HYDROLOGY OF A SURFACE COAL MINED AREA

IN RANDOLPH COUNTY, ILLINOIS

By J. V. Borghese and A. R. Klinger

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CONTENTS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply inch-pound units	By	To obtain SI (metric) unit
inch (in.)	25.40	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
foot per second (ft/s)	0.3048	meter per second (m/s)
square foot per second (ft^2/s)	0.09294	square meter per second (m^2/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06308	liter per second (L/s)
ton, short	0.9072	megagram (Mg)

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) as follows:

$$°C = 5/9\ (°F-32)$$

HYDROLOGY OF A SURFACE COAL MINED AREA
IN RANDOLPH COUNTY, ILLINOIS

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ABSTRACT

Surface mining of coal involves a land use change which affects hydrologic characteristics in and around the mined area. Hydrologic conditions that can be affected by the mining operations include stream discharge, chemical constituents of surface water and ground water, sediment load of surface water, and potentiometric surface of ground water. Ground water was monitored from October 1980 to April 1983 and surface water was monitored from October 1980 to September 1982 in the basin of Plum Creek Tributary in Randolph County, Illinois, to determine the effects of surface mining for coal. Surface water was evaluated for flow and chemical character. Ground-water changes were evaluated in 14 monitoring wells, 8 in bedrock units and 6 in unconsolidated deposits.

During the study period, the basin was being surface mined. The mine pit advanced about 100 feet into the basin every month, reducing the basin's drainage area from an initial area of 0.6 square mile in October 1980 to 0.2 square mile in May 1982. The average daily flow of Plum Creek Tributary was 0.49 cubic foot per second. Periods of no flow occurred 18 percent of the time. Peak streamflow, a major component of total flow, occurred in direct response to rainfall events.

Bedrock in the study area has been divided into three distinct geohydrologic units and the unconsolidated material has been divided into two geohydrologic units on the basis of chemical characteristics of ground water and geology. Nine wells showed a decline in hydraulic head; the largest was a 35-foot decline during a 16-month period.

Total recoverable iron, determined by Illinois Environmental Protection Agency's laboratory methods, at Plum Creek Tributary exceeded the Pollution Control Board's effluent standards. Mining activity may have been a cause. Ground-water samples from all geologic units except the unconsolidated sand unit had dissolved-solids concentrations that exceeded the Pollution Control Board's limit for potable supply. Chloride concentrations exceeded the Pollution Control Board's limits in all bedrock units except for a limestone unit.

INTRODUCTION

Coal mining is a major industry in Illinois. Coal underlies a large part of the State in a large structural basin. The coal beds occur at depths of about 1,200 feet in the center but are at or near the surface at the periphery of the basin. Coal is surface mined in the peripheral areas where it is at or near the surface.

Surface mining involves stripping the overburden from the coal, removing the coal, and filling the newly mined pit with overburden from adjacent areas. Surface-mining methods are commonly used to recover coal from depths of up to about 100 feet. Earth materials are thus disturbed and made vulnerable to weathering.

Removing the coal involves a land use change. In Illinois, this change to mining use is mostly from agricultural use. Since 1972, environmental regulations have required that land subjected to mining operations be subsequently reclaimed for beneficial use. Since 1977, companies have been required to evaluate their lands prior to mining in terms of the probable hydrologic consequences of mining.

In 1974, the U.S. Geological Survey in Illinois began a program dedicated to collecting, compiling, and analyzing hydrologic data obtained from the coal producing areas in Illinois (Toler, 1982; Zuehls and others, 1981a, 1981b; Brabets, 1984). One project in this program was to collect and interpret hydrologic data from selected sites at various phases in the mining process. The data will eventually be interpreted using available computer models to correlate observed hydrologic impacts to land use conditions in the basin prior to mining and possibly to various mining practices, and to simulate the effects of changes in watershed characteristics on streamflow.

Purpose and Scope

This report presents the data and summarizes the observations of hydrologic conditions at one site, Plum Creek Tributary basin, during about 2 years of the mining operation. The site is 6 miles northwest of the city of Sparta in Randolph County (fig. 1). The site is in a headwater tributary to Plum Creek in the Kaskaskia River basin.

Fourteen test wells were constructed to obtain geologic and hydraulic information. Geologic information was obtained by examination of materials recovered during drilling. Ground-water information was obtained from 14 monitoring wells by performing hydrologic tests, measuring water levels, and collecting samples for chemical analyses. Measurements of ground water were made periodically during the period from October 1980 to April 1983. Surface-water information included collecting samples for analyses of sediment concentration and chemical constituents; making discharge measurements; and recording stage, temperature, and specific conductance on the tributary to Plum Creek. Measurements of the surface water were made periodically during the period from October 1980 to September 1982.

Data collection was terminated before the basin was completely mined due to funding constraints and because other areas being concurrently studied proved more ideal for testing conceptual models of cause and effect.

The stratigraphic nomenclature used in this report is that of the Illinois State Geological Survey and does not necessarily follow the usage of the U.S. Geological Survey.

Description of the Area

Plum Creek Tributary basin is located in the Mt. Vernon Hill Country physiographic division of the Central Lowland Province (Leighton and others, 1948). The major features are gently rolling hills and well-developed drainage systems which have broad valleys and low gradients.

The major stream draining the area is the Kaskaskia River. The Kaskaskia River flows from east-central to southwestern Illinois where it joins the Mississippi River. It has a drainage area of 5,801 mi^2 and a length of 295 miles. The mean daily discharge of the Kaskaskia River for the 1981 water year was more than 1,700 ft^3/s (U.S. Geological Survey, 1982). Plum Creek joins the Kaskaskia River 13 miles from its mouth. Plum Creek has a drainage area of 89 mi^2 and a length of 33 miles. The study site is in a headwater tributary to Plum Creek.

Randolph County has a temperate continental climate (Denmark, 1980). Precipitation in the area during fall, winter, and spring tends to be from widespread storms. Summer rainfall generally occurs as localized thunderstorms which may be of high intensity. In a typical winter, snowfall exceeds 1 inch on only 4 to 6 days. The ground is covered with an inch or more of snow about 15 days per year, and total yearly snowfall averages 13 inches. Mean annual precipitation is 38.7 inches. Prevailing winds are from the southwest at an average of 8.5 miles per hour. November through April are the windiest months.

The National Oceanic and Atmospheric Administration maintains a weather station at Sparta. For the years 1931 through 1960, mean annual temperature was 58°F and the mean monthly temperature varied from 35°F in January to 80°F in July.

Surficial materials in Randolph County consist of Holocene alluvium and Pleistocene deposits of loess, till, and outwash. Pleistocene glaciation has left deposits up to 50 feet thick in the county. The deposits form part of the Glasford Formation which includes deposits of till, outwash, and accretion-gley. It is the most widespread glacial formation in Illinois and represents the southern limit of continental glacial deposits (Willman and Frye, 1970).

Bedrock of Pennsylvanian age immediately underlies the Pleistocene deposits in Randolph County. The bedrock dips gently to the northeast and belongs to the Modesto and Carbondale Formations. The Piasa Limestone Member of the Modesto Formation is about 5 feet thick and overlies the Carbondale Formation. The Carbondale Formation is about 175 feet thick in southwestern

Illinois and has many members which are laterally persistent in thickness and character (Willman and others, 1975). This formation contains the principal economic coals of Illinois; Herrin (No. 6), Springfield-Harrisburg (No. 5), Colchester (No. 2), and Danville (No. 7) in order of importance as reserves.

The Herrin (No. 6) coal is the most extensively mined in Illinois. It provided 86 percent of the total coal production in the State in 1981 (Illinois Department of Mines and Minerals, 1982). The coal averages more than 6 feet thick. It is a normal bright-banded coal which rests on a well-developed underclay and is present throughout much of the area of Pennsylvanian rocks (Willman and others, 1975). Major minerals within the coal are clays, 55 percent; pyrite, 21 percent; quartz, 15 percent; and calcite, 9 percent (Rao and Gluskoter, 1973).

Acknowledgments

The cooperation of the Peabody Coal Company for allowing access to their property of River King Pit No. 6 Mine is greatly appreciated. In particular, we wish to thank Larry Reuss for mining-operation and activity information.

Chemical analyses were performed at the Champaign laboratories of the Illinois Environmental Protection Agency. Roy Frazier deserves special mention for coordinating the analyses of ground- and surface-water samples.

DESCRIPTION OF THE STUDY SITE

In 1981, the mine site was one of the larger surface coal mines in Illinois, having a production of more than 2 million tons (Illinois Department of Mines and Minerals, 1982). The mining results in an elongated north-south pit (fig. 2) that effectively moves across the mine permit area as the coal is removed.

The procedure is to first remove the topsoil and store it in seeded stockpiles on unmined land. Next, the overburden, the material overlying the coal, is removed and stored to one side. At the mine, this procedure forms a pit nearly 1 mile long and about 300 feet wide. The coal is then removed from the open pit. Subsequently, overburden will be removed from adjacent areas and used to fill the open pit. This has the effect of moving the pit about 300 feet in an easterly direction.

The material which fills the open pit is called spoil. It is a nonhomogeneous loose mixture of all the previously unconsolidated and consolidated material that was overburden. Reclamation consists of regrading the spoil, replacing the topsoil previously stored on unmined land, and revegetating the recontoured land. The new surface is graded to within 4 percent of the original slope except that the new slope must not exceed 15 percent. The reclaimed land is returned to agricultural use, either row crops or pasture.

Sediment basins and drainage ditches are built as necessary to minimize erosion. During mining, surface runoff from the study basin was routed around the mine pit to sediment settling basins constructed during the removal of the topsoil. Excess water was pumped from the sediment basin across the study basin divide to other Plum Creek tributaries.

Work began at the mine in 1963. Moving in an easterly direction, the mining operation reached the western edge of the study basin in January 1981. Table 1 summarizes the major mining activities in the basin. Following the procedures outlined above, the pit moved steadily through the basin until mining temporarily ceased in May 1982. In May 1982, 42 percent (fig. 2) of the drainage area was removed from the basin by mining or topsoil removal. Those portions unaffected by mining remained in agriculture. The mine began operation again in December 1982. Reclamation work was uninterrupted during the period of no mining.

The consolidated and unconsolidated materials above the Herrin No. 6 coal in the study basin were described from samples collected during drilling of 15 wells. A generalized lithologic column of the site is shown in figure 3. Soil developed on a thin layer of loess, deposited during Wisconsinan glaciation, which overlies the Glasford Formation. The Glasford Formation is predominantly a silty clay in the western part of the study basin and includes outwash deposits of sand and gravel in the eastern part. Shale and limestone underlies the Glasford Formation and represent the lowest part of the Modesto Formation. The shale ranges in thickness from 0 to 6 feet and immediately overlies a uniform 10-foot section of limestone which is gray to buff in color. The uppermost section of the Carbondale Formation consists of a sequence of limestone, shale, and coal. The limestone is gray to buff, except for a black layer directly above the coal. The shales are gray and hard. The unconsolidated and consolidated rocks underlying the site are divided into 12 lithologic units (table 2).

