WATER QUALITY OF LARGE DISCHARGES FROM MINES IN THE ANTHRACITE REGION OF EASTERN PENNSYLVANIA

By Charles R. Wood

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4243

Prepared in cooperation with the
PENNSYLVANIA DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY

Lemoyne, Pennsylvania
1996

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
GORDON P. EATON, Director

For additional information write to:

District Chief
U.S. Geological Survey
Water Resources Division
840 Market Street
Lemoyne, Pennsylvania 17043-1586

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286, MS 517
Denver Federal Center
Denver, Colorado 80225

CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and scope	1
General description of the study area	1
Methods of study	3
Previous investigations	3
Acknowledgments	12
Water quality	12
Sites studied	15
Field measurements	15
Temperature	15
pH	15
Acidity	45
Dissolved oxygen	45
Silica	48
Cations	48
Aluminum	51
Barium	51
Boron	51
Cadmium	51
Calcium	52
Cobalt	52
Copper	52
Iron	52
Lead	60
Lithium	60
Magnesium	60
Manganese	60
Nickel	60
Potassium	62
Sodium	62
Strontium	63
Zinc	63
Anions	63
Alkalinity	63
Chloride	63
Fluoride	63
Nitrogen	64
Sulfate	64
Summary	66
Selected references	66

ILLUSTRATIONS

Page

1. Map showing locations of the four coal fields in eastern Pennsylvania 2

2-3. Graphs showing:
   2. Relation of monthly sulfate and iron concentrations to discharge for the Owl Hole Tunnel (site 30), Eastern Middle Anthracite Field, east-central Pennsylvania, 1986-91 13
   3. Relation of monthly sulfate and iron concentrations to discharge for the Centralia Drainage Tunnel (site 68), Western Middle Anthracite Field, east-central Pennsylvania, 1986-92 14

4-7. Maps showing sites where discharge water from mines was sampled in the:
   4. Northern Anthracite Field, northeast Pennsylvania 16
   5. Eastern Middle Anthracite Field, east-central Pennsylvania 17
   6. Western Middle Anthracite Field, east-central Pennsylvania 18
   7. Southern Anthracite Field, east-central Pennsylvania 19

8-12. Graphs showing:
   8. Change in pH between 1975 and 1991 for water discharged from mines in the four anthracite coal fields of eastern Pennsylvania 44
   9. Comparison of hot and cold field and laboratory acidity titrations for water discharged from the Beaver Meadow (Quakake) Tunnel (site 37), Eastern Middle Anthracite Field, east-central Pennsylvania 47
   10. Relation of dissolved oxygen concentration to acidity in water discharged from mines in the anthracite coal fields of Pennsylvania 49
   11. Relation of dissolved oxygen concentration to dissolved iron concentration in water discharged from mines in the anthracite coal fields of Pennsylvania 50
   12. Annual mean iron concentration in water discharged from the Old Forge borehole (site 13), Northern Anthracite Field, northeast Pennsylvania, 1962-91 61
   13. Annual mean sulfate concentration in water discharged from the Old Forge borehole (site 13), Northern Anthracite Field, northeast Pennsylvania, 1962-91 65

TABLES

1-4. Water-quality and discharge data for mines in the:
   1. Northern Anthracite Field, northeast Pennsylvania 4
   2. Eastern Middle Anthracite Field, east-central Pennsylvania 5
   3. Western Middle Anthracite Field, east-central Pennsylvania 7
   4. Southern Anthracite Field, east-central Pennsylvania 9

5. Results of chemical analyses for major ions, nutrients, and physical properties for water discharged from mines in the anthracite fields of Pennsylvania 20
6. Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania 32
7. Laboratory pH compared to field pH for the same sample for water discharged from selected mines in the Northern Anthracite Field, northeast Pennsylvania 46
8. Acidity of water discharged from selected mines in the Southern Anthracite Field, east-central Pennsylvania, 1965 and 1991 48
9. Aluminum concentrations for selected periods in water discharged from mines in the anthracite fields of Pennsylvania 51
10. Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania 53
11. Manganese concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania 62

CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second

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

$$°F = 9/5\ (°C) + 32$$

$$°C = 5/9\ (°F - 32)$$

Abbreviated water-quality units used in report:

µg/L micrograms per liter

µS/cm microsiemens per centimeter at 25 degrees Celsius

mg/L milligrams per liter

Water Quality of Large Discharges from Mines in the Anthracite Region of Eastern Pennsylvania

By Charles R. Wood

ABSTRACT

In 1991, 99 of the 102 coal mines in the anthracite coal fields of Pennsylvania that discharged 1.0 cubic foot per second or more when water-quality samples were collected in 1975 were revisited. Water was not discharging from 15 of these 99 mines in 1991. Discharge, water temperature, specific conductance, pH, dissolved oxygen, sulfate, iron, manganese, alkalinity, and acidity were measured in water samples collected at 84 mines to assess changes in water quality from 1975 to 1991. The pH increased in water samples of 64 of the 81 mines. However, acidity was essentially unchanged. Concentrations of iron decreased in water discharge samples from 57 of 82 mines, manganese concentrations decreased in samples from 23 of 26 mines, and sulfate concentrations decreased in samples from 62 of 77 mines. The median change in sulfate was a decrease of 139 milligrams per liter. Alkalinity increased in water discharge samples from 43 mines, remained the same at 22 mines, and decreased at 14 mines. In 1975, the samples were collected during high base flow in the spring; in 1991, samples were collected during lower-than-normal base flow in the fall. This may have affected the comparisons.

Many mine discharges have elevated concentrations of aluminum, calcium, cobalt, iron, lithium, magnesium, manganese, nickel, strontium, zinc, and sulfate.

INTRODUCTION

Long-term records are needed to indicate trends in water quality of discharges from abandoned coal mines. Specifically, discharge quality and flow need to be characterized in order to demonstrate relations among these characteristics and changes in environmental processes, land use, and other factors.

Purpose and Scope

This report presents the discharge, field measurements of water quality, and analytical results for water samples collected in 1991 from most of the larger mine discharges in the anthracite region of Pennsylvania. The results are summarized and compared to results from samples collected in prior years from the same discharges to assess changes in water quality over time. In order to characterize the quality of water discharged from the mines, this report also presents data, mostly collected by the U.S. Geological Survey (USGS) before 1976, on the concentrations of common constituents, nutrients, and trace elements. Concentrations are compared to those for ground water from areas of Pennsylvania not underlain by anthracite coal.

General Description of the Study Area

The anthracite region includes the four anthracite fields in eastern Pennsylvania and surrounding areas (fig. 1). Anthracite has been extensively mined in the Northern, Eastern Middle, Western Middle, and Southern Fields. The coal fields underlie parts of 10 counties and extend from 20 mi northeast of Harrisburg to 20 mi northeast of Scranton. Their combined area is about 408 mi^2.

The four coal fields lie within the Ridge and Valley Physiographic Province and are underlain by the Llewellyn and Pottsville Formations of Pennsylvanian age, which contain sandstone, conglomerate, shale, and several coal seams (Wood and others, 1969). Generally, coal underlies the center of the valleys. In the western part of the Southern Field, coal underlies the ridges as well as the valleys. From about

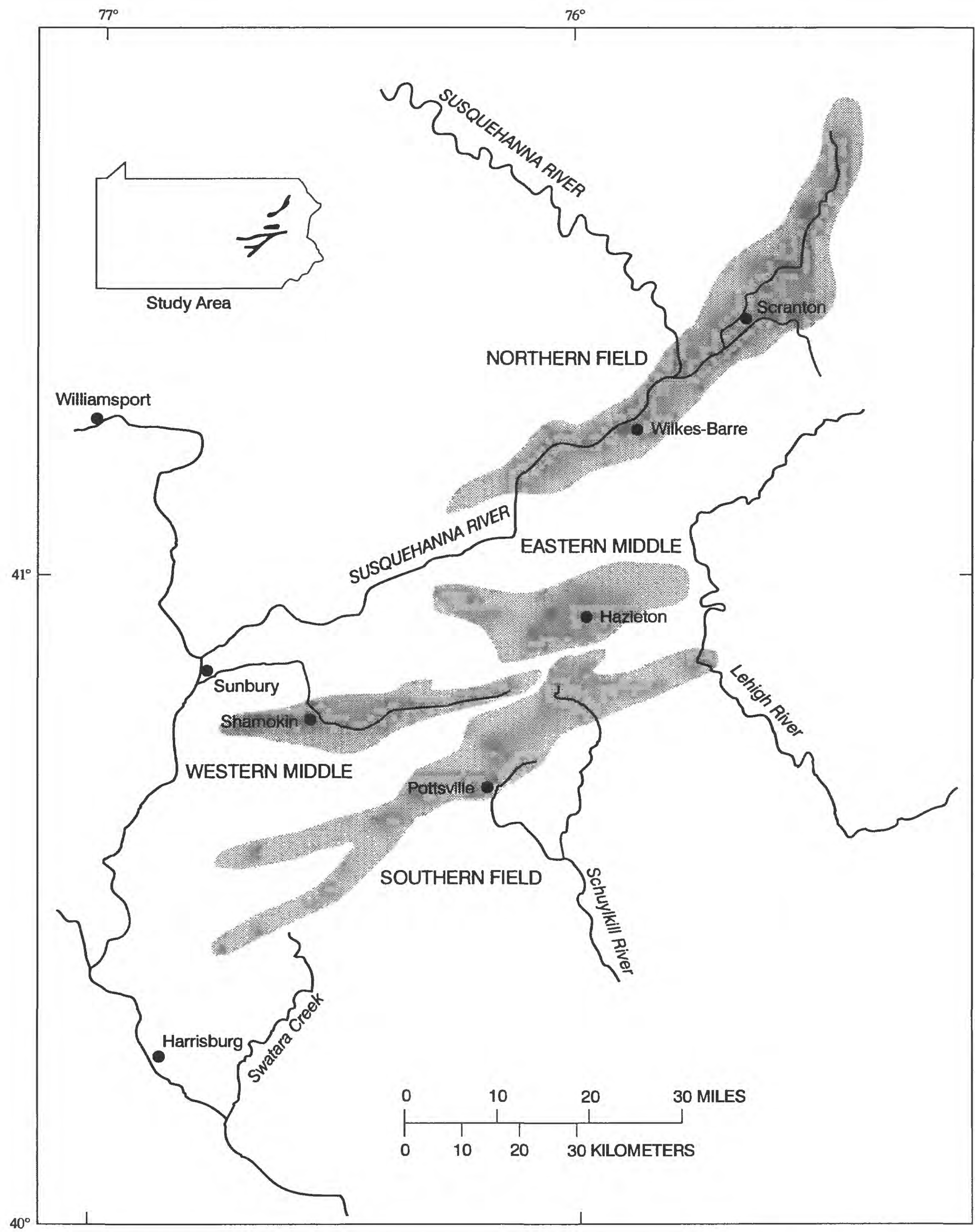


Figure 1. Locations of the four coal fields (shaded areas) in eastern Pennsylvania. (From Growitz and others, 1985, fig. 1.)

1830 to 1972, large quantities of coal were removed from underground mines. Deep mining below the water table created extensive voids that have since filled with water. Locally, small hills were created by storage of mine waste, and surface depressions have formed where the land has subsided. Depressions also were created by surface mining. In many areas, surface soils were covered or mixed with mine waste, and vegetation is sparse. Infiltration rates were increased significantly by surface depressions, by the large-grained mine wastes on the surface, by the lack of vegetation, and by fracturing of the bedrock caused by subsidence (Growitz and others, 1985, p. 2).

Methods of Study

Growitz and others (1985) measured and sampled water discharged from 251 mines in April 1975. The total flow of all the nonpumping discharges was 867 ft^3/s. Approximately 102 of these discharged 1.0 ft^3/s or more, and they accounted for 823 ft^3/s or 95 percent of the total measured discharge. Except for 15 that were dry, all but 3 of these 102 mines (figs. 4-7) were measured and sampled again in October and November 1991(tables 1-4). Discharge, water temperature, specific conductance, pH, dissolved oxygen, alkalinity, and acidity were measured in the field, and water samples were collected for laboratory chemical analysis. Water samples were analyzed for concentrations of dissolved iron, manganese, and sulfate at the USGS National Laboratory in Denver, Colo. Additional data were obtained from the files of the Pennsylvania Department of Environmental Protection (PaDEP), the U.S. Environmental Protection Agency (USEPA), the USGS, and from published reports.

In 1991, the total flow of the mines that discharged more than 1.0 ft^3/s in 1975 was 270 ft^3/s, or only 33 percent of the 1975 flow. In 1975, the discharge samples were collected during a period of high base flow in the spring; in 1991, the discharge samples were collected during lower-than-normal base flow in the fall. Thus, inferences can be made about changes in chemical concentrations but cannot be made about differences in chemical loads between 1975 and 1991. Also, because concentrations of many chemical constituents may be different in low base flow than in high base flow, comparison of 1975 to 1991 data presents problems. Such comparisons were made for some constituents but should be used with caution. The water-quality improvements that were observed may be understated or overstated. Where different periods are compared for a single site, means were used if more than one analysis exists. Where groups of sites are compared, medians were used.

Previous Investigations

The most comprehensive early work on water quality from the anthracite mines was done by the U.S. Bureau of Mines. Many of the largest discharge tunnels were sampled in 1941 and 1946. The results of these investigations were summarized by Ash and others (1949, 1951) and Felegy and others (1948). Mines are identified by code numbers in these reports, and Ash and others (1955) must be consulted to find the names and locations of the discharges.

Several investigations of specific areas were conducted by the USGS. These include studies of the Schuylkill River Basin by Biesecker and others (1968), the abandoned coal mines of the Wyoming Valley by Hollowell (1974), Lackawanna County by Hollowell and Koester (1975), the Black Creek watershed near Mocanaqua, Luzerne County, by Newport and others (1971), and the Western Middle Coal Field by Reed and others (1987). Also, Growitz and others (1985) sampled most of the mine discharges in the anthracite region in 1975.

PaDEP commissioned studies of many drainage basins in the anthracite region as part of its Operation Scarlift. These include studies by A.W. Martin Associates, Inc. (1973), Albert E. Peters Associates (1971, 1978), Anthracite Research and Development Co., Inc. (1972), Berger Associates, Inc. (1972), Gannett, Fleming, Corddry, and Carpenter, Inc. (1972a, 1972b, 1974), GEO-Technical Services, Inc. (1975, 1976), Sanders & Thomas, Inc. (1973, 1975), and Skelly and Loy (1974, 1987).

Unpublished data on water quality for water discharged from mines are available from several sources. Water samples were collected monthly at several mines by the PaDEP. Also, PaDEP permit files contain analyses of discharge water by PaDEP and private laboratories. A few analyses of discharge water are available for mines at USEPA National Priorities List sites.

Table 1. *Water quality and discharge data for mines in the Northern Anthracite Field, northeast Pennsylvania*

[--, no data; <, less than; >, greater than; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter]

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	Acidity to indicated pH as $CaCO_3$ (mg/L) 8.3
3	Klondike Mine	Vandling Drift	41°38′15″	4-15-75	4.0	9.5	185	4.7	--	92	<1	--	3	38	58
			75°27′35″	10-28-91	.00	--	--	--	--	--	--	--	--	--	--
5	Coalbrook Mine	Upper Wilson Creek	41°36′11″	4-15-75	2.6	10.0	450	6.3	--	190	<1	--	36	5	16
		(Simpson) Drift	75°29′09″	10-28-91	.81	9.3	376	6.5	7.0	150	.05	0.14	36	5	15
6	Coalbrook Mine	Lower Wilson Creek	41°36′02″	4-15-75	16	9.5	380	5.9	--	150	<1	--	34	28	40
		(Simpson) Shaft	75°29′13″	10-28-91	4.2	9.0	379	6.2	6.3	140	.09	.05	29	13	20
7	Jermyn Mine	Jermyn Slope	41°31′16″	4-16-75	39	12.0	470	5.6	--	220	1.5	--	13	20	33
			75°32′49″	10-30-91	12	10.4	454	6.0	1.1	190	.32	.76	32	30	48
9	Gravity Slope	slope (Peckville	41°28′52″	4-16-75	23	11.5	390	5.3	--	170	.32	1.5	13	20	50
	Mine	Shaft)	75°33′48″	10-29-91	5.1	9.7	376	5.9	.5	150	.48	.87	20	35	45
11	Lackawanna	Jerome Shaft	41°28′44″	4-16-75	2.4	12.0	400	4.8	--	150	20	--	2	3	58
	Mine		75°35′48″	10-29-91	.00	--	--	--	--	--	--	--	--	--	--
13	Old Forge Mine	Old Forge borehole	41°21′36″	4-24-75	97	16.0	1,470	5.6	--	780	40	5.6	27	145	210
			75°45′04″	10-29-91	68	14.3	1,050	6.4	.8	420	25	3.2	110	136	212
14	Seneca Mine	Duryea breech	41°20′51″	4-17-75	34	15.5	1,400	5.7	--	700	48	7.3	72	163	233
			75°46′42″	10-30-91	5.6	13.0	1,020	6.5	5.5	310	26	3.4	109	60	127
16	Number 9 Mine	Pittston (Butler)	41°19′36″	4-15-75	8.7	10.5	700	4.9	--	265	2.5	--	7	38	43
		Water Tunnel	75°47′25″	10-30-91	2.5	11.3	890	4.8	9.4	320	3.4	3.7	3	45	53
17	Plainsville outlet		41°17′03″	4-15-75	9.2	14.5	1,700	6.1	--	1,100	85	--	123	176	318
			75°51′20″	10-30-91	.00	--	--	--	--	--	--	--	--	--	--
18	South Wilkes-	Solomon Creek	41°13′50″	4-14-75	39	16.0	3,000	5.2	--	1,800	190	17	77	450	750
	Barre Mine	boreholes	75°55′20″	10-31-91	20	15.4	1,390	6.2	2.0	640	--	5.2	106	146	237
19	Nottingham-	Airshaft Number 22	41°13′34″	4-15-75	27	17.0	2,100	5.6	--	760	95	--	57	276	400
	Buttonwood Mine		75°56′13″	10-31-91	5.0	16.4	1,460	6.0	.4	760	53	6.6	129	222	318
20	Truesdale Mine	Askam Shaft borehole	41°11′58″	4-14-75	11	16.5	3,000	5.6	--	2,000	>100	--	87	327	613
			75°57′52″	10-31-91	.00	--	--	--	--	--	--	--	--	--	--
21	Number 7 Mine	seepage	41°12′33″	4-14-75	3.5	12.5	2,200	5.5	--	1,400	40	--	13	125	174
			76°00′07″	10-31-91	.22	10.4	1,030	6.5	3.0	420	1.0	4.5	97	25	50
22	Number 7 Mine	Susquehanna Num-	41°12′27″	4-14-75	8.5	18.0	4,800	6.0	--	2,800	>100	--	212	438	750
		ber 2 Shaft	76°00′22″	10-31-91	5.8	14.0	1,830	6.5	7.3	980	43	7.2	103	76	139
24	West End Mine	Mocanaqua Tunnel	41°09′01″	4-14-75	5.8	11.0	1,250	3.5	--	680	60	12	0	278	363
			76°08′40″	11-1-91	2.4	11.7	1,220	4.4	.1	690	75	9.7	0	207	262

Table 2. *Water-quality and discharge data for mines in the Eastern Middle Anthracite Field, east-central Pennsylvania*

[--, no data; <, less than; >, greater than; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter]

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	Acidity to indicated pH as $CaCO_3$ (mg/L) 8.3
28	Pond Creek	strip pool overflow	41°02′14″	4-16-75	13	7.0	140	5.6	--	42	<1	--	1.6	6	10
	Mine		75°51′00″	10-8-91	<.01	--	--	--	--	--	--	--	--	--	--
29	Sandy Run	Sandy Run Tunnel	41°00′58″	4-16-75	2.3	8.5	365	3.7	--	130	<1	--	0	63	74
	Mine		75°50′55″	11-4-91	.29	8.8	970	3.5	0.6	470	17	15	0	292	325
30	East Black	Owl Hole Tunnel	41°00′02″	4-16-75	4.5	7.0	620	3.5	--	390	3	--	0	267	274
	Creek Mine		75°49′11″	11-4-91	1.4	8.3	890	3.3	9.8	430	1.2	6.1	0	262	285
34	Buck	Buck Mountain	40°58′53″	4-16-75	1.7	9.0	660	3.3	--	260	5.1	4.9	0	174	183
	Mountain Mine	Tunnel	75°48′49″	11-6-91	.82	8.4	935	3.3	8.8	430	5.5	8.5	0	285	315
35	Stockton	shaft	40°58′07″	4-16-75	2.3	9.0	180	3.9	--	53	1	--	0	38	53
	Mine [1]		75°53′53″												
36	Hazle Brook	Lehman & Kovel	40°58′12″	4-16-75	1.5	7.0	350	3.5	--	110	1	--	0	79	88
	Mine [1]	strip pool overflow	75°53′51″												
37	Beaver	Beaver Meadow	40°55′09″	4-16-75	20	9.0	520	3.7	--	100	<1	--	0	93	110
	Meadow Mine	Tunnel	75°54′07″	11-6-91	5.0	9.2	493	3.6	10.2	220	1.2	2.7	0	86	91
38	Jeddo Mine	Jeddo Tunnel	41°00′19″	4-16-75	65	10.0	875	3.6	--	430	6	--	0	150	168
			75°59′38″	11-5-91	24	11.2	1,100	3.9	10.2	600	2.8	8.4	0	116	131
39	Dainty Slope	collapsed slope	40°58′12″	4-14-75	1.6	9.0	<50	4.5	--	8	<1	--	0	3	5
	Mine		76°06′30″	11-7-91	.00	--	--	--	--	--	--	--	--	--	--
40	Tomhicken	strip pool overflow	40°57′55″	4-15-75	2.7	8.5	225	5.6	--	66	12	1.5	21	38	59
	Mine		76°05′30″	11-5-91	.16	7.5	238	5.5	5.9	60	.36	1.1	5	30	38
41	Black Ridge	strip pool overflow	40°58′21″	4-15-75	1.2	8.0	180	3.9	--	30	<1	--	0	125	150
	Mine		76°02′54″	11-7-91	.00	--	--	--	--	--	--	--	--	--	--
42	Stony Creek	Stony Creek and	40°57′39″	4-15-75	4.0	5.5	<50	4.4	--	9	1	--	0	5	6
	Mine	seepage	76°02′19″	11-5-91	.27	4.8	24	4.5	9.5	7.2	.28	.15	3	5	8
45	Oneida Mine	Oneida Tunnel 1	40°55′32″	4-15-75	6.4	7.0	205	3.7	--	69	1	--	0	40	45
			76°07′25″	11-6-91	.88	10.0	416	3.6	5.9	170	1.2	1.8	0	70	83
48	Green	Green Mountain	40°53′52″	4-15-75	2.1	9.0	210	3.6	--	76	1	--	0	43	48
	Mountain Mine	Tunnel	76°04′03″	11-7-91	.50	8.5	269	3.6	10.5	95	.51	1.3	--	40	50
49	Audenreid	Audenreid Tunnel	40°53′52″	4-15-75	19	10.0	600	3.3	--	280	2	--	0	108	118
	Mine		76°03′59″	11-7-91	5.9	10.3	623	3.5	8.5	300	1.6	3.8	0	116	129

Table 2. *Water-quality and discharge data for mines in the Eastern Middle Anthracite Field, east-central Pennsylvania--Continued*

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (μS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	Acidity to indicated pH as $CaCO_3$ (mg/L) 8.3
50	Oneida Mine	Oneida Tunnel 3	40°55′06″	4-16-75	9.1	8.0	170	4.3	--	53	0.22	0.57	0	30	40
			76°08′50″	11-4-91	1.4	9.3	162	4.6	10.3	74	.10	.73	<1	25	33
52	Gowen Mine	Gowen Tunnel	40°56′54″	4-15-75	6.6	8.0	300	3.8	--	110	2	--	0	55	60
			76°10′47″	11-5-91	.27	10.5	615	3.6	8.7	250	3.0	4.5	0	103	113
53	Derringer Mine	Derringer Tunnel	40°56′48″	4-15-75	8.8	8.5	205	3.7	--	280	1	--	0	30	33
			76°10′43″	11-5-91	1.5	9.0	300	4.0	5.4	93	.08	1.3	0	30	35

[1]Unable to get permission to sample in 1991.

