U.S. GEOLOGICAL SURVEY APPLIED RESEARCH STUDIES OF THE CHEYENNE RIVER SYSTEM, SOUTH DAKOTA: DESCRIPTION AND COLLATION OF DATA, WATER YEARS 1987-88

Edited by Kimball E. Goddard

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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	micrcmoles
μS	microsiemens
mg/L	milligram per liter
mL	milliliter
mL/min	milliliter per minute
mM	millimoles
mM/g	millimole per gram
mv	millivolts

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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 1987 and 1988 water years for these research studies. Data collected in the 1985 and 1986 water years have been published in a companion report (Goddard, 1988).

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.

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.

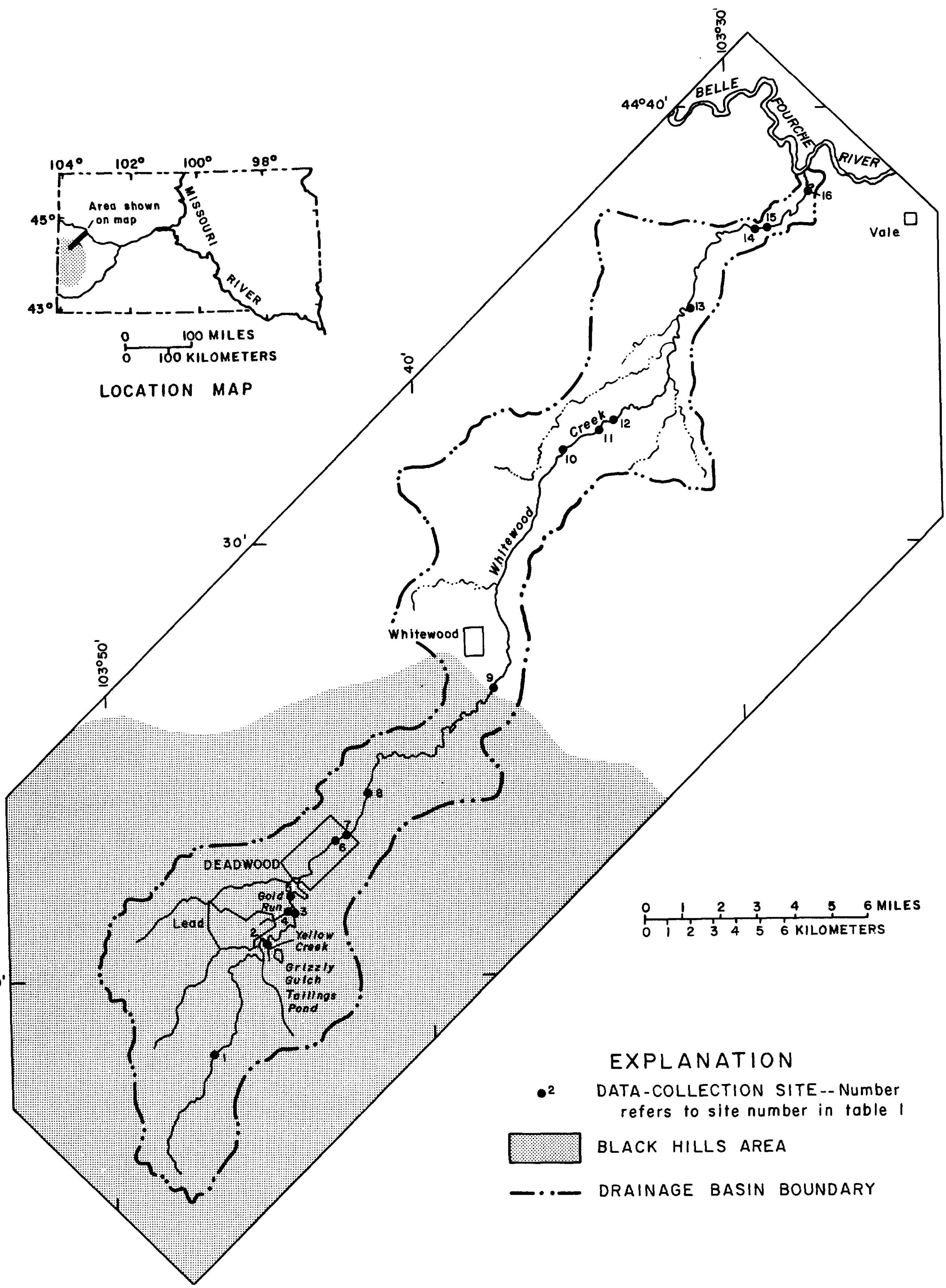

Figure 1.--Data-collection sites within the Whitewood Creek drainage basin.

