mercury, dissolved (µg/L)	27	27	31	0	0	0	.7	.9	.7	9.9	13	11
Mercury, suspended (µg/L)	30	31	33	0	0	0	.2	.2	.3	2.2	1.2	2.8
Mercury, total (µg/L)	30	32	34	0	0	0	.7	.7	.8	8.1	8.4	9.8
Molybdenum, dissolved (µg/L)	2	0	2	0	---	0	6.5	---	1.5	13	---	3
Molybdenum, suspended (µg/L)	14	14	18	0	0	0	0	0	0	0	0	0
Molybdenum, total (µg/L)	13	14	15	0	0	0	.6	.14	.5	4	1	2
Nickel, dissolved (µg/L)	11	11	10	0	0	0	2.1	1.7	2.4	6	4	5
Nickel, suspended (µg/L)	11	11	10	0	0	0	1.4	2	3.2	4	6	7
Nickel, total (µg/L)	11	11	10	0	2	3	3.2	3.6	5.6	9	7	9
Selenium, dissolved (µg/L)	23	24	28	0	0	0	0	.04	.2	0	1	2
Selenium, suspended (µg/L)	30	31	34	0	0	0	.03	.03	.06	1	1	1
Selenium, total (µg/L)	25	24	30	0	0	0	.08	.08	.3	1	1	2
Zinc, dissolved (µg/L)	25	26	23	3	3	3	12.8	13.6	17.3	60	110	100
Zinc, suspended (µg/L)	27	28	29	0	0	0	19.3	24.7	23.3	80	110	100
Zinc, total (µg/L)	30	33	37	0	10	10	29	35.4	139	110	130	3,900

Concentrations of dissolved solids in water from Brazil Creek near Red Oak ranged from 31 to 99 mg/L with a mean of 58 mg/L, whereas concentrations in water from Brazil Creek near Walls ranged from 49 to 596 mg/L with a mean of 132 mg/L. The ratios of increase in concentrations of calcium, magnesium, sodium, and potassium were approximately the same as for the dissolved solids, whereas sulfate and alkalinity more than doubled with a corresponding decrease in chloride.

Analysis of variance at the 95-percent probability level for data from all three stations showed that dissolved-solids, calcium, magnesium, sodium, potassium, alkalinity, and sulfate concentrations were not significantly different for Brazil Creek near Red Oak and Rock Creek near Red Oak and that concentrations of these constituents at both stations were significantly different from Brazil Creek near Walls. The analysis of variance also showed that chloride concentrations for Rock Creek near Red Oak and Brazil Creek near Walls were not significantly different and that concentrations at both these stations were significantly different from Brazil Creek near Red Oak.

Stream water normally tends to increase in dissolved-solids concentrations as it moves downstream, thus accounting for some of the increase between the station on Brazil Creek near Red Oak and the station near Walls. Minimum, mean, and maximum concentrations of dissolved solids in water from Rock Creek were nearly the same as that at Brazil Creek near Red Oak, consequently, Rock Creek did not contribute to the increase. Bear Creek, Jefferson Creek, and an unnamed creek flow into Brazil Creek about 4, 2, and 0.7 mi, respectively, upstream from the sampling site near Walls. These tributaries may have accounted for some of the increase in dissolved constituents but no water-quality data are available for any of them. The principal area of recent surface mining is in sec. 17, T.6 N., R.22 E. near the confluence of Bear and Brazil Creeks. Runoff from the mined area may have contributed to the dissolved solids as determined at the station near Walls.

Toxic Elements

Of the toxic elements arsenic, cadmium, chromium, lead, and mercury, all except arsenic exceeded the maximum contaminant levels established for interim primary drinking water standards (U.S. Environmental Protection Agency, 1976) in either the dissolved or suspended phase at least once (table 11). The sources of these elements are not known. Both Rock Creek near Red Oak and Brazil Creek near Walls drain areas of old or recent mining. However, no mining has been done upstream from the Brazil Creek near Red Oak, thus the presence of toxic elements in the water at this site cannot be attributed to mining. Because of the excessive levels of toxic elements at times, water in Brazil and Rock Creeks is not suitable for public supply.

The recommended limits of toxic elements in livestock water are: arsenic, 200 µg/L; cadmium, 50 µg/L; chromium, 1,000 µg/L, lead, 100 µg/L; and mercury, 10 µg/L (National Academy of Sciences and National Academy of Engineering, 1974). The limits for arsenic, cadmium, and chromium were not exceeded at any of the stations during the sampling period. The limits for lead and mercury were exceeded at times in Brazil Creek near Walls and Rock Creek near Red Oak (table 11) but no information is available as to the effect, if any, on livestock drinking the water.