Table 3. *Water-quality and discharge data for mines in the Western Middle Anthracite Field, east-central Pennsylvania*

[--, no data; <, less than; >, greater than; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter]

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	8.3
57	Vulcan-Buck	Vulcan-Buck	40°48′55″	4-16-75	9.8	9.5	375	4.3	--	160	10	--	0	63	68
	Mountain Mine	Mountain boreholes	76°07′35″	11-1-91	.86	9.0	348	4.7	0.3	140	11	1.5	2	75	86
58	Gilberton Mine	Gilberton pump	40°48′01″	4-18-75	23	14.0	1,800	6.1	--	1,000	54	16	102	108	240
		discharge	76°12′34″	10-30-91	7.8	12.0	1,400	6.0	8.8	640	51	9.4	57	131	187
59	Weston Mine	Weston Mine	40°48′30″	4-16-75	3.7	15.0	1,900	6.1	--	1,200	20	--	62	65	118
		seepage	76°14′49″	11-1-91	.03	13.5	1,230	6.7	10.8	670	9.5	8.4	71	27	53
60	Weston Mine [1]	Lost Creek borehole	40°48′25″ 76°14′49″	4-16-75	1.0	16.0	2,150	6.1	--	1,300	20	--	177	132	230
61	Hammond Mine	Connerton Village	40°48′06″	4-16-75	1.7	15.0	1,950	6.3	--	1,200	40	--	205	88	210
		boreholes	76°16′04″	10-10-91	.00	--	--	--	--	--	--	--	--	--	--
63	Girard Mine	seepage	40°47′30″	4-16-75	8.0	12.0	825	5.9	--	460	20	--	71	105	155
			76°16′06″	10-30-91	2.0	10.0	620	6.4	7.7	230	19	4.2	79	61	88
64	Packer Number	breach and	40°47′41″	4-18-75	45	15.0	2,400	5.8	--	1,300	40	--	167	68	174
	5 Mine	boreholes	76°16′48″	10-30-91	25	12.5	1,540	6.4	3.5	700	23	9.8	144	78	164
64B	Packer Number 5 Mine	breach	40°47′39″ 76°16′28″	10-30-91	3.2	13.0	1,550	6.3	2.6	760	21	9.8	150	101	178
66	Preston Mine	Tunnel	40°47′25″	4-17-75	2.2	10.0	520	5.6	--	200	20	--	46	40	80
			76°17′34″	10-30-91	.36	9.5	410	6.4	0.5	110	12	1.5	103	45	115
68	Centralia Mine	Tunnel	40°47′27″	4-16-75	11	11.0	950	3.5	--	580	10	--	0	133	145
			76°19′26″	10-30-91	2.7	11.5	1,100	3.4	9.2	660	6.8	6.1	0	154	169
70	Bast Mine	Oakland Tunnel	40°47′06″	4-17-75	6.6	14.0	1,400	6.3	--	660	20	--	118	58	110
			76°19′54″	10-30-91	6.4	12.0	1,150	6.4	6.1	520	17	3.6	172	62	108
71	Tunnel Mine [2]	drain pool area and	40°46′45″	4-17-75	1.3	17.0	1,250	6.5	--	640	30	--	98	23	48
		seepage	76°20′12″	--	--	--	--	--	--	--	--	--	--	--	--
73	Potts Mine	east breach	40°46′24″	4-17-75	3.2	15.0	2,400	6.6	--	960	40	--	328	38	170
			76°22′15″	10-10-91	.00	--	--	--	--	--	--	--	--	--	--
75	Locust Gap	Helfenstein Tunnel	40°45′04″	4-17-75	3.9	13.5	1,200	7.2	--	670	10	--	54	--	45
	Mine		76°26′12″	10-29-91	2.5	12.5	1,420	6.7	9.4	860	22	6.6	49	24	90
77	Locust Gap	Doutyville Tunnel	40°44′35″	4-18-75	13	13.0	1,280	3.6	--	700	12	6.4	0	106	135
	Mine		76°28′38″	10-29-92	1.5	11.0	970	5.9	10.6	620	15	4.5	7	40	51

Table 3. *Water-quality and discharge data for mines in the Western Middle Anthracite Field, east-central Pennsylvania--Continued*

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	8.3
80	Mid-Valley	Tunnel	40°48′48″	4-17-75	5.9	10.5	600	3.3	--	280	15	--	0	140	155
	Mine		76°24′24″	11-1-91	3.7	9.0	420	3.5	0.0	190	19	2.8	0	156	163
84	Scott Ridge	breach	40°47′30″	4-17-75	2.8	12.7	980	5.3	--	1,190	50	--	16	165	210
	Mine		76°29′26″	11-1-91	4.8	11.0	700	5.6	4.5	360	29	4.3	33	137	161
85	Scott Ridge	rock tunnel	40°47′39″	4-17-75	15	12.7	980	5.3	--	490	45	6.8	16	115	165
	Mine[3]		76°29′19″												
86	Colbert Mine	breach	40°47′26″	4-17-75	.9	12.0	900	5.3	--	510	40	--	13	118	138
			76°29′47″	11-1-91	1.7	11.0	700	5.7	4.5	350	28	4.2	37	151	179
87	Excelsior Mine	strip pool overflow	40°46′25″	4-18-75	13	12.0	810	4.9	--	400	44	5.4	5	158	185
			76°29′37″	11-1-91	6.3	10.0	640	5.5	4.0	310	31	3.6	31	140	164
88	Maysville Mine	borehole	40°47′03″	4-16-75	3.3	11.2	1,000	6.3	--	460	50	--	133	125	200
	Numbers 1 and 2		76°30′52″	10-31-91	2.2	11.0	940	6.3	4.5	440	29	4.3	106	111	165
89	Corbin Mine	Corbin Water-level	40°46′46″	4-16-75	1.0	12.0	810	4.1	--	490	40	--	0	210	230
		Drift	76°30′53″	10-31-91	.49	10.5	830	4.2	3.1	410	43	5.5	0	196	220
91	Big Mountain	Number 1 Slope	40°46′19″	4-16-75	2.0	11.5	700	3.4	--	300	20	--	0	150	160
	Mine		76°32′19″	10-31-91	.01	10.0	720	4.5	.0	360	30	4.0	0	157	188
92	Cameron Mine	air shaft	40°47′44″	4-16-75	4.0	12.2	1,470	3.4	--	790	60	--	0	355	385
			76°33′59″	10-31-91	3.1	12.0	1,180	4.1	2.0	700	66	7.3	0	248	289
93	Cameron Mine	drift	40°47′37″	4-16-75	4.7	14.0	1,700	4.1	--	1,100	150	--	0	420	474
			76°33′55″	10-31-91	.32	10.5	1,350	6.3	9.9	870	20	4.9	25	54	69
96	Cameron Mine	drift and tunnel	40°47′31″	4-16-75	1.1	14.5	1,300	5.5	--	920	60	--	38	185	210
			76°33′46″	10-31-91	.00	--	--	--	--	--	--	--	--	--	--
97	Henry Clay	pump slope	40°46′37″	4-16-75	11	13.0	950	5.6	--	470	50	--	43	145	170
	Stirling Mine		76°34′07″	10-31-91	3.0	12.0	860	5.9	.5	490	34	4.1	53	123	185
103	North Franklin	drift and borehole	40°46′17″	4-18-75	7.3	12.5	980	3.7	--	580	25	6.0	0	150	175
	Mine		76°40′44″	10-31-91	1.6	10.0	750	5.6	1.3	360	18	3.0	24	122	141
103A	North Franklin	includes site 103 and	40°46′36″	4-18-75	8.3	12.5	1,100	3.5	--	560	22	--	0	225	250
	Mine	seepage	76°40′58″	10-31-91	2.2	10.0	740	6.2	10.8	410	17	3.1	11	42	48

[1]Site 60 included with site 59 in 1991.
[2]Omitted 1991.
[3]Site 85 combined with site 84 in 1991

Table 4. *Water-quality and discharge data for mines in the Southern Anthracite Field, east-central Pennsylvania*

[--, no data; <, less than; >, greater than; ft^3/s, cubic feet per second; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter]

Site number	Name	Description	Latitude Longitude	Sampling date	Dis-charge (ft^3/s)	Water tempera-ture (°C)	Specific conduct-ance (µS/cm)	pH	Dis-solved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manga-nese (mg/L)	Alka-linity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	8.3
104	Nesquehoning	Nesquehoning	40°52′29″	4-22-75	11	12.5	1,090	6.4	--	560	6.7	4.7	36	17	48
	Mine	(Lausanne) Tunnel	75°45′49″	10-28-91	4.2	12.5	950	6.5	8.6	420	3.5	3.4	77	28	73
108	Greenwood	Greenwood pump	40°49′09″	4-23-75	7.7	16.5	2,500	6.7	--	1,600	33	11	--	40	93
	Mine	discharge	75°56′00″	11-1-91	27	13.5	2,190	6.6	5.5	1,200	9.9	6.1	204	28	171
110	Silverbrook	buried mine opening	40°52′24″	4-18-75	4.2	9.6	305	3.8	--	110	10	--	0	80	90
	Mine		76°00′17″	11-1-91	1.3	10.0	367	4.3	.0	150	19	1.9	0	234	252
114	Newkirk Mine	Newkirk Tunnel north	40°47′28″	4-23-75	1.1	9.5	750	3.1	--	300	12	4.3	0	220	230
		dip	75°59′09″	10-28-91	.49	10.0	575	3.3	10.0	240	5.2	2.9	0	211	229
118	Reevesdale	South Dip Tunnel	40°47′05″	4-18-75	2.2	10.0	260	3.7	--	120	2	--	0	65	74
	Mine		76°00′32″	10-28-91	.13	10.5	200	4.7	2.0	89	.90	1.1	2	156	192
119	Mary D Mine	strip pool overflow	40°46′12″	4-18-75	1.0	11.5	255	6.2	--	120	4	--	5	22	26
			76°01′56″	11-1-91	.09	11.5	100	6.5	10.2	32	.07	.02	9	<1	1
121	Bell Mine	Bell Water-level	40°45′12″	4-21-75	2.1	9.5	380	3.6	--	140	2	--	0	5	66
		Tunnel	76°02′55″	11-1-91	.51	11.0	283	5.0	.8	120	12	1.5	3	139	156
122	Tuscarora	Tuscarora sinkhole	40°45′31″	4-21-75	2.5	11.0	300	6.4	--	160	10	--	9	24	34
			76°02′57″	11-1-91	.06	13.0	960	3.0	7.0	310	14	4.3	0	348	370
131	Brockton Mine	strip pool overflow	40°45′38″	4-21-75	2.2	11.5	80	4.5	--	28	<1	--	0	10	14
			76°06′39″	10-7-91	.00	--	--	--	--	--	--	--	--	--	--
132	Brockton Mine	strip pool overflow	40°45′38″	4-21-75	1.3	8.0	40	4.5	--	8	<1	--	0	5	8
			76°06′37″	11-6-91	.25	11.5	88	4.7	5.8	28	.54	.96	1	30	40
149	Silver Creek	Tunnel	40°44′03″	4-22-75	4.6	12.5	500	4.5	--	270	20	--	0	30	45
	Mine		76°07′24″	11-7-91	.52	11.5	630	6.0	.0	300	27	3.5	54	156	237
157	Eagle Hill Mine	water-level drift	40°42′58″	4-22-75	1.8	12.5	850	5.4	--	430	5.8	4.0	16	60	90
			76°09′01″	11-6-91	.04	13.5	1,630	7.2	6.6	560	12	.45	352	0	91
160	Port Carbon	Lucianna Water-	40°42′17″	4-23-75	2.7	12.0	750	5.3	--	430	30	--	13	110	125
	Mine	Level Tunnel	76°08′22″	11-7-91	.17	10.0	410	6.8	2.8	89	2.3	.81	145	<1	40
161	Reynolds Mine	slope	40°41′43″	4-23-75	1.6	10.5	390	6.2	--	120	15	--	79	38	55
			76°09′10″	11-6-91	.30	11.5	525	6.5	.0	180	17	.47	119	53	144
162	Morea Mine	strip pool overflow	40°46′57″	4-16-75	15.0	8.0	440	3.2	--	140	10	--	0	90	95
			76°10′55″	11-6-91	1.4	8.0	308	4.0	1.8	110	9.7	1.6	0	156	192

Table 4. *Water-quality and discharge data for mines in the Southern Anthracite Field, east-central Pennsylvania--Continued*

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	8.3
163	Repplier Mine	Pool Tunnel	40°44′25″	4-23-75	1.3	9.3	100	3.9	--	28	<1	--	0	22	30
			76°11′52″	10-31-91	.15	10.3	82	4.4	1.3	27	.04	0.46	0	30	35
166	Repplier Mine	Repplier Water-level	40°44′06″	4-23-75	2.4	11.5	660	5.8	--	310	8	--	30	60	74
		Tunnel	76°12′02″	10-31-91	.32	12.3	600	6.5	7.1	280	17	4.3	40	78	115
167	Pine Forest	pump discharge	40°43′20″	4-23-75	14	13.0	1,400	3.2	--	780	4.5	10	0	105	125
	Mine		76°10′32″	11-6-91	2.1	12.0	1,000	5.5	0	520	.21	1.9	16	164	222
171	Wadesville Mine	pump discharge	40°42′51″	4-22-75	2.3	14.0	1,500	7.1	--	630	1.0	2.3	380	0	85
			76°12′21″	11-6-91	11	14.0	1,190	7.1	6.8	350	2.0	3.2	275	0	315
187	Pine Knot Mine	Pine Knot drainage	40°42′24″	4-21-75	26	10.5	720	5.2	--	370	8.5	4.6	5	65	90
		tunnel	76°15′06″	10-31-91	6.4	11.0	710	6.5	8.8	300	10	4.2	26	45	78
188	Oak Hill Mine	shaft, 6 boreholes,	40°42′12″	11-19-75	7.8	16.0	1,500	6.2	--	650	45	--	153	139	227
		seepage	76°15′16″	10-31-91	9.4	14.6	1,450	6.4	.0	650	23	5.9	181	111	250
190	Otto Mine	Otto Airshaft	40°39′58″	4-23-75	6.4	10.5	800	4.7	--	430	26	4.4	10	123	163
			76°19′14″	10-31-91	1.4	10.3	730	6.1	.0	300	15	3.0	66	151	232
202	Blackwood	Blackwood Water-	40°38′23″	4-25-75	2.6	13.0	380	5.8	--	170	1.1	1.6	17	50	74
	Mine	level Tunnel	76°19′36″	10-30-91	.45	12.0	279	6.2	9.0	120	.34	1.2	23	2	38
215	Middle Creek	strip pool overflow	40°38′20″	4-23-75	9.8	9.5	490	4.2	--	180	.28	2.4	0	63	100
	Mine		76°22′45″	10-30-91	2.0	12.0	365	6.8	10.2	150	4.7	.35	22	1	30
218	Eureka Mine	drift	40°38′41″	4-22-75	1.1	12.0	170	4.3	--	170	3	--	0	13	15
			76°24′30″	10-30-91	.11	12.0	120	4.4	9.3	29	.88	0.95	0	25	30
238	Rausch Creek	Lower Paoli Tunnel	40°36′40″	4-21-75	1.4	11.0	625	3.4	--	310	35	--	0	112	120
	East Franklin		76°25′30″	10-29-91	.01	9.3	910	6.2	3.6	460	9.6	1.4	19	38	68
	Mine														
244	Lincoln Mine	Rowe Drainage	40°35′42″	4-21-75	6.4	11.0	340	4.5	--	130	10	--	0	52	62
		Tunnel	76°26′32″	10-31-91	.84	10.5	285	6.5	8.2	110	9.9	4.3	21	35	60
252	Tower City	Tunnel	40°36′43″	4-25-75	1.5	13.0	650	2.9	--	210	8	--	0	220	413
	Number 1 Mine		76°31′04″	10-2-91	.00	--	--	--	--	--	--	--	--	--	--
253	Erdman Coal	pump discharge	40°37′13″	4-25-75	2.1	13.0	1,500	3.9	--	880	<50	--	0	237	424
	Company	(1975)	76°31′26″	10-29-91	.34	11.6	438	6.4	.0	150	17	2.8	68	86	144
		borehole (1991)													
253A	Erdman Coal	seeps and borehole	40°37′06″	- -75	--	--	--	--	--	--	--	--	--	--	--
	Company		76°31′42″	10-29-91	.30	9.8	390	6.8	9.8	140	5.7	2.3	44	1	33
255	Good Spring	buried borehole	40°37′16″	4-23-75	1.0	11.0	540	5.8	--	230	22	--	33	88	115
	Number 1 Mine		76°31′33″	10-2-91	.00	--	--	--	--	--	--	--	--	--	--

Table 4. *Water-quality and discharge data for mines in the Southern Anthracite Field, east-central Pennsylvania--Continued*

Site number	Name	Description	Latitude Longitude	Sampling date	Discharge (ft^3/s)	Water temperature (°C)	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Sulfate (mg/L)	Iron (mg/L)	Manganese (mg/L)	Alkalinity to pH 4.5 as $CaCO_3$ (mg/L)	Acidity to indicated pH as $CaCO_3$ (mg/L) 7.0	8.3
257	Valley View	intermittent pump	40°36′47″	4-24-75	2.4	13.0	925	3.5	--	470	40	--	0	107	115
	Mine		76°33′12″	10-2-91	.00	--	--	--	--	--	--	--	--	--	--
258	Valley View	Valley View Tunnel	40°36′50″	4-24-75	7.2	12.0	320	6.1	--	110	22	--	49	65	81
	Mine		76°33′07″	10-29-91	1.4	12.0	282	6.3	7.0	100	16	2.0	39	68	108
259	Markson Mine	Markson Columnway	40°37′09″	4-23-75	2.4	11.0	950	3.6	--	410	32	--	0	182	210
			76°33′02″	10-29-91	2.2	11.0	1,330	3.4	.0	540	39	8.8	0	322	396
266	Lykens-	Big Lick Tunnel	40°34′59″	4-17-75	6.7	11.8	565	6.2	--	160	15	--	115	45	70
	Williamstown		76°39′03″	10-29-91	.00	--	--	--	--	--	--	--	--	--	--
	Mine														
267	Lykens-	Lykens Water-level	40°35′07″	4-17-75	2.1	10.5	280	5.2	--	110	15	--	10	74	90
	Williamstown	Drift	76°41′58″	10-29-91	.39	10.7	268	6.1	7.2	120	17	1.2	23	59	83
	Mine														
269	Lykens-	airshaft and pump	40°34′51″	4-17-75	6.0	13.6	640	6.2	--	200	30	--	136	80	100
	Williamstown	station	76°41′59″	10-39-91	1.1	13.0	440	6.6	.4	110	18	2.4	127	47	103
	Mine														
270	Lykens-	seepage	40°34′48″	4-17-75	2.2	13.8	570	6.4	--	210	20	--	134	70	105
	Williamstown		76°42′00″	10-29-91	.61	13.0	420	6.6	0.2	110	20	2.6	119	47	97
	Mine														
272	Rausch Creek	above East Branch	40°30′16″	4-21-81	3.3	7.0	51	4.4	--	12	.02	--	0	--	19
			76°36′13″	10-28-91	.05	10.5	36	5.0	8.5	9.8	.06	.14	2	7	9
273	East Branch	at Horseshoe Trail	40°30′18″	4-21-81	1.6	7.5	38	4.8	--	8.7	.01	--	--	--	16
	Rausch Creek		76°36′05″	10-38-91	.09	11.0	54	5.2	8.6	13	.05	.49	3	8	11
274	Rausch Creek	at Horseshoe Trail	40°29′54″	4-21-81	5.4	8.0	48	4.6	--	13	.04	--	--	--	17
		(includes 291, 292)	76°35′52″	10-28-91	.26	11.0	60	4.8	10.1	19	.02	.31	5	5	6
278	Rattling Run	at Stony Creek Road	40°26′09″	4-9-91	2.7	9.5	38	4.2	--	8.4	.04	--	0	--	10
		(includes 295, 296)	76°43′01″	10-28-91	.14	12.0	35	4.8	8.8	7.5	.04	.34	2	7	8

Many previously cited reports assess how water discharged from mines in the anthracite region affects stream quality. Several other reports assess how water discharged from mines affects stream quality but do not give data for mine discharges. These include a report by Biesecker and George (1966) on streams in Appalachia affected by coal-mine drainage and reports by Cline and Balla (1975), El-Ashry and Mattei (1974), Federal Water Pollution Control Administration (1967), Rhodes and David (1968), and Susquehanna River Basin Commission (1973) on the effects of coal-mine discharges on the Susquehanna River.

Acknowledgments

The cooperation of land and mine owners who allowed access to discharges is gratefully acknowledged. The author especially thanks Reading Energy Company for turning on pumps to allow sampling and for providing quality data for water discharged from mines and Lehigh Coal and Navigation Company for allowing access to their pumps and for providing quality data for water discharged from mines. Special thanks is given to Michael Ferko, Stephen Hedish, Keith Laslow, Bondili Rao, and Roger Hornberger of PaDEP who provided the author with water-quality data for many mines.

WATER QUALITY

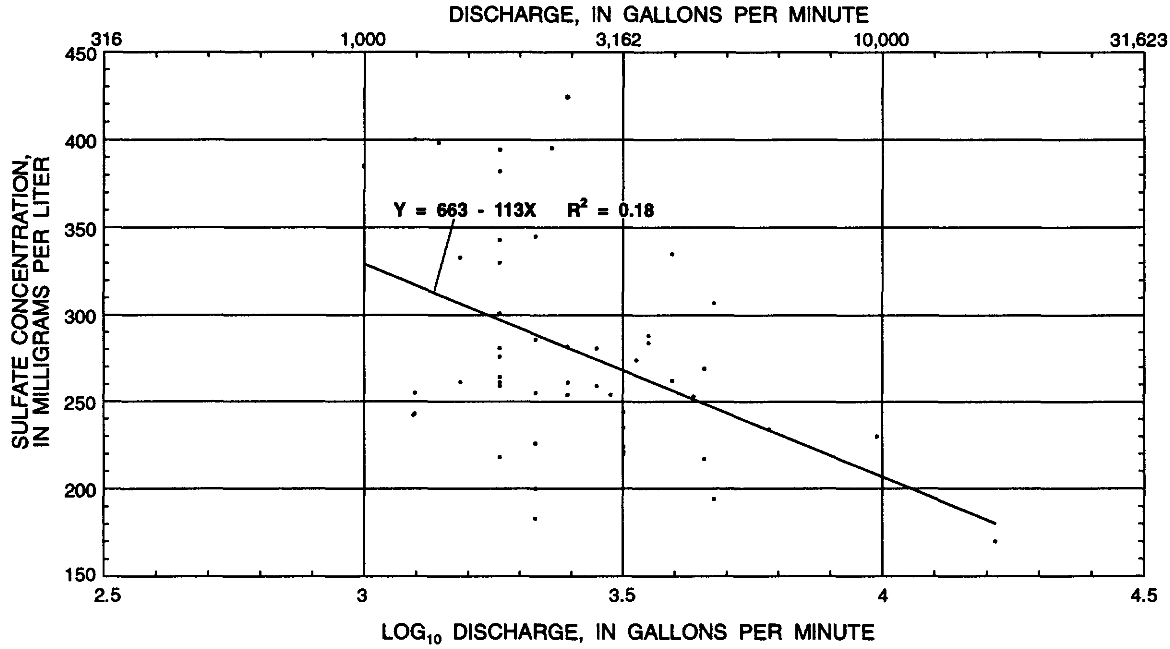
Mine drainage becomes acidic from the reaction of oxygen and water with iron-sulfide minerals, chiefly pyrite (FeS_2), which are exposed during mining, and consequent reaction between sulfuric acid produced by this reaction and other minerals. Extensive literature exists on the subject of acidic mine drainage [for example, see Braley (1954), Barnes and Clarke (1964), Barnes and others (1964), and Cravotta (1991)]. Possible chemical reactions are not discussed in detail in this report.

Some factors that affect the concentrations of the various constituents in water discharged from coal mines are (1) mineralogy of the coals, overburden, and associated host rock; (2) the quantity of water flowing through the mine workings; (3) the related variables of residence time, path length, and depth of water circulation through the mine workings; (4) the availability of oxygen and dissolved oxygen concentrations in the mine water; (5) method of mining (underground mines in the anthracite region generally discharge water with higher concentrations of iron and sulfate than strip mines)[1]; (6) dewatering (pumping) associated with active mining; and (7) exposed surface area of sulfide minerals. Changes in exposed surface area caused by dissolution and possible coating of sulfide minerals probably account for most of the improvement in water quality with time that has been observed at many mines in the anthracite region.

Concentrations of many constituents are affected by the flow rate of the water discharged from the mines. Relation of monthly sulfate and iron concentrations to discharge are shown in figures 2 and 3 for the Owl Hole Tunnel and Centralia Drainage Tunnel (data from PaDEP). For the Owl Hole Tunnel, concentrations appear to be roughly inversely proportional to discharge. Changes in concentrations may lag behind changes in flow. Not all mines exhibit such relations. For the Centralia Drainage Tunnel, little relation exists between concentration and discharge. The data in figures 2 and 3 are from a single sample for each month. If continuous flow data were available, better correlations might be developed.

Water quality may have changed at some mines where either residence time, path length, or depth of circulation were altered by installation of boreholes to act as new points of discharge (Gannett, Fleming, Corddry, and Carpenter, Inc., 1967). Installation or removal of air or hydraulic seals affects the availability of oxygen and also causes changes in the quality of water discharged from mines (GEO-Technical Services, Inc., 1982, p. 8). Construction or failure of water diversion systems affects the quantity of water flowing through the mine workings and thus changes water quality. Most diversion systems were installed when the coal mines were active and have not been maintained since mining ceased. Consequently, many of these diversion systems have failed or been destroyed.

[1] In 1975, the median concentration of sulfate measured by Growitz and others (1985) for 206 deep mine discharges was 200 mg/L, and the median concentration for 39 strip mine discharges was 78 mg/L. The median concentration of iron for the same 206 deep mine discharges was 5 mg/L, and the median concentration for the 39 strip mine discharges was 1 mg/L.



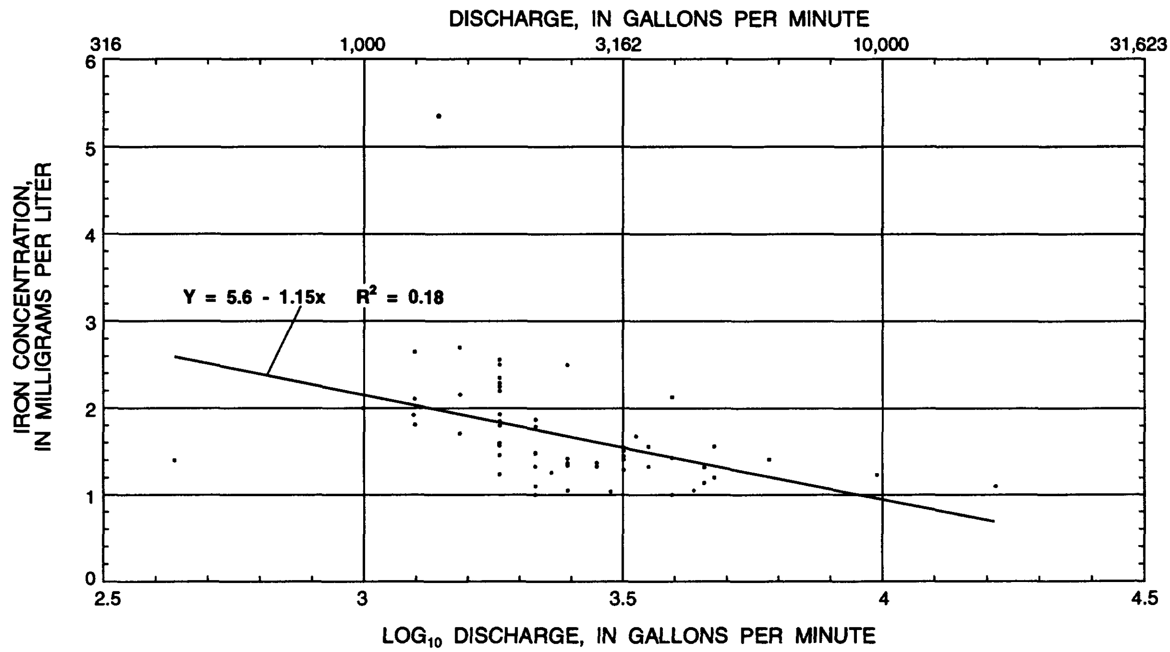
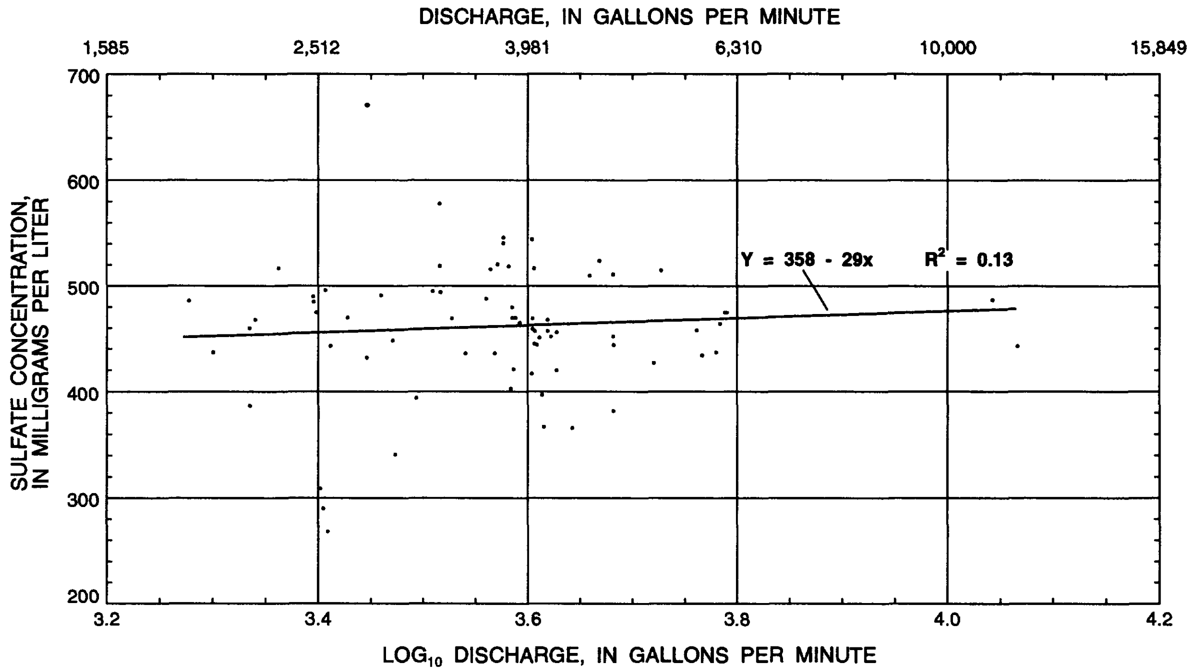


Figure 2. Relation of monthly sulfate and iron concentrations to discharge for the Owl Hole Tunnel (site 30), Eastern Middle Anthracite Field, east-central Pennsylvania, 1986-91.