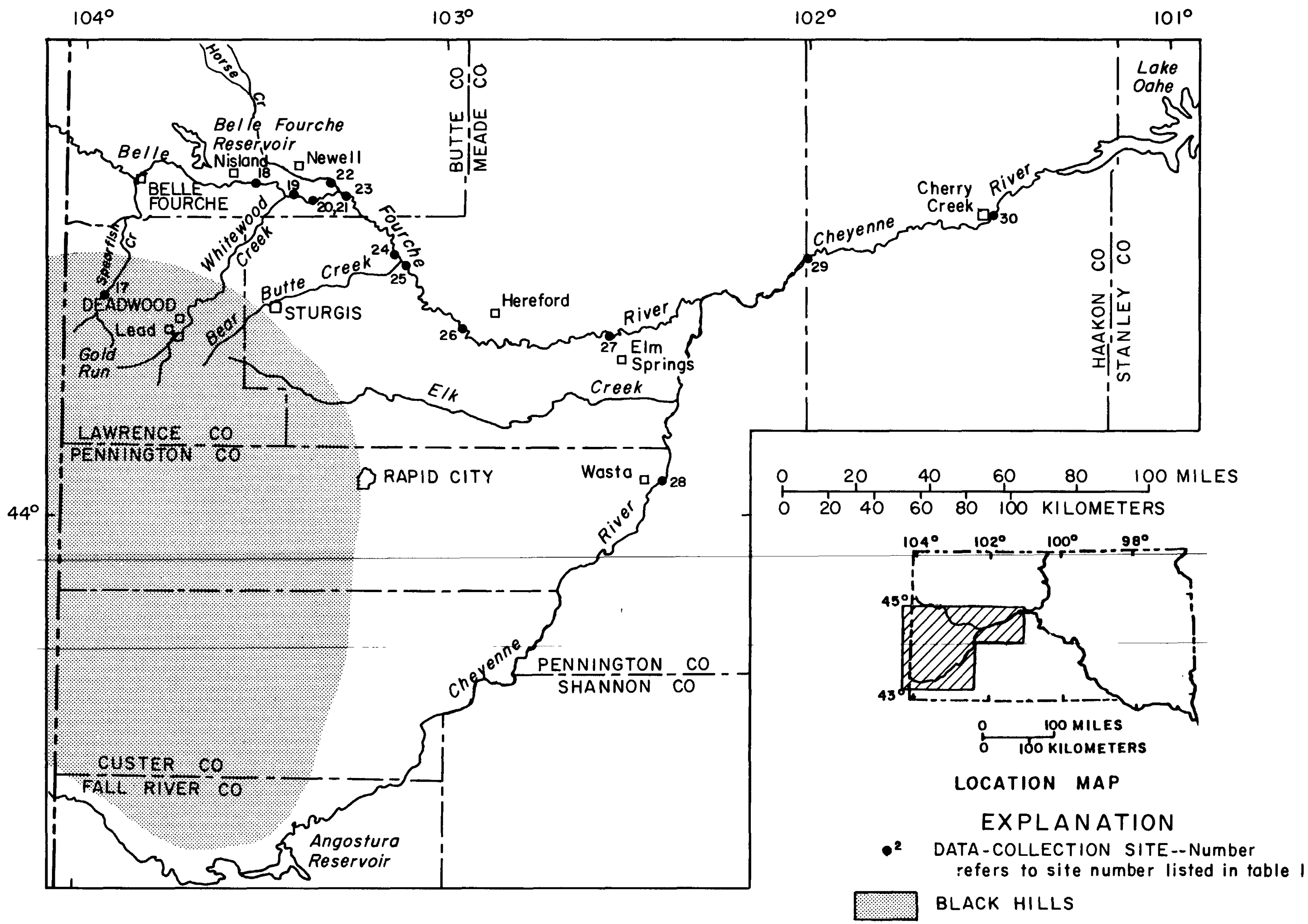

Figure 2.--Data-collection sites on the Belle Fourche and Cheyenne Rivers.

Table 1.--Names of data-collection sites discussed in text. Location of sites 1 to 16 shown in figure 1; location of sites 17-30 shown in figure 2

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

Site number	Site name	Data type	Report chapter
1	Whitewood Creek above Lead	BM,B	B,G
2	Yellow Creek near Kirk Power Plant	SW,BM	B,D
3	Whitewood Creek above Gold Run	SW,BM,B	B,E,G
4	Gold Run Creek at mouth	SW,BM	B,D,E
5	Whitewood Creek below Gold Run	B	G
6	Lead-Deadwood Sewage Treatment Plant (STP)	SW	D
7	Whitewood Creek below STP	B	E
8	Whitewood Creek below Deadwood	BM	B
9	Whitewood Creek above Whitewood	Q,SW,S,BM	B,D
10	Whitewood Creek near Whitewood	BM	B
11	Whitewood transect one (WW1)	AS	B
12	Berger site	BM,AS	B,F
13	Whitewood Creek at Custer Camp	SW	E
14	Whitewood Creek above Vale	Q,SW,S,BM,B	B,D,E
15	Whitewood transect two (WW2)	AS	B
16	Sheeler site	BM,B	B,C,G
17	Spearfish Creek	B	G
18	Belle Fourche River below Nisland	S	B
19	Belle Fourche River at Vale	AS	A
20	Belle Fourche transect one (BF1)	AS	B
21	Belle Fourche River at old Vale bridge	BM,AS	B
22	Horse Creek above Vale	SW	D,E
23	Belle Fourche River below Vale	BM,AS	B
24	Belle Fourche River near Sturgis	Q,SW,S,BM,AS	A,B,D
25	Belle Fourche transect three (BF3)	AS	B
26	Belle Fourche River near Hereford	BM,AS	A,B
27	Belle Fourche River near Elm Springs	Q,SW,S,BM,AS	A,B,D
28	Cheyenne River near Wasta	SW,S	B,D
29	Cheyenne River transect one (CR1)	AS	B
30	Cheyenne River at Cherry Creek	Q,SW,S,BM	B,D

Purpose and Scope

This report presents basic data collected in the 1987 and 1988 water years during U.S. Geological Survey research studies of the tailings contamination in the Cheyenne River basin. The report is a companion to a previously published report (Goddard, 1988) which presents basic data collected in the 1985 and 1986 water years. These reports were 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 these reports have been published in conjunction with interpretive reports.

