EFFECTS OF ABANDONED LEAD AND ZINC MINES AND TAILINGS PILES ON WATER QUALITY IN THE JOPLIN AREA, MISSOURI

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 77-75

Prepared in cooperation with
the Ozark Gateway Council of Governments

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No.

4. Title and Subtitle

EFFECTS OF ABANDONED LEAD AND ZINC MINES AND TAILINGS PILES ON WATER QUALITY IN THE JOPLIN AREA, MISSOURI

5. Report Date

August 1977

6.

7. Author(s)

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8. Performing Organization Rept. No. USGS/WRI-77-75

9. Performing Organization Name and Address

U.S. Geological Survey, Water Resources Division
1400 Independence Road Mail Stop 200
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10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

U.S. Geological Survey, Water Resources Division
1400 Independence Road Mail Stop 200
Rolla, Missouri 65401

13. Type of Report & Period Covered

Final

14.

15. Supplementary Notes

Prepared in cooperation with the Ozark Gateway Council of Governments.

16. Abstracts

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17. Key Words and Document Analysis. 17a. Descriptors

*Mine drainage, *Mine wastes, *Acid mine water, Mine water, Mines, Metals, Heavy metals, Lead, Zinc, Water pollution, Water quality.

17b. Identifiers/Open-Ended Terms

Tri-State District

17c. COSATI Field/Group

18. Availability Statement

No restriction on distribution

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 49

22. Price

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Effects of Abandoned Lead and Zinc Mines and Tailings Piles on Water Quality in the Joplin Area, Missouri

By James H. Barks

ABSTRACT

Dissolved zinc concentrations averaged 9,400 µg/L (micrograms per liter) in water from abandoned lead and zinc mines, some of which discharge at the surface. Contamination of the shallow aquifer (cherty limestones) by the highly mineralized mine water is limited to the immediate mining area. The quality of water in the deep aquifer (cherty dolomites and sandstone) is generally excellent.

Dissolved zinc concentrations averaged 16,000 µg/L in runoff from tailings areas. However, during a summer storm, runoff from a 7-acre tailings area contained maximum dissolved zinc, lead, and cadmium concentrations of 200,000; 400; and 1,400 µg/L, respectively.

Mine-water discharges increase dissolved zinc concentrations in receiving streams from a background of about 40 µg/L to about 500 µg/L during periods of low flow. The higher concentrations are sustained during high flow by runoff from the tailings areas. Deposition of tailings on stream bottoms increases zinc concentrations in bottom material from a background of about 100 µg/g (micrograms per gram) to about 2,500 µg/g and increases lead concentrations in bottom material from about 20 µg/g to about 450 µg/g.

INTRODUCTION

Commercial development of the mineral resources of southwestern Missouri began about 1850 and spread into southeastern Kansas and northeastern Oklahoma, forming the Tri-State District with Joplin as the urban center. The value of the Tri-State mineral production from 1850 to 1950 exceeded one billion dollars, and until 1945 the region was the world's leading producer of lead and zinc concentrates, accounting for one-half of the zinc and one-tenth of the lead produced in the United States (Gibson, 1972). By 1950 most of the rich ores had been extracted, and mining and milling operations declined during the 1950's and ceased in the 1960's.

Throughout the mining era ground water remained a problem to the district. The natural level of the water table was usually higher than the mines and flooding of the mines was controlled only by constant pumping. When pumpage declined in the 1950's and 1960's the mine drifts and shafts filled with water.

The mining involved bringing the crude ores to the surface where they were milled into lead and zinc concentrates. Barren rock was discarded in piles while the ore-bearing rock was crushed and ground into a fine gravel. The minerals were separated from the rock by a jigging process and the tailings were skimmed off and discarded in large piles.

In 1976 the U.S. Geological Survey made a study of the effects of the abandoned and flooded mines and tailings piles on water quality in the southwestern Missouri part of the Tri-State District (fig. 1). The study area covers approximately the southwestern quarter of Jasper County, an area of about 280 mi^2 (square miles), and is bounded by long 94°15' W. and the Missouri-Kansas state line, and lat 37°15' N. and the Jasper-Newton County line. Although some mining was done in Newton County, most was done in Jasper County within a few miles of Joplin.

In conjunction with the mine-related study, flow characteristics were determined for streams in the Joplin area of southwestern Missouri (Skelton, 1977). The report by Skelton is an update and revision of flow-frequency and flow-duration data from a previous report by Feder and others (1969).

For the convenience of readers who may want to use metric units, English units may be converted to metric units using the following conversion factors:

English	Multiply by	Metric
acres	0.004047	square kilometers (km^2)
cubic feet per second (ft^3/s)	0.02832	cubic meters per second (m^3/s)
cubic yards (yd^3)	0.7646	cubic meters (m^3)
feet (ft)	0.3048	meters (m)
inches (in)	25.40	millimeters (mm)
miles (m)	1.609	kilometers (km)
square miles (mi)	2.590	square kilometers (km^2)

PURPOSE AND SCOPE

The principal objective of this study was to evaluate the extent to which abandoned mines and tailings piles are affecting ground and surface waters in the Joplin area, with emphasis on Center and Turkey Creeks. The approach involved characterizing the quality and determining the movement of mine water, and seepage and runoff from tailings areas. It also involved delineating specific reaches of streams that are affected and, as possible, separating the effects of mine-water discharge from those of tailings area discharge.

MINERALIZATION AND METAL LIBERATION

Sphalerite (zinc sulfide) and galena (lead sulfide) were the most important minerals in the Joplin area. Other minerals commonly associated with the zinc and lead were pyrite, marcasite, dolomite, calcite, chert, and jasperoid (Feder and others, 1969, p. 10).

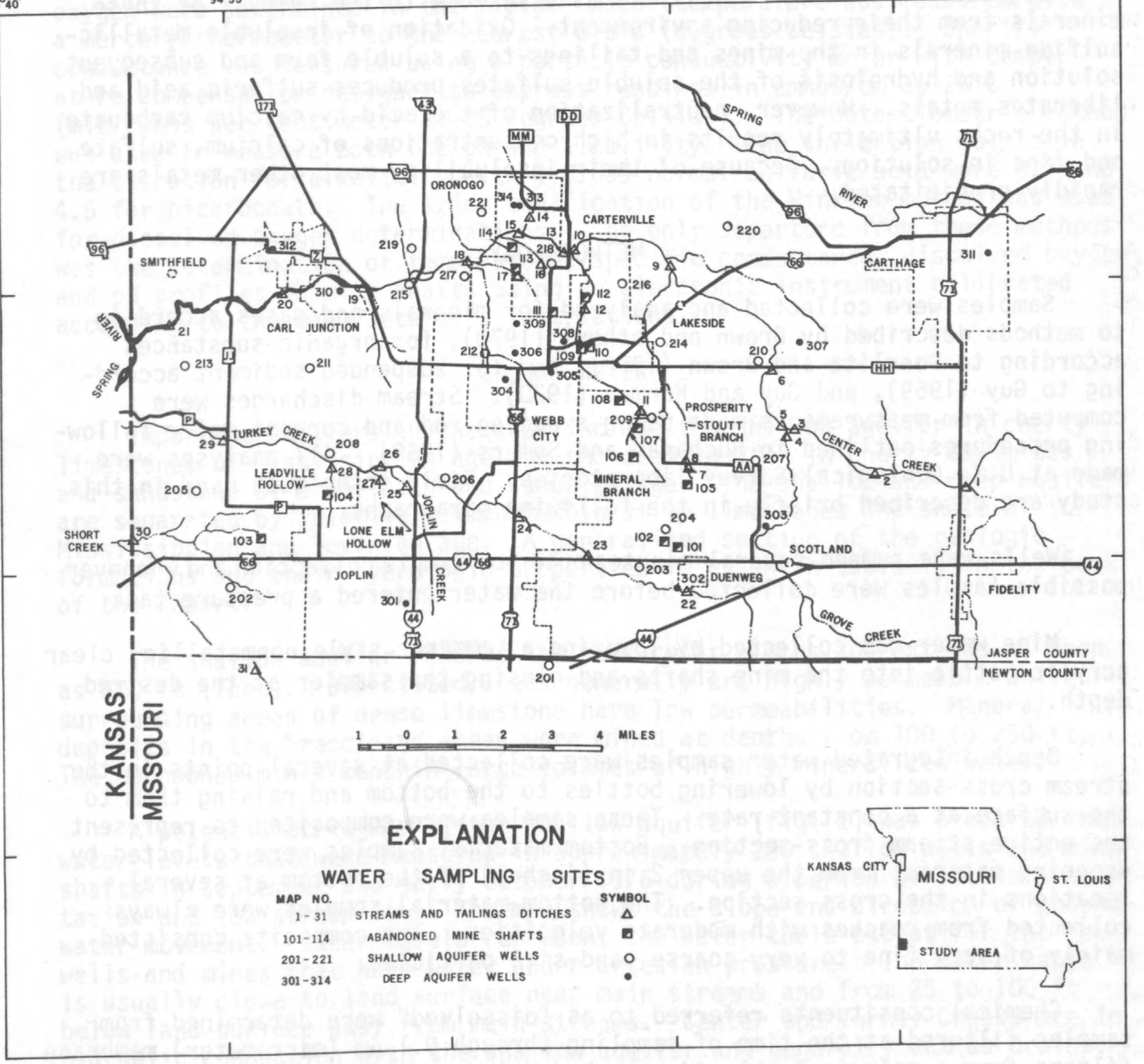

Figure 1.--Map of the Joplin area, Missouri, showing associated water sampling sites.

Degradation of water quality is associated with the removal of these minerals from their reducing environment. Oxidation of insoluble metallic-sulfide minerals in the mines and tailings to a soluble form and subsequent solution and hydrolosis of the soluble sulfates produces sulfuric acid and liberates metals. However, neutralization of the acid by calcium carbonate in the rocks ultimately results in high concentrations of calcium, sulfate, and zinc in solution. Because of their insolubility most other metals are rapidly precipitated.

METHODOLOGY

Samples were collected and analyzed for minerals and gases according to methods described by Brown and others (1970), for organic substances according to Goerlitz and Brown (1972), and for suspended sediment according to Guy (1969), and Guy and Norman (1970). Stream discharges were computed from measurements made using a wading rod and current meter following procedures outlined in Buchanan and Somers (1969). All analyses were made at U.S. Geological Survey laboratories. Field techniques used in this study are described briefly in the following paragraphs.

Wells were pumped several minutes prior to sample collection and whenever possible samples were collected before the water entered a pressure tank.

Mine water was collected by lowering a kemmerer style nonmetallic, clear acrylic bottle into the mine shafts and closing the sampler at the desired depth.

Depth-integrated water samples were collected at several points in the stream cross-section by lowering bottles to the bottom and raising them to the surface at a constant rate. These samples were composited to represent the entire stream cross-section. Bottom material samples were collected by scooping material from the upper 2 in (inches) of the bottom at several locations in the cross section. The bottom material samples were always collected from reaches with moderate velocities. The composite consisted mainly of very fine to very coarse sand-size particles.

Chemical consituents referred to as "dissolved" were determined from samples filtered at the time of sampling through 0.1 μm (micrometer) membrane filters from a polyvinyl chloride chamber using a peristaltic pump as the pressure source (Kennedy and others, 1976). The only exception was the dissolved organic carbon samples which were filtered through 0.45 μm silver filters from a stainless steel chamber using compressed nitrogen as the pressure source. Chemical consituents referred to as "total" were determined from unfiltered samples and include amounts recovered from suspended sediment or bottom material by soft digestion procedures.

Samples to be analyzed for cations were acidified with double-distilled analytical-grade nitric acid to a pH of less than 3.

Water temperature, specific conductance, pH, alkalinity, and dissolved oxygen were determined in the field. Water temperature was measured with a mercury thermometer to the nearest 0.5°C (degrees Celsius). Specific conductance was measured using a portable conductivity meter with temperature compensation designed to express readings in µmhos/cm at 25°C (micromhos per centimeter at 25 degrees Celsius). The potentiometric method was used to measure both the pH and alkalinity. The inflection points in the titration for alkalinity with 0.01639 normal sulfuric acid were 8.3 and 4.5 for bicarbonate. The azide modification of the Winkler method was used for dissolved oxygen determinations. The only departure from these methods was the determination of temperature, specific conductance, dissolved oxygen, and pH profiles in mine shafts using an electronic instrument calibrated according to the manufacturer's instructions.

GROUND WATER

Important aquifers in the area include the shallow aquifer in cherty limestones of Mississippian age and the deep aquifer in cherty dolomites and sandstone of Ordovician and Cambrian age. The shallow and deep aquifers are separated by relatively impermeable silty limestones and shale of Mississippian and Devonian age. A generalized section of the geologic formations and their hydrologic properties is given in table 1, in the back of the report.

The shallow aquifer reaches the surface at places and extends as deep as 500 ft (feet). Brecciated areas generally are highly permeable while surrounding areas of dense limestone have low permeabilities. Mineral deposits in the brecciated areas were mined at depths from 100 to 250 ft. The abandoned mines contain large volumes of highly mineralized water.

A potentiometric map of the shallow aquifer (fig. 2) was prepared from water levels that were measured in approximately 200 shallow wells and mine shafts in September and early October 1976 during a period of little precipitation and low streamflow. The map shows the slope and direction of ground-water movement. Water levels represent the water table except for the few wells and mines that have water under artesian pressure. The water table is usually close to land surface near main streams and from 25 to 100 ft below land surface away from main streams. Center and Turkey Creeks are in hydraulic connection with the shallow aquifer and generally act as drains. Hydrologic divides generally correspond to topographic divides and movement of the ground water is from the divide areas to the streams. Regional movement of the water in the shallow aquifer is toward the west.

A comparison of the September-October 1976 and June 1966 (Feder and others, 1969, p. 28) potentiometric maps shows that except for the area north of Duenweg, the altitude of the water table and movement of the ground water is unchanged. In 1966 heavy pumping in the area north of Duenweg formed a cone od depression and altered the ground-water flow pattern causing water to flow into the cone to replace water that had been pumped out. Most of the pumpage stopped soon after the 1966 water-level measurements were made. The 1976 measurements show a recovery of about 100 to 150 ft in water-table altitude in the Duenweg area. Consequently, the 1976

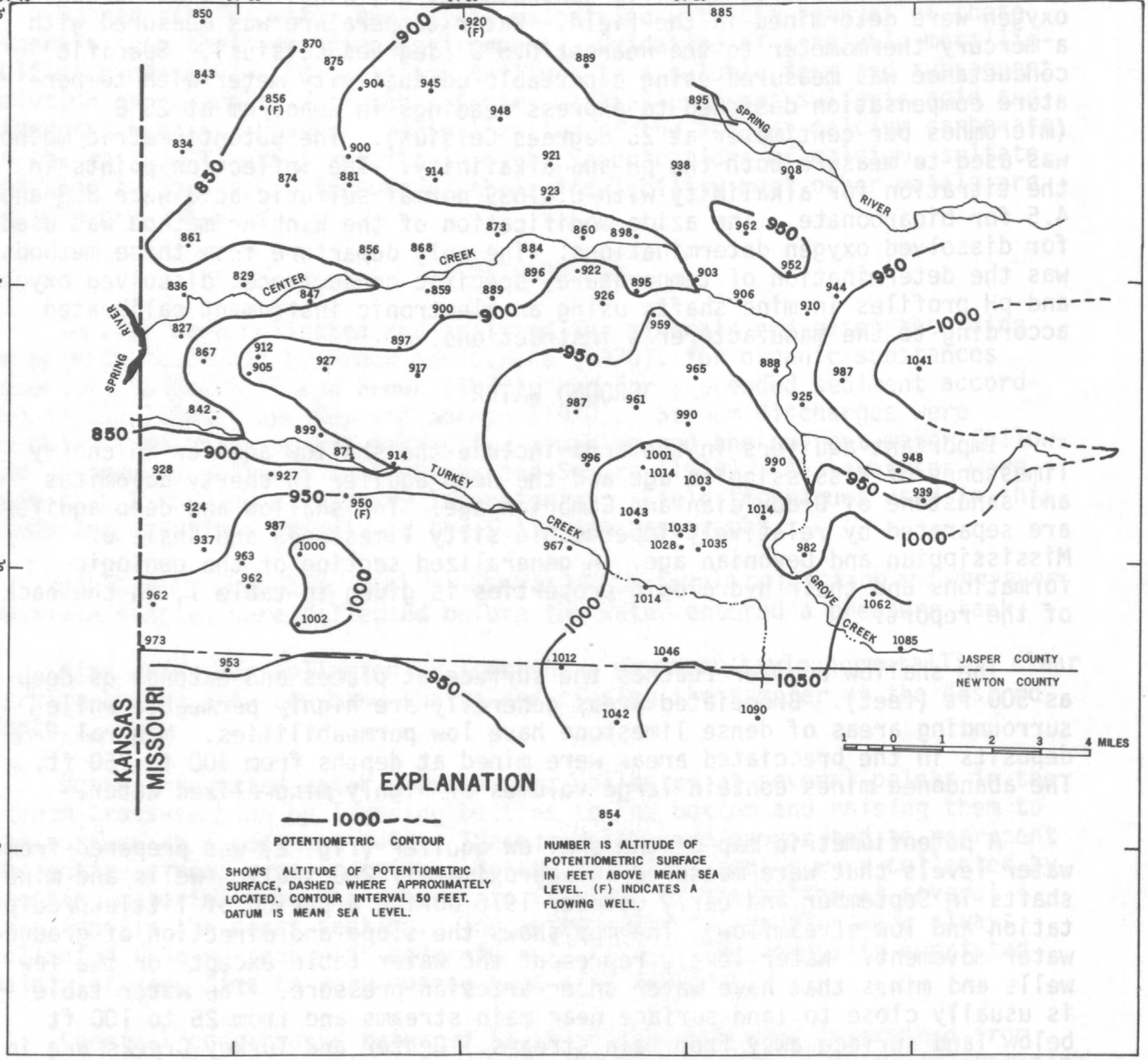

Figure 2.--Potentiometric map of the shallow aquifer for September-October 1976.

map does not show a depression in the water table north of Duenweg.