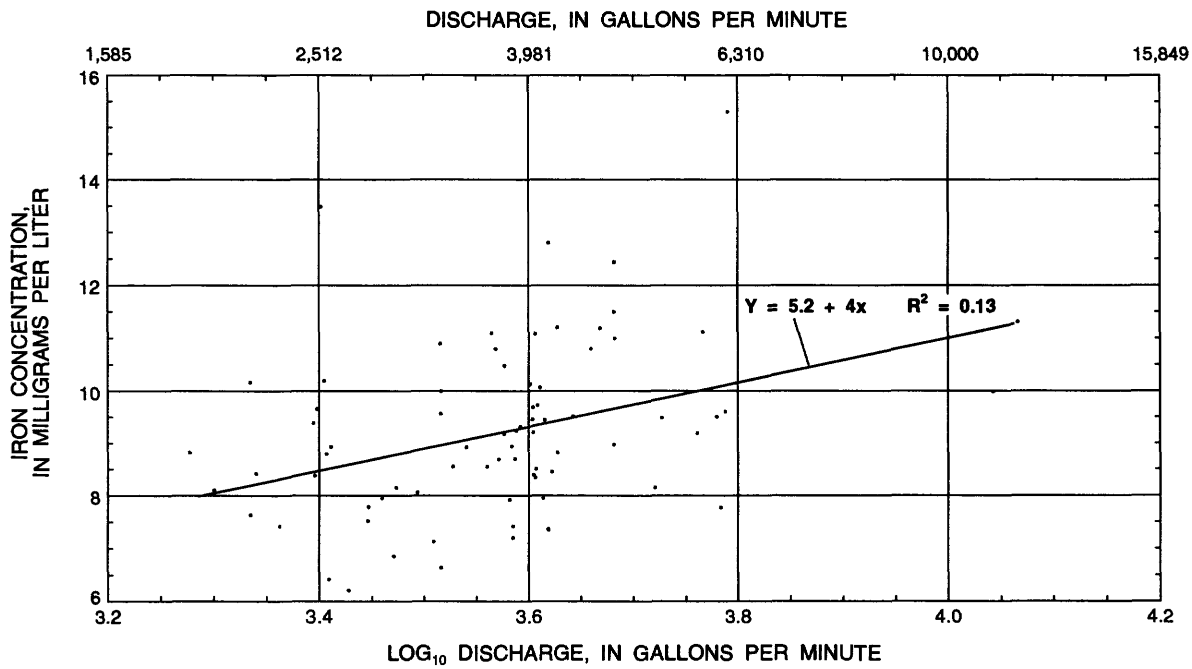


Figure 3. Relation of monthly sulfate and iron concentrations to discharge for the Centralia Drainage Tunnel (site 68), Western Middle Anthracite Field, east-central Pennsylvania, 1986-92.

The effects of the factors discussed above on the observed changes in water quality at each mine cannot be fully understood without knowing the history of that mine and of any activities that have taken place in its drainage area since mining ceased. Unfortunately, compiling such a history is beyond the scope of this study. Thus, changes in quality in water discharging from mines are discussed only for large groups of mines.

Sites Studied

In 1991, 99 of the 102 coal mines that discharged 1.0 ft^3/s or more in 1975 were revisited. Fifteen of these sites were dry or nearly so. The remaining 84 discharges were sampled; 2 discharges were combined at both the Weston and Scott Ridge Mines. The results of the 1991 field determinations and laboratory analyses are compared with the 1975 results in tables 1-4. The site numbers used in the tables follow those of Growitz and others (1985) and are shown on figures 4-7.

Physical properties and chemical analyses for major ions, nutrients, metals, and other trace constituents were not determined for discharge samples collected in 1991, except as given in tables 1-4. The results of earlier, more complete analyses of mine-discharge samples that were collected by the USGS or by or for the USEPA are given in tables 5-6.

Field Measurements

For the mines sampled in 1991 and 1975 (Growitz and others, 1985), discharge, water temperature, specific conductance, pH, alkalinity, and acidity were measured in the field. Dissolved oxygen also was measured in 1991. Specific conductance data are not discussed in this report, but the data are reported in tables 1-4. The alkalinity data are discussed with the data for other anions.

Temperature

In 1975, temperatures in the water discharged from the mines, excluding stream sites 42 and 272 to 278, ranged from 7.0 to 18.0°C; the median was 11.6°C. In 1991, temperatures ranged from 7.5 to 16.4°C; the median was 11.0°C. The principal factors affecting the temperatures are air temperature; elevation of the mine workings; depth of circulation and residence time; degree of urbanization; for one or two discharges, mine fires; and for sites that are pumped, some heating by the pump and by line friction.

In 1975, the median temperature in water discharged from 10 boreholes was 16.5°C, 13.5°C in water discharged from 6 pumps, 8.2°C in water discharged from 10 strip mines, and 13.2°C in water discharged from 4 seeps. In 1991, the median temperature in water discharged from seven boreholes was 12.5°C, 12.8°C in water discharged from four pumps, 10.8°C in water discharged from six strip mines, and 11.7°C in water discharged from four seeps. The higher temperatures in water discharged from boreholes and pumps is most probably caused by a greater than average depth of circulation for these discharges. (Temperatures increase naturally with depth at the rate of the geothermal gradient of about 1°C per 100 ft.)

Water discharged from mines 13 to 22, which are in the most highly urbanized area of the anthracite coal fields, have some of the highest temperatures—the median temperature in water from nine of these mines was 16°C in 1975 and in water from seven of these mines was 14°C in 1991. (Paulachok (1984, p. 6) noted that urbanization in Philadelphia greatly affected (increased) ground-water temperatures.) However, these mines are among the deepest in the anthracite region and the effects of depth of circulation and residence time on temperature of the discharge water cannot be distinguished from the effects of urbanization.

Seeps seem to respond quickly to changes in air temperature; however, water discharged from strip mines seems to be affected by temperatures over the preceding several weeks—the median temperature in water discharged from strip mines was several degrees lower than the median temperature in all discharges in April 1975 but was similar to the median in all discharges in the fall of 1991.

pH

For water discharged from 81 mines that had field pH measurements in 1975 and 1991, 64 had an increase in pH, 4 showed no change, and 13 had a decrease in pH (fig. 8). Only 2 of the 13 that showed a decrease changed by more than 0.2 pH units. The median change in pH was +0.4 units from 1975 to

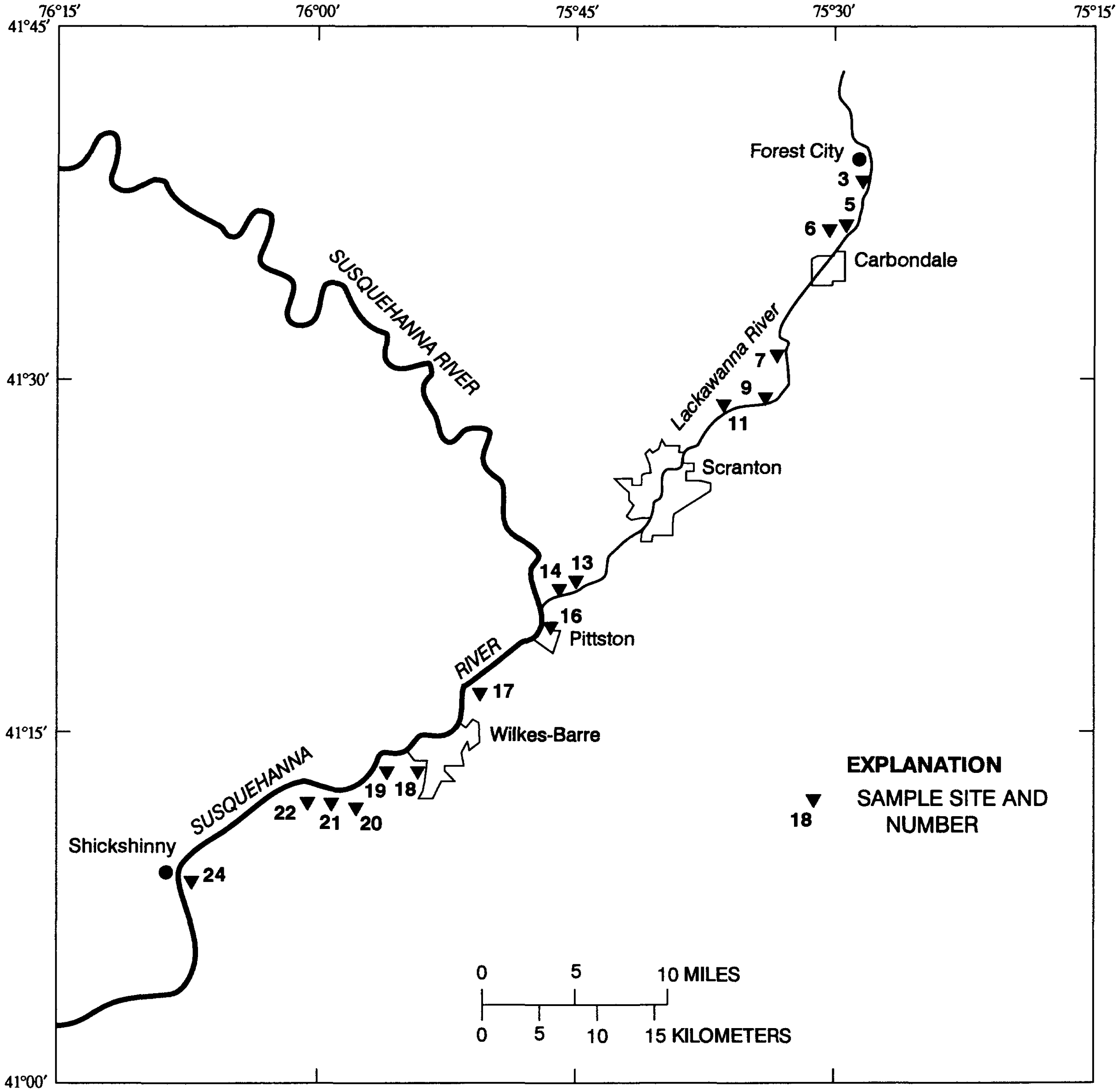


Figure 4. Sites where discharge water from mines was sampled in the Northern Anthracite Field, northeast Pennsylvania. (Modified from Growitz and others, 1985, fig. 2.)

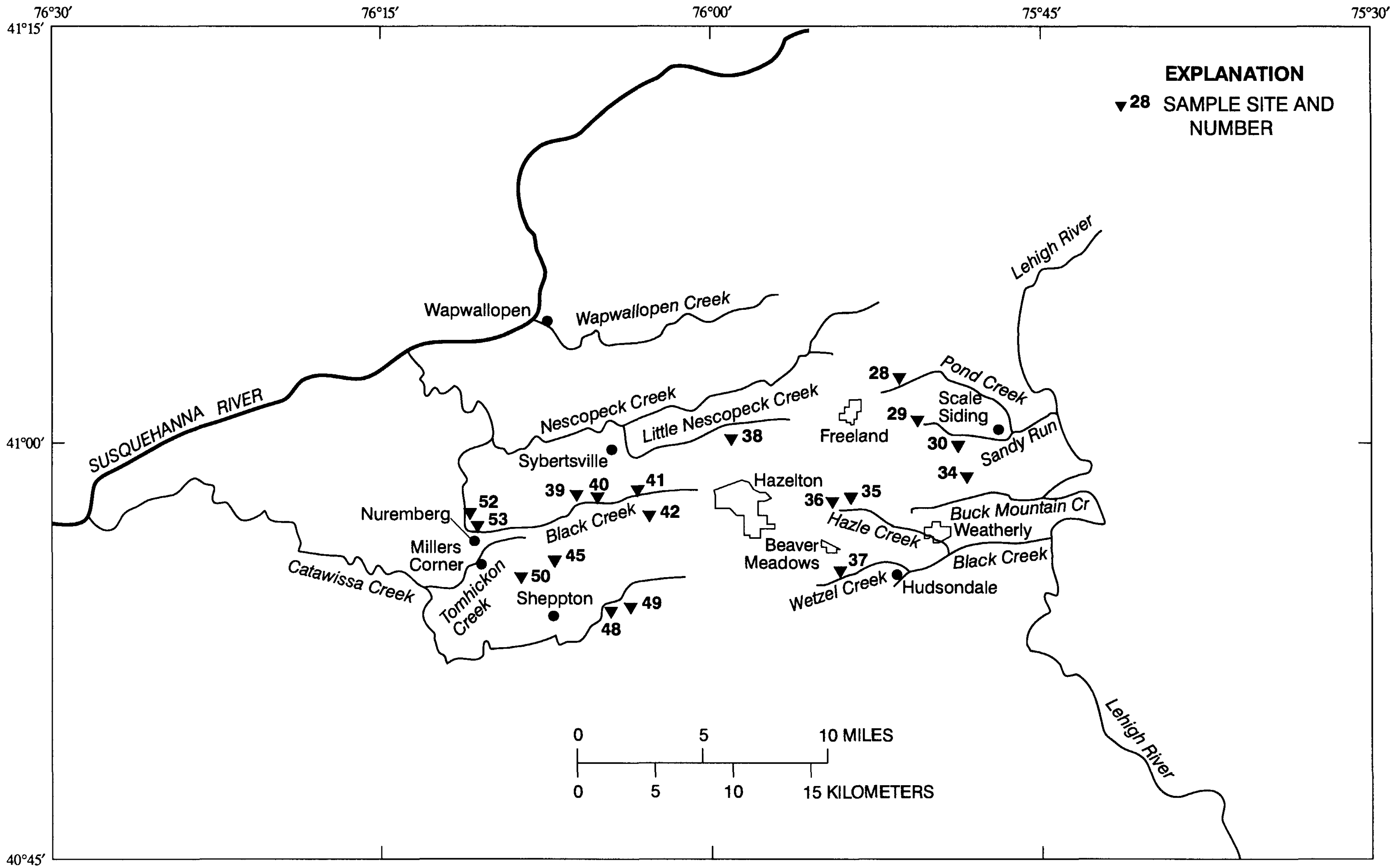


Figure 5. Sites where discharge water from mines was sampled in the Eastern Middle Anthracite Field, east-central Pennsylvania. (Modified from Growitz and others, 1985, fig. 3.)

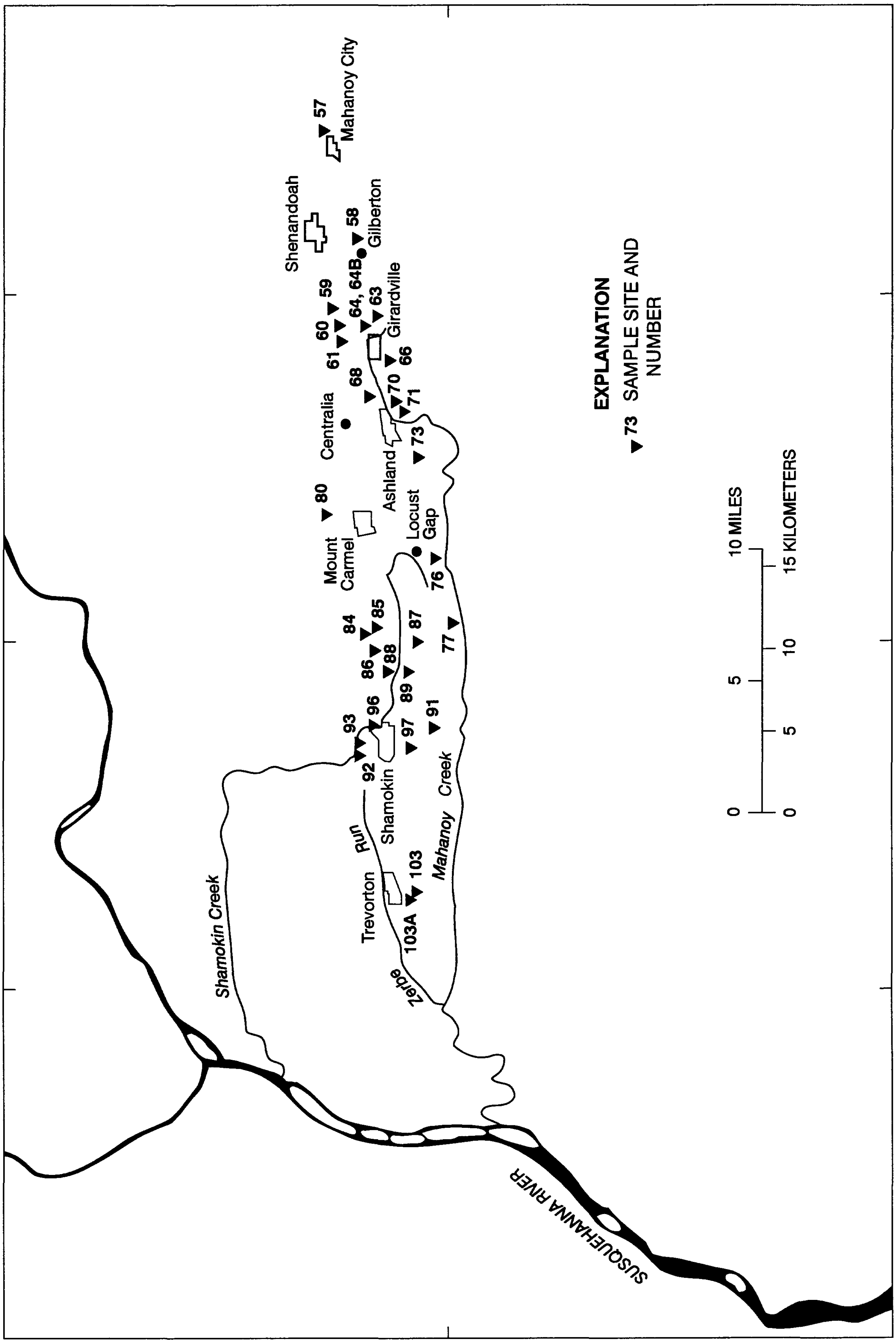


Figure 6. Sites where discharge water from mines was sampled in the Western Middle Anthracite Field, east-central Pennsylvania. (Modified from Growitz and others, 1985, fig. 5.)

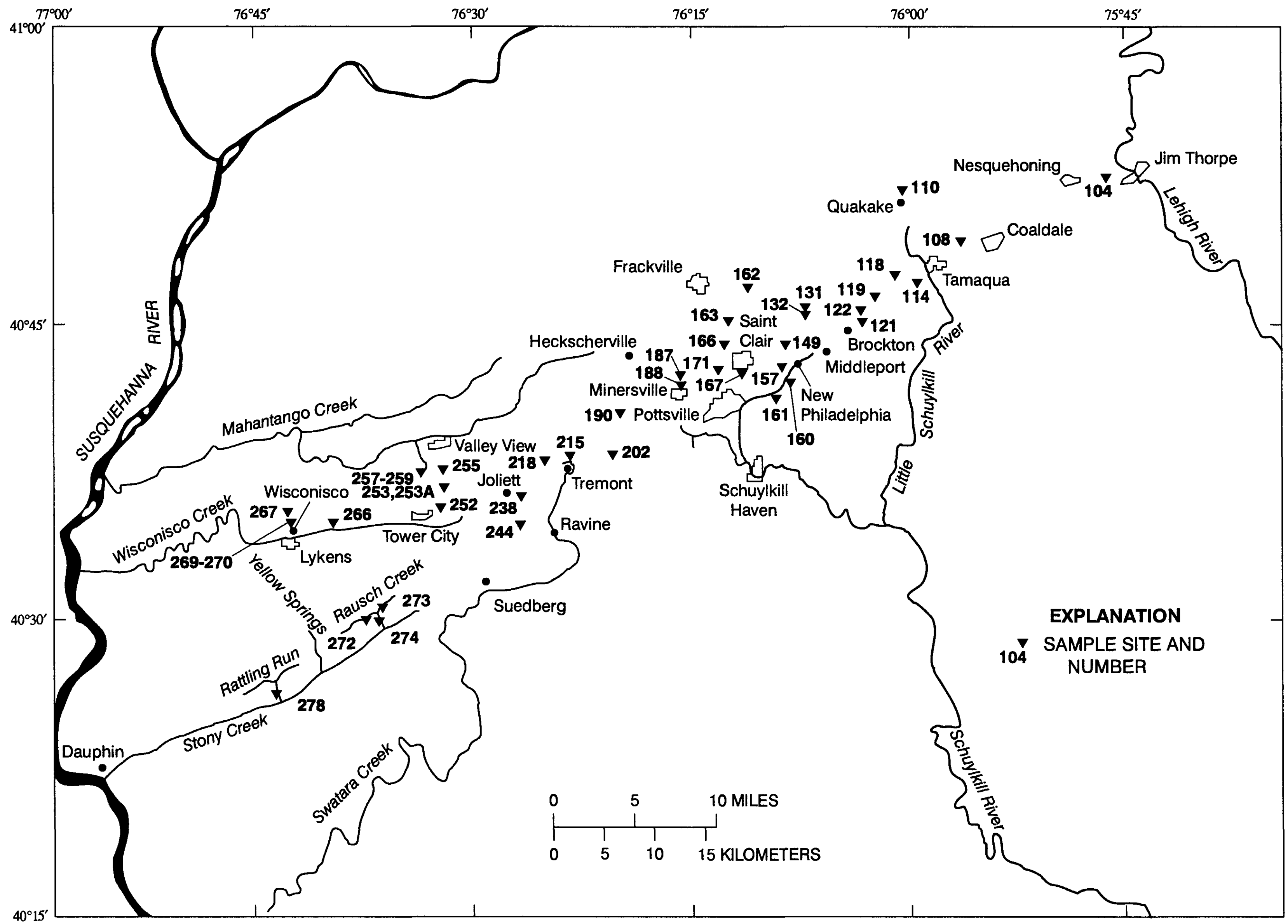


Figure 7. Sites where discharge water from mines was sampled in the Southern Anthracite Field, east-central Pennsylvania. (Modified from Growitz and others, 1985, fig. 6.)

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

[--, no data; <, less than; °C, degrees Celsius; E, estimated; Lat, latitude; Long, longitude; mg/L, milligrams per analyzing sample: 1028, U.S. Geological Survey; 9801, private laboratory; 9813, Pennsylvania Department

Date	Discharge, inst., cubic feet per second	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Site 3 - 413815075273501 VANDLING										
Apr. 16, 1969	11	197	4.7	7.5	72	70	--	--	7.0	--
Site 5 - 413611075290901 UPPER WILSON										
Oct. 30, 1969	1.6	470	6.4	10.0	220	--	45	25	2.0	1.6
Apr. 8, 1971	--	455	6.5	9.5	--	--	--	--	--	--
Site 6 - 413602075291301 LOWER WILSON										
Apr. 16, 1969	3.0	454	5.5	9.5	220	200	--	--	17	--
Oct. 30, 1969	4.5	437	5.9	10.0	210	--	41	26	2.5	1.6
Site 7 - 413116075324901 JERMYN										
Apr. 16, 1969	40	637	3.7	10.0	260	260	--	--	--	--
Site 9 - 412852075334801 PECKVILLE										
Apr. 16, 1969	22	455	4.7	9.0	210	210	--	--	--	--
Oct. 30, 1969	4.2	605	5.0	9.5	270	--	56	32	4.2	2.0
Apr. 8, 1971	--	495	5.7	9.5	--	--	--	--	--	--
Apr. 16, 1975	23	403	5.3	11.5	170	170	33	21	4.6	1.3
Site 13 - 412136075450401 OLD FORGE										
Apr. 16, 1969	58	1,770	4.8	14.0	980	980	--	--	--	--
Oct. 30, 1969	40	1,690	4.9	16.0	990	--	200	120	17	4.0
Apr. 8, 1971	--	1,500	5.1	15.0	--	--	--	--	--	--
Apr. 24, 1975	97	1,440	5.6	16.0	790	760	150	100	14	2.4
Site 14 - 412051075464201 DURYEA										
Apr. 16, 1969	47	1,870	5.3	15.0	930	930	--	--	--	--
Apr. 17, 1975	34	1,400	5.7	15.5	760	--	140	100	13	2.9
Nov. 1, 1986	31	--	6.1	--	--	--	--	--	--	--
Apr. 1, 1987	47	--	6.0	--	--	--	--	--	--	--
Oct. 31, 1989	37	--	--	--	420	--	83	52	19	3.0
Feb. 20, 1990	28	--	--	--	410	--	79	51	17	2.6
Site 16 - 411936075472501 PITTSTON										
Dec. 17, 1986	8.0	--	4.9	--	--	--	--	--	--	--
Apr. 1, 1987	--	--	4.8	--	--	--	--	--	--	--
July 16, 1990	--	--	--	--	210	--	27	34	44	2.0

for water discharged from mines in the anthracite fields of Pennsylvania

liter; µg/L, micrograms per liter; µS/cm, microsiemens per centimeter; inst., instantaneous; agency of Environmental Protection; 80010, U.S. Geological Survey--Atlanta Central Laboratory, Georgia]

Bicar-bonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constit-uents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phos-phorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
DRIFT (Lat 41 38 15N Long 075 27 35W)										
3	74	21	--	--	162	--	0.14	--	--	1028
CREEK DRIFT (Lat 41 36 11N Long 075 29 09W)										
--	230	3.1	0.2	6.2	349	--	.09	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
CREEK SHAFT (Lat 41 36 02N Long 075 29 13W)										
23	200	5.4	--	--	340	--	.11	--	--	1028
--	220	4.5	.3	7.1	338	--	.05	--	--	1028
SLOPE (Lat 41 31 16N Long 075 32 49W)										
0	280	6.2	--	--	456	--	.18	--	--	1028
SHAFT (Lat 41 28 52N Long 075 33 48W)										
4	210	3.6	--	--	329	--	.05	--	--	1028
--	360	3.0	.4	11	501	--	.13	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
16	170	5.5	.3	7.6	267	253	.07	<0.01	<0.01	1028
BOREHOLE (Lat 41 21 36N Long 075 45 04W)										
0	1,200	13	--	--	1,860	--	.02	--	--	1028
--	1,300	2.5	--	15	1,870	--	1.80	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
33	780	22	.2	12	1,220	1,150	.01	.01	<.01	1028
BREECH (Lat 41 20 51N Long 075 46 42W)										
0	1,300	14	--	--	1,900	--	<.01	--	--	1028
--	700	19	<.1	10	1,100	1,090	<.01	.01	<.01	1028
--	--	--	--	--	869	--	--	--	--	9801
--	--	--	--	--	825	--	--	--	--	9801
--	--	--	--	--	--	--	--	--	--	9801
--	--	--	--	--	--	--	--	--	--	9801
WATER TUNNEL (Lat 41 19 36N Long 075 47 25W)										
--	--	--	--	--	500	--	--	--	--	9801
--	--	--	--	--	476	--	--	--	--	9801
--	--	--	--	--	--	--	--	--	--	1028