Table 11. - Concentrations of cadmium, chromium, lead, and mercury in water from Brazil and Rock Creeks exceeding maximum contaminant levels for public water supplies (U.S. Environmental Protection Agency, 1976)

[All values in micrograms per liter (µg/L). Maximum contaminant levels are: cadmium, 10 µg/L; chromium, 50 µg/L; lead, 50 µg/L; and mercury, 2 µg/L]

Date	Cadmium			Chromium		
	Dissolved	Suspended recoverable 1/	Total recoverable 2/	Dissolved	Suspended recoverable 1/	Total recoverable 2/
			Brazil Creek near Red Oak (station 07249060)			
11-21-78	27	---	19	---	---	---
			Rock Creek near Red Oak (station 07249070)			
11-21-78	11	---	9	---	---	---
12-12-78	7	---	13	---	---	---
08-29-79	---	---	---	60	0	<20
04-17-80	2	8	10	---	---	---
			Brazil Creek near Walls (07249080)			
11-29-78	<2	---	13	---	---	---
12-07-78	5	---	13	---	---	---
04-15-78	1	19	20	---	---	---
05-30-78	<1	---	10	---	---	---
06-19-78	0	10	10	---	---	---
07-24-80	3	7	10	---	---	---
08-13-80	<1	---	60	---	---	---

Date	Lead			Mercury		
	Dissolved	Suspended recoverable 1/	Total recoverable 2/	Dissolved	Suspended recoverable 1/	Total recoverable 2/
			Brazil Creek near Red Oak (station 07249060)			
11-21-78	260	---	200	---	---	---
06-21-78	---	---	---	8.9	.0	7.3
07-11-78	---	---	---	9.9	.0	8.1
12-06-79	10	90	100	---	---	---
01-10-80	---	---	---	0	2.2	2.2
10-01-80	---	---	---	6	94	100
			Rock Creek near Red Oak (station 07249070)			
11-21-78	82	---	80	---	---	---
12-12-78	78	---	<200	---	---	---
06-20-79	---	---	---	8.9	.0	7.5
07-11-79	---	---	---	13	.0	8.4
08-29-79	---	---	---	1.3	1.2	2.5
02-14-80	0	100	100	---	---	---
03-25-80	0	100	100	---	---	---
04-17-80	---	---	---	---	---	---
			Brazil Creek near Walls (07249080)			
11-29-78	95	---	200	---	---	---
12-07-78	54	---	140	---	---	---
06-20-79	---	---	---	5.8	2.8	8.6
07-11-79	---	---	---	11	.0	9.8
08-23-79	---	---	---	2.4	---	---
01-09-80	0	100	100	---	---	---
02-13-80	0	100	100	---	---	---
03-19-80	0	100	100	---	---	---
06-19-80	0	100	100	---	---	---

1/ Suspended, recoverable is the amount of a given constituent that is in solution after the part of a representative water-suspended sample that is retained on a 0.45-µm membrane filter has been digested by a method (usually using a dilute acid solution) that results in dissolution of only readily soluble substances.

2/ Total, recoverable is the amount of a given constituent that is in solution after a representative water-suspended sediment sample has been digested by a method (usually using a dilute acid solution that results in dissolution of only readily soluble substances.

Aluminum, Iron, and Manganese

The mean dissolved aluminum and iron concentrations were not significantly different at the three stations, whereas the mean concentrations of dissolved manganese at Brazil Creek near Walls was about eight times as great as that for Rock Creek near Red Oak and Brazil Creek near Red Oak. The mean concentration of suspended iron at Brazil Creek near Walls was about two times as great as that at Rock Creek near Red Oak and four times as great as that at Brazil Creek near Red Oak. The mean concentration of suspended manganese at Brazil Creek near Walls was about three times as great as that at Rock Creek near Red Oak and about six times as great as that at Brazil Creek near Red Oak. To summarize, these data show that dissolved manganese, suspended iron, and suspended manganese increase significantly between the sampling sites upstream and downstream from areas of old and recent surface mining.

Suspended Sediment and Streambed Materials

The quantity and characteristics of suspended sediment transported by a stream are affected by many interrelated environmental conditions. Major conditions are quantity and intensity of precipitation, soil characteristics, land cover and use, and length and degree of slope. In the Red Oak area, about one-third of the annual precipitation falls during thunderstorms of varying intensity in spring and early summer; the largest sediment loads can be expected during this time.

The two major soil associations in Brazil Creek basin are the Lee-Philo-Pope and the Hector-Linker-Enders (Brinlee and Wilson, 1981). Lee-Philo-Pope soils are alluvial and occur in nearly level to gently-sloping bottomlands. The surface cover is predominantly grass used for pasture. Lee and Philo soils have silty loam surface layers and silty clay loam subsoils. Pope soils consist of sandy loam throughout the profile. The Hector-Linker-Enders association consists of loamy soils in gently sloping to steep areas generally under forest cover. Hector soils have shallow profiles whereas Linker soils have deep profiles; both were formed primarily from sandstone. Enders soils were formed from shales and have deep profiles.

Suspended-sediment samples from streams in the Red Oak area were collected irrespective of stream stage, either rising or falling, and seldom corresponded to peak discharge. The frequency of sampling was periodic. Samples were taken with a depth-integrating sampler, usually at several verticals in the stream cross section. Each vertically-sampled zone extended from the water surface to about 0.3 ft above the streambed, a limit established by nozzle and sample shape. Suspended-sediment concentration is the velocity-weighted concentration in the sampled zone expressed as milligrams of dry sediment per liter of water-sediment mixture. Suspended-sediment discharge is expressed in tons per day.