The deep aquifer is reached at a minimum depth of about 300 ft and extends as deep as 1,800 ft. Water in the deep aquifer is under artesian pressure, but water-level measurements indicate that the potentiometric surface of the deep aquifer is below that of the shallow aquifer (Feder and others, 1969, p. 12). This relationship favors downward seepage of water, and where faults, fracture openings, and wells connect the aquifers, water can leak directly from the shallow aquifer to the deep aquifer. Where the aquifers are separated by the Northview Formation, the Chattanooga Shale, or both, these shales act as confining beds permitting little water movement.

In 1976 water samples were collected from 14 mines, 21 shallow wells, and 14 deep wells. Results of analyses of these samples are shown in tables 2, 3, and 4, respectively, in the back of the report. The data are summarized in table 5 and figure 3 and discussed under the topics, "Mines," "Shallow wells," and "Deep wells."

Mines

Dissolved-solids concentrations in water from mine drifts are generally greater than 1,000 mg/L (milligrams per liter). In ground-water recharge areas (higher altitudes away from main streams) downward water movement prevents water in the drifts from circulating up into the mine shafts, and water in these shafts contain less than 500 mg/L dissolved solids. Conversely, in ground-water discharge areas (lower altitudes near main streams or water under artesian pressure) upward water movement causes water in the drifts to circulate up through the mine shafts. This phenomenon is illustrated by the sketch in figure 4 and by specific conductance, pH, temperature, and dissolved oxygen profiles (fig. 5) that represent average characteristics for seven mines (map nos. 101, 102, 103, 106, 107, 108, and 113) in recharge areas and for three mines (map nos. 104, 112, and 114) in discharge areas. Average depth to the water surface was 35 ft in recharge areas and 1 ft in discharge areas. The relation between dissolved solids (DS) and specific conductance (SC) for water in the drifts and shafts is $DS=(0.99XSC)-121$; the standard error of estimate is 49 mg/L DS. In table 2, in the back of the report, those analyses with dissolved-solids concentrations less than 500 mg/L are for water collected from shafts in ground-water recharge areas. Those with dissolved-solids concentrations greater than 900 mg/L are for water collected from drifts in the recharge areas or from shafts in ground-water discharge areas. All of the analyses were used to compute values shown for mines in table 5 and figure 3.

Water in limestone rocks is usually a calcium bicarbonate type, but water in the abandoned mines is a calcium sulfate type (fig. 3), reflecting the sulfide mineralization.

Average concentrations of dissolved iron, manganese, cadmium, and zinc in the mine water (table 5) exceed concentrations of 300, 50, 10, and 5,000 µg/L, respectively, recommended as drinking water standards (U.S. Public Health Service, 1962). Concentrations of other metals in the mine water are

Table 5.--Average values of characteristics and dissolved constituents of water from mines, shallow wells, and deep wells

Characteristic or constituent	Average value		
	Mines	Shallow wells	Deep wells
Silica (SiO_2), in mg/L-------	12	9.2	9.4
Calcium (Ca), in mg/L--------	264	89	44
Magnesium (Mg), in mg/L-----	7.6	7.7	16
Sodium (Na), in mg/L---------	5.7	8.1	8.1
Potassium (K), in mg/L-------	1.4	1.5	2.2
Bicarbonate (HCO_3), in mg/L--	140	214	195
Sulfate (SO_4), in mg/L-------	580	72	28
Chloride (Cl), in mg/L-------	2.9	7.4	6.8
Fluoride (F), in mg/L--------	0.6	0.2	0.2
Dissolved solids, in mg/L----	1,030	327	207
Hardness as $CaCO_3$, in mg/L--	690	250	180
Alkalinity as $CaCO_3$, in mg/L--	115	176	160
Specific conductance, in μmhos/cm at 25°C-----------	1,160	522	373
pH, in units----------------	6.9	6.9	7.4
Temperature, in °C----------	15.0	17.5	18.5
Aluminum (Al), in μg/L------	10	20	10
Cadmium (Cd), in g/L--------	25	4	0
Chromium (Cr), in μg/L-------	0	---------	---------
Cobalt (Co), in μg/L---------	5	---------	---------
Copper (Cu), in μg/L---------	2	2	1
Iron (Fe), in μg/L-----------	5,100	350	30
Lead (Pb), in μg/L-----------	10	10	6
Manganese (Mn), in μg/L------	180	60	10
Mercury (Hg), in μg/L--------	0.5	---------	---------
Nickel (Ni), in. g/L---------	46	7	0
Silver (Ag), in μg/L---------	0	---------	---------
Zinc (Zn), in μg/L-----------	9,400	1,100	70

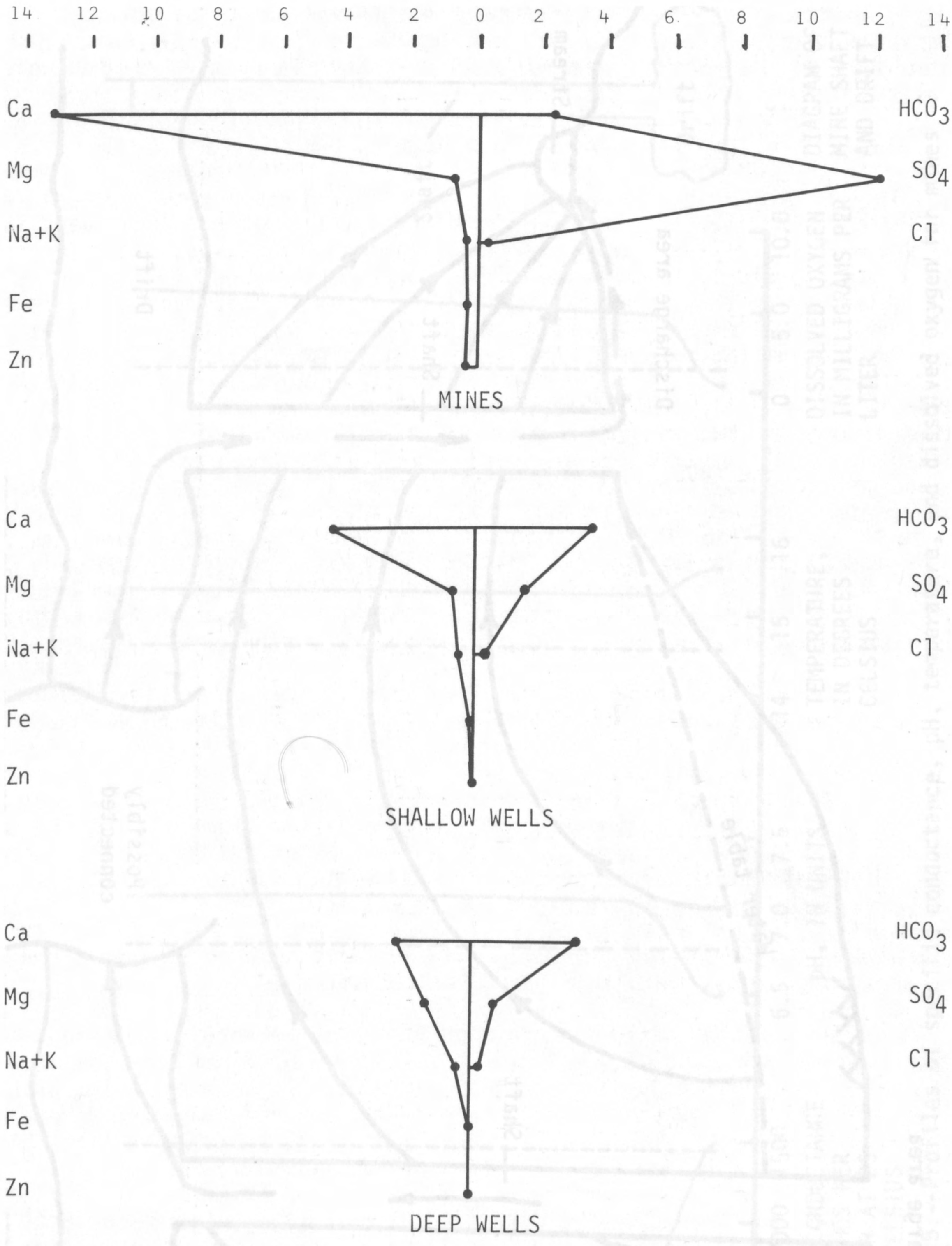

Figure 3.--Chemical character of water from mines, shallow wells, and deep wells.

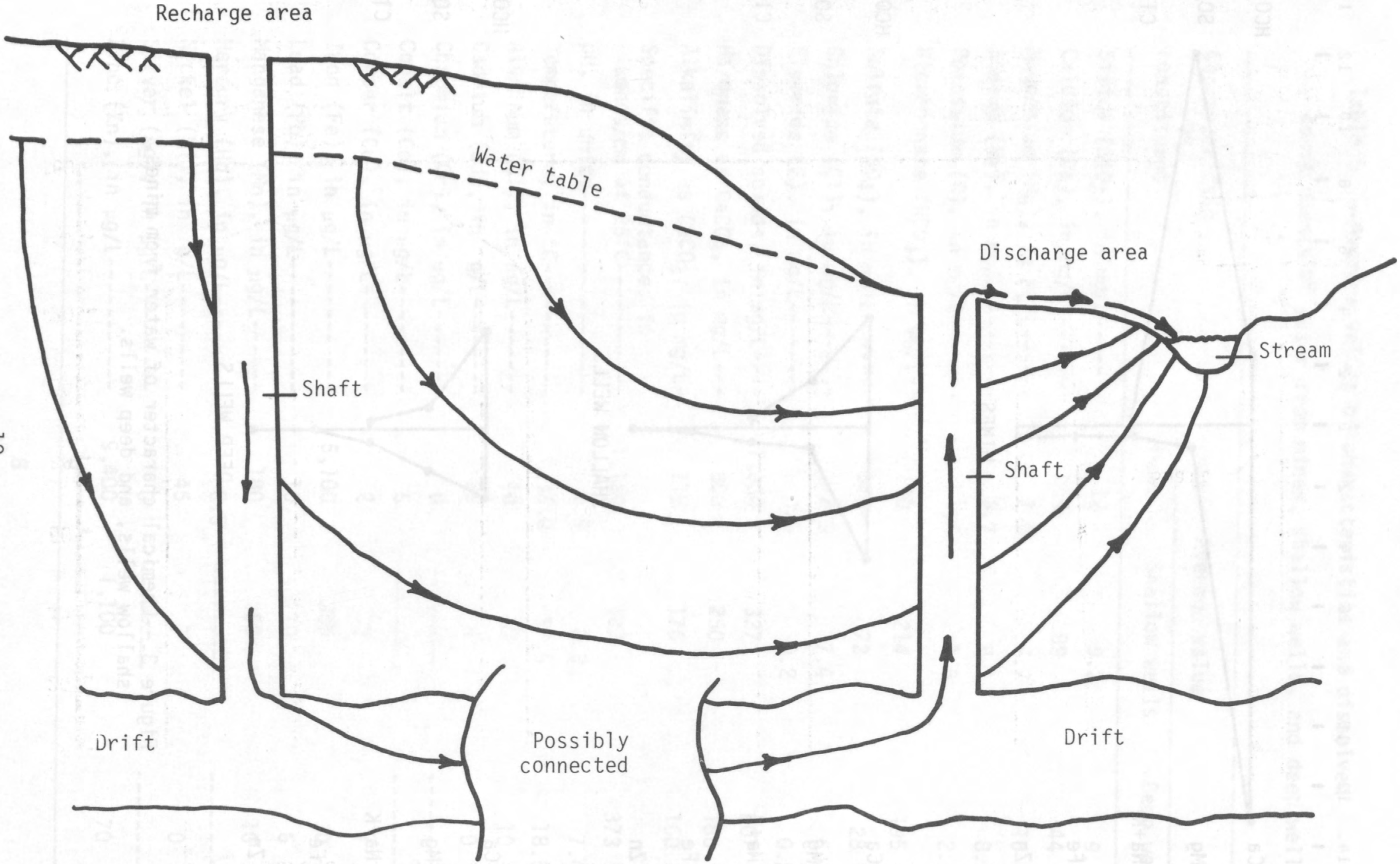

Figure 4.--Cross-sectional sketch showing mine-water circulation. Vertical scale is highly exaggerated.

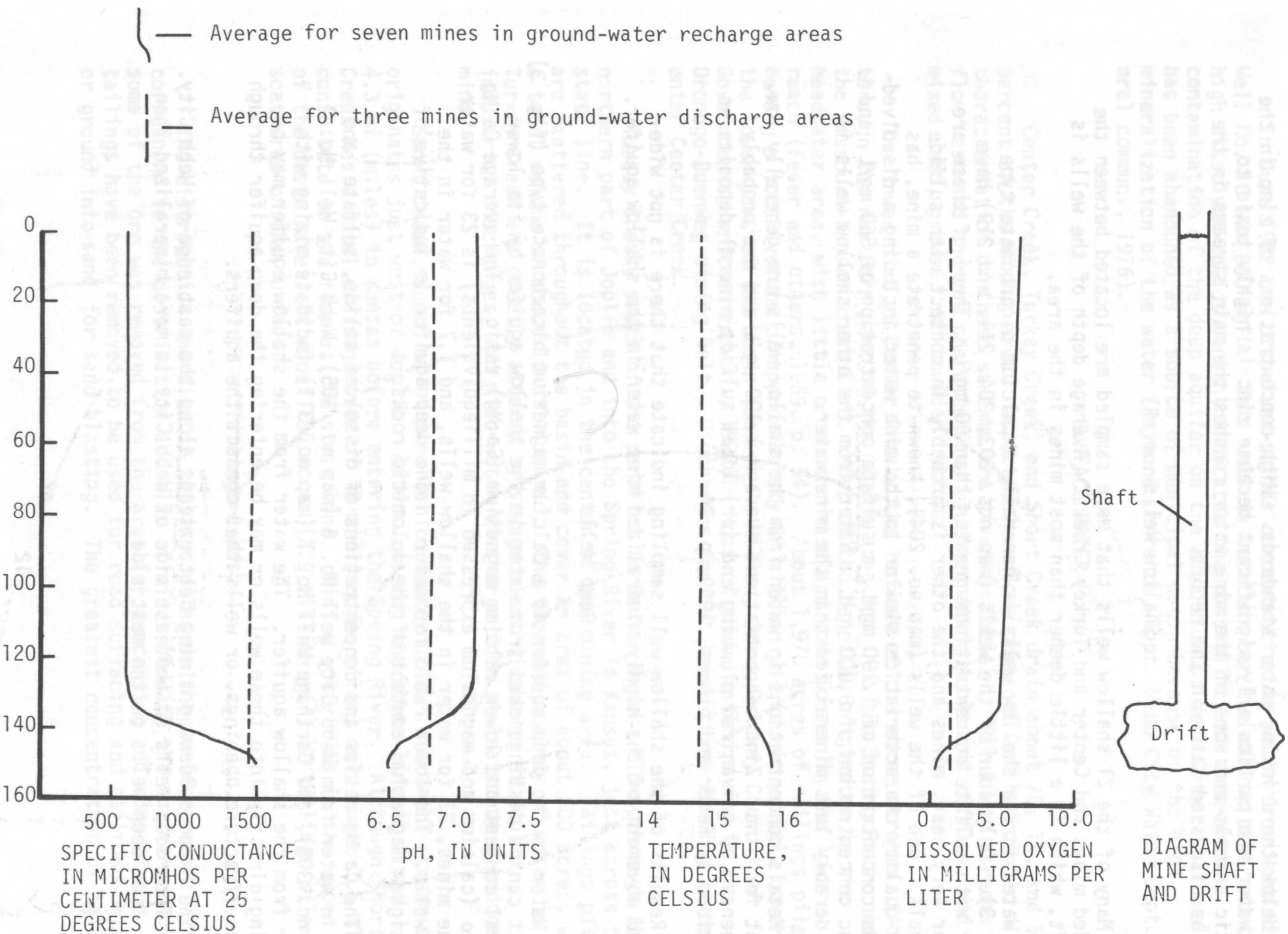

Figure 5.--Profiles of specific conductance, pH, temperature, and dissolved oxygen for mines in ground-water recharge areas and ground-water discharge areas.

well below the drinking water standards. High concentrations of zinc in the mine water are particularly significant because zinc is highly toxic to aquatic animals and some of the mine water reaches the main streams in the area as discussed later in the report.