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

Date	Discharge, inst., cubic feet per second	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
							Site 18 - 411350075552001 SOLOMON CREEK			
June 16, 1972	--	--	--	--	--	--	--	--	--	--
Aug. 30, 1972	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1975	--	--	--	--	--	--	--	--	--	--
Apr. 14, 1975	39	3,000	5.2	16.0	1,400	--	250	180	82	3.6
							Site 19 - 411334075561301 NOTTINGHAM-			
June 16, 1972	--	--	--	--	--	--	--	--	--	--
Aug. 8, 1972	--	--	--	--	--	--	--	--	--	--
Aug. 30, 1972	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	--	--	--	--	--	--
Nov. 1, 1986	24	--	5.7	--	--	--	--	--	--	--
Apr. 1, 1987	43	--	5.9	--	--	--	--	--	--	--
Nov. 1, 1989	26	--	--	--	640	--	140	74	32	3.8
Feb. 20, 1990	29	--	--	--	610	--	130	72	25	3.4
							Site 24 - 410901076084001 MOCANAQUA			
Oct. 4, 1965	--	--	--	--	--	--	--	--	--	--
Feb. 17, 1966	10	1,800	--	--	750	--	130	100	--	--
Apr. 14, 1975	5.8	1,610	3.5	11.0	570	570	100	78	2.7	1.9
							Site 34 - 405853075484901 BUCK MOUNTAIN			
Apr. 16, 1975	1.7	652	3.3	9.0	96	96	12	16	1.4	1.3
							Site 40 - 405755076053001 TOMHICKEN			
Apr. 15, 1975	2.7	225	5.6	8.5	58	--	11	7.3	8.6	1.9
							Site 50 - 405506076085001 ONEIDA			
Apr. 16, 1975	9.1	170	4.3	8.0	31	--	4.0	5.2	3.3	.9
							Site 57 - 404855076073501 VULCAN-BUCK			
July 1, 1975	7.1	380	4.5	10.5	--	--	--	--	--	--
Sept. 3, 1975	3.7	460	4.5	10.0	--	--	--	--	--	--
Oct. 1, 1975	11	460	4.7	10.0	--	--	--	--	--	--
Nov. 5, 1975	6.2	460	4.6	9.5	--	--	--	--	--	--
Dec. 30, 1975	6.1	440	4.6	9.5	--	--	--	--	--	--
Feb. 11, 1976	6.5	430	4.6	9.5	--	--	--	--	--	--
Mar. 3, 1977	6.5	420	4.6	9.5	--	--	--	--	--	--

for water discharged from mines in the anthracite fields of Pennsylvania--Continued

Bicar- bonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constit- uents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phos- phorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
BOREHOLES (Lat 41 13 50N Long 075 55 20W)										
--	--	--	--	--	3,670	--	--	--	--	1028
--	--	--	--	--	5,730	--	--	--	--	9813
--	--	--	--	--	6,420	--	--	--	--	9813
--	1,800	27	<0.1	20	2,770	2,620	0.01	0.01	<0.01	1028
BUTTONWOOD (Lat 41 13 34N Long 075 56 13W)										
--	--	--	--	--	2,730	--	--	--	--	1028
--	--	--	--	--	2,830	--	--	--	--	9813
--	--	--	--	--	3,230	--	--	--	--	9813
--	--	--	--	--	3,620	--	--	--	--	9813
--	--	--	--	--	--	--	--	--	--	9801
--	--	--	--	--	1,430	--	--	--	--	9801
--	--	--	--	--	--	--	--	--	--	9801
--	--	--	--	--	--	--	--	--	--	9801
TUNNEL (Lat 41 09 01N Long 076 08 40W)										
--	--	--	--	--	2,340	--	--	--	--	1028
--	1,100	--	--	--	1,800	--	--	--	--	1028
0	680	.50	.3	19	1,130	959	.02	<.01	<.01	1028
TUNNEL (Lat 40 58 53N Long 075 48 49W)										
0	260	1.1	.3	19	382	326	.08	.01	<.01	1028
STRIP PIT (Lat 40 57 55N Long 076 05 30W)										
--	66	12	<.1	7.5	131	141	.04	.01	<.01	1028
TUNNEL 3 (Lat 40 55 06N Long 076 08 50W)										
--	53	5.6	.2	8.0	86	--	.14	<.01	<.01	1028
MOUNTAIN BOREHOLES (Lat 40 48 55N Long 076 07 35W)										
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

Date	Discharge, inst., cubic feet per second	Specific conduct-ance (µS/cm)	pH, field (stand-ard units)	Tempera-ture, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncar-bonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magne-sium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potas-sium, dissolved (mg/L as K)
Site 57 - 404855076073501 VULCAN-BUCK MTN										
Mar. 24, 1977	--	410	4.2	--	--	--	--	--	--	--
Aug. 14, 1978	--	465	4.4	10.0	--	--	--	--	--	--
Site 58 - 404801076123401 GILBERTON										
Apr. 18, 1975	23	1,800	6.1	14.0	950	--	200	110	14	1.9
Site 64 - 404741076164801 PACKER BREACH										
June 25, 1975	49	2,250	6.2	16.5	--	--	--	--	--	--
Sept. 4, 1975	41	2,300	6.3	16.0	--	--	--	--	--	--
Oct. 1, 1975	44	2,300	6.1	15.5	--	--	--	--	--	--
Nov. 5, 1975	44	2,700	6.1	15.0	--	--	--	--	--	--
Dec. 3, 1975	39	2,200	6.0	15.0	--	--	--	--	--	--
Dec. 30, 1975	38	2,150	6.1	15.5	--	--	--	--	--	--
Feb. 11, 1976	40	2,000	6.0	14.0	--	--	--	--	--	--
Mar. 4, 1976	41	2,050	6.1	15.5	--	--	--	--	--	--
Mar. 25, 1977	--	1,930	6.2	--	--	--	--	--	--	--
Apr. 1, 1977	--	2,000	6.3	--	--	--	--	--	--	--
Site 68 - 404727076192601 CENTRALIA DRAINAGE										
Apr. 16, 1975	11	950	3.5	11.0	--	--	--	--	--	--
Site 70 - 404706076195401 OAKLAND										
Sept. 2, 1976	--	1,300	6.4	--	--	--	--	--	--	--
Site 77 - 404435076283801 DOUTYVILLE										
Apr. 18, 1975	13	1,360	3.6	13.0	730	730	110	110	3.6	1.4
Site 85 - 404739076291901 SCOTT RIDGE										
Apr. 17, 1975	15	980	5.3	12.5	450	--	80	60	6.2	2.0
Site 87 - 404625076293701 EXCELSIOR										
Apr. 18, 1975	13	844	4.9	12.0	330	330	50	50	4.5	2.1
Dec. 6, 1977	--	760	6.0	--	--	--	--	--	--	--
Aug. 15, 1978	--	825	6.3	--	--	--	--	--	--	--
Site 88 - 404703076305201 MAYSVILLE MINE										
Sept. 15, 1976	--	975	--	--	--	--	--	--	--	--
Site 97 - 404637076340701 HENRY CLAY STIRLING										
May 24, 1977	--	875	6.7	--	--	--	--	--	--	--

for water discharged from mines in the anthracite fields of Pennsylvania--Continued

Bicar-bonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constit-uents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phos-phorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
BOREHOLES (Lat 40 48 55N Long 076 07 35W)--Continued										
--	--	--	--	--	--	--	--	--	--	1028
--	140	--	--	--	--	--	--	--	--	80010
PUMP (Lat 40 48 01N Long 076 12 34W)										
--	1,000	9.1	0.1	12	1,600	1,480	0.01	<0.01	<0.01	1028
AND BOREHOLE (Lat 40 47 41N Long 076 16 48W)										
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
--	--	--	--	--	--	--	--	--	--	1028
TUNNEL (Lat 40 47 27N Long 076 19 26W)										
--	570	--	--	--	--	--	--	--	--	1028
TUNNEL (Lat 40 47 06N Long 076 19 54W)										
--	--	--	--	--	--	--	--	--	--	1028
TUNNEL (Lat 40 44 35N Long 076 28 38W)										
0	700	1.9	.3	14	1,090	962	.03	<.01	<.01	1028
MINE TUNNEL (Lat 40 47 39N Long 076 29 19W)										
--	490	5.2	<.1	14	772	721	.01	<.01	<.01	1028
STRIP PIT (Lat 40 46 25N Long 076 29 37W)										
0	400	5.6	<.1	13	617	578	.01	.01	<.01	1028
--	390	--	--	--	--	--	--	--	--	1028
--	370	--	--	--	--	--	--	--	--	1028
BOREHOLE (Lat 40 47 03N Long 076 30 52W)										
--	--	--	--	--	--	--	--	--	--	1028
SLOPE (Lat 40 46 37N Long 076 34 07W)										
--	--	--	--	--	--	--	--	--	--	1028

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

Date	Discharge, inst., cubic feet per second	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
Site 103 - 404617076404401 NORTH FRANKLIN										
Apr. 18, 1975	7.3	1,230	3.7	12.5	560	560	85	85	2.4	1.6
Sept. 23, 1977	--	800	6.1	--	--	--	--	--	--	--
Site 104 - 405229075454901 NESQUEHONING										
Mar. 22, 1965	8.2	--	4.7	--	--	--	--	--	--	--
Nov. 15, 1965	4.0	1,290	4.5	12.0	--	--	--	--	--	--
Apr. 22, 1975	11	1,050	6.4	12.5	610	600	110	82	4.2	.9
Site 108 - 404909075560001 GREENWOOD										
Apr. 23, 1975	7.7	2,510	6.7	16.5	1,200	1,200	290	120	11	1.2
Site 114 - 404728075590901 NEWKIRK TUNNEL										
July 28, 1964	2.6	1,590	3.1	--	350	--	60	49	1.5	1.4
Feb. 16, 1965	1.6	1,590	3.1	--	--	--	--	--	--	--
Feb. 24, 1965	1.4	1,570	3.2	--	--	--	--	--	--	--
Mar. 22, 1965	2.8	--	3.0	--	--	--	--	--	--	--
Apr. 7, 1965	3.7	--	3.1	--	--	--	--	--	--	--
July 21, 1965	.36	1,550	--	--	350	--	58	50	2.0	.3
Nov. 15, 1965	.15	--	3.4	--	--	--	--	--	--	--
Apr. 23, 1975	1.1	750	3.1	9.5	180	--	29	25	.9	.4
Site 118 - 404705076003201 REEVESDALE										
Mar. 22, 1965	1.1	--	3.6	--	--	--	--	--	--	--
Nov. 15, 1965	.12	610	3.2	9.0	--	--	--	--	--	--
SITE 119 - 404612076015601 MARY D										
Mar. 22, 1965	2.4	--	4.3	--	--	--	--	--	--	--
Nov. 15, 1965	1.2	640	4.3	8.0	--	--	--	--	--	--
Site 121 - 404512076025501 BELL WATER										
Mar. 22, 1965	--	--	4.3	--	--	--	--	--	--	--
Nov. 15, 1965	.37	530	4.2	9.5	--	--	--	--	--	--
Site 132 - 404538076063701 BROCKTON										
Mar. 22, 1965	.63	--	4.0	--	--	--	--	--	--	--
Site 149 - 404403076072401 SILVER CREEK										
Mar. 22, 1965	1.1	--	4.8	--	--	--	--	--	--	--
Nov. 15, 1965	.16	810	4.8	10.0	--	--	--	--	--	--

for water discharged from mines in the anthracite fields of Pennsylvania--Continued

Bicarbonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
MINE (Lat 40 46 17N Long 076 40 44W)										
0	580	1.3	0.1	14	872	803	0.01	<0.01	<0.01	1028
--	--	--	--	--	--	--	--	--	--	1028
TUNNEL (Lat 40 52 29N Long 075 45 49W)										
--	960	--	--	--	1,630	--	--	--	--	1028
--	960	--	--	--	1,540	--	--	--	--	1028
44	560	3.8	.4	10	882	805	.04	.01	<.01	1028
PUMP (Lat 40 49 09N Long 075 56 00W)										
46	1,600	2.8	.3	9.7	2,530	2,100	.06	.01	<.01	1028
NORTH DIP (Lat 40 27 28N Long 075 59 09W)										
0	670	1.2	.2	25	1,060	--	.18	--	--	1028
0	750	--	--	--	1,030	--	--	--	--	1028
0	740	--	--	--	1,010	--	--	--	--	1028
0	620	--	--	--	1,070	--	--	--	--	1028
0	640	--	--	--	990	--	--	--	--	1028
0	710	1.0	.2	23	995	--	.54	--	--	1028
--	--	--	--	--	1,020	--	--	--	--	1028
--	300	.50	.4	17	475	--	.03	.00	.00	1028
SOUTH DIP TUNNEL (Lat 40 47 05N Long 076 00 32W)										
--	170	--	--	--	276	--	--	--	--	1028
--	240	--	--	--	376	--	--	--	--	1028
STRIP PIT (Lat 40 46 12N Long 076 01 56W)										
--	260	--	--	--	436	--	--	--	--	1028
--	390	--	--	--	564	--	--	--	--	1028
LEVEL TUNNEL (Lat 40 45 12N Long 076 02 55W)										
--	250	--	--	--	432	--	--	--	--	1028
--	260	--	--	--	462	--	--	--	--	1028
STRIP PIT PIPE (Lat 40 45 38N Long 076 06 37W)										
--	190	--	--	--	306	--	--	--	--	1028
MINE TUNNEL (Lat 40 44 03N Long 076 07 24W)										
--	460	--	--	--	764	--	--	--	--	1028
--	510	--	--	--	567	--	--	--	--	1028

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

Date	Discharge, inst., cubic feet per second	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
							Site 157 - 404258076090101 EAGLE HILL			
May 25, 1964	--	2,100	6.7	--	--	--	--	--	--	--
July 28, 1964	0.51	1,170	6.3	--	510	--	110	57	63	1.8
Mar. 22, 1965	1.3	--	7.1	--	--	--	--	--	--	--
Apr. 7, 1965	.96	1,500	7.0	--	--	--	--	--	--	--
July 21, 1965	.00	945	--	--	470	--	100	51	13	1.2
May 12, 1966	1.4	--	--	--	--	--	--	--	--	--
Apr. 22, 1975	1.8	811	5.4	12.5	410	410	76	53	7.8	.6
							Site 160 - 404217076082201 LUCIANNA			
Mar. 22, 1965	1.2	--	6.0	--	--	--	--	--	--	--
Nov. 15, 1965	.70	--	6.2	--	--	--	--	--	--	--
							Site 162 - 404657076105501 MOREA			
Mar. 22, 1965	4.3	--	3.3	--	--	--	--	--	--	--
							Site 166 - 404406076120201 REPPLIER WATER			
Feb. 17, 1965	7.4	1,380	5.2	--	--	--	--	--	--	--
Feb. 24, 1965	4.8	1,250	5.4	--	--	--	--	--	--	--
Mar. 22, 1965	4.2	910	5.5	--	--	--	--	--	--	--
Apr. 7, 1965	3.7	925	5.7	--	--	--	--	--	--	--
July 21, 1965	.28	1,210	--	--	520	--	84	76	2.0	.2
Nov. 15, 1965	1.2	1,380	5.3	--	--	--	--	--	--	--
							Site 167 - 404320076103201 PINE			
July 28, 1964	4.0	2,150	4.5	12.0	950	--	150	140	4.8	2.0
Apr. 23, 1975	14	1,480	3.3	13.0	740	740	130	100	3.2	.9
							Site 171 - 404251076122101 WADESVILLE			
Mar. 22, 1965	.81	--	7.0	--	--	--	--	--	--	--
Nov. 15, 1965	1.2	1,600	7.0	12.0	--	--	--	--	--	--
Apr. 22, 1975	2.3	1,470	7.1	14.0	850	580	160	110	33	1.4
							Site 187 - 404224076150601 PINE KNOT			
May 25, 1964	--	900	3.5	--	--	--	--	--	--	--
July 28, 1964	13	1,450	3.3	--	630	--	96	95	3.3	1.6
Dec. 1, 1964	7.2	1,710	--	--	710	--	110	100	3.0	1.2
Feb. 16, 1965	65	861	3.5	--	--	--	--	--	--	--
Feb. 24, 1965	39	1,030	3.5	--	--	--	--	--	--	--

Bicarbonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
DRIFT (Lat 40 42 58N Long 076 09 01W)										
--	--	--	--	--	--	--	--	--	--	1028
22	600	1.0	0.2	12	937	871	<0.01	--	--	1028
--	960	--	--	--	1,770	--	--	--	--	1028
--	810	--	--	--	1,450	--	--	--	--	1028
0	490	1.0	.1	14	726	--	<.01	--	--	1028
--	--	--	--	--	2,120	--	--	--	--	1028
20	430	.70	.1	13	642	601	.02	0.01	<0.01	1028
TUNNEL (Lat 40 42 17N Long 076 08 22W)										
--	360	--	--	--	1,630	--	--	--	--	1028
--	340	--	--	--	584	--	--	--	--	1028
STRIP PIT (Lat 40 46 57N Long 076 10 55W)										
--	320	--	--	--	504	--	--	--	--	1028
LEVEL TUNNEL (Lat 40 44 06N Long 076 12 02W)										
--	710	--	--	--	1,000	--	--	--	--	1028
--	650	--	--	--	937	--	--	--	--	1028
--	560	--	--	--	918	--	--	--	--	1028
--	810	--	--	--	940	--	--	--	--	1028
0	550	.0	.3	12	845	--	.18	--	--	1028
--	810	--	--	--	1,250	--	--	--	--	1028
FOREST MINE (Lat 40 43 20N Long 076 10 32W)										
0	1100	3.0	.4	19	1,720	--	.14	--	--	1028
0	780	.90	.4	15	1,230	1,050	.04	<.01	<.01	1028
PUMP (Lat 40 42 51N Long 076 12 21W)										
--	460	--	--	--	1,080	--	--	--	--	1028
--	580	--	--	--	1,260	--	--	--	--	1028
460	630	6.0	.1	7.9	1,230	1,180	.09	.02	<.01	1028
DRAINAGE TUNNEL (Lat 40 42 24N Long 076 15 06W)										
--	--	--	--	--	--	--	--	--	--	1028
0	720	1.2	.2	16	1,100	--	.05	--	--	1028
0	810	1.3	.3	16	1,230	--	.09	--	--	1028
--	380	--	--	--	563	--	--	--	--	1028
--	450	--	--	--	694	--	--	--	--	1028

Table 5. *Results of chemical analyses for major ions, nutrients, and physical properties*

Date	Discharge, inst., cubic feet per second	Specific conductance (µS/cm)	pH, field (standard units)	Temperature, water (°C)	Hardness, total (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)
										Site 187 - 404224076150601 PINE KNOT
Mar. 22, 1965	29	--	3.6	--	--	--	--	--	--	--
Apr. 7, 1965	33	--	3.6	--	--	--	--	--	--	--
July 21, 1965	9.1	1,370	--	--	630	--	100	93	2.0	0.4
Nov. 15, 1965	13	1,360	3.2	9.0	--	--	--	--	--	--
Apr. 21, 1975	26	781	5.2	10.5	370	370	56	56	3.7	.7
										Site 188 - 404212076151601 OAK
Mar. 22, 1965	4.5	--	5.9	--	--	--	--	--	--	--
Nov. 15, 1965	--	2,400	6.2	12.0	--	--	--	--	--	--
										Site 190 - 403958076191401 OTTO
Mar. 22, 1965	5.2	--	5.1	--	--	--	--	--	--	--
Nov. 15, 1965	1.4	1,230	5.9	11.0	--	--	--	--	--	--
May 12, 1966	5.0	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	6.4	839	4.7	10.5	360	360	54	54	7.0	.8
										Site 202 - 403823076193601 BLACKWOOD
Apr. 25, 1975	--	381	5.8	13.0	190	170	33	26	1.0	.5
										Site 215 - 403820076224501 MIDDLE CREEK
Apr. 23, 1975	9.8	464	4.2	9.5	180	180	26	28	8.4	.6

for water discharged from mines in the anthracite fields of Pennsylvania--Continued

Bicarbonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Solids, residue at 180°C, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)	Nitrogen, nitrate, dissolved (mg/L as N)	Nitrogen, nitrite, dissolved (mg/L as N)	Phosphorus, ortho, dissolved (mg/L as P)	Agency analyzing sample (code number)
DRAINAGE TUNNEL (Lat 40 42 24N Long 076 15 06W)--Continued										
--	460	--	--	--	756	--	--	--	--	1028
--	450	--	--	--	692	--	--	--	--	1028
0	680	0.0	0.2	15	1,040	--	0.16	--	--	1028
--	640	--	--	--	918	--	--	--	--	1028
6	370	5.3	.3	10	592	518	.03	0.01	<0.01	1028
HILL MINE (Lat 40 42 12N Long 076 15 16W)										
--	1,200	--	--	--	1,920	--	--	--	--	1028
--	1200	--	--	--	1,990	--	--	--	--	1028
AIR SHAFT (Lat 40 39 58N Long 076 19 14W)										
--	530	--	--	--	908	--	--	--	--	1028
--	640	--	--	--	964	--	--	--	--	1028
--	560	--	--	--	937	--	--	--	--	1028
12	430	2.1	.1	13	675	597	.02	.01	.01	1028
TUNNEL (Lat 40 38 23N Long 076 19 36W)										
21	170	.3	.2	10	268	254	.03	.01	<.01	--
STRIP PIT (Lat 40 38 20N Long 076 22 45W)										
0	180	16	.3	10	328	273	.05	<.01	<.01	1028

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania*

[--, no data; <, less than; >, greater than; Lat, Latitude; Long, Longitude; mg/L, milligrams per liter; µg/L, micrograms per liter; inst., instantaneous; ND, not detected]

Date	Discharge, inst. cubic feet per second	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Bismuth, dissolved (µg/L as Bi)	Boron, dissolved (µg/L as B)	Bromide, dissolved (mg/L as Br)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)
Site 5 - 413611075290901 UPPER WILSON CREEK DRIFT (Lat 41 36 11N Long 075 29 09W)											
Oct. 30, 1969	1.6	30	--	--	20	<1	<6	30	--	<6	<6
Apr. 8, 1971	--	--	--	--	--	--	--	--	--	<1	<1
Site 6 - 413602075291301 LOWER WILSON CREEK SHAFT (Lat 41 36 02N Long 075 29 13W)											
Oct. 30, 1969	4.5	170	--	--	20	1	<5	30	--	<50	<5
Apr. 16, 1969	3.0	300	--	--	--	--	--	--	--	--	--
Site 7 - 413116075324901 JERMYN SLOPE (Lat 41 31 16N Long 075 32 49W)											
Apr. 16, 1969	40	1,200	--	--	--	--	--	--	--	--	--
Site 9 - 412852075334801 PECKVILLE SHAFT (Lat 41 28 52N Long 075 33 48W)											
Apr. 16, 1969	22	1,600	--	--	--	--	--	--	--	--	--
Oct. 30, 1969	4.2	5,600	--	--	20	10	<8	40	--	<80	<8
Apr. 8, 1971	--	--	--	--	--	--	--	--	--	2	<1
Apr. 16, 1975	23	--	--	<1	--	--	--	--	--	--	--
Apr. 16, 1975	23	1,400	--	--	21	5	<2	8	--	<2	<2
Site 13 - 412136075450401 OLD FORGE BOREHOLE (Lat 41 21 36N Long 075 45 04W)											
Apr. 16, 1969	58	--	--	--	--	--	--	--	--	--	--
Oct. 30, 1969	40	320	--	--	30	<6	<30	90	--	<60	<30
Apr. 8, 1971	--	--	--	--	--	--	--	--	--	3.0	<1
Apr. 24, 1975	97	--	--	2	--	--	--	--	--	--	--
Apr. 24, 1975	97	120	--	--	22	<2	<7	30	--	ND	<7
Site 14 - 412051075464201 DURYEA BREECH (Lat 41 20 51N Long 075 46 42W)											
Apr. 16, 1969	47	--	--	--	--	--	--	--	--	--	--
Apr. 17, 1975	34	400	--	2	23	2	<6	40	--	ND	<6
Nov. 1, 1986	31	--	<10	10	--	8	--	--	--	5	<5
Apr. 1, 1987	47	--	<5	<5	--	19	--	--	--	7	<5
Oct. 31, 1989	37	100	<60	2	17	<5	--	--	--	<5.0	60
Feb. 20, 1990	28	210	35	5	<200	<5	--	--	--	6	30
Site 16 - 411936075472501 PITTSTON WATER TUNNEL (Lat 41 19 36N Long 075 47 25W)											
Apr. 1, 1987	--	--	<5	12	--	110	--	--	--	6.0	<5
July 16, 1990	--	4,200	26	<10	19	5	--	--	--	2.0	5

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Gallium, dissolved (µg/L as Ga)	Germanium, dissolved (µg/L as Ge)	Iron, dissolved (µg/L as Fe)	Lanthanum, total (µg/L as La)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)
Site 5 - 413611075290901 UPPER WILSON CREEK DRIFT (Lat 41 36 11N Long 075 29 09W)											
Oct. 30, 1969	<10	10	--	<6	1,900	--	6	20	600	--	<1
Apr. 8, 1971	<1	<1	--	--	200	--	10	--	170	--	--
Site 6 - 413602075291301 LOWER WILSON CREEK SHAFT (Lat 41 36 02N Long 075 29 13W)											
Oct. 30, 1969	20	ND	--	<5	170	--	6	30	530	--	<1
Apr. 16, 1969	--	--	--	--	180	--	--	--	620	--	--
Site 7 - 413116075324901 JERMYN SLOPE (Lat 41 31 16N Long 075 32 49W)											
Apr. 16, 1969	--	--	--	--	5,600	--	--	--	3,300	--	--
Site 9 - 412852075334801 PECKVILLE SHAFT (Lat 41 28 52N Long 075 33 48W)											
Apr. 16, 1969	--	--	--	--	1,300	--	--	--	2,200	--	--
Oct. 30, 1969	120	50	--	<8	120	--	20	40	3,700	--	<2
Apr. 8, 1971	100	12	--	--	680	--	<1	--	1,900	--	--
Apr. 16, 1975	--	--	--	--	320	--	--	--	1,500	<0.5	--
Apr. 16, 1975	60	15	0	<2	350	--	11	30	2,100	--	<1
Site 13 - 412136075450401 OLD FORGE BOREHOLE (Lat 41 21 36N Long 075 45 04W)											
Apr. 16, 1969	--	--	--	--	88,000	--	--	--	--	--	--
Oct. 30, 1969	260	10	--	<30	98,000	--	<30	150	11,000	--	<6
Apr. 8, 1971	170	3	--	--	66,000	--	20	--	8,000	--	--
Apr. 24, 1975	--	--	--	--	47,000	--	--	--	5,600	.6	--
Apr. 24, 1975	110	<2	<3	<10	45,000	--	<7	120	7,900	--	<2
Site 14 - 412051075464201 DURYEA BREECH (Lat 41 20 51N Long 075 46 42W)											
Apr. 16, 1969	--	--	--	--	100,000	--	--	--	--	--	--
Apr. 17, 1975	150	<2	<3	<9	48,000	--	<6	100	7,300	<.5	<3
Nov. 1, 1986	--	10	--	--	35,000	--	18	--	--	--	--
Apr. 1, 1987	--	<5	--	--	35,000	--	92	--	--	--	--
Oct. 31, 1989	50	35	--	--	31,000	--	<5	--	3,800	<.2	--
Feb. 20, 1990	50	35	--	--	30,000	--	<5	--	3,500	<.2	--
Site 16 - 411936075472501 PITTSTON WATER TUNNEL (Lat 41 19 36N Long 075 47 25W)											
Apr. 1, 1987	--	49	--	--	1,300	--	45	--	--	--	--
July 16, 1990	70	26	--	--	2,000	--	8	--	2,300	<.2	--