REFERENCES

Goddard, K.E., ed., 1988, U.S. Geological Survey applied research studies of the Cheyenne River system, South Dakota: Description and collation of data, Water years 1985-86: U.S. Geological Survey Open-File Report 88-484, 158 p.

Chapter A. Physical and Chemical Characteristics of Metal-Contaminated Flood-Plain Deposits Downstream from Lead

By Donna C. Marron

Data in this section have been published previously as part of a more comprehensive report by Marron (1988)

SAMPLE COLLECTION AND HANDLING PROCEDURES

Samples of flood-plain sediments were collected during the summer of 1987 to approximately characterize the spatial variability of arsenic concentrations and grain-size characteristics in representative deposits. Samples were collected from auger holes that were dug along transects that were perpendicular to the Belle Fourche River at sites 19, 24, 26, and 27 (figure 2, table 1). Three transects extend away from the channel on the insides of two consecutive meander bends at each site. Transect and auger-hole locations were surveyed using a level and tagline. Stainless steel implements were used to scrape samples from the sides of the auger holes at 0.4 m or smaller depth intervals. Samples were stored in plastic bags and were air dried before analysis.

ANALYTICAL PROCEDURES AND RESULTS

Arsenic concentration was determined by a semiquantitative confined-spot method (O'Leary and Meier, 1986). The sample is partly dissolved by molten potassium hydroxide and the melt is dissolved with hydrochloric acid. Further treatment of the solution with stannous chloride and metallic zinc releases arsine gas which is reacted with mercuric chloride paper to form a yellow- to orange-colored spot. The colored spot is compared against colored standards for estimation of arsenic content. This method yielded values of 1,400 $\mu g/g$ and 2,100 $\mu g/g$ for samples for which total digestion arsenic concentrations were determined to be 1,800 $\mu g/g$ and 2,400 $\mu g/g$. Arsenic concentrations of samples collected from the auger holes are shown in figures 3, 4, 5, and 6. These figures also show the relation of flood-plain and channel morphology to the sampling site.

Grain-size data are listed in tables 2, 3, 4, and 5. These data were obtained using wet sieving to separate the greater than 64-μm fraction, and pipette analysis was used for the less than 64-μm fraction. Duplicate values of grain-size distributions are listed in table 6.

REFERENCES

Marron, D.C., 1988, Field and laboratory data describing physical and chemical characteristics of metal-contaminated flood-plain deposits downstream from Lead, West-Central South Dakota: U.S. Geological Survey Open-File Report 88-349, 32 p.

O'Leary, R.M., and Meier, A.L., 1986, Analytical methods used in geochemical exploration, 1984: U.S. Geological Survey Circular 948, p. 6-8.