Shallow Wells

Many of the 21 shallow wells that were sampled are located between the flooded mines and Center and Turkey Creeks. Average depth of the wells is 243 ft, which is a little deeper than most mines in the area.

Water in the shallow wells is generally a calcium bicarbonate type (fig. 3). Only four of the wells (map nos. 203, 204, 211, and 219) have water with sulfate concentrations greater than 60 mg/L. Three of these are in, or very near, mines and the other is probably in contact with sulfide minerals. One of the wells (map no. 204), known to penetrate a mine, has water-quality characteristics similar to the mine water including a dissolved-solids concentration of 1,190 mg/L, a sulfate concentration of 560 mg/L, and a zinc concentration of 8,800 μg/L. Water from the other shallow wells is considerably less mineralized than the mine water.

Metals concentrations in water from the shallow wells are generally low, except for zinc. Zinc concentrations average 1,100 μg/L and are probably influenced by galvanized plumbing and (or) local sulfide mineral deposits as described by Feder and others, 1969, p. 34.

Results of the shallow well sampling indicate that there is not widespread movement of the highly mineralized mine water in the shallow aquifer.

Deep Wells

Water in the deep aquifer is a calcium magnesium bicarbonate type (fig. 3) and it can be distinguished from water in the shallow aquifer by its lower mineral content and lower calcium magnesium (Ca:Mg) ratio. The average Ca:Mg ratio (calcium and magnesium expressed in milliequivalents) is 23 for water in the mines, 23 for water in the shallow wells, and 1.7 for water in the deep wells. The lower ratio for water in the deep aquifer is indicative of the higher magnesium content of the dolomitic rocks.

The Ca:Mg ratios and concentrations of dissolved solids, sulfate, and zinc in water from Webb City Well No. 6 (map no. 305), Webb City Well No. 7 (map no. 308), and Carthage Well No. 1 (map no. 311) indicate mixing with water from the shallow aquifer. The water from the shallow aquifer may be leaking directly into these wells or may be entering the deep aquifer through faults, fracture openings, or wells that connect the aquifers.

The Oronogo-Duenweg mining belt extends along the east edge of Webb City. Water from deep wells on the east side of Webb City is more mineralized than water from deep wells on the west side.

In June 1972 the dissolved-solids concentration in water from Webb City Well No. 10 was 840 mg/L. This well is located near the mining belt and the high dissolved-solids content indicates the possibility of mine-water contamination of the deep aquifer on the east side of Webb City. This well has been abandoned as a source of municipal water because of the high mineralization of the water (Raymond Lawrence, Supt. Webb City Water Dept., oral commun., 1976).

SURFACE WATER

Center Creek, Turkey Creek, and Short Creek drain about 70, 18, and 5 percent of the mining area, respectively. Some physical and hydrologic characteristics of these streams are given in table 6. All three streams flow westward and are characterized by alternating pools and riffles, and mixed sand, gravel, and boulder bottoms.

The lower part of Center Creek, the largest of the three streams, flows through the northern part of the mining area and into the Spring River near the Missouri-Kansas state line. Most of the baseflow originates in the headwater area, with little or no increase and some losses in the lower reach (Feder and others, 1969, p. 54). About 1,970 acres of tailings piles having a total volume of approximately 38 million yd^3 (cubic yards), cover the lower part of the basin (Joseph R. Miller, Ozark Gateway Council of Governments, written commun., 1977). Most of these tailings are in the Oronogo-Duenweg mining belt. Discharges from at least three flowing mines enter Center Creek.

Turkey Creek, south of and parallel to Center Creek, flows through the northern part of Joplin and into the Spring River in Kansas, just across the state line. It is located in the center of the mining area. Tailings piles are scattered throughout the basin and cover an area of about 600 acres, with a total volume of about 10 million yd^3. The flow and quality of water in Turkey Creek are greatly altered by sewage plant discharge at Joplin, industrial discharges, and mine-water discharge from at least one abandoned mine.

Short Creek, south of and parallel to Turkey Creek is a small stream that originates just west of Joplin. After crossing the state line it flows 4.3 mi (miles) in Kansas before entering the Spring River. Although Short Creek has a total drainage area of 18 mi^2 (square miles) only about 7.6 mi^2 contribute to the flow at the state line. Mining activities in the upper part of the basin have left about 185 acres (2.9 million yd^3) of tailings piles scattered on the surface.

Tailings Areas

The distribution and size of tailings piles on the surface generally correspond to the distribution and size of mines beneath the surface. However, some of the ore was removed from the area for processing and some of the tailings have been removed to be used for road surfacing and railroad ballast, or ground into sand for sand blasting. The greatest concentration of tailings

Table 6.--Physical and hydrologic characteristics of Center, Turkey, and Short Creeks

Stream	Drainage area (mi^2)		Length (mi)		Discharge at Missouri-Kansas state line (ft^3/s)	
	Total	In Missouri	Total	In Missouri	Average	7-day Q_{10}[1]
Center Creek---	302	302	60	60	240	11
Turkey Creek---	46	45	18	17	36	-----([2]).
Short Creek----	18	7.6	10	5.7	6	0

[1] 7-day Q_{10} is the 7-day average minimum flow with a recurrence interval of 10 years.

[2] 7-day Q_{10} for Turkey Creek is indeterminent because of irregular patterns of stream regulation.

piles is in the Oronogo-Duenweg mining belt (fig. 6), which is about 2 mi wide and 10 mi long, reaching from Oronogo to Duenweg. This mining area is in the Center Creek basin, except for the southwestern edge which is in the Turkey Creek basin. Outside the Oronogo-Duenweg belt the tailings piles are generally scattered and intermixed with woodlands and farmlands. Regardless of the location, runoff and seepage from the tailings piles reach the main streams, either directly or through natural or man-made drainages.

Surface drainage to Center Creek from the Oronogo-Duenweg mining belt is primarily by Mineral Branch, located in the center part of the belt (fig 1). It originates southwest of Prosperity and flows into Center Creek at Highway D about 1.5 mi upstream from Oronogo. Another drainage, Stoutt Branch, originates in the mining belt southeast of Prosperity, but leaves the mining area and runs through farmlands and woodlands before entering Center Creek just downstream from Lakeside. The Sunset mine (map no. 109) and a nearby unnamed mine (map no. 110) discharge about 1 ft^3/s of water to Mineral Branch at Carterville during periods of low flow. Otherwise, Mineral Branch is dry upstream from Carterville and Stoutt Branch is dry throughout its length during periods of little or no rainfall, but both carry large volumes of water during periods of heavy rainfall. These two branches are important from the standpoint of the effects of the tailings areas on water quality in Center Creek.

Reconnaissance.--During the reconnaissance sampling in March 1976 water flowing at eight tailings sites was collected and analyzed to determine the variation in types and concentrations of major ions and minor elements, as shown in table 7 in the back of the report. The eight tailings sites are scattered throughout the area, but most are located in the Oronogo-Duenweg mining belt. Sources of the water samples vary from seepage directly out of individual tailings piles to flow in ditches draining areas completely covered by tailings, to flow in ditches draining areas that are only partly covered by tailings. Water at two of the sites, Mineral Branch at Carterville and Leadville Hollow near Joplin, is derived in part from mines that discharge at the surface. The samples were collected during a period of moderate rainfall while surface runoff was taking place.

In table 8 characteristics and dissolved constituents of water from the tailings areas are compared with those for a March 1976 sample collected from Center Creek upstream from the mining area. Water from the tailings areas is more mineralized than water from Center Creek near Fidelity, and is a calcium sulfate type rather than calcium bicarbonate. The higher sulfate concentrations reflect the oxidation and solution of sulfide minerals still present in the tailings.

Chromium, cobalt, mercury, nickel, and silver are present in tailings area water at about the same low concentrations as in water from Center Creek upstream from the mining area. Aluminum, iron, and manganese concentrations are considerably higher in the tailings water, but these metals are generally nontoxic to aquatic animals. Metals that are toxic to aquatic animals

Figure 6.--Photograph of tailings piles in the Oronogo-Duenweg mining belt.

Table 8.--Characteristics and dissolved constituents of water flowing from eight tailings sites and Center Creek, March 1976

Character or constituent	Eight tailings sites			Center Creek near Fidelity, Mo.
	Maximum	Minimum	Average	(one analysis)
Calcium (Ca), in mg/L---	230	15	95	45
Bicarbonate (HCO_3), in mg/L---------------	176	0	62	136
Sulfate (SO_4), in mg/L--	490	79	230	8.2
Dissolved solids, in mg/L---------------	838	162	414	134
Specific conductance, in µmhos/cm at 25°C-------	1,100	234	583	266
pH, in units-----------	7.7	3.5	6.4	7.8
Aluminum (Al) in µg/L---	4,200	0	600	30
Cadmium (Cd), in µg/L---	60	1	26	1
Chromium (Cr), in µg/L--	5	0	2	0
Cobalt (Co), in µg/L----	10	0	4	1
Copper (Cu), in µg/L----	360	0	46	0
Iron (Fe), in µg/L------	390	10	120	30
Lead (Pb), in µg/L-----	1,300	0	380	4
Manganese(Mn), in µg/L--	360	40	200	0
Mercury (Hg), in µg/L---	0.9	0.0	0.2	0.1
Nickel (Ni), in µg/L----	30	7	16	2
Silver (Ag), in µg/L----	0	0	0	0
Zinc (Zn), in µg/L------	35,000	540	16,000	20

at low concentrations but occurred in the tailings water at moderate to high concentrations include zinc, lead, copper, and cadmium. Of particular significance are the high concentrations of zinc. Uniformly high zinc concentrations (11,000 to 35,000 μg/L) were in water at all six of the sites where 80 to 100 percent of the flow was considered to be derived from tailings seepage or runoff. Water from the other two sites (map nos. 14 and 28) was derived from predominantly nontailings areas and contained zinc concentrations of less than 2,000 μg/L. The maximum concentration (35,000 μg/L) was in water with the lowest pH (3.5), but the pH of water from other sites with high zinc concentrations ranged from 4.9 to 7.2. Lead concentrations were generally less than 5 μg/L in water with pH values greater than 7.0, but were as high as 1,100 and 1,300 μg/L in the water with pH values of 4.9 and 3.5, respectively. Copper concentrations were less than 16 μg/L except for the acid-water drainage sample (pH 3.5) which had the maximum concentration of 350 μg/L. Cadmium concentrations ranged from 25 to 60 μg/L in water from the six sites where the flow was considered to be mostly tailings seepage and runoff, but were 1 and 3 μg/L at the two sites where only a small part of the flow was derived from tailings areas.

In May 1976 specific conductance and pH were determined for 50 water samples collected from tailings seepage and drainage ditches located throughout the area. Specific conductance ranged from 191 to 1,800 and averaged 588 μmhos/cm at 25°C and pH ranged from 3.5 to 7.9 and averaged 6.6. These values compare closely with those determined in the eight samples from which other characteristics and dissolved constituents were determined, table 8. The maximum specific conductance was for water in a drainage ditch receiving discharge from a mine and the minimum pH was for seepage directly out of a tailings pile.

In samples from 24 open pits and lakes, specific conductance ranged from 177 to 1,800 and averaged 939 μmhos/cm at 25°C. Some of this water is highly mineralized because of long exposure to sulfide minerals and calcium carbonate rocks. However, pH values ranged from 3.2 to 8.2 and averaged 7.3, indicating that acid formed by the solution and hydrolosis of the soluble sulfates is neutralized by the calcium carbonate rocks. Only three pH values were less than 7.0.

Small area storm runoff.--The area selected for storm runoff sampling (fig. 7) is 7.0 acres in size. The surface is 100 percent tailings, consisting mainly of a large tailings pile, but including parts of three smaller barren rock piles. The proportion and types of material present appear to be representative of that found throughout the mining area. Drainage from the 7-acre site is well defined and enters Stoutt Branch about 200 ft upstream from the reconnaissance site (map no. 8).

A continuous-stage recorder and weir were installed at the sampling site (map no. 7) so that runoff from the area could be computed. On June 23, 1976, 5.14 in. of rain fell on the area between 0430 and 1430 h (hours). Antecedent conditions consisted of several days dry weather with no flow at the site.

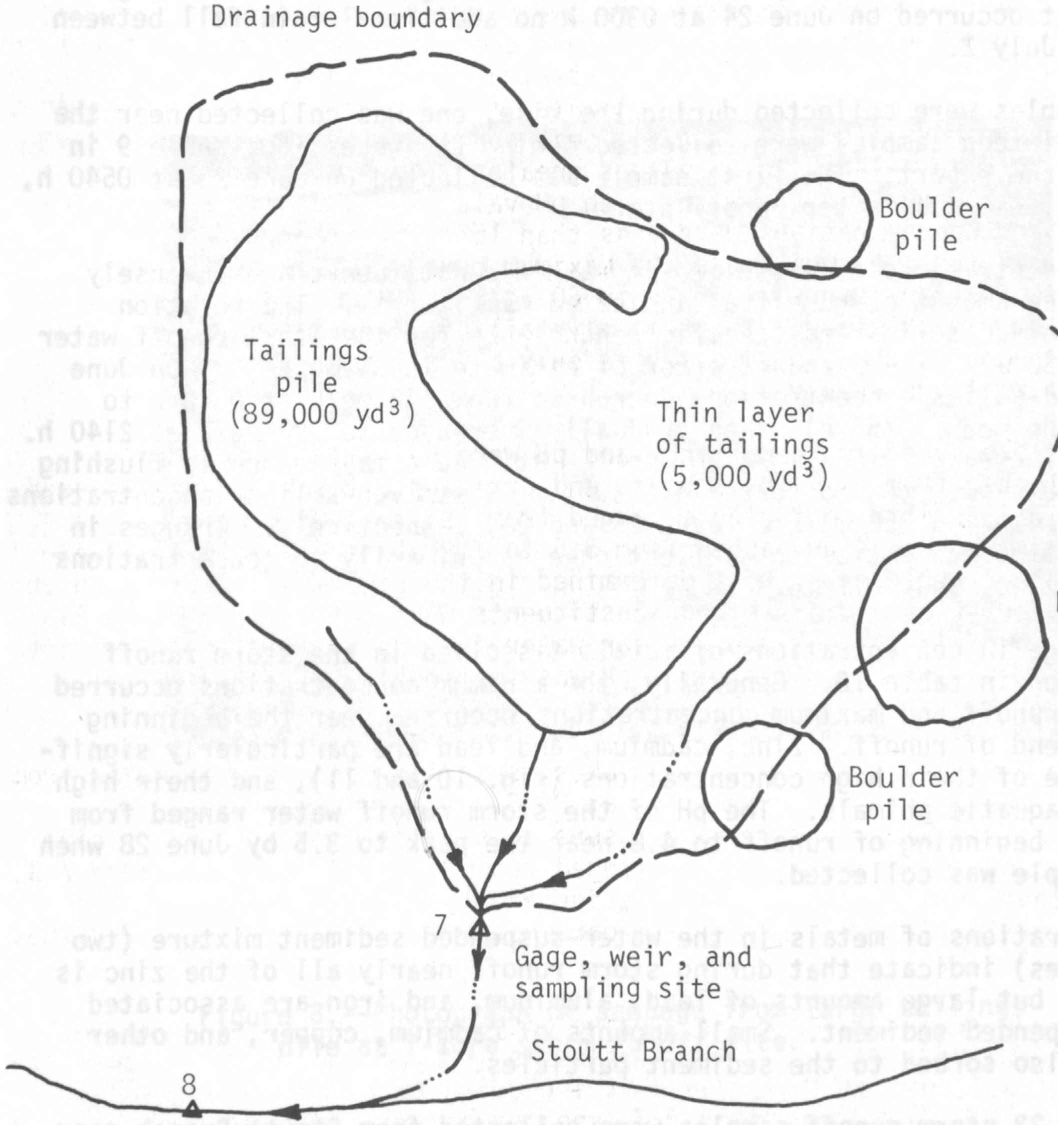

Figure 7.--Sketch of 7-acre tailings area storm runoff site (not to scale). Site numbers 7 and 8 refer to those on figure 1.