Two coal beds were encountered while drilling; a 1-foot discontinuous coal bed approximately 75 feet below land surface, and the Herrin (No. 6) coal bed which is uniformly 5 to 7 feet thick and is approximately 110 feet below land surface.

Runoff from the site reaches Plum Creek through a larger tributary which joins Plum Creek 27 miles from the mouth. Plum Creek Tributary prior to mining had a natural drainage area of 0.6 mi^2, a relief of 55 feet and a length, summing the lengths of the north and south branches (fig. 4), of 2 miles. The tributary has a gradient of 20 ft/mi and flows eastward with only slight meanders and a slight increase in width. Both banks are formed in silt and clay, and lined with shrubs, ivy, thick grass, and tree roots. Few trees are actually in the channel. The channel bed is soft clayey silt which grades into a firmer clayey silt about half way up the banks. Manning's n values vary slightly along the channel and average 0.05.

Mining and agriculture are the two major land uses in the study basin. As of May 1982, 42 percent of the basin had been converted from agriculture to mining use. Row crops of soybeans, corn, winter wheat, and alfalfa, and grazing are the principal agricultural uses. A small part of the basin, mostly the stream banks, is forested.

SURFACE WATER

Streamflow

A gaging station, Plum Creek Tributary near Tilden, Illinois (05595270), was installed 250 feet downstream from the two branches that form Plum Creek Tributary. A broad-crested rectangular weir having end contractions was built to control the stage-discharge relation at medium to low stages. The station was equipped with a manometer to sense stage, electrical resistance sensors for temperature and specific conductance, and an automated suspended-sediment sampler. The suspended-sediment sampler was stage activated, and the sampling interval varied with stage. Rainfall was measured by a float gage. Stage and rainfall were recorded on punched paper tape at either 5- or 15-minute intervals. Temperature and specific conductance were recorded at 15-minute intervals.

Mean daily flow of the stream during the period of streamflow data collection (April 1981 through September 1982) was 0.49 ft^3/s. Eliminating the three major storms from the calculation, the mean daily flow decreases to 0.16 ft^3/s. Defining average daily flow as the flow exceeded 50 percent of the time, the average flow in this stream was 0.06 ft^3/s. Figure 5 shows the hydrograph of mean daily discharge for water year 1982. Periods of no flow occurred 18 percent of the time. The periods of no flow and the position of ground-water levels well below the stream channel indicate that there was no significant ground-water discharge to surface water.

The maximum instantaneous discharge during the period of streamflow data collection was 175 ft^3/s, which occurred on May 20, 1981. The maximum daily mean discharge was 40 ft^3/s (January 31, 1982). The January 31 peak, and all other peak discharges, occurred in direct response to rainfall. Figure 6, shows discharge hydrographs for two storms. The basin's drainage area was approximately 0.3 mi^2 for the October 17, 1981, storm and 0.2 mi^2 for the July 3, 1982, storm.

Surface-Water Quality

Five samples were collected at the Plum Creek Tributary gaging station for analysis of chemical constituents (table 3). Most constituents occurred in concentrations within the range measured at other streams draining unmined land in the general area (U.S. Geological Survey, 1982; Stahl and others, 1983). Only total-recoverable iron concentrations exceeded the Pollution Control Board's effluent standards of 2.0 mg/L (Pollution Control Board, 1984). The three samples that were analyzed for total-recoverable iron had concentrations of 24, 38, and 94 mg/L. Zuehls and others (1981a) reported that surface mining in southern Illinois increases the amount of iron in streams by exposing more surface area of iron-bearing sedimentary rocks to weathering. Concentrations of iron generally increase as streamflow increases. Most other constituents decrease in concentration with increasing streamflow.

Higher concentration in unfiltered samples compared to concentrations in filtered samples indicate that sediment is a carrier for most constituents. Clay and silt-sized sediment which occur in high concentrations have high cation-anion exchange capacities due to their large surface areas. Hence, they act as excellent vehicles for chemical transport in the suspended phase (Parker and Carey, 1980).

Sediment

Particle-size analyses show that 99.9 percent of suspended sediment and 97 to 99 percent of bed material was typically finer than 0.062 mm. For very fine sediment, the quantity moved by a stream is often more closely related to environmental factors affecting availability than to flow conditions in the channel (Guy, 1964).

Sediment-concentration hydrographs and storm-runoff hydrographs of many small basins have similar shapes (Colby, 1963, p. 22). Peak concentrations of fine material usually coincide with or somewhat precede peak flow. Loose soil particles are eroded by the first direct runoff of appreciable amount. Figure 7 illustrates this similarity for Plum Creek Tributary.

Although discharge may increase continuously with continuing rainfall, sediment concentrations are more likely to level off or decrease because of reduced availability of transportable material. The suspended-sediment concentration and discharge hydrographs for a storm on August 31, 1982 (fig. 7), show maximum concentrations at discharges between 30 and 60 ft^3/s on the rising limbs of the discharge hydrograph, again indicating that most of the erosion takes place early in the storm.

GROUND WATER

Domestic and livestock water supplies can generally be obtained from the unconsolidated deposits or bedrock in Randolph County. Sand and gravel aquifers within the unconsolidated deposits may yield dependable quantities of water, but their occurrence is local. Shallow bedrock aquifers in Pennsylvanian rocks yield some small supplies (Pryor, 1956).

Fourteen observation wells were drilled in or adjacent to the study basin. Placement of some wells (fig. 4) was dictated by proposed mining activities. Six of the wells were screened in unconsolidated deposits. The other eight wells were cased with 6-inch polyvinylchloride (PVC) pipe to bedrock. Casings were grouted in place, and a 5-inch hole was drilled into the bedrock. Average depths were about 114 feet below land surface. Nested piezometers were constructed in the open boreholes of the bedrock wells, two in each well, in November 1981. The nested piezometers consisted of 2-inch PVC pipe with either 3- or 6-foot slotted PVC screens.

Each well, except 8010B, 8015B, 8022, 8016A, 8016B, 8021A, and 8021B was sampled at least once for analysis of chemical constituents (table 4). The exceptions were not sampled because of obstructions in the well, lack of water, or because the wells were destroyed or could not be properly developed. The wells were developed prior to sampling to insure that the sample was representative of formation water. Development consisted of pumping the wells dry numerous times and allowing them to recover. Samples were collected after the well was pumped dry while the water level was returning to the prepumping level. Samples were treated and preserved according to standards set by Erdman and others (1982). Analyses were performed by the Illinois Environmental Protection Agency laboratory in Champaign, Illinois. The geologic logs (driller logs and geophysical logs) and water-quality analyses of samples from these wells reveal several geohydrologic units. A geologic section of the study site (fig. 8) shows the division of geologic and geohydrologic units. Table 5 presents the classifications of lithologic units into geologic and geohydrologic units, including the lithology at screened intervals.

The major cation and anion were determined for sampled water from each well. Each geohydrologic unit's water had unique concentrations of predominant constituents. The concentrations of the major cation and anion associated with geohydrologic units are shown in table 6.

Water from geohydrologic units A and C have concentrations of chloride in excess of the limit of 250 mg/L for potable supply set by the Pollution Control Board (1984). Units A, B, C, and D have concentrations of dissolved solids that are in excess of the potable supply limit of 500 mg/L. Water from unit E yields water meeting the standards for potable supply, except from well 8017. Well 8017 was screened in clayey sand (unit E) but differed from other wells screened in this unit by yielding water having calcium as the major cation in concentrations of 158 and 177 mg/L. Well 8017 is located where Unit E begins to thin and become clayey. This change is possibly responsible for the dissolved-solids concentrations which are in excess of the potable supply limits.

Some fluctuation of the hydraulic head of ground water occurs naturally due to the dynamic nature of the system. Mining through the hydrogeologic units created a hydraulic gradient causing ground water to flow toward the open pit. The heads were lowered in the vicinity of the open pit.

During the period of ground-water level monitoring (December 1981 through April 1983), mining moved eastward into the basin, placing the pit closer to the observation wells and affecting hydraulic heads. Each hydrogeologic unit was affected differently because each unit has its own hydraulic characteristics.

The mining had little affect on the shallow wells, with the exception of well 8019 and well 8022. Well 8019, screened in unit E, lost 2.44 feet of head during the period of record because it was near the mining operations. Well 8022 was drilled adjacent to the pit and remained nearly dry until September 1982. At this time the pit was 3,400 feet from the well and the old pit adjacent to the well was filled with spoil. Recharge to the spoil caused water to enter the well. Other shallow wells showed only seasonal fluctuations.

The potentiometric surfaces in bedrock wells 8010A, 8011A, 8011B, 8012A, 8012B, 8015A, 8023A, and 8023B were depressed. The head loss in each of these wells for the period of January 1982 through April 1983 is shown in table 7. Figure 9 shows the water level measured in well 8023B for the 1982 calendar year.

Wells 8016A, 8016B, 8021A, and 8021B contained only a few feet of water and were adjacent to the pit or spoil material during most of the period of record. In March 1982, the potentiometric surface in these wells began to rise. As in well 8022, this increase in a result of recharging the spoil material.

SUMMARY

Plum Creek Tributary prior to mining had a natural drainage area of 0.6 mi^2. Since January 1981, the basin has been disturbed by surface mining. The basin is characteristic of surface-mined areas in southern Illinois. It was previously used for agricultural purposes, had low relief, and was well drained. Major changes in land use are caused by surface mining of coal. There was a reduction of Plum Creek Tributary drainage area from 0.6 mi^2 to 0.2 mi^2 by May 1982.

The bedrock underlying the study site is of Pennsylvanian age and consists of coal, shale, and limestone. The unconsolidated material overlying the bedrock consists of till and outwash deposits from Pleistocene glaciation.

Plum Creek Tributary drains into the Kaskaskia River system. The mean daily flow of the stream for the period of streamflow data collection (April 1981 through September 1982) is 0.49 ft^3/s. Runoff from storms is the major component of annual runoff. Periods of no flow occurred 18 percent of the time. The maximum instantaneous discharge during the period of record was 175 ft^3/s on May 20, 1981. The maximum daily mean discharge was 40 ft^3/s (January 31, 1982). The January 31 peak, and all other peak discharges, occurred in direct response to rainfall. Water-quality analyses of surface water had a concentration of total-recoverable iron of 24, 38, and 94 mg/L. The effluent standards set by the Pollution Control Board for total iron is 2.0 mg/L. Particle-size analyses show that 99.9 percent of suspended sediment and 97 to 99 percent of bed material were finer than 0.062 mm.