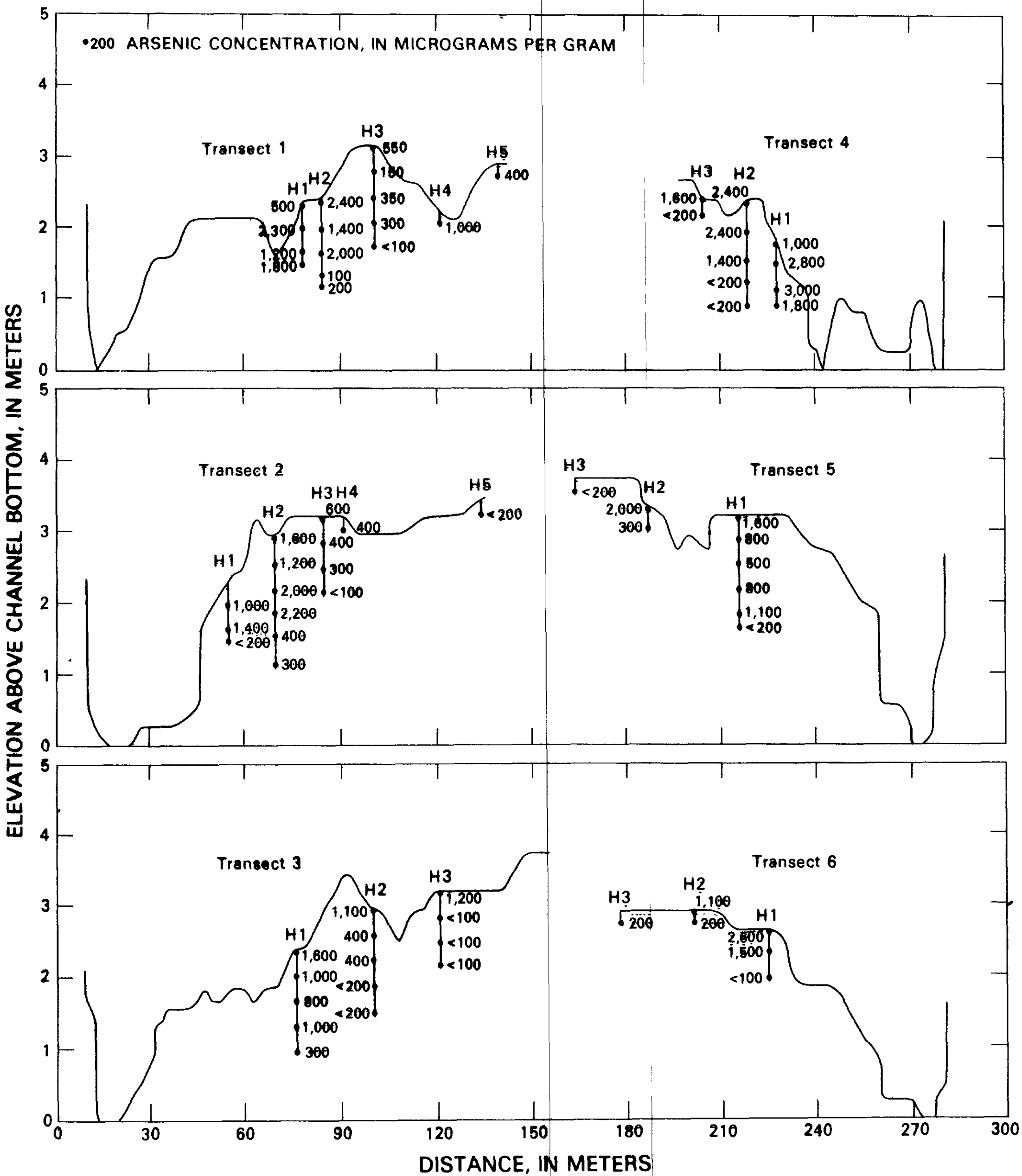

Figure 3.--Transect profiles, auger-hole locations, and depths and arsenic concentrations of sediment samples at site 19.

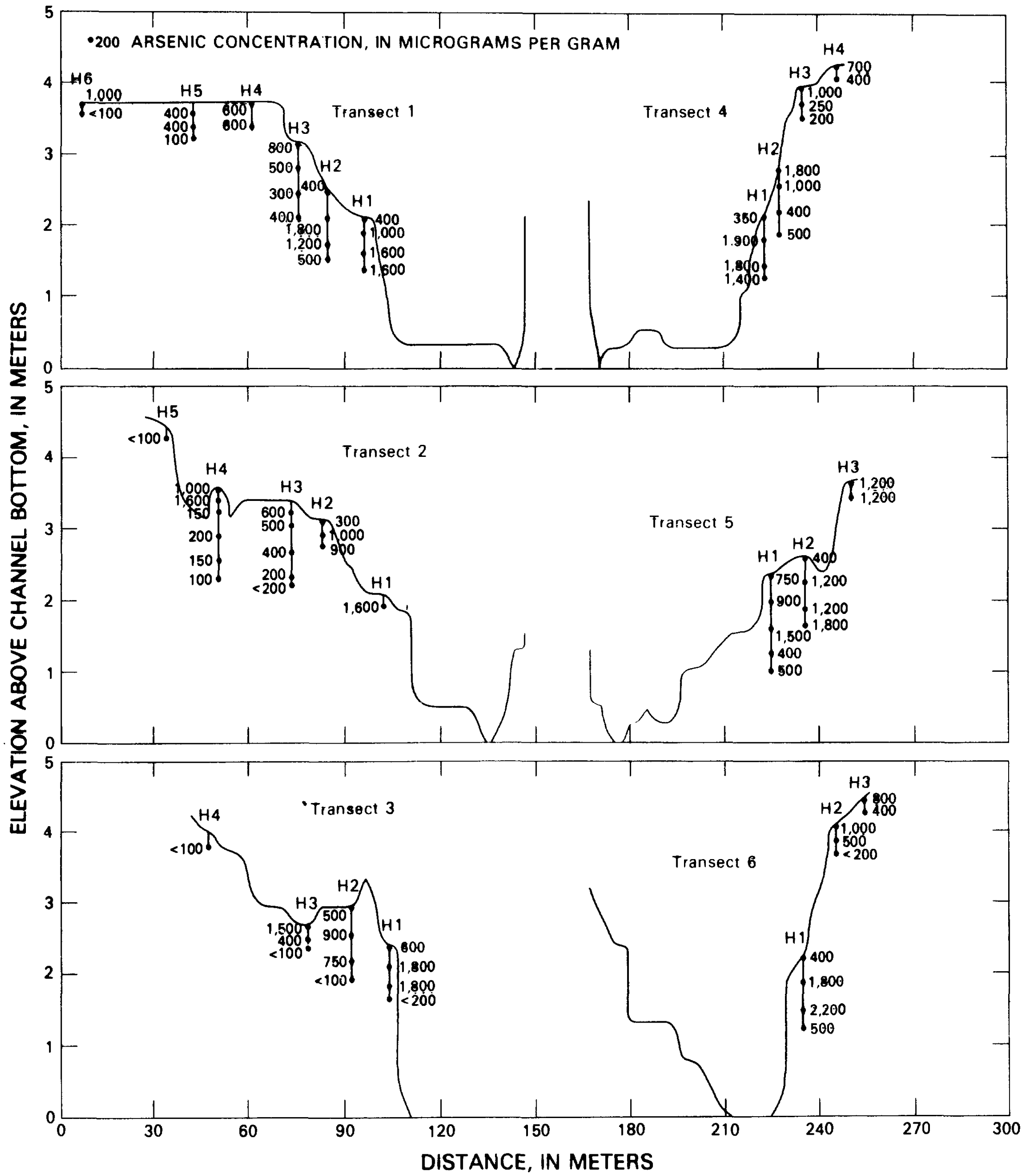

Figure 4.--Transect profiles, auger-hole locations, and depths and arsenic concentrations of sediment samples at site 24.