Runoff at the gage increased from 0 ft^3/s (cubic feet per second) at 0430 h to a peak of about 10 ft^3/s at 0800 h, then gradually decreased to 0.6 ft^3/s at 1200 h. Flow that occurred after 1200 h was mainly seepage out of the large tailings pile (fig. 8). This seepage gradually decreased until it stopped on July 2, about 9 days after the runoff began. Except for light rainfall that occurred on June 24 at 0300 h no additional rain fell between June 23 and July 2.

Six samples were collected during the rise, one was collected near the peak, and thirteen samples were collected during the recession, table 9 in the back of the report. The first sample was collected on June 23 at 0540 h, about 30 min (minutes) after runoff started.

The concentrations of dissolved inorganic constituents are inversely related to the amount of runoff as indicated by figure 9. The relation between dissolved solids and specific conductance for the storm runoff water is DS-(0.79XSC)-37; the standard error of estimate is 35 mg/L DS. On June 23, dissolved-solids concentrations decreased from 348 mg/L at 0540 h to 38 mg/L at the peak (0755 h), then gradually increased to 392 mg/L at 2140 h. Part of the increase to 664 mg/L on June 24 at 0840 h may be due to flushing caused by the shower that occurred at 0300 h. Dissolved-solids concentrations decreased to 410 and 358 mg/L on June 25 and 28, respectively. Changes in dissolved-solids concentrations reflect changes primarily in concentrations of calcium, zinc, and sulfate.

The range in concentrations of metals dissolved in the storm runoff water is given in table 10. Generally, the minimum concentrations occurred during peak runoff and maximum concentrations occurred near the beginning or near the end of runoff. Zinc, cadmium, and lead are particularly significant because of their high concentrations (fig. 10 and 11), and their high toxicity to aquatic animals. The pH of the storm runoff water ranged from 4.2 near the beginning of runoff to 4.8 near the peak to 3.5 by June 28 when the last sample was collected.

Concentrations of metals in the water-suspended sediment mixture (two of the samples) indicate that during storm runoff nearly all of the zinc is in solution, but large amounts of lead, aluminum, and iron are associated with the suspended sediment. Small amounts of cadmium, copper, and other metals are also sorbed to the sediment particles.

On June 23 storm runoff samples were collected from Stoutt Branch near Prosperity (map no. 8) at 1115 h, and Mineral Branch at Carterville (map no. 12) at 1330 h (see table 7 in the back of the report). Although the flow had peaked, an estimated 120 ft^3/s was still flowing in Stoutt Branch. The dissolved-solids concentration was 74 mg/L and pH of the water was 6.3. Concentrations of dissolved metals were low except zinc (5,000 µg/L) and cadmium (60 µg/L). The flow had also peaked in Mineral Branch but an estimated 400 ft^3/s of water was still flowing. The dissolved-solids concentration was 236 mg/L and the pH of the water was 6.7. Concentrations of

Figure 8.--Photograph of seepage from large tailings pile at 7-acre storm runoff site.

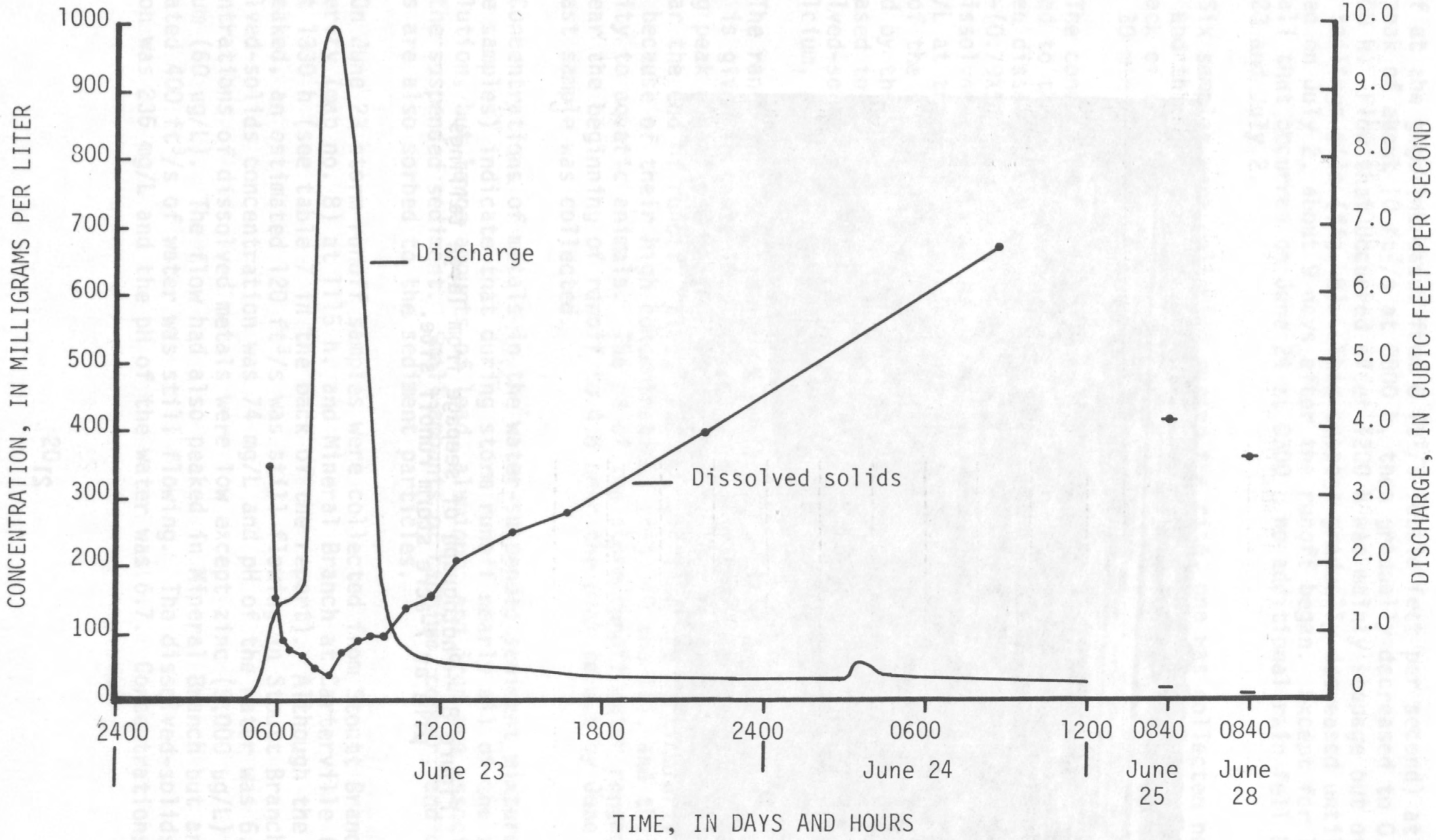

Figure 9.--Dissolved-solids concentrations in storm runoff from 7-acre tailings area, June 23-28, 1976.

Table 10.--Range in concentrations of dissolved metals in storm runoff from 7-acre tailings area, June 23-28, 1976

[Results in micrograms per liter]

Metal	Concentration Minimum	Concentration Maximum
Aluminum (Al)	0	860
Cadmium (Cd)	46	1,400
Chromium (Cr)	0	0
Cobalt (Co)	0	20
Copper (Cu)	3	50
Iron (Fe)	30	340
Lead (Pb)	56	400
Manganese (Mn)	50	700
Mercury (Hg)	0.2	0.8
Nickel (Ni)	2	29
Silver (Ag)	0	0
Zinc (Zn)	3,800	200,000

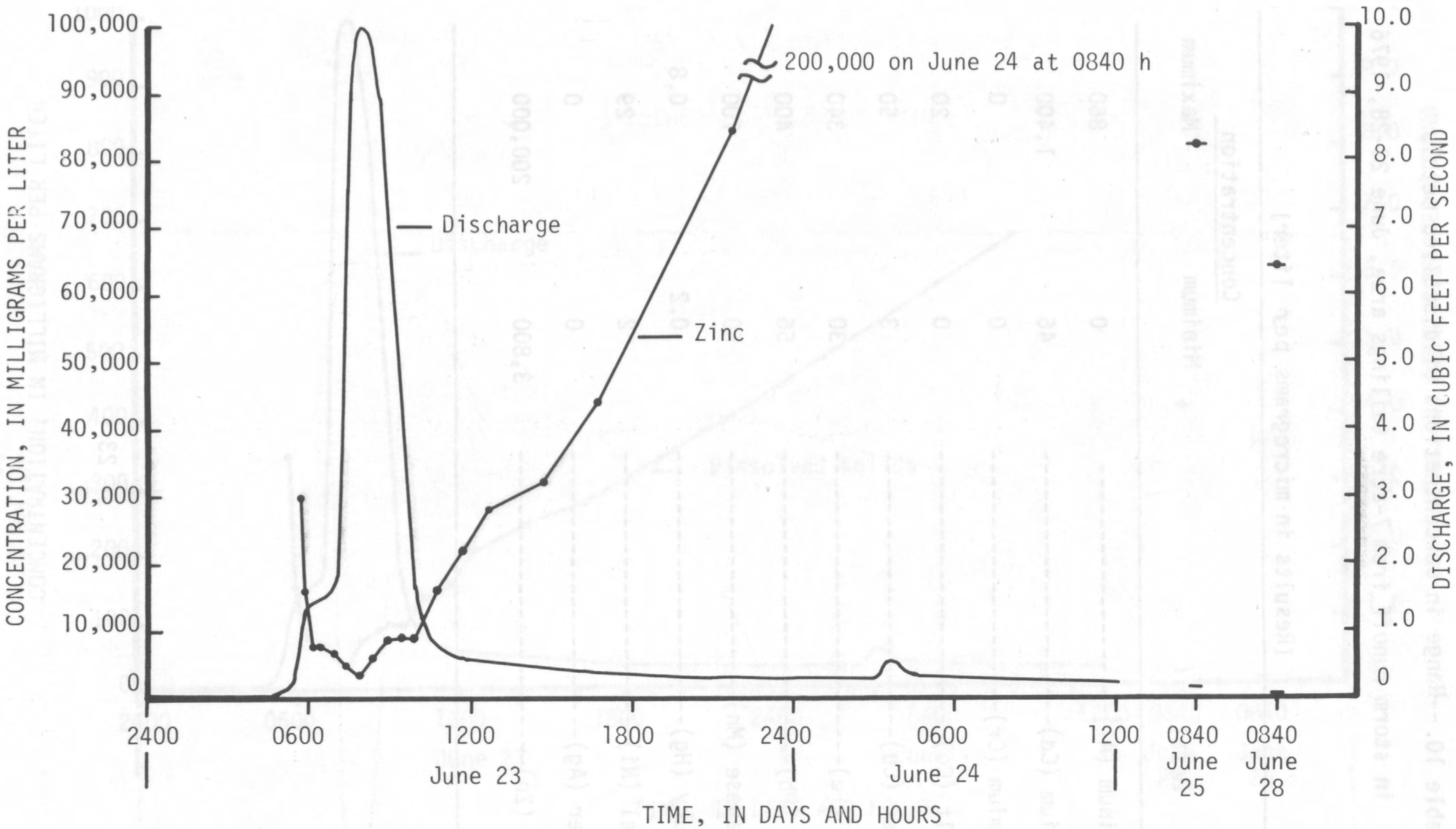

Figure 10.--Dissolved zinc concentrations in storm runoff from 7-acre tailings area, June 23-28, 1976.

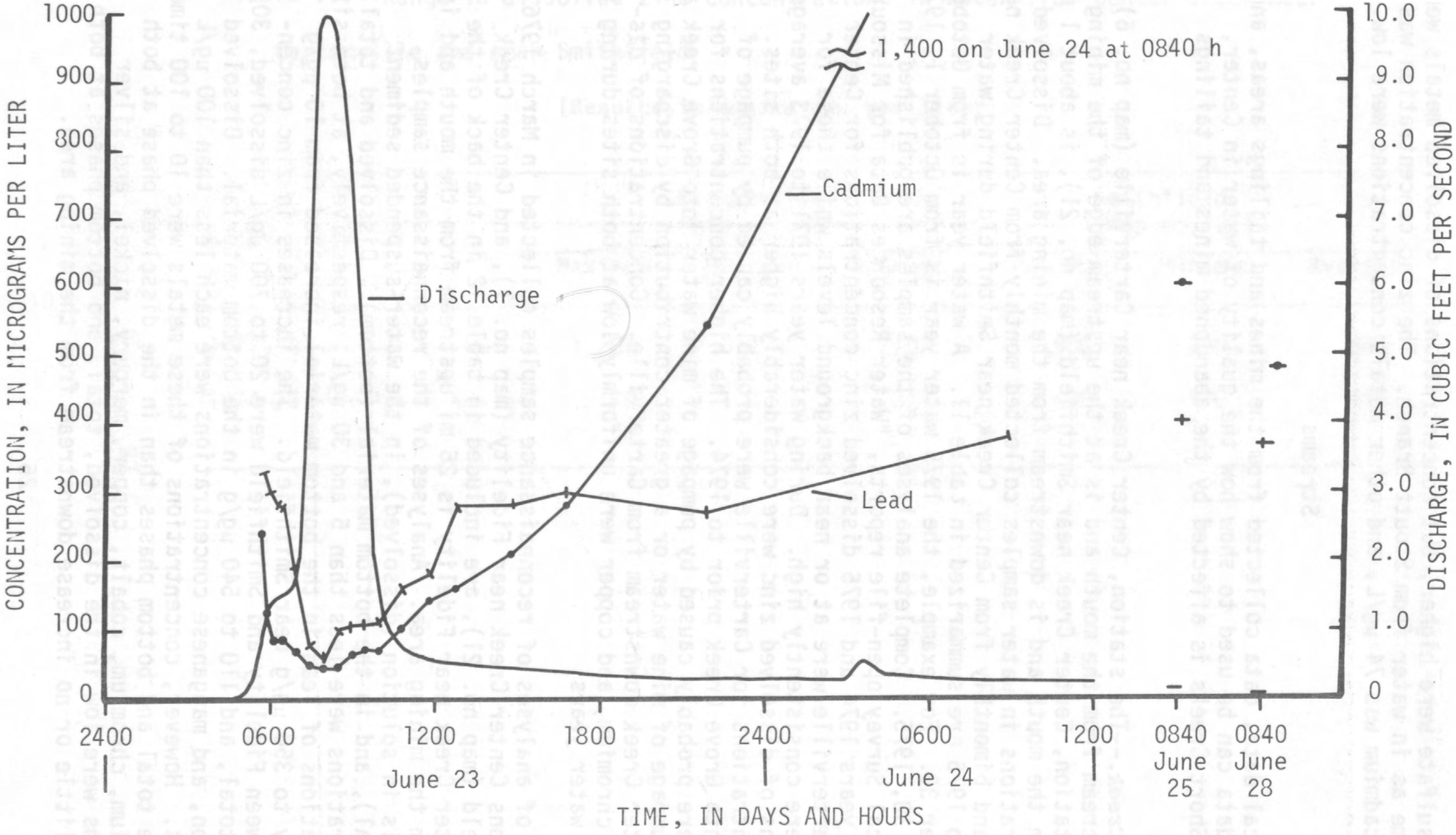

Figure 11.--Dissolved cadmium and lead concentrations in storm runoff from 7-acre tailings area, June 23-28, 1976.

calcium and sulfate were higher, but concentrations of dissolved metals were about the same as in water from Stoutt Branch. The zinc concentration was 6,000 μg/L, cadmium was 74 μg/L, and other metals concentrations were low.

Streams

Historical data, data collected from the mines and tailings areas, and seepage-run data can be used to show how the quality of water in Center, Turkey, and Short Creeks is affected by the abandoned mines and tailings piles.

Center Creek.--The station, Center Creek near Carterville (map no. 6), is 19 mi upstream from the mouth and is at the upstream edge of the mining area. The station, Center Creek near Smithfield (map no. 21), is about 1 mi upstream from the mouth and is downstream from the mining area. Dissolved zinc concentrations in water samples collected monthly from Center Creek near Carterville and bimonthly from Center Creek near Smithfield during water years 1971 to 1975 are summarized in table 11. A water year is from October 1 to September 30. For example, the 1975 water year is from October 1, 1974 to September 30, 1975. Complete analyses of the samples are published in U.S. Geological Survey open-file reports, "Water Resources Data for Missouri." During water years 1974 and 1975 dissolved zinc concentrations for Center Creek near Carterville were at or near background levels while those for Smithfield were consistently high. During water years 1971 to 1973 average concentrations of dissolved zinc were considerably higher at both sites. The higher concentrations for Carterville were probably caused by pumpage of mine water into Grove Creek prior to 1974. The higher concentrations for Smithfield were probably caused by pumpage of mine water into Grove Creek and additional pumpage of mine water or a greater contribution by discharging mines to Center Creek downstream from Carterville. Concentrations of dissolved lead, chromium, and copper were uniformly low at both sites during the 1971 to 1975 water years.