The relationship between stream discharge and suspended-sediment discharge is fairly well defined for Brazil Creek near Walls (fig. 10) and Rock Creek near Red Oak at discharges greater than 10 ft^3/s although additional samples at discharges greater than 100 ft^3/s would be desirable. The relationship at Brazil Creek near Red Oak is not well defined because of the lack of data at discharges greater than 15 ft^3/s. Some scatter of the data points on the graph is attributed to plotting data provided by samples collected during both rising and falling stages. Under such conditions, such scatter is not unrealistic because rising-stage discharge would be expected to transport significantly more sediment than falling-stage discharge. Also, some scatter is inherent with low-flow sampling. Suspended-sediment data are summarized in table 12 and all available data given in tables 13-15.

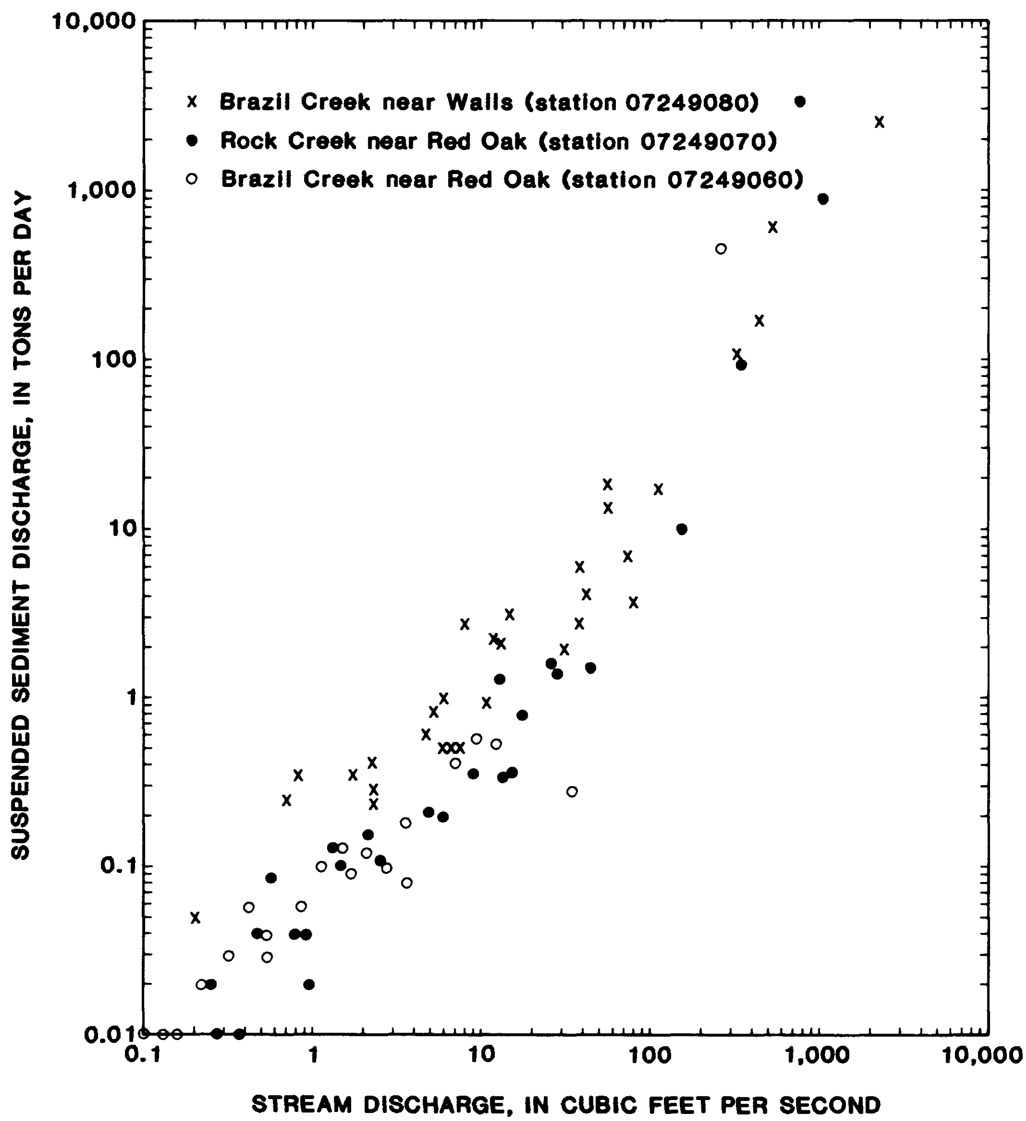


Figure 10. - Relationship between stream discharge and suspended-sediment discharge

Table 12. - Summary of suspended-sediment data

[A, Brazil Creek near Red Oak (station 07249060); B, Rock Creek near Red Oak (station 07249070); C, Brazil Creek near Walls (station 07249080)]

Sediment characteristic	Number of determinations			Minimum			Median			Maximum		
	A	B	C	A	B	C	A	B	C	A	B	C
Suspended-sediment concentration (milligrams per liter)	40	41	47	4	5	17	20	16	62	612	1,590	413
Suspended-sediment discharge (tons per day)	40	41	47	0	0	0	.02	.10	2.1	446	3,318	2,500
Suspended-sediment sieve diameter (percent finer than 0.062 millimeter)	40	41	47	65	74	73	94	90	97	99	99	100