Fourteen observation wells were used to monitor the ground-water system in the study area. Six of the wells were screened in the glacial deposits and eight of the wells were screened in bedrock. Geologic logs and water-quality analyses of samples from these wells revealed several geohydrologic units. The five geohydrologic units are classified A, B, C, D, and E. Water sampled from geohydrologic units A and C had concentrations of chloride in excess of the limit of 250 mg/L for potable supply set by the Pollution Control Board. Units A, B, C, and D water samples have concentrations of dissolved solids that are in excess of the potable supply limit of 500 mg/L. Water from unit E meets the standards for potable supply.

The hydraulic heads of ground water were lowered in the vicinity of the open pit. The greatest decline of 35 feet was observed in well 8023B for the period of January to April 1983.

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FIGURES 1-9; TABLES 1-7

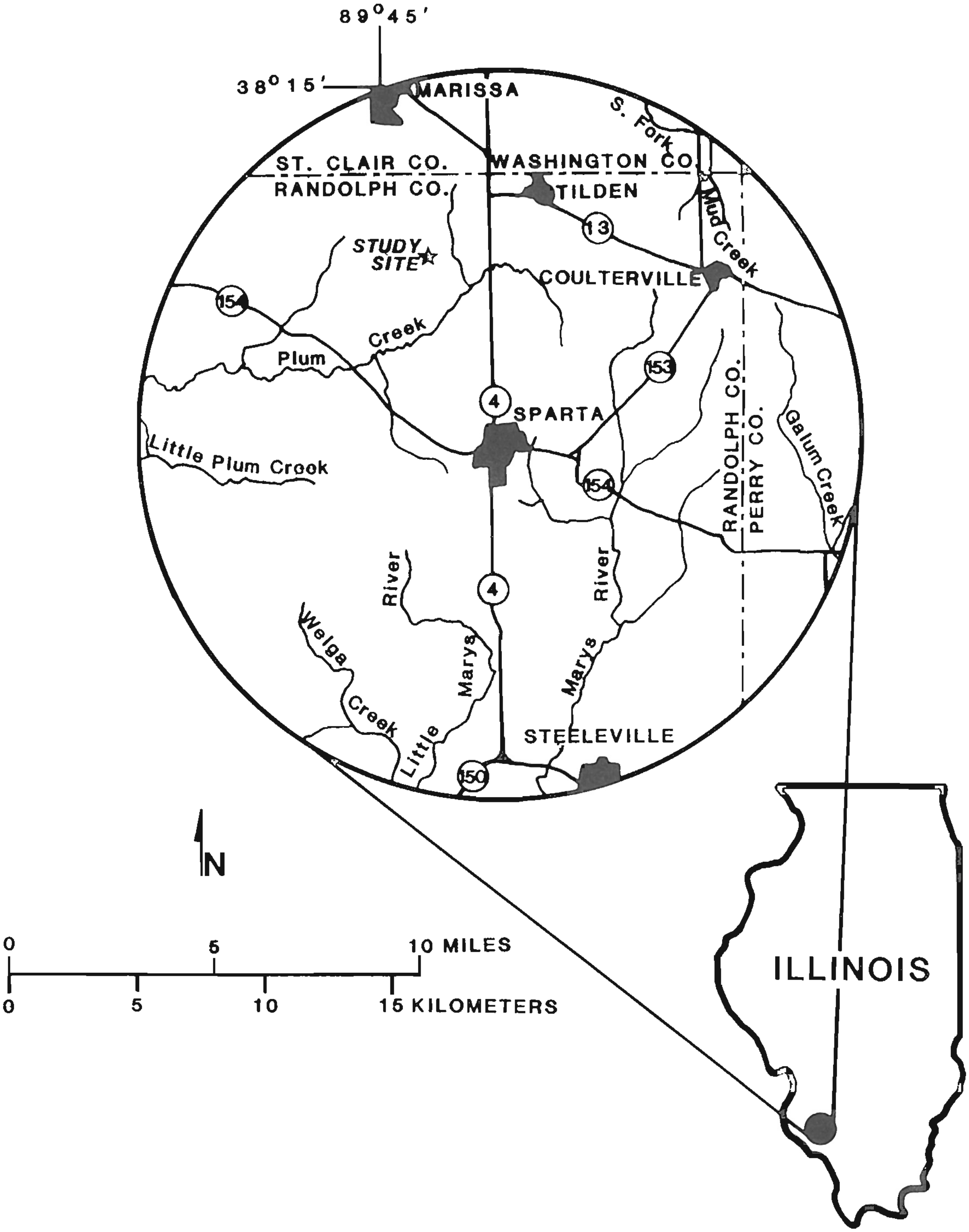

Figure 1.--Location of study site in Randolph County, Illinois.

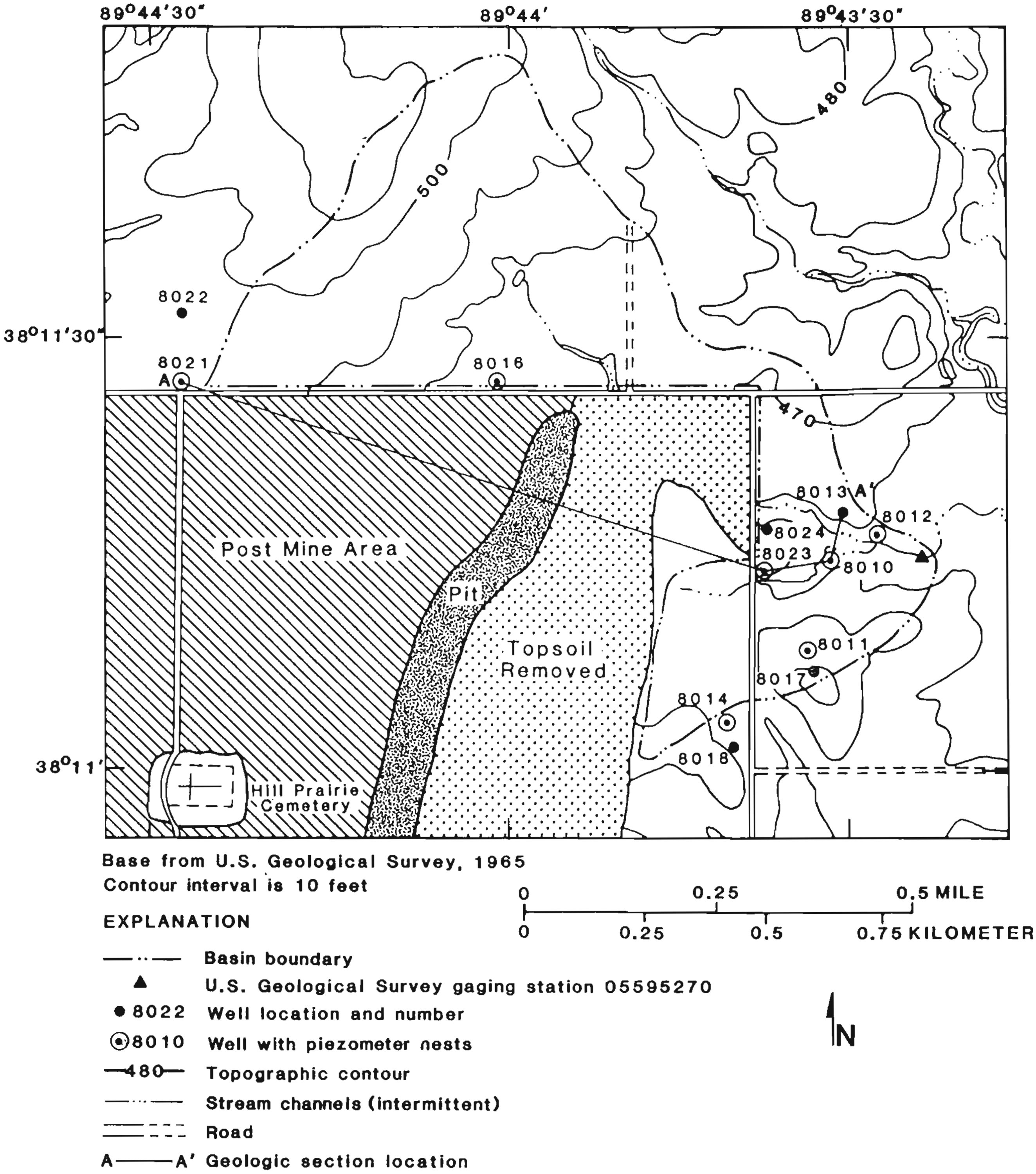

Figure 2.--Plum Creek Tributary basin, March 1982.