Results of analyses of reconnaissance samples collected in March 1976 at the stations Center Creek near Fidelity (map no. 1), and Center Creek near Smithfield (map no. 21), are included in table 12 in the back of the report. Center Creek near Fidelity is 26 mi upstream from the mouth and is upstream from the mining area. Analyses of the reconnaissance samples include metals in solution (dissolved), in the water-suspended sediment mixture (total), and in the bottom material (bottom). Dissolved and total lead concentrations were less than 5 and 30 μg/L, respectively, at both sites, but concentrations of lead in the bottom material increased from 10 μg/g near Fidelity to 350 μg/g near Smithfield. The increases in zinc concentrations between Fidelity and Smithfield were 20 to 700 μg/L dissolved, 30 to 800 μg/L total, and 110 to 540 μg/g in the bottom material. Dissolved aluminum, iron, and manganese concentrations were each less than 100 μg/L at both sites. However, concentrations of these metals were 10 to 100 times higher in the total and bottom phases than in the dissolved phase at both sites. Cadmium, chromium, cobalt, copper, mercury, nickel, and silver concentrations were low in the dissolved, total, and bottom phases at both sites, with little or no increase downstream from the mining area.

Table 11.--Range in dissolved zinc concentrations in water from Center Creek near Carterville and near Smithfield

[Results in micrograms per liter]

Water years	Carterville (map no. 6)			Smithfield (map no. 21)		
	Maximum	Minimum	Average	Maximum	Minimum	Average
1971-73-----------------	1,200	0	270	1,900	380	880
1974-75-----------------	70	0	31	630	170	440

Discharge measurements were made at 13 sites on Center Creek and near the mouths of Grove Creek and Mineral Branch during a September 1976 seepage run. Specific conductance, pH, and bicarbonate were measured at each site and water and bottom material samples were collected and analyzed for dissolved calcium and sulfate and for zinc and lead in solution, in the water-suspended sediment mixture, and in the bottom material, table 13 in the back of the report.

The relation of discharge and specific conductance to distance upstream from the mouth of Center Creek is shown in figure 12. At the time the seepage run was made the flow in Center Creek was about twice the 7-day 2-year minimum discharge. Although the discharge measurements were not made during a period of exceptionally low baseflow, they delineate areas where baseflow gains and losses may be expected. Surface inflow between Fidelity and Smithfield included 4.4 ft^3/s from Grove Creek, 1.0 ft^3/s from Mineral Branch (discharge from the Sunset and a nearby unnamed mine), and an estimated 1.0 ft^3/s from the D.C. and E. mine below Oronogo which was not discovered until after the seepage run was completed. Stoutt Branch was dry and appears to flow only during periods of moderate to heavy rainfall. Other increases in discharge are attributed to ground-water inflow and decreases are attributed to seepage losses from the stream. The loss reach between Highway HH and Lakeside and the one downstream from Oronogo were verified by additional measurements. Specific conductance increased from 305 μmhos/cm at 25°C near Fidelity to 468 μmhos/cm at 25°C near Smithfield. The difference is due mainly to sudden increases caused by surface inflow from Grove Creek, Mineral Branch, and the D.C. and E. mine and by ground-water inflow along a short reach upstream from Oronogo. The reach just upstream from Oronogo is in a swampy area and is the only place where mine workings cross Center Creek. The increases in specific conductance were caused mainly by increases in calcium and sulfate that, except for Grove Creek, were accompanied by significant increases in dissolved zinc (fig. 13). The results indicate that during base-flow conditions nearly all of the increase in dissolved zinc concentration in Center Creek is caused by mine water discharge from the Sunset and a nearby unnamed mine into Mineral Branch at Carterville that enters Center Creek 1.5 mi upstream from Oronogo, subsurface seepage of mine water into Center Creek about one-fourth mi upstream from Oronogo, and discharge from the D.C. and E. mine that enters Center Creek 0.4 mi downstream from Oronogo.

During high-flow conditions the high dissolved zinc concentrations are sustained by seepage and runoff from the tailings areas that are discharged mainly through Stoutt and Mineral Branches. Total zinc concentrations were usually about 30 μg/L higher than dissolved concentrations indicating most of the zinc is in solution, but some is associated with suspended sediments. Dissolved and total lead concentrations ranged from 1 to 29 and 5 to 59 μg/L, respectively, with no apparent increase downstream from the mining area. Concentrations of zinc and lead in the bottom material (fig. 14) increased about 25 fold downstream from Stoutt Branch and Mineral Branch, the two streams that drain most of the tailings area between Oronogo and Duenweg.

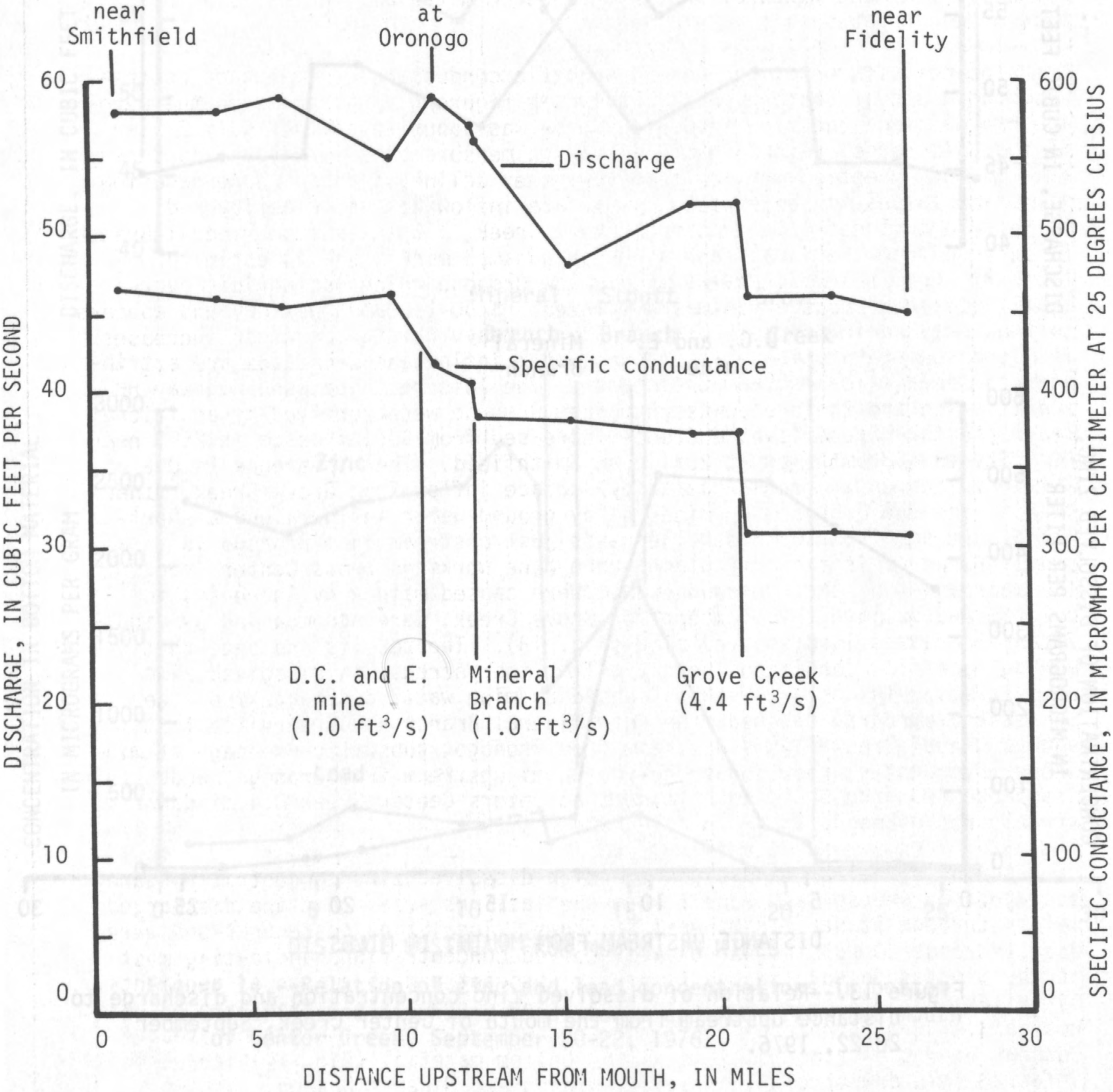

Figure 12.--Relation of discharge and specific conductance to distance upstream from the mouth of Center Creek, September 20-22, 1976.

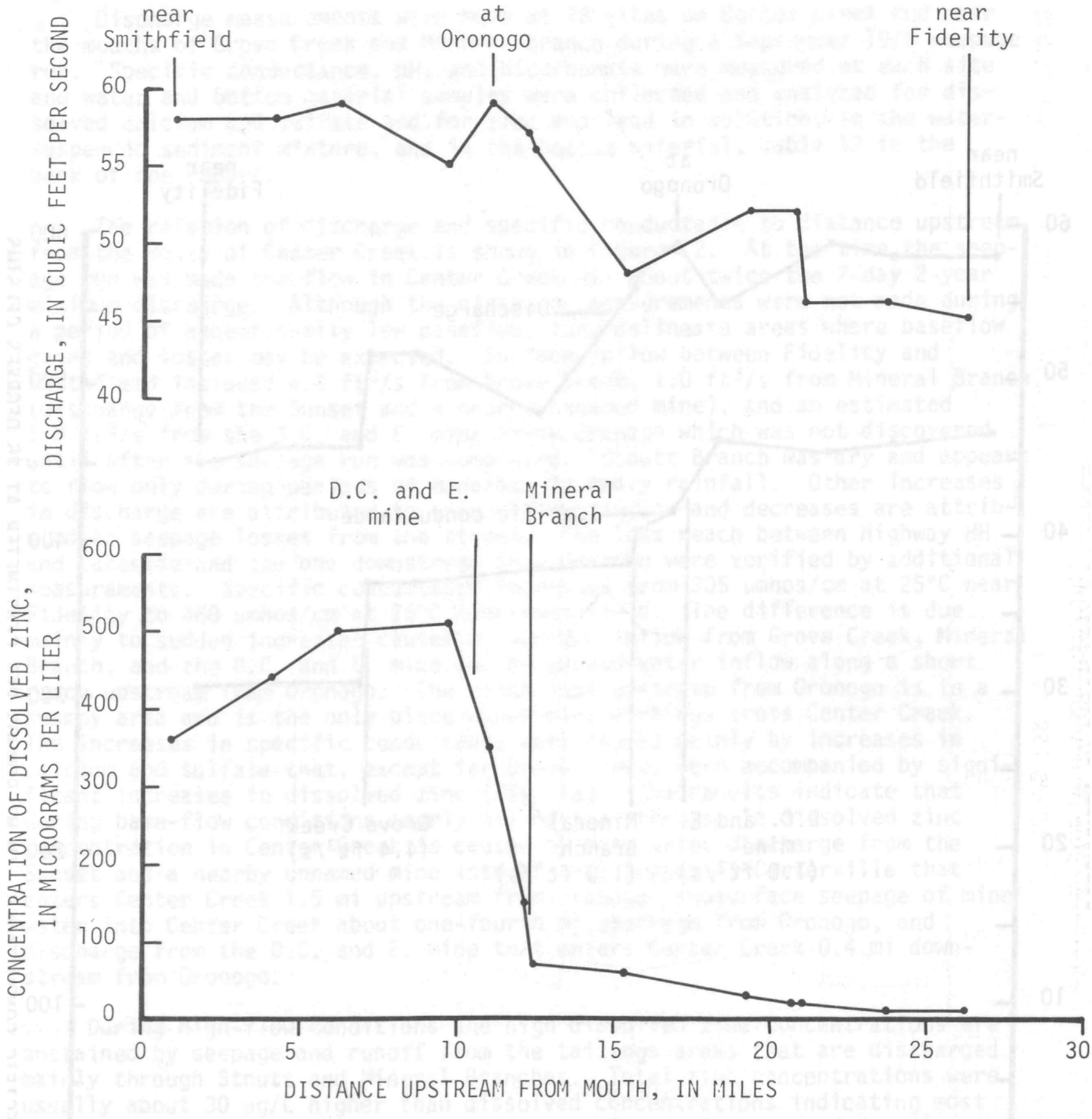

Figure 13.--Relation of dissolved zinc concentration and discharge to distance upstream from the mouth of Center Creek, September 20-22, 1976.

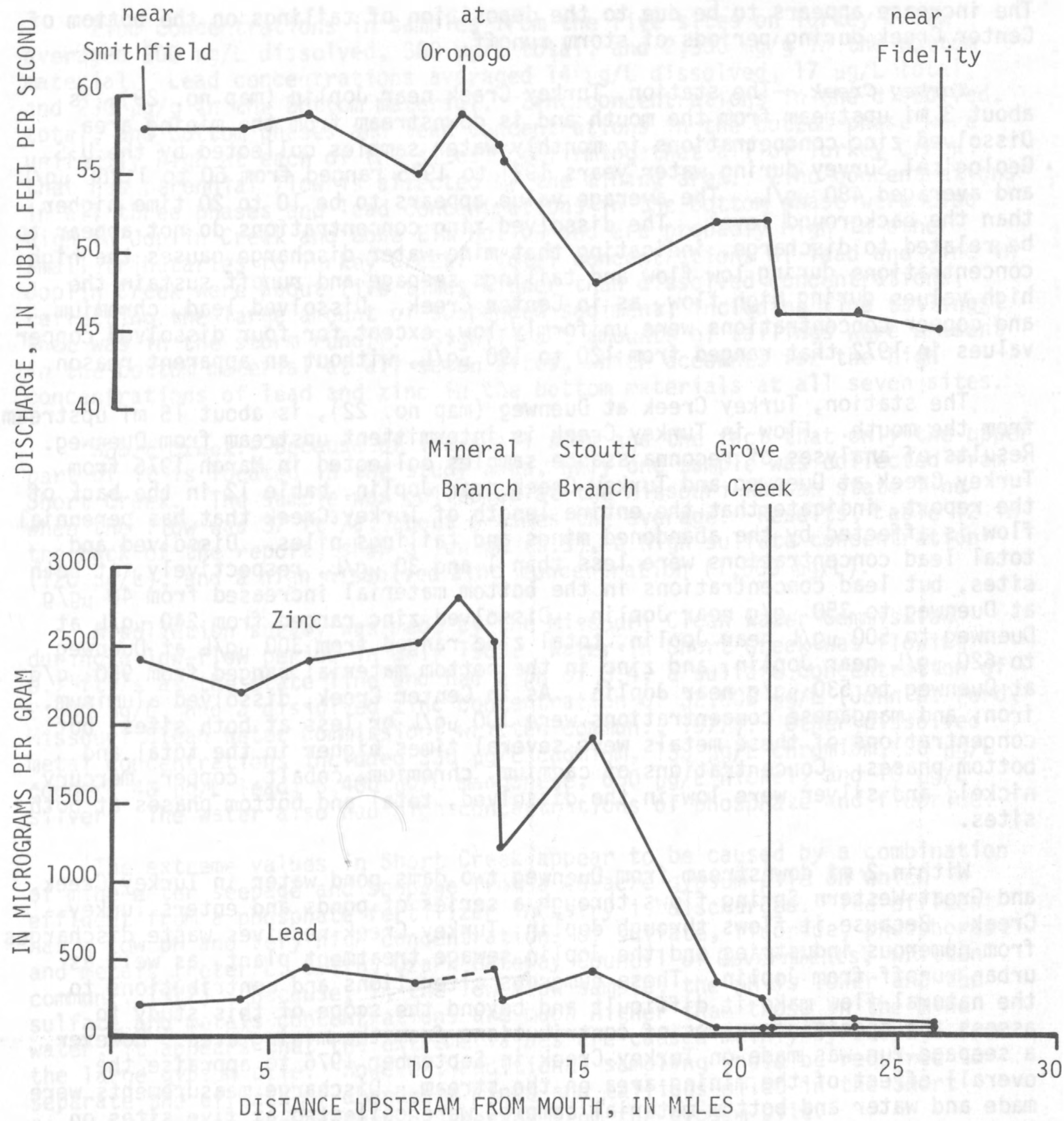

Figure 14.--Relation of zinc and lead concentrations in bottom material and discharge to distance upstream from the mouth of Center Creek, September 20-22, 1976.

The increase appears to be due to the deposition of tailings on the bottom of Center Creek during periods of storm runoff.

Turkey Creek.--The station, Turkey Creek near Joplin (map no. 29), is about 3 mi upstream from the mouth and is downstream from the mining area. Dissolved zinc concnetrations in monthly water samples collected by the U.S. Geological Survey during water years 1971 to 1975 ranged from 60 to 1,260 μg/L and averaged 480 μg/L. The average value appears to be 10 to 20 time higher than the background level. The dissolved zinc concentrations do not appear to be related to discharge, indicating that mine-water discharge causes the high concentrations during low flow and tailings seepage and runoff sustain the high values during high flow, as in Center Creek. Dissolved lead, chromium, and copper concentrations were uniformly low, except for four dissolved copper values in 1972 that ranged from 120 to 190 μg/L, without an apparent reason.