Table 13. - Suspended-sediment data for Brazil Creek near Walls (station 07249080)

Date	Instantaneous streamflow (cubic feet per second)	Suspended-sediment concentration (milligrams per liter)	Suspended-sediment discharge (tons per day)	Percent of suspended sediment finer than 0.062 millimeter
		Water Year October 1978 to September 1979		
Nov. 29	23	75	4.7	98
Dec. 19	5.3	58	.83	99
Jan. 31	43	34	4	94
Feb. 07	39	26	2.7	88
Feb. 22	530	413	591	95
Mar. 07	81	17	3.7	96
Mar. 21	331	120	107	94
Apr. 05	76	34	7	100
Apr. 18	57	86	13	76
May 02	39	56	5.9	100
May 23	450	139	169	95
Jun. 05	117	54	17	100
Jun. 20	12	68	2.2	96
Jul. 10	11	316	9.4	97
Aug. 08	6	63	1	97
Aug. 23	57	118	18	96
Sept. 12	.72	129	.25	73
Sept. 27	15	77	3.1	96
		Water Year October 1979 to September 1980		
Oct. 03	1.8	72	.35	95
Oct. 25	.81	154	.34	98
Nov. 07	.20	86	.05	98
Nov. 29	2.4	44	.28	99
Dec. 05	2.4	36	.23	97
Dec. 20	2.4	62	.40	96
Jan. 09	7.1	26	.50	98
Jan. 24	4.6	50	.62	96
Feb. 13	31	23	1.9	97
Mar. 19	8	125	2.7	99
Apr. 15	6.6	28	.5	99
May 30	13	60	2.1	96
Jun. 19	2,300	402	2,500	97
Jul. 24	.01	71	0	92
Aug. 13	6	30	.49	94
Sept. 17	.0	---	---	---
		Water Year October 1980 to September 1981		
Oct. 29	3.2	82	.71	99
Dec. 22	4.5	28	.34	98
Jan. 26	.62	27	.05	97
Feb. 21	5.5	43	.64	99
Mar. 19	18	62	3	99
Apr. 15	5.3	43	.62	96
May 13	74	49	9.8	96
May 24	395	264	282	96
May 24	250	114	77	97
Jun. 7	1,280	159	550	95
Jun. 11	50	60	8.1	98
Jul. 15	3.4	42	.39	97
Aug. 14	1.3	92	.32	99
Sept. 4	.76	47	.10	96

Table 14. - Suspended-sediment data for Rock Creek near Red Oak (station 07249070)

Date	Instantaneous streamflow (cubic feet per second)	Suspended-sediment concentration (milligrams per liter)	Suspended-sediment discharge (tons per day)	Percent of suspended sediment finer than 0.062 millimeter
	Water Year October 1978 to September 1979			
Nov. 21	1.4	34	.13	99
Dec. 12	1.5	24	.10	93
Dec. 19	.98	8	.02	94
Jan. 31	5.1	15	.21	76
Feb. 07	2.6	16	.11	81
Feb. 28	155	25	10	90
Mar. 08	14	9	.34	87
Mar. 21	45	12	1.5	84
Apr. 05	16	8	.35	91
Apr. 19	9.4	14	.36	74
May 02	18	16	.78	78
May 21	1,040	320	899	74
May 22	354	100	96	75
Jun. 05	26	23	1.6	96
Jun. 20	.94	17	.04	87
Jul. 11	.38	13	.01	84
Aug. 09	.25	26	.02	91
Aug. 29	.01	68	.00	96
Sept. 13	.16	18	.01	96
Nov. 04	.00	---	---	---
Nov. 25	.00	---	---	---
	Water Year October 1979 to September 1980			
Nov. 07	.57	58	.09	98
Nov. 29	.98	---	---	---
Dec. 06	.49	33	.04	98
Dec. 20	5.5	---	---	---
Jan. 10	7.2	23	.45	94
Jan. 24	2.2	27	.16	80
Feb. 14	6.3	12	.20	96
Mar. 25	13	38	1.3	90
Apr. 17	.81	17	.04	95
May 22	28	19	1.4	90
Jun. 18	.28	19	.01	79
Jun. 19	773	1,590	3,318	98
Jul. 24	.00	---	---	---
Aug. 13	.00	---	---	-----
Sept. 17	.00	---	---	---
	Water Year October 1980 to September 1981			
Oct. 29	.08	11	.0	86
Dec. 26	.58	9	.01	89
Jan. 27	.17	5	.0	89
Feb. 19	2.0	6	.03	98
Mar. 20	3.6	7	.07	91
Mar. 26	2.0	7	.04	89
Apr. 14	1.2	9	.03	96
May 15	26	14	.98	96
Jun. 11	7.5	14	.28	94
Jul. 16	.21	13	.01	96
Aug. 20	.12	11	.0	86
Sept. 11	.02	11	.0	89

Table 15. - Suspended-sediment data for Brazil Creek near Red Oak (station 07249060)

