U.S. GEOLOGICAL SURVEY APPLIED RESEARCH STUDIES OF THE CHEYENNE RIVER SYSTEM, SOUTH DAKOTA: DESCRIPTION AND COLLATION OF DATA, WATER YEARS 1985-86

Edited by Kimball E. Goddard

U.S. GEOLOGICAL SURVEY

Open-File Report 88-484

Huron, South Dakota
1988

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who may prefer to use inch-pound units rather than International System (SI) units or International System units rather than inch-pound units, the conversion factors for the terms in this report are listed below:

Multiply	By	To obtain
centimeter (cm)	0.06102	inch
gram (g)	0.0022	pound
kilometer (km)	0.6214	mile
liter (L)	0.2642	gallon
meter (m)	3.281	foot
milligram (mg)	0.0000353	ounce
millimeter (mm)	25.4	inch
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
foot per second (ft/s)	0.3048	meter per second
inch	25.4	millimeter
mile (mi)	1.609	kilometer

Convert degrees Celsius (°C) to degrees Fahrenheit (°F) by using the formula:

$$°F = 1.8°C + 32$$

Additional abbreviations:

counts/µs	counts per microsecond
g/L	gram per liter
g/m^2	gram per square meter
µg/g	microgram per gram
µg/L	microgram per liter
µm	micrometer
µM	micromoles
µS	microsiemens
mg/L	milligram per liter
mL	milliliter
mL/min	milliliter per minute
mM	millimoles
mM/g	millimole per gram
mv	millivolts

Use of brand names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

U.S. GEOLOGICAL SURVEY APPLIED RESEARCH STUDIES OF THE CHEYENNE RIVER SYSTEM, SOUTH DAKOTA: DESCRIPTION AND COLLATION OF DATA, WATER YEARS 1985-86

Edited by Kimball E. Goddard

ABSTRACT

The Cheyenne River System in western South Dakota has been impacted by the discharge of about 100 million metric tons of gold-mill tailings to Whitewood Creek near Lead, South Dakota. In April 1985, the U.S. Geological Survey initiated an extensive series of research studies to investigate the magnitude of the impact and to define important processes acting on the contaminated sediments present in the system. The report presents all data collected during the 1985 and 1986 water years for these research studies. Some of the data included have been published previously.

Hydrologic, geochemical, and biologic data are available for sites on Whitewood Creek, the Belle Fourche and Cheyenne Rivers, and for the Cheyenne River arm of Lake Oahe. Data complexity varies from routine discharge and water-quality to very complex photon-correlation spectroscopy and energy-dispersive x-ray analysis. Methods for sample collection, handling and preservation, and laboratory analysis are also presented. No interpretations or complex statistical summaries are included.

INTRODUCTION

Beginning in the 1960's, people became more aware of the serious environmental hazard and economic damage that could result from the continued use of our Nation's rivers and streams for waste disposal. Resulting legislation, such as the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500), the Toxic Substances Control Act of 1976 (P.L. 97-469), and the National Pollutant Discharge Elimination System (NPDES) Permit Program provided the impetus for a nationwide cleanup of rivers and streams. As a result, the quality of the Nation's rivers and streams has improved substantially in several respects, reflected by increased dissolved-oxygen concentrations and decreased bacterial populations, that are largely attributable to measures for controlling point-source discharges and the construction or improvement of wastewater-treatment facilities. However, numerous other water-quality issues remain and the focus of concern is shifting from sewage disposal to control of potentially more hazardous wastes such as toxic metals and synthetic organic compounds.

Recent studies on the geochemical reactions of toxic metals and synthetic organic compounds in river and stream systems have demonstrated that these constituents are commonly associated with river or stream sediments. The extremely low solubilities of some metals, such as mercury and lead, in normal

stream water and the affinity of many synthetic organic compounds for sediments, generally result in very small to undetectable dissolved concentrations of these constituents in surface water. However, these constituents may accumulate in bottom sediments in sufficiently large concentrations so as to allow uptake by aquatic plants, benthic organisms, or bottom-feeding fish. Although toxic constituents concentrated in bottom sediments may be isolated from the environment for long periods by burial, they can be exposed and transported during floods. It is clear that the adsorption of hazardous constituents onto channel bottom sediments exacerbates the difficulty of understanding the processes responsible for the movement and fate of these constituents in river systems.

In 1985, the U.S. Geological Survey initiated the Toxic Substances in Surface Waters and Sediments Thrust Program. The program is designed to: (1) define the occurrence of toxic substances in water, sediment, and biota, (2) conduct research on the transport of toxic substances, and (3) conduct research to improve sampling and analytical methods. In April 1985, the Cheyenne River basin in western South Dakota was selected for study. Investigative efforts at the study site are cooperatively divided between District and National Research Program personnel.

Problem

About 100 million metric tons of finely ground gold-mill tailings were discharged into Whitewood Creek near Lead, South Dakota, between 1876 and 1977. The tailings contained substantial concentrations of arsenic, mercury, and other trace elements resulting in widespread contamination of the alluvial sediments along Whitewood Creek and the Belle Fourche and Cheyenne Rivers (figs. 1 and 2). The primary contaminant is arsenic derived from, or still present as, the sulfide mineral arsenopyrite (FeAsS), a gangue mineral common to the gold-bearing deposits at Lead. The trace elements antimony, cadmium, copper, iron, manganese, mercury, and silver also are associated with the mill tailings and are present in the contaminated alluvial sediments.

The gross contamination of Whitewood Creek and the downstream rivers was alleviated by the discontinuance of tailings discharge in December 1977. However, the huge deposits of contaminated sediments present along Whitewood Creek and the Belle Fourche and Cheyenne Rivers continues to degrade surface water and ground water in the affected portion of the Cheyenne River basin. Because the contaminated sediment deposits were formed by natural surface flow, the contaminated sediments are subject to resuspension and downstream movement, particularly during periods of high discharge when sediment enters the flow from streambed scouring, bank collapse, or by input from overland runoff. Suspended-sediment samples collected from Whitewood Creek and the Belle Fourche and Cheyenne Rivers since 1977 continue to have unusually large concentrations of total arsenic, iron, and manganese. Dissolved arsenic, thought to be derived from alluvial ground-water and desorbed from streambed material, is present in substantial concentrations in Whitewood Creek. Portions of the alluvial aquifers along Whitewood Creek and the Belle Fourche River are contaminated by leachate derived from overlying contaminated sediment deposits.

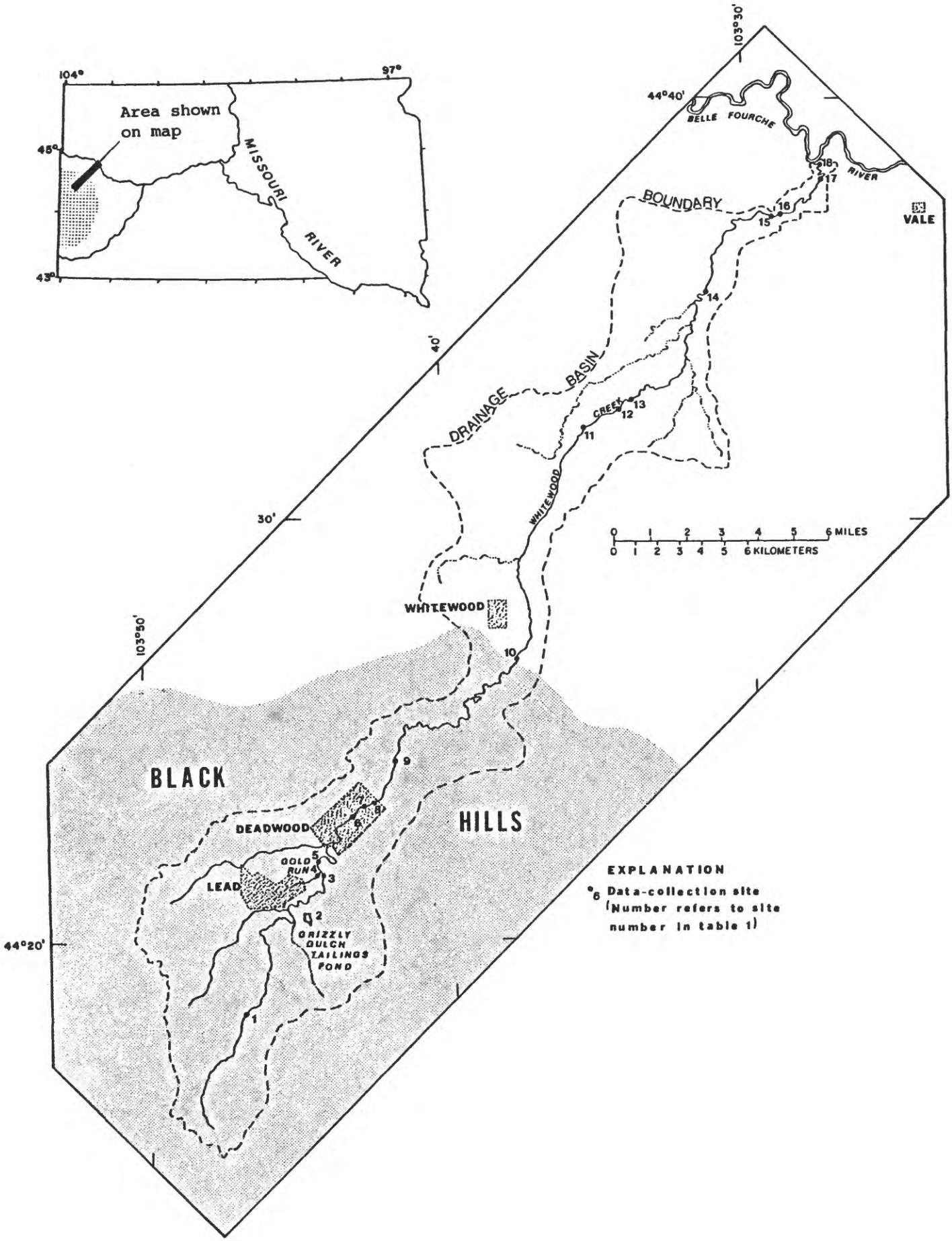

Figure 1.--Data-collection sites within the Whitewood Creek drainage basin.

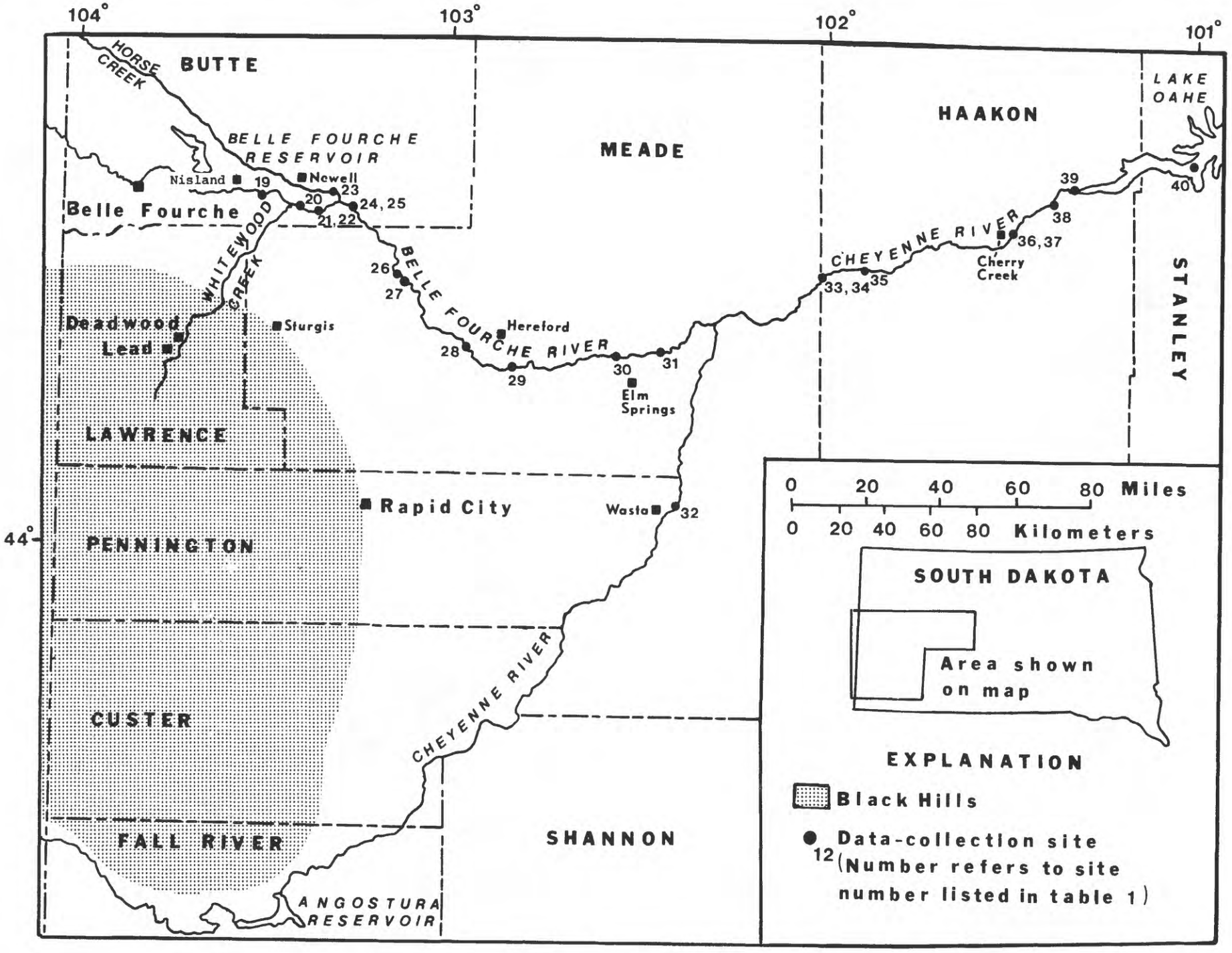

Figure 2.--Data-collection sites on the Belle Fourche and Cheyenne Rivers.

Table 1.--Names of data-collection sites discussed in text. Location of sites 1 to 18 shown in figure 1; location of sites 19-40 shown in figure 2

[Q, continuous discharge; SW, surface-water chemistry; S, suspended-sediment chemistry; BM, bottom-material chemistry; AS, alluvial-sediment chemistry; GW, ground-water chemistry; B, biologic]

Site number	Site name	Date type	Report chapter
1	Whitewood Creek above Lead	SW,BM,B	C,E,J
2	Grizzly Gulch tailings pond	AS	A
3	Whitewood Creek above Gold Run	SW,BM	C,E
4	Gold Run at mouth	SW	E
5	Whitewood Creek below Gold Run	SW,B	E,J
6	Whitewood Creek at Deadwood	SW,B	E,F,J
7	Whitewood Creek above Deadwood STP	SW,B	E,J
8	Whitewood Creek below Deadwood STP	SW,B	E,J
9	Whitewood Creek below Deadwood	SW,BM,B	C,E,J
10	Whitewood Creek above Whitewood	Q,SW,S,BM	A,C,E,F
11	Whitewood Creek near Whitewood	BM	C
12	Whitewood transect one (WW1)	AS	B
13	Berger site	SW,AS,GW,B	A,E,F,G,I,J
14	Whitewood Creek at Custer Camp	MV	C
15	Whitewood Creek above Vale	Q,SW,S,BM,B	A,C,E,I,J
16	Whitewood transect two (WW2)	AS	B
17	Sheeler site	SW,AS,GW,B	A,E,F,G,H,I,J
18	Whitewood Creek near mouth	B	J
19	Belle Fourche River below Nisland	SW,S,BM,B	A,C,E,J
20	Belle Fourche River at Vale	BM	C,F
21	Belle Fourche transect one (BF1)	AS	B
22	Belle Fourche River at old Vale bridge	BM	C
23	Horse Creek above Vale	SW,S	E
24	Belle Fourche River below Vale	S	E
25	Belle Fourche transect two (BF2)	AS	B
26	Belle Fourche River near Sturgis	Q,SW,S,BM	A,C,E
27	Belle Fourche transect three (BF3)	AS	B
28	Belle Fourche River near Hereford	SW, S	A
29	Belle Fourche transect four (BF4)	AS	B
30	Belle Fourche River near Elm Springs	SW,S,BM	A,C,E
31	Belle Fourche transect five (BF5)	AS	B
32	Cheyenne River near Wasta	SW,S	E
33	Cheyenne River transect one (CR1)	AS	B
34	Cheyenne River near Plainview	BM	C
35	Cheyenne River at SD Hwy 34 bridge	B	J
36	Cheyenne River transect two (CR2)	AS	B
37	Cheyenne River at Cherry Creek	Q,SW,S,BM	C,E
38	Cheyenne River at Carlin Flat	SW,S	E
39	Cheyenne River at SD Hwy 63 bridge	BM	C
40	Cheyenne River arm of Lake Oahe	AS	D

Although the magnitude of arsenic and other trace element contamination in the Cheyenne River basin has been documented by previous investigations, many process-oriented questions remain. It is apparent that the original source of arsenic contamination was arsenopyrite present in the tailings discharge at Lead. The current source of contamination is much less obvious because of the dispersed nature of the contaminated sediments. How much of the originally discharged material remains in the basin, how much of the arsenic mass still exists as arsenopyrite, what mechanisms are responsible for arsenic transport, and what are the annual rates of downstream transport, are all questions that remain to be answered. In addition, although it has been documented that dissolved arsenic is present in substantial concentrations in some ground water and in Whitewood Creek, the source of the dissolved arsenic, and the factors controlling the dissolved arsenic concentration, are also not currently understood.

Purpose and Scope

This report presents basic data collected in the 1985 and 1986 water years during U.S. Geological Survey research studies of the tailings contamination in the Cheyenne River basin. The report was prepared so that methodology and data obtained during a wide variety of research studies would be easily available. No interpretations or complex statistical summaries are included. Persons interested in interpretation of these data should contact individual authors who have prepared interpretive reports or papers for most chapters. Some of the data included in this report have been previously published.

Chapter A. Geochemical Characteristics of Contaminated Sediments from Deposits along Whitewood Creek

By Thomas E. McKallip, Kimball E. Goddard, Ray W. Wuolo, and Reinhard W. Leinz

PHYSICAL AND CHEMICAL CHARACTERISTICS

Sample Collection and Handling Procedures

Four sediment samples, considered to be representative of the contamination problem in the Whitewood Creek system, were collected in early April 1986. Two of the samples were mill tailings collected from the Grizzly Gulch tailings disposal pond while the second pair were highly contaminated sediments collected from deposits along Whitewood Creek. The sample number, description, and location are listed in table 2. The two contaminated sediment samples were collected from sites at which there are additional hydrologic and geochemical data available.

Sediment samples were collected by hand using a small epoxy-covered metal trowel. Samples were placed directly into acid-rinsed wide-mouth gallon bottles. The samples were air-dried on plastic plates, then stored at room temperature in the original field-sample containers until analysis.

Table 2.--Sample number, source, description, and location for sediment samples collected in April 1986

Sample number	Source	Description	Location
1	Grizzly Gulch tailings pond	Black sand	44°19'40" 103°44'15" T4N R3E Sec. 3 SE¼SE¼
2	Grizzly Gulch tailings pond	Gray fine silt	44°19'10" 103°44'05" T4N R3E Sec. 10 NE¼NE¼
3	Whitewood Creek (Berger site)	Blue-gray very fine silt	44°33'02" 103°32'55" T7N R5E Sec. 19 NE¼SE¼
4	Whitewood Creek (Sheeler site)	Red-orange sandy silt	44°38'24" 103°27'23" T8N R5E Sec. 24 NW¼SE¼

Analytical Procedures and Results

Total digestion analysis was performed on subsamples from the bulk samples by J. Motooka of the U.S. Geological Survey, Geologic Division, Branch of Exploration Geochemistry, Arvada, Colorado. Digestion was by $HF/HClO_4/HNO_3$ acid with detection by inductively coupled plasma atomic emission spectrometer. Analytical results are listed in table 3.

Table 3.--Total analysis of representative tailings and contaminated sediment samples

[%, weight percent; µg/g, micrograms per gram; <, less than]

Sample number[1]	Iron (%)	Manganese (%)	Aluminum (%)	Titanium (%)	Calcium (%)	Magnesium (%)	Potassium (%)	Sodium (%)	Arsenic (µg/g)	Antimony (µg/g)
1	17	0.55	2.3	0.09	1.4	2.4	0.65	0.11	3,500	<30
2	21	.57	3.3	.13	2.1	2.8	1.08	.14	1,800	<30
3	22	.65	4.1	.21	2.2	4.0	.84	.12	4,200	<30
4	17	.32	1.7	.14	1.1	.8	.88	.19	3,000	<30

Sample number[1]	Barium (µg/g)	Beryllium (µg/g)	Bismuth (µg/g)	Boron (µg/g)	Cadmium (µg/g)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Lanthanum (µg/g)	Lead (µg/g)	Lithium (µg/g)
1	100	0.8	<50	23	5.6	73	34	21	76	32	<30	13
2	250	1.4	<50	21	3.0	66	46	21	87	27	<30	19
3	230	1.0	<50	23	3.3	69	55	15	120	30	<30	20
4	250	.7	<50	27	4.4	63	21	8.3	43	24	<30	9.4

Sample number[1]	Molybdenum (µg/g)	Nickel (µg/g)	Niobium (µg/g)	Phosphorus (µg/g)	Strontium (µg/g)	Tin (µg/g)	Tungsten (µg/g)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)	Zirconium (µg/g)
1	<4	33	<25	590	32	<18	<18	39	9.5	93	13
2	<4	38	<25	550	120	<18	<18	67	9.5	150	23
3	<4	20	<25	710	56	<18	<18	77	9.2	160	16
4	<4	14	<25	440	53	<18	<18	42	9.8	64	20

[1]Sample number refers to number listed in table 2.

Subsamples from the bulk samples were further split by specific gravity and magnetic properties by John Unruh, U.S. Geological Survey, Geologic Division, Arvada, Colorado. Samples were washed first in water to remove clay-size particles which will not gravity settle in bromoform. Samples were then split into light (specific gravity less than 2.8) and heavy (specific gravity greater than 2.8) fractions using bromoform flotation. The heavy fraction was further split into magnetic, weakly magnetic, and non-magnetic fractions. The resultant splits underwent semi-quantitative analysis using D. C. Arc spectrography. The results of the separations and the analytical results are listed in table 4. The elements antimony, bismuth, cadmium, molybdenum, niobium, thorium, tin, tungsten, and zinc were included in the analysis but are not listed in table 4 because they were below the detection limits.

Subsamples from the bulk samples underwent sequential digestion and arsenic analysis by R. F. Sanzolone, U.S. Geological Survey, Geologic Division, Arvada, Colorado. The sequential digestion procedure involved attacking the sample with increasing strength acids to determine what fraction of the sample contained arsenic. Arsenic concentrations were determined using an inductively coupled plasma atomic emission spectrometer. The sequential digestion procedure used and the analytical results are listed in table 5.

ADSORPTION/DESORPTION CHARACTERISTICS

Sample Collection and Handling Procedures

Sediments for adsorption/desorption studies were collected from the streambank and flood plain of Whitewood Creek at a location considered typical of the lower portion of the drainage basin (Wuolo, 1986). The location, commonly referred to as the Berger site by previous investigators, is shown in figure 1 and listed in table 1. The Berger site has been extensively studied (Stach and others, 1978; Cherry and others, 1984; and Goddard, in press). Large amounts of additional hydrologic and geochemical data are available.

In October 1985, four large samples were collected at the Berger site for the characterization of physical and chemical properties and adsorption/desorption. Three samples of contaminated sediment (Tc-1, Tc-2, Tc-3) and one of uncontaminated sediment (Ac-1) were obtained using an acid-rinsed plastic spatula. About 7 inches of surface material was removed before collection. Samples were stored in large sealable plastic bags and frozen for storage. In order to simulate field conditions in the column leaching experiments, seven additional samples were collected adjacent to the large adsorption/desorption samples. Permeability samples were collected by driving a shelby-tube sampler vertically (flood plain) or horizontally (streambank) into sediments.

Table 4.--Semi-quantitative D.C. arc spectrographic analysis of specific gravity and magnetic separation splits of representative tailings and contaminated sediment samples

[µg/g, micrograms per gram; <, less than; >, greater than; ND, not detected; --, not analyzed]

Sample number[1]	Split	Percent of sample	Iron (%)	Manganese (%)	Titanium (%)	Calcium (%)	Mangnesium (%)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Boron (µg/g)	Chromium (µg/g)	Cobalt (µg/g)
1	Clay[2]	0	--	--	--	--	--	--	--	--	--	--	--
	Lights[3]	44	2	0.07	0.1	0.5	0.7	<500	100	<2	20	<20	ND
	Heavies[3]												
	Magnetic	5	50	.2	.15	.5	1.5	1,000	300	<2	20	50	50
	Weakly-magnetic	48	30	>1.0	.3	1.5	5.0	3,000	200	<2	20	50	20
	Non-magnetic	1	20	.01	.07	.7	.05	>20,000	200	<2	20	<20	200
2	Clay[2]	21	15	.5	.2	1.5	2.0	1,500	500	3	30	50	15
	Lights[3]	43	2	.07	.07	.5	.5	--	70	<2	20	<20	ND
	Heavies[3]												
	Magnetic	2	50	.2	.05	.5	1.0	<500	100	<2	20	50	50
	Weakly-magnetic	31	20	.7	.2	1.0	5.0	500	200	2	20	50	20
	Non-magnetic	1	7	.01	.1	1.5	.1	>20,000	500	<2	20	<20	50
3	Clay	100	10	.3	.2	1.0	2.0	3,000	200	<2	20	50	15
4	Clay[2]	12	20	.1	.2		.3	5,000	700	<2	30	30	ND
	Lights[3]	60	7	.1	.1	.7	.2	2,000	200	<2	20	<20	ND
	Heavies[3]												
	Magnetic	1	30	.2	.2	.3	.7	3,000	150	<2	20	30	15
	Weakly-magnetic	23	20	.7	.3	.3	1.0	3,000	200	<2	30	50	15
	Non-magnetic	1	2	.02	.5	.1	.05	1,000	1,500	<2	30	<20	ND

Table 4.--Semi-quantitative D.C. arc spectrographic analysis of specific gravity and magnetic separation splits of representative tailings and contaminated sediment samples--Continued

Sample number[1]	Split	Copper (µg/g)	Gold (µg/g)	Lanthanum (µg/g)	Lead (µg/g)	Nickel (µg/g)	Scandium (µg/g)	Silver (µg/g)	Strontium (µg/g)	Vanadium (µg/g)	Ytterbium (µg/g)	Zirconium (µg/g)
1	Clay[2]	--	--	--	--	--	--	--	--	--	--	--
	Lights[3]	10	ND	ND	ND	<10	ND	ND	ND	50	<20	70
	Heavies[3]											
	Magnetic	700	ND	<50	<20	200	ND	1.5	ND	50	20	500
	Weakly-magnetic	150	ND	<50	<20	30	10	ND	ND	70	30	100
	Non-magnetic	100	ND	ND	100	50	ND	3	ND	20	20	100
2	Clay[2]	150	ND	50	50	15	15	<1	300	150	30	100
	Lights[3]	10	ND	ND	ND	<10	ND	ND	ND	30	<20	50
	Heavies[3]											
	Magnetic	1,000	ND	50	<20	200	ND	5	ND			ND
	Weakly-magnetic	100	ND	50	<20	20	10	<1	ND	100	50	70
	Non-magnetic	100	ND	ND	30	20	ND	2	ND	20	30	100
3	Clay	150	ND	70	<20	<10	15	<1	ND	150	30	100
4	Clay[2]	100	ND	70	70	<10	<10	5	ND	100	20	100
	Lights[3]	50	ND	50	<20	<10	ND	1	ND	50	<20	70
	Heavies[3]											
	Magnetic	70	20	70	<20	<10	<10	2	ND	100	30	150
	Weakly-magnetic	70	ND	100	<20	10	15	<1	ND	100	70	150
	Non-magnetic	<10	ND	ND	ND	ND	ND	ND	ND	50	30	>2,000

[1]Sample number refers to number listed in table 2.
[2]Clay-size fraction obtained from flotation in water. This procedure is not quantitative and should be considered a rough estimate.
[3]Lights are non-clay fraction with a specific gravity of less than 2.8. Heavies are non-clay fraction with a specific gravity of more than 2.8.

Table 5.--Sequential digestion procedure and arsenic concentrations measured in representative tailings and contaminated sediment samples

[<, less than]

Digestion	Recovered fraction	Arsenic concentration in fraction (micrograms per gram)			
		Sample number[1]			
		1	2	3	4
0.1M KH_2PO_4	Water soluble/ exchangeable	<250	<250	<250	250
4 N HCl	Oxide/carbonate	<250	<250	<250	3,000
$KClO_3$/HCl	Sulfide	3,300	1,600	3,400	<250
HF/$HClO_4$/HNO_3	Silicates	<250	<250	<250	<250
HF/$HClO_4$/HNO_3	Total	3,700	1,600	3,700	3,000

[1]Sample number refers to number listed in table 2.

Analysis of Physical and Chemical Properties

Mineralogy of these samples was determined by x-ray diffraction analysis of freeze-dried splits. Results are reported in weight fractions and variances for major minerals (table 6) and total oxide contents (table 7).

Grain-size analysis of sample splits of 200 g of Ac-1, Tc-1, Tc-2, and Tc-2 was done using the sample pretreatment procedure outlined by Bodman (1928). The greater than 62-µm fraction was dried and mechanically separated by sieving. The less than 62-µm fraction was separated down to 2 µm using the pipet method outlined by Friedman and Johnson (1982). The results of grain-size analysis are given in table 8.

Permeabilities were determined by converting the shelby sampler into a permeameter. Hydrologic conductivity was calculated using variations of Darcy's law as proposed by Fetter (1980). Porosities were determined by extruding saturated samples, weighing them, and subtracting the weight of the sample after it was oven dried for 26 hours at 125 °C. Permeability and porosity results are given in table 9.

Table 6.--Mineral composition of samples from the Berger site (October 1985), as determined by x-ray diffraction analysis

[--, less than the x-ray detection limit of about 1 percent]

	Sample identifier							
	AC-1		TC-1		TC-2		TC-3	
Mineral	Weight %	Variation ± %	Weight %	Variation ± %	Weight %	Variation ± %	Weight %	Variation ± %
Illite	11	1.4	--	--	2.6	0.36	--	--
Grunerite	--	--	2.3	0.31	4.4	.57	4.6	0.57
Chlorite	--	--	3.7	.67	12	1.9	11	1.8
Jarosite	.45	.06	--	--	.94	.13	2.5	.32
Quartz	52	4.3	64	3.8	56	2.7	50	2.9
Oligoclase	4.3	.58	2.7	.38	1.9	.26	2.1	.28
Dolomite	12	1.7	.5	.08	.49	.08	--	--
Hematite	--	--	2.1	.46	.72	.16	1.7	.36
Limonite[1]	3.1	2.8	16	2.2	22	2.5	20	2.6
Gupsum	.58	.12	.45	.09	--	--	3.0	.57
Otyhoclase	5.7	1.9	7.9	2.5	--	--	.92	.33
Kaolinite	3.5	.93	--	--	--	--	--	--
Mscovite	--	--	--	--	--	--	4.4	.59
Calcite	7.7	4.1	--	--	--	--	--	--
Sum	100.63		99.7		101.1		100.2	

[1]Amorphous.

Table 7.--Weight percent of major oxides for samples from the Berger site, as determined by x-ray diffraction analysis (October 1985)

Oxide	Sample identifier			
	AC-1	TC-1	TC-2	TC-3
	Weight %	Weight %	Weight %	Weight %
SiO_2	65	73	64	60
Al_2O_3	6.7	3.4	4.2	4.9
No_2O	.64	.43	.23	.36
K_2O	1.6	1.0	.24	.63
CaO	8.1	.53	.42	1.3
FeO	.45	1.4	3.3	3.3
Fe_2O_3	3.2	15	18.7	19
MgO	2.6	1.0	3.0	2.8
H_2O	1.9	2.8	4.7	5.2
CO_2	8.9	.23	.23	.02
SO_3	.41	.20	.30	2.2
MnO	.13	.12	.36	.35
TiO_2	.06	.02	.04	.04
PbO	0	0	0	0
NiO	.01	0	0	0
CuO	0	0	0	0
V_2O_3	0	0	0	0
P_2O_5	.01	.05	.06	.06
Cr_2O_3	0	0	0	.03
As_2O_3	0	0	0	0
MnO_2	0	0	0	0
BaO	0	.01	0	.02
SrO	0	0	0	0
Li_2O	0	0	0	0
ZnO	0	0	0	0
Sum	99.9	99.9	99.9	99.9

Table 8.--Grain-size analysis of samples from the Berger site (October 1985)

Micrometers	Method	Mass of size fraction for sample identifier (grams)			
		AC-1	TC-1	TC-2	TC-3
1,000					
	Sieve	0.00	1.07	0.15	0.00
710					
	do.	.00	2.57	.15	.00
500					
	do.	.00	9.69	.40	.08
420					
	do.	.25	6.76	.49	.18
300					
	do.	1.02	35.84	.82	.93
210					
	do.	2.93	31.23	2.09	1.67
177					
	do.	3.16	11.03	2.57	2.02
149					
	do.	5.45	8.52	4.02	3.42
125					
	do.	2.64	2.72	11.72	5.75
74					
	do.	40.73	9.24	38.38	28.65
63					
	Pipette	68.5	13.5	24.0	24.0
31					
	do.	49.0	9.5	20.0	7.5
15.6					
	do.	44.5	7.0	14.5	5.5
7.8					
	do.	42.0	4.5	14.5	4.0
3.9					
	do.	27.0	4.5	9.0	3.5
2.0					
	do.	8.0	3.0	8.0	1.0

Table 9.--Summary of permeability test results of samples from the Berger site (October 1985)

Sediment type	Sampling orientation	Porosity (percent)	Hydraulic conductivity (feet per second)
Uncontaminated	Horizontal	49	1.90×10^{-7}
Contaminated	do.	37	4.92×10^{-5}
Do.	do.	52	1.80×10^{-7}
Do.	do.	56	3.28×10^{-5}
Do.	Vertical	47	1.97×10^{-6}
Do.	do.	61	2.46×10^{-4}
Do.	do.	59	5.91×10^{-6}

Determination of Adsorption/Desorption Characteristics

In preparation for batch experiments, freeze-dried splits of Ac-1 and Tc-2 were sieved through a 500-µm polypropolene screen, and the coarser fraction was discarded. Samples were handled with plastic spatulas. The average major ion concentrations in the alluvial ground water are known from previous studies by Cherry and others (1984), Fox Associates (1984), and Goddard (in press). These ion concentrations were simulated using reagent-grade compounds. Stock solution for As+3 and As+5 were prepared with reagent grade $NaAsO_2$ and $Na_2HAsO_4 \cdot 7H_2O$ daily in bottles rinsed and soaked in 3 percent nitric acid overnight.

Reaction vessels were 250-mL polypropylene bottles that had been acid rinsed, double rinsed in distilled water, and soaked overnight in distilled water prior to each use. Solid and liquid were combined in the reaction vessel. An aliquot of the appropriate arsenic species was pipetted into the vessel to obtain the desired arsenic concentration. The pH of the contents of each reaction vessel was titrated to the desired pH by the addition of a small aliquot of 10 percent NaOH or 10 percent HCL and the vessel was shaken for one hour in a wrist-action shaker. The pH was remeasured and adjusted as necessary. The unadjusted redox potential was recorded with a combination platinum electrode, but redox potential is reported with respect to a standard hydrogen electrode. Temperature also was recorded.

Redox potential and pH were measured in a glove bag filled with nitrogen gas to prevent atmospheric oxygen from entering the sample. The solution was filtered through a 0.45-µm cellulose-nitrate membrane filter into 250-mL, acid-rinsed bottles using a peristaltic pump and preserved with nitric-acid for arsenic analysis. Samples used for sulfate analysis were filtered into bottles not rinsed with acid and were not preserved with acid.

All filtered samples were sent to the U.S. Geological Survey Water Resources Division Central Laboratory in Arvada, Colorado, for arsenic and sulfate analysis. Arsenic analyses were by atomic-adsorption spectroscopy following hydride generation. Sulfate analyses were by turbidimetric methods. Detection limits for arsenic and sulfate were 1 µg/L and 0.2 mg/L respectively (Feltz and Anthony, 1985).

Adsorption characteristics of the reaction vessels were determined by using 200 mL of simulated water as a blank and shaking the sample for 24 hours at fixed, various pHs (table 10). Based on previous work by Olsen and Watanabe (1957) and Frost and Griffen (1977), a sediment-to-liquid ratio of 1:20 was decided upon for the remaining batch experiments. The effect of varying the solid-to-liquid ratio is shown in table 11.

Batch experiments were run with contaminated sediment (Tc-2) at varying durations to determine the effect equilibrium time on adsorption. The pH of each sample was adjusted to 7.0 ±0.3 prior to shaking. The results are contained in table 12.

The effect of pH on adsorption was explored for both uncontaminated and contaminated sediments at four different concentrations of As(III) and As(V). Solid and simulated water were allowed to equilibrate for about 1 hour before the pH was adjusted. A final equilibration period of 1 hour was allowed and the pH was "fine-tuned" to ±0.3 pH units from the desired pH values of 3.5, 6.5, 9.5, and 12.5.

Various initial As^{+3} and As^{+5} concentrations were employed. Shake time was 24 hours. Initial SO_4 concentration was 656 mg/L. The solution's pH, Eh, and temperature were measured prior to filtration and the results are listed in tables 13 and 14.

The effect of sulfate concentration on arsenic adsorption was examined in batch experiments with both the uncontaminated sediment (Ac-1) and contaminated sediment (Tc-2) samples. Initial sulfate concentrations were varied. As+5 was used because its ionic character is more like sulfate than As+3 (Ferguson and Gavis, 1972). Results are listed in table 15.

Contaminated sediment samples were used in duplicate batch experiments to determine the variability of adsorption among samples and sample splits. Final arsenic and sulfate concentration are analyzed for. Results are listed in table 16.

Partical-size splits of both the uncontaminated sediment (Ac-1) and contaminated sediment (Tc-2) were obtained using polypropylene sieves. Batch experiments using both As+3 and As+5 initial concentrations were run to determine the effect of grain size on adsorption. Results are listed in table 17.