The station, Turkey Creek at Duenweg (map no. 22), is about 15 mi upstream from the mouth. Flow in Turkey Creek is intermittent upstream from Duenweg. Results of analyses of reconnaissance samples collected in March 1976 from Turkey Creek at Duenweg and Turkey Creek near Joplin, table 12 in the back of the report, indicate that the entire length of Turkey Creek that has perennial flow is affected by the abandoned mines and tailings piles. Dissolved and total lead concentrations were less than 1 and 30 μg/L, respectively, at both sites, but lead concentrations in the bottom material increased from 40 μg/g at Duenweg to 350 μg/g near Joplin. Dissolved zinc ranged from 240 μg/L at Duenweg to 500 μg/L near Joplin, total zinc ranged from 300 μg/L at Duenweg to 620 μg/L near Joplin, and zinc in the bottom material ranged from 950 μg/g at Duenweg to 530 μg/g near Joplin. As in Center Creek, dissolved aluminum, iron, and manganese concentrations were 100 μg/L or less at both sites, but concentrations of these metals were several times higher in the total and bottom phases. Concentrations of cadmium, chromium, cobalt, copper, mercury, nickel, and silver were low in the dissolved, total and bottom phases at both sites.

Within 2 mi downstream from Duenweg two dams pond water in Turkey Creek, and Great Western Spring flows through a series of ponds and enters Turkey Creek. Because it flows through Joplin, Turkey Creek receives waste discharges from numerous industries and the Joplin sewage treatment plant, as well as urban runoff from Joplin. These numerous alterations and contributions to the natural flow make it difficult and beyond the scope of this study to assess the specific sources of contributions from the mining area. However, a seepage run was made on Turkey Creek in September 1976 to appraise the overall effect of the mining area on the stream. Discharge measurements were made and water and bottom material samples were collected at five sites on Turkey Creek and near the mouths of Joplin Creek and Lone Elm Hollow, table 14 in the back of the report. A rainstorm occurred just before Joplin Creek was sampled causing urban runoff in Joplin Creek. At the time the seepage run was made the Crackerjack mine (map no. 104) was discharging about 0.5 ft^3/s into Turkey Creek through Leadville Hollow.

Zinc concentrations in samples from the five sites on Turkey Creek averaged 200 μg/L dissolved, 300 μg/L total, and 2,300 μg/g in the bottom material. Lead concentrations averaged 14 μg/L dissolved, 17 μg/L total, and 230 μg/g in the bottom material. Zinc concentrations in the dissolved, total, and bottom phases and lead concentrations in the bottom phase were uniformly high at each of the sites, confirming that all of Turkey Creek that has perennial flow is affected by the mining area. Zinc concentrations in all three phases and lead concentrations in the bottom phase were also high in Joplin Creek and Lone Elm Hollow and are probably high in other small tributaries to Turkey Creek. Total concentrations of lead and zinc in Joplin Creek were about five times higher than dissolved concentrations, reflecting the large amount of suspended sediment, including fine tailings, that was in the storm runoff. Significant amounts of tailings were present in the bottom material at all seven sites, which accounts for the high concentrations of lead and zinc in the bottom materials at all seven sites.

Short Creek.--Because of its small size and the fact that only the upper part of it is located in the study area, only one sample was collected from Short Creek. The sample was collected at the Missouri-Kansas state line when the flow was 37 ft^3/s, about 6 times the average. Results, table 12 in the back of the report, show a low pH (5.9), a high sulfate concentration (120 μg/L), and a high dissolved zinc concentration (1,600 μg/L).

A pollution survey was made by the Missouri Clean Water Commission during a low-flow period in July 1969. Water in Short Creek was flowing 0.7 ft^3/s at the state line and had a pH of 3.4, a sulfate concentration of 2,500 μg/L, and a dissolved zinc concentration of 32,000 μg/L (John C. Ford, Missouri Clean Water Commission, written commun., 1977). Other dissolved metal concentrations included 330 μg/L cadmium, 130 μg/L chromium, 90 μg/L copper, 40 μg/L lead, 6,400 μg/L manganese, 650 μg/L nickel, and 10 μg/L silver. The water also had high concentrations of phosphate and fluoride.

The extreme values in Short Creek appear to be caused by a combination of mine-water seepage and seepage from a 40-acre gypsum pile on which effluent from a phosphate fertilizer industry is discharged. The effluent has a low pH and very high concentrations of sulfate, fluoride, phosphorus, and metals (Peter L. Smith, Ozark Gateway Council of Governments, written commun., 1977). Because, in the low-flow sample, the pH is lower and the sulfate and metals concentrations are much higher than those in the mine water, it appears that the extreme values are caused mainly by seepage from the large gypsum pile. However, additional sampling would be required to separate the effects of abandoned mines and tailings piles in the Short Creek basin from the effects of seepage from the gypsum pile.

SUMMARY AND CONCLUSIONS

Mine water in the Joplin area has high average concentrations of dissolved calcium (264 mg/L), sulfate (580 mg/L), and zinc (9,400 μg/L). Concentrations of other metals in the mine water are generally low because of the neutralizing effect of calcium carbonate in the rocks. Although wells located in or very near mines may be seriously affected by the mine water, there does not appear to be widespread dispersion of the highly mineralized mine water in the cherty limestones of the shallow aquifer. The deep aquifer, composed of cherty dolomites and sandstone, is separated from the shallow aquifer by confining beds, but faults, fracture openings, or poorly constructed wells can connect the aquifers resulting in downward leakage. The only places where there is evidence that this may be happening, however, is in the Webb City and Carthage areas. In general, quality of water in the deep aquifer is excellent, but an insufficient number of deep wells are available to completely evaluate the quality of water beneath the mines.

Runoff from tailings areas has high average concentrations of dissolved calcium (95 mg/L), sulfate 230 mg/L), and zinc (16,000 μg/L). Runoff from a few tailings piles has a low pH and, consequently, high concentrations of dissolved cadmium, copper, and lead. However, these metals precipitate rapidly after mixing with high pH water, which ususally occurs very near the source.

The significant effects of the abandoned mines and tailings areas on Center and Turkey Creeks appear to be about a 10-fold increase in dissolved zinc and a 25-fold increase in zinc and lead in the bottom material. Based primarily upon analyses of samples collected from Center Creek upstream from the mining area, background concentrations appear to be about 40 μg/L dissolved zinc, 100 μg/g zinc in the bottom material, and 20 μg/g lead in the bottom material.

During low flow the increase in dissolved zinc concentrations in Center Creek are caused mainly by discharges from the Sunset and a nearby mine that enter Center Creek through Mineral Branch 1.5 mi upstream from Oronogo, subsurface seepage of mine water into Center Creek about one-fourth mile upstream from Oronogo, and discharge from the D.C. and E. mine that enters Center Creek 0.4 mi downstream from Oronogo. The high dissolved zinc concentrations are sustained during high flow by runoff from the tailings areas that is discharged mainly through Stoutt and Mineral Branches. High zinc and lead concentrations in the bottom material are caused by deposition of tailings on the stream bottom, particularly downstream from Stoutt and Mineral Branches.

The numerous alterations and contributions to the natural flow in Turkey Creek make it difficult and beyond the scope of this study to assess the specific sources of contributions from the mining area. However, reconnaissance and seepage-run data show that all of Turkey Creek that has perennial flow (downstream from Duenweg) has high concentrations of dissolved zinc and zinc and lead in the bottom material. As in Center Creek, the high dissolved zinc concentrations are caused by mine-water discharge and seepage during low flow and are sustained by tailings area runoff during high flow. The Crackerjack mine discharges water to Turkey Creek through Leadville Hollow. Tailings are mixed with the bottom material downstream from Duenweg where flow is perennial. Some of the tailings are washed directly into the stream, but most are transported through Joplin Creek and the numerous small ditches that enter Turkey Creek.

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Table 1.--Generalized section of geologic formations in the Joplin area, Missouri (from Feder and others, 1969)

[The stratigraphic nomenclature generally follows that of the U.S. Geological Survey and the Missouri Geological Survey; however, there are some variations from the current usage of the U.S. Geological Survey.]

SYSTEM	SERIES	GROUP	Stratigraphic Unit	Thickness Feet	Physical Character	Depth to Top of Formation, Feet	Aquifer	Water-bearing Character
QUATERNARY	Holocene		Alluvium	0-30	Unconsolidated silt, sand, and gravel	Outcrop		Yields small supplies for domestic and stock use
PENNSYLVANIAN	Desmoinesian	Cherokee		0-100+	Shales and sandstones with beds of coal	Outcrop		Yields little water to shallow dug wells
MISSISSIPPIAN	Chesterian		Carterville Formation	0-100	Limestones, shales, and siltstones; generally found filling depressions in underlying rocks	Outcrop to 50		Does not yield water to wells
MISSISSIPPIAN	Meramecian		Warsaw Formation	80-150	Dense limestone with some chert	Outcrop to 150		Yields little water except in isolated solution channels
MISSISSIPPIAN	Osagean		Burlington and Keokuk Limestones	50-150	Dense cherty limestone, sometimes mineralized with zinc and lead	Outcrop to 300	Shallow Aquifer	Yields little water where massive, but can yield over 100 gpm in brecciated areas. Solution channels may yield large supplies
MISSISSIPPIAN	Osagean		Elsey Formation	30±	Fine-grained, very cherty limestone; sometimes all chert and mineralized with zinc and lead	Outcrop to 450	Shallow Aquifer	Generally yields adequate supply for domestic and stock use, rarely over 50 gpm. Supplies many springs
MISSISSIPPIAN	Osagean		Reeds Spring Formation	5-100	Dark, very cherty, argillaceous limestone; sometimes mineralized with zinc and lead	Outcrop to 500	Shallow Aquifer	Generally yields adequate domestic or stock supply. Supplies many springs
MISSISSIPPIAN	Kinderhookian		Pierson Formation	10-30	Cherty dolomitic limestone in upper portion; silty dolomite in lower portion	100-600		Yields very small quantities of water
MISSISSIPPIAN	Kinderhookian		Northview Formation	0-15	Shale or shaly limestone; absent in parts of the area	125-625		Confining bed
MISSISSIPPIAN	Kinderhookian		Compton Formation	0-20	Shaly limestone	125-625		Generally does not yield water
MISSISSIPPIAN	Kinderhookian		Bachelor Formation	0-0.5	Sandstone	125-625		Does not yield water to wells
DEVONIAN			Chattanooga Shale	0-10	Fissile, black, carbonaceous shale; absent throughout most of area	150-500		Confining bed
ORDOVICIAN	Lower		Cotter Dolomite	200±	Cherty dolomite; some sandstone beds	150-650	Deep Aquifer	Yields small quantities of water
ORDOVICIAN	Lower		Jefferson City Dolomite	200±	Cherty dolomite	350-850	Deep Aquifer	Yields small quantities of water
ORDOVICIAN	Lower		Roubidoux Formation	175±	Cherty dolomite and several sandstone beds	550-1,000	Deep Aquifer	Generally yields good supply of water; most supplies between 50-150 gpm
ORDOVICIAN	Lower		Gasconade Dolomite	300±	Cherty limestone and dolomite; sandstone bed at bottom of formation	700-1,150	Deep Aquifer	Yields small supplies of water
CAMBRIAN	Upper		Eminence and Potosi Dolomites	200±	Dolomite with drusy chert in lower 50 feet	1,000-1,450	Deep Aquifer	Generally yields good supply of water, especially from lower portion; between 50-400 gpm
CAMBRIAN	Upper		Derby-Doerun, Davis and Bonneterre Formations undifferentiated	150±	Silty dolomites; some siltstones and shales	1,200-1,650	Deep Aquifer	Yields small quantities of water
CAMBRIAN	Upper		Lamotte Sandstone	0-150	Quartzose sandstone	1,350-1,750	Deep Aquifer	Yields vary considerably. Formation may be absent over Precambrian highs
PRECAMBRIAN					Granites and rhyolites	1,350-1,850		Generally does not yield water

Table 2.--Water-quality data for mines

STATION NUMBER	MAP NUMBER	MINE NAME	DATE OF SAMPLE	TOTAL DEPTH OF HOLE (FT. BELOW LSD)	DEPTH TO WATER SURFACE (FT. BELOW LSD)	DEPTH TO SAMPLE COLLECTION (FT. BELOW LSD)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)
370516094245501	101	ST. REGIS	76-05-25	208	28.00	38	8.6	120	9.7	2.9	1.2	180
			76-05-25	208	28.00	198	23	290	19	6.5	3.5	64
370519094251601	102	KING WILLIAM	76-05-25	206	44.00	54	8.0	87	4.0	2.7	.4	116
370527094340901	103	GIBSON	76-05-27	179	10.00	20	12	140	6.5	8.2	.6	216
370613094323801	104	CRACKERJACK	76-05-28	106	0.00	10	9.7	250	13	11	2.0	260
370623094244501	105	VOGEY	76-05-25	170	21.00	31	13	360	6.9	6.8	1.6	98
370650094255801	106	NOWATA	76-05-25	188	52.00	62	9.1	69	2.9	2.5	.9	30
370716094255801	107	FLORINE	76-05-26	197	52.00	62	11	130	5.3	5.0	.6	158
370752094261501	108	MCGREGOR	76-05-26	172	45.00	55	17	97	3.0	2.5	1.6	52
			76-05-26	172	45.00	162	18	240	4.9	4.2	1.6	148
370850094270701	109	SUNSET	76-10-21	--	0.00	--	--	530	8.0	--	--	154
370851094265701	110	UNNAMED	76-10-21	--	0.00	--	--	480	7.3	--	--	116
370925094274001	111	ICE PLANT	76-05-26	185	--	90	12	480	8.8	7.3	1.7	182
370941094265501	112	RHEA	76-05-26	114	3.00	13	12	450	8.6	8.0	1.9	184
371009094282601	113	STAR 43	76-05-27	163	13.00	23	11	100	5.7	2.9	.8	78
			76-05-27	163	13.00	153	9.6	350	7.7	7.0	1.4	172
371038094282701	114	UNITY	76-05-27	155	0.00	10	10	320	8.0	7.5	1.6	180

DATE OF SAMPLE	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION
76-05-25	190	1.5	.1	440	426	340	190	148	610	7.2	15.5	4.3	43
76-05-25	940	4.9	.5	1570	1390	800	750	53	1730	5.7	16.0	.5	5
76-05-25	140	.6	.2	327	307	230	140	95	460	7.3	15.0	5.4	53
76-05-27	220	1.8	.2	495	497	380	200	177	670	6.9	15.0	.5	5
76-05-28	480	7.2	.4	961	904	680	460	213	1120	7.0	14.5	2.4	23
76-05-25	830	3.1	.6	1390	1290	930	850	80	1530	7.1	16.5	9.0	92
76-05-25	170	1.1	.1	324	285	180	160	25	430	7.3	14.5	8.0	78
76-05-26	210	1.1	.4	476	442	350	220	130	600	7.6	15.0	9.0	89
76-05-26	200	.9	.3	427	362	250	210	43	535	6.9	16.0	9.0	91
76-05-26	530	1.5	.7	945	889	620	500	121	1100	6.5	16.0	.3	3
76-10-21	1100	--	--	1900	--	1400	1200	126	2100	6.4	--	--	--
76-10-21	1100	--	--	1750	--	1200	1100	95	1970	7.1	--	--	--
76-05-26	1100	4.9	1.2	1740	1720	1200	1100	149	1810	6.8	14.5	3.5	34
76-05-26	1000	5.6	1.2	1760	1590	1200	1000	151	1850	6.8	15.0	.8	8
76-05-27	240	1.1	.7	447	414	270	210	64	585	6.6	15.5	.8	8
76-05-27	710	4.2	.9	1280	1190	910	760	141	1300	6.8	15.0	.6	6
76-05-27	700	4.6	.9	1210	1150	830	680	148	1280	6.6	14.5	1.4	14

DATE OF SAMPLE	CARBON DIOXIDE (CO2) (MG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SILVER (AG) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
76-05-25	18	10	13	0	0	3	40	6	0	.6	14	0	3000
76-05-25	204	0	30	0	37	2	67000	28	800	.6	98	0	6300
76-05-25	9.3	10	29	0	0	3	30	6	10	.7	18	0	6400
76-05-27	44	10	4	0	5	0	60	24	60	.6	20	0	540
76-05-28	42	10	4	0	0	0	20	8	0	.6	47	0	2500
76-05-25	12	0	31	0	0	7	170	4	100	.5	52	0	17000
76-05-25	2.4	10	41	0	4	4	50	8	330	.7	19	0	14000
76-05-26	6.4	10	8	0	0	3	30	9	0	.6	12	0	630
76-05-26	10	0	31	0	0	1	30	10	20	.6	43	0	14000
76-05-26	75	20	41	0	6	3	2500	10	150	.4	50	0	12000
76-10-21	98	--	2	--	--	--	17000	11	550	--	--	--	12000
76-10-21	15	--	4	--	--	--	20	7	340	--	--	--	12000
76-05-26	46	10	27	0	7	3	40	15	110	.3	74	0	12000
76-05-26	47	10	26	0	7	1	200	9	110	.4	84	0	12000
76-05-27	31	10	54	0	3	1	30	7	400	.4	40	0	13000
76-05-27	44	0	49	0	4	1	30	7	70	.5	62	0	13000
76-05-27	72	10	31	0	3	0	50	8	10	.4	60	0	10000