Date	Instantaneous streamflow (cubic feet per second)	Suspended-sediment concentration (milligrams per liter)	Suspended-sediment discharge (tons per day)	Percent of suspended sediment finer than 0.062 millimeter
	Water Year October 1978 to September 1979			
Nov. 21	0.23	25	0.02	99
Dec. 12	.30	16	.01	88
Dec. 19	.36	10	.01	99
Jan. 31	.56	18	.03	84
Feb. 08	.50	27	.04	80
Feb. 28	37	28	2.8	96
Mar. 08	2.9	13	.10	77
Mar. 21	13	15	.53	83
Apr. 05	3.9	8	.08	99
Apr. 19	1.6	29	.13	98
May 02	.90	25	.06	94
May 21	270	612	446	65
Jun. 05	10	21	.57	92
Jun. 21	.34	34	.03	95
Jul. 11	.43	55	.06	97
Aug. 09	.14	21	.01	86
Sept. 13	.10	21	.01	86
Nov. 04	.00	---	---	---
Nov. 25	.00	---	---	---
	Water Year October 1979 to September 1980			
Nov. 08	.08	31	.01	96
Nov. 29	7.3	21	.41	96
Dec. 06	.08	20	0	94
Dec. 20	.54	25	.04	92
Jan. 10	.12	18	0	92
Jan. 24	1.2	32	.10	99
Feb. 14	1.8	18	.09	91
Mar. 25	2.2	21	.12	91
Apr. 17	.01	10	0	99
May 23	3.8	19	.19	94
Jun. 18	.01	21	---	85
Jul. 24	.00	---	---	---
Aug. 13	.00	---	---	---
Sept. 17	.00	---	---	---
	Water Year October 1980 to September 1981			
Oct. 23	.05	14	.0	98
Nov. 12	.01	20	.0	92
Dec. 26	.05	8	.0	90
Jan. 27	.01	4	.0	85
Feb. 19	.24	11	.01	94
Mar. 20	.26	6	.0	99
Mar. 26	1.3	6	.02	99
Apr. 14	.11	12	.0	93
May 15	2.0	14	.07	94
Jun. 11	1.1	22	.07	96
Jul. 16	.05	13	.0	98
Aug. 20	.02	10	.0	91

Particle-size determinations separate the sediment into sand (diameters greater than 0.062 millimeter) and silt-clay (diameters less than 0.062 millimeter). As would be expected in an area with predominantly loamy soils, the median for the silt-clay fraction was 93 percent for Brazil Creek near Red Oak, 90 percent for Rock Creek near Red Oak, and 96 percent for Brazil Creek near Walls (table 12).

Analyses of streambed materials show that concentrations of aluminum, copper, iron, lead, and manganese were extremely variable (table 16). The sources of these elements are not known. The causes for the extreme variations probably are related to sampling periods and techniques.

Table 16. - Selected trace constituents and nutrients in streambed material

[A, Brazil Creek near Red Oak (station 07249060); B, Rock Creek near Red Oak (station 07249070); C, Brazil Creek near Lodi (station 07249073); D, Brazil Creek near Walls (station 07249080)]
[All values are in micrograms per gram except nitrogen and phosphorus, which are in milligrams per gram]

Site	Date	Nitrogen (NO_2+NO_3)	Nitrogen (NH_4)	Nitrogen (NH_4+ organic)	Phosphorus	Aluminum	Arsenic	Cadmium	Chromium
A	Apr. 05, 1979	8.5	18	490	460	7,500	20	0	27
A	Jul. 11, 1979	6	22	86	500	0	64	0	0
A	Jan. 10, 1980	4.9	4.9	269	250	560	16	0	10
A	Jun. 18, 1980	720	1,100	560	280	770	21	1	9
B	Apr. 05, 1979	2.7	9.5	240	1,100	1,500	23	0	10
B	Jul. 11, 1979	1.1	27	145	610	5	15	0	1
B	Jan. 10, 1980	3.4	3.4	263	550	160	37	0	8
B	Jun. 18, 1980	560	190	4,500	230	470	27	1	18
C	Jun. 18, 1980	330	110	5,800	130	1,000	24	1	14
D	Apr. 05, 1979	5.2	28	670	1,000	5,200	23	0	6
D	Jul. 10, 1979	3.7	26	300	720	0	25	0	0
D	Jan. 09, 1980	5.9	9.9	457	700	300	36	0	10

Site	Date	Cobalt	Copper	Iron	Lead	Manganese	Mercury	Molybdenum	Zinc
A	Apr. 05, 1979	20	12	32,000	20	920	.02	0	52
A	Jul. 11, 1979	0	0	0	0	42	.02	0	0
A	Jan. 10, 1980	25	750	24,000	3,000	370	.01	2	32
A	Jun. 18, 1980	20	4	5,600	10	1,300	.02	2	20
B	Apr. 05, 1979	0	3	7,200	0	210	.01	0	19
B	Jul. 11, 1979	0	0	0	0	39	.01	0	0
B	Jan. 10, 1980	15	250	6,900	1,500	270	.01	3	21
B	Jun. 18, 1980	10	4	6,900	10	250	.01	0	23
C	Jun. 18, 1980	20	12	14,000	20	1,100	.03	0	54
D	Apr. 05, 1979	30	12	18,000	30	1,400	.02	0	51
D	Jul. 10, 1979	0	0	0	0	150	.02	0	0
D	Jan. 09, 1980	35	4,000	20,000	4,000	850	.02	2	36