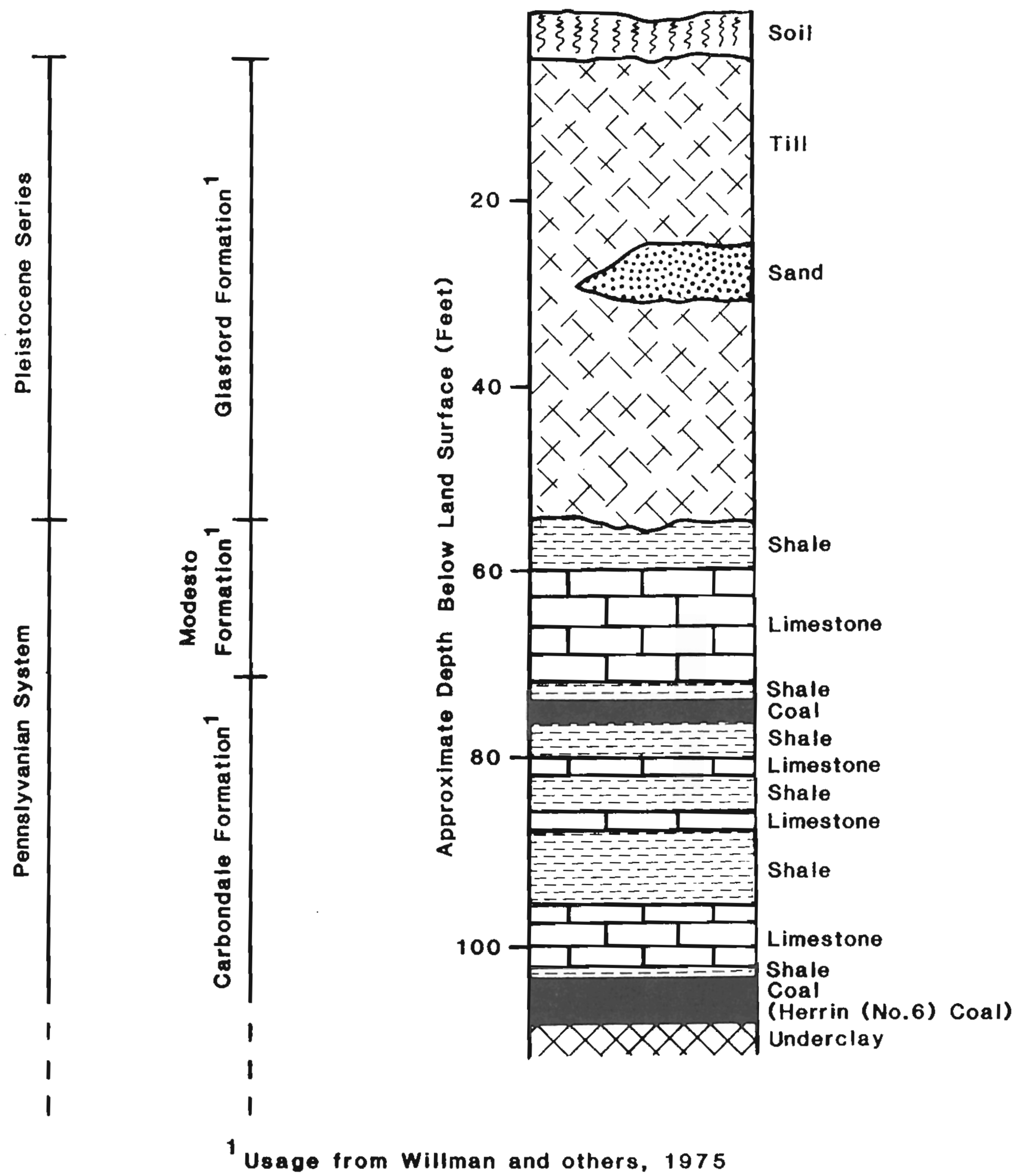

Figure 3.--Generalized lithologic column of study site.

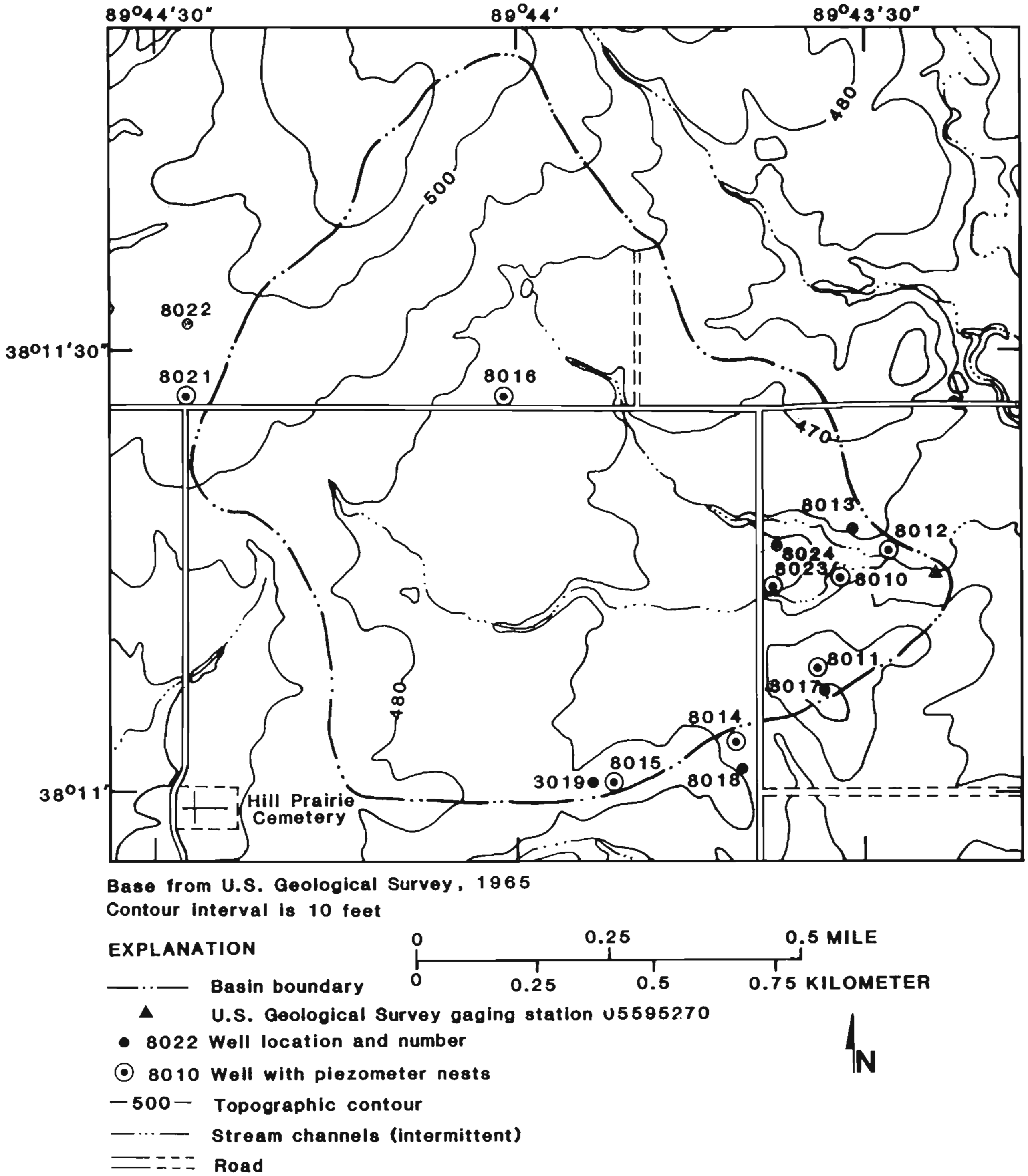

Figure 4.--Plum Creek Tributary basin, January 1981.

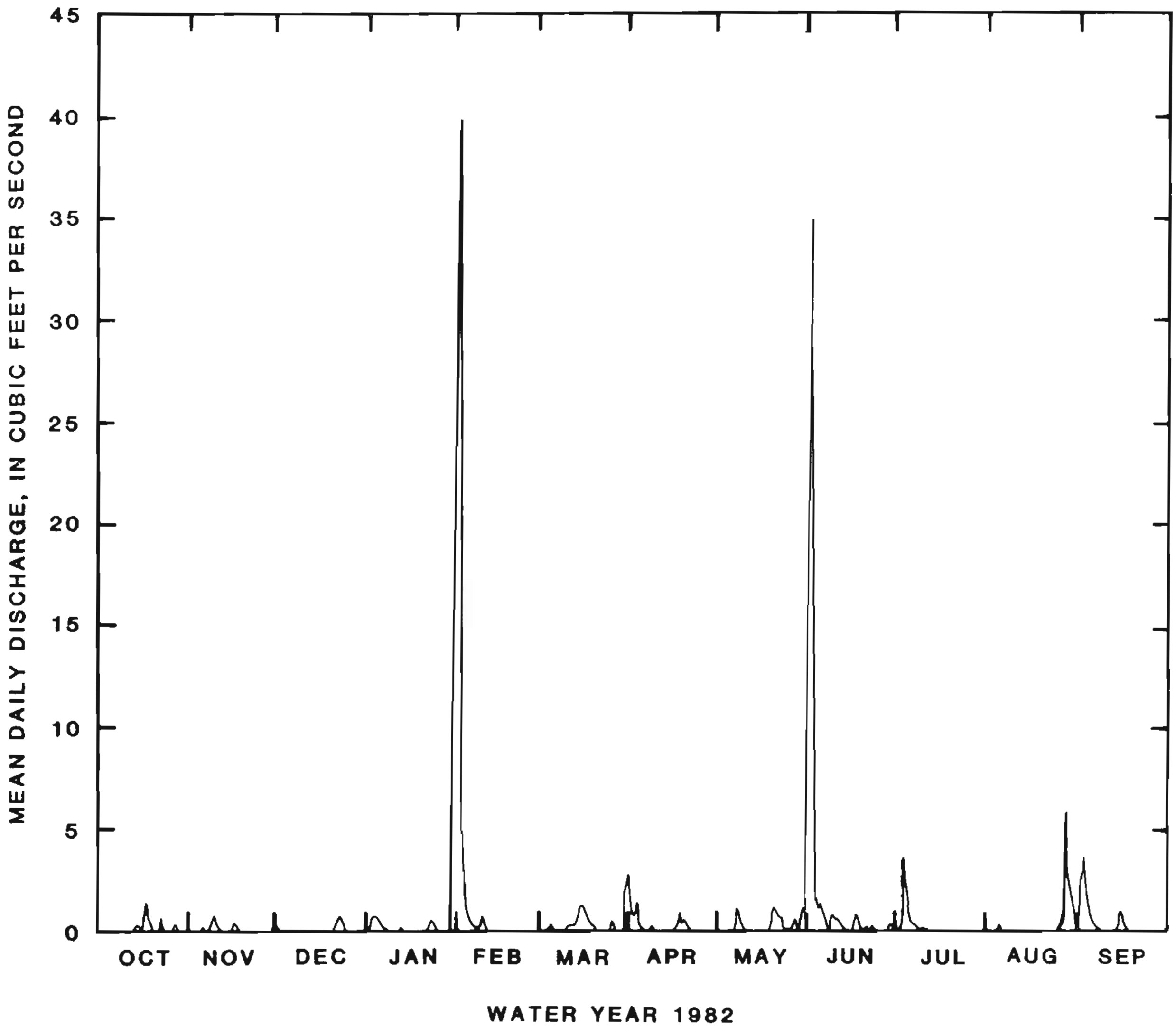

Figure 5.--Mean daily discharge of Plum Creek Tributary.