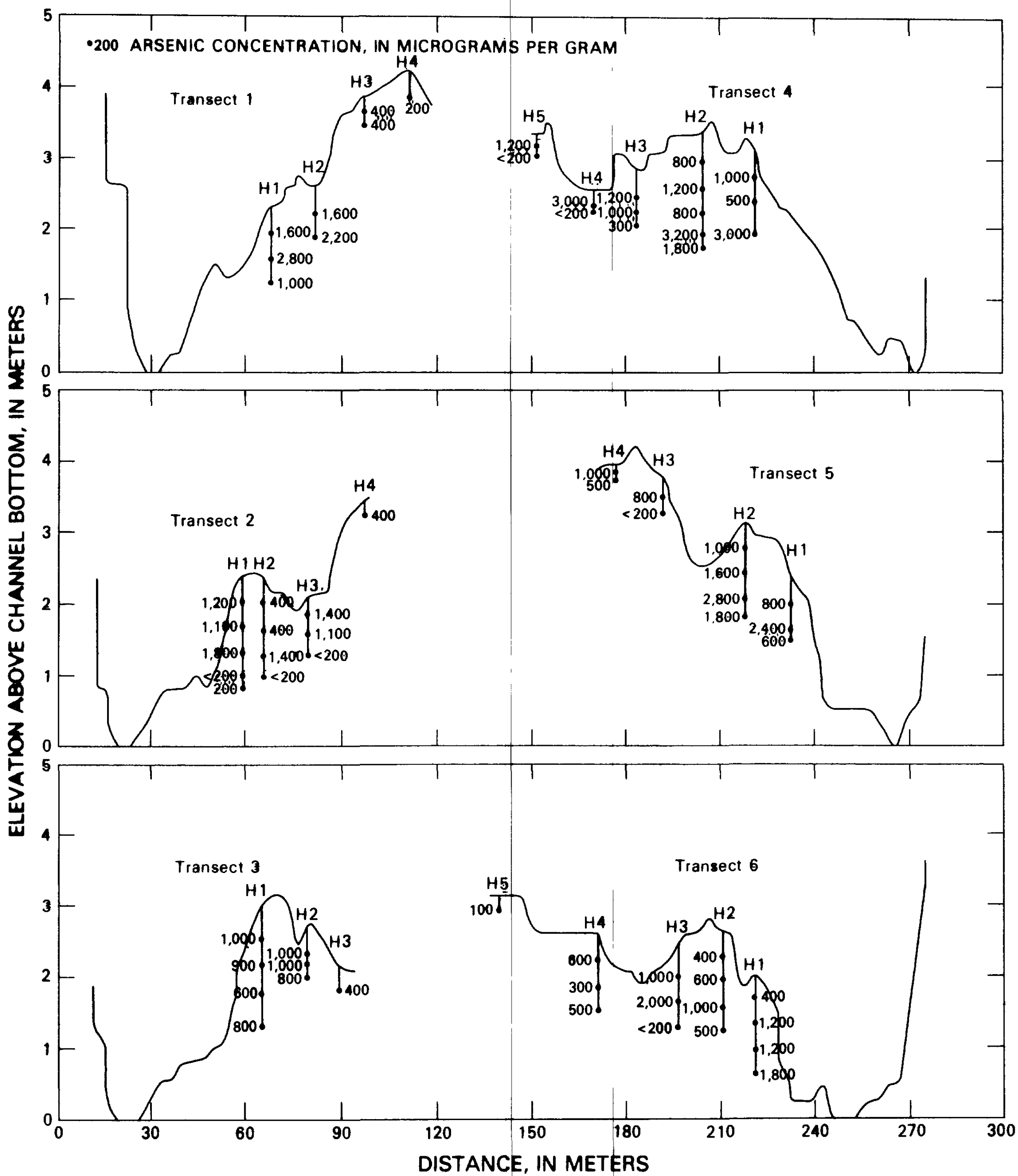

Figure 5.--Transect profiles, auger-hole locations, and depths and arsenic concentrations of sediment samples at site 26.