Mine-Pond Water

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 have no flow several months of the year. As part of a regional study of coal-field hydrology, selected water-quality data have been collected at 57 mine ponds; one of those ponds is in the Red Oak area (pl. 2). Profiles of temperature, specific conductance, and pH were made at three sites on this pond and water samples were analyzed in the laboratory for chloride, sulfate, iron, and manganese. Comparison of the data from this pond with that from other ponds of similar age elsewhere in the southern part of the coal field shows that the quality is about the same except that concentrations of manganese are greater. Spoil adjacent to this pond has not been reclaimed but is vegetated to varying degrees with trees, brush, and weeds. Water in the pond, which is used for livestock, is derived mainly from runoff from the adjacent spoil and direct precipitation.

The chemical quality of water in the pond (table 17) varies with location, time, and depth. In general, specific conductance, which is an approximation of dissolved-solids concentrations, ranges from a minimum of 150 µmho near the pond surface to a maximum 250 µmho near the bottom. The pH of the water increases with depth but generally is greater than 7, indicating that the water is alkaline.

Another mine pond in the SW 1/4, sec. 16, T.6 N., R.21 E. is the water supply for the town of Red Oak (population 676 in 1980) at the southern edge of the area. Water from the pond is treated by coagulation, filtration, and addition of lime to reduce corrosiveness. Analyses by the Oklahoma Department of Health from 1979 to 1982 show that none of the toxic elements--arsenic, cadmium, chromium, lead, mercury, selenium, or silver--exceeded the maximum contaminant levels established by the U.S. Environmental Protection Agency (1976).

WATER DEVELOPMENT AND USE

Wells are the source of water for rural domestic supply in the Red Oak area. Of the wells inventoried for this study, mostly in 1978-79, 55 were in use; a few additional wells may have been drilled since that time. Total ground-water use is estimated to be about 12,000 gal/d. Water supply for the town of Red Oak is taken from a mine pond as noted in the preceding paragraph; the amount of water used averages 50,000 gal/d (Oklahoma State Department of Health, 1983).

Water for livestock is provided mainly by streams, mine ponds, and approximately 300 farm ponds constructed primarily for this purpose. The amount of water used for stock is estimated at 100,000 gal/d.

Streams in the area are ephemeral and therefore provide only limited habitat for wildlife, and they do not support fish of interest to fishermen. A few of the larger farm ponds have been stocked with fish and some may be used occasionally for boating or swimming.

Table 17. - Selected physical properties and chemical constituents in mine-pond water

[Depth, feet below water surface; µmhos, micromhos per centimeter at 25° Celsius; mg/L, milligrams per liter; ug/L, micrograms per liter]

Depth (feet)	Temperature (degrees Celsius)	Specific conductance (µmho)	pH (units)	Chloride (mg/L)	Sulfate (mg/l)	Iron (µg/L)	Manganese (µg/L)
		Site number: 06N-14E-14 CDD 1 Date sampled: 8-31-77					
4	28	260	8.7	---	---	---	---
7	27.5	260	8.5	---	---	---	---
10	27	260	8.2	6	37	10	15
13	26	280	7.4	---	---	---	---
19	16.5	450	7.2	---	---	---	---
25	12.5	520	7.4	9	64	1,880	5,420
		Date sampled: 8-8-79					
3	31	150	8.3	4	16	60	10
12	21	270	7.2	4	33	40	60
17	15.5	320	7.1	---	---	---	---
21	13	350	7.0	---	---	---	---
25	12.5	370	6.7	9	76	90	4,100
		Site number: 06N-21E-14 DCB 1 Date sampled: 8-8-79					
3	32	150	8.2	4	20	60	10
6	30.5	160	8.0	---	---	---	---
9	25	210	7.2	---	---	---	---
12	21	265	7.0	4	28	10	110
15	19	300	7.0	---	---	---	---
		Site number: 06N-21E-14 DDB 1 Date sampled: 8-31-77					
4	28	260	8.5	---	---	---	---
7	28	260	8.5	---	---	---	---
10	27	265	8.2	6	37	50	10
13	26	275	7.7	---	---	---	---
16	21	350	7.5	---	---	---	---
19	17	395	7.4	---	---	---	---
22	14.5	460	7.4	6	60	160	2,590
23.5	14	475	7.4	---	---	---	---
		Date sampled: 8-8-79					
3	31	150	8.1	4	22	20	40
9	25.5	190	7.1	3	21	10	30
12	20	225	7.0	---	---	---	---
14	18	245	6.8	---	---	---	---
16	15.5	270	6.7	---	---	---	---
19	14	325	6.7	5	9	120	3,080
24	13	420	6.3	---	---	---	---
26	13	490	---	---	---	---	---

HYDROLOGIC EFFECTS OF SURFACE MINING

Surface mining for coal and subsequent reclamation may cause beneficial or adverse changes in the hydrologic environment; these changes may be either short or long term. The following description of the mining process as practiced in Oklahoma is summarized from Johnson (1974) to show how some of these changes may occur. The first step in the mining operation (fig. 11) is to remove and stockpile the topsoil. Next, a trench is dug through the overburden to expose the coal which is then removed. As each succeeding cut is made, the overburden or spoil is placed in the cut previously excavated. Successive cuts are mined until the overburden thickness becomes so great, usually 100-150 ft, that the coal can no longer be mined profitably. The final cut leaves an open cut bounded by the last spoil pile on one side and the undisturbed highwall on the other. Reclamation involves grading the spoil to a rolling topography, replacing the topsoil, adding lime or fertilizer as needed, and seeding with pasture grasses or legumes. The final mine cut and other depressions left in the reclaimed area partly fill with water from runoff and ground-water seepage.