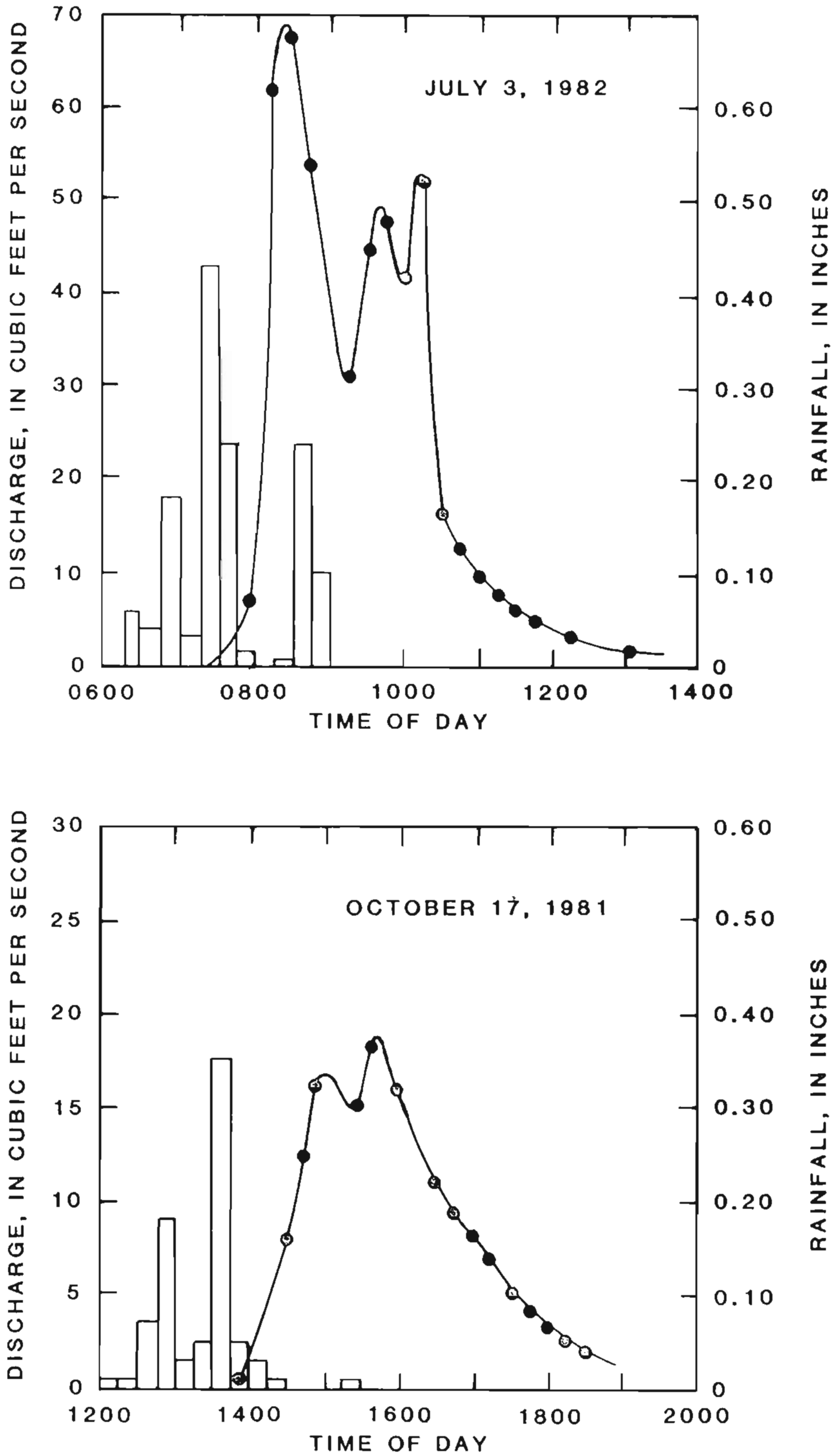

Figure 6.--Discharge hydrographs and precipitation for selected storms.

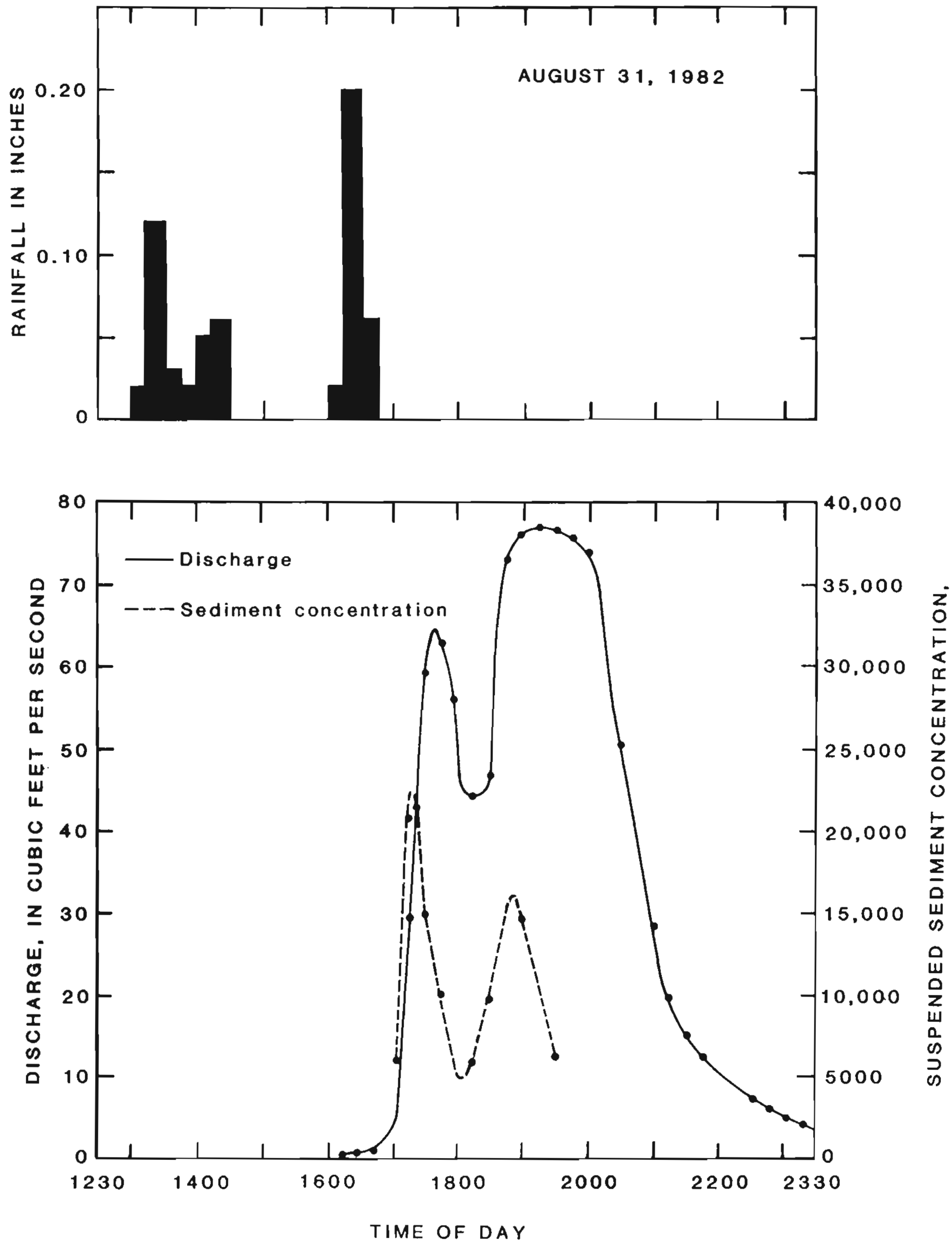

Figure 7.--Sediment concentration, discharge hydrograph, and precipitation for storm on August 31, 1982.

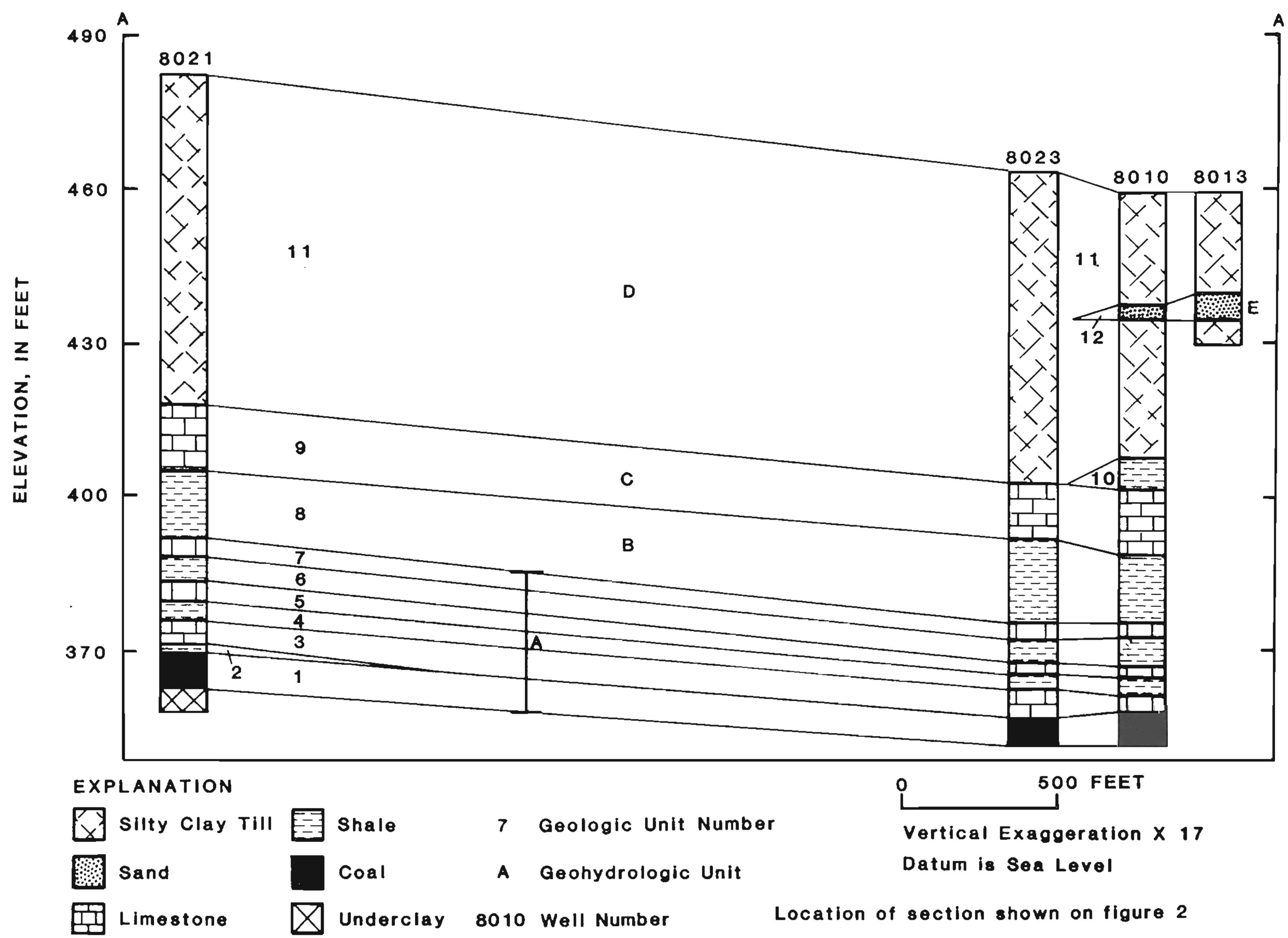

Figure 8.--Geologic section divided into geologic and geohydrologic units.