Table 10.--Reaction vessel adsorption characteristics of contaminated sediment samples from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius. Initial sulfate concentration = 656 mg/L; shake time = 24 hours]

Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
100	100	+3	3.6	6.1	356	321	18	19
100	97	+3	6.7	9.0	324	121	18	19
100	110	+3	9.1	9.4	249	86	18	19
100	90	+5	3.6	5.7	356	346	18	19
100	100	+5	6.7	7.5	324	186	18	19
100	110	+5	9.1	8.3	249	96	18	19

Table 11.--The effect of solid/liquid ratio on adsorption of contaminated sediment samples from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius. Initial sulfate concentration = 656 mg/L]

Solid liquid ratio	Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
1:2	100,000	110	+5	7.0	4.6	416	436	18	19
1:10	100,000	130	+5	7.0	6.0	346	396	18	19
1:20	100,000	490	+5	7.0	6.0	346	396	18	19
1:50	100,000	6,700	+5	7.1	6.3	346	396	18	19

Table 12.--Equilibrium time of adsorption of contaminated sediment samples from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius; --, not analyzed. Initial sulfate concentration = 656 mg/L]

Shake time (hours)	Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
3.13	50,000	--	+3	7.2	7.3	291	308	15	15
10.22	50,000	1,500	+3	7.3	7.1	291	296	15	18
51.17	50,000	--	+3	7.5	6.0	321	346	17	18
73.42	50,000	1,200	+3	7.4	5.8	321	360	17	19
3.13	50,000	140	+5	7.4	6.9	291	298	15	15
10.22	50,000	--	+5	7.4	6.6	281	341	15	18
51.17	50,000	110	+5	7.5	6.6	296	356	17	18
73.42	50,000	9	+5	7.4	5.8	296	355	17	19

Table 13.--The effect of pH on the arsenic adsorption/desorption of uncontaminated sediments (Ac-1) from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius; --, not speciated. Initial sulfate concentration = 656 mg/L]

Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
0	82	--	3.2	5.4	525	406	19	18
0	3	--	5.6	6.4	456	436	18	18
0	18	--	9.8	9.2	206	231	18	18
0	110	--	13.0	12.8	61	136	18	18
50	16	+3	3.3	5.5	535	426	19	18
50	7	+3	6.2	6.5	445	356	19	18
50	11	+3	9.8	9.1	276	226	18	18
50	52	+3	13.0	12.7	71	111	18	18
300	83	+3	3.4	5.5	545	366	19	18
300	11	+3	5.9	7.8	346	216	18	18
300	20	+3	9.9	9.2	206	236	18	18
300	58	+3	13.0	13.0	91	86	18	18
5,000	1,800	+3	3.0	5.3	515	366	19	18
5,000	1,600	+3	5.7	7.9	346	229	18	18
5,000	1,100	+3	9.6	9.3	241	211	18	18
5,000	5,100	+3	13.0	12.8	71	81	18	18
50	16	+5	2.9	5.9	545	406	19	18
50	5	+5	6.2	6.4	421	401	18	18
50	50	+5	9.6	9.2	236	236	18	18
50	75	+5	13.1	12.9	96	136	18	18
300	30	+5	3.1	5.4	535	436	19	18
300	5	+5	5.7	7.4	331	231	18	18
300	20	+5	9.8	9.0	211	246	18	18
300	47	+5	13.1	12.4	81	126	18	18
5,000	280	+5	3.0	5.4	525	416	19	18
5,000	810	+5	5.7	7.8	351	216	18	18
5,000	900	+5	9.8	9.2	211	236	18	18
5,000	570	+5	12.8	12.7	66	94	18	18

Table 14.--The effect of pH on the arsenic adsorption/desorption of contaminated sediments (Tc-2) from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius; --, not speciated. Initial sulfate concentration = 656 mg/L]

Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
0	31	--	3.4	3.5	536	506	18	18
0	6	--	6.9	4.8	416	546	18	18
0	67	--	9.6	8.2	236	246	18	18
0	19,000	--	12.9	11.6	111	151	18	18
50	51	+3	3.6	3.5	545	466	19	18
50	4	+3	3.6	3.5	545	466	19	18
50	10	+3	9.4	8.3	166	156	18	18
50	7,000	+3	12.5	11.5	106	156	18	18
300	35	+3	3.5	3.5	545	466	19	18
300	7	+3	7.1	4.9	456	546	18	18
300	8	+3	9.5	8.6	176	284	18	18
300	8,900	+3	12.6	11.5	96	146	18	18
5,000	690	+3	3.4	3.4	536	501	18	18
5,000	120	+3	6.6	4.9	416	566	18	18
5,000	13	+3	9.4	8.4	186	246	18	18
5,000	21,000	+3	12.9	12.0	131	141	18	18
50	30	+5	3.5	3.5	545	496	19	18
50	10	+5	6.8	4.9	446	536	18	18
50	8	+5	9.4	9.0	181	266	18	18
50	12,000	+5	12.6	11.1	109	186	18	18
300	24	+5	3.2	3.4	545	506	19	18
300	5	+5	6.5	4.7	406	556	18	18
300	8	+5	9.2	8.7	191	306	18	18
300	20,000	+5	9.2	8.7	191	306	18	18
5,000	30	+5	3.5	3.5	426	511	18	18
5,000	4	+5	7.0	5.0	446	541	18	18
5,000	10	+5	9.4	8.8	181	326	18	18
5,000	33,000	+5	13.2	12.7	76	96	18	18

Table 15.--The effect of sulfate on adsorption of uncontaminated (Ac-1) and contaminated (Tc-2) sediments from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius]

Sample identifier	Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Initial sulfate concentration (mg/L)	Final sulfate concentration (mg/L)	Initial pH	Final pH	Final Eh (mv)	Initial Eh (mv)	Initial temperature (°C)	Final temperature (°C)
Ac-1	300	13	0	110	7.4	7.1	306	386	18	18
Tc-2	300	3	0	330	7.8	6.4	335	276	18	18
Ac-1	300	8	1,000	1,400	7.3	7.0	311	366	18	18
Tc-2	300	4	1,000	1,500	7.7	6.0	348	291	18	18
Ac-1	300	7	3,000	3,200	7.2	7.0	316	386	18	18
Tc-2	300	5	3,000	3,200	7.9	5.8	366	278	18	18
Ac-1	300	21	6,000	6,300	7.4	7.3	316	356	18	18
Tc-2	300	6	6,000	11,000	8.2	6.0	383	306	18	18

Table 16.--Adsorption/desorption variability of contaminated sediments from the Berger site (October 1985)

[µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius]

Sample identifier	Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial sulfate concentration (mg/L)	Final sulfate concentration (mg/L)	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
Tc-2	300,000	5	+5	656	530	7.7	5.8	309	466	18	18
Tc-2	300,000	5	+5	656	520	7.7	5.7	308	416	18	18
Tc-2	300,000	12	+5	656	550	7.7	5.9	311	426	18	18
Tc-2	300,000	5	+5	656	460	7.8	5.8	310	466	18	18
Tc-1	300,000	18	+5	656	800	7.8	6.4	336	426	18	18
Tc-3	300,000	7	+5	656	1,700	8.0	5.5	326	216	18	18
Tc-3	300,000	7	+3	656	1,700	7.4	5.0	349	466	18	18
Tc-1	300,000	15	+3	656	1,800	8.0	6.1	306	446	18	18

Table 17.--The effect of grain size on the adsorptive properties of uncontaminated (Ac-1) and contaminated sediments (Tc-2) from the Berger site (October 1985)

[µm, micrometers; µg/L, micrograms per liter; mg/L, milligrams per liter; mv, millivolts; °C, degrees Celsius; <, less than. Initial sulfate concentration = 656 mg/L]

Sample identifier	Grain size (µm)	Initial arsenic concentration (µg/L)	Final arsenic concentration (µg/L)	Arsenic species	Initial pH	Final pH	Initial Eh (mv)	Final Eh (mv)	Initial temperature (°C)	Final temperature (°C)
Ac-1	1,000-500	50,000	35,000	+3	7.0	7.5	271	286	19	17
Ac-1	500-100	50,000	38,000	+3	7.0	7.6	246	286	19	17
Ac-1	100-63	50,000	28,000	+3	7.1	7.3	246	281	19	17
Ac-1	<63	50,000	31,000	+3	7.2	7.6	256	266	19	17
Ac-1	1,000-500	50,000	32,000	+5	7.1	7.6	286	276	19	17
Ac-1	500-100	50,000	34,000	+5	7.1	7.6	281	276	19	17
Ac-1	100-63	50,000	37,000	+5	7.0	7.6	296	286	19	17
Ac-1	<63	50,000	35,000	+5	7.0	7.5	306	296	19	17
Tc-2	1,000-500	50,000	460	+3	7.3	5.8	396	411	18	17
Tc-2	500-100	50,000	1,300	+3	7.3	5.5	346	426	18	17
Tc-2	100-63	50,000	24,000	+3	7.2	5.6	356	416	18	17
Tc-2	<63	50,000	550	+3	7.6	6.2	366	401	18	17
Tc-2	1,000-500	50,000	36	+5	7.5	5.6	396	421	18	17
Tc-2	500-100	50,000	23	+5	7.6	5.4	416	436	18	17
Tc-2	100-63	50,000	54	+5	7.6	5.7	426	416	18	17
Tc-2	<63	50,000	30	+5	7.2	6.2	406	406	18	17

Foot-long columns made from PVC pipe were rinsed thoroughly and soaked overnight in distilled water. Uncontaminated (Ac-1) and contaminated (Tc-2) freeze-dried sediment was sieved with a 1-mm polypropylene screen and hand packed in the columns using increments of 10 g of sediment. Resultant permeability approximated field values. Column tops and bottoms were packed with 0.25 inch of glass wool.

Columns were first saturated for 7 days under constant head by water with varied sulfate concentrations, and the leachate was sampled for arsenic. Then water containing varied arsenic and sulfate concentrations was fed to the columns under constant head. Periodically, lab parameters were measured and leachate was sampled for arsenic analysis. Sediment porosities were measured after completion of the experiment. Column hydraulic characteristics are listed in table 18. Results of column experiments are listed in tables 19 and 20.

Table 18.--Hydraulic characteristics, in columns, of uncontaminated (Ac-1) and contaminated (Tc-2) sediments from the Berger site (October 1985)

[ft^3/s, cubic feet per second; ft/s, feet per second]

Column	Deposit	Pore volume (ft^3/s)	Porosity (%)	Hydraulic conductivity (ft/s)
1	Ac-1	4.802×10^{-3}	0.50	9.51×10^{-7}
2	Ac-1	4.346×10^{-3}	.44	2.79×10^{-7}
3	Ac-1	4.717×10^{-3}	.48	3.346×10^{-6}
4	Ac-1	4.799×10^{-3}	.48	8.53×10^{-6}
5	Tc-2	6.073×10^{-3}	.62	1.94×10^{-5}
6	Tc-2	5.897×10^{-3}	.58	8.86×10^{-6}
7	Tc-2	5.720×10^{-3}	.57	1.48×10^{-5}
8	Tc-2	6.002×10^{-3}	.60	3.543×10^{-5}

Table 19.--Adsorption/desorption of uncontaminated sediment (Ac-1) from the Berger site (October 1985) under near field-flow conditions

[mg/L, milligrams per liter; µg/L, micrograms per liter; mv, millivolts; mL, milliliters]

Reservoir characteristics												
Sulfate concen-tration (mg/L)	Arsenic species	Arsenic concen-tration (µg/L)	pH	Eh (mv)	Column	Arsenic concen-tration (µg/L)	Pore volume eluted (mL)	Volume eluted (mL)	Time (hours)	pH	Eh (mv)	Hydraulic head (inches)
656	--	0	6.9	310	1	8	0.0	0.0	0.0	7.5	200	11.4
						9	.73	100.0	41.3	7.1	215	11.4
						--	1.12	152.0	112.5	7.3	195	10.6
						34	1.97	260.0	229.5	7.3	235	13.8
656	+3	5,000	6.9	302	2	5	.0	.0	.0	7.4	225	8.3
						13	1.18	145.0	48.8	7.1	195	8.3
						--	2.07	255.0	88.5	7.2	185	7.9
						8	2.76	340.0	209.0	7.4	215	7.5
656	+5	5,000	6.9	306	3	8	.0	.0	.0	7.6	195	9.8
						10	1.33	178.0	65.0	7.6	225	9.4
						8	2.73	365.0	109.0	7.3	215	9.4
						--	3.18	425.0	136.0	7.2	205	9.4
						10	3.90	525.0	160.0	7.1	235	10.2
3,000		0	6.5	304	4	8	.0	.0	.0	6.7	275	5.9
						7	1.84	250.0	75.2	7.4	215	5.5
						--	2.09	284.0	81.9	6.9	233	5.1
						7	4.22	574.0	146.2	6.7	210	5.1
						15	5.76	784.0	190.8	7.4	255	5.1

Table 20.--Adsorption/desorption of contaminated sediment (Tc-2) from the Berger site (October 1985) under near field-flow conditions

[mg/L, milligrams per liter; µg/L, micrograms per liter; mv, millivolts; mL, milliliters]

Reservoir characteristics												
Sulfate concentration (mg/L)	Arsenic species	Arsenic concentration (µg/L)	pH	Eh (mv)	Column	Arsenic concentration (µg/L)	Pore volume eluted (mL)	Volume eluted (mL)	Time (hours)	pH	Eh (mv)	Hydraulic head (inches)
656	--	0	--	310	5	12	0.0	0.0	0.0	3.6	460	13.0
						16	2.67	460.0	14.3	3.6	445	13.0
						--	4.07	700.0	22.6	3.7	460	11.8
						--	6.37	1,095.0	40.6	3.7	445	11.4
						33	8.26	1,420.0	62.9	3.7	455	10.6
						--	10.17	1,750.0	111.8	3.9	434	10.2
						16	11.57	1,990.0	163.9	4.1	365	9.4
656	+3	5,000	6.9	302	6	20	.0	.0	.0	3.8	455	9.4
						54	1.5	250.0	56.5	3.8	445	8.9
						--	2.69	450.0	82.7	3.8	405	8.1
						12	3.77	630.0	146.3	3.9	423	7.9
						--	4.82	805.0	170.8	3.9	395	7.3
						12	6.77	1,130.0	223.0	4.0	395	12.2
656	+5	5,000	6.8	306	7	13	.0	.0	.0	4.3	405	11.8
						22	1.54	250.0	22.7	3.7	455	11.2
						--	4.69	760.0	34.4	3.8	455	10.0
						--	5.77	935.0	48.5	3.7	440	9.6
						31	8.30	1,345.0	63.5	3.7	455	10.4
						--	10.90	1,765.0	85.5	3.7	455	9.6
						11	13.06	1,115.0	112.3	3.8	450	9.4
3,000		0	6.5	304	8	11	.0	.0	0.0	3.6	455	7.0
						42	2.35	400.0	14.2	3.6	455	6.9
						--	3.53	600.0	20.7	3.6	460	6.1
						55	4.71	800.0	48.2	3.7	407	5.1
						--	6.76	1,150.0	63.5	3.7	450	6.3
						--	8.76	1,490.0	85.8	3.8	425	5.7
						13	10.24	1,740.0	112.3	3.8	425	5.1
						--	12.41	1,110.0	130.0	3.9	410	5.9

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Chapter B. Trace-Element Geochemistry of Sediments Collected from the Flood Plains of Whitewood Creek and the Belle Fourche and Cheyenne Rivers

By Donna C. Marron

SAMPLE COLLECTION AND HANDLING PROCEDURES

Samples of flood-plain sediment were collected for chemical analysis during the summers of 1985 and 1986. Samples were collected from soil pits that were dug to a depth of 1 m along the flood plains of Whitewood Creek, the Belle Fourche River, and the Cheyenne River. The soil pits were arranged along transects that were perpendicular to the modern stream channel. Transect locations are shown in figures 1 and 2 and listed in table 1.

The stratigraphy that was observed in each soil pit was measured and described. A variety of layers was sampled. Plastic containers and sampling utensils were used. The containers and sampling utensils were soaked in 5 percent HCL, rinsed with deionized water, and air dried before use. Samples were frozen at the end of the day they were collected. Distilled water was added to the frozen samples to make a slurry immediately before freeze drying. The slurry was then frozen onto the insides of freeze-drying flasks and freeze dried. The freeze-drying flasks were soaked in 5 percent HCL and rinsed with deionized water before use.

Splits of samples were made using a plastic or a stainless steel splitter. Splits of samples were collected in glass or ceramic dishes. Utensils used for splitting samples were rinsed in 5 percent HCL and deionized water, and then were air dried before use. Splits of four samples were separated into grain-size fractions using an air elutriator.

ANALYTICAL PROCEDURES AND RESULTS

Several types of digestion procedures were used. "Partial" digestion analyses for arsenic used a nitric and sulfuric acid digestion (Method I-6062-85 in Fishman and Friedman, 1985) and atomic absorption spectrometry. "Partial" digestion analyses for aluminum, antimony, chromium, copper, manganese, and zinc used a weak-acid digestion (Method I-5485-85 in Fishman and Friedman, 1985) and atomic absorption spectrometry. "Partial" digestion analyses for mercury used method I-5462-85 of Fishman and Friedman, 1985. "Total" digestion analyses were done using total digestion of the sample with $HF/HClO_4/HNO_3$ acid with detection by inductively coupled plasma atomic emission spectrometer. Analytical results are listed in tables 21, 22, and 23. Selected samples were analyzed for grain-size distributions and the results are listed in table 24.

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Table 21.--Partial digestion analysis of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche River

[All units in micrograms per gram]

Sample identifier	Aluminum	Antimony	Arsenic	Chromium	Copper	Iron	Manganese	Mercury	Zinc
WW1B1	2,100	30	1,500	50	44	46,000	88	0.69	14
WW1B2	5,300	8	700	1,500	63	50,000	500	2.2	42
WW1C1	3,300	18	1,500	80	23	44,000	85	1.3	12
WW1C2	5,900	9	560	100	12	20,000	91	2.4	14
WW2A1	4,500	57	3,300	80	39	46,000	1,100	1.5	40
WW2A3	5,200	120	5,700	90	61	51,000	1,300	3.0	37
WW2B1	3,900	34	3,200	80	27	45,000	97	1.2	22
WW2B3	7,200	43	1,200	170	73	45,000	3,200	3.1	49
BF1C1	8,000	29	2,900	160	68	62,000	1,700	3.1	44
BF3A1	4,600	57	4,000	110	43	57,000	130	3.1	19
BF3A2	7,200	3	250	750	32	18,000	1,900	.10	93
BF3B1	6,500	19	1,800	280	49	45,000	260	.10	33
BF3B2	7,500	35	3,600	210	59	49,000	2,600	2.3	48
BF4B1	5,800	5	620	100	35	33,000	1,300	.3	63
BF5A1	6,600	8	770	900	39	32,000	1,200	.4	69
BF5B1	6,400	9	1,000	240	43	49,000	1,600	.3	54
BF5B3	5,500	18	1,300	130	45	51,000	1,400	1.4	43
BF5C1[1]	6,900	11	470	130	37	32,000	1,300	.3	73
BF5C1[1]	7,600	17	480	140	38	35,000	1,400	.3	79
BF5C2[1]	6,700	35	1,400	110	51	51,000	900	.7	58
BF5C2[1]	5,900	13	1,200	110	48	48,000	1,000	.6	50

[1]Duplicate pair.

Table 22.--Total digestion analysis of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche and Cheyenne Rivers

[µg/g, micrograms per gram]

Sample identifier	Aluminum (%)	Calcium (%)	Iron (%)	Potassium (%)	Magnesium (%)	Sodium (%)	Phosphorous (%)	Titanium (%)	Arsenic (µg/g)
WW1A1	4.1	1.1	11	1.6	1.4	0.31	0.07	0.19	1,400
WW1A2	1.6	.14	17	.63	.89	.15	.07	.12	2,100
WW1A3	3.4	2.0	13	.80	1.7	.19	.05	.17	1,300
WW1B1	1.6	.06	17	.65	.90	.14	.07	.11	1,900
WW1B2	3.0	.55	14	1.2	.74	.24	.07	.17	980
WW1B2	3.1	.76	13	1.2	.78	.23	.06	.16	970
WW1C1[1]	1.8	.62	13	.72	.95	.15	.06	.11	1,900
WW1C1[1]	2.0	.66	14	.88	1.1	.16	.06	.10	1,700
WW1C2	2.3	1.1	9.4	.69	1.3	.16	.03	.14	760
WW2A1	2.9	2.5	11	.98	1.1	.22	.05	.14	3,400
WW2A2	2.8	1.8	13	.81	1.3	.19	.05	.14	4,100
WW2A3	2.5	1.5	15	.65	1.4	.17	.05	.13	6,500
WW2A4	3.2	1.3	15	.91	1.7	.18	.05	.14	4,600
WW2B1	2.6	.34	14	1.1	1.0	.22	.05	.13	3,800
WW2B2	2.3	.74	11	.96	.88	.17	.06	.10	1,500
WW2B3	3.7	.76	14	1.1	1.2	.19	.08	.17	1,400
WW2B4	5.1	2.6	2.5	1.4	.37	.39	.08	.17	40
BF1A1	4.2	1.7	4.4	1.5	.83	.35	.06	.19	320
BF1A2	2.8	1.5	5.8	1.1	.62	.22	.05	.12	590
BF1A3	2.6	1.2	11	1.2	.86	.21	.04	.11	1,100
BF1B2	4.5	2.4	12	1.4	2.0	.29	.07	.20	2,100
BF1B3	2.4	1.3	10	1.1	.97	.21	.04	.09	1,400
BF1C1[1]	3.0	1.4	16	.73	2.1	.22	.05	.16	3,100
BF1C1[1]	3.3	1.2	16	.83	2.2	.23	.05	.15	2,700
BF1C2	5.1	2.1	12	1.4	2.5	.27	.07	.21	2,300
BF2A1	3.1	.27	12	1.1	1.2	.30	.05	.15	2,000
BF2A2	4.6	1.4	12	1.3	2.2	.26	.06	.19	720
BF2B1	2.7	1.1	12	.94	1.4	.27	.04	.13	1,600
BF2B2	3.3	1.4	11	1.1	1.4	.24	.06	.15	670
BF2C1	4.3	1.0	11	1.2	1.8	.34	.06	.19	1,700
BF2C2	2.6	1.4	14	.72	1.2	.21	.04	.13	2,200
BF2C3	2.6	1.5	11	.61	1.4	.20	.04	.12	1,400
BF2D2	5.1	1.5	5.9	1.6	.90	.49	.06	.22	450
BF2D3	2.9	.87	9.7	1.1	.93	.26	.06	.15	770
BF2E	5.6	1.5	2.9	1.7	.85	.49	.06	.25	10
BF2N1	5.4	1.6	2.7	1.7	.96	.51	.06	.25	20
BF2N2[1]	3.7	4.4	1.7	1.5	.88	.45	.06	.16	<10
BF2N2[1]	4.0	4.6	1.9	1.9	.96	.45	.06	.16	<10
BF3A1	2.3	2.0	16	.65	1.3	.30	.04	.14	5,000
BF3A2	7.6	1.3	4.8	1.7	1.4	.54	.05	.31	260
BF3B1	3.0	1.3	14	.75	1.5	.25	.04	.14	1,700
BF3B2[1]	3.8	1.4	13	.87	2.0	.22	.06	.18	2,800
BF3B2[1]	4.0	1.2	13	.96	2.1	.23	.06	.17	2,400
BF4A1	4.0	1.1	11	1.1	1.6	.33	.06	.17	1,800
BF4A3	5.8	1.6	6.9	1.5	1.3	.43	.06	.24	570
BF4B3	3.6	.75	7.4	1.2	.91	.31	.05	.16	710
BF4B4	3.5	1.4	6.4	1.2	.91	.29	.05	.14	410
BF4R1[1]	3.8	1.7	12	.82	2.0	.25	.05	.17	1,700
BF4R1[1]	4.1	1.7	13	.93	2.1	.25	.06	.17	1,800
BF4R2	3.6	1.3	10	.91	1.7	.30	.05	.16	1,400
BF5A1	5.2	.86	7.8	1.5	1.3	.43	.07	.23	850
BF5B1	4.3	.99	11	1.1	1.7	.35	.06	.19	1,300
BF5B2	4.9	.86	11	1.1	2.1	.36	.05	.21	1,200
BF5B3	3.3	1.6	12	.86	1.6	.31	.06	.16	1,900
BF5B4	6.4	1.0	6.2	1.7	1.4	.54	.07	.26	490
BF5C1	5.6	1.6	7.1	1.5	1.4	.41	.07	.24	650
BF5C2	4.1	1.3	12	.99	1.4	.35	.06	.18	1,700
BF5C3	4.0	1.1	11	.96	1.9	.36	.06	.18	1,300
CR1A1	5.5	3.1	3.7	1.8	.91	1.0	.07	.20	200
CR1A2[1]	5.5	2.2	5.8	1.7	1.3	.85	.07	.22	410
CR1A2[1]	5.6	2.1	6.0	1.7	1.3	.81	.07	.22	430
CR1A3	8.4	1.7	5.5	2.1	1.5	.57	.08	.33	260
CR1A4	5.1	2.2	7.8	1.5	1.6	.76	.07	.22	830
CR2B1	4.4	2.1	3.4	1.6	.72	.77	.06	.17	170
CR2B2	4.3	1.9	3.6	1.6	.70	.82	.06	.18	180

[1]Duplicate pair.

Table 22.--Total digestion analysis of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche and Cheyenne Rivers--Continued

Sample identifier	Barium (µg/g)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Gallium (µg/g)	Lanthanum (µg/g)	Lithium (µg/g)	Manganese (µg/g)
WW1A1	420	51	75	20	78	13	28	28	2,500
WW1A2	240	59	36	10	57	7	33	10	1,700
WW1A3	280	35	56	8	30	13	19	18	1,200
WW1B1	200	36	34	12	65	5	21	10	1,200
WW1B2	320	49	58	16	97	10	27	19	960
WW1B2	300	36	47	16	79	11	20	19	960
WW1C1[1]	220	28	25	8	38	6	17	11	1,100
WW1C1[1]	250	34	29	7	48	7	21	13	1,200
WW1C2	250	29	30	6	20	8	17	13	1,100
WW2A1	300	36	35	17	57	10	20	18	2,000
WW2A2	270	39	44	22	73	12	22	16	3,800
WW2A3	210	31	32	14	92	10	19	13	2,300
WW2A4	260	36	51	10	120	12	19	17	1,800
WW2B1	280	28	33	8	44	10	17	13	1,400
WW2B2	250	45	37	12	55	8	25	15	1,400
WW2B3	320	29	58	22	91	14	17	21	3,400
WW2B4	340	57	52	61	190	12	30	52	4,200
BF1A1	570	48	50	11	31	10	27	26	1,000
BF1A2	440	37	28	11	31	8	21	16	1,400
BF1A3	310	39	28	12	53	8	22	15	1,500
BF1B2	400	50	73	19	89	14	28	30	2,900
BF1B31	290	23	25	7	20	8	15	10	1,400
BF1C1[1]	230	26	42	18	80	13	16	16	3,300
BF1C1[1]	250	33	49	15	87	12	20	18	3,100
BF1C2	390	52	81	16	99	17	29	35	3,300
BF2A1	400	32	46	8	50	9	19	15	1,600
BF2A2	380	40	65	14	60	15	22	35	3,000
BF2B1	290	35	40	7	43	9	20	15	1,800
BF2B2	340	39	46	14	51	11	22	24	2,400
BF2C1	440	46	59	18	70	14	25	31	3,400
BF2C2	240	29	42	10	70	9	16	13	1,300
BF2C3	240	26	39	11	52	10	16	15	2,500
BF2D2	680	54	63	16	40	13	31	33	1,600
BF2D3	450	49	38	14	48	9	27	20	2,100
BF2E	760	52	65	12	23	12	29	37	490
BF2N1	760	54	53	11	21	12	30	37	400
BF2N2[1]	670	43	34	8	12	8	23	22	350
BF2N2[1]	680	44	37	8	15	8	27	24	370
BF3A1	230	27	31	6	45	8	16	11	1,700
BF3A2	500	43	82	27	37	20	24	41	3,600
BF3B1	250	27	41	10	63	10	16	15	1,800
BF3B2[1]	320	34	47	15	76	14	20	25	3,900
BF3B2[1]	340	37	53	14	81	14	23	28	4,000
BF4A1	490	42	56	16	65	11	24	24	3,000
BF4A3	690	44	71	18	44	16	24	39	2,200
BF4B3	670	49	42	18	47	10	27	23	2,200
BF4B4	530	42	53	15	40	9	23	24	1,900
BF4R1[1]	300	32	56	15	68	14	18	23	4,200
BF4R1[1]	340	32	69	14	76	15	20	24	4,200
BF4R2	420	36	49	13	55	12	20	24	2,900
BF5A1	640	42	58	17	44	15	23	32	2,000
BF5B1	500	36	52	18	53	13	20	26	2,900
BF5B2	440	37	68	14	56	15	21	31	2,800
BF5B3	400	34	40	13	65	12	20	18	2,700
BF5B4	1,000	57	82	17	39	15	32	42	1,300
BF5C1	600	39	67	16	41	14	22	35	1,800
BF5C2	490	32	49	16	59	13	18	23	2,000
BF5C3	560	37	59	15	60	13	21	27	3,500
CR1A1	940	50	45	10	21	12	29	27	1,000
CR1A2[1]	850	49	56	13	32	14	28	31	1,600
CR1A2[1]	890	46	55	13	32	13	29	32	1,500
CR1A3	710	60	100	16	39	20	34	59	1,200
CR1A4	780	51	58	13	41	13	29	28	2,200
CR2B1	1,000	54	32	11	21	10	31	23	930
CR2B2	1,000	48	37	11	21	10	28	22	990

[1]Duplicate pair.

Table 22.--Total digestion analysis of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche and Cheyenne Rivers--Continued

Sample identifier	Neodymium (µg/g)	Nickel (µg/g)	Lead (µg/g)	Scandium (µg/g)	Strontium (µg/g)	Thorium (µg/g)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)
WW1A1	25	40	31	8	120	11	14	13	130
WW1A2	27	12	19	4	42	9	45	4	62
WW1A3	17	10	17	7	43	7	60	5	67
WW1B1	17	14	36	4	35	9	46	3	80
WW1B2	22	30	18	6	79	10	61	6	92
WW1B2	19	29	21	6	79	14	63	6	96
WW1C1[1]	14	7	19	4	49	9	55	2	70
WW1C1[1]	15	8	15	4	51	11	55	5	60
WW1C2	14	8	13	5	46	12	49	6	60
WW2A1	18	28	18	5	93	7	57	10	83
WW2A2	19	25	19	6	71	7	50	7	80
WW2A3	16	15	16	5	62	8	49	7	97
WW2A4	17	15	26	7	59	8	54	6	100
WW2B1	13	12	18	5	67	10	51	5	71
WW2B2	21	15	18	4	96	10	52	7	81
WW2B3	16	25	14	7	59	13	78	4	100
WW2B4	26	78	12	6	160	10	80	13	110
BF1A1	25	34	17	7	93	8	70	17	82
BF1A2	17	23	16	4	80	7	48	11	66
BF1A3	19	18	13	5	74	10	45	7	80
BF1B2	23	35	30	8	110	9	81	13	110
BF1B31	11	11	10	4	60	6	38	4	54
BF1C1[1]	13	18	13	6	54	8	60	8	87
BF1C1[1]	15	18	15	6	56	6	62	8	90
BF1C2	25	31	49	9	120	11	92	13	130
BF2A1	15	12	13	6	64	7	59	6	62
BF2A2	20	22	18	8	120	10	80	9	140
BF2B1	17	10	12	5	63	7	49	5	61
BF2B2	18	24	15	6	110	9	63	10	97
BF2C1	23	31	22	8	90	9	85	13	100
BF2C2	14	13	14	5	61	7	48	4	60
BF2C3	13	18	11	5	57	5	47	5	68
BF2D2	27	66	18	8	110	9	98	22	97
BF2D3	23	25	19	5	95	9	56	12	78
BF2E	26	31	19	9	140	9	100	19	83
BF2N1	27	30	17	8	150	9	97	18	76
BF2N2[1]	22	17	13	5	130	7	52	14	39
BF2N2[1]	24	19	13	6	140	7	58	15	43
BF3A1	13	7	16	5	120	8	47	7	49
BF3A2	22	66	19	13	110	12	170	14	130
BF3B1	14	14	13	6	61	8	59	7	70
BF3B2[1]	17	26	10	7	87	9	74	9	93
BF3B2[1]	17	27	14	7	87	7	75	9	100
BF4A1	21	28	20	7	94	9	76	12	90
BF4A3	21	45	20	10	120	8	120	15	110
BF4B3	23	36	15	6	96	9	69	13	84
BF4B4	20	39	16	6	93	7	66	10	79
BF4R1[1]	15	38	13	7	73	8	70	8	96
BF4R1[1]	14	38	15	7	82	8	76	8	100
BF4R2	17	23	14	7	96	7	69	8	87
BF5A1	23	38	16	9	120	11	110	15	110
BF5B1	19	35	16	8	94	9	90	12	110
BF5B2	19	28	19	9	87	8	97	11	100
BF5B3	18	22	14	6	99	8	65	9	91
BF5B4	28	41	23	11	150	10	130	19	120
BF5C1	20	39	20	10	140	10	120	16	100
BF5C2	17	24	17	8	110	8	89	11	96
BF5C3	19	33	19	7	99	7	83	11	96
CR1A1	24	22	17	6	290	9	66	16	64
CR1A2[1]	24	29	18	7	220	9	82	16	79
CR1A2[1]	22	28	20	8	240	9	87	16	82
CR1A3	30	45	22	14	180	12	160	20	120
CR1A4	26	24	18	7	220	10	76	15	79
CR2B1	27	25	17	5	200	8	62	16	66
CR2B2	24	23	17	5	200	7	60	15	66

[1]Duplicate pair.

Table 23.--Total digestion analysis of particle-size splits of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche River

[µm, micrometers; µg/g, micrograms per gram]

Sample identifier	Particle-size split (µm)	Aluminum (%)	Calcium (%)	Iron (%)	Potassium (%)	Magnesium (%)	Sodium (%)	Phosphorous (%)	Titanium (%)
WW1C2	0-4	5.0	3.3	15	1.4	2.2	0.13	0.10	0.29
	4-64	2.8	.49	12	.69	1.7	.23	.04	.23
	>64	1.8	.42	7.8	.64	1.0	.17	.02	.10
WW2A2	0-4	3.7	4.5	20	1.0	1.2	.11	.08	.15
	4-16	3.8	1.3	20	.95	1.8	.19	.08	.20
	16-64	2.3	.99	13	.69	1.2	.24	.07	.18
	>64	2.5	1.2	13	.78	1.2	.21	.05	.14
BF5B2	0-4	7.3	1.7	8.3	1.7	1.6	.40	.06	.30
	4-16	5.2	.81	13	1.1	2.4	.38	.06	.24
	16-64	2.9	.60	9.6	.67	1.7	.35	.05	.13
	>64	3.5	.67	11.0	.72	2.1	.27	.03	.14
BF5C2	0-4	6.9	.99	12	1.6	1.4	.39	.08	.29
	4-16	5.1	.52	14	1.2	1.6	.53	.08	.26
	16-64	3.3	.42	12	.80	1.4	.43	.06	.19
	>64	2.8	1.5	11	.71	1.3	.31	.05	.14

Table 23.--Total digestion analysis of particle-size splits of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche River--Continued

Sample identifier	Arsenic (µg/g)	Barium (µg/g)	Cerium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Gallium (µg/g)	Lanthanum (µg/g)	Lithium (µg/g)
WW1C2	2,800	650	54	82	11	480	20	34	29
	750	280	37	49	8	52	10	21	15
	480	140	22	26	5	14	6	11	11
WW2A2	13,000	370	42	58	21	440	14	25	24
	8,100	310	40	58	19	180	14	24	22
	4,000	270	41	39	12	81	8	23	12
	3,800	240	32	34	21	63	9	18	14
BF5B2	2,300	570	50	89	16	350	18	29	48
	1,700	430	35	66	16	89	16	19	31
	810	340	29	38	11	83	9	16	17
	490	290	24	44	15	30	2	12	20
BF5C2	2,700	580	46	85	16	320	16	26	42
	2,400	570	40	69	19	120	15	22	28
	1,400	710	38	45	13	59	10	22	16
	1,100	470	32	32	15	42	9	17	14

Table 23.--Total digestion analysis of particle-size splits of sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche River--Continued

Sample identifier	Manganese (µg/g)	Neodymium (µg/g)	Nickel (µg/g)	Lead (µg/g)	Scandium (µg/g)	Strontium (µg/g)	Thorium (µg/g)	Vanadium (µg/g)	Yttrium (µg/g)	Zinc (µg/g)
WW1C2	1,000	23	170	63	14	130	29	100	6	350
	1,600	17	18	12	7	45	12	58	4	97
	1,000	10	7	4	4	31	7	38	3	44
WW2A2	2,700	20	100	62	8	130	10	76	10	270
	3,000	21	39	25	7	73	10	76	7	160
	2,600	19	26	15	5	65	7	44	8	83
	3,200	16	23	12	5	63	7	48	6	79
BF5B2	1,500	24	66	42	13	150	10	160	15	290
	3,100	15	36	19	9	87	7	110	10	130
	3,000	13	31	14	5	64	6	58	7	100
	2,800	9	26	9	6	50	6	68	5	94
BF5C2	1,100	22	62	40	13	140	11	160	13	250
	2,000	19	48	22	9	110	9	120	12	140
	2,800	18	25	12	6	98	7	68	13	96
	2,400	13	20	9	5	96	6	56	8	81

Table 24.--Grain-size distributions of selected sediment samples collected during 1985 and 1986 from the flood plains of Whitewood Creek and the Belle Fourche River

[Units are weight percent less than; mm, millimeter]

Sample identifier	Grain-size distributions (percent)									
	1.000 (mm)	0.500 (mm)	0.250 (mm)	0.125 (mm)	0.062 (mm)	0.031 (mm)	0.016 (mm)	0.008 (mm)	0.004 (mm)	0.002 (mm)
WW1B1	100.0	97.3	50.2	15.8	9.5	6.8	1.9	3.4	2.3	1.4
WW1B2	100.0	98.3	92.8	86.6	44.3	20.1	9.5	5.9	4.1	3.0
WW1C1	98.9	91.6	73.1	30.9	12.8	8.2	5.5	3.8	2.5	1.8
WW1C2	100.0	98.4	95.8	84.3	47.8	20.2	8.9	5.3	3.2	2.3
WW2A1	100.0	100.0	99.5	92.7	55.4	30.90	21.2	16.3	11.8	9.3
WW2A3[1]	100.0	99.5	96.6	89.7	52.2	20.9	12.7	9.0	5.8	3.7
WW2A3[1]	100.0	100.0	97.6	90.8	51.5	22.6	13.5	9.1	6.1	3.9
WW2B1	100.0	100.0	99.5	95.3	47.8	22.9	16.0	12.3	9.3	8.0
WW2B3[1]	99.8	98.7	97.5	94.8	85.3	51.7	23.9	13.8	7.9	6.8
WW2B3[1]	99.5	98.7	96.5	93.1	82.7	53.3	24.9	13.9	8.3	6.7
BF1A2	100.0	100.0	98.5	61.0	26.3	17.7	14.0	11.5	9.5	7.6
BFA13	100.0	100.0	98.4	63.1	21.5	13.6	10.3	7.9	5.9	4.8
BF1B2	100.0	100.0	99.3	97.5	91.5	63.3	38.3	27.3	21.0	15.4
BF1B3	100.0	100.0	99.2	76.7	16.8	8.1	5.3	3.8	2.7	2.3
BF1C1	100.0	98.7	96.2	92.5	79.3	40.1	15.	9.7	6.2	5.2
BF3A1[1]	100.0	97.6	94.2	89.1	57.0	32.5	21.9	17.1	14.2	11.7
BF3A1[1]	100.0	99.2	95.3	90.3	61.5	30.3	20.0	15.5	11.9	10.4
BF3A2	100.0	99.3	98.3	96.0	94.8	90.7	85.5	78.0	68.2	56.9
BF3B1	100.0	100.0	100.0	96.4	60.1	34.1	22.2	16.5	12.9	9.5
BF3B2	100.0	99.7	98.9	93.0	72.0	48.8	27.7	17.8	12.7	8.9
BF4B1	100.0	100.07	99.7	97.6	66.1	40.2	29.2	24.3	20.7	17.1
BF5A1	100.0	100.0	99.7	98.5	87.5	50.8	34.5	24.9	16.5	8.8
BF5B1	100.0	100.0	100.0	98.7	78.4	50.8	35.8	28.9	24.7	20.6
BF5B3	100.0	100.0	100.0	97.2	84.5	39.7	21.5	15.1	12.5	9.7
BF5C1	100.0	100.0	99.8	99.3	90.1	69.2	55.2	45.8	39.1	32.8
BF5C2	100.0	100.0	99.4	96.5	68.9	44.7	34.3	29.2	24.1	21.7

[1]Duplicate pair.

Chapter C. Trace-Element Geochemistry of Bottom Sediment Samples Collected from Whitewood Creek and the Belle Fourche and Cheyenne Rivers

By Kimball E. Goddard, Arthur J. Horowitz, and Kent A. Elrick

SAMPLE COLLECTION AND HANDLING PROCEDURES

Bottom sediment materials were collected from 15 sites along Whitewood Creek and the Belle Fourche and Cheyenne Rivers between August 6 and 13, 1985. The site locations are shown in figures 1 and 2 and listed in table 1. Additional site information is provided in table 25.

Samples were collected by scooping bottom sediments into a plastic 64-µm sieve-bucket using a small plastic shovel. Individual scoops were collected randomly from 5 to 20 locations within the wetted perimeter of the active stream channel at each location and composited in the sieve. The materials were washed with native stream water and the material passing the sieve was retained. All materials not passing the sieve were discarded. Field sieving was necessary to remove coarse gravel and cobbles, living and dead plant materials, and to insure a sufficient amount of less than 64 µm material to allow analysis. Many of the Whitewood Creek sites had rock and cobble bottoms that precluded whole-volume bottom-sediment sample collection. The sediment-water slurry retained after sieving was pored into wide-mouth jars and chilled on ice to 4 °C for transport to the sample preparation laboratory. All implements used during sample collection were washed in 3 percent nitric acid solution and rinsed in deionized and native water before sampling.

The bottom material samples were concentrated by centrifugation. A Beckman model J2-21 centrifuge with a JA-10 fixed-angle rotor was used to spin 500 mL subsamples at 5,000 rpm for 5 minutes. The subsamples were subsequently composted into a single 500-mL centrifuge bottle. The freeze-dried samples, in the original centrifuge bottles, were kept at room temperature until analysis.

ANALYTICAL PROCEDURES AND RESULTS

Subsamples for total arsenic and metals analysis, total recoverable arsenic and metals analysis, and total organic carbon analysis were obtained from the whole samples following homogenization of the powdered, freeze-dried sample.