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Nickel, dissolved (µg/L as Ni)	Rubidium, dissolved (µg/L as Rb)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Tin, dissolved (µg/L as Sn)	Titanium, dissolved (µg/L as Ti)	Vanadium, dissolved (µg/L as V)	Ytterbium, dissolved (µg/L as Yb)	Yttrium, total (µg/L as Y)	Zinc, dissolved (µg/L as Zn)	Zirconium, dissolved (µg/L as Zr)
Site 5 - 413611075290901 UPPER WILSON CREEK DRIFT (Lat 41 36 11N Long 075 29 09W)											
Oct. 30, 1969	50	3	<0.6	<250	<6	<6	<6	--	--	80	--
Apr. 8, 1971	<1	--	--	230	--	--	--	--	--	8	--
Site 6 - 413602075291301 LOWER WILSON CREEK SHAFT (Lat 41 36 02N Long 075 29 13W)											
Oct. 30, 1969	100	4	<.5	170	<5	<5	<5	--	--	300	--
Apr. 16, 1969	--	--	--	--	--	--	--	--	--	--	--
Site 7 - 413116075324901 JERMYN SLOPE (Lat 41 31 16N Long 075 32 49W)											
Apr. 16, 1969	--	--	--	--	--	--	--	--	--	--	--
Site 9 - 412852075334801 PECKVILLE SHAFT (Lat 41 28 52N Long 075 33 48W)											
Apr. 16, 1969	--	--	--	--	--	--	--	--	--	--	--
Oct. 30, 1969	260	<5	<.8	310	<8	<8	<8	--	--	670	--
Apr. 8, 1971	120	--	--	280	--	--	--	--	--	94	--
Apr. 16, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 16, 1975	110	--	ND	220	<2	<1	<2	--	--	180	<3
Site 13 - 412136075450401 OLD FORGE BOREHOLE (Lat 41 21 36N Long 075 45 04W)											
Apr. 16, 1969	--	--	--	--	--	--	--	--	--	--	--
Oct. 30, 1969	240	20	<3.0	1,900	<30	<30	<30	--	--	220	--
Apr. 8, 1971	230	--	--	1,800	--	--	--	--	--	22	--
Apr. 24, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 24, 1975	220	--	ND	1,800	<7	<5	<7	--	--	40	<10
Site 14 - 412051075464201 DURYEA BREECH (Lat 41 20 51N Long 075 46 42W)											
Apr. 16, 1969	--	--	--	--	--	--	--	--	--	--	--
Apr. 17, 1975	180	--	0	990	<7	<3	<4	--	--	90	<10
Nov. 1, 1986	100	--	1.0	--	--	--	--	--	--	50	--
Apr. 1, 1987	70	--	1.0	--	--	--	--	--	--	47	--
Oct. 31, 1989	97	--	4.0	--	--	--	<50	--	--	110	--
Feb. 20, 1990	65	--	7.0	--	--	--	7	--	--	58	--
Site 16 - 411936075472501 PITTSTON WATER TUNNEL (Lat 41 19 36N Long 075 47 25W)											
Apr. 1, 1987	150	--	<1.0	--	--	--	--	--	--	530	--
July 16, 1990	110	--	5.0	--	--	--	<50	--	--	420	--

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Dis-charge, inst. cubic feet per second	Alumi-num, dissolved (µg/L as Al)	Anti-mony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryl-lium, dissolved (µg/L as Be)	Bismuth, dissolved (µg/L as Bi)	Boron, dissolved (µg/L as B)	Bromide, dissolved (mg/L as Br)	Cad-mium, dissolved (µg/L as Cd)	Chro-mium, dissolved (µg/L as Cr)
Site 18 - 411350075552001 SOLOMON CREEK BOREHOLES (Lat 41 13 50N Long 075 55 20W)											
June 16, 1972	--	140	5	49	4	4	1	50	--	5	3
Sept. 20, 1972	--	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	--	--	--	--	--	--	--
Apr. 14, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 14, 1975	39	1,000	--	27	22	5	<15	20	--	ND	<20
Site 19 - 411334075561301 NOTTINGHAM-BUTTONWOOD MINE (Lat 41 13 34N Long 075 56 13W)											
June 16, 1972	--	2,200	5	46	3	3	1	40	--	5	3
Aug. 8, 1972	--	--	--	--	--	--	--	--	--	--	--
Aug. 30, 1972	--	--	--	--	--	--	--	--	--	--	--
Sept. 20, 1972	--	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	--	--	--	--	--	--	--
Nov. 1, 1986	24	--	10	12	--	30	--	--	--	10	<5
Apr. 1, 1987	43	--	5	9	--	30	--	--	--	12	<5
Nov. 1, 1989	26	100	<60	5	13	<5	--	--	--	6	20
Feb. 20, 1990	29	190	32	6	<200	<5	--	--	--	6	20
Site 20 - 411158075575201 ASKAM SHAFT BOREHOLE (Lat 41 11 58N Long 075 57 52W)											
June 16, 1972	--	7,400	50	180	10	19	1	130	--	5	10
Site 24 - 410901076084001 MOCANAQUA TUNNEL (Lat 41 09 01N Long 076 08 40W)											
Oct. 4, 1965	--	16,000	--	--	12	23	--	30	--	--	<20
Feb. 17, 1966	10	13,000	--	--	20	18	--	<90	--	--	<50
Apr. 14, 1975	5.8	6,000	--	--	19	10	<6	<20	--	ND	<6
Apr. 14, 1975	5.8	--	--	1	--	--	--	--	--	--	--
Site 34 - 405853075484901 BUCK MOUNTAIN TUNNEL (Lat 40 58 53N Long 075 48 49W)											
Apr. 16, 1975	--	21,000	--	--	24	11	<2	8	--	16	<3
Apr. 16, 1975	1.7	--	--	1	--	--	--	--	--	--	--
Site 40 - 405755076053001 TOMHICKEN STRIP PIT (Lat 40 57 55N Long 076 05 30W)											
Apr. 15, 1975	2.7	200	--	0	35	0	<1	310	--	2	ND
Site 50- 405506076085001 ONEIDA TUNNEL 3 (Lat 40 55 06N Long 076 08 50W)											
Apr. 16, 1975	9.1	2,700	--	1	28	2	ND	10	--	2	<2
Site 58 - 404801076123401 GILBERTON PUMP (Lat 40 48 01N Long 076 12 34W)											
Apr. 18, 1975	23	700	--	8	21	3	<8	<8	--	ND	<8

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Gallium, dissolved (µg/L as Ga)	Germa-nium, dissolved (µg/L as Ge)	Iron, dissolved (µg/L as Fe)	Lantha-num, total (µg/L as La)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manga-nese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybde-num, dissolved (µg/L as Mo)
Site 18 - 411350075552001 SOLOMON CREEK BOREHOLES (Lat 41 13 50N Long 075 55 20W)											
June 16, 1972	20	10	20	50	260,000	45	1	110	16,000	--	1
Sept. 20, 1972	--	--	--	--	400,000	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	510,000	--	--	--	39,000	--	--
Apr. 14, 1975	--	--	--	--	160,000	--	--	--	22,000	--	--
Apr. 14, 1975	220	<3	<7	<20	190,000	--	14	180	17,000	0.5	<3
Site 19 - 411334075561301 NOTTINGHAM-BUTTONWOOD MINE (Lat 41 13 34N Long 075 56 13W)											
June 16, 1972	340	10	20	40	160,000	36	2	140	22,000	--	ND
Aug. 8, 1972	--	--	--	--	190,000	--	--	--	23,000	--	--
Aug. 30, 1972	--	--	--	--	190,000	--	--	--	16,000	--	--
Sept. 20, 1972	--	--	--	--	150,000	--	--	--	20,000	--	--
Dec. 7, 1972	--	--	--	--	150,000	--	--	--	22,000	--	--
Nov. 1, 1986	--	10	--	--	72,000	--	24	--	--	--	--
Apr. 1, 1987	--	<5	--	--	64,000	--	92	--	--	--	--
Nov. 1, 1989	60	10	--	--	56,000	--	<5	--	7,100	<.2	--
Feb. 20, 1990	70	8	--	--	51,000	--	<5	--	6,700	<.2	--
Site 20 - 411158075575201 ASKAM SHAFT BOREHOLE (Lat 41 11 58N Long 075 57 52W)											
June 16, 1972	1,200	10	60	130	910,000	110	3	180	56,000	--	ND
Site 24 - 410901076084001 MOCANAQUA TUNNEL (Lat 41 09 01N Long 076 08 40W)											
Oct. 4, 1965	660	14	--	--	>150,000	--	29	100	32,000	--	4
Feb. 17, 1966	450	70	--	--	130,000	--	<50	80	21,000	--	<20
Apr. 14, 1975	370	13	<3	<9	59,000	--	10	120	14,000	--	<3
Apr. 14, 1975	--	--	--	--	60,000	--	--	--	12,000	<.5	--
Site 34 - 405853075484901 BUCK MOUNTAIN TUNNEL (Lat 40 58 53N Long 075 48 49W)											
Apr. 16, 1975	410	200	<1	<2	5,100	--	20	40	4,200	--	<2
Apr. 16, 1975	--	--	--	--	5,100	--	--	--	4,900	<.5	--
Site 40 - 405755076053001 TOMHICKEN STRIP PIT (Lat 40 57 55N Long 076 05 30W)											
Apr. 15, 1975	40	5	ND	<1	12,000	--	3	15	1,500	.6	ND
Site 50 - 405506076085001 ONEIDA TUNNEL 3 (Lat 40 55 06N Long 076 08 50W)											
Apr. 16, 1975	40	35	ND	ND	220	--	5	14	570	<.5	ND
Site 58 - 404801076123401 GILBERTON PUMP (Lat 40 48 01N Long 076 12 34W)											
Apr. 18, 1975	320	<2	<4	<10	54,000	--	<8	70	16,000	.5	<2

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Nickel, dissolved (µg/L as Ni)	Rubidium, dissolved (µg/L as Rb)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Tin, dissolved (µg/L as Sn)	Titanium, dissolved (µg/L as Ti)	Vanadium, dissolved (µg/L as V)	Ytterbium, dissolved (µg/L as Yb)	Yttrium, total (µg/L as Y)	Zinc, dissolved (µg/L as Zn)	Zirconium, dissolved (µg/L as Zr)
Site 18 - 411350075552001 SOLOMON CREEK BOREHOLES (Lat 41 13 50N Long 075 55 20W)											
June 16, 1972	78	--	4	3,400	50	6	35	6	50	200	100
Sept. 20, 1972	--	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	--	--	--	--	--	--	--
Apr. 14, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 14, 1975	560	--	<2	3,700	<20	<10	<15	--	--	140	<30
Site 19 - 411334075561301 NOTTINGHAM-BUTTONWOOD MINE (Lat 41 13 34N Long 075 56 13W)											
June 16, 1972	480	--	3	1,700	40	10	30	3	31	960	50
Aug. 8, 1972	--	--	--	--	--	--	--	--	--	--	--
Aug. 30, 1972	--	--	--	--	--	--	--	--	--	--	--
Sept. 20, 1972	--	--	--	--	--	--	--	--	--	--	--
Dec. 7, 1972	--	--	--	--	--	--	--	--	--	--	--
Nov. 1, 1986	170	--	2	--	--	--	--	--	--	100	--
Apr. 1, 1987	80	--	<1	--	--	--	--	--	--	45	--
Nov. 1, 1989	77	--	7	--	--	--	5	--	--	31	--
Feb. 20, 1990	75	--	5	--	--	--	6	--	--	34	--
Site 20 - 411158075575201 ASKAM SHAFT BOREHOLE (Lat 41 11 58N Long 075 57 52W)											
June 16, 1972	2,200	--	10	8,100	100	20	90	33	300	8,800	840
Site 24 - 410901076084001 MOCANAQUA TUNNEL (Lat 41 09 01N Long 076 08 40W)											
Oct. 4, 1965	1,200	7	<2	880	<20	<20	<15	--	--	<720	<30
Feb. 17, 1966	830	5	5	720	<90	<30	<45	--	--	<2,300	<90
Apr. 14, 1975	340	--	ND	360	<6	<3	<4	--	--	530	<10
Apr. 14, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 34 - 405853075484901 BUCK MOUNTAIN TUNNEL (Lat 40 58 53N Long 075 48 49W)											
Apr. 16, 1975	400	--	ND	67	<2	<2	<2	--	--	1,000	<3
Apr. 16, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 40 - 405755076053001 TOMHICKEN STRIP PIT (Lat 40 57 55N Long 076 05 30W)											
Apr. 15, 1975	50	--	ND	50	<1	ND	<1	--	--	<100	2
Site 50 - 405506076085001 ONEIDA TUNNEL 3 (Lat 40 55 06N Long 076 08 50W)											
Apr. 16, 1975	65	--	ND	31	ND	ND	ND	--	--	240	ND
Site 58 - 404801076123401 GILBERTON PUMP (Lat 40 48 01N Long 076 12 34W)											
Apr. 18, 1975	380	--	<1	1,500	<8	<6	<8	--	--	510	<20

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Dis-charge, inst. cubic feet per second	Alumi-num, dissolved (µg/L as Al)	Anti-mony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryl-lium, dissolved (µg/L as Be)	Bismuth, dissolved (µg/L as Bi)	Boron, dissolved (µg/L as B)	Bromide, dissolved (mg/L as Br)	Cad-mium, dissolved (µg/L as Cd)	Chro-mium, dissolved (µg/L as Cr)
Site 77 - 404435076283801 DOUTYVILLE TUNNEL (Lat 40 44 35N Long 076 28 38W)											
Apr. 18, 1975	--	7,700	--	--	23	5	<8	<6	--	<2	<6
Apr. 18, 1975	13	--	--	2	--	--	--	--	--	--	--
Site 85 - 404739076291901 SCOTT RIDGE MINE TUNNEL (Lat 40 47 39N Long 076 29 19W)											
Apr. 17, 1975	15	900	--	2	18	3	<4	30	--	ND	<4
Site 87 - 404625076293701 EXCELSIOR STRIP PIT (Lat 40 46 25N Long 076 29 37W)											
Apr. 18, 1975	--	950	--	--	17	3	<5	<20	--	ND	<4
Apr. 18, 1975	13	--	--	1	--	--	--	--	--	--	--
Dec. 6, 1977	--	--	--	--	--	--	--	--	--	--	--
Aug. 15, 1978	--	--	--	--	--	--	--	--	--	--	--
Site 103 - 404617076404401 NORTH FRANKLIN MINE (Lat 40 46 17N Long 076 40 44W)											
Apr. 18,1975	--	3,400	--	--	18	4	<5	<5	--	ND	<5
Apr. 18, 1975	7.3	--	--	2	--	--	--	--	--	--	--
Sept. 23, 1977	--	--	--	--	--	--	--	--	--	--	--
Site 104 - 405229075454901 NESQUEHONING TUNNEL (Lat 40 52 29N Long 075 45 49W)											
Apr. 22, 1975	--	50	--	--	24	<1	<5	6	--	4	<5
Apr. 22, 1975	11	--	--	<1	--	--	--	--	--	--	--
Site 108 - 404909075560001 GREENWOOD PUMP (Lat 40 49 09N Long 075 56 00W)											
Apr. 23, 1975	7.7	--	--	6	--	--	--	--	--	--	--
Apr. 23, 1975	--	80	--	--	25	<3	<12	<20	--	ND	<10
Site 114 - 404728075590901 NEWKIRK TUNNEL NORTH DIP (Lat 40 47 28N Long 075 59 09W)											
July 28, 1964	2.6	40,000	--	--	--	--	--	--	--	--	--
Feb. 16, 1965	1.6	--	--	--	--	--	--	--	--	--	--
Feb. 24, 1965	1.4	--	--	--	--	--	--	--	--	--	--
July 21, 1975	.36	50,000	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	1.1	>12,000	--	0	17	6	<3	<3	--	5	<3
Site 157 - 404258076090101 EAGLE HILL DRIFT (Lat 40 42 58N Long 076 09 01W)											
July 28, 1964	.51	--	--	--	--	--	--	--	--	--	--
July 21, 1965	.0	--	--	--	--	--	--	--	--	--	--
Apr. 22, 1975	1.8	--	--	1	--	--	--	--	--	--	--
Apr. 22, 1975	--	620	--	--	22	2	<3	<20	--	ND	<3

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Gallium, dissolved (µg/L as Ga)	Germanium, dissolved (µg/L as Ge)	Iron, dissolved (µg/L as Fe)	Lanthanum, total (µg/L as La)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)
Site 77 - 404435076283801 DOUTYVILLE TUNNEL (Lat 40 44 35N Long 076 28 38W)											
Apr. 18, 1975	180	25	<3	<8	15,000	--	<6	80	8,100	--	<3
Apr. 18, 1975	--	--	--	--	12,000	--	--	--	6,400	<0.5	--
Site 85 - 404739076291901 SCOTT RIDGE MINE TUNNEL (Lat 40 47 39N Long 076 29 19W)											
Apr. 17, 1975	280	2	<2	<6	45,000	--	<4	90	6,800	7	<2
Site 87 - 404625076293701 EXCELSIOR STRIP PIT (Lat 40 46 25N Long 076 29 37W)											
Apr. 18, 1975	140	<20	<2	<5	50,000	--	<4	60	7,000	--	<2
Apr. 18, 1975	--	--	--	--	44,000	--	--	--	5,400	<.5	--
Dec. 6, 1977	--	--	--	--	46,000	--	--	--	--	--	--
Aug. 15, 1978	--	--	--	--	42,000	--	--	--	--	--	--
Site 103 - 404617076404401 NORTH FRANKLIN MINE (Lat 40 46 17N Long 076 40 44W)											
Apr. 18, 1975	320	20	<2	<7	30,000	--	<5	40	7,000	--	<1
Apr. 18, 1975	--	--	--	--	25,000	--	--	--	6,000	<.5	--
Sept. 23, 1977	--	--	--	--	45,000	--	--	--	--	--	--
Site 104 - 405229075454901 NESQUEHONING TUNNEL (Lat 40 52 29N Long 075 45 49W)											
Apr. 22, 1975	170	<2	<2	<6	8,600	--	<5	60	6,100	--	<1
Apr. 22, 1975	--	--	--	--	6,700	--	--	--	4,700	<.5	--
Site 108 - 404909075560001 GREENWOOD PUMP (Lat 40 49 09N Long 075 56 00W)											
Apr. 23, 1975	--	--	--	--	33,000	--	--	--	11,000	.6	--
Apr. 23, 1975	220	<3	<6	<20	33,000	--	<12	60	14,000	--	<3
Site 114 - 404728075590901 NEWKIRK TUNNEL NORTH DIP (Lat 40 47 28N Long 075 59 09W											
July 28, 1964	--	--	--	--	5,500	--	--	--	10,000	--	--
Feb. 16, 1965	--	--	--	--	6,700	--	--	--	--	--	--
Feb. 24, 1965	--	--	--	--	6,400	--	--	--	8,400	--	--
July 21, 1965	--	--	--	--	41,000	--	--	--	7,300	--	--
Apr. 23, 1975	190	100	<1	<4	12,000	--	10	35	4,300	<.5	<1
Site 157 - 404258076090101 EAGLE HILL DRIFT (Lat 40 42 58N Long 076 09 01W)											
July 28, 1964	--	--	--	--	6,000	--	--	--	4,700	--	--
July 21, 1965	--	--	--	--	26,000	--	--	--	4,700	--	--
Apr. 22, 1975	--	--	--	--	5,800	--	--	--	4,000	<.5	--
Apr. 22, 1975	110	6	<2	<5	8,000	--	3	20	5,000	--	<1

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Nickel, dissolved (µg/L as Ni)	Rubidium, dissolved (µg/L as Rb)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Tin, dissolved (µg/L as Sn)	Titanium, dissolved (µg/L as Ti)	Vanadium, dissolved (µg/L as V)	Ytterbium, dissolved (µg/L as Yb)	Yttrium, total (µg/L as Y)	Zinc, dissolved (µg/L as Zn)	Zirconium, dissolved (µg/L as Zr)
Site 77 - 404435076283801 DOUTYVILLE TUNNEL (Lat 40 44 35N Long 076 28 38W)											
Apr. 18, 1975	340	--	ND	590	<6	<3	<6	--	--	550	<8
Apr. 18, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 85 - 404739076291901 SCOTT RIDGE MINE TUNNEL (Lat 40 47 39N Long 076 29 19W)											
Apr. 17, 1975	320	--	ND	320	<5	<2	<3	--	--	250	<9
Site 87 - 404625076293701 EXCELSIOR STRIP PIT (Lat 40 46 25N Long 076 29 37W)											
Apr. 18, 1975	240	--	ND	300	<4	<2	<4	--	--	330	<5
Apr. 18, 1975	--	--	--	--	--	--	--	--	--	--	--
Dec. 6, 1977	--	--	--	--	--	--	--	--	--	--	--
Aug. 15, 1978	--	--	--	--	--	--	--	--	--	--	--
Site 103 - 404617076404401 NORTH FRANKLIN MINE (Lat 40 46 17N Long 076 40 44W)											
Apr. 18, 1975	520	--	ND	150	<5	<3	<5	--	--	650	<9
Apr. 18, 1975	--	--	--	--	--	--	--	--	--	--	--
Sept. 23, 1977	--	--	--	--	--	--	--	--	--	--	--
Site 104 - 405229075454901 NESQUEHONING TUNNEL (Lat 40 52 29N Long 075 45 49W)											
Apr. 22, 1975	240	--	ND	780	<5	<3	<5	--	--	420	<9
Apr. 22, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 108 - 404909075560001 GREENWOOD PUMP (Lat 40 49 09N Long 075 56 00W)											
Apr. 23, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	320	--	<2	3,000	<10	<9	<12	--	--	470	<30
Site 114 - 404728075590901 NEWKIRK TUNNEL NORTH DIP (Lat 40 47 28N Long 075 59 09W)											
July 28, 1964	--	--	--	--	--	--	--	--	--	--	--
Feb. 16, 1965	--	--	--	--	--	--	--	--	--	--	--
Feb. 24, 1965	--	--	--	--	--	--	--	--	--	--	--
July 21, 1965	--	--	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	290	--	ND	100	<4	<2	<3	--	--	600	<5
Site 157 - 404258076090101 EAGLE HILL DRIFT (Lat 40 42 58N Long 076 09 01W)											
July 28, 1964	--	--	--	--	--	--	--	--	--	--	--
July 21, 1965	--	--	--	--	--	--	--	--	--	--	--
Apr. 22, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 22, 1975	180	--	ND	660	<3	<3	<3	--	--	210	<7

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Discharge, inst. cubic feet per second	Aluminum, dissolved (μg/L as Al)	Antimony, dissolved (μg/L as Sb)	Arsenic, dissolved (μg/L as As)	Barium, dissolved (μg/L as Ba)	Beryllium, dissolved (μg/L as Be)	Bismuth, dissolved (μg/L as Bi)	Boron, dissolved (μg/L as B)	Bromide, dissolved (mg/L as Br)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)
Site 166 - 404406076120201 REPPLIER WATER LEVEL TUNNEL (Lat 40 44 06N Long 076 12 02W)											
July 21, 1965	0.28	1,800	--	--	--	--	--	--	--	--	--
Site 167 - 404320076103201 PINE FOREST MINE (Lat 40 43 20N Long 076 10 32W)											
July 28, 1964	4.0	16,000	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	--	7,800	--	--	21	9	<6	<6	--	<2	<6
Apr. 23, 1975	14	--	--	<1	--	--	--	--	--	--	--
Site 171 - 404251076122101 WADESVILLE PUMP (Lat 40 42 51N Long 076 12 21W)											
Apr. 22, 1975	2.3	--	--	1	--	--	--	--	--	--	--
Apr. 22, 1975	--	40	--	--	42	<2	<10	30	--	ND	<7
Site 187 - 404224076150601 PINE KNOT DRAINAGE TUNNEL (Lat 40 42 24N Long 076 15 06W)											
July 28, 1964	13	14,000	--	--	--	--	--	--	--	--	--
Dec. 1, 1964	7.2	16,000	--	--	--	--	--	--	--	--	--
Feb. 16, 1965	65	--	--	--	--	--	--	--	--	--	--
Feb. 24, 1965	39	--	--	--	--	--	--	--	--	--	--
July 21, 1965	9.1	10,000	--	--	--	--	--	--	--	--	--
Apr. 21, 1975	--	2,100	--	--	22	2	<3	<3	--	<2	<3
Apr. 21, 1975	26	--	--	2	--	--	--	--	0.00	--	--
Site 190 - 403958076191401 OTTO AIR SHAFT (Lat 40 39 58N Long 076 19 14W)											
Apr. 23, 1975	--	3,200	--	--	24	5	<4	<4	--	<2	<4
Apr. 23, 1975	6.4	--	--	2	--	--	--	--	--	--	--
Site 202 - 403823076193601 BLACKWOOD TUNNEL (Lat 40 38 23N Long 076 19 36W)											
Apr. 25, 1975	--	--	--	<1	--	--	--	--	--	--	--
Apr. 25, 1975	--	290	--	--	21	1	<2	5	--	<20	<5
Site 215 - 403820076224501 MIDDLE CREEK STRIP PIT (Lat 40 38 20N Long 076 22 45W)											
Apr. 23, 1975	--	2,200	--	--	40	2	<2	6	--	<5	<5
Apr. 23, 1975	9.8	--	--	<1	--	--	--	--	--	--	--

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Gallium, dissolved (µg/L as Ga)	Germa-nium, dissolved (µg/L as Ge)	Iron, dissolved (µg/L as Fe)	Lantha-num, total (µg/L as La)	Lead, dissolved (µg/L as Pb)	Lithium, dissolved (µg/L as Li)	Manga-nese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybde-num, dissolved (µg/L as Mo)
Site 166 - 404406076120201 REPPLIER WATER LEVEL TUNNEL (Lat 40 44 06N Long 076 12 02W)											
July 21, 1965	--	--	--	--	40,000	--	--	--	1,200	--	--
Site 167 - 404320076103201 PINE FOREST MINE (Lat 40 43 20N Long 076 10 32W)											
July 28, 1964	--	--	--	--	6,700	--	--	--	32,000	--	--
Apr. 23, 1975	300	60	<3	<9	5,900	--	<6	50	12,000	--	<2
Apr. 23, 1975	--	--	--	--	4,500	--	--	--	10,000	0.6	--
Site 171 - 404251076122101 WADESVILLE PUMP (Lat 40 42 51N Long 076 12 21W)											
Apr. 22, 1975	--	--	--	--	1,000	--	--	--	2,300	<.5	--
Apr. 22, 1975	<7	2	<3	<10	1,200	--	<7	20	2,600	--	<3
Site 187 - 404224076150601 PINE KNOT DRAINAGE TUNNEL (Lat 40 42 24N Long 076 15 06W)											
July 28, 1964	--	--	--	--	5,600	--	--	--	11,000	--	--
Dec. 1, 1964	--	--	--	--	7,700	--	--	--	15,000	--	--
Feb. 16, 1965	--	--	--	--	6,500	--	--	--	--	--	--
Feb. 24, 1965	--	--	--	--	6,800	--	--	--	--	--	--
July 21, 1965	--	--	--	--	22,000	--	--	--	1,200	--	--
Apr. 21, 1975	160	14	<2	<5	11,000	--	<3	40	6,700	--	<1
Apr. 21, 1975	--	--	--	--	8,500	--	--	--	4,600	<.5	--
Site 190 - 403958076191401 OTTO AIR SHAFT (Lat 40 39 58N Long 076 19 14W)											
Apr. 23, 1975	250	15	<2	<5	25,000	--	<4	30	5,800	--	<1
Apr. 23, 1975	--	--	--	--	26,000	--	--	--	4,400	<.5	--
Site 202 - 403382307619360 1 BLACKWOOD TUNNEL (Lat 40 38 23N Long 076 19 36W)											
Apr. 25, 1975	--	--	--	--	1,100	--	--	--	1,600	<.5	--
Apr. 25, 1975	60	7	<1	<2	1,200	--	<5	21	1,900	--	<2
Site 215 - 403820076224501 MIDDLE CREEK STRIP PIT (Lat 40 38 20N Long 076 22 45W)											
Apr. 23, 1975	90	30	<1	<2	320	--	3	17	3,300	--	<2
Apr. 23, 1975	--	--	--	--	280	--	--	--	2,400	<.5	--

Table 6. *Results of chemical analyses for metals and other trace constituents in water discharged from mines in the anthracite fields of Pennsylvania--Continued*