Table 3.--Water-quality data for wells in the shallow aquifer

STATION NUMBER	MAP NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)
370316094275301	201	76-08-11	200	9.6	49	6.8	11	.7	168	15	15	.3	214	190
370438094345201	202	76-08-11	106	9.6	69	2.4	4.0	.5	174	45	3.4	.2	238	220
370500094254801	203	76-08-09	170	8.0	110	4.2	5.3	.9	160	110	3.9	.1	364	322
370535094251301	204	76-08-09	500	10	320	.8	19	.7	104	560	30	.2	1190	1000
370620094353301	205	76-08-11	210	12	26	2.8	10	2.4	52	48	17	.4	174	152
370628094300501	206	76-08-10	247	9.2	100	11	16	2.0	290	59	28	.1	408	369
370645094230801	207	76-08-12	--	9.1	80	9.5	5.5	.9	274	9.6	5.2	.1	278	256
370659094324501	208	76-08-10	265	8.3	78	6.1	4.0	.8	276	9.3	1.7	.1	232	245
370735094252801	209	76-08-10	200	9.4	62	4.7	9.6	1.9	44	54	8.1	.1	232	172
370829094230701	210	76-08-12	362	8.1	46	17	13	1.2	244	11	3.6	.8	208	221
370834094330401	211	76-08-10	101	11	100	5.9	20	8.5	216	120	12	.2	424	384
370841094291401	212	76-08-10	250	9.4	95	3.8	6.2	.9	260	60	3.6	.1	310	310
370841094355001	213	76-08-11	--	9.2	74	7.0	3.6	.7	252	.8	2.1	.3	232	223
370853094251501	214	76-08-10	255	8.5	83	2.5	3.6	.6	212	48	1.8	.1	258	254
370953094303501	215	76-08-12	238	8.1	85	15	6.6	1.2	344	11	2.0	.1	294	299
370958094261101	216	76-08-12	--	8.5	89	4.2	2.6	.5	252	42	1.7	.1	284	274
371006094293401	217	76-08-12	190	8.4	78	6.2	4.2	.7	224	23	2.5	.1	248	234
371016094273601	218	76-08-10	206	9.3	83	1.1	1.7	.3	218	35	2.1	.1	236	241
371033094305201	219	76-08-12	285	8.1	99	36	14	2.0	288	180	2.6	.5	516	485
371100094234401	220	76-08-11	285	9.4	65	5.6	3.3	1.2	208	16	1.8	.1	222	205
371114094290601	221	76-08-10	300	9.6	82	9.1	7.7	3.4	236	54	7.2	.2	300	291

DATE OF SAMPLE	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
76-08-11	150	13	138	374	7.4	16.5	20	4	4	0	9	0	1	60
76-08-11	180	39	143	400	7.0	17.5	20	4	2	20	6	10	4	360
76-08-09	290	160	131	620	6.1	22.0	20	16	5	0	2	30	10	340
76-08-09	800	720	85	1480	5.1	21.0	40	4	0	730	3	800	64	8800
76-08-11	76	34	43	265	6.4	20.0	20	2	0	2600	9	100	44	5000
76-08-10	300	57	238	680	7.0	16.0	20	0	0	20	15	10	0	250
76-08-12	240	14	225	540	7.3	16.0	20	1	7	20	8	10	2	1300
76-08-10	220	0	226	450	7.2	19.0	20	0	0	250	16	10	0	680
76-08-10	170	140	36	415	5.3	16.0	20	4	2	0	3	0	3	430
76-08-12	180	0	200	420	7.6	17.0	40	3	0	10	13	10	0	120
76-08-10	270	97	177	690	7.0	18.0	20	1	2	40	8	0	3	30
76-08-10	250	40	213	545	7.1	16.5	20	1	0	2500	8	50	4	20
76-08-11	210	7	207	420	7.4	17.0	20	0	0	850	4	50	2	20
76-08-10	220	44	174	445	6.4	16.0	20	1	2	0	3	10	5	1000
76-08-12	270	0	282	530	7.1	16.5	20	1	6	100	3	10	0	250
76-08-12	240	33	207	320	7.4	16.5	20	7	4	30	38	10	2	1400
76-08-12	220	37	184	320	7.4	15.5	20	1	0	40	5	60	2	560
76-08-10	210	33	179	425	7.2	16.5	20	6	2	20	13	10	2	900
76-08-12	400	160	236	735	7.3	16.5	20	2	0	40	10	10	0	920
76-08-11	190	15	171	376	7.2	16.5	0	3	4	0	22	0	0	250
76-08-10	240	49	194	520	7.1	17.5	40	30	3	20	15	10	7	1200

Table 4.--Water-quality data for wells in the deep aquifer

STATION NUMBER	MAP NUMBER	DATE OF SAMPLE	TOTAL DEPTH OF WELL (FT)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)
370416094305201	301	76-09-08	990	9.2	33	15	3.2	1.9	160	15	3.1	.2	145	160
370433094245501	302	76-09-08	1228	9.2	45	18	3.0	2.1	202	14	1.9	.0	227	193
370532094230501	303	76-09-08	1402	9.5	44	18	6.8	2.1	176	49	3.3	.1	224	220
370818094284501	304	76-09-09	1475	9.3	32	14	3.3	1.8	152	14	2.8	.2	142	152
370827094273901	305	76-09-07	1015	9.7	69	22	4.3	2.3	198	110	2.5	.2	321	318
370842094283301	306	76-09-09	930	9.3	32	14	3.6	2.0	160	17	2.4	.3	128	160
370850094221101	307	76-09-08	1473	9.6	34	15	8.5	1.8	166	15	5.9	.1	166	172
370852094273001	308	76-09-07	1415	10	48	18	4.3	1.8	224	25	2.1	.2	224	220
370911094282901	309	76-09-09	1500	9.4	36	15	5.6	2.0	188	15	2.9	.2	159	179
370956094322901	310	76-09-08	1400	9.2	29	13	40	3.1	178	15	44	.5	238	242
371030094175901	311	76-09-08	1250	10	90	11	8.0	2.0	258	39	10	.1	325	298
371040094335601	312	76-09-08	900	8.8	40	19	7.2	3.1	210	18	4.9	.5	206	205
371120094283101	313	76-09-07	1335	9.6	40	19	9.3	2.5	230	20	6.1	.3	184	220
371120094283201	314	76-09-07	925	9.1	44	20	5.8	2.9	224	24	3.9	.3	215	221

DATE OF SAMPLE	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
76-09-08	140	13	131	282	7.7	19.0	10	0	0	0	3	0	0	20
76-09-08	190	21	166	338	7.5	18.0	0	0	2	0	4	20	0	60
76-09-08	180	40	144	381	7.7	19.0	0	2	3	0	11	10	0	40
76-09-09	140	13	125	270	7.7	19.0	10	0	0	10	2	10	0	20
76-09-07	260	100	162	515	7.4	18.5	10	0	0	170	1	20	0	140
76-09-09	140	6	131	285	7.7	18.5	10	0	2	10	2	20	0	40
76-09-08	150	11	136	328	7.0	19.5	0	2	0	40	11	10	0	20
76-09-07	190	10	184	392	7.6	19.0	10	0	0	110	2	10	2	80
76-09-09	150	0	154	312	7.6	18.5	0	0	0	20	3	20	0	20
76-09-08	130	0	146	435	7.5	19.0	10	0	0	70	5	10	0	40
76-09-08	270	58	212	515	6.8	17.0	10	2	5	10	31	20	2	350
76-09-08	180	6	172	368	7.6	18.0	10	0	16	70	3	10	0	20
76-09-07	180	0	189	386	6.9	19.5	10	0	0	10	5	10	0	60
76-09-07	190	8	184	415	7.0	17.5	20	0	0	170	3	20	0	80

Table 7.--Water-quality reconnaissance data for tailings areas

DATE	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)
07186406 - STOUTT BRANCH NEAR PROSPERITY, MO - MAP NUMBER 8												
MAR , 1976												
10...	1.6	10	52	2.3	3.6	1.7	36	140	2.2	.2	246	248
JUN												
23...	120	3.2	11	.5	.9	2.7	10	25	1.0	.2	74	55
07186416 - MINERAL BRANCH AT PROSPERITY, MO - MAP NUMBER 11												
MAR , 1976												
10...	.53	13	47	.8	1.2	.8	4	150	.6	.3	238	237
07186418 - MINERAL BRANCH AT CARTERVILLE, MO - MAP NUMBER 12												
MAR , 1976												
09...	12	12	200	3.3	3.7	2.0	74	460	2.8	.5	732	732
JUN												
23...	400	6.2	52	.8	1.2	2.3	30	130	1.4	.2	236	215
07186425 - TAILINGS DITCH AT ORONOGO, MO - MAP NUMBER 14												
MAR , 1976												
09...	3.9	7.6	63	3.5	5.5	2.7	110	88	4.3	.5	234	230
07186432 - TAILINGS SEEPAGE NEAR ORONOGO, MO - MAP NUMBER 16												
MAR , 1976												
09...	.30	11	20	.8	.7	.5	14	79	.0	.2	162	144
07186440 - TAILINGS DITCH NEAR WEBB CITY, MO - MAP NUMBER 17												
MAR , 1976												
10...	.10	7.4	230	5.5	3.5	1.4	84	490	3.6	.5	838	802
07186550 - LEADVILLE HOLLOW NEAR JOPLIN, MO - MAP NUMBER 28												
MAR , 1976												
09...	4.8	9.0	130	7.4	11	2.0	176	220	8.3	.3	462	477
07187520 - GORDON HOLLOW NEAR JOPLIN, MO - MAP NUMBER 31												
MAR , 1976												
11...	.20	32	15	1.7	1.5	1.6	0	210	2.2	.5	402	307

Table 7.--Water-quality reconnaissance data for tailings areas--Continued

DATE	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	CARBON DIOXIDE (CO2) (MG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)
07186406 - STOUTT BRANCH NEAR PROSPERITY, MO - MAP NUMBER 8											
MAR , 1976											
10...	140	110	30	386	6.9	15.0	9.6	95	7.3	40	27
JUN											
23...	30	21	8	104	6.3	18.0	8.2	85	8.0	30	60
07186416 - MINERAL BRANCH AT PROSPERITY, MO - MAP NUMBER 11											
MAR , 1976											
10...	120	120	3	362	4.9	17.0	8.6	89	81	560	27
07186418 - MINERAL BRANCH AT CARTERVILLE, MO - MAP NUMBER 12											
MAR , 1976											
09...	510	450	61	990	7.1	13.0	9.1	86	9.4	10	25
JUN											
23...	130	110	25	330	6.7	18.5	--	--	9.6	20	74
07186425 - TAILINGS DITCH AT ORONOGO, MO - MAP NUMBER 14											
MAR , 1976											
09...	170	82	90	386	7.3	10.5	9.0	80	8.8	20	1
07186432 - TAILINGS SEEPAGE NEAR ORONOGO, MO - MAP NUMBER 16											
MAR , 1976											
09...	53	42	11	234	6.7	10.0	9.7	86	4.5	0	27
07186440 - TAILINGS DITCH NEAR WEBB CITY, MO - MAP NUMBER 17											
MAR , 1976											
10...	600	530	69	1100	7.2	16.5	8.5	87	8.5	0	60
07186550 - LEADVILLE HOLLOW NEAR JOPLIN, MO - MAP NUMBER 28											
MAR , 1976											
09...	360	210	144	710	7.7	10.5	9.2	82	5.6	10	3
07187520 - GORDON HOLLOW NEAR JOPLIN, MO - MAP NUMBER 31											
MAR , 1976											
11...	44	44	0	495	3.5	11.5	8.7	80	.0	4200	40

Table 7.--Water-quality reconnaissance data for tailings areas--Continued

DATE	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SILVER (AG) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)
07186406 - STOUTT BRANCH NEAR PROSPERITY, MO - MAP NUMBER 8											
MAR , 1976											
10...	2	2	3	40	34	360	.9	12	0	18000	--
JUN											
23...	0	4	3	20	9	90	.4	4	0	5000	4600
07186416 - MINERAL BRANCH AT PROSPERITY, MO- MAP NUMBER 11											
MAR , 1976											
10...	0	8	15	390	1100	300	.1	14	0	19000	--
07186418 - MINERAL BRANCH AT CARTERVILLE, MO - MAP NUMBER 12											
MAR , 1976											
09...	5	7	1	30	3	220	.1	30	0	11000	--
JUN											
23...	0	9	3	90	18	130	.6	12	0	6000	6000
07186425 - TAILINGS DITCH AT ORONOGO, MO - MAP NUMBER 14											
MAR , 1976											
09...	0	2	0	80	0	60	.3	7	0	540	--
07186432 - TAILINGS SEEPAGE NEAR ORONOGO, MO - MAP NUMBER 16											
MAR , 1976											
09...	3	4	0	10	450	90	.0	11	0	24000	--
07186440 - TAILINGS DITCH NEAR WEBB CITY, MO - MAP NUMBER 17											
MAR , 1976											
10...	2	2	0	10	120	40	.1	29	0	18000	--
07186550 - LEADVILLE HOLLOW NEAR JOPLIN, MO - MAP NUMBER 28											
MAR , 1976											
09...	0	0	1	20	0	200	.2	16	0	1700	--
07187520 - GORDON HOLLOW NEAR JOPLIN, MO - MAP NUMBER 31											
MAR , 1976											
11...	5	10	350	360	1300	360	.0	12	0	35000	--

Table 9.--Water-quality data for storm runoff from 7-acre tailings area

07186405 - TAILING AREA STORM RUNOFF - MAP NUMBER 7

DATE	TIME	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED SILICA (SIO2) (MG/L)	DISSOLVED CALCIUM (CA) (MG/L)	DISSOLVED MAGNESIUM (MG) (MG/L)	DISSOLVED SODIUM (NA) (MG/L)	DISSOLVED POTASSIUM (K) (MG/L)	BICARBONATE (HCO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	DISSOLVED CHLORIDE (CL) (MG/L)	DISSOLVED FLUORIDE (F) (MG/L)	DISSOLVED SOLIDS (RESIDUE AT 180 C) (MG/L)
JUN												
23...	0540	.75	1.5	55	.7	1.1	.6	0	220	.7	.2	348
23...	0555	1.3	1.0	24	.2	.6	.4	0	91	.5	.1	150
23...	0610	1.5	1.2	14	.1	.3	.4	0	50	.3	.1	92
23...	0625	1.5	1.4	13	.1	.4	.4	0	42	.4	.1	78
23...	0655	1.6	2.3	9.2	.1	.4	.5	0	38	.4	.1	66
23...	0725	6.2	1.8	9.8	.1	.3	.7	0	23	.4	.1	42
23...	0755	10	2.1	5.6	.1	.3	.6	2	22	.2	.1	38
23...	0825	9.4	3.7	9.9	.2	.4	1.5	0	34	.5	.1	74
23...	0855	7.6	4.8	12	.2	.5	2.1	0	46	.8	1.0	84
23...	0925	4.2	5.2	12	.2	.5	1.9	0	49	.7	.1	98
23...	0955	1.9	5.2	9.9	.4	.5	1.7	0	48	.6	.9	92
23...	1040	.78	7.5	17	.4	.5	1.6	0	69	.8	.1	136
23...	1140	.60	9.7	17	.5	.7	2.4	0	84	1.0	.1	156
23...	1240	.54	12	25	.6	.8	1.5	0	110	.9	.2	204
23...	1440	.44	15	29	.6	.9	1.4	0	140	.9	.2	246
23...	1640	.36	17	27	.5	1.0	1.4	0	150	.7	.2	276
23...	2140	.30	19	31	.6	1.2	.8	0	220	.6	.2	392
24...	0840	.29	25	36	.5	1.5	.8	0	390	.6	.4	664
25...	0840	.15	23	31	.4	1.2	.7	0	250	.6	.2	410
28...	0840	.04	21	34	.4	1.1	.7	0	230	.7	.2	358