Total digestion analysis for iron, manganese, aluminum, titanium, arsenic, antimony, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and zinc were conducted on subsamples by Arthur J. Horowitz and Kent Elrick, U.S. Geological Survey, Doraville, Georgia. Procedures followed were those of Horowitz and Elrick (1985) and Elrick and Horowitz (1985; 1986). For all elements except mercury, samples were digested with a combination of $HF/HClO_4/HNO_3$ acids at 200 °C. For mercury, samples were digested with LeForte aqua regia at 100 °C. Quantitation was by atomic absorption spectrophotometry. Analytical results are listed in table 26.

Table 25.--Site number and name, station number, and location for sites at which bottom sediment material samples were collected during August 1985

Site number in figures 1 and 2, table 1	Site name	U.S. Geological Survey station number[1]	Location
1	Whitewood Creek above Lead	06436150	44°18'07" 103°46'57" T4N R3E Sec. 17 NW¼SE¼
3	Whitewood Creek above Gold Run	--	
6	Whitewood Creek below Deadwood	--	
7	Whitewood Creek above Whitewood	06436180	44°26'32" 103°37'44" T6N R4E Sec. 33 NE¼NE¼
8	Whitewood Creek near Whitewood	06436190	44°32'30" 103°34'16" T7N R4E Sec. 25 SE¼NE¼
11	Whitewood Creek at Custer Camp	--	
12	Whitewood Creek above Vale	06436198	44°37'04" 103°28'52" T8N R5E Sec. 35 NE¼NW¼
15	Belle Fourche River near Nisland	06436100	
16	Belle Fourche River at Vale	06436250	44°38'10" 103°25'37" T8N R6E Sec. 19 SE¼NE¼
18	Belle Fourche River at old Vale bridge	--	
22	Belle Fourche River near Sturgis	06437000	44°30'47" 103°08'11" T6N R8E Sec. 3 SE¼NW¼
26	Belle Fourche River near Elm Springs	06438000	44°22'11" 102°33'56" T5N R13E Sec. 29 NE¼NE¼
30	Cheyenne River near Plainview	06438500	44°31'16" 101°59'34" T7N R18E Sec. 31 NE¼SW¼
32	Cheyenne River at Cherry Creek	06439300	44°36'10" 101°29'24" T7N R22E Sec. 5 NE¼NW¼
34	Cheyenne River at Hwy 63 bridge	--	

[1]Indicates U.S. Geological Survey streamflow-gaging station. Some discharge and water-quality data are available.

Table 26.--Total analysis of bottom sediment materials collected from Whitewood Creek and the Belle Fourche and Cheyenne Rivers during August 1985

[Iron, manganese, aluminum, and titanium in weight percent; all other values in micrograms per gram; <, less than; --, not analyzed]

Site number in figures 1 and 2, table 1	Iron	Manganese	Aluminum	Titanium	Arsenic	Antimony	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Nickel	Selenium	Zinc
1	2.5	0.04	5.7	0.27	21	3.2	<0.5	47	12	14	31	0.11	11	1.4	77
3	7.8	.24	6.3	.27	350	10	1.3	94	29	121	43	.41	79	2.2	336
6	9.5	.20	4.6	.25	920	14.4	2.1	71	28	286	133	1.04	105	4.2	764
7	7.5	.24	4.3	.22	1,000	13.2	2.0	63	30	259	110	1.05	103	3.8	576
8	5.2	.20	2.4	.11	1,100	2.9	1.0	33	20	111	35	.45	34	3.4	145
11	4.5	.16	5.9	.31	580	1.5	<.5	75	17	47	15	.22	36	1.8	107
12	5.0	.16	5.0	.30	880	1.5	.8	62	13	44	22	.29	26	1.9	94
15	3.0	.05	8.3	.31	6.0	1.3	--	80	13	19	19	.46	30	3.4	114
16	4.3	.08	7.7	.32	300	1.2	<.5	86	13	34	18	.16	29	3.2	114
18	6.1	.12	7.5	.32	1,100	1.1	<.5	80	13	41	13	.72	31	3.0	107
22	5.2	.12	7.2	.31	560	1.0	<.5	73	20	33	10	.25	29	2.1	100
26	4.8	.14	7.0	.30	230	1.0	<.5	77	19	35	11	.17	41	2.1	120
30	3.3	.06	7.3	.30	35	1.0	<.5	53	16	21	15	.07	23	.6	95
32	3.4	.05	9.8	.30	27	1.0	<.5	63	13	22	15	.04	28	1.1	97
34	3.5	.05	8.6	.32	23	1.0	<.5	54	16	22	11	.04	27	.8	98

Total recoverable digestion analysis for iron, manganese, aluminum, arsenic, antimony, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and zinc were conducted on subsamples by the U.S. Geological Survey laboratory at Arvada, Colorado. Procedures followed were standard U.S. Geological Survey procedures for the analysis of bottom materials as described by Skougstad and others (1970). For elements except arsenic, antimony, mercury, and selenium, samples were digested with 6 Molar HC1 at 100 °C. For arsenic and antimony, samples were digested with a combination of H_2SO_4 and HNO_3 at 100 °C. For mercury, samples were digested with a potassium permanganate/potassium persulfate acid solution at 95 °C followed by reduction with stannous chloride. Finally, selenium was recovered using potassium permanganate at 100 °C, followed by digestion with 6 M HC1 at 100 °C. Quantitation was by atomic absorption. Analytical results are listed in table 27.

Analyses for total organic carbon were conducted on subsamples by the U.S. Geological Survey laboratory at Arvada, Colorado. Procedures followed were standard U.S. Geological Survey procedures for the analysis of bottom materials as described by Wershaw and others (1983). Organic carbon is recovered from the sample using a persulfate oxidation process. Analytical results are also listed in table 27.

Subsamples for particle-size analysis were obtained from the whole samples following homogenization of the powdered, freeze-dried sample. Sample analysis was performed by the U.S. Geological Survey sediment laboratory in Iowa City, Iowa. Procedures followed were standard U.S. Geological Survey procedures for the enumeration of fluvial sediment as described by Guy (1969). Analysis results are listed in table 28.

Table 27.--Total recoverable arsenic and trace metals, and total organic carbon analysis of bottom sediment materials collected from Whitewood Creek and the Belle Fourche and Cheyenne Rivers during August 1985

[Iron, manganese, aluminum, and titanium in weight percent; all other values in micrograms per gram; <, less than; --, not analyzed]

Site number in figures 1 and 2, table 1	Iron	Manganese	Aluminum	Titanium	Arsenic	Antimony	Cadmium	Chromium	Cobalt	Copper	Lead	Mercury	Nickel	Selenium	Zinc	Total organic carbon
1	1.0	0.04	0.53	--	16	1	<1	90	<10	12	10	0.2	10	<1	61	37
3	5.3	.24	0.93	--	250	5	2	210	20	95	20	.7	70	-	300	34
6	6.7	.19	.61	--	--	6	3	150	20	280	120	2.0	100	-	750	53
7	--	--	--	--	800	6	--	--	--	--	--	1.8	--	2	--	59
8	--	--	--	--	--	6	--	--	--	--	--	.7	--	-	--	68
11	2.2	.13	.47	--	610	6	1	90	10	39	10	.4	30	<1	65	28
12	2.3	.12	.45	--	900	6	1	90	10	41	10	.5	30	<1	63	25
15	1.5	.05	.50	--	11	<1	2	100	10	20	10	.9	30	1	96	29
16	1.9	.07	.52		390	4	1	100	10	30	10	.3	30	1	87	27
18	3.0	.10	.60	--	1,500	11	1	110	10	36	10	1.0	30	<1	79	25
22	2.4	.10	.65	--	640	4	1	120	10	31	10	.8	30	<1	78	21
26	2.6	.11	.84	--	260	2	1	130	10	33	10	.3	30	<1	91	25
30	.9	.05	.76	--	36	1	1	80	<10	14	10	.2	10	<1	35	14
32	1.3	.04	.82	--	17	<1	1	100	<10	21	10	.1	20	1	68	13
34	1.0	.05	.65	--	13	<1	<1	80	<10	15	10	.1	20	1	46	13

Table 28.--Particle-size analysis of bottom sediment materials collected from Whitewood Creek and the Belle Fourche and Cheyenne Rivers during August 1985

[Samples field sieved to <0.064 mm (millimeter)]

Site number in figures 1 and 2, table 1	Sieve diameter % finer than 0.064 mm	Fall diameter % finer than 0.032 mm	Fall diameter % finer than 0.016 mm	Fall diameter % finer than 0.008 mm	Fall diameter % finer than 0.004 mm	Fall diameter % finer than 0.002 mm
1	100	74	48	36	28	21
3	100	85	47	27	15	7
6	100	78	56	36	19	11
7	100	81	58	37	19	9
8	100	87	62	37	15	1
11	100	84	63	46	33	20
12	100	85	65	52	41	31
15	100	90	79	69	54	40
16	100	89	78	67	52	38
18	100	82	67	55	43	33
22	100	91	77	65	53	41
26	100	96	84	70	57	43
30	100	96	89	76	66	56
32	100	98	85	68	56	46
34	100	92	84	72	62	53

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Chapter D. Trace-Element Geochemistry of Sediment Cores Collected from the Cheyenne River Arm of Lake Oahe

By Arthur J. Horowitz, Kent A. Elrick, and Edward Callender

SAMPLE COLLECTION AND HANDLING PROCEDURES

During August 1985, a series of six cores were obtained along the line of the Old Cheyenne River channel between the present mouth of the Cheyenne River, through the Cheyenne River arm of Lake Oahe, to the lake proper (fig. 3). The line of the old river channel was located by fathometer and was selected for two reasons: (1) To obtain, if possible, samples from the channel deposited prior to the closing of the Missouri River by the Oahe Dam in 1958; and (2) to avoid contact with the numerous tree trunks which still extend above the sediment from the former river banks, which were submerged after 1958. Cores were obtained using a Benthos gravity corer with either a 4- or 8-ft (approximately 122 or 244 cm) plastic-lined barrel. Several cores were obtained at each site for different purposes. Those destined for trace-metal analysis were extruded on site using a series of rubber stoppers inserted into the plastic core liner. Specific sections were excised from each core. Usually the entire core was sampled; care was taken to limit samples to single bands in the cores. Once a section was obtained, it was placed immediately in a large-mouth plastic bottle, chilled on ice to 4 °C in a cooler, and shipped to Atlanta, Georgia, for subsequent processing and chemical analysis. Individual sample bottles were kept refrigerated until processing could begin.

ANALYTICAL PROCEDURES AND RESULTS

Individual sample bottles were removed from the refrigerator and thoroughly homogenized using acid-rinsed glass rods. Subsamples were then removed, placed in porcelain evaporating dishes, and freeze dried. The remaining sample was returned to the refrigerator for storage. Chemical analyses for iron, manganese, aluminum, titanium, copper, zinc, cadmium, lead, nickel, cobalt, chromium, arsenic, antimony, selenium, and mercury were carried out on freeze-dried samples following the procedures of Horowitz and Elrick (1985) and Elrick and Horowitz (1985, 1987). For all elements other than arsenic, antimony, selenium, and mercury, 500-mg samples were digested with a combination of HF-$HClO_4$-HNO_3 acids in teflon beakers at 200 °C; the resulting salts were brought into solution with 50 mL of 2 percent HCL. Quantification was by flame atomic absorption spectrophotometry using a Varian model AA-975 and mixed-salt standards. The determination of arsenic, antimony, and selenium used the same digestion, but final solutions were made up in 50 percent HCL. Quantification was by hydride generation and atomic absorption spectrophotometry using a Varian VGA-76 hydride generator and the AA-975. Mercury was determined using a 500-mg sample digested with LeFort aqua regia at 100 °C with quantification by a cold-vapor technique using the VGA-76 system in conjunction with the AA-975. Precision and bias (generally better than ±10%) were monitored by replicate analyses of selected samples and by the concomitant digestion and analysis of National Bureau of Standards sediment and U.S. Geological Survey rock standards. Total volatile solids (loss on ignition) was used as a measure of the organic carbon, sulfur and

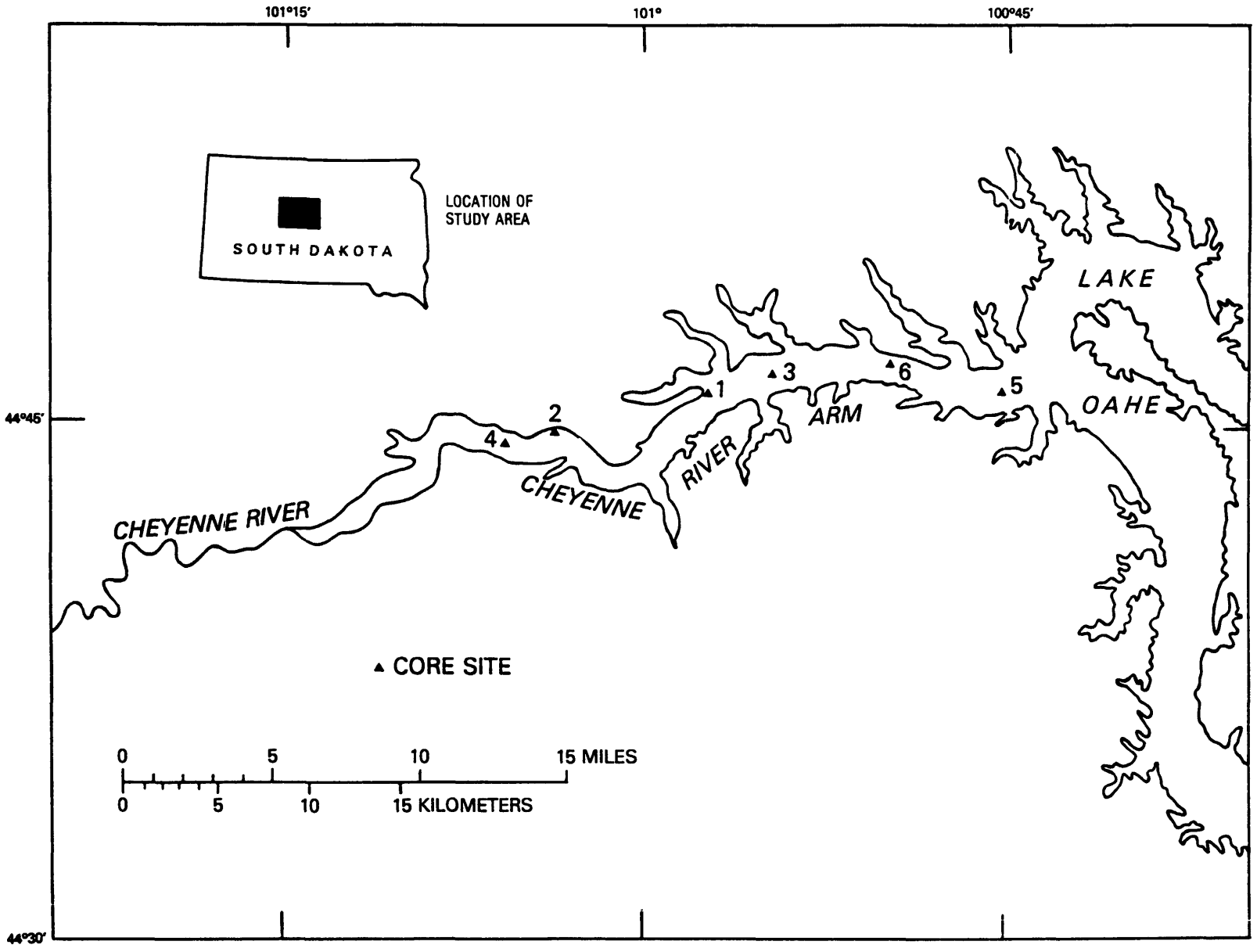

Figure 3.--Location of sediment cores taken from the Cheyenne River arm, Lake Oahe, during August 1985.

water of hydration in each sample and was determined following the procedures outlined in Skougstad and others (1979). This entailed the ignition of pre-weighed samples and their subsequent re-weighing after 1 hour at 550 °C in a muffle furnace. Analytical results for all the samples are given in table 29; cadmium has been omitted because almost all the samples had concentrations below the detection limit of 0.5 µg/g.

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Table 29.--Chemical composition of sediment core samples taken from the Cheyenne River arm of Lake Oahe during August 1985

[Aluminum, iron, manganese, titanium, and LOI in weight percent; all others values in micrograms per gram; cm, centimetera]

Sample interval (cm)	Aluminum	Iron	Manganese	Titanium	LOI[1]	Antimony	Arsenic	Chromium	Cobalt	Copper	Mercury	Nickel	Lead	Selenium	Zinc
Core 1:															
0-1	7.9	3.8	0.30	0.38	11.2	1.6	28	89	14	32	0.02	40	15	1.2	124
4-8	7.8	3.9	.08	.43	8.0	1.0	30	81	15	29	.09	32	14	.9	117
11-12.5	8.0	4.5	.06	.38	10.6	1.6	120	82	14	34	.12	37	17	1.1	121
16.5-21	7.5	3.9	.07	.35	10.3	1.2	27	57	13	27	.04	25	17	.5	105
22.5-23	8.4	3.8	.06	.36	13.2	2.0	32	81	18	29	.06	46	12	.8	123
23-25	7.6	4.2	.10	.38	6.3	1.1	29	86	14	30	.06	42	18	.9	134
27.5-31	7.5	3.8	.11	.40	7.9	1.1	20	91	16	29	.05	30	9	1.2	124
35-38	8.2	4.7	.10	.43	8.5	.9	74	90	14	32	.11	38	14	1.1	126
46-49	8.0	4.3	.09	.37	9.1	1.6	50	87	15	34	.06	45	15	1.1	131
53.5-55	7.8	4.6	.08	.37	10.8	1.6	36	92	14	32	.06	40	12	.9	126
59-63	8.4	4.2	.08	.43	8.0	1.1	37	85	16	30	.07	40	16	.9	132
67-71	7.7	4.1	.08	.41	7.3	1.1	22	90	13	30	.06	40	14	.9	132
75-79	8.2	3.8	.05	.41	7.0	1.1	11	84	16	28	.04	40	12	1.0	130
83-87	8.0	3.8	.08	.38	7.5	1.0	21	67	15	27	.09	33	14	.7	117
91-95	8.0	4.0	.06	.42	6.7	1.1	25	84	15	31	.14	42	12	1.0	132
99-103	8.4	4.2	.05	.43	7.7	1.0	10	96	14	29	.06	45	15	1.0	142
107-111	8.3	3.9	.05	.44	6.4	1.1	6.6	97	16	29	.06	48	20	1.1	146
Core 2:															
0-3	7.4	3.8	.09	.38	10.8	1.6	20	82	14	31	.02	38	19	1.3	118
3-6	7.4	3.8	.07	.33	10.4	1.2	14	80	14	28	.06	31	12	.9	110
9-11	7.0	3.8	.07	.33	7.3	.9	12	61	12	26	.05	28	19	.6	115
12-14	8.0	4.0	.06	.41	11.4	.9	32	72	12	27	.07	34	19	.6	121
17-20	7.5	3.9	.06	.33	9.0	1.2	24	50	15	25	.04	24	18	.3	104
27-30	7.7	4.0	.07	.40	8.5	.9	33	65	12	28	.08	33	18	.7	122
37-42	7.8	4.2	.05	.38	7.3	1.2	45	80	14	32	.04	37	14	.9	119
44-47	8.3	4.1	.04	.37	11.3	1.2	20	77	13	31	.05	39	21	.8	120
47-52	8.3	4.1	.05	.42	7.3	.9	19	81	14	29	.06	38	22	.8	129
55-60	8.0	4.0	.06	.38	7.8	.9	17	56	15	27	.03	28	20	.4	119
65-70	8.3	4.1	.04	.37	9.4	1.2	18	78	11	29	.04	34	21	.7	114
70-75	7.8	4.2	.05	.34	9.3	1.2	15	70	12	28	.16	35	23	.6	114
80-85	8.5	4.0	.05	.40	7.6	.9	19	69	13	28	.07	37	20	.5	125
90-95	8.7	4.1	.05	.40	7.3	.8	19	74	14	28	.50	37	22	.6	126
100-105	8.2	4.0	.05	.40	7.8	.9	14	73	13	28	.26	35	19	.5	127
105-110	8.4	4.1	.05	.39	8.6	.9	17	69	16	28	.05	32	18	.5	125
Core 3:															
0-2	7.6	4.0	.13	.37	12.2	1.2	11	90	15	34	.02	48	14	1.1	140
4-7	8.0	3.7	.06	.40	8.8	1.2	8	82	16	35	.06	47	13	1.3	145
10-13	7.0	4.3	.09	.37	9.4	1.6	12	91	12	35	.09	49	18	1.3	138
13-16	7.9	4.1	.10	.37	9.8	1.2	11	90	14	35	.06	50	20	1.2	141
20-23	7.5	4.2	.07	.38	9.6	1.6	19	86	13	36	.04	50	19	1.2	145
28-32	7.4	4.0	.06	.34	11.2	1.2	14	51	10	27	.14	29	24	.4	108
35-39	7.7	4.1	.07	.42	6.5	1.2	10	98	16	33	.06	47	10	1.3	151
46-50	7.5	4.0	.09	.40	6.8	1.1	7.7	95	15	32	.05	49	15	1.1	156
58-62	7.4	4.0	.07	.38	8.7	1.6	13	92	13	35	.07	49	19	1.2	140
66-70	7.4	4.6	.09	.38	6.2	1.2	15	89	14	33	.06	51	16	1.2	160
65-69	7.8	4.2	.09	.41	6.3	1.2	11	89	16	32	.05	46	12	1.3	150
70-74	6.4	3.9	.09	.36	6.4	1.3	10	80	15	33	.06	52	17	1.4	145
72-76	7.4	3.5	.08	.40	6.3	1.3	14	77	18	31	.05	45	17	1.3	141
80-84	8.4	4.2	.09	.42	7.7	1.2	11	83	17	33	.06	51	13	1.1	158
88-92	6.8	4.3	.07	.38	9.2	1.2	8	97	11	34	.06	50	18	1.2	146
96-100	8.4	4.0	.08	.40	8.0	1.3	7.9	95	15	37	.04	52	18	1.2	157
108-112	7.3	4.2	.08	.36	5.7	1.2	6	88	14	32	.06	48	16	1.2	155
112-116	7.2	4.1	.08	.37	5.5	1.2	6	87	14	32	.05	50	17	1.2	154

Table 29.--Chemical composition of sediment core samples taken from the Cheyenne River arm of Lake Oahe during August 1985--Continued

Sample interval (cm)	Aluminum	Iron	Manganese	Titanium	LOI[1]	Antimony	Arsenic	Chromium	Cobalt	Copper	Mercury	Nickel	Lead	Selenium	Zinc
Core 4:															
0-3	7.3	3.5	0.06	0.37	15.0	0.8	12	45	11	27	0.06	20	19	0.3	103
6-9	7.4	3.8	.06	.37	11.6	1.0	13	43	16	29	.02	26	21	.3	115
15-18	7.6	3.7	.06	.41	11.4	1.0	11	52	15	29	.02	26	20	.2	116
26-30	7.2	3.5	.06	.38	9.3	.9	14	52	15	26	.03	27	21	.3	106
35-39	7.2	3.8	.07	.39	10.1	1.0	25	59	16	30	.04	29	18	.5	115
44-48	7.4	3.8	.06	.38	11.1	1.0	13	38	16	29	.02	26	23	.2	111
53-57	7.6	3.8	.06	.40	9.3	1.0	13	43	16	27	.02	25	23	.2	112
62-66	8.3	4.2	.07	.42	7.8	1.2	56	85	19	34	.09	43	19	.9	130
71-75	7.6	4.2	.06	.37	9.6	1.2	78	83	11	31	.05	40	17	1.1	114
80-84	7.7	3.9	.07	.41	6.8	1.1	27	79	13	31	.06	39	23	.7	123
91-95	8.3	4.3	.07	.42	7.8	1.1	44	94	17	34	.07	42	16	.8	142
100-104	7.2	4.2	.07	.37	6.9	1.0	37	83	13	30	.08	38	18	1.0	129
110-112	7.4	3.9	.07	.33	8.1	.9	26	62	13	26	.05	30	21	.6	113
112-114	7.1	3.9	.07	.33	7.6	.9	22	43	9	26	.05	30	16	.4	115
Core 5:															
0-2	6.9	3.9	.13	.33	8.0	1.1	20	77	10	31	.07	44	10	.8	135
2-4	6.9	3.8	.10	.33	7.9	1.1	15	84	9	30	.06	43	9	.8	133
4-6	7.6	4.2	.09	.34	8.7	1.0	45	84	10	32	.14	43	15	.8	132
6-8	8.0	4.3	.09	.36	7.8	1.0	76	82	11	31	.14	38	12	.9	131
8-10	7.4	4.1	.10	.33	8.6	.9	35	67	10	27	.07	33	15	.5	121
10.5-15	7.3	3.9	.08	.38	11.0	1.2	35	82	14	32	.07	37	17	.8	117
31-32	7.0	3.5	.10	.36	11.2	1.2	29	83	14	31	.06	45	16	.8	119
32-37	7.9	3.8	.10	.38	10.5	1.2	32	89	14	32	.04	46	14	1.0	126
50-53	7.5	4.8	.15	.37	11.4	1.6	170	80	12	37	.14	36	26	.9	124
53-58	7.5	3.8	.09	.39	9.7	1.6	27	87	9	31	.03	42	22	1.1	134
58-63.5	7.5	3.8	.10	.37	10.6	1.2	25	80	11	31	.05	37	18	.7	125
63.5-67.5	7.3	4.3	.11	.33	9.0	1.0	64	71	11	30	.14	37	16	.6	130
67.5-72	8.3	4.1	.08	.41	10.8	1.2	41	86	10	32	.12	39	19	.9	134
72-76	7.8	4.8	.12	.38	10.3	1.2	180	77	13	36	.62	37	19	.9	123
76-82.5	7.7	3.9	.07	.37	10.1	1.2	22	86	10	30	.21	40	21	.9	127
83-85	7.7	3.7	.06	.35	12.5	1.6	38	72	11	30	.08	49	20	1.0	132
91.5-99	7.6	3.8	.07	.36	11.0	1.2	90	80	11	32	.15	42	19	1.0	128
95-101	8.2	4.7	.09	.38	11.5	1.2	90	79	14	32	.40	34	20	.7	120
101-106.5	8.3	4.3	.07	.39	11.5	1.2	68	84	14	32	.30	36	19	.8	126
106.5-107.5	7.0	4.0	.06	.35	8.9	1.1	27	81	11	31	.07	45	13	.9	141
114.5-116.5	7.4	3.8	.10	.35	12.3	1.6	29	60	17	30	.06	53	17	1.2	133
123.5-127	8.0	4.2	.09	.37	10.8	1.2	80	75	12	31	.31	30	18	.6	120
138.5-139	8.6	3.7	.06	.36	13.2	1.2	44	66	17	28	.08	37	19	.7	121
147-152.5	8.3	4.0	.04	.39	10.1	1.2	52	83	13	29	.08	34	21	.7	119
165.5-170.5	7.9	4.6	.07	.38	9.0	1.2	100	75	12	32	.32	33	17	.6	120
178-179	6.6	4.4	.06	.30	9.3	1.0	140	58	8	29	.28	43	14	.7	136
179-188	8.0	4.7	.08	.37	8.3	1.2	100	78	14	36	.52	35	17	.9	121
195-201	8.3	4.6	.07	.38	8.4	1.2	68	89	15	35	.30	39	16	1.2	131
Core 6:															
0-2	7.8	3.9	.12	.40	12.5	1.2	30	75	14	32	.05	37	18	.9	122
4-6	8.3	4.3	.09	.41	9.9	1.1	60	83	16	34	.08	39	16	.7	135
10-13	8.0	4.1	.11	.35	12.6	1.2	32	84	12	33	.08	44	15	1.0	124
17-23.5	7.7	4.2	.10	.34	11.4	1.2	26	85	10	33	.10	45	18	.8	124
28.5-35	7.9	4.3	.09	.41	10.0	1.2	68	81	16	35	.12	45	18	.8	140
38-40.5	7.6	4.0	.06	.33	12.2	1.4	44	80	12	31	.12	49	19	1.2	121
43-44.5	7.2	4.5	.10	.30	9.8	1.4	150	61	11	36	.34	34	24	1.0	108
48.5-49.5	9.1	4.4	.09	.42	11.5	1.2	125	90	15	38	.41	43	16	.7	145
54.5-57.5	7.6	4.2	.06	.32	10.5	1.4	44	74	12	32	.11	44	18	1.3	122
60-61	8.0	4.1	.06	.33	12.4	1.4	42	70	12	30	.12	41	20	1.5	115
66-74.5	7.8	4.3	.06	.36	8.5	1.2	106	72	12	34	.24	35	23	.8	113
74.5-84	6.9	5.1	.10	.34	7.6	1.2	260	67	10	35	.29	32	17	1.0	109
84-87	4.7	2.8	.05	.33	6.8	1.0	44	47	11	18	.05	25	17	.8	79
95-103	5.2	2.9	.08	.36	5.1	1.0	28	47	12	17	.05	26	17	.5	87
111-119	5.9	3.2	.06	.36	6.1	1.0	9.8	54	16	20	.04	31	17	.6	101
127-133	5.3	2.8	.06	.35	4.8	1.1	9.7	51	14	19	.03	31	20	.5	85

[1]Loss on ignition, total volatile solids.

Chapter E. Discharge and Surface-Water Quality at Selected Sites on Whitewood Creek and the Belle Fourche and Cheyenne Rivers

By William R. Roddy and Thomas E. McKallip

METHODS

Discharge Data

Continuous discharge data were obtained at 4 streamflow-gaging stations, and instantaneous discharge data were obtained at 16 miscellaneous water-quality sites (figs. 1 and 2, table 1). Discharge data were obtained following procedures by Buchanan and Somers (1969, 1982), Craig (1983), and Kennedy (1983, 1984).

Discharge measurements were calculated by summing the products of width, depth, and velocity at 20 to 40 sub-sections along a cross section of the stream. Depths were measured with a graduated wading rod or with sounding weights suspended by a metal cable. Water velocities were determined using either a Price "AA" or a pygmy meter. Widths were measured based on the midpoints between sub-sections. In a few instances, because of ice effects or fast-rising stages, measurements were made with fewer sub-sections or with less time for velocity measurements than published guidelines. In every case, these measurements were checked against the water stage-discharge rating and were found to be acceptably accurate.

Calculation of daily mean discharges (tables 30 through 33) at continuous-record gages was based on water stages recorded every 15 minutes and on the water stage-discharge ratings. Water stages were sensed by a bubble-gage manometer and punched on paper tape by a digital recorder. Water stage-discharge ratings were derived from the relation between monthly and high-flow discharge measurements and corresponding water stages. Records are accurate except for periods in winter when ice covered the streams. Records during periods of ice cover have been adjusted and are considered poor.

Table 30.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Whitewood, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	14	14	12	10	8.0	13	19	17	13	12	9.6	10
2	15	14	11	11	8.5	12	21	16	13	11	9.4	11
3	15	14	10	15	9.0	12	26	16	15	11	9.3	12
4	18	14	10	18	9.5	12	28	16	13	11	9.6	10
5	19	14	11	20	10	12	22	16	14	10	9.0	9.7
6	22	13	13	20	10	13	20	15	14	10	9.5	9.6
7	18	15	16	18	11	14	19	15	13	10	9.8	9.2
8	19	14	17	17	11	18	19	16	13	9.1	9.2	10
9	17	14	18	16	12	16	20	15	12	9.2	9.3	11
10	17	14	18	15	12	15	21	15	17	10	9.1	11
11	18	15	17	14	12	15	23	17	16	10	8.9	11
12	17	14	16	13	13	14	29	16	14	10	8.9	12
13	17	14	14	14	13	14	28	14	13	11	8.9	10
14	18	14	15	16	13	15	25	14	13	11	9.2	11
15	18	14	16	17	13	16	25	14	13	11	9.1	10
16	18	14	15	16	13	17	25	14	12	11	9.1	11
17	18	13	11	13	14	18	24	13	12	11	8.9	10
18	19	13	10	10	14	18	23	15	12	11	8.8	11
19	17	14	10	8.0	14	18	24	15	15	11	10	11
20	16	13	12	8.0	13	18	27	13	15	13	9.6	11
21	16	13	14	8.5	13	19	23	13	16	11	9.4	11
22	15	13	12	9.0	13	18	23	14	14	11	9.5	12
23	15	13	10	11	12	16	22	15	12	10	9.2	12
24	15	13	9.0	13	13	16	20	14	12	11	9.3	12
25	15	13	9.0	14	13	19	20	13	12	11	9.0	18
26	15	13	11	13	14	19	19	20	15	9.9	9.3	14
27	15	13	14	12	12	18	18	17	13	9.6	10	14
28	15	13	14	10	13	18	18	15	11	9.6	10	14
29	14	14	11	9.0	---	17	18	14	11	9.8	11	13
30	14	13	10	7.5	---	17	17	15	13	11	11	12
31	14	---	10	7.5	---	18	---	14	---	10	9.9	---
TOTAL	513	409	396.0	403.5	336.0	495	666	466	401	327.2	292.8	343.5
MEAN	16.5	13.6	12.8	13.0	12.0	16.0	22.2	15.0	13.4	10.6	9.45	11.4
MAX	22	15	18	20	14	19	29	20	17	13	11	18
MIN	14	13	9.0	7.5	8.0	12	17	13	11	9.1	8.8	9.2
AC-FT	1020	811	785	800	666	982	1320	924	795	649	581	681

CAL YR 1984 TOTAL 12972.0 MEAN 35.4 MAX 266 MIN 9.0 AC-FT 25730
WTR YR 1985 TOTAL 5049.0 MEAN 13.8 MAX 29 MIN 7.5 AC-FT 10010

Table 30.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Whitewood, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12	13	5.0	9.5	16	24	26	77	25	25	20	15
2	13	13	7.0	9.5	15	26	26	73	25	20	19	18
3	15	13	8.5	9.0	15	24	36	67	27	18	19	17
4	13	14	11	8.5	15	24	31	64	39	17	19	16
5	13	14	12	8.0	15	26	33	66	27	16	19	20
6	13	14	9.0	8.0	14	24	47	57	25	15	18	21
7	13	14	8.0	8.5	12	22	61	54	24	14	17	17
8	13	13	7.0	9.5	10	23	67	55	23	13	18	16
9	13	12	7.0	11	9.0	26	65	80	39	13	18	16
10	13	11	6.5	12	8.0	26	63	72	130	14	18	22
11	13	10	7.5	12	7.0	24	58	70	105	14	18	19
12	14	9.0	8.0	13	6.0	24	50	67	79	13	18	17
13	14	8.5	9.5	12	7.5	22	47	66	64	11	17	16
14	14	10	9.0	11	9.0	21	41	61	54	10	16	16
15	13	13	9.0	12	10	21	40	56	46	9.5	15	15
16	13	12	9.0	13	12	20	38	52	39	9.0	15	15
17	13	10	9.0	13	14	20	41	49	35	8.1	15	14
18	11	9.0	9.5	13	14	19	46	45	31	17	15	15
19	12	7.5	9.5	15	14	18	45	43	30	18	14	18
20	12	7.0	9.5	15	15	18	52	41	28	18	14	15
21	12	7.0	9.5	14	16	19	65	38	26	22	14	15
22	13	7.0	9.5	13	16	20	108	38	25	19	15	14
23	14	7.0	9.5	12	17	19	152	38	23	19	15	14
24	13	7.0	9.5	14	20	19	135	37	22	21	14	15
25	13	7.5	9.0	14	25	22	150	33	21	24	14	25
26	13	7.5	9.0	12	29	21	136	32	22	25	15	16
27	13	7.0	9.0	11	25	20	121	30	23	23	15	15
28	13	6.5	9.5	11	22	23	109	30	22	20	15	14
29	13	6.0	9.5	12	---	24	99	29	21	20	15	14
30	13	6.0	10	14	---	26	89	28	31	19	15	14
31	14	---	9.5	14	---	27	---	27	---	20	15	---
TOTAL	404	295.5	274.0	363.5	407.5	692	2077	1575	1131	524.6	504	494
MEAN	13.0	9.85	8.84	11.7	14.6	22.3	69.2	50.8	37.7	16.9	16.3	16.5
MAX	15	14	12	15	29	27	152	80	130	25	20	25
MIN	11	6.0	5.0	8.0	6.0	18	26	27	21	8.1	14	14
AC-FT	801	586	543	721	808	1370	4120	3120	2240	1040	1000	980

CAL YR 1985 TOTAL 4704.5 MEAN 12.9 MAX 29 MIN 5.0 AC-FT 9330
WTR YR 1986 TOTAL 8742.1 MEAN 24.0 MAX 152 MIN 5.0 AC-FT 17340

Table 31.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Vale, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	13	16	17	6.0	5.2	17	20	16	11	6.0	1.3	2.9
2	13	17	15	7.0	5.4	15	19	15	7.2	3.4	1.2	1.1
3	14	18	14	8.0	5.6	14	14	15	19	3.0	1.0	1.9
4	15	15	14	9.5	5.8	13	19	15	20	1.9	1.4	2.3
5	18	15	14	11	6.2	12	15	14	14	4.6	1.3	1.2
6	21	15	16	11	7.0	12	14	14	13	3.8	2.3	.72
7	18	16	17	10	7.5	13	9.7	12	12	2.6	2.5	1.2
8	17	16	17	10	9.5	14	8.4	11	6.6	1.3	3.1	1.6
9	16	17	16	9.5	9.0	15	13	11	7.7	.27	2.2	3.2
10	16	18	15	8.5	8.0	17	15	12	12	1.9	2.8	2.3
11	15	19	11	8.0	11	21	20	14	15	1.1	2.3	2.8
12	16	19	8.6	9.5	13	25	24	17	10	.49	2.0	3.2
13	16	19	8.0	11	14	34	29	12	9.3	.51	2.0	2.5
14	16	20	9.0	12	15	44	28	14	7.9	2.7	2.6	2.2
15	17	19	10	12	16	40	26	15	8.1	3.6	1.6	3.4
16	19	20	8.0	12	15	30	27	10	6.2	2.9	.81	3.4
17	19	17	8.0	11	15	24	26	11	4.0	1.4	.33	3.1
18	20	17	8.4	10	15	25	24	9.5	4.9	1.1	.08	3.0
19	21	17	9.0	9.5	15	24	24	13	8.1	2.1	.00	3.3
20	18	16	9.4	9.0	16	22	28	12	9.8	3.1	.89	6.3
21	18	17	9.6	9.8	15	22	27	8.4	11	.00	1.8	5.5
22	18	18	9.0	11	15	22	27	11	11	.00	2.7	5.7
23	17	19	8.0	12	15	19	25	16	5.8	1.4	2.9	6.4
24	16	18	6.0	15	15	19	23	12	3.0	2.0	.93	8.5
25	17	16	6.5	14	14	20	25	8.6	1.7	2.7	.03	11
26	15	12	7.5	13	14	21	22	28	4.2	2.4	.31	12
27	14	10	9.0	11	16	21	21	55	5.8	1.7	2.3	9.0
28	16	16	7.6	8.0	17	22	20	34	2.3	1.5	3.1	11
29	14	20	6.6	7.0	---	20	19	23	3.4	1.4	3.0	11
30	14	19	6.0	6.0	---	19	17	12	5.1	2.7	3.3	11
31	15	---	5.5	5.0	---	20	---	22	---	2.0	2.8	---
TOTAL	512	511	325.7	306.3	335.2	656	629.1	492.5	259.1	65.57	54.88	142.72
MEAN	16.5	17.0	10.5	9.88	12.0	21.2	21.0	15.9	8.64	2.12	1.77	4.76
MAX	21	20	17	15	17	44	29	55	20	6.0	3.3	12
MIN	13	10	5.5	5.0	5.2	12	8.4	8.4	1.7	.00	.00	.72
AC-FT	1020	1010	646	608	665	1300	1250	977	514	130	109	283

CAL YR 1984 TOTAL 16211.2 MEAN 44.3 MAX 604 MIN 5.5 AC-FT 32150
WTR YR 1985 TOTAL 4290.07 MEAN 11.8 MAX 55 MIN .00 AC-FT 8510