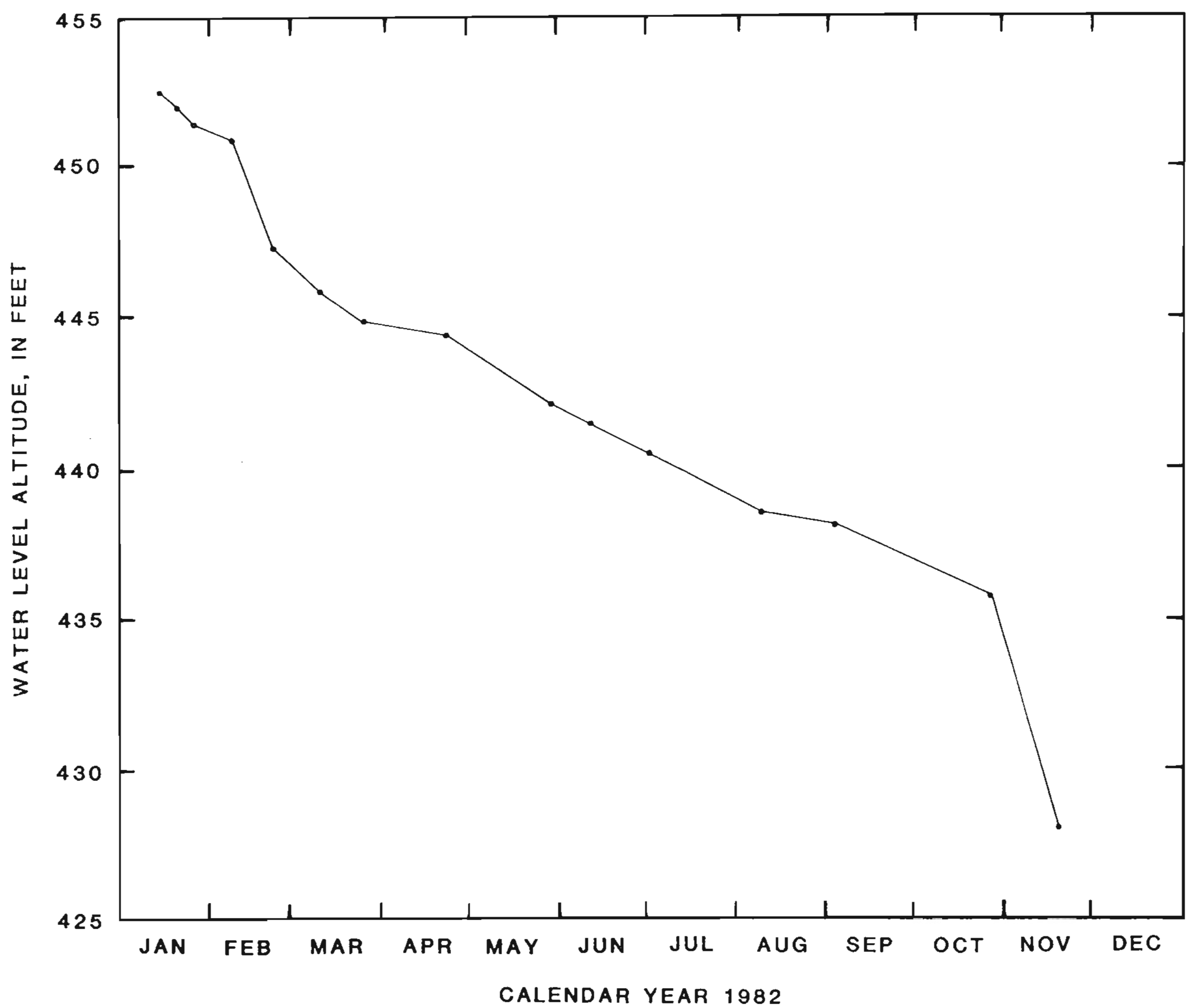

Figure 9.--Water level altitude in well 8023B.

Table 1.--Summary of major mining activities in basin

September 1980	Drainage area is 0.6 mi^2. Basin unaffected by mining operations.
January 1981	Mining operations at western edge of basin.
January 1982	North branch of tributary routed to newly dug ditch along road. Drainage area is 0.3 mi^2.
May 1982	Mining operations stopped. Drainage area is 0.2 mi^2.
December 1982	Mining operations resumed.

Table 2.--Geologic unit description

Formation name[1]	Geologic unit number	Average thickness (feet)	Description
Glasford	12	2-25	Sand, varying from a clayey fine sand to a pebbly sand.
	11	65	Silty clay till.
Modesto	10	6	Dark gray, fissile shale.
	9	11	Buff, fractured limestone.
Carbondale	8	18	Fissile black shale, containing a discontinuous thin bed of limestone and another thin discontinuous bed of coal.
	7	3	Buff limestone.
	6	5	Gray fissile shale.
	5	2	Gray, fossiliferous, argillaceous limestone.
	4	5	Gray shale interbedded with thin discontinuous limestone.
	3	6	Dark gray to black, slightly mottled massive fossiliferous limestone.
	2	4	Dark fissile shale.
	1	5	Normal bright-banded coal, having a well developed underclay.

[1] Usage from Willman and others, 1975.

Table 3.--Chemical analyses of surface water, Plum Creek Tributary

Date	Time	Stream-flow, instan-taneous (cfs)	Spe-cific con-duct-ance (μmhos)	pH (stand-are units)	Temper-ature (deg C)	Hard-ness (mg/L as $CaCO_3$)	Hard-ness, noncar-bonate (mg/L $CaCO_3$)	Acidity total heated (mg/L as $CaCO_3$)	Calcium total recov-erable (mg/L as Ca)	Calcium dis-solved (mg/L as Ca)
JUL 1981										
23...	1100	11	--	6.4	--	27	27	--	--	8.1
NOV										
05...	1010	.06	820	6.9	13.5	--	--	0.00	--	--
19...	1315	1.6	3000	8.2	12.0	--	--	0.00	--	--
DEC										
22...	1735	13	180	8.0	0.0	51	23	--	61	13
JUL 1982										
07...	1330	3.9	530	8.1	16.5	52	--	0.00	67	15

Date	Magne-sium, total recov-erable (mg/L as Mg)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, total recov-erable (mg/L as Na)	Sodium, dis-solved (mg/L as Na)	Potas-sium, total recov-erable (mg/L as K)	Potas-sium, dis-solved (mg/L as K)	Alka-linity lab (mg/L as $CaCO_3$)	Sulfate dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)
JUL 1981										
23	--	1.7	--	8.4	--	4.5	--	--	--	--
NOV										
05...	--	--	--	--	--	--	200	110	95	0.6
19...	--	--	--	--	--	--	300	940	170	1.7
DEC										
22...	16	4.6	27	65	9.1	2.9	29	--	--	--
JUL 1982										
07...	28	3.4	99	74	11	3.2	<10	42	19	0.8

Date	Silica, dis-solved (mg/L as SiO_2)	Solids, residue at 180 deg. C dis-solved (mg/L)	Solids, sum of consti-tuents, dis-solved (mg/L)	Nitro-gen, NO_2+NO_3 dis-solved (mg/L as N)	Nitro-gen organic total (mg/L as N)	Nitro-gen, organic dis-solved (mg/L as N)	Nitro-gen, am-monia + organic total (mg/L as N)	Nitro-gen, am-monia + organic dis. (mg/L as N)	Nitro-gen, total (mg/L as N)	Nitro-gen dis-solved (mg/L as N)
JUL 1981										
23...	6.8	--	31	0.33	1.6	1.5	1.6	1.5	1.6	1.8
NOV										
05...	7.1	555	332	--	--	--	--	--	--	--
19...	4.5	2260	1290	--	--	--	--	--	--	--
DEC										
22...	--	235	105	--	--	--	--	--	--	--
JUL										
07...	17	427	181	0.66	--	--	--	--	--	--

Table 3.--Chemical analyses of surface water, Plum Creek Tributary--Continued

Date	Phosphorus, total (mg/L as P)	Phosphorus total (mg/L as PO_4)	Phosphorus, dissolved (mg/L as PO_4)	Phosphorus, dissolved (mg/L as P)	Arsenic total (µg/L as As)	Arsenic dissolved (µg/L as As)	Barium, total recoverable (µg/L as Ba)	Barium, dissolved (µg/L as Ba)	Beryllium, total recoverable (µg/L as Be)	Beryllium, dissolved (µg/L AS BE)
JUL 1981										
23...	0.62	1.9	--	--	3	--	--	--	--	--
NOV										
05...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
DEC										
22...	--	--	--	--	--	--	840	35	3	<1
JUL 1982										
07...	0.05	--	--	3.10	10	<1	770	30	22	<1

Date	Boron, total recoverable (µg/L as B)	Boron, dissolved (µg/L as B)	Cadmium, total recoverable (µg/L as Cd)	Cadmium dissolved (µg/L as Cd)	Chromium, total recoverable (µg/L as Cr)	Chromium, dissolved (µg/L as Cr)	Cobalt, total recoverable (µλ/L as Co)	Cobalt, dissolved (µg/L as Co)	Copper, total recoverable (µg/L as Cu)	Copper, dissolved (µg/L as Cu)
JUL 1981										
23...	280	--	<1	2	30	10	--	--	20	5
NOV										
05...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
DEC										
22...	22	120	10	<3	20	7	40	<5	60	23
JUL 1982										
07...	280	97	<10	<3	90	<5	90	<5	100	6

Date	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)	Lead, total recoverable (µg/L as Pb)	Lead, dissolved (µg/L as Pb)	Manganese, total recoverable (µg/L as Mn)	Manganese, dissolved (µg/L as Mn)	Mercury total recoverable (µg/L as Hg)	Mercury dissolved (µg/L as Hg)	Nickel, total recoverable (µg/L as Ni)	Nickel, dissolved (µg/L as Ni)
JUL 1981										
23...	24000	340	30	--	680	20	0.2	0.2	20	--
NOV										
05...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
DEC										
22...	37620	1200	<50	<50	1400	28	--	--	90	6
JUL 1982										
07...	93630	180	170	<50	1600	<5	<0.1	0.1	180	<5

Table 3.--Chemical analyses of surface water, Plum Creek Tributary--Continued

Date	Selenium, total (μg/L as Se)	Selenium, dissolved (μg/L as Se)	Silver, total recoverable (μg/L as Ag)	Silver, dissolved (μg/L as Ag)	Strontium, total recoverable (μg/L as Sr)	Strontium, dissolved (μg/L as Sr)	Vanadium, total (μg/L as V)	Vanadium, dissolved (μg/L as V)	Zinc, total recoverable (μg/L as Zn)	Zinc, dissolved (μg/L as Zn)
JUL 1981										
23...	--	--	--	--	--	--	--	--	90	10
NOV										
05...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
DEC										
22...	--	--	4	<3	290	60	77	<5	<200	<200
JUL 1982										
07...	9	9	<10	<3	590	120	130	<5	4500	<50