Date	Nickel, dissolved (µg/L as Ni)	Rubidium, dissolved (µg/L as Rb)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Tin, dissolved (µg/L as Sn)	Titanium, dissolved (µg/L as Ti)	Vanadium, dissolved (µg/L as V)	Ytterbium, dissolved (µg/L as Yb)	Yttrium, total (µg/L as Y)	Zinc, dissolved (µg/L as Zn)	Zirconium, dissolved (µg/L as Zr)
Site 166 - 404406076120201 REPPLIER WATER LEVEL TUNNEL (Lat 40 44 06N Long 076 12 02W)											
July 21, 1965	--	--	--	--	--	--	--	--	--	--	--
Site 167 - 404320076103201 PINE FOREST MINE (Lat 40 43 20N Long 076 10 32W)											
July 28, 1964	--	--	--	--	--	--	--	--	--	--	--
Apr. 23, 1975	390	--	ND	1,000	<6	<5	<6	--	--	130	<10
Apr. 23, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 171 - 404251076122101 WADESVILLE PUMP (Lat 40 42 51N Long 076 12 21W)											
Apr. 22, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 22, 1975	15	--	ND	1,600	<7	<3	<7	--	--	ND	<10
Site 187 - 404224076150601 PINE KNOT DRAINAGE TUNNEL (Lat 40 42 24N Long 076 15 06W)											
July 28, 1964	--	--	--	--	--	--	--	--	--	--	--
Dec. 1, 1964	--	--	--	--	--	--	--	--	--	--	--
Feb. 16, 1965	--	--	--	--	--	--	--	--	--	--	--
Feb. 24, 1965	--	--	--	--	--	--	--	--	--	--	--
July 21, 1965	--	--	--	--	--	--	--	--	--	--	--
Apr. 21, 1975	200	--	ND	320	<3	<2	<3	--	--	250	<7
Apr. 21, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 190 - 403958076191401 OTTO AIR SHAFT (Lat 40 39 58N Long 076 19 14W)											
Apr. 23, 1975	360	--	ND	500	<4	<3	<4	--	--	710	<7
Apr. 23, 1975	--	--	--	--	--	--	--	--	--	--	--
Site 202 - 403823076193601 BLACKWOOD TUNNEL (Lat 40 38 23N Long 076 19 36W)											
Apr. 25, 1975	--	--	--	--	--	--	--	--	--	--	--
Apr. 25, 1975	<200	--	ND	120	<2	<1	<2	--	--	210	<2
Site 215 - 403820076224501 MIDDLE CREEK STRIP PIT (Lat 40 38 20N Long 076 22 45W)											
Apr. 23, 1975	130	--	ND	140	<2	<1	<4	--	--	600	<3
Apr. 23, 1975	--	--	--	--	--	--	--	--	--	--	--

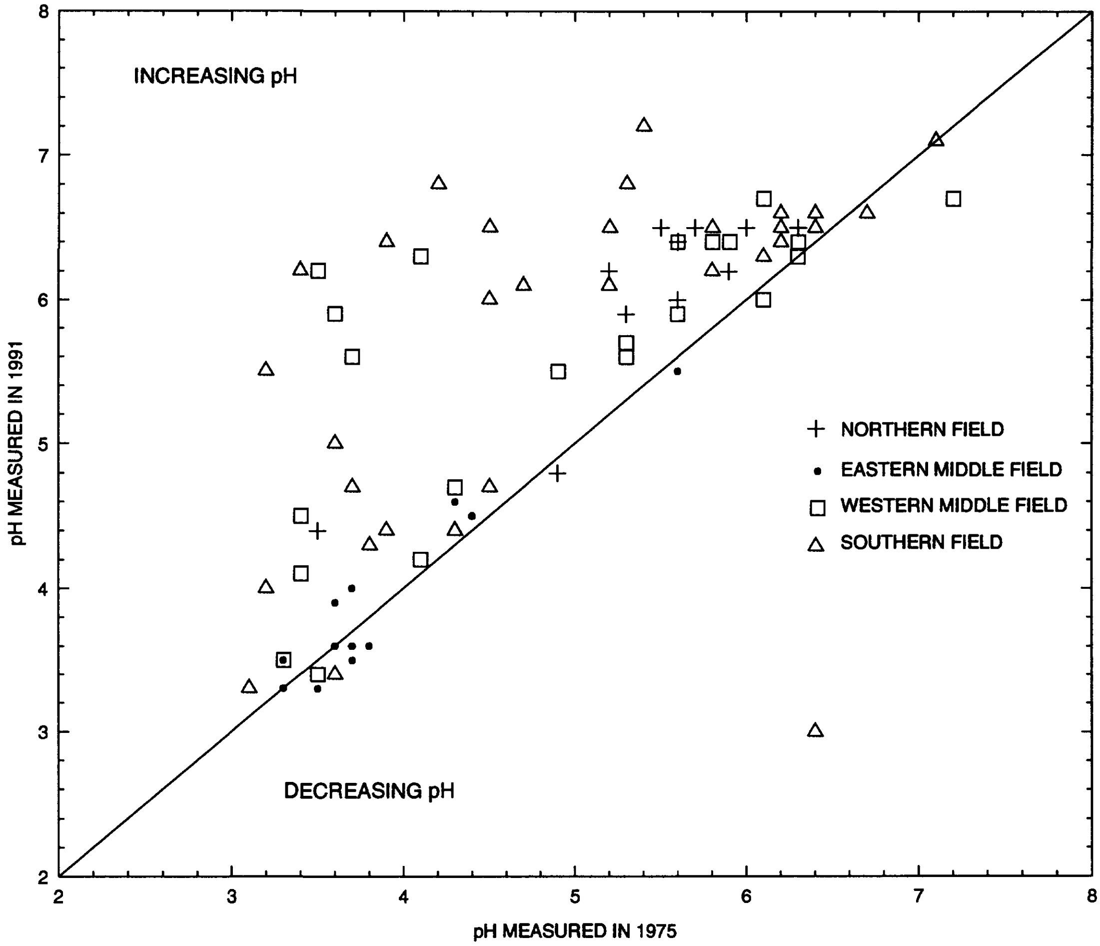


Figure 8. Change in pH between 1975 and 1991 for water discharged from mines in the four anthracite coal fields of eastern Pennsylvania.

1991. The median pH was 4.9 in 1975 and 6.0 in 1991. In addition, at 23 mines, field pH of discharge water was measured by various investigators between 1964 and 1969 (table 5). The pH of the discharge water increased at all 23 of these mines between 1964-69 and 1991. The median change was +0.8 units.

Only field pH is evaluated in this report. The pH of water discharged from coal mines is unstable and can change rapidly when the water is in contact with the atmosphere. Table 7 shows the magnitude of the change between the field pH and the laboratory pH of three discharges in the Northern Anthracite Field. Although pH was higher in the laboratory than in the field for a few samples, it was about 2 pH units lower in the laboratory for most samples, as much as 3.4 pH units lower. This change was probably caused by iron oxidation and hydrolysis. The magnitude of the change is affected by the concentrations of the constituents present in the water, the time between collection and analysis, temperature, and loss or gain of dissolved gasses. Consequently, laboratory pH should be used with great caution, if at all, in evaluating the quality of water discharged from mines. Most of the pH determinations by PaDEP and the consultants working for them on Operation Scarlift were done in the laboratory.

Acidity

The acidities measured in 1991 for this study and those measured in 1975 by Growitz and others (1985) were determined in the field on a cold (ambient temperature) sample to end points of both pH 7.0 and pH 8.3 (tables 1-4). The acidities reported by Biesecker and others (1968) used the same method. However, most acidities reported in the literature were determined in the laboratory. The PaDEP determines acidity to an endpoint of pH 8.3 on a sample that has been heated and oxidized with hydrogen peroxide. Other acidities reported in the literature seem to have been determined on cold, hot, and hot oxidized samples to end points of pH 4.5 (free mineral acidity), pH 7.0, and pH 8.3. In many instances, the method used is not indicated, and field and laboratory analyses are not identified. GEO-Technical Services, Inc. (1982) showed substantial differences between hot and cold field and laboratory acidities for water from the Beaver Meadow (Quakake) Tunnel discharge (fig. 9). Consequently, comparison of results of acidity determinations from various sources is difficult, if not impossible. Oxidation of metals between the time of sampling and analysis can greatly change acidity. Oxidation of ferrous to ferric iron and subsequent precipitation of ferric iron is one of the most important reactions at most mines, although aluminum can also contribute to acidity (GEO-Technical Services, Inc., 1982; Ott, 1986).

For water discharged from 81 mines that had cold field acidities determined to an end point of pH 8.3 in 1975 and 1991, 42 had higher acidities in 1991 than in 1975; the median change was +2 mg/L as $CaCO_3$. The median acidity was 105 mg/L in 1975 and 115 mg/L in 1991. The slight increase in acidity may have been related to the lower discharges in 1991. For water discharged from 16 mines in the Southern Anthracite Field that had cold field acidities on March 22, 1965, 11 had lower acidities and 5 had higher acidities on October 28-November 7, 1991. However, for 12 of these mines that had cold acidities on November 15, 1965, 6 had lower acidities and 6 had higher acidities on October 28-November 7, 1991. This illustrates the difficulties of comparing data for different seasons. The data in table 8 support the conclusion that although large changes in acidity in the water have taken place over time at individual discharges, little change in acidity has taken place for water discharged from anthracite mines as a group.

Dissolved Oxygen

In 1991, concentrations of dissolved oxygen (DO) in discharge water ranged from 0 mg/L at 12 percent of the 81 mines sampled to 10.8 mg/L (tables 1-4). DO concentration was less than 1 mg/L at 26 percent of the discharges, and the median concentration was 5.5 mg/L. DO concentrations show little correlation with pH and concentrations of aluminum, manganese, and sulfate. Although the data exhibit considerable scatter, acidity (cold titration to pH 8.3) appears to decrease with increasing DO concentration for the 81 discharges sampled in 1991 (fig. 10). Concentrations of iron also have considerable scatter when compared to DO (fig. 11). Changes in DO concentration with time cannot be determined because DO was rarely measured prior to 1991.

Table 7. *Laboratory pH compared to field pH for the same sample for water discharged from selected mines in the Northern Anthracite Field, northeast Pennsylvania* [1]

	Solomon Creek boreholes (site number 18)		Plainsville outlet (site number 17)		Askam borehole (site number 20)	
	Field pH	Laboratory pH	Field pH	Laboratory pH	Field pH	Laboratory pH
	5.4	2.9	4.6	5.6	5.9	5.5
	5.3	4.8	5.7	3.4	5.3	3.2
	5.2	2.9	6.6	3.4	5.6	3.9
	5.2	3.0	5.9	3.5	5.8	3.6
	5.4	3.1	6.1	5.5	5.8	3.6
	5.2	3.1	5.8	6.1	5.7	3.7
	5.5	4.3	5.8	5.5	5.7	3.3
	5.4	3.0	6.1	4.1	5.5	3.0
	5.4	2.9	6.1	3.7	6.3	3.3
	5.5	2.7	6.4	6.0	6.3	3.1
	5.4	3.0	6.1	3.9	6.8	3.4
	5.4	2.5	5.7	4.7	6.0	5.3
			6.2	5.5	5.8	3.8
			6.1	5.1	5.5	5.1
			5.6	3.9	5.8	4.1
			4.2	4.2	5.4	4.9
					5.7	5.7
					5.9	4.0
					5.7	4.5
					6.5	4.9
					6.8	4.6
					5.3	3.4
					3.5	3.5
Maximum	5.5	4.8	6.6	6.1	6.8	5.5
Minimum	5.2	2.5	4.2	3.4	3.5	3.0
Median	5.4	3.0	6.0	4.4	5.8	3.8

[1]Data from GEO-Technical Services, Inc. (1976, p. 42, B18-89).

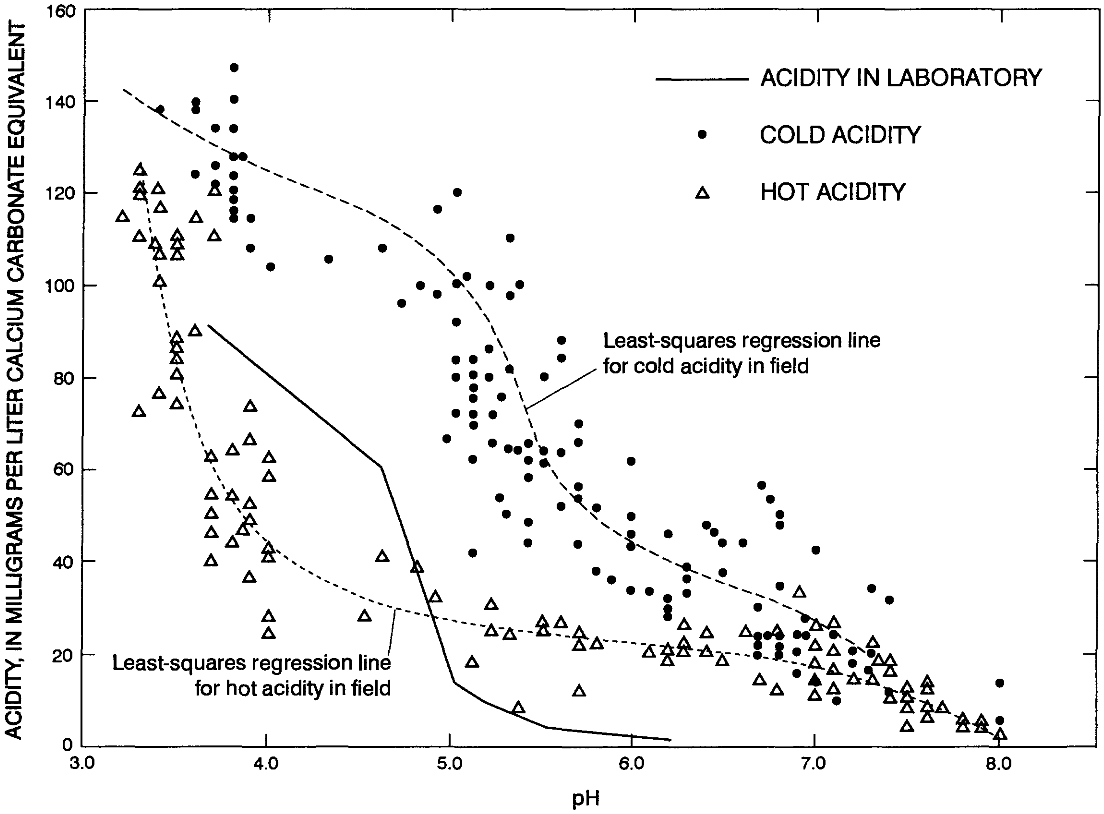


Figure 9. Comparison of hot and cold field and laboratory acidity titrations for water discharged from the Beaver Meadow (Quakake) Tunnel (site 37) Eastern Middle Anthracite Field, east-central Pennsylvania. (From GEO-Technical Servicess,Inc., 1982, fig. 7.11.)

Table 8. *Acidity of water discharged from selected mines in the Southern Anthracite Field, east-central Pennsylvania, 1965 and 1991*

[mg/L, milligrams per liter; --, no data]

Site number	Cold acidity to pH 8.3 as $CaCO_3$ (mg/L)		
	Mar. 22, 1965	Nov. 15, 1965	Oct. 28–Nov. 7, 1991
104	122	98	73
108	214	--	171
114	420	250	229
118	87	78	192
119	51	60	1
121	122	122	156
132	52	--	40
149	245	224	237
157	90	--	91
160	163	163	40
162	233	--	192
166	224	245	113
171	212	55	315
187	122	189	78
188	182	100	250
190	326	214	232

Silica

Silica concentration was measured by various investigators in water discharged from 26 mines from 1964 through 1975 (table 5). The mean concentration from one or more water samples at each mine ranged from 6.2 to 22 mg/L. The median was 12 mg/L, and the mean was 12 mg/L. Ninety-five percent of the silica concentrations in 1,608 water samples from wells and springs in the Delaware River Basin in Pennsylvania reported by Koester and Miller (1982b) were between 5 and 30 mg/L. Becher (1991) reported median concentrations of 6.9 and 4.6 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively.

Cations

The principal (median concentrations more than 1 mg/L) cations in water discharged from coal mines in the anthracite region, in decreasing order of abundance, are calcium, magnesium, iron, sodium, manganese, aluminum, and potassium. The geochemistry of these constituents and some trace elements in water discharged from anthracite mines was discussed by Newport and others (1971). Trace metals are discussed in this section only if more than 50 percent of the water samples had concentrations above detection limits. In decreasing order of abundance, these are strontium, zinc, nickel, cobalt, lithium, barium, boron, copper, lead, and cadmium. Many of the data for cations (except for iron, manganese, and aluminum) are for water samples collected in 1975 (table 6). Concentrations for some cations have decreased since then. Also, the accuracy of the laboratory determinations for some trace metals has improved with the introduction of new methods and the older data may be inaccurate. In the following sections, if more than one analysis is available for a mine, the mean for the mine has been used to determine the median and mean concentration in water discharged from the mine.

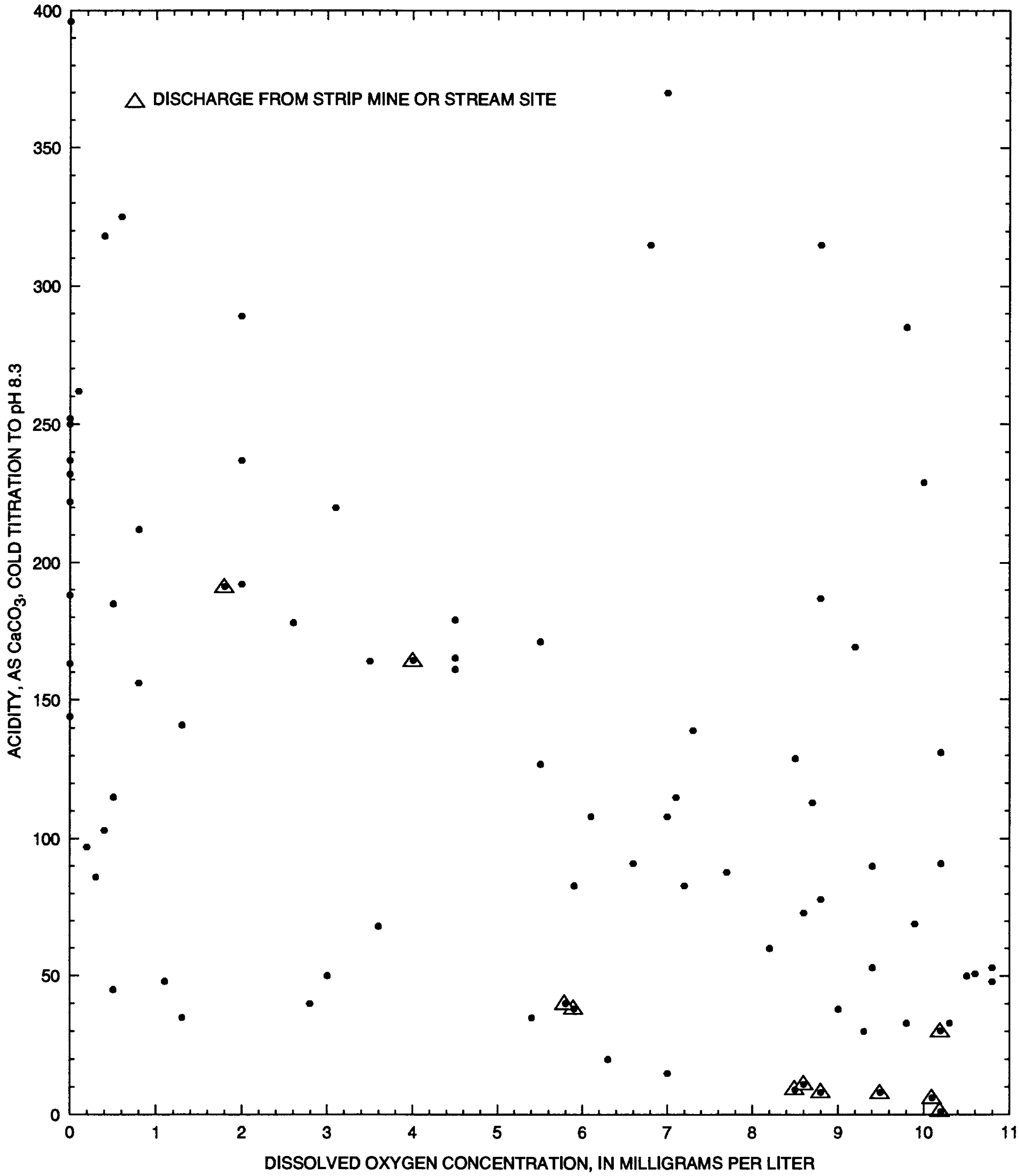


Figure 10. Relation of dissolved oxygen concentration to acidity in water discharged from mines in the anthracite coal fields of Pennsylvania.

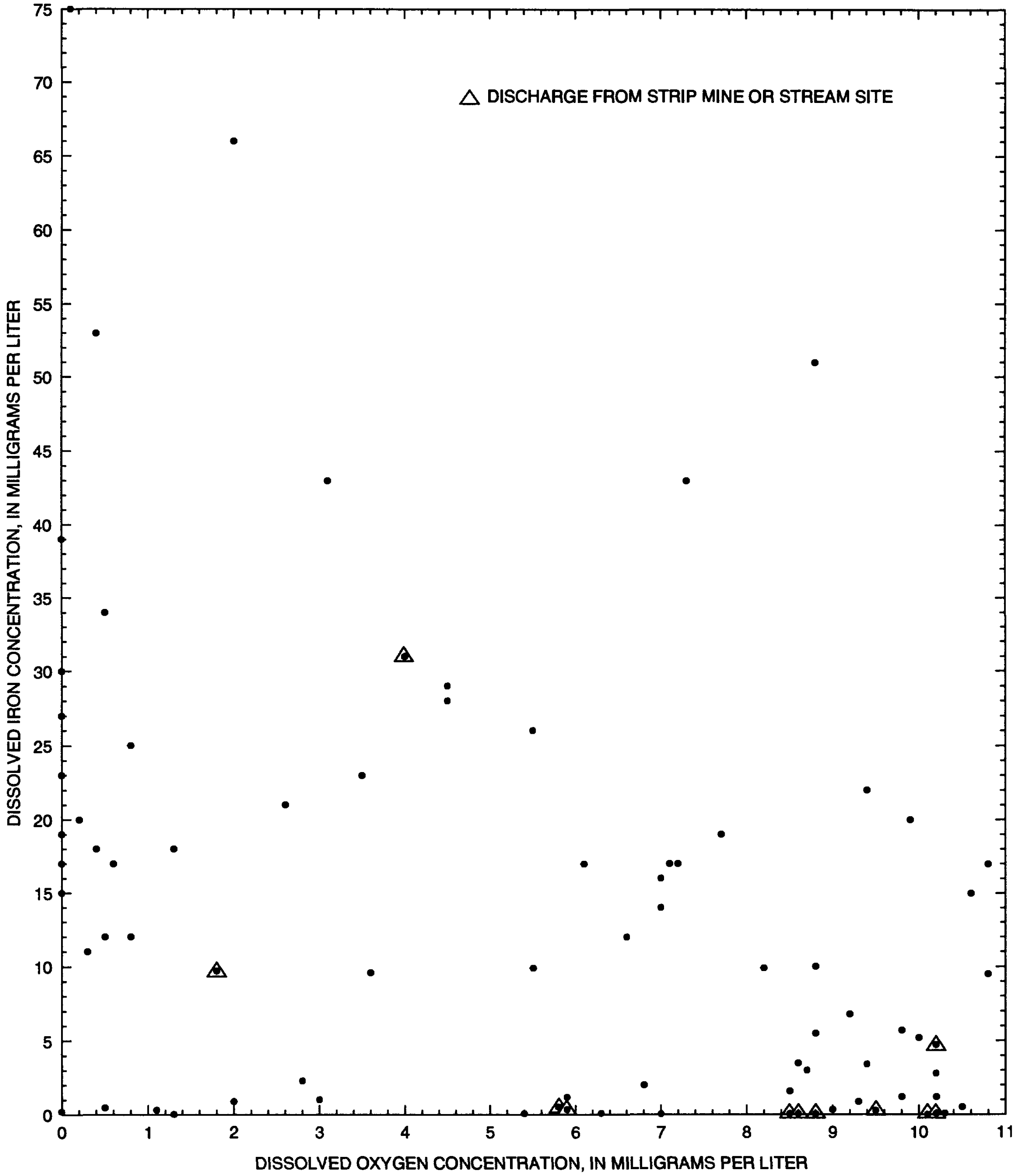


Figure 11. Relation of dissolved oxygen concentration to dissolved iron concentration in water discharged from mines in the anthracite coal fields of Pennsylvania.

"Greater than" values have been omitted from the statistics. Except where otherwise stated, "less than" values have been treated as if they were the determined value unless the detection limit was higher than the highest determined value, in which case the value was omitted. "Not detected" values have been treated as zeros, except that they have been omitted if a determined value was available for water discharged from the same mine.

In the following section, median concentrations for constituents in mine drainage are compared to regional medians for constituents in ground water given by Barker (1984), medians derived from data given by Koester and Miller (1982a, 1982b), and medians given by Becher (1991). If these sources could not be used to obtain a median for a large data set, medians given by Sloto (1994) for ground-water samples from Chester County, Pa., are given.

Aluminum

Aluminum concentration was measured by various investigators in water-discharge samples collected from 29 mines from 1964 through 1990 (table 6). The mean concentration from one or more water samples collected at each mine ranged from 0.03 to 45 mg/L. The median concentration was 0.95 mg/L, and the mean was 4.7 mg/L. Concentrations of aluminum in ground water from outside the mined area generally are very low. For example, Sloto (1994) reported a median concentration of 10 µg/L for 82 ground-water samples from Chester County, Pa. For water discharged from 10 mines where aluminum concentrations can be compared for different periods of time (table 9), concentrations increased at 4 mines and decreased at 6. Thus, consistent changes with time cannot be proven.

Table 9. *Aluminum concentrations for selected periods in water discharged from mines in the anthracite fields of Pennsylvania*

Site number	Concentrations of aluminum in milligrams per liter for indicated period in years			
	1964-69	1970-74	1975-80	1985-90
9	[1]3.6	--	1.4	--
13	.32	--	.12	--
14	[1].16	--	.40	--
18	--	0.14	1.0	--
19	--	2.2	--	[1]0.14
24	[1]16	--	6.0	--
34	--	--	21	[1]38
37	--	[1]17	[1]9.8	--
167	16	--	7.8	--
202	--	--	.29	[1].91

[1]Mean of two or more values.

Barium

Barium concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1965 through 1990 (table 6). The mean concentration from one or more water-discharge samples at each mine ranged from 8 to 42 µg/L. The median concentration was 21 µg/L. Sloto (1994) reported a median concentration of 45 µg/L for 201 ground-water samples from Chester County, Pa. The elevated concentrations of sulfate in mine water cause precipitation of barium sulfate, which is very insoluble, thus lowering the barium concentration (Newport and others, 1971, p. 113).

Boron

Boron concentration was measured by various investigators in water-discharge samples collected from 27 mines from 1969 through 1975 (table 6). The mean concentration from one or more water samples at each mine ranged from less than 3 to 310 µg/L. The median concentration was less than 20 µg/L. Sloto (1994) reported a median concentration of less than 20 µg/L for 98 ground-water samples from Chester County, Pa. The median concentration in water discharged from mines in the Northern Anthracite Field is 38 µg/L.

Cadmium

Cadmium concentration was measured by various investigators in water-discharge samples collected from 25 mines from 1969 through 1990 (table 6). The mean concentration from one or more water samples at each mine ranged from less than the detection limit to 16 µg/L. The median concentration was less than

2 µg/L. (Only analyses with a detection limit of less than 2 µg/L were used to compute the median.) Sloto (1994) reported a median concentration of less than 1 µg/L for 255 ground-water samples from Chester County, Pa.