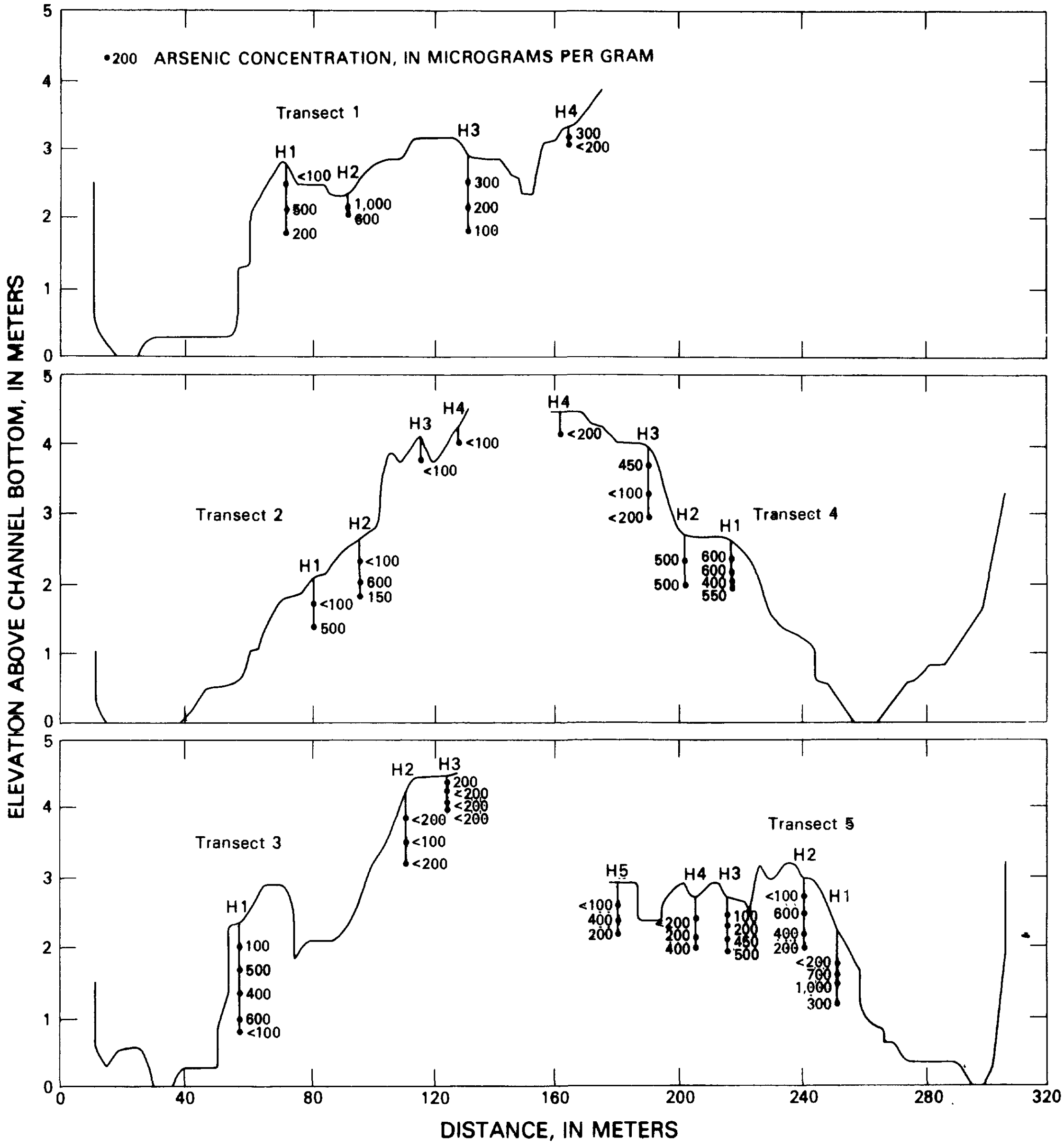

Figure 6.--Transect profiles, auger-hole locations, and depths and arsenic concentrations of sediment samples at site 27.

Table 2.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 19

[<, less than; --, data not available]

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T1-H1	Surface	15	9	76	500
	0.4	23	28	49	2,000
	[1]0.4	--	--	--	2,600
	0.8	22	33	45	1,200
	1.0	21	23	56	1,800
T1-H2	Surface	16	22	62	2,400
	0.4	30	28	42	1,400
	0.8	23	25	52	2,000
	1.2	16	2	82	100
	1.4	16	28	56	200
T1-H3	Surface	30	11	59	550
	0.4	28	29	43	150
	0.8	25	29	46	350
	1.0	33	37	30	300
T1-H4	0.2	31	32	37	1,000
T1-H5	0.2	22	24	54	400
T2-H1	Surface	41	26	33	1,000
	0.4	20	46	34	1,000
	0.8	12	7	81	1,400
	1.0	18	19	63	<200
T2-H2	Surface	24	15	61	1,600
	0.4	17	20	63	1,200
	0.8	17	10	73	2,000
	1.2	17	11	72	2,200
	1.6	16	17	67	400
	2.0	18	30	52	300
T2-H3	Surface	33	30	37	600
	0.4	24	20	56	400
	0.8	41	45	14	300
	1.2	35	31	34	<100
T2-H4	0.2	35	23	42	400
T2-H5	0.2	19	15	66	<200
T3-H1	Surface	28	27	45	1,600
	0.4	20	29	51	1,000
	0.8	18	28	54	800
	1.2	22	23	55	1,000
	1.6	20	27	53	300
	[1]1.6	--	--	--	400

Table 2.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 19--Continued

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T3-H2	Surface	15	20	65	1,100
	0.4	27	17	56	400
	0.8	31	43	26	400
	1.2	12	25	63	<200
T3-H3	Surface	19	--	--	1,200
	0.4	30	23	47	<100
T4-H1	Surface	41	33	26	1,000
	0.4	25	38	37	2,800
	0.8	19	58	23	3,000
	1.0	18	28	54	1,800
T4-H2	Surface	18	20	62	2,400
	0.4	21	26	53	2,400
	0.8	14	24	62	1,400
	1.2	41	31	28	<200
	1.6	48	15	37	<200
T4-H3	Surface	22	22	56	1,600
	0.4	26	17	57	<200

[1]Duplicate value.