Table 4.--Chemical analyses of ground water

Well number	Date of sample	Time	Specific conductance (µmhos)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Acidity total heated (mg/L as $CaCO_3$)	Calcium total recoverable (mg/L as Ca)	Calcium dissolved (mg/L as Ca)
8010A	82-03-11	1700	10700	7.7	12.0	--	--	.00	82	--
	82-04-22	0930	11600	8.1	17.0	250	--	.00	52	52
	82-07-07	1625	11800	7.4	21.0	220	--	.00	--	47
8011A	82-03-10	1430	11600	7.2	16.0	220	--	.00	44	43
8011B	81-11-18	1147	1920	7.6	17.0	--	--	.00	--	--
	82-03-11	1410	2030	7.4	14.0	--	--	.00	--	--
	82-05-13	1030	--	7.5	15.5	160	--	.00	--	23
	82-07-07	1655	1820	7.7	16.5	130	--	--	--	18
8012A	82-03-09	1645	11000	7.3	12.5	170	--	.00	--	34
8012B	82-03-10	1500	9850	7.5	15.5	170	--	.00	--	30
8013	81-12-22	1520	750	7.7	10.5	240	--	.00	--	57
	82-01-27	1000	--	7.3	10.5	270	--	.00	--	65
	82-03-09	1620	780	7.1	11.5	280	--	.00	68	67
8014A	81-11-18	1537	9570	7.7	15.0	--	--	.00	--	--
	82-03-11	1600	12100	7.3	14.0	260	--	.00	--	40
8014B	81-11-18	1600	9030	7.7	15.0	--	--	.00	--	--
	82-03-11	1630	11000	7.3	14.5	300	--	.00	--	53
8015A	82-03-11	0950	14300	7.2	14.0	230	--	.00	40	39
8017	81-12-23	1025	1810	6.8	11.0	750	560	.00	--	160
	82-01-27	0930	--	6.8	12.0	820	260	.00	--	170
	82-03-10	1415	1720	6.7	15.0	--	--	.00	170	--
	82-05-13	1230	--	7.0	14.0	850	290	.00	--	180
8018	82-01-12	1330	780	7.0	15.5	370	--	.00	--	81
	82-01-26	1630	--	7.0	10.5	370	--	.00	--	83
	82-03-11	1525	820	7.0	14.5	370	--	.00	87	85
8019	81-12-22	1130	870	7.3	14.0	200	--	.00	--	48
	82-01-26	1510	--	7.2	13.0	200	--	.00	--	49
	82-03-09	0845	860	6.9	12.5	220	--	.00	55	54
8023A	82-03-11	1430	16400	7.2	15.5	330	--	.00	--	64
8023B	82-03-11	1515	2960	8.4	15.5	44	--	.00	--	8.6
8024	81-12-22	1305	800	7.2	12.5	210	--	.00	--	54
	82-01-26	1700	--	7.2	8.0	220	--	.00	--	57
	82-03-08	2047	790	7.0	9.5	220	--	.00	61	55

Table 4.--Chemical analyses of ground water--Continued

Well number	Date of sample	Magnesium, total recoverable (mg/L as Mg)	Magnesium, dissolved (mg/L as Mg)	Sodium, total recoverable (mg/L as Na)	Sodium, dissolved (mg/L as Na)	Potassium, total recoverable (mg/L as K)	Potassium, dissolved (mg/L as K)	Alkalinity field (mg/L as $CaCO_3$)	Alkalinity lab (mg/L as $CaCO_3$)	Chloride, dissolved (mg/L as Cl)
8010A	82-03-11	33	--	2400	--	15	--	710	710	3000
	82-04-22	29	29	3000	3000	15	14	740	710	3300
	82-07-07	--	25	--	3300	--	14	660	700	3800
8011A	82-03-10	27	26	2700	2700	16	16	830	830	3400
8011B	81-11-18	--	--	--	--	--	--	570	570	150
	82-03-11	--	--	--	--	--	--	600	620	270
	82-05-13	--	25	--	380	--	4.2	540	540	240
	82-07-07	--	21	--	440	--	4.3	540	520	270
8012A	82-03-09	--	20	--	2600	--	14	820	770	3100
8012B	82-03-10	--	22	--	2300	--	15	770	750	5400
8013	81-12-22	--	24	--	88	--	.90	--	330	9.1
	82-01-27	--	26	--	83	--	.91	360	340	8.6
	82-03-09	27	27	80	80	1.0	.95	340	370	11
8014A	81-11-18	--	--	--	--	--	--	680	680	2600
	82-03-11	--	38	--	2800	--	17	680	680	3700
8014B	81-11-18	--	--	--	--	--	--	680	670	2200
	82-03-11	--	41	--	2600	--	19	670	690	2900
8015A	82-03-11	30	30	3300	3300	17	17	750	750	4500
8017	81-12-23	--	87	--	150	--	3.1	--	200	5.3
	82-01-27	--	95	--	130	--	2.8	560	560	4.0
	82-03-10	95	--	130	--	2.7	--	560	560	7.1
	82-05-13	--	98	--	130	--	2.5	--	550	6.7
8018	82-01-12	--	40	--	56	--	2.3	--	440	4.3
	82-01-26	--	39	--	51	--	1.7	450	450	2.1
	82-03-11	40	39	56	56	2.0	1.7	440	460	5.2
8019	81-12-22	--	19	--	140	--	1.0	--	360	7.3
	82-01-26	--	19	--	130	--	1.1	380	370	6.8
	82-03-09	21	21	120	120	1.0	1.0	360	380	7.1
8023A	82-03-11	--	40	--	3800	--	19	660	650	5000
8023B	82-03-11	--	5.4	--	680	--	11	780	770	410
8024	81-12-22	--	18	--	100	--	1.1	--	320	15
	82-01-26	--	18	--	100	--	1.1	340	330	11
	82-03-08	23	19	110	110	1.5	1.1	330	340	12

Table 4.--Chemical analyses of ground water--Continued

Well number	Date of sample	Fluoride, total (mg/L as F)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, redidue at 180 deg. C dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, NO_2+NO_3 dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Arsenic total (µg/L as As)	Arsenic dissolved (µg/L as As)
8010A	82-03-11	1.9	--	--	5920	3460	--	--	5	--
	82-04-22	1.8	1.8	9.8	6730	6820	<.100	.020	3	3
	82-07-07	--	1.5	9.4	6800	7570	<.100	.020	--	3
8011A	82-03-10	1.9	1.9	11	6400	6660	<.100	.080	2	2
8011B	81-11-18	--	1.0	11	1270	507	--	--	--	--
	82-03-11	--	1.7	11	1190	647	.280	.070	--	--
	82-05-13	--	2.0	9.6	1710	1000	--	.060	--	5
	82-07-07	--	2.0	8.7	976	1090	<.100	.020	--	5
8012A	82-03-09	--	2.3	8.9	6230	6320	.130	.060	--	6
8012B	82-03-10	--	2.1	12	7900	8240	<.100	.210	--	15
8013	81-12-22	--	.8	14	385	394	<.100	.030	--	--
	82-01-27	--	.7	15	505	415	.200	.020	--	<1
	82-03-09	.5	.5	14	694	407	<.100	.080	1	<1
8014A	81-11-18	--	1.7	8.8	5440	3040	--	--	--	--
	82-03-11	--	1.8	8.0	16700	7040	.100	.000	--	1
8014B	81-11-18	--	1.0	12	5330	2660	--	--	--	--
	82-03-11	--	1.6	12	16300	6000	<.100	.150	--	5
8015A	82-03-11	1.7	1.7	11	8130	8370	<.100	.000	5	5
8017	81-12-23	--	.2	12	1030	532	<.100	.020	--	--
	82-01-27	--	.3	15	1290	765	.240	.000	--	<1
	82-03-10	.2	.2	15	1300	360	.600	.030	<1	--
	82-05-13	--	.2	15	1380	764	--	.000	--	<1
8018	82-01-12	--	.6	17	468	469	<.100	.010	--	<1
	82-01-26	--	.6	18	475	472	.260	.020	--	<1
	82-03-11	.6	.5	18	885	475	<.100	.040	1	<1
8019	81-12-22	--	.7	13	466	447	.120	.040	--	--
	82-01-26	--	.8	14	791	452	.280	.020	--	<1
	82-03-09	.6	.6	14	527	436	<.100	--	1	1
8023A	82-03-11	--	2.3	9.3	19400	9330	.430	.020	--	3
8023B	82-03-11	--	3.3	9.6	1700	1600	<.100	.120	--	8
8024	81-12-22	--	.7	14	419	398	.810	.020	--	--
	82-01-26	--	.7	13	479	409	.260	.000	--	1
	82-03-08	.6	.5	12	710	403	.230	.040	10	2

Table 4.--Chemical analyses of ground water--Continued

Well number	Date of sample	Barium, total recov- erable (µg/L as Ba)	Barium, dis- solved (µg/L as Ba)	Beryl- lium, total recov- erable (µg/L as Be)	Beryl- lium, dis- solved (µg/L as Be)	Boron, total recov- erable (µg/L as B)	Boron, dis- solved (µg/L as B)	Cadmium total recov- erable (µg/L as Cd)	Cadmium dis- solved (µg/L as Cd)
8010A	82-03-11	1600	--	1	--	1000	--	<3	--
	82-04-22	3600	3500	<1	<1	1000	1000	<10	<10
	82-07-07	--	3600	--	<1	--	990	--	12
8011A	82-03-10	2300	2300	<1	<1	1100	1100	<10	<10
8011B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	--	--	--	--	--	--	--
	82-05-13	--	150	--	<1	--	1100	--	5
	82-07-07	--	130	--	<1	--	950	--	3
8012A	82-03-09	--	1100	--	<1	--	1100	--	<3
8012B	82-03-10	--	1000	--	<1	--	1200	--	<3
8013	81-11-18	--	84	--	<1	--	42	--	<3
	82-01-27	--	90	--	<1	--	31	--	<3
	82-03-09	88	85	<1	<1	31	28	<3	<3
8014A	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	3200	--	<1	--	1300	--	<3
8014B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	1200	--	1	--	1200	--	<3
8015A	82-03-11	2900	2900	2	2	1100	1100	<10	<10
8017	81-12-23	--	75	--	<1	--	90	--	<3
	82-01-27	--	61	--	<5	--	78	--	<3
	82-03-10	62	--	<1	--	71	--	4	--
	82-05-13	--	51	--	<1	--	82	--	<3
8018	82-01-12	--	370	--	<1	--	130	--	<3
	82-01-26	--	410	--	<1	--	130	--	<3
	82-03-11	470	400	<1	<1	130	130	<3	<3
8019	81-12-22	--	180	--	<1	--	25	--	4
	82-01-26	--	170	--	<1	--	11	--	<3
	82-03-09	190	190	<1	<1	16	11	<3	<3
8023A	82-03-11	--	2200	--	<2	--	1200	--	<10
8023B	82-03-11	--	160	--	<.5	--	890	--	<3
8024	81-12-22	--	92	--	<1	--	50	--	<3
	82-01-26	--	96	--	<1	--	32	--	<3
	82-03-08	140	97	<1	<1	30	29	<3	<3