Table 31.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Vale, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	11	11	8.0	15	19	35	29	90	28	42	19	16
2	10	11	9.0	14	20	35	29	86	27	26	17	17
3	10	11	11	13	19	33	37	81	29	23	16	17
4	13	12	12	11	19	30	39	77	50	21	18	16
5	12	11	10	10	19	30	58	79	35	21	15	17
6	11	11	10	9.4	18	28	59	72	39	23	12	22
7	11	11	10	9.0	17	31	62	67	37	25	12	19
8	11	11	9.0	11	15	26	66	76	31	26	11	18
9	12	11	8.7	13	13	26	67	251	35	26	11	18
10	11	11	9.4	15	12	28	67	103	124	25	10	22
11	11	10	10	17	10	27	63	90	119	23	8.9	23
12	12	9.5	11	18	8.0	25	58	84	94	22	8.4	19
13	12	9.0	12	17	9.0	25	58	81	80	20	13	18
14	12	8.7	13	18	11	23	66	75	72	18	11	18
15	12	8.7	14	18	16	24	54	70	63	17	9.4	18
16	11	9.5	12	17	20	23	51	66	53	16	9.3	18
17	11	9.7	12	17	22	22	88	62	49	19	8.8	18
18	10	9.7	12	14	23	23	176	55	42	22	8.6	18
19	9.7	9.7	13	12	23	23	64	52	40	31	6.5	21
20	10	9.7	13	10	24	23	55	50	38	21	6.5	19
21	10	9.7	13	8.5	26	24	69	45	34	29	6.8	19
22	10	9.7	13	8.0	29	24	89	41	33	20	8.6	19
23	11	9.7	14	8.5	32	24	153	43	30	19	8.2	18
24	12	9.7	13	9.0	35	24	148	44	28	18	9.2	390
25	11	9.4	14	10	44	23	161	39	26	19	9.8	207
26	11	9.0	13	11	80	24	149	37	27	32	8.8	43
27	10	8.8	13	14	51	24	169	35	27	31	8.7	30
28	11	8.4	13	17	37	24	131	33	26	23	8.0	25
29	11	8.2	14	18	---	26	111	31	23	20	9.7	23
30	10	8.0	14	19	---	28	102	30	26	19	10	21
31	11	---	14	19	---	28	---	31	---	20	14	---
TOTAL	340.7	295.8	367.1	420.4	671.0	813	2528	2076	1365	717	333.2	1167
MEAN	11.0	9.86	11.8	13.6	24.0	26.2	84.3	67.0	45.5	23.1	10.7	38.9
MAX	13	12	14	19	80	35	176	251	124	42	19	390
MIN	9.7	8.0	8.0	8.0	8.0	22	29	30	23	16	6.5	16
AC-FT	676	587	728	834	1330	1610	5010	4120	2710	1420	661	2310

CAL YR 1985 TOTAL 3944.97 MEAN 10.8 MAX 55 MIN .00 AC-FT 7820
WTR YR 1986 TOTAL 11094.2 MEAN 30.4 MAX 390 MIN 6.5 AC-FT 22010

Table 32.--Daily mean discharge, in cubic feet per second, for Belle Fourche River near Sturgis, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	191	54	58	24	20	150	83	39	385	261	403	336
2	140	52	47	26	21	140	81	38	350	240	403	329
3	113	52	40	30	22	130	80	36	345	216	359	389
4	93	50	37	33	24	110	83	35	351	203	312	412
5	82	50	37	35	26	100	83	67	296	219	279	376
6	84	50	38	34	27	180	76	57	259	216	257	317
7	91	49	41	31	28	200	67	53	226	215	269	313
8	84	48	44	29	29	220	63	44	204	243	244	335
9	77	48	46	28	28	250	59	51	166	263	242	365
10	73	50	43	26	25	270	56	61	134	244	224	282
11	68	52	40	24	26	300	55	101	162	225	228	163
12	67	52	35	25	28	320	53	164	183	273	244	116
13	65	52	30	26	30	350	51	163	181	309	236	102
14	63	54	28	28	31	370	55	155	161	328	221	92
15	59	56	26	28	33	450	55	169	148	348	236	77
16	58	56	25	29	37	540	52	139	145	358	250	68
17	58	56	24	31	41	700	50	147	150	351	280	64
18	57	54	24	28	45	1000	50	170	127	376	269	62
19	59	52	26	26	55	1500	50	197	103	368	262	59
20	62	49	32	24	70	2340	49	224	104	357	263	56
21	60	47	32	24	80	1220	49	243	140	344	253	56
22	57	51	29	25	90	747	53	241	163	336	281	59
23	57	52	26	26	100	454	53	248	173	317	334	59
24	57	58	23	28	110	306	51	240	187	299	338	56
25	57	47	25	28	110	244	46	256	195	252	347	56
26	57	54	28	28	100	197	44	300	180	256	371	55
27	58	19	35	27	140	158	44	510	193	256	358	58
28	57	58	35	26	160	140	44	526	225	252	340	58
29	52	85	30	25	---	109	44	482	238	273	322	55
30	52	75	26	23	---	93	41	408	247	303	338	56
31	54	---	24	18	---	83	---	384	---	380	345	---
TOTAL	2262	1582	1034	843	1536	13371	1720	5948	6121	8881	9108	4881
MEAN	73.0	52.7	33.4	27.2	54.9	431	57.3	192	204	286	294	163
MAX	191	85	58	35	160	2340	83	526	385	380	403	412
MIN	52	19	23	18	20	83	41	35	103	203	221	55
AC-FT	4490	3140	2050	1670	3050	26520	3410	11800	12140	17620	18070	9680

CAL YR 1984 TOTAL 141880 MEAN 388 MAX 5910 MIN 11 AC-FT 281400
WTR YR 1985 TOTAL 57287 MEAN 157 MAX 2340 MIN 18 AC-FT 113600

Table 32.--Daily mean discharge, in cubic feet per second, for Belle Fourche River near Sturgis, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	56	46	26	46	56	1060	107	432	109	215	279	297
2	59	46	30	45	54	975	99	312	96	242	266	354
3	58	46	37	42	52	1720	96	253	76	254	264	413
4	55	46	46	40	49	1390	124	217	84	267	278	385
5	53	47	47	37	47	1780	280	195	100	262	314	315
6	54	47	47	37	45	1870	1110	180	158	257	335	362
7	53	47	47	39	43	1060	571	193	283	254	300	365
8	53	46	45	40	42	1000	525	223	314	269	290	337
9	50	46	41	41	40	761	360	3970	305	270	317	337
10	51	45	39	43	40	791	224	6520	334	292	360	317
11	53	46	38	43	42	782	177	3880	408	293	356	334
12	53	47	37	44	45	789	148	1300	316	264	345	340
13	55	47	36	45	49	645	133	590	262	276	326	276
14	55	47	36	45	53	546	182	410	275	315	309	254
15	54	50	38	46	58	441	130	360	280	341	315	248
16	54	54	38	47	60	337	135	291	211	355	323	261
17	53	54	36	48	56	280	197	237	196	343	311	258
18	50	52	36	50	54	252	1530	204	187	324	314	221
19	49	50	38	54	52	201	2230	178	154	411	311	239
20	49	49	41	52	54	148	1030	162	175	480	278	238
21	48	47	44	52	60	256	687	145	196	431	228	222
22	49	46	46	52	72	348	410	133	199	400	251	216
23	49	39	45	52	82	309	327	124	207	379	273	216
24	47	32	41	54	130	324	326	123	193	387	286	201
25	47	26	38	54	170	337	512	122	170	379	291	4520
26	48	24	40	50	300	265	791	114	171	365	339	6490
27	47	23	40	50	800	201	1580	105	181	352	324	1940
28	48	23	41	51	1530	166	1470	96	181	363	293	949
29	47	24	42	52	---	146	1270	89	196	352	306	477
30	47	25	43	52	---	130	733	82	199	276	308	316
31	46	---	45	52	---	119	---	76	---	256	283	---
TOTAL	1590	1267	1244	1455	4135	19429	17494	21316	6216	9924	9373	21698
MEAN	51.3	42.2	40.1	46.9	148	627	583	688	207	320	302	723
MAX	59	54	47	54	1530	1870	2230	6520	408	480	360	6490
MIN	46	23	26	37	40	119	96	76	76	215	228	201
AC-FT	3150	2510	2470	2890	8200	38540	34700	42280	12330	19680	18590	43040

CAL YR 1985 TOTAL 56510 MEAN 155 MAX 2340 MIN 18 AC-FT 112100
WTR YR 1986 TOTAL 115141 MEAN 315 MAX 6520 MIN 23 AC-FT 228400

Table 33.--Daily mean discharge, in cubic feet per second, for Cheyenne River at Cherry Creek, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1984 TO SEPTEMBER 1985
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	412	247	130	130	80	230	482	214	443	261	522	274
2	397	220	110	140	70	220	428	213	401	252	587	281
3	344	183	90	150	55	200	400	219	404	247	497	276
4	287	204	90	160	55	200	381	190	412	266	421	278
5	260	211	85	170	60	220	365	181	407	242	375	291
6	242	213	80	160	60	220	360	177	393	213	321	335
7	226	222	90	160	60	240	382	176	379	195	260	327
8	217	215	120	150	62	250	356	162	322	207	243	309
9	211	214	160	140	65	250	326	154	298	201	210	315
10	209	215	200	130	70	250	299	157	285	194	209	752
11	209	218	190	115	90	270	286	135	270	205	182	659
12	209	239	180	130	110	270	269	134	270	203	184	537
13	204	244	180	140	120	280	262	131	330	202	152	370
14	196	242	190	160	130	300	252	136	301	196	149	286
15	190	282	200	160	130	500	244	163	285	224	223	293
16	184	290	190	170	140	1700	238	212	252	252	243	309
17	184	242	180	180	140	5050	232	222	215	265	191	245
18	182	240	170	180	150	4210	233	219	198	347	177	200
19	180	250	180	170	150	3950	234	206	185	480	172	184
20	178	250	190	150	160	4280	244	198	181	392	178	173
21	176	240	180	160	160	5200	252	202	169	367	186	173
22	178	236	170	160	180	3300	253	214	166	341	686	176
23	183	219	170	180	200	2500	261	253	160	295	421	174
24	188	220	150	180	200	2100	242	252	153	312	305	178
25	190	210	160	170	210	1750	237	239	151	303	281	181
26	189	200	160	180	200	1500	228	247	167	272	297	185
27	180	200	170	170	200	1300	218	266	178	247	325	199
28	178	180	160	150	230	781	211	289	193	212	335	199
29	184	170	150	140	---	681	207	440	205	222	288	192
30	190	160	130	120	---	595	213	575	210	231	276	187
31	196	---	120	100	---	536	---	529	---	352	253	---
TOTAL	6753	6676	4725	4755	3537	43333	8595	7105	7983	8198	9149	8538
MEAN	218	223	152	153	126	1398	286	229	266	264	295	285
MAX	412	290	200	180	230	5200	482	575	443	480	686	752
MIN	176	160	80	100	55	200	207	131	151	194	149	173
AC-FT	13390	13240	9370	9430	7020	85950	17050	14090	15830	16260	18150	16940

CAL YR 1984 TOTAL 387820 MEAN 1060 MAX 17400 MIN 50 AC-FT 769200
WTR YR 1985 TOTAL 119347 MEAN 327 MAX 5200 MIN 55 AC-FT 236700

Table 33.--Daily mean discharge, in cubic feet per second, for Cheyenne River at Cherry Creek, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1985 TO SEPTEMBER 1986
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	184	156	80	100	250	11800	930	5080	437	474	418	400
2	184	156	75	100	260	10800	788	2830	400	665	320	400
3	171	156	80	100	270	10700	681	1800	400	907	320	380
4	169	161	80	95	270	10500	907	1400	400	802	300	464
5	168	165	80	95	260	10400	2450	1030	450	834	300	430
6	166	162	80	90	250	10600	5800	817	520	790	350	520
7	158	162	85	90	240	10200	8870	767	486	676	366	740
8	156	172	85	100	210	6540	5380	1310	448	550	350	560
9	158	160	80	140	180	5800	3940	8410	508	500	430	480
10	160	150	80	200	160	6790	2670	21400	810	582	430	470
11	154	150	75	300	120	6460	1560	20900	10800	700	400	500
12	163	160	75	320	110	5910	1070	12200	5050	600	400	560
13	166	180	70	320	110	5930	877	7300	2990	450	400	490
14	210	180	80	330	130	5420	681	4980	7470	420	422	380
15	236	180	90	330	130	4090	630	3740	6680	470	650	340
16	204	170	85	350	150	3080	1000	3000	5320	600	550	320
17	191	170	85	400	160	2280	2000	3500	4370	550	450	340
18	173	180	80	400	150	2220	6700	2500	2800	500	400	470
19	163	160	80	420	150	1780	12200	2000	2100	450	380	1500
20	162	140	100	450	140	1410	11400	1600	1540	500	345	700
21	157	120	115	420	140	1280	6040	1300	1180	469	357	550
22	151	120	110	400	140	2660	4890	1200	946	580	270	380
23	145	110	105	350	140	5560	3420	1100	810	520	300	590
24	148	110	95	300	153	4800	2050	900	676	550	330	450
25	154	120	95	270	300	3670	1760	800	609	500	350	1000
26	156	110	100	260	800	3200	2310	700	571	450	345	2770
27	163	90	100	250	5000	2570	9760	650	509	450	410	5400
28	164	80	95	270	17600	2000	13400	600	460	500	383	3670
29	162	80	90	270	---	1580	8370	571	450	550	360	1710
30	161	80	90	270	---	1330	6350	500	469	450	380	941
31	159	---	95	250	---	1070	---	464	---	400	360	---
TOTAL	5216	4290	2715	8040	27973	162430	128884	115349	60659	17439	11826	27905
MEAN	168	143	87.6	259	999	5240	4296	3721	2022	563	381	930
MAX	236	180	115	450	17600	11800	13400	21400	10800	907	650	5400
MIN	145	80	70	90	110	1070	630	464	400	400	270	320
AC-FT	10350	8510	5390	15950	55480	322200	255600	228800	120300	34590	23460	55350

CAL YR 1985 TOTAL 113414 MEAN 311 MAX 5200 MIN 55 AC-FT 225000
WTR YR 1986 TOTAL 572726 MEAN 1569 MAX 21400 MIN 70 AC-FT 1136000

Water-Quality Data

Water-quality data were obtained at 18 sites during the 1985-86 water years (figs. 1 and 2, table 1). Monthly samples and storm runoff samples were taken at four streamflow gaging stations--Whitewood Creek above Whitewood, Whitewood Creek above Vale, Belle Fourche River near Sturgis, and Cheyenne River at Cherry Creek. One to five samples were collected at each of the other sites.

Samples were collected and analyzed according to procedures published by the U.S. Geological Survey (Guy, 1969; Barnett and Mallory, 1971; Skougstad and others, 1979; Friedman and Erdmann, 1982; Guy and Norman, 1982; Wershaw and others, 1987). Samples for inorganic and suspended-sediment analyses normally were obtained by wading the stream and collecting depth-integrated aliquots with a sampling rod that held two 2-L bottles equipped with sampling nozzles. Aliquots were collected at from 10 to 25 equally spaced verticals across the channel and were composited in a U.S. Geological Survey sample-splitting churn. Except for total organic carbon, samples for raw-water analyses were filled from the churn. Bottles for dissolved constituents were filled by pumping the water from the churn with a peristaltic pump and filtering the water through a 0.45-µm cellulose filter. Samples to be analyzed for nitrogen species and phosphorus were placed in brown polyethelene bottles and preserved with mercuric-chloride and put on ice. Samples to be analyzed for dissolved trace metals and major cations were preserved with nitric acid. Samples to be analyzed for dissolved mercury were placed in glass bottles and preserved with chromic acid. Samples to be analyzed for cyanide were preserved with NaOH and put on ice. Samples were then shipped to the U.S. Geological Survey's Central Laboratory in Arvada, Colorado, for analysis. Chemical analysis data are listed in tables 34 through 38.

Suspended-sediment samples were concentrated by centrifugation using a Beckman model with a JA-10 fixed angle rotor. Samples were spun at 5,000 revolutions per minute for 5 minutes. Supernate was removed from the sediment with a peristaltic pump and the sediment was freeze dried, aggregated, powdered, and homogenized before subsampling for total chemical analysis.

Total chemical analyses of subsamples for iron, manganese, aluminum, titanium, arsenic, antimony, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and zinc were performed by Arthur J. Horowitz and Kent Elrick, U.S. Geological Survey, Doraville, Georgia. The procedures followed were those of Horowitz and Elrick (1985, 1986). Subsamples for all elements except mercury were digested with a combination of $HF/HClO_4/HNO_3$ acids at 200 °C. Subsamples for mercury were digested with Laforte aqua regia at 100 °C. Quantification was by atomic hydride generation. The procedures followed for total organic carbon analyses were standard U.S. Geological Survey procedures for the analysis of bottom materials as described by Wershaw and others (1987). The result of 56 analyses of suspended sediment from 10 sites are listed in table 39.

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)
JUN 1985											
06...	1000	--	--	14	--	916	--	--	--	8.40	2.3
10...	1500	--	--	20	--	850	--	--	--	8.40	3.9
18...	0900	12.5	670	12	958	--	10.1	109	8.80	--	--
21...	1145	14.5	748	20	847	859	9.7	97	8.90	8.50	3.9
26...	0900	12.0	669	13	929	940	9.5	101	8.80	8.40	3.9
JUL											
03...	1000	18.5	--	11	968	--	--	--	9.20	--	--
08...	1000	21.0	650	9.1	931	923	9.8	130	9.30	8.80	2.4
17...	0940	20.0	670	11	1010	--	9.2	116	9.10	--	--
23...	1000	20.5	662	11	1070	--	8.7	112	9.10	--	--
30...	0900	15.5	670	11	1020	--	--	--	8.70	--	--
AUG											
06...	1400	25.0	670	11	1120	1090	8.5	118	9.20	8.70	3.4
14...	0930	12.0	671	8.6	1070	--	9.7	103	8.80	--	--
21...	0930	19.5	670	9.4	1060	--	8.1	101	8.60	--	--
27...	0900	17.5	670	9.6	1100	--	9.0	108	8.60	--	--
SEP											
02...	0900	17.0	660	10	1070	1060	12.0	145	8.70	8.50	3.0
10...	1330	--	--	11	--	--	--	--	--	--	--
17...	1000	12.0	660	10	1050	--	10.0	108	8.50	--	--
24...	0845	3.5	660	11	917	--	11.3	99	8.50	--	--
OCT											
02...	0940	7.5	670	12	969	--	10.0	95	8.30	--	--
08...	0930	3.5	670	14	945	986	10.6	91	8.40	8.40	2.4
16...	0930	6.0	660	13	1000	--	9.9	93	8.20	--	--
23...	1200	8.0	660	13	948	--	10.5	103	8.50	--	--
29...	1010	6.0	680	12	955	--	11.7	106	8.50	--	--
NOV											
05...	0945	7.5	666	13	1080	1100	11.9	114	8.40	8.40	2.1
14...	1030	0.0	672	13	1040	--	11.6	91	8.11	--	--
21...	1015	0.0	653	71	1210	--	13.1	105	7.92	--	--
DEC											
04...	1330	0.0	670	16	1010	1050	11.6	91	8.20	8.10	3.9

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DIS-SOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	HARD-NESS (MG/L AS CACO3) (00900)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3) (95902)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)
JUN 1985											
06...	3.2	0.020	0.02	616	390	220	168	81	45	51	1
10...	3.1	0.020	0.02	568	350	200	145	71	41	48	1
18...	--	--	--	--	--	--	--	--	--	--	--
21...	3.8	0.030	0.03	573	380	220	159	81	43	48	1
26...	2.3	0.020	0.02	646	410	230	174	86	47	49	1
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	2.4	0.030	0.04	634	410	220	192	86	48	49	1
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
06...	3.2	0.00	0.02	789	470	300	171	99	55	69	1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
02...	2.4	0.030	0.03	729	460	280	177	99	52	63	1
10...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
02...	--	--	--	--	--	--	--	--	--	--	--
08...	1.9	0.040	0.04	675	410	230	178	85	47	54	1
16...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
NOV											
05...	2.1	0.030	0.03	744	430	270	167	91	50	67	1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
04...	2.3	0.030	0.03	720	410	270	145	89	46	70	2

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	PERCENT SODIUM (00932)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	POTASSIUM, TOTAL RECOVERABLE (MG/L AS K) (00937)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	ARSENIC DISSOLVED (UG/L AS AS) (01000)	ARSENIC SUSPENDED TOTAL (UG/L AS AS) (01001)	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DISSOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOVERABLE (UG/L AS B) (01022)	CADMIUM DISSOLVED (UG/L AS CD) (01025)
JUN 1985											
06...	22	12	13	18	260	31	23	54	100	100	<1
10...	22	11	10	13	250	30	32	62	90	90	<1
18...	--	--	--	--	--	--	--	--	--	--	--
21...	21	9.4	9.2	12	240	33	40	73	90	110	<1
26...	20	9.6	9.5	17	280	43	--	--	100	130	<1
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	20	7.9	8.2	18	270	51	--	--	100	120	<1
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
06...	23	12	12	16	380	75	13	88	140	160	1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
02...	22	11	12	17	340	46	4	50	120	170	<1
10...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
02...	--	--	--	--	--	--	--	--	--	--	--
08...	22	9.7	9.9	19	290	35	4	39	110	110	<1
16...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
NOV											
05...	24	13	11	18	360	31	1	32	120	140	<1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
04...	26	14	16	25	350	22	--	34	120	140	<1

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, SUS-PENDED RECOV-ERABLE (UG/L AS CU) (01041)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE) (01044)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
JUN 1985										
06...	<1	<10	<10	7	10	17	1900	1900	6	<1
10...	<1	<10	<10	7	13	20	3900	3900	9	<1
18...	--	--	--	--	--	--	--	--	--	--
21...	<1	<10	10	5	27	32	5900	5900	17	5
26...	1	<10	<10	3	25	28	5200	5200	8	5
JUL										
03...	--	--	--	--	--	--	--	--	--	--
08...	<1	<10	<10	5	3	8	230	230	5	<1
17...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--
AUG										
06...	<1	<10	<10	5	11	16	130	140	6	<1
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--
SEP										
02...	<1	<10	<10	4	2	6	440	450	11	<1
10...	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--
OCT										
02...	--	--	--	--	--	--	--	--	--	--
08...	<1	<10	<10	4	5	9	730	740	13	1
16...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--
NOV										
05...	<1	<10	<10	2	3	5	150	160	7	1
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
DEC										
04...	1	<10	<10	1	--	3	--	290	10	<1

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	LEAD, SUS-PENDED RECOV-ERABLE (UG/L AS PB) (01050)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN) (01054)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
JUN 1985										
06...	--	7	90	140	53	<0.1	<0.10	2	<1	17
10...	--	20	150	210	64	<0.1	0.20	<1	1	<3
18...	--	--	--	--	--	--	--	--	--	--
21...	4	9	280	310	35	<0.1	0.20	<1	1	5
26...	1	6	250	270	16	<0.1	<0.10	<1	1	7
JUL										
03...	--	--	--	--	--	--	--	--	--	--
08...	--	<1	20	20	3	<0.1	<0.10	<1	<1	6
17...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--
AUG										
06...	--	3	90	110	18	<0.1	0.10	<1	1	13
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--
SEP										
02...	--	1	30	50	20	<0.1	<0.10	<1	<1	9
10...	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--
OCT										
02...	--	--	--	--	--	--	--	--	--	--
08...	6	7	30	100	69	<0.1	<0.10	<1	<1	9
16...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--
NOV										
05...	1	2	20	40	24	<0.1	<0.10	1	<1	9
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
DEC										
04...	--	2	--	50	39	0.1	<0.10	<1	1	16

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN) (01091)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ALUM-INUM, SUS-PENDED RECOV. (UG/L AS AL) (01107)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE) (01146)	SELE-NIUM, TOTAL (UG/L AS SE) (01147)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)
JUN 1985										
06...	30	50	360	40	320	2	0	1	72	100
10...	--	50	680	40	640	2	0	1	81	98
18...	--	--	--	--	--	--	--	--	51	99
21...	60	60	1100	30	1100	2	--	--	73	94
26...	50	60	970	20	950	2	--	--	106	96
JUL										
03...	--	--	--	--	--	--	--	--	6	88
08...	10	20	90	30	60	2	--	--	6	90
17...	--	--	--	--	--	--	--	--	8	90
23...	--	--	--	--	--	--	--	--	13	94
30...	--	--	--	--	--	--	--	--	31	99
AUG										
06...	7	20	<10	40	--	2	0	2	17	92
14...	--	--	--	--	--	--	--	--	5	95
21...	--	--	--	--	--	--	--	--	6	94
27...	--	--	--	--	--	--	--	--	6	87
SEP										
02...	10	20	100	80	20	3	0	2	6	85
10...	--	--	--	--	--	--	--	--	20	96
17...	--	--	--	--	--	--	--	--	3	81
24...	--	--	--	--	--	--	--	--	3	76
OCT										
02...	--	--	--	--	--	--	--	--	6	83
08...	10	20	240	30	210	2	0	2	10	94
16...	--	--	--	--	--	--	--	--	4	92
23...	--	--	--	--	--	--	--	--	16	98
29...	--	--	--	--	--	--	--	--	2	90
NOV										
05...	1	10	50	20	30	2	0	2	1	87
14...	--	--	--	--	--	--	--	--	3	89
21...	--	--	--	--	--	--	--	--	5	90
DEC										
04...	--	20	40	<10	--	3	--	3	3	64

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)
FEB 1986												
06...	1000	0.5	667	19	953	986	12.3	98	--	8.20	--	--
21...	1015	--	--	16	--	990	--	--	--	8.10	--	--
25...	1115	4.5	668	25	767	848	10.2	90	8.30	8.20	0.90	--
26...	1530	--	--	28	--	--	--	--	--	--	--	--
27...	1440	--	--	25	--	--	--	--	--	--	--	--
28...	1345	--	--	21	--	--	--	--	--	--	--	--
MAR												
03...	1015	--	--	24	--	--	--	--	--	--	--	--
05...	1415	--	--	26	--	--	--	--	--	--	--	--
10...	1030	--	--	26	--	--	--	--	--	--	--	--
APR												
06...	1318	11.0	667	47	582	595	8.4	87	8.60	8.20	0.40	--
23...	1330	10.0	663	165	305	--	9.0	92	8.20	--	--	--
28...	1215	--	--	115	--	--	--	--	--	--	--	--
MAY												
20...	1055	13.0	670	42	467	--	11.5	125	9.20	--	--	--
JUN												
04...	1315	17.5	671	49	548	--	8.3	99	8.90	--	--	2.10
09...	1435	15.0	670	39	572	--	8.5	96	8.50	--	--	--
09...	1855	--	--	96	--	--	--	--	--	--	--	--
09...	1955	14.0	668	102	484	496	8.8	98	8.40	7.90	0.50	2.10
10...	0030	13.5	669	96	426	--	8.6	94	8.20	--	--	1.40
10...	1515	--	--	178	--	--	--	--	--	--	--	0.800
JUL												
17...	1330	25.0	668	16	829	780	8.2	114	8.80	8.80	0.70	--
AUG												
12...	1250	21.5	667	19	861	853	8.5	111	9.10	9.00	0.50	--
SEP												
18...	1300	14.0	668	14	926	897	9.6	107	8.80	8.60	0.70	--

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS (MG/L AS CACO3) (00900)	HARDNESS NONCARBONATE (MG/L AS CACO3) (95902)	ALKALINITY LAB (MG/L AS CACO3) (90410)
FEB 1986												
06...	--	--	--	1.9	1.9	0.130	0.14	673	--	360	210	143
21...	--	--	--	--	--	0.190	0.19	671	--	380	230	153
25...	6.00	--	0.160	--	--	--	0.14	559	--	--	--	136
26...	--	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	3.10	--	--	5.6	2.7	--	0.06	377	340	240	130	115
23...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
20...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	0.610	--	7.6	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	2.00	0.610	0.140	39	--	--	0.02	313	310	220	91	129
10...	--	1.20	--	18	--	--	--	--	--	--	--	--
10...	--	0.610	--	14	--	--	--	--	--	--	--	--
JUL												
17...	5.60	--	0.196	2.7	2.1	--	0.01	568	540	350	200	157
AUG												
12...	7.00	--	0.300	2.3	2.8	--	0.02	621	590	380	230	151
SEP												
18...	7.60	--	0.220	2.1	2.0	--	0.03	730	620	400	250	148

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	POTAS-SIUM, TOTAL RECOV-ERABLE (MG/L AS K) (00937)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUO-RIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)
FEB 1986												
06...	80	38	58	1	26	9.5	9.1	18	310	--	--	20
21...	84	41	61	1	25	9.1	8.8	24	310	--	--	29
25...	72	>5.0	>5.0	--	--	8.6	--	20	240	0.90	9.3	20
26...	--	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	55	25	26	0.8	19	5.2	--	13	140	0.60	9.3	16
23...	--	--	--	--	--	--	--	--	--	--	--	17
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
20...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	50	23	19	0.6	16	4.4	--	13	110	0.50	9.6	23
10...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
17...	77	39	38	0.9	19	8.1	--	13	260	0.70	11	40
AUG												
12...	80	43	47	1	21	8.8	--	14	290	0.70	11	34
SEP												
18...	84	45	52	1	22	9.1	--	16	310	0.80	9.5	33

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DIS-SOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOV-ERABLE (UG/L AS B) (01022)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
FEB 1986												
06...	--	120	130	<1	1	<10	<10	3	7	780	68	<1
21...	37	110	80	<1	<1	<10	<10	3	8	950	65	<1
25...	--	--	--	--	--	--	--	8	--	--	45	--
26...	--	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	--	--	--	--	--	--	--	7	--	--	9	--
23...	--	--	--	<1	--	--	--	2	--	--	20	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
20...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	<1	--	--	--	5	--	--	59	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
17...	--	--	--	<1	--	--	--	4	--	--	5	--
AUG												
12...	--	--	--	<1	--	--	--	5	--	--	7	--
SEP												
18...	--	--	--	<1	--	--	--	3	--	--	5	--

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)
FEB 1986												
06...	1	170	120	0.1	0.20	<1	<1	6	70	--	90	20
21...	1	210	150	0.1	0.30	<1	<1	4	30	--	120	20
25...	--	--	120	0.1	--	--	--	<3	--	1	--	--
26...	--	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	--	--	74	<0.1	--	--	--	<3	--	1	--	--
23...	--	--	70	<0.1	--	--	--	<10	--	1	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
20...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	130	<0.1	--	--	--	5	--	2	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
17...	--	--	11	<0.1	--	--	--	<3	--	2	--	--
AUG												
12...	--	--	6	<0.1	--	--	--	7	--	2	--	--
SEP												
18...	--	--	17	<0.1	--	--	--	9	--	2	--	--

Table 34.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	SELENIUM, DISSOLVED (UG/L AS SE) (01145)	SELENIUM, TOTAL (UGN AS SE) (01147)	SEDIMENT, SUSTHAN (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER .500 MM (70345)
FEB 1986												
06...	3	3	10	85	--	--	--	--	--	--	--	--
21...	3	2	--	--	--	--	--	--	--	--	--	--
25...	3	--	67	91	--	--	--	--	--	--	--	--
26...	--	--	66	98	--	--	--	--	--	--	--	--
27...	--	--	19	--	--	--	--	--	--	--	--	--
28...	--	--	10	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	12	--	--	--	--	--	--	--	--	--
05...	--	--	24	--	--	--	--	--	--	--	--	--
10...	--	--	18	98	--	--	--	--	--	--	--	--
APR												
06...	--	--	27	97	--	--	--	--	--	--	--	--
23...	--	--	213	88	--	--	--	--	--	--	--	--
28...	--	--	34	96	--	--	--	--	--	--	--	--
MAY												
20...	--	--	7	95	--	--	--	--	--	--	--	--
JUN												
04...	--	--	189	100	--	--	--	--	--	--	--	--
09...	--	--	55	97	--	--	--	--	--	--	--	--
09...	--	--	404	--	31	45	--	76	97	99	100	--
09...	--	--	728	--	30	43	60	74	98	100	100	100
10...	--	--	466	98	41	56	--	87	0	--	--	--
10...	--	--	247	--	--	--	--	--	--	--	--	--
JUL												
17...	--	--	16	88	--	--	--	--	--	--	--	--
AUG												
12...	--	--	3	66	--	--	--	--	--	--	--	--
SEP												
18...	--	--	4	90	--	--	--	--	--	--	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)
OCT 1984											
23...	1230	7.5	--	16	1010	1130	--	--	--	8.10	--
NOV											
30...	1515	0.0	--	19	1120	1080	--	--	--	8.20	--
DEC											
14...	1645	0.0	--	9.0	1200	1290	--	--	--	8.10	--
JAN 1985											
14...	1650	0.0	--	12	1150	1230	--	--	--	8.00	--
JUN											
07...	1030	20.5	688	12	1200	1200	7.9	98	8.50	8.20	1.7
18...	1100	18.0	694	7.2	1270	--	8.0	93	8.50	--	--
21...	1345	16.0	736	8.4	1120	1120	10.2	107	8.60	8.30	2.0
26...	1115	14.0	690	4.2	1220	--	9.9	107	8.50	--	--
JUL											
03...	1130	23.0	--	2.4	1210	--	--	--	8.60	--	--
08...	1200	28.0	654	2.2	1480	1490	14.5	219	8.80	8.30	1.2
17...	1115	23.0	690	1.0	1410	--	13.1	171	8.70	--	--
23...	1100	E24.5	681	1.1	1640	--	12.8	--	8.60	--	--
30...	1030	E16.0	690	3.0	1460	--	--	--	8.30	--	--
AUG											
07...	1300	26.5	686	2.6	1530	1440	10.6	148	8.40	8.30	2.4
14...	1100	16.5	690	2.3	1450	--	12.3	140	8.50	--	--
21...	1200	25.0	680	3.8	1550	--	14.3	197	8.50	--	--
27...	1145	19.5	690	0.53	1510	--	12.5	152	8.40	--	--
SEP											
02...	1130	22.0	680	1.3	1520	1560	21.5	277	8.50	8.40	2.0
10...	1315	--	--	2.6	--	--	--	--	--	--	--
17...	1130	18.5	680	3.0	1400	--	14.3	172	8.40	--	--
24...	1000	5.0	680	8.4	1300	--	10.6	93	8.40	--	--
OCT											
02...	1110	11.0	690	9.9	1250	--	11.9	120	8.20	--	--
08...	1130	4.0	690	11	1240	1260	13.2	112	8.10	8.20	1.5
16...	1115	8.5	690	11	1220	--	12.2	115	8.00	--	--
23...	1345	9.0	680	13	1260	--	10.8	106	8.10	--	--
29...	1205	9.0	700	11	1230	--	11.8	112	8.00	--	--
NOV											
05...	1230	7.5	683	11	1270	--	11.5	108	8.10	--	--
14...	1200	0.0	695	8.7	1290	--	12.5	94	8.05	--	--
21...	1200	0.0	653	9.7	1570	--	8.8	71	7.74	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DIS-SOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	HARD-NESS (MG/L AS CACO3) (00900)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3) (95902)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)
OCT 1984											
23...	--	0.010	0.02	848	550	380	168	120	61	39	0.7
NOV											
30...	--	0.030	0.03	804	560	430	133	130	57	37	0.7
DEC											
14...	--	0.020	0.02	984	690	510	182	160	70	44	0.8
JAN 1985											
14...	--	0.030	0.03	924	650	450	199	150	66	43	0.8
JUN											
07...	4.0	<0.010	<0.01	894	600	460	140	130	66	49	0.9
18...	--	--	--	--	--	--	--	--	--	--	--
21...	30	<0.010	<0.01	815	550	380	165	120	60	47	0.9
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	3.9	<0.010	0.02	1170	770	630	144	160	90	57	0.9
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
07...	5.4	<0.010	<0.01	1150	740	600	136	150	88	58	1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
02...	2.3	<0.010	<0.01	1240	810	670	137	170	94	60	0.9
10...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
02...	--	--	--	--	--	--	--	--	--	--	--
08...	1.9	0.020	0.02	952	590	360	224	130	64	48	0.9
16...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
NOV											
05...	--	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	PERCENT SODIUM (00932)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	POTASSIUM, TOTAL RECOVERABLE (MG/L AS K) (00937)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	FLUORIDE, DISSOLVED (MG/L AS F) (00950)	ARSENIC DISSOLVED (UG/L AS AS) (01000)	ARSENIC SUSPENDED TOTAL (UG/L AS AS) (01001)	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DISSOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOVERABLE (UG/L AS B) (01022)
OCT 1984											
23...	13	8.5	--	13	430	0.60	33	--	64	--	--
NOV											
30...	12	8.1	--	15	430	0.60	23	--	--	--	--
DEC											
14...	12	9.9	--	16	540	0.60	21	--	--	--	--
JAN 1985											
14...	12	9.5	--	15	480	0.60	20	--	77	--	--
JUN											
07...	15	13	12	16	480	--	58	21	79	120	120
18...	--	--	--	--	--	--	--	--	--	--	--
21...	15	11	10	15	420	--	61	33	94	100	130
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	14	15	18	18	660	--	110	--	--	160	180
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
07...	14	12	13	18	660	--	130	70	200	170	230
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
02...	14	13	1.4	19	730	--	79	41	120	170	170
10...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
02...	--	--	--	--	--	--	--	--	--	--	--
08...	15	10	9.5	18	490	--	48	24	72	110	130
16...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
NOV											
05...	--	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, SUS-PENDED RECOV-ERABLE (UG/L AS CU) (01041)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE) (01044)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
OCT 1984											
23...	1	<10	--	--	<10	--	10	--	580	12	--
NOV											
30...	<1	<10	--	--	<10	--	20	--	1200	11	--
DEC											
14...	<1	<10	--	--	<10	--	20	--	830	14	--
JAN 1985											
14...	<1	<10	--	--	<10	--	60	--	850	16	--
JUN											
07...	<1	<1	<10	<10	2	1	3	370	380	8	3
18...	--	--	--	--	--	--	--	--	--	--	--
21...	<1	<1	<10	20	3	0	3	660	670	10	4
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	<1	<1	<10	<10	2	0	2	730	740	6	<1
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
07...	<1	<1	<10	<10	1	1	2	470	480	10	<1
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
02...	<1	<1	<10	<10	<1	--	2	400	410	7	<1
10...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
02...	--	--	--	--	--	--	--	--	--	--	--
08...	<1	<1	<10	<10	2	0	2	330	340	11	1
16...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
NOV											
05...	--	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	LEAD, SUS-PENDED RECOV-ERABLE (UG/L AS PB) (01050)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN) (01054)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
OCT 1984										
23...	--	--	--	190	170	<0.1	<0.10	<1	1	--
NOV										
30...	--	--	--	210	170	<0.1	<0.10	<1	<1	--
DEC										
14...	--	--	--	310	300	<0.1	<0.10	<1	<1	--
JAN 1985										
14...	--	--	--	230	220	<0.1	0.10	<1	<1	--
JUN										
07...	0	1	20	90	70	<0.1	<0.10	<1	<1	<3
18...	--	--	--	--	--	--	--	--	--	--
21...	0	2	70	110	45	<0.1	0.10	<1	<1	5
26...	--	--	--	--	--	--	--	--	--	--
JUL										
03...	--	--	--	--	--	--	--	--	--	--
08...	--	<1	20	160	140	<0.1	<0.10	<1	<1	4
17...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--
AUG										
07...	--	1	20	60	41	<0.1	<0.10	<1	<1	7
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--
SEP										
02...	--	1	10	80	66	<0.1	<0.10	1	1	13
10...	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--
OCT										
02...	--	--	--	--	--	--	--	--	--	--
08...	--	<1	20	120	99	0.3	0.30	<1	<1	9
16...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--
NOV										
05...	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN) (01091)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ALUM-INUM, SUS-PENDED RECOV. (UG/L AS AL) (01107)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE) (01146)	SELE-NIUM, TOTAL (UG/L AS SE) (01147)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)
OCT 1984										
23...	--	--	--	--	--	1	--	--	21	47
NOV										
30...	--	--	--	--	--	1	--	--	53	78
DEC										
14...	--	--	--	--	--	2	--	--	20	62
JAN 1985										
14...	--	--	--	--	--	2	--	--	19	65
JUN										
07...	--	40	30	<10	--	2	--	<1	4	94
18...	--	--	--	--	--	--	--	--	4	79
21...	5	10	120	<10	--	1	--	--	29	97
26...	--	--	--	--	--	--	--	--	12	91
JUL										
03...	--	--	--	--	--	--	--	--	75	97
08...	30	30	70	<10	--	2	--	--	5	79
17...	--	--	--	--	--	--	--	--	5	90
23...	--	--	--	--	--	--	--	--	4	87
30...	--	--	--	--	--	--	--	--	7	91
AUG										
07...	--	<10	20	10	10	1	0	1	3	76
14...	--	--	--	--	--	--	--	--	4	76
21...	--	--	--	--	--	--	--	--	2	87
27...	--	--	--	--	--	--	--	--	4	86
SEP										
02...	0	10	20	20	0	5	0	2	2	92
10...	--	--	--	--	--	--	--	--	64	89
17...	--	--	--	--	--	--	--	--	2	82
24...	--	--	--	--	--	--	--	--	2	63
OCT										
02...	--	--	--	--	--	--	--	--	2	76
08...	1	10	30	20	10	2	0	2	6	84
16...	--	--	--	--	--	--	--	--	1	77
23...	--	--	--	--	--	--	--	--	4	89
29...	--	--	--	--	--	--	--	--	2	95
NOV										
05...	--	--	--	--	--	--	--	--	1	100
14...	--	--	--	--	--	--	--	--	40	60
21...	--	--	--	--	--	--	--	--	114	51