Table 3.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 24

[<, less than; --, data not available]

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T1-H1	Surface	47	24	29	400
	0.3	40	32	28	1,000
	0.6	35	34	31	1,600
	0.8	67	27	6	1,600
T1-H2	Surface	30	18	52	400
	0.4	28	28	44	1,800
	0.8	13	11	76	1,200
	1.0	57	31	12	500
T1-H3	Surface	32	27	41	800
	0.4	17	20	63	500
	0.8	26	32	42	200
	1.2	25	43	32	400
T1-H4	Surface	39	21	40	600
	Surface[1]	--	--	--	400
T1-H5	0.2	38	28	34	400
	0.4	45	25	30	400
	0.5	30	6	64	100
T1-H6	Surface	30	29	41	1,000
	0.2	58	34	8	<100
T3-H1	Surface	36	14	50	600
	0.3	26	26	48	1,800
	0.6	30	38	32	1,800
	0.8	29	16	55	<200
T3-H2	Surface	16	4	80	500
	0.4	32	22	46	900
	0.8	37	17	46	750
	1.1	27	10	63	<100
T3-H3	Surface	45	36	19	1,500
	0.2	13	9	78	400
	0.3	18	0	82	<100
T3-H4	0.2	16	2	82	<100
T4-H1	Surface	35	30	35	350
	0.4	22	33	45	1,900
	0.8	24	40	36	1,800
	1.0	27	16	57	1,400

Table 3.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 24--Continued

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T4-H2	Surface	18	24	58	1,800
	0.4	20	29	51	1,000
	0.8	26	40	34	400
	1.2	33	38	29	500
T4-H3	Surface	33	22	45	1,000
	0.3	27	3	70	250
	0.5	28	2	70	200
T4-H4	Surface	25	13	62	700
	0.2	29	53	18	400

[1]Duplicate value.

Table 4.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 26

[<, less than; --, data not available]

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T1-H1	0.4	36	--	--	1,600
	.8	29	37	34	2,800
	1.2	49	33	18	1,000
T1-H2	.4	31	46	23	1,600
	.8	33	28	39	2,200
T1-H3	.3	21	38	41	400
	.5	27	18	55	400
T1-H4	.2	30	16	54	200
T3-H1	.4	31	18	51	1,000
	.8	17	22	61	900
	1.2	21	16	63	600
	1.7	54	38	8	800
T3-H2	.4	19	18	63	400
T3-H3	.2	23	52	25	1,000
	.4	40	31	29	1,000
	.6	35	17	48	800
T4-H1	.4	30	33	37	1,000
	.8	28	14	58	500
	1.3	--	--	--	3,000
T4-H2	.4	45	21	34	800
	.8	27	23	50	1,200
	1.2	27	10	63	800
	1.6	23	14	63	3,200
	1.8	24	27	49	1,800
T4-H3	.4	32	34	34	1,200
	.6	33	37	30	1,000
	.8	71	19	10	300
T4-H4	.2	36	34	30	3,000
	.3	19	5	76	<200
T4-H5	.2	40	48	12	1,200
	.3	38	1	61	<200
T6-H3	1.2	--	--	--	500
	[1]1.2	--	--	--	400

[1]Duplicate value.

Table 5.--Grain-size distribution and arsenic concentration of selected samples collected from auger holes at site 27

[<, less than; --, data not available]

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers	Arsenic content (micrograms per gram)
T1-H1	0.4	37	4	59	<100
	.8	--	--	--	500
	1.0	56	21	23	200
T1-H2	.2	32	25	43	1,000
	.3	38	30	32	600
T1-H3	.4	44	18	38	300
	.8	46	6	48	200
	1.2	41	9	50	100
T1-H4	.3	30	42	28	300
	.4	76	17	7	<200
T3-H1	.4	7	25	68	100
	.8	28	20	52	500
	1.2	34	18	48	400
	1.6	40	46	14	600
	1.8	65	30	5	<100
T3-H2	.4	19	6	75	<200
	.8	37	11	52	<100
	1.2	44	11	45	<200
T3-H3	.1	61	16	23	200
	.3	10	4	86	<200
	.4	40	19	41	<200
	.5	50	31	19	<200
T4-H1	.4	50	27	23	600
	.6	39	36	25	600
	.7	37	28	35	400
	.8	41	32	27	550
T4-H2	.4	45	32	23	500
	.8	37	34	29	500
T4-H3	.4	39	19	42	450
	.8	58	28	14	<100
	1.2	50	17	33	<200
T4-H4	.2	--	--	--	<200

Table 6.--Duplicate values of grain-size distribution

Transect and hole numbers	Depth (meters)	Weight percent less than 16 micrometers	Weight percent 16 to 64 micrometers	Weight percent greater than 64 micrometers
T1-H1	0.4	23	28	49
T1-H1	.4	26	34	40
T1-H2	1.2	16	2	82
T1-H2	1.2	13	5	82
T4-H1	.8	19	58	23
T4-H1	.8	23	45	32
T1-H1	.6	35	34	31
T1-H1	.6	45	31	24
T1-H4	Surface	39	21	40
T1-H4	Surface	34	34	32
T1-H6	0.2	58	34	8
T1-H6	.2	59	35	6
T3-H2	.4	32	22	46
T3-H2	.4	26	22	52
T4-H1	.8	24	40	36
T4-H1	.8	21	38	41
T1-H4	.2	30	16	54
T1-H4	.2	31	16	53
T4-H1	1.3	18	37	45
T4-H1	1.3	15	43	42
T1-H1	.8	32	35	33
T1-H1	.8	42	30	28
T1-H4	.3	30	42	28
T1-H4	.3	37	36	27
T4-H2	.8	37	34	29
T4-H2	.8	45	30	25
T4-H4	.2	48	21	31
T4-H4	.2	53	24	23

Chapter B. Chemical Quality of Sediments in the Cheyenne River Basin

By Thomas E. McKallip

SAMPLE COLLECTION AND PREPARATION

Suspended and bottom sediments were collected from Oct. 1, 1986, to Sept. 30, 1988, from the active channels of Whitewood Creek and the Belle Fourche and Cheyenne Rivers, and unoxidized flood-plain sediments were collected from the flood plains of Whitewood Creek and the Belle Fourche River.