A significant change in the hydrologic environment resulting from mining is the creation of additional storage of water in the last mine cut shown in figure 11. A mine pond 0.5 mi long, 200 ft wide, and containing 30 ft of water has a volume of about 360 acre-ft. Such a pond provides habitat for wildlife and some have been stocked with fish. Also, water from the ponds may be used for stock, domestic, municipal, and irrigation supply if the quality is suitable. As presented elsewhere in this report (table 17), water in at least one mine pond has low concentrations of dissolved solids as indicated by the specific conductance of 150 to 520 µmho and is not acidic. Although water from this pond has relatively large concentrations of iron and manganese, these constituents are readily removed by aeration or filtration. Another mine pond provides water for the town of Red Oak and analyses by the Oklahoma State Department of Health show that the water did not contain excessive levels of toxic elements.

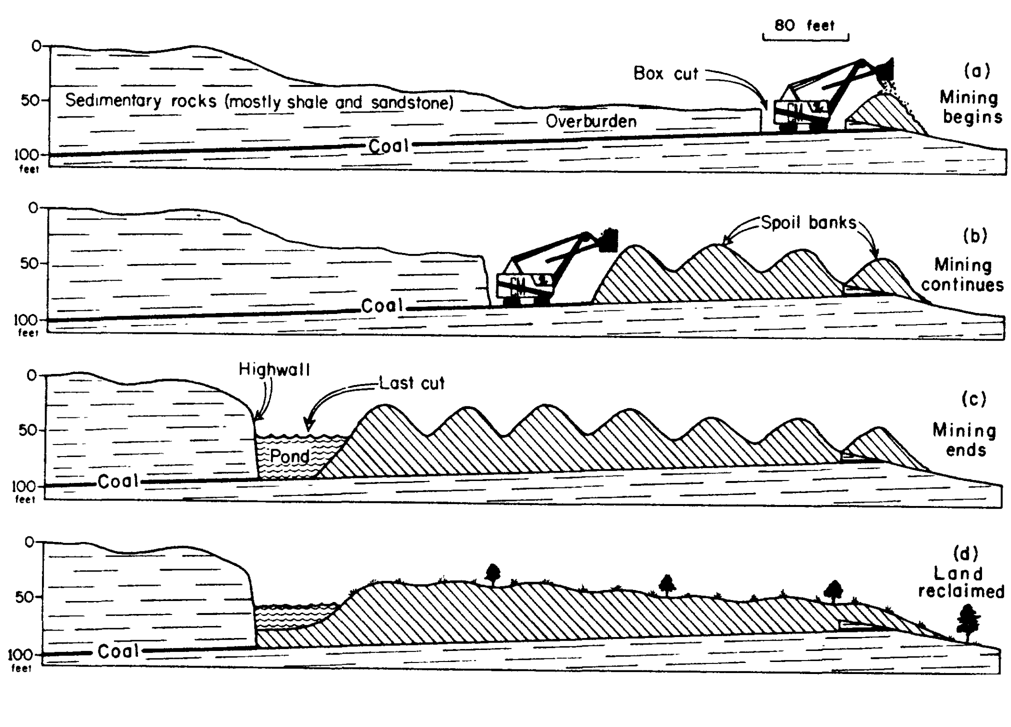


Figure 11. - Schematic cross sections showing stages of surface mining coal (from Johnson, 1974)

In addition to increasing the storage of water in mine ponds, other changes in the hydrologic environment might 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 Red Oak area consists of shale and siltstone which have limited porosity and permeability. During mining, however, the overburden is broken and shattered to produce spoil with many openings that facilitate the entry, movement, and storage of ground water. 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 may be plugged, thus limiting the volume and rate of infiltration. Eventually, however, the spoil will become saturated below a certain depth. If the void space, or porosity, of the spoil is assumed to be 5 percent, then a square mile of spoil with a saturated thickness of 50 ft would contain about 1,600 acre-ft or about 500 million gallons of water. Water stored in the spoil may be slowly discharged to streams, used by plants, or move into adjacent bedrock.

2. Changes in runoff and streamflow characteristics:

Surface mines in the Red Oak area, as in most of the Oklahoma coal field, are in valleys where the land is used mainly for unmanaged pastures of native grasses. Where appropriate reclamation practices are followed and the new pastures are properly managed, particularly by preventing overgrazing, the new vegetation generally is more lush and has a denser growth than the original native vegetation. The denser plant growth tends to retard storm runoff so that it has more time to soak into the spoil and, as a consequence, less water reaches the streams during times of normally peak flow. Conversely, water stored in the spoil is slowly released to streams thereby maintaining baseflow for a longer period of time following rainfall. For example, the baseflow of Coal Creek in eastern Haskell County is partly maintained by drainage from spoil and mine ponds. Coal Creek has a basin of 18.1 mi^2 of which about 5 percent is unreclaimed spoil and ponds. During the 1979-81 water years, the creek had no flow for only 6 days. During the same period, Brazil Creek in the Red Oak area with a basin of 69.1 mi^2 had no flow for 112 days indicating that water stored in the spoil in the Red Oak area does not contribute significantly to baseflow.