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

		TEMPERATURE (DEG C) (00010)	BAROMETRIC PRESSURE (MM HG) (00025)	STREAMFLOW, INSTAN- (CFS) (00061)	SPECIFIC CONDUCT- (US/CM) (00095)	SPECIFIC CONDUCTANCE (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENTATION) (00301)	PH (STAND- UNITS) (00400)	PH LAB (STAND- UNITS) (00403)	NITROGEN, AMMONIA + ORGANIC DIS. AS N) (00623)	NITROGEN, NO2+NO3 TIME AS N) (00630)	WATER
DEC 1985													
05...	1315	0.0	692	10	1340	1400	10.8	82	7.80	7.90	--	--	
FEB 1986													
07...	1000	0.0	693	27	1300	1380	12.6	95	8.10	8.00	--	--	
26...	1130	0.5	687	92	761	815	10.1	78	7.90	7.60	0.90	--	
27...	1330	--	--	50	--	--	--	--	--	--	--	--	
28...	1230	--	--	37	--	--	--	--	--	--	--	--	
MAR													
03...	1100	--	--	32	--	--	--	--	--	--	--	--	
05...	1315	--	--	33	--	--	--	--	--	--	--	--	
06...	1530	1.5	--	28	1090	--	--	--	--	--	--	--	
10...	1200	--	--	28	--	--	--	--	--	--	--	--	
12...	1030	--	--	25	--	--	--	--	--	--	--	--	
APR													
06...	1645	16.0	--	50	845	871	8.2	--	8.50	8.30	0.40	--	
24...	1445	11.5	683	145	484	--	9.3	95	8.00	--	--	--	
28...	1520	--	--	126	--	--	--	--	--	--	--	--	
MAY													
21...	1310	19.0	680	46	835	--	7.9	96	8.50	--	--	--	
JUN													
04...	1600	22.5	691	49	840	--	6.7	86	8.20	--	--	1.60	
10...	1345	--	--	158	--	--	--	--	--	--	--	1.10	
23...	1405	25.0	690	32	909	876	8.1	109	--	8.50	0.30	--	
JUL													
16...	1400	28.5	681	16	1090	1020	7.9	115	8.30	8.20	0.50	--	
AUG													
12...	1720	28.5	684	9.2	1150	--	7.2	104	8.17	--	--	--	
SEP													
18...	1655	13.5	688	16	1150	1040	9.7	103	8.37	8.10	0.40	--	

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS (MG/L AS CACO3) (00900)	HARDNESS NONCARBONATE (MG/L AS CACO3) (95902)	ALKALINITY LAB (MG/L AS CACO3) (90410)
DEC 1985												
05...	--	--	--	3.0	2.0	0.020	0.02	525	--	690	480	207
FEB 1986												
07...	--	--	--	3.4	3.1	0.020	0.02	1040	--	650	460	192
26...	2.50	--	0.040	--	--	--	0.02	558	--	--	--	104
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	2.00	--	0.023	7.8	3.4	--	0.02	611	580	380	240	136
24...	--	--	--	12	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
21...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	0.210	--	9.0	--	--	--	--	--	--	--	--
10...	--	2.10	--	40	--	--	--	--	--	--	--	--
23...	1.70	--	0.020	2.2	2.3	--	<0.01	658	620	440	260	174
JUL												
16...	1.80	--	0.153	1.9	2.0	--	0.01	815	790	540	390	155
AUG												
12...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
18...	3.20	--	0.027	2.1	1.7	--	0.01	940	800	540	400	139

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	POTAS-SIUM, TOTAL RECOV-ERABLE (MG/L AS K) (00937)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUO-RIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)
DEC 1985												
05...	160	71	51	0.9	14	10	15	20	570	--	--	17
FEB 1986												
07...	150	67	57	1	16	11	11	21	550	--	--	18
26...	84	>5.0	>5.0	--	--	7.8	--	11	280	0.60	6.5	20
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	88	39	38	0.9	18	6.5	--	12	310	0.60	7.1	37
24...	--	--	--	--	--	--	--	--	--	--	--	31
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
21...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
23...	100	45	32	0.7	14	7.1	--	14	310	0.60	11	58
JUL												
16...	120	59	45	0.9	15	9.4	--	16	440	0.70	10	64
AUG												
12...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
18...	120	59	47	0.9	16	9.7	--	17	450	0.70	8.5	60

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DIS-SOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOV-ERABLE (UG/L AS B) (01022)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)
DEC 1985												
05...	38	100	120	<1	1	<10	<10	2	2	230	24	<1
FEB 1986												
07...	--	100	140	<1	1	<10	<10	<1	2	660	13	<1
26...	--	--	--	--	--	--	--	1	--	--	21	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	--	--	--	--	--	--	--	4	--	--	<3	--
24...	--	--	--	<1	--	--	--	2	--	--	20	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
21...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	<1	--	--	--	2	--	--	8	--
JUL												
16...	--	--	--	<1	--	--	--	4	--	--	9	--
AUG												
12...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
18...	--	--	--	<1	--	--	--	2	--	--	17	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)
DEC 1985												
05...	1	240	220	0.1	0.10	<1	1	<3	20	--	<10	<10
FEB 1986												
07...	<1	310	270	0.1	0.20	<1	<1	8	140	--	70	<10
26...	--	--	170	0.1	--	--	--	7	--	2	--	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
03...	--	--	--	--	--	--	--	--	--	--	--	--
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
06...	--	--	180	<0.1	--	--	--	<3	--	2	--	--
24...	--	--	100	<0.1	--	--	--	<10	--	2	--	--
28...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
21...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
04...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	150	<0.1	--	--	--	9	--	2	--	--
JUL												
16...	--	--	52	<0.1	--	--	--	5	--	3	--	--
AUG												
12...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
18...	--	--	94	<0.1	--	--	--	18	--	2	--	--

Table 35.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	SELENIUM, DISSOLVED (UG/L AS SE) (01145)	SELENIUM, TOTAL (UG/L AS SE) (01147)	SEDIMENT, SUSPENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)
DEC 1985											
05...	2	2	40	45	--	--	--	--	--	--	--
FEB 1986											
07...	3	3	17	70	--	--	--	--	--	--	--
26...	2	--	1160	--	38	46	55	69	98	100	--
27...	--	--	167	97	--	--	--	--	--	--	--
28...	--	--	46	--	--	--	--	--	--	--	--
MAR											
03...	--	--	44	--	--	--	--	--	--	--	--
05...	--	--	37	--	--	--	--	--	--	--	--
06...	--	--	37	--	--	--	--	--	--	--	--
10...	--	--	42	--	--	--	--	--	--	--	--
12...	--	--	20	--	--	--	--	--	--	--	--
APR											
06...	--	--	123	98	--	--	--	--	--	--	--
24...	--	--	380	--	34	43	--	64	88	93	100
28...	--	--	193	96	--	--	--	--	--	--	--
MAY											
21...	--	--	13	90	--	--	--	--	--	--	--
JUN											
04...	--	--	86	--	--	--	--	--	--	--	--
10...	--	--	1390	--	39	53	66	78	97	99	100
23...	--	--	20	--	--	--	--	--	--	--	--
JUL											
16...	--	--	7	95	--	--	--	--	--	--	--
AUG											
12...	--	--	5	98	--	--	--	--	--	--	--
SEP											
18...	--	--	4	82	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)
JUN 1985											
26...	1310	15.5	697	186	1710	--	9.2	101	8.60	--	--
JUL											
03...	1330	26.0	--	221	1810	--	--	--	8.60	--	--
08...	1500	28.0	653	248	1900	1910	6.6	100	8.50	8.20	--
11...	1015	24.0	--	237	1780	--	--	--	--	--	--
17...	1245	24.0	690	344	1830	--	7.8	103	8.50	--	--
23...	1400	24.5	688	315	E1810	--	9.5	--	8.60	--	--
30...	1200	17.5	690	300	1890	--	9.0	104	8.50	--	--
AUG											
08...	1300	25.5	685	240	1980	1940	9.8	135	8.60	8.00	--
14...	1230	17.5	698	221	1970	--	9.6	110	8.50	--	--
22...	1300	24.5	653	284	2010	--	8.3	117	8.50	--	--
27...	1145	22.0	700	354	1880	--	9.1	114	8.40	--	--
SEP											
03...	1330	22.5	690	400	1890	1910	8.6	111	8.30	8.20	--
10...	1130	--	--	282	--	--	--	--	--	--	--
19...	1330	15.5	690	59	2460	--	9.1	102	8.10	--	--
24...	1115	6.0	690	56	2450	--	15.0	135	8.30	--	--
OCT											
01...	1330	9.5	--	59	2450	2510	--	--	8.50	8.20	1.30
02...	1250	13.0	690	57	2420	--	10.3	109	8.10	--	--
10...	1330	8.0	695	45	2580	2610	13.1	122	7.80	8.20	--
16...	1045	12.5	690	50	2610	--	8.6	90	7.90	--	--
24...	1400	11.0	698	44	2640	--	11.4	114	8.70	--	--
30...	1250	9.5	690	46	2660	--	9.7	95	8.00	--	--
NOV											
06...	1415	5.5	692	30	2670	--	10.4	92	8.00	--	--
15...	1500	0.0	--	53	2820	2900	--	--	8.00	8.00	3.00
21...	1330	0.0	693	47	3250	--	9.5	73	7.96	--	--
DEC											
09...	1300	0.0	708	41	3080	3120	7.9	59	7.70	7.80	--
JAN 1986											
23...	1515	0.0	--	52	2680	2770	--	--	7.90	7.90	5.50
FEB											
07...	1524	0.0	--	547	2760	2900	8.9	--	8.00	7.80	--
27...	1100	--	--	1170	--	--	--	--	--	--	--
28...	1045	--	--	1400	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	PHOS-PHORUS, TOTAL (MG/L AS P) (00665)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DIS-SOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DIS-SOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	HARD-NESS (MG/L AS CACO3) (00900)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3) (95902)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)
JUN 1985											
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	--	--	5.7	5.6	<0.010	0.01	1610	--	950	810	144
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
08...	--	--	7.4	5.9	<0.010	<0.01	--	--	940	800	146
14...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	--	--	6.5	5.1	<0.010	<0.01	1600	--	920	770	147
10...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
01...	0.010	0.020	--	--	<0.010	--	--	2000	1100	930	200
02...	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	3.9	3.8	<0.010	<0.01	2180	--	1400	1200	201
16...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	--	--	--
15...	<0.010	0.020	--	--	--	--	--	2400	1400	1100	255
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
09...	--	--	13	4.2	<0.010	<0.01	2690	--	1700	1300	329
JAN 1986											
23...	0.040	0.010	--	--	--	--	--	2400	1200	940	270
FEB											
07...	--	--	5.8	5.6	<0.010	<0.01	2580	--	1000	760	256
27...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	POTAS-SIUM, TOTAL RECOV-ERABLE (MG/L AS K) (00937)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUO-RIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)
JUN 1985											
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	230	91	120	2	21	8.5	9.1	5.0	920	--	--
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
08...	230	90	120	2	21	8.8	8.2	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	230	83	99	1	19	8.9	8.4	16	970	--	--
10...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
01...	270	110	160	2	23	9.4	--	15	1300	0.50	5.0
02...	--	--	--	--	--	--	--	--	--	--	--
10...	320	150	180	2	22	9.7	10	28	1400	--	--
16...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	--	--	--
15...	290	160	220	3	26	10	--	29	1500	0.50	5.7
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
09...	350	190	250	3	25	10	15	39	1700	--	--
JAN 1986											
23...	270	130	230	3	29	10	--	51	1500	0.50	6.2
FEB											
07...	210	120	270	4	36	11	10	31	1400	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	ARSENIC SUS-PENDED TOTAL (UG/L AS AS) (01001)	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DIS-SOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOV-ERABLE (UG/L AS B) (01022)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, SUS-PENDED RECOV-ERABLE (UG/L AS CU) (01041)
JUN 1985											
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	18	--	--	270	310	<1	<1	<10	<10	2	2
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
08...	--	3	21	300	380	<1	<1	<10	10	1	--
14...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	15	18	33	270	270	<1	<1	<10	<10	1	4
10...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
01...	14	--	--	410	--	<1	--	1	--	3	--
02...	--	--	--	--	--	--	--	--	--	--	--
10...	12	4	16	420	430	<1	<1	<10	<10	2	1
16...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	460	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
09...	6	--	7	470	480	<1	1	<10	<10	1	--
JAN 1986											
23...	--	--	--	360	--	--	--	--	--	--	--
FEB											
07...	7	--	--	350	390	1	1	<10	10	<1	--
27...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE) (01044)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, SUS-PENDED RECOV-ERABLE (UG/L AS PB) (01050)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN) (01054)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)
JUN 1985											
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	4	2400	2400	5	6	--	<1	120	130	7	<1.0
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
08...	<1	250	260	7	<1	--	4	100	100	5	--
14...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	5	3000	3000	4	<1	--	2	120	130	7	<0.1
10...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
01...	--	--	--	40	2	--	--	--	--	60	--
02...	--	--	--	--	--	--	--	--	--	--	--
10...	3	140	170	30	3	0	1	10	70	60	<0.1
16...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
09...	1	--	180	40	<1	--	1	--	190	180	0.1
JAN 1986											
23...	--	--	--	--	--	--	--	--	--	--	--
FEB											
07...	2	--	550	20	<1	--	<1	--	210	200	0.1
27...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN) (01091)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ALUM-INUM, SUS-PENDED RECOV. (UG/L AS AL) (01107)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SELE-NIUM, SUS-PENDED TOTAL AS SE) (01146)
JUN 1985											
26...	--	--	--	--	--	--	--	--	--	--	--
JUL											
03...	--	--	--	--	--	--	--	--	--	--	--
08...	<0.10	<1	<1	7	20	30	1800	<10	--	5	--
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
AUG											
08...	<0.10	<1	<1	7	3	10	790	10	780	5	0
14...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	0.20	<1	<1	17	3	20	1500	10	1500	5	0
10...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
OCT											
01...	<0.10	<1	--	20	--	--	--	--	--	5	--
02...	--	--	--	--	--	--	--	--	--	--	--
10...	<0.10	<1	<1	<10	--	10	40	<10	--	6	0
16...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	--	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
DEC											
09...	0.10	<1	1	<10	--	20	90	<10	--	12	--
JAN 1986											
23...	--	--	--	--	--	--	--	--	--	--	--
FEB											
07...	0.20	<1	<1	10	--	20	100	<10	--	17	--
27...	--	--	--	--	--	--	--	--	--	--	--
28...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	SELE-NIUM, TOTAL (UG/L AS SE) (01147)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER THAN .500 MM (70345)
JUN 1985											
26...	--	244	99	--	--	--	--	--	--	--	--
JUL											
03...	--	218	99	--	--	--	--	--	--	--	--
08...	--	245	98	--	--	--	--	--	--	--	--
11...	--	--	--	--	--	--	--	--	--	--	--
17...	--	134	96	--	--	--	--	--	--	--	--
23...	--	145	96	--	--	--	--	--	--	--	--
30...	--	225	99	--	--	--	--	--	--	--	--
AUG											
08...	5	214	99	--	--	--	--	--	--	--	--
14...	--	192	95	--	--	--	--	--	--	--	--
22...	--	172	99	--	--	--	--	--	--	--	--
27...	--	224	99	--	--	--	--	--	--	--	--
SEP											
03...	5	214	97	--	--	--	--	--	--	--	--
10...	--	158	99	--	--	--	--	--	--	--	--
19...	--	7	80	--	--	--	--	--	--	--	--
24...	--	3	56	--	--	--	--	--	--	--	--
OCT											
01...	--	--	--	--	--	--	--	--	--	--	--
02...	--	3	80	--	--	--	--	--	--	--	--
10...	6	3	81	--	--	--	--	--	--	--	--
16...	--	9	96	--	--	--	--	--	--	--	--
24...	--	5	85	--	--	--	--	--	--	--	--
30...	--	6	94	--	--	--	--	--	--	--	--
NOV											
06...	--	4	93	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--	--
21...	--	235	75	--	--	--	--	--	--	--	--
DEC											
09...	13	108	26	--	--	--	--	--	--	--	--
JAN 1986											
23...	--	--	--	--	--	--	--	--	--	--	--
FEB											
07...	--	43	12	--	--	--	--	--	--	--	--
27...	--	2720	--	46	54	63	70	91	98	100	100
28...	--	774	--	58	68	78	85	97	100	100	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, TOTAL (MG/L AS N) (00600)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)
MAR 1986												
03...	1400	1.0	704	1190	1060	1140	10.9	83	7.90	7.70	--	1.5
05...	1015	--	--	1440	--	--	--	--	--	--	--	--
06...	1400	--	--	1800	--	--	--	--	--	--	--	--
10...	1300	--	--	788	--	--	--	--	--	--	--	--
12...	1200	--	--	770	--	--	--	--	--	--	--	--
21...	1205	9.5	696	236	2160	--	10.5	101	8.30	--	--	--
APR												
09...	1230	12.5	697	338	1520	1530	9.1	94	8.10	7.70	--	0.50
MAY												
01...	1425	13.5	702	401	1460	1480	--	--	--	7.90	--	--
08...	1445	9.0	--	230	2110	2130	--	--	8.50	8.10	--	0.60
JUN												
02...	1130	23.5	693	92	2460	--	7.1	93	8.40	8.20	--	0.40
JUL												
08...	1430	28.0	698	252	1820	1910	8.2	116	8.30	8.10	--	0.50
AUG												
13...	1500	22.0	692	315	1700	1730	9.3	118	8.35	8.00	1.1	0.40
SEP												
19...	1415	15.0	696	233	1930	1920	10.1	111	8.20	8.10	1.6	0.70
25...	1254	15.0	679	6460	725	711	3.2	36	--	7.70	2.3	0.90
26...	1315	13.5	690	5360	621	--	6.8	73	8.20	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS (MG/L AS CACO3) (00900)	HARDNESS NONCARBONATE (MG/L AS CACO3) (95902)	ALKALINITY LAB (MG/L AS CACO3) (90410)
MAR 1986												
03...	--	3.40	0.540	0.030	--	--	<0.01	803	720	330	240	96
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
09...	--	1.20	0.830	0.019	29	6.2	<0.01	1160	1100	520	410	110
MAY												
01...	1.00	--	0.230	--	17	--	--	--	--	--	--	124
08...	--	1.40	0.070	<0.005	8.8	6.7	<0.01	1780	1600	840	660	181
JUN												
02...	--	0.330	0.030	<0.005	5.5	5.0	<0.01	2180	2000	1100	970	163
JUL												
08...	--	0.860	0.030	0.005	5.6	5.2	<0.01	1640	1500	870	710	153
AUG												
13...	0.300	0.260	0.050	0.007	4.6	4.4	0.01	1460	1300	790	650	143
SEP												
19...	1.10	1.10	0.020	0.005	4.5	3.6	0.01	1620	1500	900	770	132
25...	0.700	0.640	0.190	0.032	36	4.4	<0.01	535	500	260	150	107
26...	--	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUO-RIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	BORON, DIS-SOLVED (UG/L AS B) (01020)
MAR 1986												
03...	74	36	110	3	41	7.5	14	430	0.30	4.1	6	110
05...	--	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
09...	110	59	150	3	38	7.7	16	660	0.50	7.4	5	210
MAY												
01...	--	--	--	--	--	--	--	--	--	--	--	--
08...	170	100	190	3	33	7.9	32	1000	0.40	5.9	13	300
JUN												
02...	240	130	190	3	27	9.9	47	1300	0.50	1.1	11	380
JUL												
08...	200	89	140	2	26	8.9	25	940	0.50	5.1	16	--
AUG												
13...	190	77	98	2	21	8.2	12	780	0.50	4.9	14	--
SEP												
19...	210	92	120	2	22	7.9	19	940	0.50	4.5	10	--
25...	65	23	45	1	27	8.5	6.2	280	0.40	3.0	12	--
26...	--	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)
MAR 1986											
03...	<1	<1	1	19	1	56	0.1	1.1	<1	6	<1
05...	--	--	--	--	--	--	--	--	--	--	--
06...	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--	--
12...	--	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--	--
APR											
09...	--	--	5	10	--	2	<0.1	--	--	5	1
MAY											
01...	--	--	--	--	--	--	--	--	--	--	--
08...	<1	--	4	20	--	130	<0.1	--	--	<10	<1
JUN											
02...	<1	--	<1	40	--	50	<0.1	--	--	<10	<1
JUL											
08...	<1	--	2	4	--	6	<0.1	--	--	11	<1
AUG											
13...	<1	--	6	6	--	4	<0.1	--	--	62	1
SEP											
19...	<1	--	1	3	--	17	<0.1	--	--	9	<1
25...	<1	--	1	8	--	5	<0.1	--	--	11	<1
26...	--	--	--	--	--	--	--	--	--	--	--

Table 36.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	SELENIUM, DISSOLVED (UG/L AS SE) (01145)	SEDIMENT, SUSPENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER THAN .500 MM (70345)
MAR 1986											
03...	10	3960	--	46	54	64	72	92	96	99	100
05...	--	4070	--	57	67	76	84	98	99	100	--
06...	--	4860	--	54	64	73	81	96	99	100	--
10...	--	1480	--	63	74	83	90	99	100	--	--
12...	--	1320	99	64	74	83	92	--	--	--	--
21...	--	339	99	--	--	--	--	--	--	--	--
APR											
09...	--	2070	100	74	85	94	98	--	--	--	--
MAY											
01...	--	870	100	71	82	92	96	100	--	--	--
08...	--	66	--	--	--	--	--	--	--	--	--
JUN											
02...	--	18	98	--	--	--	--	--	--	--	--
JUL											
08...	--	54	96	--	--	--	--	--	--	--	--
AUG											
13...	--	46	99	--	--	--	--	--	--	--	--
SEP											
19...	--	21	97	--	--	--	--	--	--	--	--
25...	--	7070	94	50	62	74	83	94	97	99	100

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)
OCT 1984												
28...	1200	11.5	--	171	--	--	--	--	--	--	--	--
JUN 1985												
10...	1100	--	--	278	--	2040	--	--	--	7.90	--	--
19...	1000	18.5	720	188	1830	--	10.1	115	8.40	--	--	--
JUL												
05...	1800	27.0	740	230	2160	--	9.3	121	8.60	--	--	--
09...	1145	27.0	720	202	2250	2250	9.4	127	8.50	8.20	--	--
17...	1545	26.5	710	261	2110	--	8.0	108	8.50	--	--	--
25...	1145	25.0	720	294	1980	--	11.9	153	8.50	--	--	--
31...	1140	17.0	721	367	1950	--	10.1	112	8.40	--	--	--
AUG												
09...	1130	19.5	701	205	2140	2080	9.2	109	8.50	7.80	--	--
13...	1400	20.5	653	148	2110	--	8.4	110	8.40	--	--	--
22...	1000	23.0	653	790	2020	--	5.7	78	7.90	--	--	--
30...	1345	26.0	710	273	2170	--	8.7	117	8.30	--	--	--
SEP												
03...	0940	23.0	710	273	2170	2190	8.7	110	8.30	8.10	--	--
09...	1030	16.0	721	316	1960	--	9.7	105	8.20	--	--	--
19...	1115	16.5	710	188	2250	--	9.9	110	8.10	--	--	--
26...	1200	10.0	710	188	2410	--	10.5	101	8.20	--	--	--
OCT												
03...	1200	10.0	630	178	2800	--	10.6	115	8.40	--	--	--
10...	1010	5.0	720	162	2520	2550	13.3	111	8.10	8.10	--	--
17...	1130	10.0	720	191	1840	--	10.4	98	7.90	--	--	--
24...	1200	9.5	693	145	2420	--	11.2	109	8.40	--	--	--
30...	1000	6.0	720	162	2340	--	12.6	107	8.20	--	--	--
NOV												
06...	1045	4.0	714	162	2330	2440	12.6	103	8.10	8.10	--	--
APR 1986												
11...	1430	21.0	697	1440	--	1260	--	--	8.00	8.30	0.62	--
22...	1245	12.5	--	4890	1000	1120	--	--	8.00	7.60	--	0.500
29...	1230	9.0	712	8120	1040	1050	--	--	7.90	7.80	0.50	--
MAY												
07...	1330	--	--	428	2070	--	--	--	7.90	--	--	--
14...	1130	16.0	716	5240	956	929	7.9	86	7.74	7.90	--	--
29...	1240	24.0	722	565	2590	2610	7.7	98	8.40	8.30	0.30	<0.100

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS (MG/L AS CACO3) (00900)	HARDNESS NONCARBONATE (MG/L AS CACO3) (95902)	ALKALINITY LAB (MG/L AS CACO3) (90410)
OCT 1984												
28...	--	--	--	--	--	--	--	--	--	--	--	--
JUN 1985												
10...	--	--	--	6.4	4.6	0.010	0.01	1680	--	820	720	105
19...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
05...	--	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	4.7	5.3	<0.010	0.01	1900	--	950	850	99
17...	--	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
09...	--	--	--	7.9	4.1	<0.010	<0.01	1750	--	900	800	97
13...	--	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
03...	--	--	--	7.9	5.6	<0.010	<0.01	1880	--	1000	920	103
09...	--	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
03...	--	--	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	3.7	3.2	<0.010	<0.01	2120	--	1000	890	141
17...	--	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
06...	--	--	--	4.6	3.7	<0.010	<0.01	2030	--	1000	920	126
APR 1986												
11...	0.094	--	0.026	35	7.8	--	<0.01	949	880	250	130	113
22...	--	0.460	--	39	--	--	--	--	--	--	--	111
29...	0.730	--	0.020	37	6.8	--	<0.01	739	720	270	170	99
MAY												
07...	--	--	--	--	--	--	--	--	--	--	--	--
14...	0.360	--	0.030	--	--	--	--	656	600	240	130	104
29...	<0.100	0.060	0.005	5.3	5.4	--	<0.01	2150	2100	900	730	161

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	POTAS-SIUM, TOTAL RECOV-ERABLE (MG/L AS K) (00937)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)	SULFATE DIS-SOLVED (MG/L AS SO4) (00945)	FLUO-RIDE, DIS-SOLVED (MG/L AS F) (00950)	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)
OCT 1984												
28...	--	--	--	--	--	--	--	--	--	--	--	--
JUN 1985												
10...	190	84	170	3	31	10	14	41	950	--	--	5
19...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
05...	--	--	--	--	--	--	--	--	--	--	--	--
09...	200	110	190	3	30	13	13	10	1100	--	--	7
17...	--	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--	--
AUG												
09...	210	91	150	2	26	11	15	33	1100	--	--	9
13...	--	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
03...	250	96	160	2	25	12	12	38	1100	--	--	6
09...	--	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
03...	--	--	--	--	--	--	--	--	--	--	--	--
10...	230	110	240	3	33	12	12	96	1200	--	--	3
17...	--	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--	--
NOV												
06...	220	120	230	3	32	12	10	97	1200	--	--	2
APR 1986												
11...	82	10	160	5	58	7.1	--	14	530	0.30	7.9	3
22...	--	--	--	--	--	--	--	--	--	--	--	--
29...	70	23	120	3	48	6.3	--	11	420	0.30	8.0	4
MAY												
07...	--	--	--	--	--	--	--	--	--	--	--	--
14...	66	17	100	3	47	6.5	--	8.3	330	0.30	7.1	1
29...	220	84	280	4	40	12	--	54	1300	0.40	5.7	4

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	ARSENIC SUS-PENDED TOTAL (UG/L AS AS) (01001)	ARSENIC TOTAL (UG/L AS AS) (01002)	BORON, DIS-SOLVED (UG/L AS B) (01020)	BORON, TOTAL RECOV-ERABLE (UG/L AS B) (01022)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	CADMIUM TOTAL RECOV-ERABLE (UG/L AS CD) (01027)	CHRO-MIUM, DIS-SOLVED (UG/L AS CR) (01030)	CHRO-MIUM, TOTAL RECOV-ERABLE (UG/L AS CR) (01034)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	COPPER, SUS-PENDED RECOV-ERABLE (UG/L AS CU) (01041)	COPPER, TOTAL RECOV-ERABLE (UG/L AS CU) (01042)
OCT 1984											
28...	--	--	--	--	--	--	--	--	--	--	--
JUN 1985											
10...	11	16	280	300	1	1	10	20	1	11	12
19...	--	--	--	--	--	--	--	--	--	--	--
JUL											
05...	--	--	--	--	--	--	--	--	--	--	--
09...	--	--	360	400	<1	<1	<10	10	1	4	5
17...	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
AUG											
09...	3	12	330	340	<1	<1	<10	10	2	7	9
13...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	9	15	350	340	<1	<1	<10	<10	1	4	5
09...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--
OCT											
03...	--	--	--	--	--	--	--	--	--	--	--
10...	2	5	330	340	<1	<1	<10	<10	2	1	3
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	2	4	320	370	<1	<1	<10	10	1	3	4
APR 1986											
11...	--	--	--	--	--	--	--	--	5	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	--	--	<1	--	--	--	3	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	<1	--	<1	--	7	--	--
29...	--	--	--	--	<9	--	--	--	2	--	--

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	IRON, SUS-PENDED RECOV-ERABLE (UG/L AS FE) (01044)	IRON, TOTAL RECOV-ERABLE (UG/L AS FE) (01045)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	LEAD, DIS-SOLVED (UG/L AS PB) (01049)	LEAD, SUS-PENDED RECOV-ERABLE (UG/L AS PB) (01050)	LEAD, TOTAL RECOV-ERABLE (UG/L AS PB) (01051)	MANGA-NESE, SUS-PENDED RECOV. (UG/L AS MN) (01054)	MANGA-NESE, TOTAL RECOV-ERABLE (UG/L AS MN) (01055)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)
OCT 1984											
28...	--	--	--	--	--	--	--	--	--	--	--
JUN 1985											
10...	1400	1400	20	1	--	8	--	780	10	0.1	0.30
19...	--	--	--	--	--	--	--	--	--	--	--
JUL											
05...	--	--	--	--	--	--	--	--	--	--	--
09...	3100	3100	20	4	--	<1	--	160	<10	<0.1	<0.10
17...	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
AUG											
09...	530	560	30	<1	--	4	180	190	10	<0.1	<0.10
13...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	3000	3000	30	<1	--	3	--	150	<10	<0.1	<0.10
09...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--
OCT											
03...	--	--	--	--	--	--	--	--	--	--	--
10...	870	900	30	2	0	2	40	90	50	<0.1	<0.10
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	1900	1900	40	<1	--	2	70	110	40	<0.1	0.20
APR 1986											
11...	--	--	7	--	--	--	--	--	2	<0.1	--
22...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	20	--	--	--	--	--	2	<0.1	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	1	--	--	--	--	<1	0.4	--
29...	--	--	20	<5	--	--	--	--	20	<0.1	--

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	SILVER, DIS-SOLVED (UG/L AS AG) (01075)	SILVER, TOTAL RECOV-ERABLE (UG/L AS AG) (01077)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ZINC, SUS-PENDED RECOV-ERABLE (UG/L AS ZN) (01091)	ZINC, TOTAL RECOV-ERABLE (UG/L AS ZN) (01092)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	ALUM-INUM, TOTAL RECOV-ERABLE (UG/L AS AL) (01105)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)	ALUM-INUM, SUS-PENDED RECOV. (UG/L AS AL) (01107)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SELE-NIUM, SUS-PENDED TOTAL (UG/L AS SE) (01146)
OCT 1984											
28...	--	--	--	--	--	--	--	--	--	--	--
JUN 1985											
10...	1	1	10	60	70	--	<5400	10	--	4	0
19...	--	--	--	--	--	--	--	--	--	--	--
JUL											
05...	--	--	--	--	--	--	--	--	--	--	--
09...	<1	<1	<10	--	100	--	4800	<10	--	4	--
17...	--	--	--	--	--	--	--	--	--	--	--
25...	--	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	--	--	--	--	--	--	--	--
AUG											
09...	<1	<1	<10	--	30	--	5600	10	5600	3	0
13...	--	--	--	--	--	--	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
SEP											
03...	<1	<1	10	20	30	--	3400	10	3400	4	0
09...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--	--
OCT											
03...	--	--	--	--	--	--	--	--	--	--	--
10...	<1	<1	10	0	10	--	1400	10	1400	3	0
17...	--	--	--	--	--	--	--	--	--	--	--
24...	--	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	--	--	--	--	--	--	--	--
NOV											
06...	<1	<1	10	10	20	--	3800	20	3800	3	0
APR 1986											
11...	--	--	<3	--	--	1	--	--	--	--	--
22...	--	--	--	--	--	--	--	--	--	--	--
29...	--	--	8	--	--	<1	--	--	--	--	--
MAY											
07...	--	--	--	--	--	--	--	--	--	--	--
14...	<1	--	10	--	--	--	--	20	--	3	--
29...	--	--	<10	--	--	<1	--	--	--	--	--

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	SELE-NIUM, TOTAL (UG/L AS SE) (01147)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER THAN .500 MM (70345)
OCT 1984											
28...	--	36	89	--	--	--	--	--	--	--	--
JUN 1985											
10...	2	1040	--	20	23	--	28	33	33	35	85
19...	--	303	100	48	53	--	59	--	--	--	--
JUL											
05...	--	406	97	--	--	--	--	--	--	--	--
09...	--	160	99	76	88	--	98	--	--	--	--
17...	--	228	99	70	79	--	94	--	--	--	--
25...	--	278	98	68	75	--	98	--	--	--	--
31...	--	391	99	--	57	66	80	--	--	--	--
AUG											
09...	3	230	99	57	68	--	95	--	--	--	--
13...	--	700	100	80	87	94	98	--	--	--	--
22...	--	28600	--	62	74	86	96	100	--	--	--
30...	--	407	100	--	--	--	--	--	--	--	--
SEP											
03...	4	316	99	--	--	--	--	--	--	--	--
09...	--	308	99	--	--	--	--	--	--	--	--
19...	--	1300	--	81	89	96	98	99	99	100	--
26...	--	167	99	36	55	84	99	--	--	--	--
OCT											
03...	--	184	99	41	70	91	97	--	--	--	--
10...	3	187	100	--	--	--	--	--	--	--	--
17...	--	10900	100	82	91	97	98	--	--	--	--
24...	--	108	99	--	--	--	--	--	--	--	--
30...	--	369	100	80	90	--	99	--	--	--	--
NOV											
06...	3	274	100	--	--	--	--	--	--	--	--
APR 1986											
11...	--	--	--	--	--	--	--	--	--	--	--
22...	--	6030	--	51	61	70	77	91	94	98	99
29...	--	8040	--	46	55	63	69	82	86	90	91
MAY											
07...	--	429	--	--	--	--	--	--	--	--	--
14...	--	6870	--	--	--	--	--	97	--	--	--
29...	--	199	98	--	--	--	--	--	--	--	--

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, TOTAL (MG/L AS N) (00600)
JUN 1986											
11...	1500	21.5	--	12900	--	968	--	--	8.55	7.90	--
26...	1310	29.0	--	977	1910	--	--	--	8.20	--	--
JUL											
10...	1340	24.5	713	565	2180	2160	8.0	103	8.40	8.20	--
24...	1324	26.5	718	525	1960	--	8.5	113	8.40	--	--
AUG											
07...	1530	26.0	E718	352	2130	--	8.3	--	8.40	--	--
14...	1710	26.0	--	432	2190	2110	7.8	--	8.29	8.00	--
21...	1315	18.5	--	352	2140	--	--	--	8.20	--	--
26...	1434	20.5	724	339	2280	--	--	--	8.28	--	--
SEP											
04...	1527	20.5	720	475	1830	2010	9.1	108	8.40	7.70	--
27...	1405	14.5	713	8700	954	934	7.5	79	8.00	7.60	16

DATE	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS (MG/L AS CACO3) (00900)
JUN 1986											
11...	0.40	1.10	1.00	18.0	0.059	59	--	<0.01	662	670	88
26...	--	<0.100	--	--	--	6.4	--	--	--	--	--
JUL											
10...	0.40	<0.100	<0.100	0.280	0.003	7.0	4.3	<0.01	1760	--	--
24...	--	<0.100	--	0.210	--	11	--	--	--	--	--
AUG											
07...	--	<0.100	--	0.070	--	8.1	--	--	--	--	--
14...	0.30	<0.100	<0.100	0.110	<0.005	6.9	5.5	<0.01	1750	1500	770
21...	--	<0.100	--	0.096	--	10	5.2	--	--	--	--
26...	--	<0.100	--	0.100	--	6.2	4.4	--	--	--	--
SEP											
04...	<0.20	<0.100	<0.100	0.500	<0.005	8.6	4.5	<0.01	1530	1500	700
27...	0.80	1.20	1.20	0.040	0.048	55	5.0	<0.01	787	680	280

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	HARDNESS NONCARBONATE (MG/L AS CACO3) (95902)	ALKALINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DISSOLVED (MG/L AS CA) (00915)	MAGNESIUM, DISSOLVED (MG/L AS MG) (00925)	SODIUM, DISSOLVED (MG/L AS NA) (00930)	SODIUM ADSORPTION RATIO (00931)	PERCENT SODIUM (00932)	POTASSIUM, DISSOLVED (MG/L AS K SO4) (00935)	CHLORIDE, DISSOLVED (MG/L (00940)	SULFATE DISSOLVED (MG/L (00945)
JUN 1986										
11...	0	117	28	4.5	180	9	80	7.6	9.5	350
26...	--	--	--	--	--	--	--	--	--	--
JUL										
10...	--	130	--	--	--	--	--	11	50	1000
24...	--	--	--	--	--	--	--	--	--	--
AUG										
07...	--	--	--	--	--	--	--	--	--	--
14...	640	123	170	83	210	3	37	16	35	950
21...	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--
SEP										
04...	600	98	170	67	190	3	37	12	43	1000
27...	170	108	71	24	97	3	42	8.4	13	400

DATE	FLUORIDE, DISSOLVED (MG/L AS F) (00950)	SILICA, DISSOLVED (MG/L AS SIO2) (00955)	ARSENIC DISSOLVED (UG/L AS AS) (01000)	CADMIUM DISSOLVED (UG/L AS CD) (01025)	COPPER, DISSOLVED (UG/L AS CU) (01040)	IRON, DISSOLVED (UG/L AS FE) (01046)	MANGANESE, DISSOLVED (UG/L AS MN) (01056)	MERCURY DISSOLVED (UG/L AS HG) (71890)	ZINC, DISSOLVED (UG/L AS ZN) (01090)	ANTIMONY, DISSOLVED (UG/L AS SB) (01095)
JUN 1986										
11...	0.70	21	4	<1	7	14	1	<0.1	4	1
26...	--	--	--	--	--	--	--	--	--	--
JUL										
10...	0.40	6.5	3	<1	2	20	<10	<0.1	<10	<1
24...	--	--	--	--	--	--	--	--	--	--
AUG										
07...	--	--	--	--	--	--	--	--	--	--
14...	0.50	5.0	3	<1	3	20	10	<0.1	<10	<1
21...	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--
SEP										
04...	0.50	5.1	4	<1	1	30	<10	<0.1	10	<1
27...	0.50	5.2	4	<1	3	7	1	<0.1	12	<1

Table 37.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	SEDIMENT, SUSPENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER THAN .500 MM (70345)
JUN 1986										
11...	27600	--	64	74	82	89	99	100	--	--
26...	188	95	--	--	--	--	--	--	--	--
JUL										
10...	517	99	66	78	90	95	--	--	--	--
24...	201	98	--	--	--	--	--	--	--	--
AUG										
07...	160	99	--	--	--	--	--	--	--	--
14...	432	99	63	76	89	95	--	--	--	--
21...	159	100	--	--	--	--	--	--	--	--
26...	71	99	--	--	--	--	--	--	--	--
SEP										
04...	504	99	74	87	--	99	--	--	--	--
27...	17200	--	51	63	72	79	91	95	98	100