Calcium

Calcium concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1964 through 1990 (table 5). The mean concentration from one or more water samples at each mine ranged from 4 to 290 mg/L. The median concentration was 84 mg/L, and the mean was 93 mg/L. Barker (1984) reported median concentrations of calcium that ranged from 9.8 to 42 mg/L for seven regions of noncarbonate consolidated rocks in Pennsylvania, and Becher (1991) reported median concentrations of 20 and 2.7 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively. Thus, concentrations of calcium are elevated in water discharged from coal mines. Calcium is the most abundant cation in water from many of the mines. Most of the calcium concentrations are for samples collected in 1975, and calcium concentration has almost certainly decreased in some mines since then. (Sulfate, the most abundant anion, is known to have lower concentrations for many mines in 1991 compared to 1975, and cation-anion balance calculations show that calcium plus magnesium decreased substantially from 1975 to 1991.)

Cobalt

Cobalt concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1969 through 1990 (table 6). The mean concentration in one or more water samples at each mine ranged from less than 6 to 1,200 µg/L. The median concentration was 158 µg/L. Concentrations of cobalt in ground water outside of the mined areas generally are very low. For example, Sloto (1994) reported a median concentration of less than the maximum detection limit of 3 µg/L for 63 ground-water samples from Chester County, Pa. Newport and others (1971, p. 115) discussed the elevated cobalt concentrations in the Black Creek watershed and noted that cobalt is present as a sulfide in coals and may be dispersed in the aluminosilicate lattice. Dana and Ford (1955, p. 434) state that cobalt sometimes replaces part of the iron in pyrite.

Copper

Copper concentration was measured by various investigators in water-discharge samples collected from 27 mines from 1965 through 1990 (table 6). The mean concentration in one or more water samples at each mine ranged from less than 2 to 200 µg/L. The median concentration was 10 µg/L. (Only analyses with a detection limit of less than 3 µg/L were used to compute the median.) Barker (1984) reported median concentrations that ranged from 3.5 to 30 µg/L for nine regions of consolidated rocks in Pennsylvania.

Iron

In 1991, concentrations of iron in water-discharge samples from 82 mines ranged from 0.04 to 75 mg/L (table 1). The median concentration was 10 mg/L. Only 8 of the 82 discharges had concentrations of iron less than the USEPA's secondary maximum contaminant level of 0.3 mg/L. Because of its association with sulfur in FeS_2, concentrations of iron commonly are elevated in water discharged from coal mines.

Mean concentrations of iron for 1-, 2-, and, in a few cases, 3-year periods in water discharged from each of 85 mines are shown in table 10. Means were used, rather than medians, because only means were published for some data sets, and the original data have not been found. A comparison of the iron concentrations for the earliest period of data with the most recent period shows that concentrations of iron have decreased at 57 mines, are unchanged at 1 mine, and have increased at 24 mines. Data are inadequate to determine if change has occurred at three mines. For many of the mines that have increases in concentration with time, active mining is known to have taken place after the first set of samples was collected. The median change in iron concentration in discharge water for 82 mines was a decrease of 2.1 mg/L. Decreases of more than 100 mg/L occurred at sites 13, 18, 19, 20, and 93. The change in mean annual concentration of iron at

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania*

[mg/L, milligrams per liter; --, no data; <, less than; >, greater than; WY, water year; PaDEP, Pennsylvania Department of Environmental Protection; USEPA, U.S. Environmental Protection Agency; PDH, Pennsylvania Department of Health; PVT, private laboratory; SL, reports from Operation Scarlift; USGS, U.S. Geological Survey]

				Iron (Fe)		Sulfate (SO_4)		
Site number	Site name Site description	Latitude Longitude	Period (years)	Number of samples	Mean concentration (mg/L)	Number of samples	Mean concentration (mg/L)	Source of data
3	Klondike Mine	41°38′15″	1969-71	19	0.44	22	104	SL, USGS
	Vandling Drift[1]	75°27′35″	1975	1	<1	1	92	USGS
5	Coalbrook Mine	41°36′11″	1969-71	23	.49	22	253	SL, USGS
	Upper Wilson Creek	75°29′09″	1975	1	<1	1	190	USGS
	(Simpson) Drift		1991	1	.05	1	150	USGS
6	Coalbrook Mine	41°36′02″	1969-71	23	.27	23	236	SL, USGS
	Lower Wilson Creek	75°29′13″	1975	1	<1	1	150	USGS
	(Simpson) Shaft		1991	1	.09	1	140	USGS
7	Jermyn Mine	41°31′16″	1969	1	5.6	1	284	USGS
	Jermyn Slope	75°32′49″	1971-72	10	.73	10	194	SL
			1975	1	1.5	1	220	USGS
			1983-84	22	2.5	22	200	PaDEP
			1985-86	13	1.7	13	187	PaDEP
			1991	1	.32	1	190	USGS
9	Gravity Slope Mine	41°28′52″	1969	2	.71	2	288	USGS
	slope (Peckville Shaft)	75°33′48″	1971-73	15	.53	14	198	SL, USGS
			1975	1	.32	1	170	USGS
			1983-84	22	.97	22	165	PaDEP
			1985-86	13	1.0	14	147	PaDEP
			1991	1	.48	1	150	USGS
11	Lackawanna Mine	41°28′44″	1971-73	10	2.4	10	192	SL
	Jerome Shaft[2]	75°35′48″	1975	1	20	1	150	USGS
			1983-84	15	11	15	141	PaDEP
			1985-86	12	13	13	151	PaDEP
13	Old Forge Mine	41°21′36″	1962	6	290	6	3,560	PDH
	Old Forge borehole	75°45′04″	1963	23	226	23	2,640	PDH
			1964	30	146	29	1,790	PDH
			1965	32	135	30	1,720	PDH
			1966	31	115	29	1,280	PDH
			1969	2	93	2	1,255	USGS
			1971-72	12	43	11	866	SL, USGS
			1975	1	47	1	780	USGS
			1983-84	22	30	22	501	PaDEP
			1985-86	13	31	14	522	PaDEP
			1991	1	25	1	420	USGS
14	Seneca Mine	41°20′51″	1964	1	126	1	1,400	PDH
	Duryea breech	75°46′42″	1969	1	104	1	1,300	USGS
			1971-72	9	38	9	768	SL
			1975	1	48	1	700	USGS
			1983-84	22	37	22	452	PaDEP
			1985-86	14	37	14	495	PaDEP, USEPA
			1987	1	35	--	--	USEPA
			1989-91	3	29	1	310	USEPA, USGS

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

Site number	Site name Site description	Latitude Longitude	Period (years)	Iron (Fe) Number of samples	Iron (Fe) Mean concentration (mg/L)	Sulfate (SO_4) Number of samples	Sulfate (SO_4) Mean concentration (mg/L)	Source of data
16	Number 9 Mine	41°19′36″	1975	1	2.5	1	265	USGS
	Pittston (Butler)	75°47′25″	1987	1	3	--	--	USEPA
	Water Tunnel		1990-91	2	2.7	1	320	USGS, USEPA
17	Plainsville outlet[2]	41°17′03″	1975-76	17	80	16	1,086	SL, USGS
		75°51′20″	1983-84	17	62	17	635	PaDEP
			1985-86	12	59	13	620	PaDEP
18	South Wilkes-Barre Mine	41°13′50″	1972	3	392	--	--	PaDEP, USGS
	Solomon Creek boreholes	75°55′20″	1973	4	370	4	2,150	SL
			1974	8	304	8	1,716	SL
			1975-76	17	171	17	1,782	SL, USGS
			1983-84	22	103	22	988	PaDEP
			1985-86	14	94	14	921	PaDEP
			1991	1	[3].55	1	640	USGS
19	Nottingham-Buttonwood Mine	41°13′34″	1972	5	167	--	--	PaDEP, USGS
	Airshaft Number 22	76°56′13″	1973-74	11	159	11	1,375	SL
			1975-76	12	106	12	1,209	SL, USGS
			1983-84	22	77	22	863	PaDEP
			1985-86	15	69	14	859	PaDEP, USEPA
			1989-91	3	53	1	760	USEPA, USGS
20	Truesdale Mine	41°11′58″	1972	1	910	--	--	USGS
	Askam Shaft borehole[4]	75°57′52″	1973-74	8	213	8	1,900	SL
			1975-76	15	150	16	1,909	SL, USGS
			1983-84	1	76	14	1,002	PaDEP
			1985-86	14	67	14	974	PaDEP
21	Number 7 Mine	41°12′33″	1973-74	13	26	13	695	SL
	seepage	76°00′07″	1975	1	40	1	1,400	USGS
			1991	1	[3]1.0	1	420	USGS
22	Number 7 Mine	41°12′27″	1975	1	>100	1	2,800	USGS
	Susquehanna Number 2 Shaft	76°00′22″	1991	1	43	1	980	USGS
24	West End Mine	41°09′01″	1966 WY	36	143	36	1,210	USGS
	Mocanaqua Tunnel	76°08′40″	1967 WY	45	153	45	1,240	USGS
			1975	1	60	1	680	USGS
			1991	1	75	1	690	USGS
29	Sandy Run Mine	41°00′58″	1975	1	<1	1	130	USGS
	Sandy Run Tunnel	75°50′55″	1991	1	17	1	470	USGS
30	East Black Creek Mine	41°00′02″	1975	1	3	1	390	USGS
	Owl Hole Tunnel	75°49′11″	1986-87	21	2.0	19	280	PaDEP
			1988-89	24	1.7	19	280	PaDEP
			1990-91	15	1.3	15	280	PaDEP, USGS
			1992	3	1.5	3	308	PaDEP
34	Buck Mountain Mine	40°58′53″	1975	1	5.1	1	260	USGS
	Buck Mountain Tunnel	75°48′49″	1986-87	21	4.9	20	346	PaDEP
			1988-89	24	4.3	20	410	PaDEP
			1990-91	19	3.3	19	335	PaDEP, USGS
			1992	6	2.8	6	272	PaDEP

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

Site number	Site name Site description	Latitude Longitude	Period (years)	Iron (Fe) Number of samples	Iron (Fe) Mean concentration (mg/L)	Sulfate (SO_4) Number of samples	Sulfate (SO_4) Mean concentration (mg/L)	Source of data
37	Beaver Meadow Mine	40°55′09″	1969-70	10	3.7	10	359	SL
	Beaver Meadow Tunnel	75°54′07″	1973-74	22	2.3	22	237	SL
			1975	1	<1	1	100	USGS
			1979-80	238	.83	238	144	SL
			1991	1	1.2	1	220	USGS
38	Jeddo Mine	41°00′19″	1975	1	6	1	430	USGS
	Jeddo Tunnel	75°59′38″	1986-87	21	9.2	20	435	PaDEP
			1988-89	24	7.2	22	406	PaDEP
			1990-91	13	17	13	378	PaDEP, USGS
40	Tomhicken Mine	40°57′55″	1975	1	12	1	66	USGS
	strip pool overflow	76°05′30″	1991	1	.36	1	60	USGS
42	Stony Creek Mine	40°57′39″	1975	1	1	1	9	USGS
	Stony Creek and seepage	76°02′19″	1991	1	.28	1	7.2	USGS
45	Oneida Mine	40°55′32″	1975	1	1	1	69	USGS
	Oneida Tunnel 1	76°07′25″	1991	1	1.2	1	170	USGS
48	Green Mountain Mine	40°53′52″	1975	1	1	1	76	USGS
	Green Mountain Tunnel	76°04′03″	1991	1	.51	1	95	USGS
49	Audenreid Mine	40°53′52″	1969-70	10	4.8	10	504	SL
	Audenreid Tunnel	76°03′59″	1975	1	2	1	280	USGS
			1991	1	1.6	1	300	USGS
50	Oneida Mine	40°55′06″	1975	1	.22	1	53	USGS
	Oneida Tunnel 3	76°08′50″	1991	1	.10	1	74	USGS
52	Gowen Mine	40°56′54″	1975	1	2	1	110	USGS
	Gowen Tunnel	76°10′47″	1991	1	3.0	1	250	USGS
53	Derringer Mine	40°56′48″	1975	1	1	1	280	USGS
	Derringer Tunnel	76°10′43″	1991	1	.08	1	93	USGS
57	Vulcan-Buck Mountain Mine	40°48′55″	1973-74	12	11	12	229	SL
	Vulcan-Buck Mountain bore-holes	76°07′35″	1975-76	7	9	1	160	USGS
			1977-78	2	6.8	1	140	USGS
			1991	1	11	1	140	USGS
58	Gilberton Mine	40°48′01″	1973-74	9	59	9	862	SL
	Gilberton pump discharge	76°12′34″	1975	1	54	1	1,000	USGS
			1991	1	51	1	640	USGS
59	Weston Mine	40°48′30″	1975	1	20	1	1,200	USGS
	Weston Mine seepage	76°14′49″	1991	1	9.5	1	670	USGS
63	Girard Mine	40°47′30″	1973-74	12	24	12	[5] 457	SL
	seepage	76°16′06″	1975	1	20	1	460	USGS
			1991	1	19	1	230	USGS
64	Packer Number 5 Mine	40°47′41″	1973-74	12	32	12	1,235	SL
	breach and boreholes	76°16′48″	1975-76	8	32	1	1,300	USGS
			1977	2	28	--	--	USGS
			1991	1	23	1	700	USGS

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

				Iron (Fe)		Sulfate (SO_4)		
Site number	Site name Site description	Latitude Longitude	Period (years)	Number of samples	Mean concentration (mg/L)	Number of samples	Mean concentration (mg/L)	Source of data
64B	Packer Number 5 Mine	40°47′39″	1973-74	12	30	12	1,036	SL
	breach	76°16′28″	1975	1	40	1	1,300	USGS
			1991	1	21	1	760	USGS
66	Preston Mine	40°47′25″	1973-74	12	14	12	240	SL
	Tunnel	76°17′34″	1975	1	20	1	200	USGS
			1991	1	12	1	110	USGS
68	Centralia Mine	40°47′27″	1973-74	12	11	12	607	SL
	Tunnel	76°19′26″	1975	1	10	1	580	USGS
			1978	1	6.7	1	570	USGS
			1986-87	20	8.5	20	443	PaDEP
			1988-89	.24	10	22	475	PaDEP
			1990-91	25	8.6	22	468	PaDEP, USGS
			1992	8	9.6	8	439	PaDEP
70	Bast Mine	40°47′06″	1973-74	12	30	12	648	SL
	Oakland Tunnel	76°19′54″	1975	1	20	1	660	USGS
			1976	1	75	--	--	USGS
			1991	1	17	1	520	USGS
75	Locust Gap Mine	40°45′04″	1973-74	12	13	12	548	SL
	Helfenstein Tunnel	76°26′12″	1975	1	10	1	670	USGS
			1991	1	22	1	860	USGS
77	Locust Gap Mine	40°44′35″	1973-74	12	23	12	805	SL
	Doutyville Tunnel	76°28′38″	1975	1	12	1	700	USGS
			1991	1	15	1	620	USGS
80	Mid-Valley Mine	40°48′48″	1975	1	15	1	280	USGS
	Tunnel	76°24′24″	1991	1	19	1	190	USGS
84	Scott Ridge Mine	40°47′30″	1975	1	50	1	1,190	USGS
	breach	76°29′26″	1991	1	29	1	360	USGS
86	Colbert Mine	40°47′26″	1975	1	40	1	510	USGS
	breach	76°29′47″	1991	1	28	1	350	USGS
87	Excelsior Mine	40°46′25″	1975	1	44	1	400	USGS
	strip pool overflow	76°29′37″	1977-78	2	44	2	380	USGS
			1991	1	31	1	310	USGS
88	Maysville Mine	40°47′03″	1975	1	50	1	460	USGS
	Numbers 1 & 2	76°30′52″	1976	1	80	--	--	USGS
	borehole		1991	1	29	1	440	USGS
89	Corbin Mine	40°46′46″	1975	1	40	1	490	USGS
	Corbin Water-level Drift	76°30′53″	1991	1	43	1	410	USGS
91	Big Mountain Mine	40°46′19″	1975	1	20	1	300	USGS
	Number 1 Slope	76°32′19″	1991	1	30	1	360	USGS
92	Cameron Mine	40°47′44″	1975	1	60	1	790	USGS
	air shaft	76°33′59″	1991	1	66	1	700	USGS
93	Cameron Mine	40°47′37″	1975	1	150	1	1,100	USGS
	drift	76°33′55″	1991	1	20	1	870	USGS

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

Site number	Site name Site description	Latitude Longitude	Period (years)	Iron (Fe) Number of samples	Iron (Fe) Mean concentration (mg/L)	Sulfate (SO_4) Number of samples	Sulfate (SO_4) Mean concentration (mg/L)	Source of data
97	Henry Clay Sterling Mine	40°46′37″	1975	1	50	1	470	USGS
	pump slope	76°34′07″	1977	1	35	--	--	USGS
			1991	1	34	1	490	USGS
103	North Franklin Mine	40°46′17″	1973-74	12	38	12	535	SL
	drift and borehole	76°40′44″	1975	1	25	1	580	USGS
			1977	1	45	--	--	USGS
			1991	1	18	1	360	USGS
103A	North Franklin Mine	40°46′36″	1975	1	22	1	560	USGS
	site 103 plus seepage	76°40′58″	1991	1	17	1	410	USGS
104	Nesquehoning Mine	40°52′29″	1965	--	--	2	964	USGS
	Nesquehoning (Lausanne)	75°45′49″	1975	1	6.7	1	560	USGS
	Tunnel		1987-88	9	6.6	8	472	PVT
			1989-90	8	4.6	8	254	PVT
			1991-92	7	3.4	7	387	PVT, USGS
108	Greenwood Mine	40°49′09″	1972	2	58	2	1,725	SL
	Greenwood pump discharge	75°56′00″	1975	1	33	1	1,600	USGS
			1991	1	9.9	1	1,200	USGS
110	Silverbrook Mine	40°52′24″	1970-72	18	6.5	18	236	SL
	buried mine opening	76°00′17″	1975	1	10	1	110	USGS
			1989-90	6	7.7	6	109	PVT
			1991-92	9	12	9	111	USGS, PVT
			1993	4	9.7	4	98	PVT
114	Newkirk Mine	40°47′28″	1964-65	4	15	6	687	USGS
	Newkirk Tunnel north dip	75°59′09″	1970-72	18	10	18	446	SL
			1975	1	12	1	300	USGS
			1991	1	5.2	1	240	USGS
118	Reevesdale Mine	40°47′05″	1965	--	--	2	208	USGS
	South Dip Tunnel	76°00′32″	1970-72	18	1.9	18	144	SL
			1975	1	2	1	120	USGS
			1991	1	.9	1	89	USGS
119	Mary D Mine	40°46′12″	1965	--	--	2	326	USGS
	strip pool overflow	76°01′56″	1975	1	4	1	120	USGS
			1991	1	.07	1	32	USGS
121	Bell Mine	40°45′12″	1965	--	--	2	254	USGS
	Bell Water-level Tunnel	76°02′55″	1975	1	2	1	140	USGS
			1990	1	4.1	1	87	PaDEP
			1991	1	12	1	120	USGS
122	Tuscarora	40°45′31″	1975	1	10	1	160	USGS
	Tuscarora sinkhole	76°02′57″	1991	1	14	1	310	USGS
132	Brockton Mine	40°45′38″	1965	--	--	1	188	USGS
	strip pool overflow	76°06′37″	1975	1	<1	1	8	USGS
			1991	1	.54	1	28	USGS

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

Site number	Site name Site description	Latitude Longitude	Period (years)	Iron (Fe) Number of samples	Iron (Fe) Mean concentration (mg/L)	Sulfate (SO_4) Number of samples	Sulfate (SO_4) Mean concentration (mg/L)	Source of data
149	Silver Creek Mine	40°44′03″	1965	--	--	2	491	USGS
	Tunnel	76°07′24″	1975	1	20	1	270	USGS
			1991	1	27	1	300	USGS
157	Eagle Hill Mine	40°42′58″	1965	2	16	4	718	USGS
	water-level drift	76°09′01″	1975	1	5.8	1	430	USGS
			1983	2	13	2	495	PVT
			1985	1	18	1	550	PaDEP
			1987-88	19	16	19	626	PVT, PaDEP
			1989-90	15	13	15	588	PVT, PaDEP
			1991-92	8	14	8	563	PVT, PaDEP, USGS
160	Port Carbon Mine	40°42′17″	1965	--	--	2	350	USGS
	Lucianna Water-level Tunnel	76°08′22″	1975	1	30	1	430	USGS
			1991	1	2.3	1	89	USGS
161	Reynolds Mine	40°41′43″	1975	1	15	1	120	USGS
	slope	76°09′10″	1991	1	17	1	180	USGS
162	Morea Mine	40°46′57″	1965	--	--	1	316	USGS
	strip pool overflow	76°10′55″	1975	1	10	1	140	USGS
			1991	1	9.7	1	110	USGS
163	Repplier Mine	40°44′25″	1975	1	<1	1	28	USGS
	Pool Tunnel	76°11′52″	1991	1	.04	1	27	USGS
166	Repplier Mine	40°44′06″	1965	3	18	6	693	USGS
	Repplier Water-level Tunnel	76°12′02″	1975	1	8	1	310	USGS
			1991	1	17	1	280	USGS
167	Pine Forest Mine	40°43′20″	[6]1964-65	1	6.7	1	1,130	USGS
	pump discharge	76°10′32″	[6]1975	1	4.5	1	780	USGS
			1991	1	.21	1	520	USGS
171	Wadesville Mine	40°42′51″	1965	--	--	2	518	USGS
	pump discharge	76°12′21″	1975	1	1.0	1	630	USGS
			1991	1	2.0	1	350	USGS
187	Pine Knot Mine	40°42′24″	1964-65	5	9.7	8	573	USGS
	Pine Knot drainage tunnel	76°15′06″	1975	1	8.5	1	370	USGS
			1991	1	10	1	300	USGS
188	Oak Hill Mine	40°42′12″	1965	--	--	2	1,190	USGS
	shaft, 6 boreholes, seepage	76°15′16″	1975	1	45	1	650	USGS
			1991	1	23	1	650	USGS
190	Otto Mine	40°39′58″	1965-66	--	--	3	577	USGS
	Otto Airshaft	76°19′14″	1975	1	26	1	430	USGS
			1991	1	15	1	300	USGS
202	Blackwood Mine	40°38′23″	1975	1	1.1	1	170	USGS
	Blackwood Water-level Tunnel	76°19′36″	1985-86	18	1.8	18	119	Skelly & Loy, 1987
			1991	1	.34	1	120	USGS
215	Middle Creek Mine	40°38′20″	1975	1	.28	1	180	USGS
	strip pool overflow	76°22′45″	1991	1	4.7	1	150	USGS

Table 10. *Mean iron and sulfate concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania--Continued*

Site number	Site name Site description	Latitude Longitude	Period (years)	Iron (Fe) Number of samples	Iron (Fe) Mean concentration (mg/L)	Sulfate (SO_4) Number of samples	Sulfate (SO_4) Mean concentration (mg/L)	Source of data
218	Eureka Mine	40°38′41″	1975	1	3	1	170	USGS
	drift	76°24′30″	1991	1	.88	1	29	USGS
238	Rausch Creek/Franklin Mine	40°36′40″	1970-71	--	28	--	281	SL
	Lower Paoli Tunnel	76°25′30″	1975	1	35	1	310	USGS
			1985-86	--	16	--	248	Skelly & Loy, 1987
			1991	1	9.6	1	460	USGS
244	Lincoln Mine	40°35′42″	1970-71	--	17	--	118	SL
	Rowe Drainage Tunnel	76°26′32″	1975	1	10	1	130	USGS
			1985-86	53	11	--	113	SL
			1991	1	9.9	1	110	USGS
253	Erdman Coal Company	40°37′13″	1975	1	<50	1	880	USGS
	pump discharge	76°31′26″	1991	1	17	1	150	USGS
258	Valley View Mine	40°36′50″	1975	1	22.5	1	110	USGS
	Valley View Tunnel	76°33′07″	1991	1	16	1	100	USGS
259	Markson Mine	40°37′09″	1975	1	32	1	410	USGS
	Markson Columnway	76°33′02″	1981-82	70	41	70	337	PaDEP
			1983-84	97	26	97	294	PaDEP
			1985-86	86	28	86	270	PaDEP
			1991	1	39	1	540	USGS
266	Lykens-Williamstown Mine	40°34′59″	1970-71	12	1.6	12	80	SL
	Big Lick Tunnel [7]	76°39′03″	1975	1	15	1	160	USGS
267	Lykens-Williamstown Mine	40°35′07″	1970-71	11	15	12	175	SL
	Lykens Water-level Drift	76°41′58″	1975	1	15	1	110	USGS
			1991	1	17	1	120	USGS
269	Lykens-Williamstown Mine	40°34′51″	1970-71	12	10	12	194	SL
	airshaft and pump station	76°41′59″	1975	1	30	1	200	USGS
			1991	1	18	1	110	USGS
270	Lykens-Williamstown Mine	40°34′48″	1970-71	12	18	12	174	SL
	seepage	76°42′00″	1975	1	20	1	210	USGS
			1991	1	20	1	110	USGS

[1]Not flowing October 28, 1991.
[2]Not flowing October 30, 1991.
[3]Low value may be due to laboratory error.
[4]Not flowing October 31, 1991.
[5]Discharge weighted mean for two largest seeps.
[6]Pumping.
[7]Not flowing October 29, 1991.

the Old Forge borehole[2] (site 13) from 1962 to 1991 is shown in figure 12. This figure shows the substantial decrease in iron concentration that has taken place since the mine workings were flooded. Flattening of the curve indicates that further decreases in concentration will occur slowly. Similar curves can be plotted for some sites from the data in table 10, but no other site has as many analyses over as long a period of time.

Lead

Lead concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1965 through 1990 (table 6). The mean concentration from one or more samples at each mine ranged from less than 3 to 26 µg/L. The median concentration was less than 6 µg/L. (Only analyses with a detection limit of less that 12 µg/L were used to compute the mean.) The median concentration of lead in water samples from mines in the Northern Anthracite Field is 12 µg/L. Barker (1984) reported median concentrations that ranged from 2 to 5 µg/L for nine regions of consolidated rocks in Pennsylvania. Sloto (1994) reported a median concentration of 1 µg/L for 256 ground-water samples from Chester County, Pa.

Lithium

Lithium concentration was measured by various investigators in water-discharge samples collected from 26 mines from 1965 through 1975 (table 6). The mean concentration from one or more samples at each mine ranged from 14 to 180 µg/L. The median concentration was 40 µg/L. Sloto (1994) reported a median concentration of lithium of less than 10 µg/L for 90 ground-water samples from Chester County, Pa.

[2]Rhodes and Davis (1968) noted that, "In January 1961, the pools of water developing in the abandoned underground workings broke through to the surface in a gravity discharge to the Lackawanna River at Duryea, approximately two miles from its mouth. This was the largest discharge in the Anthracite Field and has been since separated into two parts; the "Duryea Gravity Discharge" [site 14] and the discharge from a borehole at Old Forge. The borehole was drilled [in 1962] one mile upstream from Duryea to stabilize the level of the underground pools."

Magnesium

Magnesium concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1964 through 1990 (table 5). The mean concentration from one or more samples at each mine ranged from 5.2 to 180 mg/L. The median concentration was 64 mg/L, and the mean was 64 mg/L. Barker (1984) reported median concentrations that ranged from 1.3 to 18 mg/L for nine regions of consolidated rocks in Pennsylvania, and Becher (1991) reported medians of 7.2 and 1.7 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively. Thus, magnesium concentration is elevated in water discharged from coal mines. Most of the magnesium concentrations are for samples collected in 1975, and, as with calcium, magnesium concentration has almost certainly decreased for some discharges.