DATE	DISSOLVED SOLIDS (SUM OF CONSTITUENTS) (MG/L)	HARDNESS (CA,MG) (MG/L)	NONCARBONATE HARDNESS (MG/L)	TOTAL ACIDITY AS H+ (MG/L)	TOTAL ACIDITY AS CACO3 (MG/L)	ALKALINITY AS CACO3 (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	TEMPERATURE (DEG C)	DISSOLVED OXYGEN (MG/L)	PERCENT SATURATION	DISSOLVED ORGANIC CARBON (C) (MG/L)
JUN												
23...	312	140	140	.1	5.0	0	435	4.2	--	--	--	7.1
23...	135	61	61	.2	10	0	255	4.1	--	--	--	3.2
23...	75	35	35	.1	5.0	0	153	4.2	--	--	--	5.8
23...	67	33	33	.2	10	0	153	4.0	--	--	--	--
23...	59	23	23	.2	10	0	155	3.9	--	--	--	--
23...	41	25	25	.0	.0	0	84	4.5	--	--	--	--
23...	36	14	13	.0	.0	2	72	4.8	--	--	--	--
23...	57	26	26	.1	5.0	0	121	4.3	--	--	--	--
23...	77	31	31	.1	5.0	0	139	4.3	--	--	--	--
23...	79	31	31	.1	5.0	0	153	4.3	--	--	--	--
23...	77	26	26	.1	5.0	0	154	4.2	--	--	--	--
23...	114	44	44	.2	10	0	205	4.1	--	--	--	7.0
23...	139	45	45	.2	10	0	246	4.1	18.0	8.3	86	--
23...	181	65	65	.2	10	0	335	3.8	18.0	--	--	--
23...	222	75	75	.3	15	0	415	3.6	--	--	--	3.5
23...	244	70	70	.4	20	0	435	3.6	23.5	--	--	--
23...	360	80	80	.4	20	0	585	3.6	20.0	--	--	--
24...	658	92	92	.4	20	0	750	3.6	21.0	6.0	67	--
25...	391	79	79	.4	20	0	590	3.6	19.0	--	--	--
28...	355	87	87	.5	25	0	580	3.5	20.0	--	--	--

Table 9.--Water quality data for storm runoff from 7-acre tailings area--Continued

07186405 - TAILING AREA STORM RUNOFF - MAP NUMBER 7

DATE	DIS-SOLVED ALUM-INUM (AL) (UG/L)	DIS-SOLVED CAD-MIUM (CD) (UG/L)	DIS-SOLVED CHRO-MIUM (CR) (UG/L)	DIS-SOLVED COBALT (CO) (UG/L)	DIS-SOLVED COPPER (CU) (UG/L)	DIS-SOLVED IRON (FE) (UG/L)	DIS-SOLVED LEAD (PB) (UG/L)	DIS-SOLVED MAN-GANESE (MN) (UG/L)	DIS-SOLVED MERCURY (HG) (UG/L)	DIS-SOLVED NICKEL (NI) (UG/L)	DIS-SOLVED SILVER (AG) (UG/L)	DIS-SOLVED ZINC (ZN) (UG/L)
JUN												
23...	860	240	0	20	17	30	330	700	.4	24	0	30000
23...	370	130	0	4	12	30	300	240	.5	15	0	16000
23...	180	82	0	14	6	50	280	140	.5	10	0	7800
23...	260	82	0	4	8	330	280	170	.2	8	0	8000
23...	180	71	0	3	7	80	190	120	.5	4	0	7000
23...	70	52	0	2	5	60	78	70	.5	3	0	4800
23...	60	46	0	4	3	40	56	50	.4	2	0	3800
23...	140	54	0	3	7	80	100	80	.3	4	0	6000
23...	200	66	0	4	10	120	110	110	.5	7	0	8400
23...	200	72	0	9	10	150	120	130	.7	6	0	8800
23...	200	70	0	9	10	170	110	120	.8	6	0	8600
23...	340	100	0	0	10	280	160	180	.5	10	0	16000
23...	560	140	0	9	13	250	180	190	.2	11	0	22000
23...	640	160	0	20	16	290	280	280	.2	16	0	28000
23...	800	210	0	13	17	340	280	330	.4	18	0	32000
23...	700	280	0	16	19	290	300	300	.2	15	0	44000
23...	510	540	0	13	23	130	270	340	.2	18	0	84000
24...	0	1400	0	3	50	40	380	420	.2	29	0	200000
25...	240	600	0	9	50	130	400	330	.3	19	0	82000
28...	560	480	0	9	42	210	370	280	.2	22	0	64000

DATE	TOTAL ALUM-INUM (AL) (UG/L)	TOTAL CAD-MIUM (CD) (UG/L)	TOTAL CHRO-MIUM (CR) (UG/L)	TOTAL COBALT (CO) (UG/L)	TOTAL COPPER (CU) (UG/L)	TOTAL IRON (FE) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL MAN-GANESE (MN) (UG/L)	TOTAL MERCURY (HG) (UG/L)	TOTAL NICKEL (NI) (UG/L)	TOTAL SILVER (AG) (UG/L)	TOTAL ZINC (ZN) (UG/L)
JUN												
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	2200	90	10	11	12	3100	920	200	.7	14	0	8000
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	2800	60	10	6	23	14000	2000	60	1.4	6	0	3800
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--

Table 12.--Water-quality reconnaissance data for streams

DATE	INSTAN-TANEOUS DIS-CHARGE (CFS)	DIS-SOLVED SILICA (SIO2) (MG/L)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	DIS-SOLVED MAG-NE-SIUM (MG) (MG/L)	DIS-SOLVED SODIUM (NA) (MG/L)	DIS-SOLVED PO-TAS-SIUM (K) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	DIS-SOLVED CHLO-RIDE (CL) (MG/L)	DIS-SOLVED FLUO-RIDE (F) (MG/L)	DIS-SOLVED SOLIDS (RESI-DUE AT 180 C) (MG/L)	DIS-SOLVED SOLIDS (SUM OF CONSTI-TUENTS) (MG/L)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1												
MAR , 1976												
10...	224	9.7	45	2.1	3.8	1.6	136	8.2	4.9	.2	134	143
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21												
MAR , 1976												
10...	560	9.8	59	2.5	6.1	2.0	130	49	6.3	.5	206	200
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22												
MAR , 1976												
10...	5.8	8.2	16	1.4	2.9	1.7	44	13	3.2	.2	68	69
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29												
MAR , 1976												
10...	40	10	70	4.5	12	2.8	148	81	13	.3	276	267
07186650 - SHORT CREEK AT MO-KANS STATE LINE - MAP NUMBER 30												
MAR , 1976												
09...	37	8.8	54	5.8	7.3	3.0	48	120	5.3	1.7	228	232

DATE	HARD-NESS (CA,MG) (MG/L)	NON-CAR-BONATE HARD-NESS (MG/L)	ALKA-LINITY AS CACO3 (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	DIS-SOLVED OXYGEN (MG/L)	PER-CENT SATUR-ATION	CARBON DIOXIDE (CO2) (MG/L)	SUS-PENDED SEDI-MENT (MG/L)	DIS-SOLVED ALUM-INUM (AL) (UG/L)	TOTAL ALUM-INUM (AL) (UG/L)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1												
MAR , 1976												
10...	120	9	112	266	7.8	9.5	9.2	80	3.4	32	30	800
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21												
MAR , 1976												
10...	160	51	107	370	7.6	11.0	9.3	84	5.2	54	30	1200
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22												
MAR , 1976												
10...	46	10	36	136	7.7	9.0	9.5	82	1.4	12	40	650
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29												
MAR , 1976												
10...	190	69	121	470	7.4	12.5	7.9	74	9.4	19	10	250
07186650 - SHORT CREEK AT MO-KANS STATE LINE - MAP NUMBER 30												
MAR , 1976												
09...	160	120	39	400	5.9	9.5	10.1	88	97	--	320	--

Table 12.--Water-quality reconnaissance data for streams--Continued

DATE	TOTAL ALUMINUM IN BOTTOM MATERIAL (UG/G)	DISSOLVED CADMIUM (CD) (UG/L)	TOTAL CADMIUM (CD) (UG/L)	TOTAL CADMIUM IN BOTTOM MATERIAL (UG/G)	DISSOLVED CHROMIUM (CR) (UG/L)	TOTAL CHROMIUM (CR) (UG/L)	TOTAL CHROMIUM IN BOTTOM MATERIAL (UG/G)	DISSOLVED COBALT (CO) (UG/L)	TOTAL COBALT (CO) (UG/L)	TOTAL COBALT IN BOTTOM MATERIAL (UG/G)	DISSOLVED COPPER (CU) (UG/L)	TOTAL COPPER (CU) (UG/L)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1												
MAR , 1976 10...	3900	1	1	<10	0	<10	<10	1	2	<10	0	2
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21												
MAR , 1976 10...	2100	0	5	20	2	10	20	0	0	<10	0	4
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22												
MAR , 1976 10...	4400	1	1	20	0	<10	<10	0	2	<10	0	1
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29												
MAR , 1976 10...	650	2	7	20	0	<10	20	0	1	<10	1	11
07186650 - SHORT CREEK AT MO-KANS STATE LINE - MAP NUMBER 30												
MAR , 1976 09...	--	6	--	--	0	--	--	4	--	--	1	--

DATE	TOTAL COPPER IN BOTTOM MATERIAL (UG/G)	DISSOLVED IRON (FE) (UG/L)	TOTAL IRON (FE) (UG/L)	TOTAL IRON IN BOTTOM MATERIAL (UG/G)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL LEAD IN BOTTOM MATERIAL (UG/G)	DISSOLVED MANGANESE (MN) (UG/L)	TOTAL MANGANESE (MN) (UG/L)	TOTAL MANGANESE IN BOTTOM MATERIAL (UG/G)	DISSOLVED MERCURY (HG) (UG/L)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1											
MAR , 1976 10...	<10	30	660	6300	4	4	<10	0	50	1700	.1
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21											
MAR , 1976 10...	<10	30	970	7200	0	27	350	80	170	600	.1
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22											
MAR , 1976 10...	<10	50	52	8400	0	3	40	20	20	900	.0
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29											
MAR , 1976 10...	20	50	410	3200	0	27	350	100	110	160	.1
07186650 - SHORT CREEK AT MO-KANS STATE LINE - MAP NUMBER 30											
MAR , 1976 09...	--	440	--	--	8	--	--	200	--	--	.3

Table 12.--Water-quality reconnaissance data for streams--Continued

DATE	TOTAL MERCURY (HG) (UG/L)	TOTAL MERCURY IN BOTTOM MATERIAL (UG/G)	DIS-SOLVED NICKEL (NI) (UG/L)	TOTAL NICKEL (NI) (UG/L)	TOTAL NICKEL IN BOTTOM MATERIAL (UG/G)	DIS-SOLVED SILVER (AG) (UG/L)	TOTAL SILVER (AG) (UG/L)	TOTAL SILVER IN BOTTOM MATERIAL (UG/G)	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	TOTAL ZINC IN BOTTOM MATERIAL (UG/G)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1											
MAR , 1976											
10...	.1	.0	2	13	10	0	0	20	20	30	110
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21											
MAR , 1976											
10...	.1	.1	2	6	10	0	0	<10	700	800	540
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22											
MAR , 1976											
10...	.0	.0	0	4	10	0	0	10	240	300	950
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29											
MAR , 1976											
10...	.1	.8	3	9	<10	0	0	10	500	620	530
07186650 - SHORT CREEK AT MO-KANS STATE LINE - MAP NUMBER 30											
MAR , 1976											
09...	--	--	17	--	--	0	--	--	1600	--	--

Table 13.--Seepage-run data for Center Creek, September 1976

DATE	INSTANTANEOUS DISCHARGE (CFS)	DISSOLVED CALCIUM (CA) (MG/L)	BICARBONATE (HCO3) (MG/L)	DISSOLVED SULFATE (SO4) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS)	PH (UNITS)	DISSOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL LEAD IN BOTTOM MATERIAL (UG/G)	DISSOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	TOTAL ZINC IN BOTTOM MATERIAL (UG/G)
07186200 - CENTER CREEK NEAR FIDELITY, MO - MAP NUMBER 1												
SEP , 1976												
20...	45	55	170	5.3	305	7.9	12	11	20	10	40	50
07186210 - CENTER CREEK BELOW FIDELITY, MO - MAP NUMBER 2												
SEP , 1976												
20...	46	56	172	5.7	309	7.8	10	14	20	10	70	90
07186230 - CENTER CREEK ABOVE GROVE CREEK - MAP NUMBER 3												
SEP , 1976												
21...	46	54	172	5.8	308	7.9	9	8	18	20	20	100
07186250 - GROVE CREEK NEAR SCOTLAND, MO - MAP NUMBER 4												
SEP , 1976												
21...	4.4	86	120	140	910	7.2	5	6	150	190	200	580
07186270 - CENTER CREEK BELOW GROVE CREEK - MAP NUMBER 5												
SEP , 1976												
21...	52	58	164	18	372	7.8	10	6	20	20	40	220
07186400 - CENTER CREEK NEAR CARTERVILLE, MO. - MAP NUMBER 6												
SEP , 1976												
21...	52	59	156	18	371	7.7	1	5	20	30	40	320
07186410 - CENTER CREEK BELOW LAKESIDE, MO - MAP NUMBER 9												
SEP , 1976												
21...	48	60	148	21	380	7.6	7	59	400	60	70	1900
07186412 - CENTER CREEK ABOVE MINERAL BRANCH - MAP NUMBER 10												
SEP , 1976												
21...	56	59	146	21	383	7.7	9	8	200	70	100	1200
07186418 - MINERAL BRANCH AT CARTERVILLE, MO - MAP NUMBER 12												
SEP , 1976												
21...	1.0	260	188	530	1080	7.5	29	20	400	3900	4000	2800
07186422 - CENTER CREEK BELOW MINERAL BRANCH - MAP NUMBER 13												
SEP , 1976												
21...	57	64	148	31	405	7.7	8	22	400	150	200	2500
07186430 - CENTER CREEK AT ORONOGO, MO - MAP NUMBER 15												
SEP , 1976												
21...	59	70	150	47	418	7.7	11	14	--	350	400	2800
07186445 - CENTER CREEK BELOW ORONOGO, MO - MAP NUMBER 18												
SEP , 1976												
22...	55	77	148	63	462	7.7	4	10	320	510	600	2500
07186460 - CENTER CREEK ABOVE CARL JUNCTION, MO - MAP NUMBER 19												
SEP , 1976												
22...	59	74	152	62	455	7.7	5	12	450	500	830	2400
07186470 - CENTER CREEK AT CARL JUNCTION, MO - MAP NUMBER 20												
SEP , 1976												
22...	58	75	152	63	460	7.7	19	13	220	440	450	2200
07186480 - CENTER CREEK NEAR SMITHFIELD, MO. - MAP NUMBER 21												
SEP , 1976												
22...	58	75	152	64	468	7.8	6	14	200	360	400	2400

Table 14.--Seepage-run data for Turkey Creek, September 1976

DATE	INSTAN-TANEOUS DIS-CHARGE (CFS)	DIS-SOLVED CAL-CIUM (CA) (MG/L)	BICAR-BONATE (HCO3) (MG/L)	DIS-SOLVED SULFATE (SO4) (MG/L)	SPE-CIFIC CON-DUCT-ANCE (MICRO-MHOS)	PH (UNITS)	DIS-SOLVED LEAD (PB) (UG/L)	TOTAL LEAD (PB) (UG/L)	TOTAL LEAD IN BOTTOM MA-TERIAL (UG/G)	DIS-SOLVED ZINC (ZN) (UG/L)	TOTAL ZINC (ZN) (UG/L)	TOTAL ZINC IN BOTTOM MA-TERIAL (UG/G)
07186485 - TURKEY CREEK AT DUENWEG, MO - MAP NUMBER 22												
SEP , 1976												
23...	.02	35	106	18	242	7.2	10	4	180	280	330	1400
07186488 - TURKEY CREEK BELOW DUENWEG, MO - MAP NUMBER 23												
SEP , 1976												
23...	3.0	74	176	63	415	7.5	8	11	300	170	240	2800
07186492 - TURKEY CREEK ABOVE JOPLIN, MO - MAP NUMBER 24												
SEP , 1976												
23...	3.1	72	176	55	405	7.5	12	7	150	190	200	2300
07186496 - JOPLIN CREEK AT JOPLIN, MO - MAP NUMBER 25												
SEP , 1976												
23...	4.9	73	134	95	435	7.6	11	97	850	180	800	2800
07186500 - TURKEY CREEK AT JOPLIN, MO - MAP NUMBER 26												
SEP , 1976												
23...	5.0	85	160	100	482	7.5	31	53	320	280	480	2800
07186520 - LONE ELM HOLLOW AT JOPLIN, MO - MAP NUMBER 27												
SEP , 1976												
23...	1.4	160	194	310	1010	7.2	13	17	5000	670	730	2800
07186600 - TURKEY CREEK NEAR JOPLIN, MO - MAP NUMBER 29												
SEP , 1976												
24...	13	96	224	110	660	7.4	11	12	200	60	240	2300

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