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	SPECIFIC CONDUCTANCE LAB (US/CM) (90095)	OXYGEN, DISSOLVED (MG/L) (00300)	OXYGEN, DISSOLVED (PERCENT SATURATION) (00301)	PH (STANDARD UNITS) (00400)	PH LAB (STANDARD UNITS) (00403)	NITROGEN, TOTAL (MG/L AS N) (00600)
444121101174001 CHEYENNE RIVER AT CARLIN FLAT, S.D. (LAT 44 41 21N LONG 101 17 40W)											
AUG 1986											
14...	1425	24.5	716	503	2130	2110	7.6	99	8.15	8.10	--
21...	1230	18.5	--	441	2140	--	--	--	8.17	--	--
26...	1700	21.5	--	332	2320	--	--	--	8.30	--	--
SEP											
04...	1257	20.5	723	494	2100	--	9.0	106	8.36	--	--
442134103443501 GOLD RUN BELOW HOMESTAKE DISCHARGE (LAT 44 21 34N LONG 103 44 35W)											
MAR 1986											
13...	1200	15.5	615	5.5	1550	1530	8.6	108	7.90	8.10	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)											
AUG 1986											
13...	1230	20.5	688	60	1790	1810	8.0	100	8.07	8.00	--
SEP											
26...	1515	14.5	--	2790	540	549	6.8	--	--	7.80	0.80
442134103441901 WHITEWOOD CREEK ABOVE GOLD RUN (LAT 44 21 34N LONG 103 44 19W)											
MAR 1986											
13...	1430	15.0	620	9.3	430	437	11.7	143	--	8.40	--
06436170 WHITEWOOD CREEK AT DEADWOOD (LAT 44 22 48N LONG 103 43 25W)											
MAR 1986											
13...	1730	7.0	630	25	--	799	--	--	--	8.20	--
442314103424101 WHITEWOOD CREEK AB SEWAGE TREATMENT PLANT (LAT 44 23 14N LONG 103 42 41W)											
MAR 1986											
13...	1530	12.0	622	13	816	795	0	0	--	8.30	--
06436150 WHITEWOOD CR ABOVE LEAD SD (LAT 44 18 07N LONG 103 46 57W)											
MAR 1986											
13...	1000	3.0	615	2.6	355	381	12.4	115	--	8.50	--
442320103422301 WHITEWOOD CREEK BELOW SEWAGE TREATMENT PLANT (LAT 44 23 20N LONG 103 42 23W)											
MAR 1986											
13...	1630	7.0	624	20	786	775	11.9	121	--	8.10	--

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	NITROGEN, AMMONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITROGEN, NO2+NO3 DISSOLVED (MG/L AS N) (00631)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	PHOSPHORUS, DISSOLVED (MG/L AS P) (00666)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	CARBON, ORGANIC DISSOLVED (MG/L AS C) (00681)	CYANIDE TOTAL (MG/L AS CN) (00720)	CYANIDE DISSOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DISSOLVED (MG/L) (70300)
444121101174001 CHEYENNE RIVER AT CARLIN FLAT, S.D. (LAT 44 41 21N LONG 101 17 40W)										
AUG 1986										
14...	0.40	<0.100	<0.100	0.160	0.012	9.3	5.3	--	<0.01	1780
21...	--	<0.100	--	0.460	--	11	5.6	--	--	--
26...	--	<0.100	--	0.107	--	5.9	4.4	--	--	--
SEP										
04...	--	<0.100	--	0.113	--	6.3	4.4	--	--	--
442134103443501 GOLD RUN BELOW HOMESTAKE DISCHARGE (LAT 44 21 34N LONG 103 44 35W)										
MAR 1986										
13...	1.5	--	22.0	0.450	0.360	--	--	0.590	0.54	1130
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
AUG 1986										
13...	0.50	<0.100	<0.100	0.050	0.008	5.7	5.4	--	<0.01	1550
SEP										
26...	0.60	0.400	0.430	0.560	0.056	17	4.5	--	<0.01	380
442134103441901 WHITEWOOD CREEK ABOVE GOLD RUN (LAT 44 21 34N LONG 103 44 19W)										
MAR 1986										
13...	0.30	--	0.490	0.021	0.005	--	--	<0.010	<0.01	256
06436170 WHITEWOOD CREEK AT DEADWOOD (LAT 44 22 48N LONG 103 43 25W)										
MAR 1986										
13...	0.70	--	6.70	0.089	0.027	--	--	0.160	0.14	539
442314103424101 WHITEWOOD CREEK AB SEWAGE TREATMENT PLANT (LAT 44 23 14N LONG 103 42 41W)										
MAR 1986										
13...	0.70	--	6.40	0.137	0.040	--	--	0.120	0.11	535
06436150 WHITEWOOD CR ABOVE LEAD SD (LAT 44 18 07N LONG 103 46 57W)										
MAR 1986										
13...	0.40	--	0.180	0.029	0.016	--	--	<0.010	<0.01	204
442320103422301 WHITEWOOD CREEK BELOW SEWAGE TREATMENT PLANT (LAT 44 23 20N LONG 103 42 23W)										
MAR 1986										
13...	0.80	--	6.30	0.360	0.210	--	--	0.110	0.10	504

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	HARD-NESS (MG/L AS CACO3) (00900)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3) (95902)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)	CALCIUM DIS-SOLVED (MG/L AS CA) (00915)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG) (00925)	SODIUM, DIS-SOLVED (MG/L AS NA) (00930)	SODIUM AD-SORP-TION RATIO (00931)	PERCENT SODIUM (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)
444121101174001 CHEYENNE RIVER AT CARLIN FLAT, S.D. (LAT 44 41 21N LONG 101 17 40W)										
AUG 1986										
14...	1600	770	650	121	170	83	200	3	36	15
21...	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--
SEP										
04...	--	--	--	--	--	--	--	--	--	--
442134103443501 GOLD RUN BELOW HOMESTAKE DISCHARGE (LAT 44 21 34N LONG 103 44 35W)										
MAR 1986										
13...	--	--	--	94	110	>5.0	120	--	--	>10
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LO 103 21 59W)										
AUG 1986										
13...	1300	800	640	165	190	80	110	2	23	8.2
SEP										
26...	360	170	100	67	44	15	44	2	35	5.7
442134103441901 WHITEWOOD CREEK ABOVE GOLD RUN (LAT 44 21 34N LONG 103 44 19W)										
MAR 1986										
13...	--	--	--	149	51	>5.0	7.9	--	--	2.0
06436170 WHITEWOOD CREEK AT DEADWOOD (LAT 44 22 48N LONG 103 43 25W)										
MAR 1986										
13...	--	--	--	122	71	>39	44	--	--	7.9
442314103424101 WHITEWOOD CREEK AB SEWAGE TREATMENT PLANT (LAT 44 23 14N LONG 103 42 41W)										
MAR 1986										
13...	--	--	--	124	71	>5.0	42	--	--	>7.7
06436150 WHITEWOOD CR ABOVE LEAD SD (LAT 44 18 07N LONG 103 46 57W)										
MAR 1986										
13...	--	--	--	196	45	>5.0	2.4	--	--	1.0
442320103422301 WHITEWOOD CREEK BELOW SEWAGE TREATMENT PLANT (LAT 44 23 20N LONG 103 42 23W)										
MAR 1986										
13...	--	--	--	138	70	>5.0	42	--	--	7.2

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)	SULFATE DISSOLVED (MG/L AS SO4) (00945)	FLUORIDE, DISSOLVED (MG/L AS F) (00950)	SILICA, DISSOLVED (MG/L AS SIO2) (00955)	ARSENIC DISSOLVED (UG/L AS AS) (01000)	CADMIUM DISSOLVED (UG/L AS CD) (01025)	COPPER, DISSOLVED (UG/L AS CU) (01040)	IRON, DISSOLVED (UG/L AS FE) (01046)	MANGANESE, DISSOLVED (UG/L AS MN) (01056)	MERCURY DISSOLVED (UG/L AS HG) (71890)
444121101174001 CHEYENNE RIVER AT CARLIN FLAT, S.D. (LAT 44 41 21N LONG 101 17 40W)										
AUG 1986										
14...	42	970	0.60	5.0	3	<1	3	20	<10	<0.1
21...	--	--	--	--	--	--	--	--	--	--
26...	--	--	--	--	--	--	--	--	--	--
SEP										
04...	--	--	--	--	--	--	--	--	--	--
442134103443501 GOLD RUN BELOW HOMESTAKE DISCHARGE (LAT 44 21 34N LONG 103 44 35W)										
MAR 1986										
13...	12	650	1.2	11	39	--	17	160	220	<0.1
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
AUG 1986										
13...	14	840	0.50	5.9	1	<1	2	6	21	<0.1
SEP										
26...	7.9	200	0.30	5.4	3	<1	4	28	8	<0.1
442134103441901 WHITEWOOD CREEK ABOVE GOLD RUN (LAT 44 21 34N LONG 103 44 19W)										
MAR 1986										
13...	12	60	0.40	10	3	--	2	13	39	<0.1
06436170 WHITEWOOD CREEK AT DEADWOOD (LAT 44 22 48N LONG 103 43 25W)										
MAR 1986										
13...	13	240	0.70	11	9	--	6	53	140	<0.1
442314103424101 WHITEWOOD CREEK AB SEWAGE TREATMENT PLANT (LAT 44 23 14N LONG 103 42 41W)										
MAR 1986										
13...	13	240	0.70	11	10	--	9	30	130	<0.1
06436150 WHITEWOOD CR ABOVE LEAD SD (LAT 44 18 07N LONG 103 46 57W)										
MAR 1986										
13...	2.3	9.9	0.10	10	1	--	<1	36	6	<0.1
442320103422301 WHITEWOOD CREEK BELOW SEWAGE TREATMENT PLANT (LAT 44 23 20N LONG 103 42 23W)										
MAR 1986										
13...	19	210	0.70	11	14	--	8	37	120	<0.1

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	MERCURY TOTAL RECOV-ERABLE (UG/L AS HG) (71900)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	SELE-NIUM, DIS-SOLVED (UG/L AS SE) (01145)	SEDI-MENT, SUS-PENDED (MG/L) (80154)	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)
444121101174001 CHEYENNE RIVER AT CARLIN FLAT, S.D. (LAT 44 41 21N LONG 101 17 40W)										
AUG 1986										
14...	--	<10	1	--	652	99	65	79	90	97
21...	--	--	--	--	241	99	--	--	--	--
26...	--	--	--	--	77	99	--	--	--	--
SEP										
04...	--	--	--	--	128	91	--	--	--	--
442134103443501 GOLD RUN BELOW HOMESTAKE DISCHARGE (LAT 44 21 34N LONG 103 44 35W)										
MAR 1986										
13...	0.20	6	3	7	17	61	--	--	--	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
AUG 1986										
13...	--	10	<1	--	25	98	--	--	--	--
SEP										
26...	--	3	<1	--	2720	97	70	81	88	92
442134103441901 WHITEWOOD CREEK ABOVE GOLD RUN (LAT 44 21 34N LONG 103 44 19W)										
MAR 1986										
13...	0.20	3	<1	2	7	79	--	--	--	--
06436170 WHITEWOOD CREEK AT DEADWOOD (LAT 44 22 48N LONG 103 43 25W)										
MAR 1986										
13...	<0.10	<3	1	3	16	62	--	--	--	--
442314103424101 WHITEWOOD CREEK AB SEWAGE TREATMENT PLANT (LAT 44 23 14N LONG 103 42 41W)										
MAR 1986										
13...	<0.10	<3	<1	3	14	92	--	--	--	--
06436150 WHITEWOOD CR ABOVE LEAD SD (LAT 44 18 07N LONG 103 46 57W)										
MAR 1986										
13...	0.20	<3	<1	1	13	96	--	--	--	--
442320103422301 WHITEWOOD CREEK BELOW SEWAGE TREATMENT PLANT (LAT 44 23 20N LONG 103 42 23W)										
MAR 1986										
13...	0.10	<3	1	3	14	82	--	--	--	--

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	STREAMFLOW, INSTANTANEOUS (CFS) (00061)	SPECIFIC CONDUCTANCE (US/CM) (00095)	PH (STANDARD UNITS) (00400)	NITROGEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	PHOSPHORUS, TOTAL (MG/L AS P) (00665)	CARBON, ORGANIC TOTAL (MG/L AS C) (00680)	SEDIMENT, SUSPENDED (MG/L) (80154)
06438000 BELLE FOURCHE RIVER NEAR ELM SPRINGS (LAT 44 22 11N LONG 102 33 56W)										
MAR 1986										
06...	1115	8.0	--	--	--	--	--	--	--	893
443743103231401 BELLE FOURCHE RIVER AT VALE BRIDGE, SD (LAT 44 37 43N LONG 103 23 14W)										
MAR 1986										
05...	1200	--	--	--	--	--	--	--	--	293
06436100 BELLE FOURCHE RIVER BELOW NISLAND, SD (LAT 44 40 12N LONG 103 29 30W)										
JUL 1986										
08...	1050	--	--	14	--	--	--	--	--	76
443738103152201 BELLE FOURCHE RIVER BELOW VALE, S.D. (LAT 44 37 38N LONG 103 15 22W)										
MAR 1986										
05...	1130	--	--	--	--	--	--	--	--	3660
442252103571801 BELLE FOURCHE RIVER NEAR HEREFORD, S.D. (LAT 44 22 52N LONG 103 57 18W)										
MAR 1986										
06...	1245	--	--	--	--	--	--	--	--	6230
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)										
JUN 1986										
10...	1745	16.0	702	--	695	8.60	1.10	23.0	60	39200

Table 38.--Chemical analyses of surface-water samples collected at 14 miscellaneous sites--Continued

DATE	SED. SUSP. SIEVE DIAM. % FINER THAN .062 MM (70331)	SED. SUSP. FALL DIAM. % FINER THAN .002 MM (70337)	SED. SUSP. FALL DIAM. % FINER THAN .004 MM (70338)	SED. SUSP. FALL DIAM. % FINER THAN .008 MM (70339)	SED. SUSP. FALL DIAM. % FINER THAN .016 MM (70340)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)	SED. SUSP. FALL DIAM. % FINER THAN .250 MM (70344)	SED. SUSP. FALL DIAM. % FINER THAN .500 MM (70345)
06438000 BELLE FOURCHE RIVER NEAR ELM SPRINGS (LAT 44 22 11N LONG 102 33 56W)									
MAR 1986									
06...	100	59	70	80	87	97	99	100	--
443743103231401 BELLE FOURCHE RIVER AT VALE BRIDGE, SD (LAT 44 37 43N LONG 103 23 14W)									
MAR 1986									
05...	99	--	--	--	--	--	--	--	--
06436100 BELLE FOURCHE RIVER BELOW NISLAND, SD (LAT 44 40 12N LONG 103 29 30W)									
JUL 1986									
08...	99	--	--	--	--	--	--	--	--
443738103152201 BELLE FOURCHE RIVER BELOW VALE, S.D. (LAT 44 37 38N LONG 103 15 22W)									
MAR 1986									
05...	--	59	69	79	87	99	100	--	--
442252103571801 BELLE FOURCHE RIVER NEAR HEREFORD, S.D. (LAT 44 22 52N LONG 103 57 18W)									
MAR 1986									
06...	--	57	66	75	83	95	97	100	--
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)									
JUN 1986									
10...	--	61	70	78	85	98	99	99	99

Table 39.--Total chemical analysis of suspended sediment

[Iron, manganese, aluminum, and titanium in weight percent; µg/g, micrograms per gram; µm, micrometers; ft^3/s, cubic feet per second; mg/L, milligrams per liter; <, less than; >, greater than; --, not analyzed]

Site number in figures 1 and 2	Date	Time	Size fraction (µm)	Discharge (ft^3/s)	Sediment concentration (mg/L)	Iron	Manganese	Aluminum	Titanium
Whitewood Creek above Whitewood									
10	04-23-86	1330		165	213	8.0	0.26	5.6	0.32
10	04-23-86	1330		165	213	--	--	--	--
10	06-09-86	1955		89	728	7.7	.20	5.6	.27
10	06-10-86	0030		75	466	7.4	.20	7.0	.34
10	06-10-86	0030	<4	75	466	7.6	.20	7.8	.32
10	06-10-86	0030	4-16	75	466	7.2	.20	6.8	.26
10	06-10-86	0030	16-62	75	466	7.8	.20	7.6	.28
10	06-10-86	0030	16-62	75	466	--	--	--	--
10	06-10-86	1515		146	247	7.7	.21	6.2	.26
Whitewood Creek above Vale									
15	02-26-86	1130		92	1,160	6.1	.20	5.5	.29
15	02-26-86	1130		92	1,160	5.7	.16	6.2	.26
15	04-24-86	1445		145	380	6.7	.17	5.8	.25
15	06-10-86	1345		158	4,480	6.7	.17	6.2	.28
15	06-10-86	1345	<4	158	4,480	6.7	.18	6.6	.28
15	06-10-86	1345	4-16	158	4,480	6.4	.17	6.0	.24
15	06-10-86	1345	16-62	158	4,480	6.4	.17	5.8	.25
15	06-10-86	1345	>62	158	4,480	6.4	.16	2.4	.12
Belle Fourche River near Sturgis									
26	03-03-86	1400		1,470	3,960	4.7	.09	8.0	.36
26	03-05-86	1015		1,580	4,070	4.3	.06	7.8	.37
26	03-21-86	1205		236	340	4.8	.08	9.2	.42
26	04-09-86	1230		338	2,070	4.6	.04	1.0	.35
26	04-09-86	1230	<4	338	2,070	4.2	.04	8.6	.44
26	04-09-86	1230	4-16	338	2,070	4.2	.05	8.7	.39
26	04-09-86	1230	16-62	338	2,070	4.4	.05	9.1	.39
26	05-01-86	1425		501	870	4.4	.06	8.9	.40
26	09-25-86	1254		5,360	6,970	4.2	.08	7.9	.38

Arsenic (µg/g)	Antimoney (µg/g)	Cadmium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Lead (µg/g)	Mercury (µg/g)	Nickel (µg/g)	Selenium (µg/g)	Zinc (µg/g)	Total organic carbon (µg/g)
880	16.2	1.6	--	15	276	116	2.22	49	3.4	285	3.8
--	--	--	--	--	--	--	--	--	--	--	4.4
860	21.0	1.0	--	26	221	131	2.14	87	2.7	555	5.1
640	18.2	1.8	--	26	182	134	2.10	74	2.4	460	4.4
640	18.6	1.2	--	22	370	132	2.11	98	2.2	570	4.5
600	17.6	1.2	--	20	496	136	2.26	128	2.2	650	4.5
640	18.2	<.5	--	20	222	138	2.06	88	3.0	480	4.4
--	--	--	--	--	--	--	--	--	--	--	4.5
1,300	29.0	<.5	--	22	185	116	2.36	74	2.3	475	4.1
990	2.0	<.5	54	74	54	23	.08	23	2.0	116	--
840	2.6	<.5	--	12	61	20	.94	36	1.9	110	2.0
1,900	4.8	<.5	--	17	114	42	1.16	52	2.3	205	2.3
2,100	8.3	<.5	--	16	129	59	1.49	54	2.4	260	3.2
1,000	9.1	<.5	--	17	262	76	1.78	68	2.5	380	3.5
960	7.7	<.5	--	17	177	56	1.53	58	2.3	280	3.3
1,000	7.2	<.5	--	15	120	51	1.32	48	2.1	235	3.1
1,200	2.8	<.5	--	10	46	2	.45	20	1.4	70	1.7
210	1.2	<.5	--	12	40	13	.27	35	1.4	115	1.1
124	1.2	<.5	--	13	38	13	.25	38	1.1	124	<.1
116	1.2	<.5	--	8	40	14	.34	48	1.2	152	1.6
34	1.0	<.5	99	14	30	15	.12	43	1.0	147	--
32	1.2	7.2	--	14	1,080	72	.86	146	.8	770	1.1
36	1.3	4.8	--	14	435	41	.76	90	.9	370	1.3
30	1.3	<.5	--	15	96	22	.27	50	.9	175	1.2
52	1.3	<.5	--	13	39	15	.20	46	1.0	148	1.0
188	1.3	<.5	--	11	40	17	.36	37	1.6	126	1.3

Table 39.--Total chemical analysis of suspended sediment--Continued

Site number in figures 1 and 2	Date	Time	Size fraction (µm)	Discharge (ft^3/s)	Sediment concentration (mg/L)	Iron	Manganese	Aluminum	Titanium
Cheyenne River at Cherry Creek									
37	04-22-86	1245		4,890	6,030	4.1	0.04	8.3	.36
37	04-29-86	1230		8,120	8,040	4.2	.05	8.2	.35
37	04-29-86	1230	<4	8,120	8,040	3.8	.07	7.8	.40
37	04-29-86	1230	4-16	8,120	8,040	4.0	.70	7.9	.38
37	04-29-86	1230	4-16	8,120	8,040	--	--	--	--
37	04-29-86	1230	16-62	8,120	8,040	4.2	.06	8.6	.38
37	04-29-86	1230	16-62	8,120	8,040	--	--	--	--
37	04-29-86	1230	>62	8,120	8,040	2.1	.07	3.1	.14
37	05-07-86	1330		428	429	4.4	.07	8.3	.34
37	05-14-86	1130		5,240	6,870	4.1	.05	8.2	.35
37	05-29-86	1240		565	199	3.8	.1	7.6	.30
37	05-29-86	1240		565	199	3.5	.10	7.0	.35
37	06-11-86	1500		12,900	27,600	3.7	.05	7.9	.31
37	06-26-86	1310		977	743	3.8	.07	7.3	.28
37	07-10-86	1340		565	517	4.1	.03	8.0	.37
37	07-24-86	1230		525	201	3.3	.05	6.8	.30
37	08-07-86	1530		352	160	3.8	.05	7.4	.34
37	08-07-86	1530		352	160	3.6	.07	7.7	.34
37	08-07-86	1530		352	160	--	--	--	--
37	08-14-86	1655		432	432	4.1	.04	8.2	.38
37	08-21-86	1235		352	159	3.6	.09	7.4	.33
37	08-26-86	1440		339	71	3.5	.13	7.4	.33
37	09-04-86	1545		475	504	4.0	.05	7.7	.34
37	09-27-86	1405		8,700	17,100	3.5	.10	7.0	.35
37	09-27-86	1405		8,700	17,100	4.2	.08	8.0	.35
37	09-27-86	1405		8,700	17,100	--	--	--	--
Miscellaneous sites; names listed in table 1									
23	08-13-86	1230		61	25	3.5	.15	7.0	.50
23	09-26-86	1630		2,390	241	4.5	.04	9.6	.42
24	03-05-86	1130		--	3,660	4.2	.05	8.5	.39
24	03-05-86	1130		--	3,660	4.4	.05	9.4	.41
28	03-06-86	1245		--	6,230	4.7	.09	8.4	.39
30	03-06-86	1115		5,133	10,600	5.0	.08	8.35	.34
32	06-10-86	1745		8,100	38,300	3.65	.05	7.2	.32
38	08-14-86	1425		503	652	4.0	.04	8.0	.38
38	08-21-86	1230		441	241	3.6	.07	7.4	.33
38	08-26-86	1700		332	77	3.5	.12	7.2	.33
38	09-04-86	1257		494	127	3.8	.07	7.0	.33

Arsenic (µg/g)	Antimoney (µg/g)	Cadmium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Lead (µg/g)	Mercury (µg/g)	Nickel (µg/g)	Selenium (µg/g)	Zinc (µg/g)	Total organic carbon (µg/g)
22	1.2	<.5	76	10	29	18	0.11	40	1.2	125	--
36	1.1	<.5	71	11	26	19	.08	35	1.0	129	--
44	1.2	1.1	--	14	750	53	.33	66	.9	510	<.1
50	1.3	2.5	--	12	471	113	.68	64	.9	350	<.1
--	--	--	--	--	--	--	--	--	--	--	<.1
36	1.1	<.5	--	12	78	20	.18	38	.7	147	1.5
--	--	--	--	--	--	--	.19	--	--	--	1.4
50	1.2	<.5	--	5	-	12	.04	23	.6	55	<.1
36	1.1	<.5	78	13	31	20	.08	38	1.2	170	--
24	1.3	<.5	72	11	29	22	.09	40	1.4	171	--
32	1.1	<.5	63	7	28	13	.09	32	1.6	118	--
30	1.0	<.5	--	10	20	20	.45	35	1.0	115	2.8
12	1.0	<.5	40	8	21	21	.06	21	.04	98	--
32	.9	<.5	61	5	24	16	.05	25	1.2	102	--
13	.8	<.5	63	11	26	15	.15	35	.7	120	--
23	.7	<.5	56	7	22	15	.08	26	.8	98	--
21	.8	<.5	80	9	24	13	.17	35	.9	117	--
26	1.0	<.5	--	11	25	13	.18	32	.9	114	1.9
--	--	--	--	--	--	--	.18	--	--	--	--
15	.9	<.5	93	12	26	14	.17	40	1.0	117	--
22	.8	<.5	54	9	25	18	.16	28	.8	106	--
28	.9	<.5	55	8	24	17	.20	28	.9	108	--
13	.9	<.5	40	10	24	21	.06	24	.5	113	--
30	1.0	<.5	95	10	25	27	.45	35	1.0	115	2.8
78	1.1	<.5	--	13	36	16	.14	35	.9	120	<.1
--	--	--	--	--	--	--	--	--	--	--	<.1
10	.5	3.0	--	20	25	30	.52	30	1.5	115	2.8
14	1.1	<.5	--	16	34	20	.33	45	.9	148	.8
50	1.1	<.5	--	15	32	21	.12	36	1.1	122	.9
42	1.0	<.5	--	16	34	20	.12	38	1.1	128	.9
136	1.2	<.5	--	15	34	18	.16	37	1.1	122	<.1
140	1.0	<.5	7.5	16	32	18	.15	37	1.0	130	--
9.2	0.9	<.5	40	9	24	22	.04	20	.2	95	--
19	1.2	<.5	73	9	29	14	.11	44	1.8	126	--
19	0.9	<.5	52	8	23	19	.08	28	.7	97	--
28	0.9	<.5	53	6	23	15	.22	32	1.0	103	--
29	1.1	<.5	65	9	27	18	.21	38	1.2	116	--

Samples for organic carbon analyses normally were collected by depth integration at the centroid of the stream. Samples for total organic carbon were collected in small glass bottles. Samples for dissolved organic carbon analyses were collected in a stainless steel container, pressurized with nitrogen gas, and filtered through 0.45-µm silver filters into similar small glass bottles. The bottles were then put on ice and shipped to the Central Laboratory for analysis. Organic carbon analysis data are listed in tables 34 through 39.

There were times when normal sampling procedures could not be followed. During some storms, the streams were too deep to wade or the stage was changing too fast to take a 15-vertical sample. During these storms, aliquots were collected from a bridge or cable way at 5 to 8 verticals, or a sample was collected by wading to a point nearest the centroid as practicable. At these times, suspended-sediment samples were collected directly from the stream rather than poured from the churn, and some samples for organic carbon analyses were taken from the churn rather than from the centroid of the stream. A few other times, 5 to 8 vertical samples were collected when the stream was thickly covered with ice and weather conditions were dangerous.

Four field readings--water temperature, dissolved oxygen, pH, and specific conductance--were determined at the site. Most often readings were determined at the centroid of the stream, while at other times averages were computed from readings determined at 3 to 20 verticals across the channel. Several meters were used in the study: a Hydrolab Environmental Data Systems Model 4041 Digital four-parameter meter, an ODEC 4-parameter meter, and an Orion pH meter. The meters were calibrated at each site or at least daily during field trips.

The Hydrolab was the instrument used most often. The Hydrolab instrument consists of a Sonde unit, which contains the sensors, a connecting cable, and an indicator unit. The Sonde consists of a temperature thermistor, a four-electrode conductivity cell, a glass pH electrode, a Lazaran reference electrode, and a Clark polarographic dissolved oxygen cell. The indicator unit consists of a digital readout, a rotary switch to select the parameter for readout, and calibration controls. The instrument is fully temperature compensated. The ODEC is similar to the Hydrolab in function and was used when the Hydrolab was unavailable. The pH meters were equipped with pH and reference electrodes and were used when the Hydrolab's pH readings were slow or suspect.

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Chapter F. Arsenic and Iron Versus Filter Poresize in Whitewood Creek and the Belle Fourche River

By Christopher C. Fuller, James A. Davis, Regina G. Claypool-Frey

SAMPLE COLLECTION AND HANDLING PROCEDURES

In order to determine the dissolved and colloidal components of arsenic and iron in filtrates from the commonly used 0.45-µm filtrations, sets of serial filtrations were conducted in August 1986. Samples were collected at five sites on Whitewood Creek and one site on the Belle Fourche River: Whitewood Creek at Deadwood (site 7, above sewage treatment effluent discharge); Whitewood Creek above Whitewood (site 10); Whitewood Creek at Berger site (site 13) above and below large ground-water seep; Whitewood Creek above Vale (site 15); Whitewood Creek above Sheeler site (site 17); and Belle Fourche River at Vale (site 20) (see figs. 1 and 2, table 1).

At each site, raw water samples were collected mid-stream with a stream-water rinsed 2-L polyethylene wide mouth jar that was filled by submersion with the opening held mid-depth oriented into the flow. Splits were immediately filtered by vacuum through 0.45- and 0.1-µm pore-size cellulose nitrate membrane filters (47 mm, diameter) using polycarbonate filter towers. A fraction of the 0.45-µm filtrate was subsequently filtered through a 0.01-µm cellulose nitrate filter. An aliquot of the 0.45-µm filtrate was transferred to an acid-cleaned polyethylene bottle and stored refrigerated without acidification for major cation and anion analyses. The remaining 0.45 µm filtrates, and the 0.1- and 0.01-µm filtrates were acidified in the collection reservoirs to 1 percent (v/v) with concentrated HCL, transferred to polyethylene bottles and stored refrigerated. An aliquot of the acidified 0.1-µm filtrate was processed immediately for arsenate-arsenite speciation by the anion exchange technique of Ficklin (1983). Stream pH was measured directly in the streamflow with a combination electrode. Total CO_2 samples were collected by syringe and injected into septa sealed vials. All sample containers and sampling apparatus were acid-washed before use in the field.

ANALYTICAL TECHNIQUES AND RESULTS

Major cations were determined by flame atomic absorption. Anions (SO_4^{2-}, Cl^-) were determined by ion chromatography utilizing a conductivity detector and a borate-gluconate buffer for the mobile phase. Total CO_2 was determined via gas chromatography of the headspace in the sample vials following acidification (Culbertson and others, 1981). Total iron was determined colorimetrically by the ferrozine method (Stookey and others, 1970), utilizing 10 cm pathlength spectrophotometer cells. Total arsenic, and the separated arsenate and arsenite fractions were determined by graphite furnace atomic absorption using operating conditions similar to Ficklin's (1983).

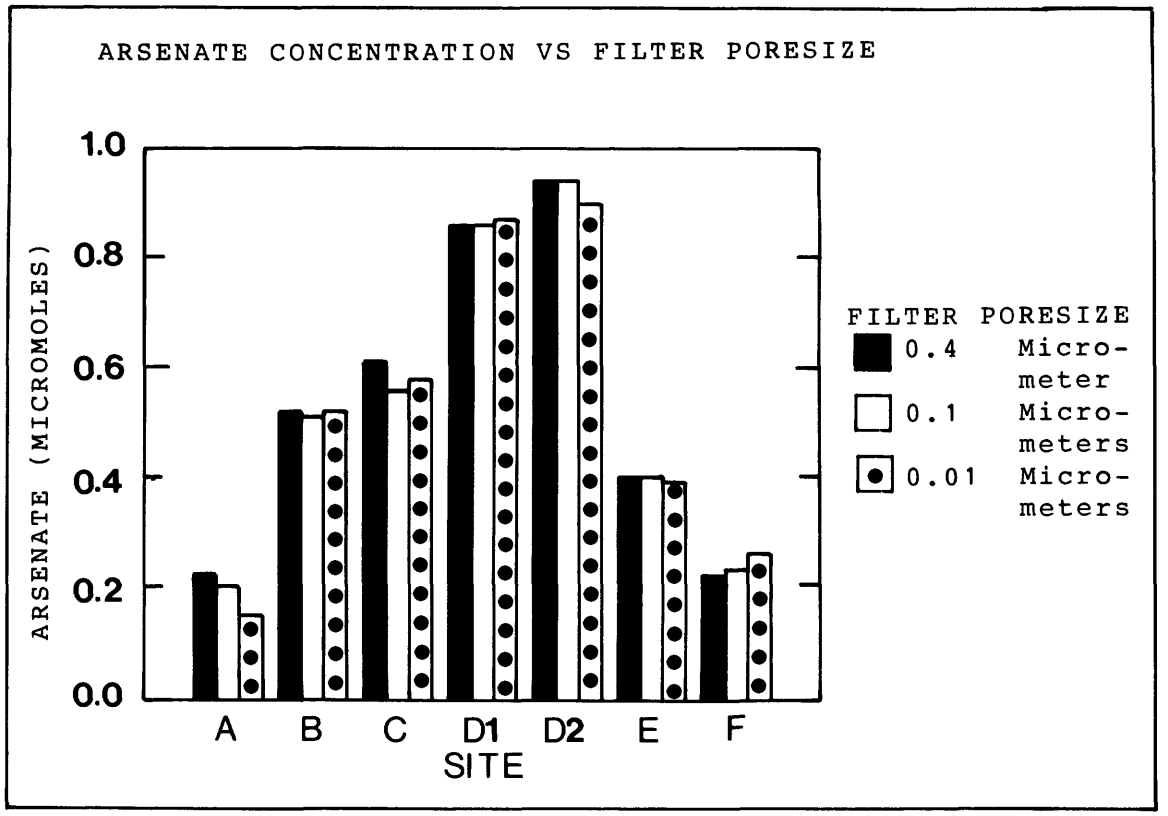
Analytical results are presented in table 40. Arsenate accounted for greater than 90 percent of the total arsenic; therefore, only total arsenic concentrations are presented. Total iron and arsenic concentrations versus filter poresize are listed in table 41 and presented graphically in figure 4.

Table 40.--Water chemistry data for Whitewood Creek/Belle Fourche River, August 1986

[mM, millimoles; --, not analyzed]

Numbers in figures 1 and 2, table 1	pH	$[SO_4^{-2}]$ mM	$[Cl^-]$ mM	Total CO_2 mM	$[Ca^{+2}]$ mM	$[Mg^{+2}]$ mM	$[K^+]$ mM	$[Na^+]$ mM
7	8.15	3.55 ± .06	0.25 ± .01	1.90	2.16 ± .04	1.98 ± .08	0.25 ± .01	2.36 ± .07
10	8.70	2.94 ± .08	0.37 ± .01	2.12	2.15 ± .01	1.85 ± .08	0.25 ± .02	2.28 ± .03
13[1]	8.30	3.54 ± .03	--	--	--	--	--	--
13[2]	8.30	3.50 ± .04	0.70 ± .05	2.01	2.83 ± .03	1.97 ± .08	0.20 ± .01	1.78 ± .06
15	7.95	4.54 ± .03	0.79 ± .03	2.11	2.81 ± .02	2.53 ± .08	0.27 ± .01	2.11 ± .04
17[1]	8.25	5.69 ± .10	0.76 ± .05	N/A	3.33 ± .01	2.94 ± .08	0.26 ± .01	2.42 ± .02
20	8.10	10.0 ± .20	--	2.17	5.61 ± .03	3.37 ± .08	0.24 ± .01	3.90 ± .20

[1]Above seep.
[2]Below seep.



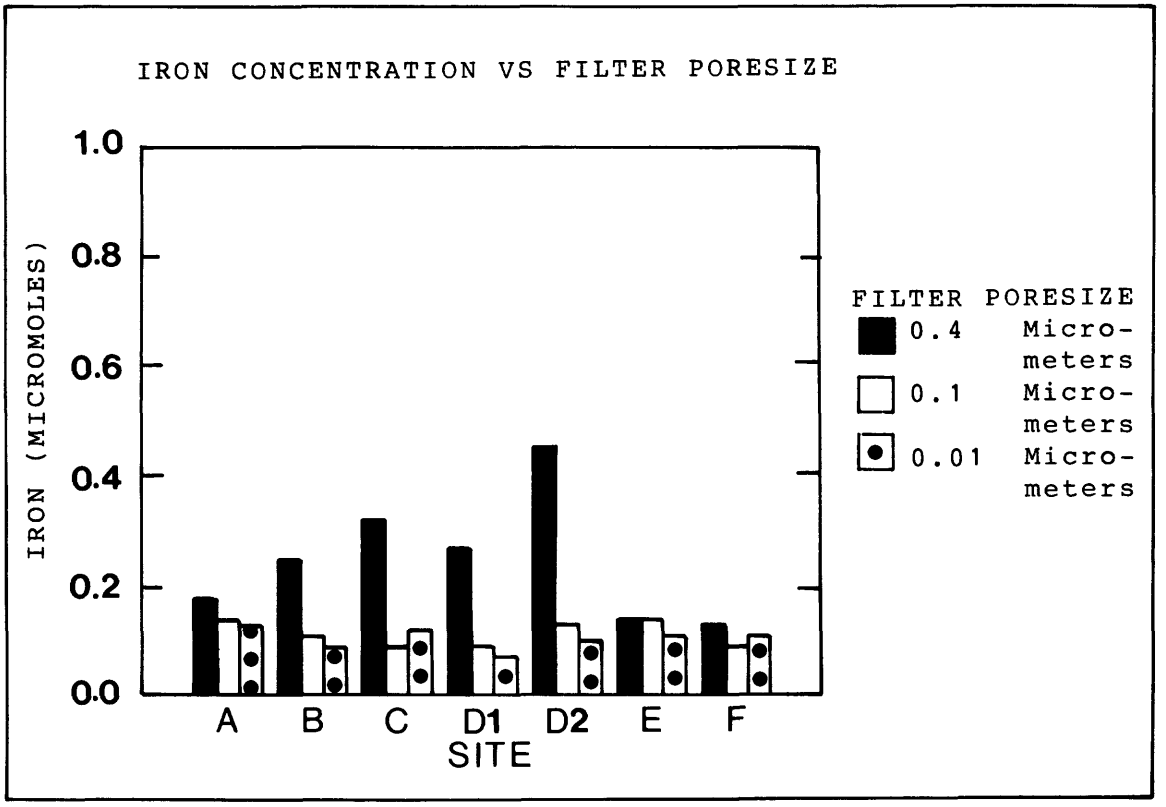


Figure 4.--Arsenate and iron versus filter poresize: Whitewood Creek/ Belle Fourche River, August 1986. (See table 40 for site code.)

Table 41.--Arsenic and iron versus filter poresize, Whitewood Creek/Belle Fourche River, August 1986

[µm, micrometers; µM, micromoles]

Numbers in figures 1 and 2, table 1	[As] µM			[Fe] µM		
	<0.4 µm	<0.1 µm	<0.01 µm	<0.4 µm	<0.1 µm	<0.01 µm
7	0.22 ± .01	0.23 ± .03	0.26 ± .02	0.13	0.09	0.11
10	0.40 ± .01	0.40 ± .01	0.39 ± .01	.14	.14	.11
13[1]	0.94 ± .03	0.94 ± .01	0.90 ± .02	.45	.13	.10
13[2]	0.86 ± .05	0.86 ± .02	0.87 ± .04	.27	.09	.07
15	0.61 ± .08	0.56 ± .05	0.58 ± .07	.32	.09	.12
17[1]	0.52 ± .01	0.51 ± .01	0.52 ± .01	.25	.11	.09
20	0.22 ± .01	0.20 ± .01	0.15 ± .02	.18	.14	.13

[1]Above seep.
[2]Below seep.

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Chapter G. Ground-Water Geochemistry along Whitewood Creek

By Christopher C. Fuller, James A. Davis, and Regina G. Claypool-Frey

SAMPLE COLLECTION AND HANDLING PROCEDURES

Ground-water samples were collected at the Berger and Sheeler sites (fig. 1 and table 1) along Whitewood Creek in August 1986. Sampling piezometers installed at these sites by an earlier study (Cherry and others, 1985) were used. The screen depth and associated aquifer materials of the wells sampled are presented in table 42.

Table 42.--Screen depth and aquifer material for ground-water wells sampled along Whitewood Creek, August 1986

Well number[1]	Aquifer material[1]	Screen depth[1] (feet)
Berger site		
B-1-4	Tailings	5.5 - 6.5[2]
B-1-2	Alluvium	13 - 14
B-1-3	Alluvium	14 - 15
B-2-1	Tailings	10.5 - 11.5[2]
B-2-2	Alluvium	11.5 - 12.5[2]
B-2-3	Alluvium	14 - 15
B-2-24	Shale (?)	12 - 24
B-4	Tailings	4 - 6.5
Sheeler site		
S-4	Tailings/alluvium	10 - 17

[1]From Cherry and others, 1985.
[2]Insufficient water to sample.