Manganese

In 1991, concentrations of manganese in water-discharge samples from 81 mines ranged from 0.02 to 15 mg/L. The median concentration was 3.2 mg/L. Manganese concentration is elevated in water discharged from nearly all coal mines. Water samples from only 2 of the 81 mines had manganese concentrations less that the USEPA's secondary maximum contaminant level of 0.05 mg/L. Manganese concentration in water discharged from most mines has decreased with time. Comparison of manganese concentrations for water samples collected in 1964-69 with samples collected in 1970-75 at 10 mines (table 11) shows that concentrations at 8 of the mines decreased. Manganese concentrations decreased at 23 of 27 mines between 1970-75 and 1991.

Nickel

Nickel concentration was measured by various investigators in water-discharge samples collected from 27 mines from 1965 through 1990 (table 6). The mean concentration from one or more samples at each mine ranged from 15 to 2,200 µg/L. The median concentration was 240 µg/L. Sloto (1994) reported a

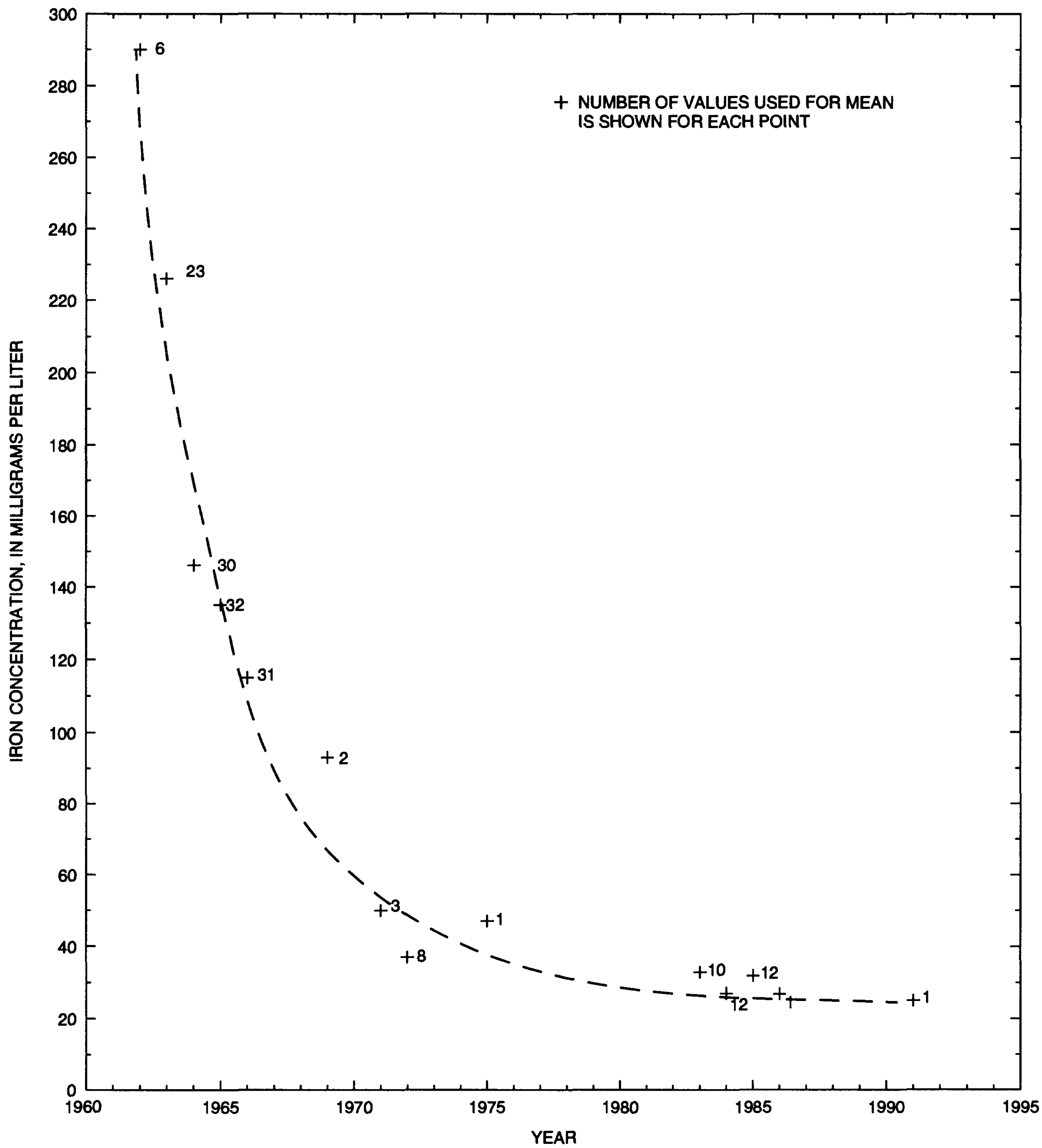


Figure 12. Annual mean iron concentration in water discharged from the Old Forge borehole (site 13), Northern Anthracite Field, northeast Pennsylvania, 1962-91.

Table 11. *Manganese concentrations in discharge water for selected periods from mines in the anthracite fields of Pennsylvania*

Site number	Concentrations of manganese in milligrams per liter for indicated period in years		
	1964-69	1970-75	1991
5	0.6	0.17	0.14
6	[1].58	--	.05
7	3.3	--	.76
9	2.2	[1]2.0	.87
13	[1]8.5	[1]6.8	3.2
14	5.0	7.3	3.7
18	--	[1]24	5.2
19	--	[1]20	6.6
24	[1]22	12	9.7
34	--	4.9	8.5
37	4.2	4.9	2.7
38	--	[1]3.4	8.4
40	--	1.5	1.1
49	--	6.7	3.8
50	--	.57	.73
58	--	16	9.4
77	--	6.4	4.5
87	--	5.4	3.6
103	--	7.0	3.0
104	--	4.7	3.4
108	--	11	6.1
114	[1]8.6	4.3	2.9
157	[1]4.7	4.0	.45
166	1.2	--	4.3
167	32	10	1.9
171	--	2.3	3.2
187	[1]9.1	4.6	4.2
190	--	4.4	3.0
202	--	1.6	1.2
215	--	2.4	.35

[1]Mean of two or more values.

median concentration of 3 µg/L for 227 ground-water samples from Chester County, Pa. Newport and others (1971, p. 115) discussed the elevated nickel concentrations for the mines in the Black Creek watershed and noted that nickel is present as a sulfide in coals and may be dispersed in the aluminosilicate lattice. Dana and Ford (1955, p. 434) state that nickel sometimes substitutes for part of the iron in pyrite.

Potassium

Potassium concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1964 through 1990 (table 5). The mean concentration from one or more samples at each mine ranged from 0.2 to 3.6 mg/L. The median concentration was 1.5 mg/L, and the mean was 1.6 mg/L. Barker (1984) reported median concentrations that ranged from 1 to 7.6 mg/L for nine regions of consolidated rocks in Pennsylvania, and Becher (1991) reported medians of 0.7 and 0.4 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively.

Sodium

Sodium concentration was measured by various investigators in water-discharge samples collected from 29 mines from 1964 through 1990 (table 5). The mean concentration from one or more samples at each mine ranged from 1.0 to 82 mg/L. The median concentration was 6.2 mg/L, and the mean was 12 mg/L. Barker (1984) reported median concentrations that ranged from 3.4 to 13 mg/L for nine regions of consolidated rocks in Pennsylvania, and Becher (1991) reported medians of 4 and 0.7 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively.

The median concentration of sodium was 13 mg/L in water samples from mines in the Northern Anthracite Field and 4.2 mg/L for mines from the other three anthracite fields. The elevated concentration of sodium for the Northern Anthracite Field may be because of more extensive use of sodium chloride to deice highways in the more urbanized Northern Field. Sludges from mine drainage treatment plants that used NaOH to neutralize acid were dumped into some abandoned mines. Leaching from these sludges may have elevated sodium concentrations in a few mines including site number 104 (Roger Hornberger, Pennsylvania Department of Environmental Protection, oral commun., 1992).

Strontium

Strontium concentration was measured by various investigators in water-discharge samples collected from 27 mines from 1965 through 1975 (table 6). The mean concentration from one or more samples at each mine ranged from 31 to 8,100 μg/L. The median concentration was 500 μg/L. The median concentration for 196 analyses of ground water in the Delaware and Susquehanna River Basins was 230 μg/L (Koester and Miller, 1982a; 1982b).

Zinc

Zinc concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1965 through 1990 (table 6). The mean concentration from one or more samples at each mine ranged from below the detection limit to 8,800 μg/L. The median concentration was 310 μg/L. Barker (1984) reported median concentrations that ranged from 20 to 55 μg/L for nine regions of consolidated rocks in Pennsylvania. Newport and others (1971, p. 112 and 116) reported elevated concentrations of zinc in mines in the Black Creek Basin.

Anions

Sulfate is the most abundant anion in water discharged from most coal mines. Bicarbonate concentrations are significant for some mines and actually exceed concentrations of sulfate in water discharged from a few coal mines. Chloride, fluoride, and nitrate generally are present at very low concentrations.

Alkalinity

In 1991, alkalinity (as $CaCO_3$) for water discharged from 81 mines ranged from 0 to 435 mg/L. Alkalinity is anthracite-field dependant—medians were 80, 0, 43, and 27 mg/L for the Northern, Eastern Middle, Western Middle, and Southern Anthracite Fields, respectively. In the Northern Anthracite Field, 7 of 8 mines had measurable alkalinity in 1991; in the Eastern Middle Field only 3 of 12 mines had measurable alkalinity (0.2 and 2.6 mg/L) in 1991.

Alkalinity generally has increased from 1975 to 1991. No change took place in the discharge water at 22 mines (alkalinity was 0 mg/L in both 1975 and 1991), alkalinity increased at 43 mines, and alkalinity decreased at 14 mines.

Chloride

Chloride concentration was measured by various investigators in water-discharge samples collected from 28 mines from 1964 through 1975 (table 5). The mean concentration from one or more samples at each mine ranged from 0 to 27 mg/L. The median concentration was 3.9 mg/L. Barker (1984) reported median concentrations that ranged from 3 to 12 mg/L for nine regions of consolidated rocks in Pennsylvania, and Becher (1991) reported medians of 4 and 1.8 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively. The median concentration of chloride measured in water discharged from mines in the Northern Anthracite Field is 6.2 mg/L; for the other three fields combined, the median is only 2.1 mg/L. The elevated concentration of chloride for the Northern Anthracite Field compared to water discharged from mines in the other coal fields might be because of more extensive use of sodium chloride to deice highways in the more urbanized Northern Field.

Fluoride

Fluoride concentration was measured by various investigators in water-discharge samples collected from 26 mines from 1964 through 1975 (table 5). The mean concentration from one or more samples at each mine ranged from less than the detection limit to 0.4 mg/L. The median concentration was 0.2 mg/L. The median concentration for 1,339 analyses of ground water in the Susquehanna River Basin (Koester and Miller, 1982a) was 0.1 mg/L, and Becher (1991) reported medians of 0.1 and 0.05 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively.

Nitrogen

Nitrogen concentration was measured by various investigators in water discharge samples collected from 28 mines from 1969 through 1975 (table 5). The mean concentration from one or more samples at each mine ranged from less than 0.01 to 0.61 mg/L. The median concentration was 0.07 mg/L, and water from only one mine had a nitrate concentration above 0.3 mg/L. Barker (1984) reported median concentrations that ranged from 0.09 to 4 mg/L for nine regions of consolidated rocks in Pennsylvania, and Becher (1991) reported medians of 0.6 and 0.09 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively. Concentrations of nitrite generally are less than 0.01 mg/L. Some of the nitrate and nitrite in the mines may have been reduced to ammonium. However, few, if any, analyses are available for ammonium.

Sulfate

In 1991, concentrations of sulfate in water-discharge samples from 81 mines ranged from 7.2 to 1,200 mg/L. The median concentration was 300 mg/L. Sulfate has long been known as a principal constituent in water discharged from coal mines. Barker (1984) reported that none of the consolidated rocks in Pennsylvania that lie outside of the coal regions had median sulfate concentrations greater than 30 mg/L. Becher (1991) reported median concentrations of 6.3 and 6.0 mg/L for water from wells in the Llewellyn and Pottsville Formations, respectively.

Mean concentrations of sulfate for 1-, 2-, and, in a few cases, 3-year periods for water discharged from each of 85 mines are given in table 10. Means were used, rather than medians, because only means were published for some data sets, and the original data have not been found. A comparison of sulfate concentrations for the earliest period of data with the most recent shows that sulfate concentrations have decreased at 62 mines and increased at 15 mines. For many of the mines with increases in concentration as a function of time, active mining has taken place after the first set of samples was collected. The median change in sulfate concentration for 77 mines was a decrease of 139 mg/L. Decreases of more than 700 mg/L occurred at sites 13, 14, 18, 20, 22, 84, and 253. The change in mean annual concentration of sulfate at the Old Forge borehole (site 13) from 1962 to 1991 is shown in figure13. This figure shows the substantial decrease in sulfate concentration that has taken place since the mine workings were flooded in 1960. Flattening of the curve indicates that further decreases in concentration will occur more slowly than in the first 20 years (1960-79) since the mine workings were flooded.

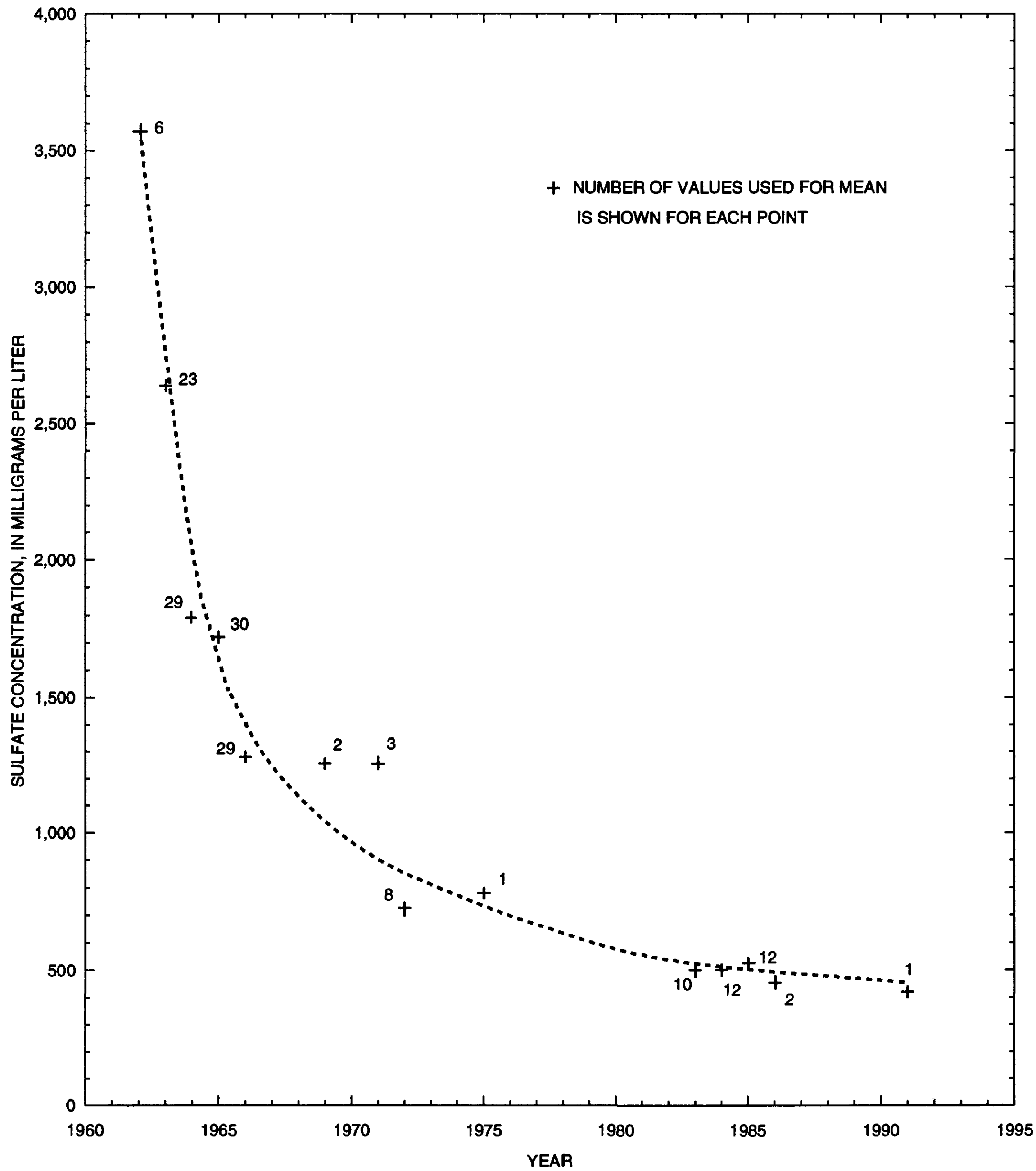


Figure 13. Annual mean sulfate concentration in water discharged from the Old Forge borehole (site 13), Northern Anthracite Field, northeast Pennsylvania, 1962-91.

SUMMARY

This study was undertaken to (1) provide long-term records of discharge and water quality at anthracite mines that discharged 1.0 cubic feet per second or more when water-quality samples were collected in 1975, (2) assemble and publish the water-quality data collected by the USGS and USEPA, (3) summarize iron and sulfate data collected by or for all State and Federal agencies, (4) characterize the quality of water discharged from the mines, and (5) analyze any changes in water quality over time. Concentrations of aluminum, calcium, cobalt, iron, lithium, magnesium, manganese, nickel, strontium, zinc, and sulfate are higher in water discharged from many coal mines in the anthracite region of Pennsylvania than in other Pennsylvania ground waters.

Water quality has been improving in water discharged from most mines in the anthracite region that have undergone active mining. For water discharged from 81 mines that had field pH measurements in 1975 and 1991, 64 had an increase in pH. The median increase was 0.4 units. However, acidity showed very little change from 1975 to 1991. Iron concentration has decreased in water discharged from 57 mines, is unchanged at 1 mine, and has increased at 24 mines. Data are inadequate to determine if a change has occurred at three mines. For many of the mines with increases in iron concentration with time, active mining took place after the first set of samples was collected. The median change in iron concentration for 82 mines was a decrease of 2.1 mg/L. Comparison of manganese concentrations for samples collected during 1970-75 to samples collected in 1991 show that concentrations had decreased at 23 of 26 mines.

In 1991, median alkalinity (as $CaCO_3$) in water discharged from mines was 80, 0, 43, and 27 mg/L for the Northern, Eastern Middle, Western Middle, and Southern Anthracite Fields, respectively. Alkalinity generally has increased from 1975 to 1991. No change occurred at 22 mines, alkalinity was higher at 43 mines, and alkalinity was lower at 14 mines. A comparison of the earliest period of data to the latest period shows that sulfate concentration in discharge water has decreased at 62 mines and has increased at 15 mines. The median decrease in sulfate concentration for 77 mines was 139 mg/L. In 1975, the discharge samples were collected during high base flow in the spring; in 1991, discharge samples were collected during lower-than-normal base flow in the fall; this may have affected the comparisons.

SELECTED REFERENCES

A.W. Martin Associates, Inc., 1973, Little Schuylkill mine drainage pollution abatement project: King of Prussia, Pa., Operation Scarlift project SL 167, 89 p.

Albert E. Peters Associates, 1971, Lackawanna River mine drainage pollution abatement project, part I: Scranton, Pa., Operation Scarlift project SL 139-1, 37 p.

_____1978, Lackawanna River mine drainage pollution abatement project, part II: Scranton, Pa., Operation Scarlift project SL 139-1, 207 p.

Anthracite Research and Development Co., Inc., 1972, Swatara Creek mine drainage pollution abatement project, part 3: Operation Scarlift project SL 126-3.

Ash, S.H., Dierks, H.A., Felegy, E.W., Huston, K.M., Kennedy, D.O., Miller, P.S., and Rosella, J.J., 1955, Corrosive and erosive effects of acid mine waters on metals and alloys for mine pumping equipment and drainage facilities: U.S. Bureau of Mines Bulletin 555, 46 p.

Ash, S.H., Eaton, W.L., Hughes, Karl, Romischer, W.M., and Westfield, James, 1949, Water pools in Pennsylvania anthracite mines: U.S. Bureau of Mines Technical Paper 727, 78 p.

Ash, S.H., Felegy, E.W., Kennedy, D.O., and Miller, P.S., 1951, Acid-mine drainage problems, anthracite region of Pennsylvania: U.S. Bureau of Mines Bulletin 508, 72 p.

Barker, J.L., 1984, Compilation of ground-water quality data in Pennsylvania: U.S Geological Survey Open-File Report 84-706, 102 p.

Barnes, Ivan, and Clarke, F.E., 1964, Geochemistry of ground water in mine drainage problems: U.S. Geological Survey Professional Paper 473-A, p. A1-A6.

Barnes, Ivan, Stuart, W.T., and Fisher, D.W., 1964, Field investigation of mine waters in the Northern Anthracite Field, Pennsylvania: U.S. Geological Survey Professional Paper 473-B, 8 p.

Becher, A.E., 1991, Groundwater resources in and near the anthracite basins of Schuylkill and adjacent counties, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resource Report 64, 59 p.

Berger Associates, Inc., 1972, Swatara Creek mine drainage pollution abatement project, part 2: Harrisburg, Pa., Operation Scarlift project SL 126-2, 166 p.

Biesecker, J.E., and George, J.R., 1966, Stream quality in Appalachia as related to coal-mine drainage, 1965: U.S. Geological Survey Circular 526, 27 p.

Biesecker, J.E., Lescinsky, J.B., and Wood, C.R., 1968, Water resources of the Schuylkill River Basin: Pennsylvania Department of Forests and Waters, Water Resources Bulletin 3, 198 p.

Braley, S.A., 1954, Summary report: Mellon Institute Industrial Research, Pennsylvania Department of Health, Fellowships 1-7, 279 p.

Cline, J.T., and Balla, Ruth, 1975, Water quality relationships as a function of acid mine drainage and sewage inputs into the Susquehanna River: Wilkes-Barre, Pa., Wilkes College, Publications in Environmental Sciences, Publication no. 2, 21 p.

Cravotta, C.A. III, 1991, Geochemical evolution of acidic ground water at a reclaimed surface coal mine in western Pennsylvania: Princeton, W. Va., Proceedings of the 1991 National Meeting of the American Society of Surface Mining and Reclamation (ASSMR), ASSMR, p. 43-68.

Dana, E.S., and Ford, W.E., 1955, A textbook of mineralogy (4th ed.): New York, John Wiley and Sons, Inc., 851 p.

El-Ashry, M.T., and Mattei, C.M., 1974, Acid mine drainage and water quality of the Susquehanna River - N.E. Pennsylvania: Wilkes-Barre, Pa., Wilkes College, Publications in Environmental Sciences, Publication no. 1.

Federal Water Pollution Control Administration, 1967, Susquehanna River Basin from Northumberland to West Pittston: CB-SRBP Working Document No. 8, FWPCA - Middle Atlantic Region.

Felegy, E.W., Johnson, L.H., and Westfield, James, 1948, Acid mine water in the anthracite region of Pennsylvania: U.S. Bureau of Mines Technical Paper 710, 49 p.

Gannett, Fleming, Corddry, and Carpenter, Inc., 1967, Lackawanna Valley mine drainage pollution abatement project: Pennsylvania Department of Health, Division of Sanitary Engineering, Publication no. 19, 47 p.

_____1972a, Mine drainage abatement measures for the Shamokin Creek watershed: Harrisburg, Pa., Operation Scarlift project SL-113.

_____1972b, Swatara Creek mine drainage abatement project, part 1: Harrisburg, Pa., Operation Scarlift project SL-126-1.

_____1974, Mine drainage abatement measures for the Jeansville Basin, Luzerne, Schuylkill, and Carbon Counties: Harrisburg, Pa., Operation Scarlift project SL 135, 65 p.

GEO-Technical Services, Inc., 1975, Mine drainage abatement study, Naticoke, Warrior & Solomon Creeks, Hanover & Wilkes-Barre Townships, Luzerne County, Pennsylvania: Harrisburg, Pa., Operation Scarlift project SL 181-3, 90 p.

_____1976, Mine drainage pollution abatement study, Mill Creek watershed, Plains, Jenkins & Wilkes-Barre Townships, Luzerne County, Pennsylvania: Harrisburg, Pa., Operation Scarlift project SL 181-4, 113 p.

_____1982, Quakake Tunnel demonstration project, limestone neutralization of acid mine drainage, Carbon County, Pennsylvania: Harrisburg, Pa., Operation Scarlift project SL 135-10, 106 p.

Growitz, D.J., Reed, L.A., and Beard, M.M., 1985, Reconnaissance of mine drainage in the coal fields of eastern Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 83-4274, 54 p.

Hollowell, J.R., 1974, Hydrology of the abandoned coal mines in the Wyoming Valley, Pennsylvania: U.S. Geological Survey Open-File Report 74-237, 47 p.

Hollowell, J.R., and Koester, H.E., 1975, Ground-water resources of Lackawanna County, Pennsylvania: Pennsylvania Geological Survey, 4th ser., Water Resources Report 41, 106 p.

Koester, H.E., and Miller, D.R., 1982a, Ground-water quality and data on wells and springs in Pennsylvania, volume II -- Susquehanna and Potomac River Basins: U.S. Geological Survey Open-File Report 81-329, 131 p.

_____1982b, Ground-water quality and data on wells and springs in Pennsylvania, volume III -- Delaware River Basin: U.S. Geological Survey Open-File Report 81-330, 111 p.

Newport, T.G., Koester, H.E., and Bergin, M.J., 1971, Geology, hydrology and geochemistry of the Black Creek watershed near Mocanaqua, Luzerne County, Pennsylvania: U.S. Geological Survey Open-File Report, 195 p.

Ott, A.N., 1986, Estimating iron and aluminum content of acid mine discharge from a north-central Pennsylvania coal field by use of acidity titration curves: U.S. Geological Survey Water-Resources Investigations Report 84-4335, 25 p.

Paulachok, G.N., 1984, Temperature of ground water at Philadelphia, Pennsylvania, 1979-1981: U.S. Geological Survey Water-Resources Investigations Report 84-4189, 14 p.

Reed, L.A., Beard, M.M., and Growitz, D.W., 1987, Quality of water in mines in the Western Middle coal field, anthracite region, east-central Pennsylvania: U.S. Geological Survey Water-Resources Investigations Report 85-4038, 51 p.

Rhodes, R.L., and David, R.S., 1968, Mine drainage in the Susquehanna River Basin: Federal Water Pollution Control Administration, 127 p.

Sanders & Thomas, Inc., 1973, Wiconisco Creek mine drainage pollution abatement project: Pottstown, Pa., Operation Scarlift project SL 170, 79 p.

_____1975, Mahoney Creek mine drainage pollution abatement project: Pottstown, Pa., Operation Scarlift project SL 197, 125 p.

Skelly and Loy, 1974, Newport Creek mine drainage pollution abatement project: Harrisburg, Pa., Operation Scarlift project SL 181-2, 105 p.

_____1987, A watershed pollution study of the Swatara Creek: Harrisburg, Pa.

Sloto, R.A., 1994, Geology, hydrology, and ground-water quality of Chester County, Pennsylvania: Chester County Water Resources Authority Water-Resource Report 2, 127 p.

Susquehanna River Basin Commission, 1973, Coal mine drainage in the Susquehanna River Basin: Harrisburg, Pa., prepared by Skelly and Loy Engineers-Consultants, 297 p.

Wood, G.H., Jr., Trexler, J.P., and Kehn, T.M., 1969, Geology of the west-central part of the Southern Anthracite Field and adjoining areas, Pennsylvania: U.S. Geological Survey Professional Paper 602, 150 p.