Table 4.--Chemical analyses of ground-water--Continued

Well number	Date of sample	Chromium, total recoverable (µg/L as Cr)	Chromium, dissolved (µg/L as Cr)	Cobalt, total recoverable (µg/L as Co)	Cobalt, dissolved (µg/L as Co)	Copper, total recoverable (µg/L as Cu)	Copper, dissolved (µg/L as Cu)	Iron, total recoverable (µg/L as Fe)	Iron, dissolved (µg/L as Fe)
8010A	82-03-11	<5	--	20	--	40	--	7200	--
	82-04-22	7	10	<5	<5	60	21	2700	140
	82-07-07	--	20	--	10	--	41	--	290
8011A	82-03-10	10	10	20	20	60	40	500	160
8011B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	--	--	--	--	--	--	--
	82-05-13	--	10	--	6	--	10	--	160
	82-07-07	--	<5	--	<5	--	<5	--	150
8012A	82-03-09	--	6	--	<5	--	<5	--	690
8012B	82-03-10	--	<5	--	10	--	15	--	230
8013	81-12-22	--	<5	--	<5	--	6	--	<5
	82-01-27	--	<5	--	<5	--	11	--	70
	82-03-09	<5	<5	<5	<5	<5	<5	310	70
8014A	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	<5	--	10	--	15	--	190
8014B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	<5	--	<5	--	9	--	290
8015A	82-03-11	<50	<50	30	30	50	42	340	220
8017	81-12-23	--	<5	--	<5	--	10	--	50
	82-01-27	--	<5	--	<5	--	21	--	110
	82-03-10	<5	--	<5	--	20	--	1100	--
	82-05-13	--	20	--	<5	--	8	--	20
8018	82-01-12	--	<5	--	<5	--	7	--	230
	82-01-26	--	8	--	<5	--	10	--	320
	82-03-11	<5	<5	7	<5	10	<5	4800	200
8019	81-12-22	--	6	--	<5	--	<5	--	90
	82-01-26	--	<5	--	<5	--	13	--	7
	82-03-09	<5	<5	<5	<5	<5	<5	450	120
8023A	82-03-11	--	<50	--	20	--	22	--	350
8023B	82-03-11	--	7	--	<5	--	5	--	50
8024	81-12-22	--	<5	--	<5	--	7	--	50
	82-01-26	--	<5	--	<5	--	6	--	130
	82-03-08	<5	<5	<5	<5	20	<5	7000	610

Table 4.--Chemical analyses of ground water--Continued

Well number	Date of sample	Lead, total recov-erable (µg/L as Pb)	Lead, dis-solved (µg/L as Pb)	Manga-nese, total recov-erable (µg/L as Mn)	Manga-nese, dis-solved (µg/L as Mn)	Mercury dis-solved (µg/L as Hg)	Nickel, total recov-erable (µg/L as Ni)	Nickel dis-solved (µg/L as Ni)	Sele-nium, total (µg/L as Se)	Sele-nium, dis-solved (µg/L as Se)
8010A	82-03-11	180	--	610	--	--	20	--	<1	--
	82-04-22	<50	<50	230	200	.2	10	11	<1	<1
	82-07-07	--	370	--	220	.1	--	18	--	<1
8011A	82-03-10	240	<50	470	440	<.1	20	23	<1	<1
8011B	81-11-18	--	--	--	--	--	--	--	--	--
	82-03-11	--	--	--	--	<.1	--	--	--	--
	82-05-13	--	77	--	100	<.1	--	18	--	<1
	82-07-07	--	53	--	56	<.1	--	<5	--	<1
8012A	82-03-09	--	<50	--	430	<.1	--	10	--	<1
8012B	82-03-10	--	<50	--	790	<.1	--	10	--	<1
8013	81-12-22	--	<50	--	33	.2	--	<5	--	--
	82-01-27	--	<50	--	35	<.1	--	<5	--	<1
	82-03-09	<50	<50	180	160	<.1	<5	<5	<1	<1
8014A	81-11-18	--	--	--	--	--	--	--	--	--
	82-03-11	--	<50	--	100	<.1	--	6	--	<1
8014B	81-11-18	--	--	--	--	<.1	--	--	--	--
	82-03-11	--	<50	--	1100	<.1	--	<5	--	<1
8015A	82-03-11	<50	<50	200	220	.1	30	29	<1	<1
8017	81-12-23	--	<50	--	860	<.1	--	<5	--	--
	82-01-27	--	<50	--	590	<.1	--	<5	--	<1
	82-03-10	250	--	550	--	<.1	<5	--	<1	--
	82-05-13	--	<50	--	140	<.1	--	6	--	<1
8018	82-01-12	--	<50	--	1700	<.1	--	<5	--	<1
	82-01-26	--	<50	--	2200	<.1	--	<5	--	<1
	82-03-11	70	<50	2000	1900	<.1	7	<5	1	<1
8019	81-12-22	--	<50	--	190	<.1	--	<5	--	--
	82-01-26	--	<50	--	70	<.1	--	<5	--	<1
	82-03-09	<50	<50	400	370	<.1	<5	<5	<1	<1
8023A	82-03-11	--	<50	--	230	<.1	--	41	--	<1
8023B	82-03-11	--	<50	--	32	<.1	--	<5	--	--
8024	81-12-22	--	<50	--	720	.2	--	<5	--	--
	82-01-26	--	<50	--	930	<.1	--	<5	--	<1
	82-03-08	<50	<50	1500	1200	<.1	<5	<5	3	<1

Table 4.--Chemical analyses of ground water--Continued

Well number	Date of sample	Silver, total recoverable (µg/L as Ag)	Silver, dissolved (µg/L as Ag)	Strontium, total recoverable (µg/L as Sr)	Strontium, dissolved (µg/L as Sr)	Vanadium, total (µg/L as V)	Vanadium, dissolved (µg/L as V)	Zinc, total recoverable (µg/L as Zn)	Zinc, dissolved (µg/L as Zn)
8010A	82-03-11	<3	--	1400	--	11	--	200	--
	82-04-22	<3	4	1800	1800	6	<5	230	510
	82-07-07	<3	<3	--	1800	--	6	--	130
8011A	82-03-10	<5	<5	1600	1600	12	11	210	<200
8011B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	--	--	--	--	--	--	--
	82-05-13	--	<3	--	450	--	7	--	210
	82-07-07	--	<3	--	400	--	<5	--	<50
8012A	82-03-09	--	<3	--	1600	--	<5	--	<200
8012B	82-03-10	--	<3	--	1200	--	8	--	<200
8013	81-12-22	--	<3	--	240	--	<5	--	<200
	82-01-27	--	<3	--	270	--	<5	--	<200
	82-03-09	<3	<3	270	270	<5	<5	<200	<200
8014A	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	<3	--	2600	--	7	--	<200
8014B	81-11-18	--	--	--	--	--	--	--	--
	82-03-11	--	<3	--	2300	--	<5	--	<200
8015A	82-03-11	<5	<5	2100	2100	19	18	230	<200
8017	81-12-23	--	<3	--	690	--	<5	--	<200
	82-01-27	--	<3	--	750	--	<5	--	<200
	82-03-10	<3	--	610	--	<5	--	330	--
	82-05-13	--	<3	--	730	--	<5	--	280
8018	82-01-12	--	<3	--	350	--	<5	--	<200
	82-01-26	--	<3	--	330	--	<5	--	<200
	82-03-11	<3	<3	350	340	<5	<5	<200	<200
8019	81-12-22	--	<3	--	140	--	<5	--	<200
	82-01-26	--	<3	--	150	--	<5	--	<200
	82-03-09	<3	<3	160	160	<5	<5	<200	<200
8023A	82-03-11	--	<5	--	2500	--	17	--	<200
8023B	82-03-11	--	<3	--	240	--	<5	--	<200
8024	81-12-22	--	<3	--	160	--	<5	--	<200
	82-01-26	--	<3	--	180	--	<5	--	<200
	82-03-08	<3	<3	180	170	10	<5	<200	<200

Table 5.--Observation wells listing lithology at screened interval and geologic and geohydrologic units

Local well No.	Lithology at screened interval[1]	Geologic unit	Geohydrologic unit
8010A	coal (Herrin No. 6)	1	A
8010B	shale	8	B
8011A	limestone	3	A
8011B	limestone	9	C
8012A	coal (Herrin No. 6)	1	A
8012B	shale	6	A
8013	clayey pebbly sand	12	E
8014A	coal (Herrin No. 6)	1	A
8014B	limestone	7	A
8015A	coal (Herrin No. 6)	1	A
8015B	shale	6	A
8016A	shale	8	B
8016B	limestone	9	C
8017	clayey sand	12	E
8018	silty clay	11	E
8019	clayey fine sand	12	E
8021A	shale	6	A
8021B	limestone	9	C
8022	silty clay	11	D
8023A	coal (Herrin No. 6)	1	A
8023B	coal and shale	8	B
8024	pebbly sand	12	E

[1] All screens are 3 feet in length except 8010A which has a 6-foot screen.

Table 6.--Concentration of major cation and anion for geohydrologic units

Geohydrologic unit	Major cation	Concentration (mg/L)	Major anion	Concentration (mg/L)
A	Sodium	2,300 to 3,800	Chloride	2,237 to 5,390
B	Sodium	68	Alkalinity as bicarbonate	769
C	Sodium	379 to 444	Alkalinity as bicarbonate	520 to 627
D	Calcium	81 to 85	Alkalinity as bicarbonate	442 to 462
E	Sodium	80 to 139	Alkalinity as bicarbonate	315 to 562

Table 7.--Head loss in selected wells for the period January 1982 through April 1983

Geohydrologic unit	Well	Head loss (feet)
A	8010A	10.90
A	8011A	14.20
C	8011B	32.20
A	8012A	30.20
A	8012B	30.20
A	8015A	20.10
A	8023A	26.10
B	8023B	35.10

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