Samples were collected by pumping through one-fourth-inch outside diameter nylon tubing inserted down the well casing to the base of the screened depth. Prior to pumping, the water depth and level in each well was measured. Wells were developed for sampling by pumping with a peristaltic pump (100 to 200 mL/min) three to four times the calculated volume of standing water in the casing. Samples were not collected from wells that were not able to produce at this flow rate.

Ground-water flow from the pump was then directed through an in-line teflon flow cell containing a combination pH electrode, with the pH value recorded after a stable reading was obtained. Total dissolved CO_2 samples were drawn by syringe from the outlet of the flow cell and immediately injected into septa-capped vials. The flow was then directed into the upper chamber of a 47-mm diameter polycarbonate filter tower which had been entirely

purged with N_2. A measured volume was then filtered by vacuum through a 0.4-µm cellulose nitrate membrane. Concentrated HCL was injected into the filtrate in the lower reservoir to obtain a final concentration of 1 percent (v/v). Sampling and filtering by this method allowed acidification of the filtrate before exposure to the atmosphere and, thus, eliminated problems resulting from oxidation of the sample. Aliquots of the acidified filtrate were then transferred into polypropylene bottles. Aliquots for major iron, total iron, Fe^{2+}, and total arsenic determinations were refrigerated until analyzed. An aliquot for As^{+3} - As^{+5} speciation was immediately processed by the anion exchange technique of Ficklin (1983) with the fractionated samples then refrigerated. All sample containers and sampling apparatus were acid-washed prior to use in the field.

ANALYTICAL TECHNIQUES AND RESULTS

Major cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) were determined by flame atomic absorption. Sulfate was determined by ion chromatography employing a conductivity detector and a borate-gluconate buffer mobile phase. Chloride was not determined since HCL was used for sample preservation. Total and ferrous iron were determined colorimetrically by the ferrozine method (Stookey, 1970) with ferric iron calculated by difference. Total As in the unfractionated aliquots, and arsenite and arsenate in the fractionated aliquots were determined by graphite furnace atomic absorption utilizing similar operating conditions to Ficklin's (1983). Total dissolved CO_2 was determined by gas chromatography of the sample vial headspace after acidification (Culbertson and others, 1981). Results are presented in table 43.

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Culbertson, C.W., Zehnder, A.J.B., Oremland, R.O., 1981, Applied environmental microbiology: v. 41, p. 396.

Ficklin, W.H., 1983, Separation of arsenic (III) and arsenic (V) in ground waters by ion exchange: Talanta, v. 30, p. 371.

Stookey, L.L., 1970, Ferrozine--A new spectrophotometric reagent for iron: Analytical Chemistry, v. 42, p. 779.

Table 43.--Ground-water geochemical data for wells sampled along Whitewood Creek, August 1986

[mM, millimoles; µM, micromoles; --, not analyzed]

	Major constituents							Arsenic and iron			
Well number	pH	$[SO_4^{-2}]$ mM	Total CO_2 mM	$[Ca^{+2}]$ mM	$[Mg^{+2}]$ mM	$[K^+]$ mM	$[NA^+]$ mM	$[Fe^{+2}]$ µM	$[Fe^{+3}]$ µM	$[AsO_3^{-3}]$ µM	$[AsO_4^{-3}]$ µM
B-1-2	7.15	4.7	2.96	3.40 ± .03	2.37 ± .01	0.28 ± .01	1.50 ± .04	13.1	0.9	0.04	0.09
B-1-3	7.10	4.5	--	3.19 ± .01	2.26 ± .01	0.28 ± .03	1.50 ± .04	14.0	1.2	.06	.18
B-2-3	7.10	5.4	2.77	3.18 ± .02	2.21 ± .01	0.31 ± .01	1.97 ± .07	46.6	3.6	1.76	1.78
B-2-24	7.20	5.3	3.11	2.47 ± .03	1.71 ± .02	0.25 ± .01	3.75 ± .04	43.0	3.6	2.88	.46
B-4	7.20	6.6	3.73	4.17 ± .02	2.88 ± .01	0.32 ± .01	1.75 ± .04	100.0	12.5	5.49	3.95
S-4	7.10	12.4	--	4.98 ± .02	5.30 ± .01	0.47 ± .01	2.54 ± .01	212.0	16	5.82	1.85

Chapter H. Colloids in Seeps and Springs along Whitewood Creek

By Terry F. Rees and James F. Ranville

INTRODUCTION

Colloids are particulates, droplets, gas bubbles, or films which have at least one dimension in the range, 0.001 to 1 µm, and are dispersed in a second continuous phase such as water. When pollutants become associated (sorbed, co-precipitated) with colloids, the pollutant's transport is no longer controlled by simple solution thermodynamics and kinetics. Rather, their transport is controlled by that of the host colloid. Very little is known about the relative importance of colloids in the transport of heavy metals in the geosphere. The U.S. Geological Survey has identified two seeps along Whitewood Creek in South Dakota as possible systems in which colloid-facilitated transport of heavy metals may be occurring.

First-year investigations (1986) were performed at the Sheeler site seeps located on Whitewood Creek approximately 1 km from its confluence with the Belle Fourche River near Newell, South Dakota (fig. 1, table 1). The seeps are a result of downcutting through a historic meander of Whitewood Creek that was filled with tailings washed down from the Homestake Mine near Lead, South Dakota. After the meander filled, Whitewood Creek eroded through the meander sediments and into the underlying shale bedrock. Ground water percolates through the tailings and fluvial sediments until it encounters the relatively impermeable bedrock. Further flow is then directed laterally across the surface of the shale, until the water discharges at the land surface near the creek. Emergent ground water then flows over the shale into small quiescent pools prior to mixing with the stream water.

SAMPLE COLLECTION AND HANDLING PROCEDURES

Samples for this study were collected during August 1986 from Whitewood Creek immediately upstream and downstream from the seeps, from a quiescent pool, from water flowing over the face of the outcrop, and from several inches into the outcrop. The subsurface seep water was collected by pushing a PVC tube several inches into the shale outcrop. The end of the tube was protected by screening to prevent it being clogged while being positioned. Water was then allowed to flow through the tube for about an hour prior to sample collection. It is believed that this procedure precludes oxidation of the ground water prior to collection. The surficial seep samples were collected using a peristaltic pump, placing the inlet tube just beneath the surface of the water. The upstream sample was a grab sample. Field-collected data are given in table 44. Due to a breakdown of the field pH meter, no pH measurements are available.

Table 44.--Specific conductance and temperature measured at the Sheeler site, Whitewood Creek, during August 1986

Sample location	Specific conductance (microsiemens)	Temperature (°C)
Whitewood Creek upstream from site	1,200	--
Surface flow over outcrop	2,200	14.0
Quiescent pool	2,000	14.0
Whitewood Creek downstream from site	1,200	19.2

Analyses for various chemical components were performed on filtered (0.40-, 0.10-, and 0.05-µm) and unfiltered fractions. Filtered samples were processed using 147-mm barrel filters fitted with Nucleopore polycarbonate membrane filters. All filtrations were performed under nitrogen to minimize oxidation. Samples for cations were immediately acidified to pH <2 with reagent-grade nitric acid. Samples for anions were left unacidified.

ANALYTICAL PROCEDURES AND RESULTS

Metals were determined by inductively-coupled plasma analysis (Garbarino and Taylor, 1979) except for arsenic, silica, and aluminum. These metals were determined by graphite furnace (As) and nitrous oxide flame (Si, Al) atomic absorption spectrometry (Fishman and Friedman, 1985). Sulfate was determined by the turbidometric procedure given in Fishman and Friedman (1985) except a photon correlation spectrometer was used to measure scattering intensity, instead of the traditional absorption method. Analytical data are given in table 45. All analyses are ±10 percent.

The presence of suspended colloids was determined using photon correlation spectrometry (PCS) (Rees, 1987). PCS gives information about colloid concentrations (from the integrated scattering intensity) and colloid size distributions. Samples for PCS analysis were collected using the same nitrogen filtration apparatus as used for the water chemistry samples. These samples were collected and sealed in glass ampules under nitrogen atmosphere, and were analyzed 2 to 4 hours after collection. PCS data is given in table 46.

Membranes used for the filtrations were retained and examined using scanning electron microscopy coupled with energy dispersive x-ray analysis. Photomicrographs and x-ray spectra for representative particles retained on the filters are given in figures 5 to 13.

Table 45.--Chemical analysis of water samples collected at the Sheeler site, Whitewood Creek, during August 1986

[All values in milligrams per liter; data accurate to ±10 percent]

Sample location	Filter used (micrometers)	Aluminum	Arsenic	Boron	Barium	Calcium	Cadmium	Cobalt	Copper	Iron	Lithium	Magnesium	Manganese
Whitewood Creek upstream from seep	0.40	0.3	0.066	0.1600	0 .0379	138.3	0.0022	0.0031	0	0.4971	0.0390	91.9	0.0738
	.05	.2	.037	.1621	.0336	136.8	.0020	0	0	.0473	.0432	90	.0599
Subsurface	None	.2	.234	.2138	.0154	310.6	.0026	.0269	0	8.116	.0441	109.2	1.002
	.40	.1	.283	.2148	.0146	310.3	.0011	.0241	0	8.093	.0467	109	1.003
	.10	.2	.256	.2108	.0148	319.1	.0016	.0239	0	8.267	.0466	109.6	1.027
Surface flow over outcrop	.40	.1	.049	.1894	.0150	311.6	0	0	0	1.266	.0381	109.8	.4818
	.10	.4	.035	.1929	.0184	316.2	.0022	0	0	1.624	.0492	109.8	.4958
	.05	0	.036	.1911	.0163	313.8	0	0	0	1.207	.0467	110	.4881
Quiesent pool	None	.3	.038	.1966	.0168	317.3	0	0	0	.9956	.0484	109.8	.4708
	.10	.2	.028	.1898	.0150	309.7	.0038	0	0	.5558	.0502	110.1	.4521
	.05	.3	.024	.1913	.0162	310.0	.0031	0	0	.3498	.0467	110.2	.4554
Whitewood Creek downstream from seep	None	.6	.079	.1525	.0388	134.1	0	0	0	.914	.0398	87.07	.1033
	.40	.2	.033	.1555	.0348	136.7	.0032	0	0	.0707	.0398	88.65	.0761
	.10	.2	.030	.1531	.0336	133.8	.0024	0	0	.0474	.0381	86.52	.0743

Table 45.--Chemical analysis of water samples collected at the Sheeler site, Whitewood Creek, during August 1986--Continued

Sample location	Filter used (micrometers)	Sodium	Nickel	Silicon	Strontium	Vanadium	Zinc	Chloride	Fluoride	Nitrate	Bromide	Sulfate
Whitewood Creek upstream from seep	0.40	54.61	0.0810	9	0.9902	0	0.0016	7.6	0.8	2.2	0.17	551
	.05	53.43	.0399	8	1.0020	0	.0019					
Subsurface	None	73.41	.1879	14	2.218	0	.0011	6.1	.8	.8	.10	1,044
	.40	73.83	.1346	14	2.221	0	.0036					
	.10	74.78	.1730	14	2.240	0	.0010	5.7	.8	.4		
Surface flow over outcrop	.40	72.88	.1559	14	2.199	0	.0039	6.3	.8	.6	.10	1,064
	.10	73.36	.1569	15	2.220	0	.0098					
	.05	72.71	.1257	14	2.205	0	.0089					
Quiesent pool	None	73.80	.1738	13	2.234	0	.0076					
	.10	71.72	.1584	13	2.179	0	.0053	5.7	.7	.2	0	1,016
	.05	72.42	.1584	13	2.185	0	.0068					
Whitewood Creek downstream from seep	None	51.98	.0954	8	.9624	0	0	8.1	.7	1.8	.12	591
	.40	53.90	.0773	8	.9836	0	.0011					
	.10	52.53	.0539	8	.9614	0	.0045					

Table 46.--Photon correlation spectroscopy results for samples collected at the Sheeler site, Whitewood Creek, during August 1986

[The Translational Diffusion Coefficient (D_t) is obtained from the Temporal Variation in Scattering Itensity (I). The Mass Median Spherical Diameter (d) is obtained from D_t assuming a spherical shape. Polydispersivity is a Measure of the Narrowness of the Particle-Size Distribution. µm, micrometers; counts/µs, counts per microsecond; cm^2/s, square centimeter per second]

Sample location	Filtrate (µm)	I (counts/µs)	D_t (cm^2/s) ($x10^8$)	d(µm)	Polydispersivity
Whitewood Creek upstream from seep	0.40	0.191	0.558	0.158	0.465
	.10	.144	.665	.158	.505
Surface flow over outcrop	.40	1.93	.053	.901	1.09
	.10	1.80	.103	4.45	.005
	.05	1.10	.245	.222	.552
Quiesent pool	.40	.45	.282	1.67	.005
	.10	.25	.255	.50	.380
	.05	.10	.278	1.85	.005
Whitewood Creek downstream from seep	.40	.141	1.01	.100	.466

Figure 5A.--Scanning-electron photomicrograph of particle 01 retained on 100-nm filter, from water sample collected from surface flow at the Sheeler Seep, Whitewood Creek, August 1986.

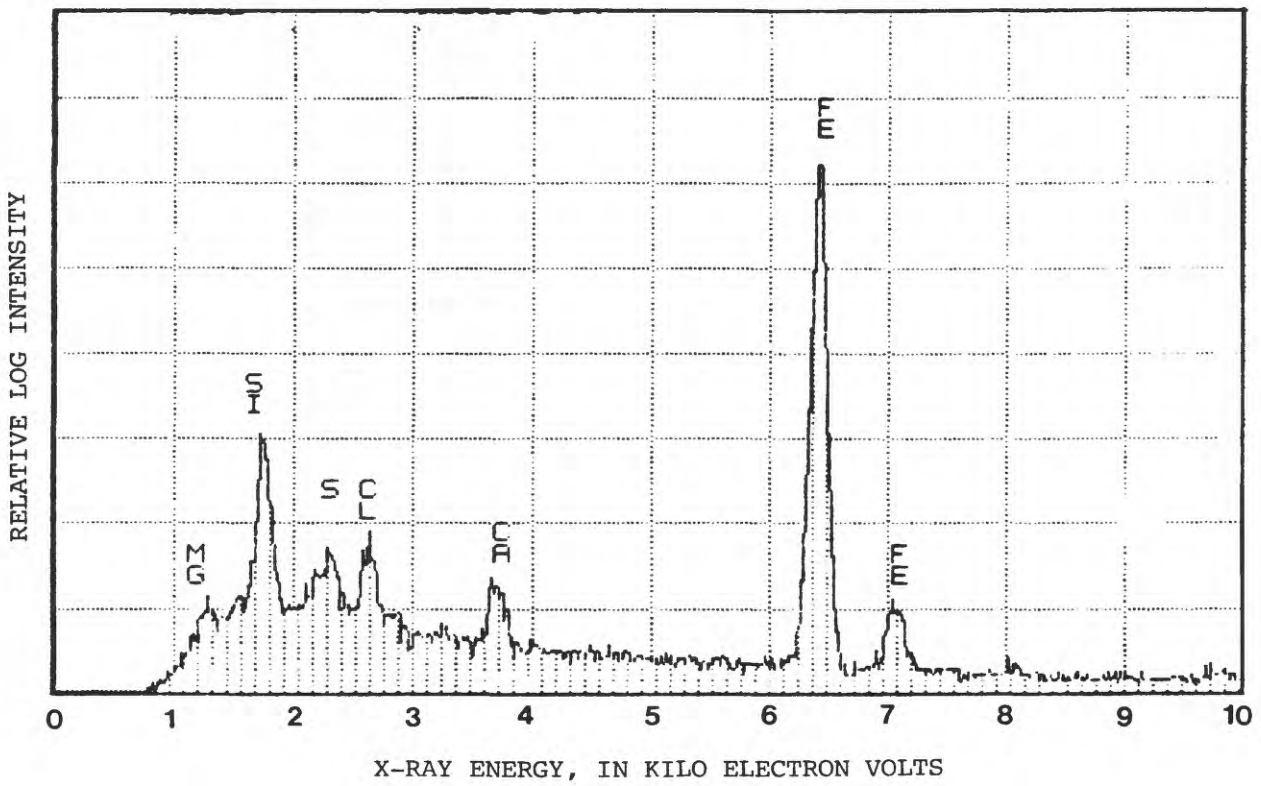

Figure 5B.--Energy dispersive X-ray analysis of particle 01 retained on 100-nm filter, from water sample collected from surface flow at the Sheeler Seep, Whitewood Creek, August 1986.

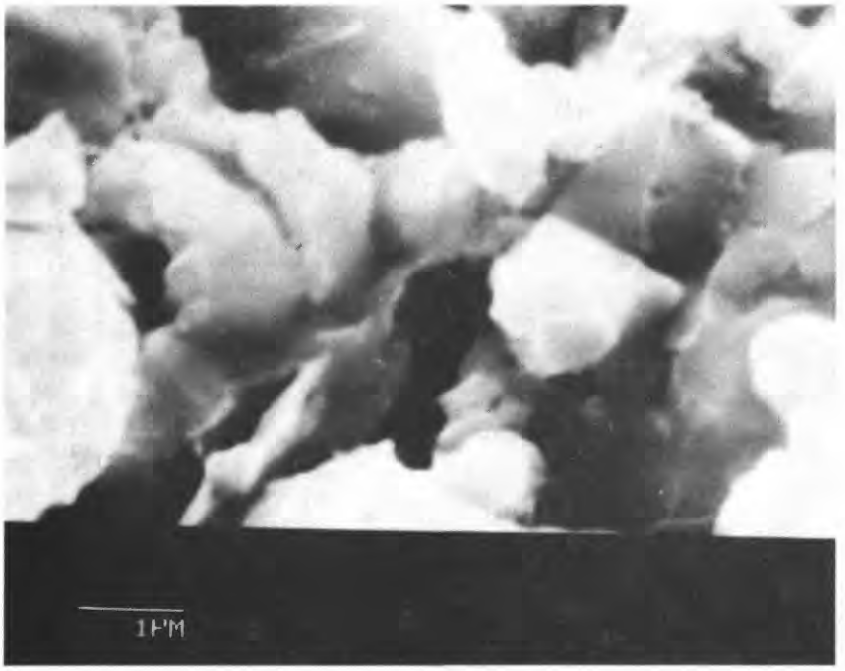

Figure 6A.--Scanning-electron photomicrograph of particle 02 retained on 450-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

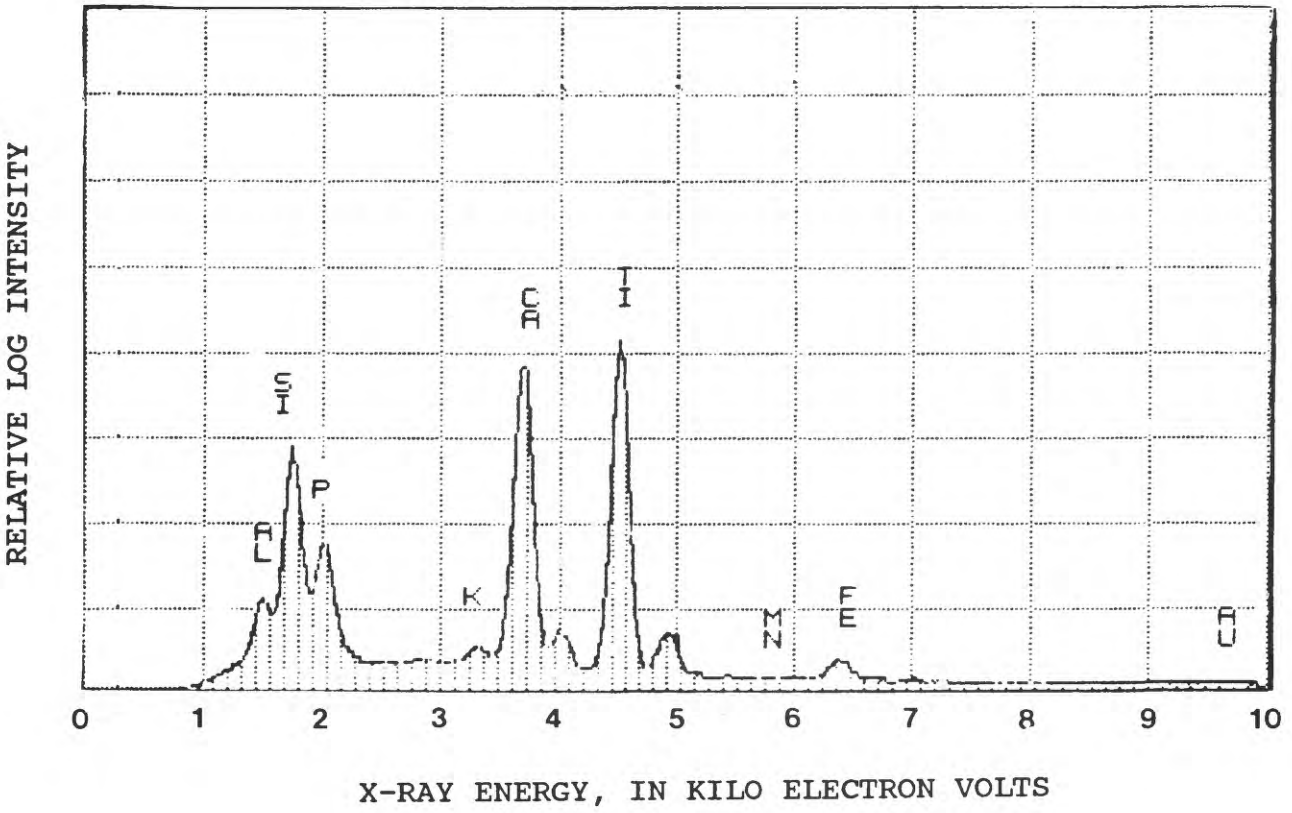

Figure 6B.--Energy dispersive X-ray analysis of particle 02 retained on 450-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

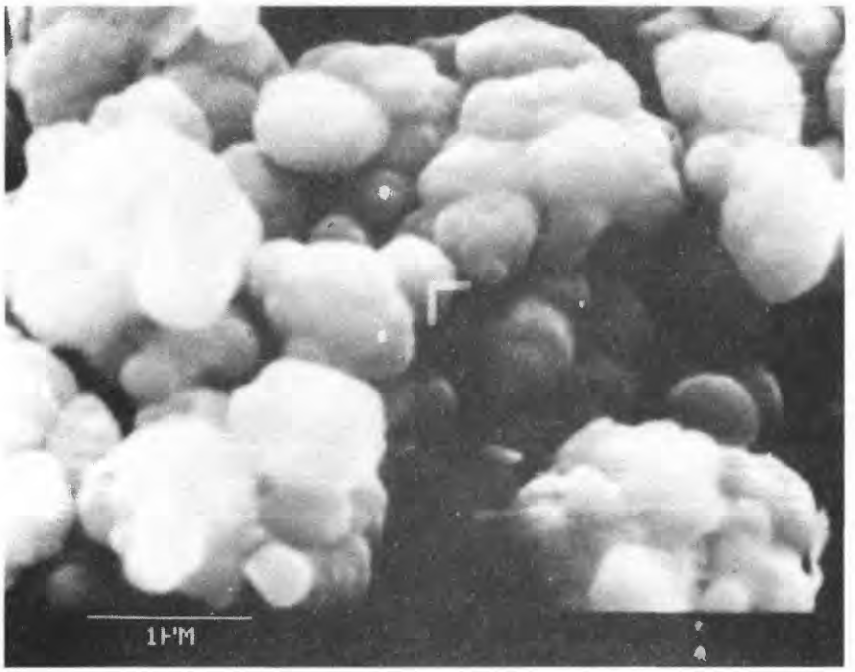

Figure 7A.--Scanning-electron photomicrograph of particle 03 retained on 450-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

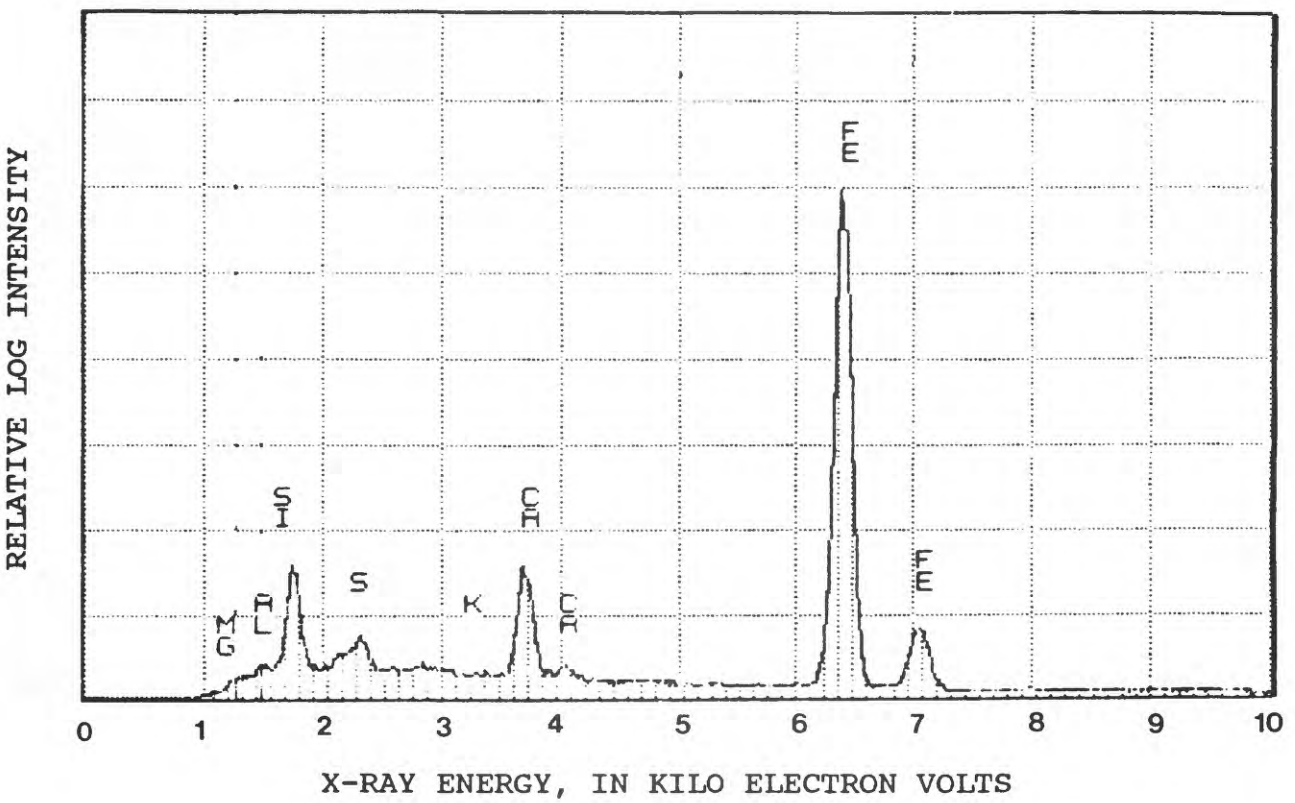

Figure 7B.--Energy dispersive X-ray analysis of particle 03 retrained on 450-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

Figure 8A.--Scanning-electron photomicrograph of particle 04 retained on 100-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

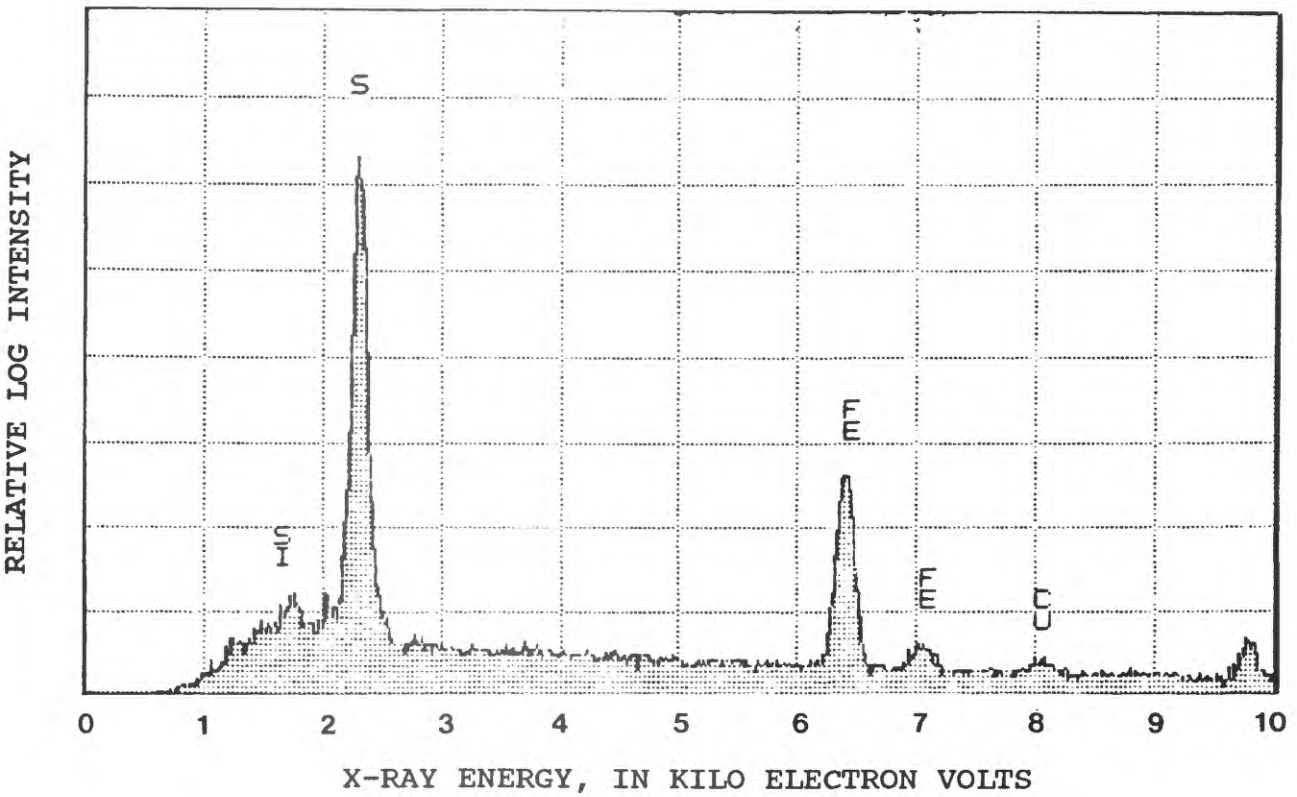

Figure 8B.--Energy dispersive X-ray analysis of particle 04 retained on 100-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

Figure 9A.--Scanning-electron photomicrograph of particle 05 retained on 100-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

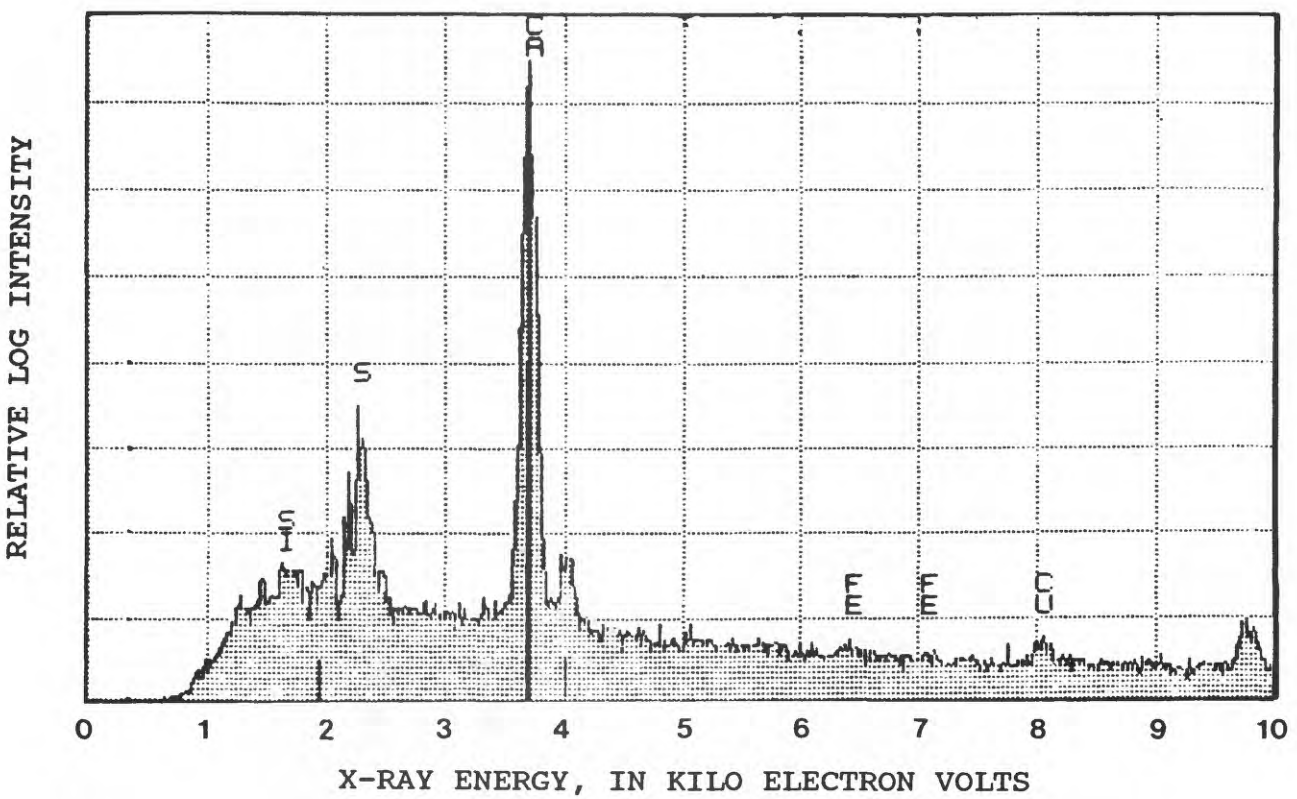

Figure 9B.--Energy dispersive X-ray analysis of particle 05 Retained on 100-NM Filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

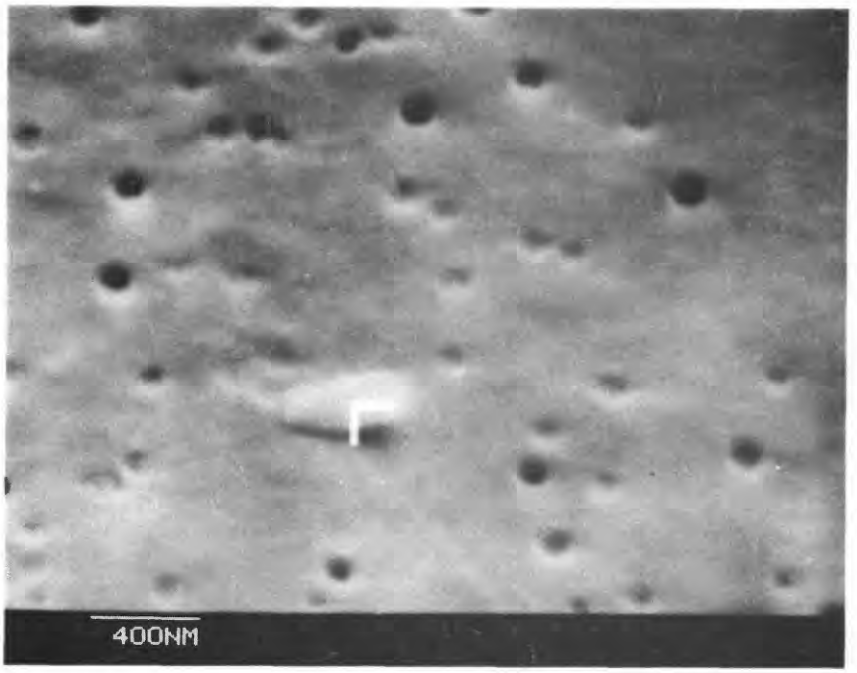

Figure 10A.--Scanning-electron photomicrograph of particle 06 retained on 100-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

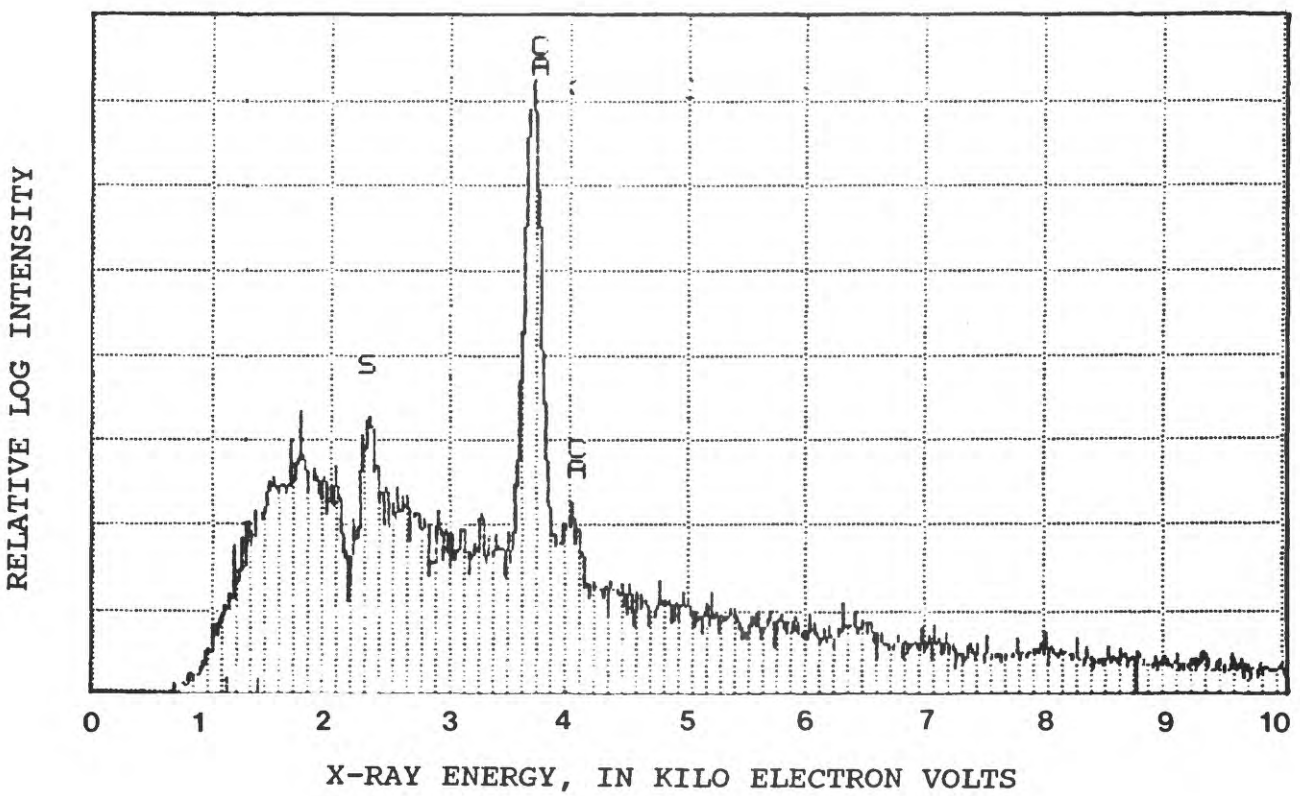

Figure 10B.--Energy dispersive X-ray analysis of particle 06 retained on 100-NM filter, from water sample collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

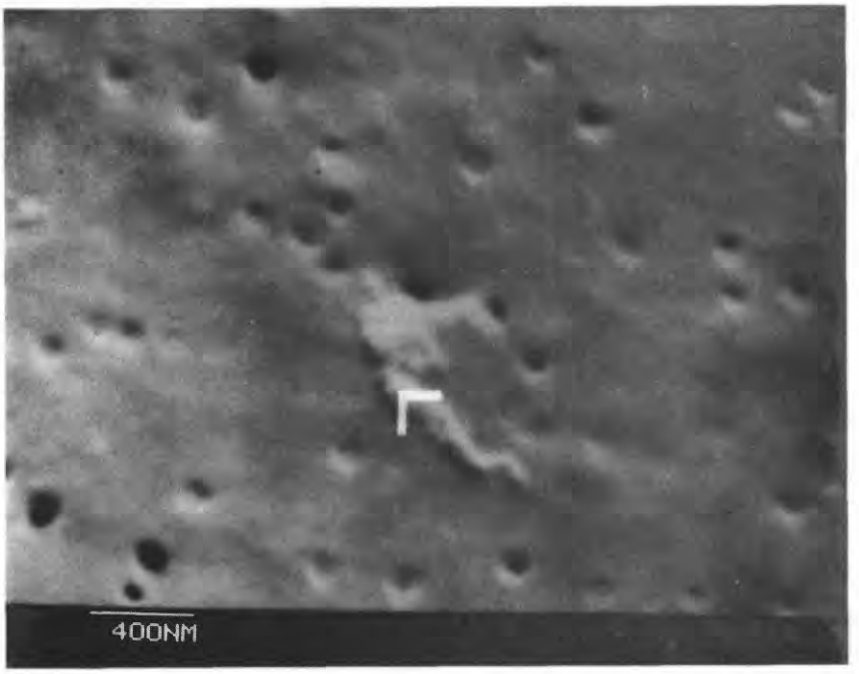

Figure 11A.--Scanning-electron photomicrograph of particle 07 retained on 100 NM filter, from water collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