The overall changes in runoff and streamflow resulting from mining may include reduced peak flows, longer periods of baseflow, and decreased total runoff. However, the magnitude of these changes would vary from basin to basin depending on the physical characteristics of each, the locations of mines in relation to streams, and the proportions of each basin disrupted by mining.

3. Changes in drainage patterns:

Surface mining may cause changes in drainage patterns by filling drainageways with spoil, mining across drainageways, and diversions necessary to keep runoff from entering active mines. In the Red Oak area, several small drainageways terminate in mine ponds as, for example, in the SE 1/4, sec. 14, T.6 N., R.21 E.; other drainageways have been diverted around ponds and spoil. These changes are of limited extent and do not have any apparent effect on the hydrologic system.

4. Changes in the chemical quality of water:

Minerals in the overburden and coal are approximately in equilibrium with their environment as long as that environment remains unchanged. Mining, however, disturbs that equilibrium and the minerals react with various components of their new environment, such as water and oxygen. 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 chemical reactions, especially in the presence of pyrite, may result in the release of various trace elements such as lead, copper, and zinc that may be present in the coal or overburden. As a consequence of these reactions, new and generally undesirable chemicals may be added to the hydrologic system.

The available data for the Red Oak area (table 10) show that mean concentrations of dissolved solids in Brazil Creek increased from 58 mg/L to 132 mg/L between the sampling sites upstream and downstream from areas of old and recent mining. Some of the increase may be natural because concentrations of dissolved solids normally tend to increase downstream. Some of the increase may be due to the addition of dissolved solids from Jefferson and Bear Creek and some may be due to runoff from mine areas.

The general direction of ground-water movement coincides with the slope of the land surface, thus any change in the chemical quality of ground water would occur downvalley from the mine areas. However, the rocks have very small permeability and the gradient of the potentiometric surface is only about 10 ft/mi, thus the movement of the water is very slow so that any change would require a long period of time. Furthermore, water that might be derived by seepage from mine ponds is not highly mineralized and therefore would not contribute greatly to the dissolved-solids concentration of the ground water. Finally, because of the natural variability in the chemical quality of ground water, any changes would be difficult or impossible to detect without continuous monitoring of water quality in strategically located wells.

5. Changes in sediment discharge:

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 the streams can be decreased. Likewise, the time available for addition of sediment can be decreased if the spoil is revegetated rapidly and effectively, including restriction of grazing until the plants have become well established.

The suspended-sediment data available for the Red Oak area (table 13) show that the median concentrations in Brazil Creek increased from 20 mg/L upstream from the mine areas to 62 mg/L downstream from those areas. Rock Creek apparently was not a source in the increased sediment because the median concentration for that stream was only 16 mg/L. Therefore, the sediment must have been added to Brazil Creek between its confluence with Rock Creek and the sampling station near Walls. The likely sources for the additional sediment were Jefferson Creek, Bear Creek, and the areas being mined during the sampling period.

SUMMARY

The water resources of the Red Oak area are limited. Wells generally yield enough water for domestic and stock supplies but larger amounts of ground water are not available. Streams do not flow about 2 months of the year and their flow is less than 1 ft^3/s about 3 months of the year. Thus, streams are not a dependable source of water without storage reservoirs and they provide only limited habitat for wildlife.

Ground water generally is suitable for domestic use although the quality is extremely variable; the causes of these variations are not known. Concentrations of dissolved solids and suspended sediment increased between sampling sites upstream and downstream from areas of old and active mining. Part of these increases may have been natural but part may have been caused by mining. Because of the excessive levels of toxic elements at times, water in Brazil and Rock Creeks is not suitable for public supply.

Current and future mining will provide additional storage of water in mine ponds and other ponds constructed during reclamation of the mine areas. Although mining may increase the concentrations of dissolved solids and sediment in streams, these increases can be reduced if appropriate mining practices are followed and reclamation is done quickly and effectively.

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Conversion of inch-pound units to International System of Units (SI)

Inch-pound units	Multiply by	To obtain SI
ft (foot)	0.3048	meter
in. (inch)	25.4	millimeter
sq mi (square mile)	2.59	square kilometer
acre-ft (acre-foot)	1,233	cubic meter
ft^3/s (cubic foot per second	0.02832	cubic meter per second
ft/mi (foot per mile)	0.1894	meter per kilometer
gal/min (gallon per minute)	0.06309	liter per second
gal/d (gallon per day)	0.003785	cubic meter per day
mi (mile)	1.609	kilometer
ton/d (ton per day)	0.9072	megagram per day
umho (micromho per centimeter at 25° Celsius)	1.0	microsiemen per centimeter at 25° Celsius

National Geodetic 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 call mean sea level. NGVD of 1929 is referred to as sea level in text of this report.

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