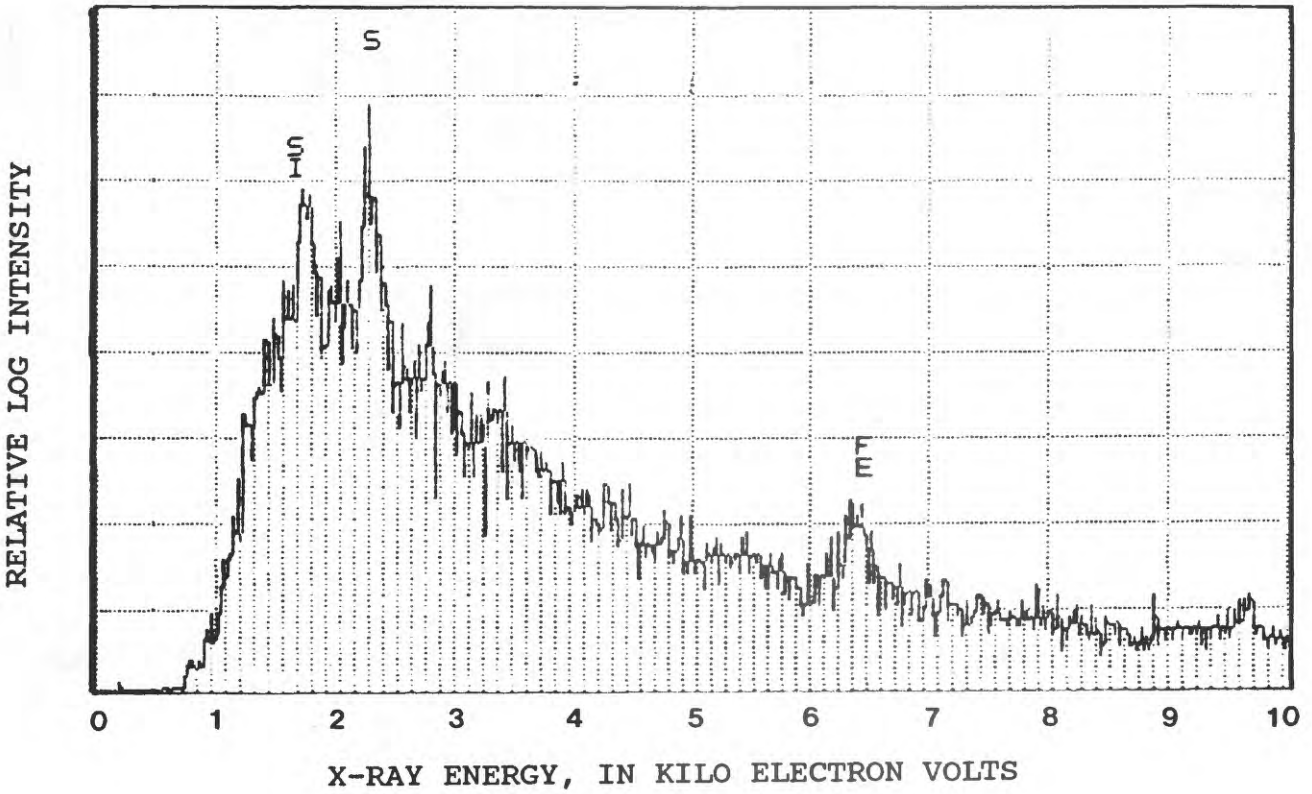

Figure 11B.--Energy dispersive X-ray analysis of particle 07 retained on 100-NM filter, from water collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

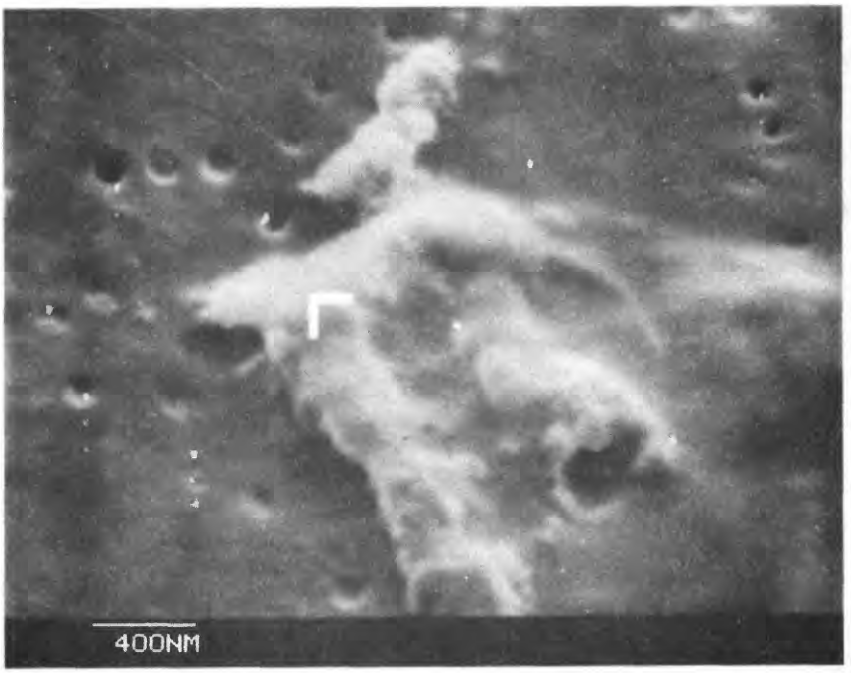

Figure 12A.--Scanning-electron photomicrograph of particle 08 retained on 100-NM filter, from water collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

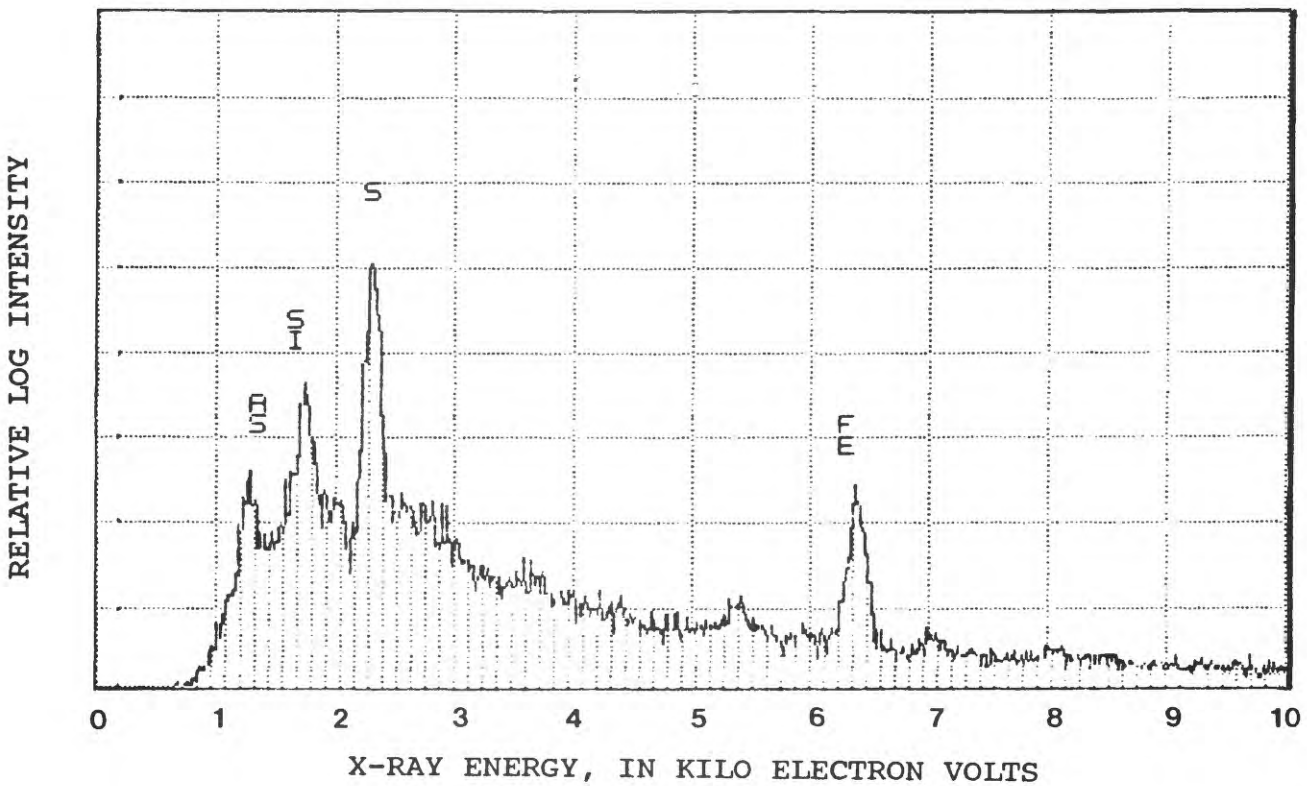

Figure 12B.--Energy dispersive X-ray analysis of particle 08 retained on 100-NM filter, from water collected from the pool at the Sheeler Seep, Whitewood Creek, August 1986.

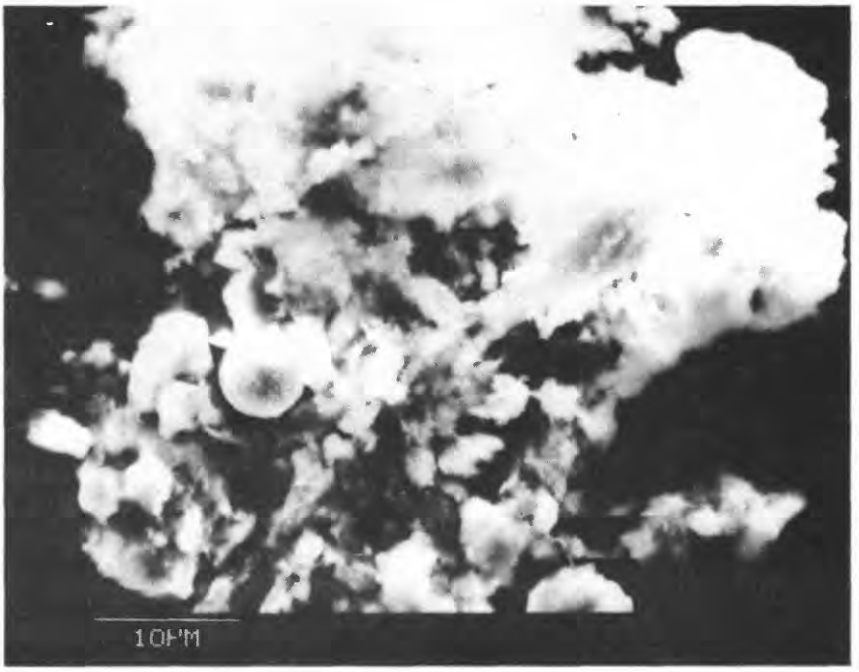

Figure 13A.--Scanning-electron photomicrograph of aggregate retained on 450-NM filter, from water collected from Whitewood Creek below the Sheeler Seep, August 1986.

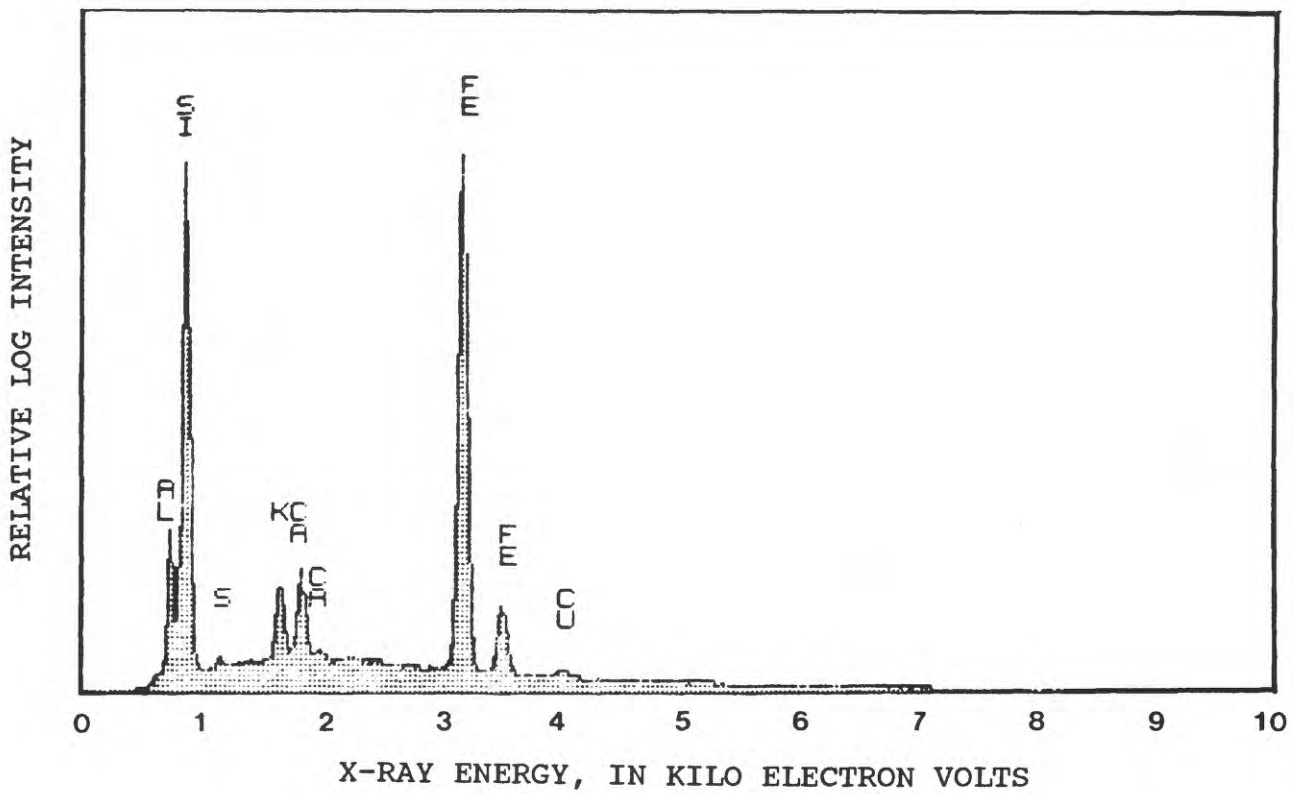

Figure 13B.--Energy dispersive X-ray analysis of aggregate retained on 450-NM filter, from water collected from Whitewood Creek below the Sheeler Seep, August 1986.

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Chapter I. Desorption of Arsenic from Iron Oxyhydroxide

By Christopher C. Fuller, James A. Davis, and Regina G. Claypool-Frey

SAMPLE COLLECTION AND HANDLING PROCEDURES

A series of experiments were conducted to determine the potential for the desorption of arsenic associated with iron oxide precipitates that form where ground waters seep out of alluvial and tailings deposits at, or just above, stream level.

Samples of iron precipitate were collected at three ground-water discharge points adjacent to Whitewood Creek: the Berger site, Whitewood Creek above Vale, and the Sheeler site (fig. 1, table 1). All apparatus and containers were acid cleaned prior to use in the field. Precipitate was collected out of pools that form below seep outlets and above stream level by drawing the floc (precipitate) off the bottom with a 50-mL syringe fitted with teflon tubing. Care was taken to minimize inclusion of coarser sediment below the precipitate. The floc was transferred into a 250-mL polypropylene centrifuge bottle and allowed to settle. The supernatant was then decanted and the bottle refilled with more precipitate. This process was repeated several times until sufficient material was obtained. An additional precipitate sample was formed by collecting water from the seep at the Sheeler site and allowing oxidation and precipitation of the iron to occur upon exposure to the atmosphere. A 12-inch section of perforated one-half-inch inside diameter PVC tubing covered with 60-µm nylon screen was inserted horizontally into the bank at the seep outlet at the contact between the overlying alluvium and the Pierre Shale. The outlet of PVC pipe was fitted with a section of one-fourth-inch outside diameter nylon tubing. Water was allowed to flow for 30 minutes before collection. During this period the outflow became clear. Flow was estimated at about 100 mL per minute. A 4-L polyethylene jar was then filled to overflowing with outlet of the tubing at the bottom of the jar. The sample was refrigerated and later purged with air to facilitate oxidation. An additional water sample was taken for chemical analyses by diverting flow into the top reservoir of a N_2-purged filtration tower, filtered through a 0.4-µm membrane filter, and preserved by acidification before exposure to the atmosphere. The sample was then processed in the same manner as ground water collected from piezometers (see Chapter G). A seep-water sample was collected at the Whitewood Creek above Vale site by syringe directly from the seep outlet and immediately filtered and processed as above. It was originally intended to collect a water sample at the Berger site; however, no sample was collected since ground-water input was from below the surface of a large pool adjacent to the stream.

ANALYTICAL PROCEDURES AND RESULTS

Water samples were processed, stored, and analyzed by the methods outlined in the ground-water geochemistry section of this report (Chapter G). Results are presented in table 47. Precipitates collected from pools below seeps were allowed to settle under refrigeration upon return to laboratory. Precipitate was then resuspended by shaking the decanted into another bottle after settling for 30 seconds. This process was repeated to ensure removal of coarser non-precipitate particulates. The supernatants were then decanted to produce a more concentrated slurry of about 50 mL. The sample precipitated from the collected seep water was concentrated by the same method. Aliquots were transferred to tared vials, dried in a laminar flow hood at room temperature, weighed and corrected for salt weight, and dissolved in cold concentrated HNO_3 for total iron and arsenic analyses. Iron was determined colorimetrically and arsenic by graphite furnace atomic absorption. Results are presented in table 48.

DESORPTION EXPERIMENTS AND RESULTS

Desorption of arsenic was studied as a function of time and phosphate concentration at pH 8.0 in an artificial stream medium initially containing no arsenic. Desorption was initiated by adding aliquots of the precipitate (1 mL) into 30 mL of artificial stream water (ASW) in sets of 40 mL polycarbonate centrifuge tubes. Phosphate was added to additional sets of tubes as it has been shown to compete with arsenate for surface adsorption sites (Goldberg, 1986). Duplicate tubes were prepared for each sampling time and phosphate concentration. The resulting solids concentration ranged from 0.4 to 1.6 g/L and was determined for each precipitate sample by the dry weights of three additional aliquots. The ASW was prepared from reagent-grade salts to yield similar major ion composition to Whitewood Creek. The pH of the ASW was adjusted to 8.0 by addition of $NaHCO_3$ and Na_2CO_3 to yield the total dissolved CO_2 and pH desired (composition in table 49). Phosphate was added during the preparation to yield 10 or 100 µM concentration. Upon addition of the iron precipitate slurry to the ASW, tubes were mixed by rotating end over end at 30 rpm. After the desired reaction period, the pH was measured on pairs of tubes for each precipitate sample and phosphate concentration. Tubes were then centrifuged at 10,000 g for 10 minutes and the supernatant was sampled by pipetting. The arsenic concentration in the supernatant was determined by hydride generation atomic absorption following reduction with KI. Results are presented in tables 50 through 53 along with corresponding streamwater arsenic concentrations and the predicted equilibrium arsenate concentration (C_{eq}) from an adsorption isotherm at pH 8 for the arsenate-amorphous iron oxide system (Pierce and Moore, 1982).

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Table 47.--Ground-water chemistry of water collected from seeps along Whitewood Creek, August 1986

[mM, millimoles; µM, micromoles; --, not analyzed]

Site number in figure 1 and table 1	Major constituents							Arsenic and iron			
	pH	$[SO_4^{-2}]$ mM	Total CO_2 mM	$[Ca^{+2}]$ mM	$[Mg^{+2}]$ mM	$[K^+]$ mM	$[NA^+]$ mM	$[Fe^{+2}]$ µM	$[Fe^{+3}]$ µM	$[AsO_3^{-3}]$ µM	$[AsO_4^{-3}]$ µM
15	6.4	10.7	--	4.92 ± .03	4.28 ± .01	0.47 ± .01	2.21 ± .03	213	25	0.27	7.60
17	6.6	12.0	--	7.02 ± .05	4.31 ± .02	0.31 ± .01	2.60 ± .04	126	25	.24	3.39

Table 48.--Arsenic and iron content of iron oxyhydroxide precipitates collected from seeps adjacent to Whitewood Creek, August 1986

[mM/g, millimoles per gram]

Site number in figure 1 and table 1	Arsenic (mM/g)	Iron (mM/g)	Ratio
13	0.0809 ± .0050	3.133 ± .167	0.0258 ± .0021
15	0.1092 ± .0067	.274 ± .73	0.0207 ± .0031
17[1]	0.0505 ± .0012[2]	5.014 ± .101[2]	0.0101 ± .0003
17[3]	0.0236 ± .0023	1.765 ± .011	0.0134 ± .0013

[1]Natural precipitate.
[2]Standard deviation of three dissolutions and analyses.
[3]Artificial precipitate.

Table 49.--Artificial stream-water composition

Species	Concentration (millimoles)
SO_4^{-2}	3.5
Cl^-	.7
Total CO_2	2.0
Ca^{2+}	1.9
Mg^{2+}	1.9
K^+	.29
Na^+	1.9

Table 50.--Desorption of arsenic from iron oxide precipitates from the seep adjacent to Whitewood Creek at the Berger site; as a function of time and phosphate concentration

[Precipitate collected in pool below inactive seep outlet]

As:Fe = 0.026 solid concentration = 0.7 grams per liter

Predicted C_{eq} = 10 μM (micromoles)

Measured [As] in stream = 0.94 ± .04 μM

Time (hours)	$[PO_4^{3-}]$ (μM)	pH (final)	[As] (μM)
1	0	8.16	0.31
24	0	8.17	.31
144	0	8.06	.31
1	10	8.25	.61
24	10	8.19	.49
144	10	8.09	.49
288	10	8.04	.48
1	100	8.25	2.9
24	100	8.12	3.3
144	100	8.12	3.1
288	100	8.01	2.9

% As desorbed: 0.4% to 4.1%.

Table 51.--Desorption of arsenic from iron oxide precipitates from the seep adjacent to Whitewood Creek above Vale; as a function of time and phosphate concentration

[Precipitate collected off rock below seep outlet, above stream]

As:Fe = 0.021 solid concentration = 1.5 grams per liter

Predicted C_{eq} = 8 μM (micromoles)

Measured [As] in stream = 0.60 ± .04 μM

Time (hours)	$[PO_4^{3-}]$ (μM)	pH (final)	[As] (μM)
1	0	8.01	0.11
24	0	7.84	.05
144	0	7.81	.07
1	10	7.95	.11
24	10	7.90	.09
144	10	7.75	.08
1	100	7.99	.13
24	100	7.82	.08
144	100	7.77	.09

% As desorbed: 0.3% to 2.5%.

Table 52.--Desorption of arsenic from iron oxide precipitates collected from the seep adjacent to Whitewood Creek at the Sheeler site; as a function of time and phosphate concentration

[Precipitate collected off rock below seep outlet, above stream]

As:Fe = 0.010 solid concentration = 1.6 grams per liter

Predicted C_{eq} = 0.7 μM (micromoles)

Measured [As] in stream = 0.52 ± .01 μM

Time (hours)	$[PO_4^{3-}]$ (μM)	pH (final)	[As] (μM)
1	0	8.02	<0.01
24	0	7.87	<.01
144	0	7.95	.03
1	10	8.00	.02
24	10	7.92	.01
144	10	7.87	.03
1	100	8.01	.04
24	100	7.91	.03
1	100	7.86	.03

% As desorbed: 0.01% to 0.05%.

Table 53.--Desorption of arsenic from iron oxide precipitates formed from water from the seep adjacent to Whitewood Creek at the Sheeler site; as a function of time and phosphate concentration

[Precipitate formed in collected seep water]

As:Fe = 0.013 solid concentration = 0.4 grams per liter

Predicted C_{eq} = 1.3 μM (micromoles)

Measured [As] in stream = 0.52 ± .01 μM

Time (hours)	$[PO_4^{3-}]$ (μM)	pH (final)	[As] (μM)
1	0	8.19	0.04
24	0	7.96	.07
144	0	8.18	.05
1	10	8.30	.20
24	10	8.06	.11
144	10	8.27	.11
288	10	8.03	.11
1	100	8.31	.33
24	100	8.12	.73
144	100	8.30	1.09
288	100	8.06	1.26

% As desorbed: 0.4% to 13%.

Chapter J. Biological Investigations - Surface-Water Toxics Program, Whitewood Creek and the Belle Fourche and Cheyenne Rivers, South Dakota

By James S. Kuwabara, Daniel J. Cain, James L. Carter, and Steven V. Fend

INTRODUCTION

Biological processes are important components of water-quality studies. Currently there are two National Research Program projects addressing different aspects of these processes in relation to the surface-water toxics studies being conducted in the Cheyenne River basin of western South Dakota. One project is studying the influence of stream algal populations on arsenic (As) transport. The other project is using stream benthic insects as bioindicators to delineate the extent of As transport in Whitewood Creek and the Belle Fourche and Cheyenne Rivers. The following section will present data from the initial sampling trips of these projects. A subsection describing periphyton studies will be presented first followed by another on the benthic insect work. In each subsection, the study objectives and sampling and analytical methods are discussed prior to the presentation of tabulated data. A brief description of future experiments also is given. Some interpretation of the initial biological data was presented as extended abstracts (Cain and others, 1988; Kuwabara and others, 1988).

WORK ON PERIPHYTON

It has been inferred in recent research that elevated arsenate concentrations inhibit primary production by interfering with phosphate metabolism (Button and others, 1973; Sanders, 1979). Algal metabolism may in turn affect the chemical speciation of arsenic in natural waters by formation and release of methylated arsenicals (Andreae, 1977) and by decomposition of senescent cellular material. The interdependence of algal growth and the transport and speciation of As in Whitewood Creek is being investigated. The creek represents an ideal site for such a study because: (1) Benthic macrophytes and algae are visibly abundant during the summer months, and (2) municipal sewage discharge into the creek, as well as As-enriched mine tailings deposited along the 25-mi study reach, generate dissolved phosphate and arsenate concentration gradients. Thus, Whitewood Creek is a logical site to examine phosphate-aresenate interactive effects. Arsenic transport parameters are being determined for isolates of a chlorophyte, Stichococcus sp., common to the four collection sites along Whitewood Creek from upstream of the discharge from a mine to a site upstream from the confluence of Whitewood Creek and the Belle Fourche River. These parameters (that is, algal standing crop, sorption and release rates, and accumulation factors) may be used in a biological component of a comprehensive transport model comprised of hydrologic, chemical, and biological terms.

The initial, and thus far only, sampling trip to Whitewood Creek occurred during August 4-9, 1986. Algal standing crop (periphyton abundance) was estimated from cobble scrappings (n=6) taken from four sites: Whitewood Creek above Lead (site 1), Whitewood Creek below Deadwood STP (site 8), Whitewood Creek above Vale (site 15), and Whitewood Creek at the Sheeler site (site 17) (fig. 1, table 1). Acetone extractions of chlorophyll-a were analyzed

fluorometrically (Franson, 1985). Ash-free dry weights were also determined from cobble scrappings in order to calculate an autotrophic index (mass ratio of periphyton to chlorophyll-a) for each site as a potential indicator of environmental stress. Estimates for periphyton abundance (table 54) represent the ash-free dry weights per unit area of scrappings multiplied by the percent coverage of algal growth at the sampling site.

Table 54.--Estimated periphyton standing crop (P_b in grams per square meter) for four sites along Whitewood Creek sampled in August 1986

[The mass ratio of periphyton to chlorophyll-a (autotrophic index) has been used as an indicator of environmental stress with increasing values indicating greater abundance of senescent algal cells or increased heterotrophic growth (Weber, 1973)]

Site (figure 1 and table 1)	Temperature (°C)	Autotrophic index	P_b (grams per square meter)
1	13.2	120	21 ± 14
8	17.5	210	34 ± 13
15	19.0	140	77 ± 27
17	24.2	190	25 ± 11

Algal species isolation procedures were conducted to obtain a species common to all four sampling sites for subsequent use in As and P sorption studies. Algal suspensions generated from periphyton scrappings were streaked on 1-percent agar plates containing an algal growth medium (Kuwabara and others, 1985) enriched with silica. Algal clusters that formed on the plates were transferred to liquid media for one week to increase algal density. This agar plate streaking and resuspension procedure was repeated until unialgal cultures were achieved. Two isolates were obtained that were common to the four sampling sites. Both were chlorophytes: Stichococcus sp. and Scenedesmus sp. It is not clear why common diatoms were not obtained from this isolation procedure, because an abundance of diatoms was observed in the initial scrappings. One possibility is that chlorophyte growth was more rapid than diatoms on these agar plates. Another possibility is that the agar color obscured diatom clusters on the plates while chlorophyte clusters were readily visible. Stichococcus isolates were selected over Scenedesmus for use in subsequent sorption experiments, because in agitated cultures, Stichococcus remained unicellular and could therefore be quickly and precisely enumerated with a particle counter. Algal isolates were maintained in a chemically defined growth medium with added arsenate and orthophosphate concentrations similar to ambient levels at their respective collection sites.

In initial sorption experiments, uptake of arsenate and phosphate were observed in living and heat-killed cells from three collection sites (Whitewood Creek above Lead, Whitewood Creek above Deadwood STP, and Whitewood Creek above Vale). Algal suspensions, in 40 mL fluoroethylene polymer Oakridge tubes, were spiked with ^{73}As and ^{32}P-labelled stock solutions yielding a 0.5 µM concentration for both total dissolved As and P. Suspensions were then placed on a mechanical shaker and agitated. After 24 and 48 hours of exposure, suspensions were centrifuged at 20,000 rpm for 10 minutes to remove the algal cells from suspension. Five-milliliter volumes of the resulting supernatant, the algal suspension before centrifugation, and an internal ^{73}As and ^{32}P standard were counted by liquid scintillation to determine the extent of As and orthophosphate uptake by these cultures (table 55).

Table 55.--Algal uptake at 24 and 48 hours of arsenate and orthophosphate by living and heat-killed cells using 3 Stichococcus isolates from sites on Whitewood Creek (August 1986)

[The calculated 95-percent confidence intervals are given for 3 replicate cultures. Culture media additions of total As and total P at 0.5 µM were used]

Site (figure 1 and table 1)	Time (hours)	Percent As sorbed		Percent P sorbed	
		Living	Heat-killed	Living	Heat-killed
1	24	25 ± 12	29 ± 11	93 ± 2	94 ± 2
	48	23 ± 8	20 ± 6	96 ± 2	95 ± 2
8	24	19 ± 3	27 ± 10	93 ± 2	90 ± 4
	48	20 ± 4	18 ± 6	96 ± 2	92 ± 2
15	24	24 ± 6	21 ± 10	88 ± 2	84 ± 2
	48	16 ± 5	19 ± 3	94 ± 2	84 ± 2

Uptake rates of arsenate and orthophosphate by algal isolates are currently being studied as a function of added concentrations of dissolved As and P. A method to determine As speciation by high performance liquid chromatography coupled with hydride generation atomic absorption spectroscopy is currently being developed by Ann Maest and Sofie Pasilis of the National Research Program in Menlo Park, California. This method will be used to determine uptake and release rates for methylated as well as inorganic forms of As for algal isolates from the four sampling sites. Periphyton will be sampled on a monthly basis and taxonomically analyzed during future studies to gain a better understanding of the dynamics of the periphyton communities along the study reach.

ARSENIC IN BENTHIC INSECTS

There are numerous methods that use aquatic organisms in the analysis of water quality. The presence, absence, and/or relative abundance of known sensitive species has been used to delineate impacted areas (Warren, 1977), while the analysis of community composition has been shown to be a sensitive measure of the effects of toxic contaminants on lotic ecosystems (Leland and others, 1984). The determination of contaminants in the tissues of aquatic organisms can be used to define areas of pollution (Bryan and others, 1985; Goldberg and others, 1978; Thomson and others, 1984). This later method can provide information on the downstream transport of a contaminant in a river system and the penetration of that contaminant into aquatic food webs.

Benthic insects were collected with kick nets (3 to 5 minutes of kicking per sample) at 10 locations in Whitewood Creek and the Belle Fourche and Cheyenne Rivers in June and August 1986 and preserved in ethanol for the analysis of community structure. Additional samples were taken at 6 of these sites for elemental analysis. Two stations were located outside the contaminated area. The insects were kept in cooled stream water for at least 6 hours to clear their digestive tract and then were frozen using dry ice. In the laboratory, the samples were thawed, thoroughly rinsed with de-ionized water, and sorted by taxonomic grouping and individual size. Individuals were pooled to attain enough biomass (ca. 100 mg dry weight) for elemental analysis. Total As was determined by modified procedures of May (1982) and Penrose and others (1975). Samples were homogenized with a Polytron high-speed blender and then lyophilized. One-hundred to 200 mg of the lyophilized material was wetted with methanol in a 125-mL erlynmeyer flask. Five milliliters of 2.7 M $Mg(NO_3)_2$, an ashing aid, and 0.5 mL of antifoaming emulsion (Dow Corning DB-110A) was added to the sample. The mixture was dried overnight at 80 °C. The samples were removed from the oven, covered, and then dry-ashed in a muffle furnace at 450 °C overnight. The temperature was increased in increments of approximately 75 °C per hour. The ashed sample was dissolved in 25 mL of 50 percent HCL. Five milliliters of this solution was transferred to a glass vial and pre-reduced with 0.5 mL of 50 percent KI solution (1 part KI:10 parts sample) 1 hour before the analysis. Arsenic was determined by hydride generation atomic absorption spectroscopy (AAS) with a Perkin-Elmer MHS-10. A 30-percent HCL solution was used for the diluent. The analytical accuracy was checked by analyzing U.S. National Bureau of Standards standard reference material (SRM 50) and by determining the recovery of As in samples spiked with As (as $NaAsO_2$). Subsamples of the ashed material also were acidified with 50 percent HCL and analyzed for Fe by flame AAS. Samples were corrected for blanks.

Recovery of As in As-spiked samples ranged between 90 and 108 percent. The As concentration determined for SRM 50 (3.23 ± 0.24 µg As/g dry weight) agreed with the recommended value (3.3 ± 0.4 µg/g).

Species abundance of samples collected in June and August 1986 is shown in table 56. The composition and abundance of species displayed considerable variation among sites and between months. The upstream portions of Whitewood Creek were dominated by cold water species (for example, Rhyacophila sp., Hesperoperla pacifica, and Ephemerella inermis) which were generally more abundant in June than in August. In contrast, warm water or silt-tolerent species (for example, Choroterpes sp., Tricorythodes sp., and Dactylobaetis sp.) were more abundant in the downstream areas in June than in August.

Arsenic concentrations in insects at Whitewood Creek below Gold Run (site 5) was 5 to 6 times greater than background concentrations at Whitewood Creek above Lead (site 1) (table 57). The highest concentrations were at Whitewood Creek above Whitewood (site 10). Arsenic concentration also varied greatly among species within a site.

Iron concentrations were more variable and did not display as strong a downstream gradient as As (table 58).

Future research will compare As concentrations in insects against As concentrations of sediments and in solution. In order to eliminate problems relating to the limited geographical distribution of individual species, we will examine different sampling techniques, and evaluate the effect of grouping organisms at taxonomic levels higher than species. The influence of trophic level as a source of the interspecific variation in As concentration also will be studied. Longer-term goals are to study the mechanisms of As uptake by benthic insects and the effects of benthic insect grazing on the uptake of As by algae.

Table 56.--Relative abundance in 3-5 minute kick samples of selected benthic insects in Whitewood Creek, Belle Fourche River, and the Cheyenne River

[Relative abundance[1] of selected taxa, June 1986]

	Site number[2]									
	1	5	8	10	13	17	19	20	26	35
Baetid Mayflies										
Baetis tricaudatus	6	6			6	4				
Baetis brunneicolor	4		3	5	1					
Baetis flavigistra			2	6	2		1			
Baetis nr. pygmaeus								2	1	1
Baetis sp.								1	1	
Dactylobaetis sp.							1	3	4	
Paracloeodes minutus							1	2	4	
Pseudocloeon sp.			1	1	5	6		3	2	1
Miscellaneous Taxa										
Ephemerella inermis	4	4	1	2						
Choroterpes sp.					3	4	1	4	3	
Tricorythodes sp.					4	3	1	1	1	
Leucrocuta sp.					1	2	2	5	1	
Hesperoperla pacifica	2									
Rhyacophila sp.	2									
Limnephilus sp.			1	1						
Hydropsychid Caddisflies										
Hydropsyche oslari ?	2									
Hydropsyche slossonae	1		1							
Hydropsyche bronta ?				1		1	4	1		
Cheumatopsyche sp. 1							1	1		
Cheumatopsyche sp. 2				1			4			

Table 56.--Relative abundance in 3-5 minute kick samples of selected benthic insects in Whitewood Creek, Belle Fourche River, and the Cheyenne River--Continued

	Site number[2]					
	1	8	13	17	20	26
Baetid Mayflies						
Baetis tricaudatus	4	6				
Baetis brunneicolor ?	3		4	3	5	4
Baetis flavigistra					4	
Dactylobaetis sp.			1	4	4	3
Paracloeodes minutus						1
Pseudocloeon sp.		1	3	5	5	1
Miscellaneous Taxa						
Choroterpes sp.			5	4	5	5
Tricorythodes sp.			5	4	4	1
Isonychia sp.				1	3	1
Ephoron album			5	2	1	2
Limnephilus sp.	1	1				
Hydropsychid Caddisflies						
Hydropsyche slossonae	1	6				
Hydropsyche bronta ?		4	4	5	6	1
Cheumatopsyche sp. 1				4	6	3
Cheumatopsyche sp. 2			3	3	6	1

[1]Abundance categories:

1	0-5	4	20-50
2	5-10	5	50-100
3	10-20	6	>100

[2]Site number refers to numbers in figures 1 and 2, table 1.

Table 57.--Concentrations of As in benthic insects collected in Whitewood Creek and Belle Fourche River, June 1986

[Values are mean ±1 standard error (micrograms per gram dry weight). Sample size, n, is given in parenthesis. NS, not sampled]

Site number[1]	*E. infrequens*	Hydropsychids	*H. pacifica*	*Rhyacophila* sp.	*Limnephilus* sp.
1	11.3 ± 0.5(2)	3.1(1)	0.8 ± 0.05(2)	0.2(1)	NS
5	65.3 ± 8.1(3)	22.4(1)	NS	NS	NS
8	NS	NS	NS	NS	3.6(1)[2] 19.5(1)[3]
10	NS	46.4 ± 3.9(2)	NS	NS	2.0 ± 0.02(2)[2] 12.4 ± 1.8(2)[3]
19	NS	26.3 ± 6.4(3)	NS	NS	NS
20	NS	1.7 ± 0.3(4)	NS	NS	

[1]Refers to site number shown in figures 1 and 2, table 1.
[2]Pupa of *Limnephilus* sp.
[3]Larva of *Limnephilus* sp.

Table 58.--Concentrations of Fe in benthic insects collected in Whitewood Creek and Belle Fourche River, June 1986

[Values are mean ±1 standard error (micrograms per gram dry weight). Sample size, n, is given in parenthesis. NS, not sampled]

Site number[1]	*E. infrequens*	Hydropsychids	*H. pacifica*	*Rhyacophila* sp.	*Limnephilus* sp.
1	5,168 ± 274(2)	1,618(1)	748 ± 154(2)	2,118(1)	NS
5	3,744 ± 370(3)	2,419(1)	NS	NS	NS
8	NS	NS	NS	NS	476(1)[2] 1,594(1)[3]
10	NS	2,968 ± 550(2)	NS	NS	394 ± 10(2)[2] 907 ± 51(2)[2]
19	NS	1,074 ± 279(3)	NS	NS	NS
20	NS	2,118 ± 427(4)	NS	NS	

[1]Refers to site number shown in figures 1 and 2, table 1.
[2]Pupa of *Limnephilus* sp.
[3]Larva of *Limnephilus* sp.

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☆U.S. GOVERNMENT PRINTING OFFICE:1988-655-353/80086