Suspended-sediment samples were collected concurrently with water-quality samples using sampling methods and samplers described in Chapter D. Samples were collected in depth-integrated aliquots from 10 to 25 verticals across the stream channel. Aliquots were composited and chilled for transport to the sediment processing lab. The suspended sediment was concentrated by centrifugation using a Beckman model J2-21 centrifuge with a JA-10 fixed angle rotor. Samples were spun at 5,000 rpm for five 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.

Bottom sediments were collected within the wetted perimeter of the stream channel at 10 to 20 stations across the channel. The sediments were scooped from the top 30 to 50 mm of the channel bottom using a 250-mL plastic cup with a 60-mm opening. The scooping action was in the upstream direction so that fine sediment was retained within the cup. Sediments were aggregated and sieved in the field through a 63-μm screen and the larger than 63-μm fraction was discarded. The less-than-63-μm fraction was chilled at 4 °C, and excess water was decanted after the sediment settled. The bottom sediment samples were then freeze-dried before subsampling for analysis.

Samples of visibly unoxidized (gray) flood-plain and oxidized (red) flood-plain sediments that appeared to be transported tailings were collected from cut banks on Whitewood Creek and the Belle Fourche River and freeze-dried for analysis.

CHEMICAL ANALYSIS

Subsamples of sediments were analyzed chemically by the U.S. Geological Survey in Denver, Colorado, and the U.S. Geological Survey in Doraville, Georgia. The subsamples analyzed in Colorado were digested totally with $HF/HClO_4/HNO_3$ acid and quantified by inductively coupled plasma atomic-emission spectroscopy. Analysis of subsamples in Georgia followed the procedures of Horowitz and Elrick (1985) and Elrick and Horowitz (1985, 1987). Subsamples of 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 hydride generation and atomic absorption spectrophotometry. 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). Precision at both U.S. Geological Survey laboratories was monitored by replicate analyses and was generally better than 10 percent.

Forty-six analyses of suspended sediments are listed in tables 7 and 8; 26 analyses of bottom sediment are listed in tables 9 and 10; and 6 analyses of unoxidized flood-plain sediment samples and 2 analyses of oxidized flood-plain sediment samples are listed in table 11.

Table 7.--Total chemical analysis of suspended sediment performed by the U.S. Geological Survey in Atlanta, Georgia

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

Site number in figures 1 and 2	Date	Time	Discharge (ft^3/s)	Sediment concentration (mg/L)	Iron	Manganese	Aluminum	Titanium	Arsenic (µg/g)
Whitewood Creek above Whitewood									
9	04-07-87	1900	63	101	8.4	0.24	5.2	0.26	820
9	04-07-87	1900	63	101	8.7	.22	6.0	.26	920
9	05-20-87	1645	79	519	7.0	.20	5.7	.26	570
9	05-23-87	1950	83	1,640	7.8	.15	7.3	.33	330
Whitewood Creek above Vale									
14	03-05-87	1740	70	448	5.3	0.10	7.7	0.33	480
14	04-06-87	1500	88	244	5.4	.11	6.5	.27	600
14	04-06-87	1500	88	244	5.4	.11	6.1	.27	660
14	05-20-87	1100	40	62	6.2	.15	6.1	.27	670
14	05-23-87	2207	112	894	5.6	.15	4.9	.25	770
Belle Fourche River near Sturgis									
24	03-06-87	1640	1,270	3,960	4.6	0.09	7.7	0.33	200
24	04-06-87	1720	1,960	3,920	4.1	.05	7.9	.35	60
24	04-06-87	1720	1,960	3,920	4.4	.04	8.8	.48	50
24	04-27-87	1435	434	153	3.5	.14	6.1	.27	200
24	06-01-87	1925	505	684	3.7	.13	7.4	.29	83
24	06-01-87	1925	505	684	4.5	.14	7.9	.30	83
24	06-01-87	1925	501	684	3.8	.13	6.8	.30	80
Belle Fourche River near Elm Springs									
27	03-07-87	1240	1,210	7,960	4.9	0.11	7.5	0.36	240
27	03-07-87	1240	1,210	7,960	5.0	.12	7.5	.35	200
27	04-16-87	1230	624	534	3.9	.11	7.5	.29	60
27	05-27-87	1425	4,920	12,900	4.4	.05	8.4	.36	22
Cheyenne River at Cherry Creek									
30	02-19-87	1225	400	[1]314	3.7	0.08	7.5	0.35	20
30	04-01-87	1650	5,460	8,270	3.9	.05	8.7	.33	25
30	04-28-87	1255	1,020	160	2.9	.09	5.4	.24	40
30	06-01-87	1425	3,520	1,460	4.0	.06	8.8	.34	22
30	06-01-87	1425	3,520	1,460	4.0	.06	7.8	.34	22
30	06-19-87	1200	530	232	2.9	.08	6.0	.27	20
30	08-31-87	1040	405	[1]3,400	3.8	.06	7.9	.33	11
30	08-31-87	1040	405	[1]3,400	3.7	.05	7.8	.32	11
Miscellaneous sites									
20	03-07-87	1650	603	3,510	3.5	0.04	8.8	0.39	60
28	03-07-87	1015	3,340	15,600	2.7	.06	6.7	.29	6.2

[1]Average of duplicate analyses.

Anti-mony (µg/g)	Cad-mium (µg/g)	Chro-mium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Lead (µg/g)	Mer-cury (µg/g)	Nickel (µg/g)	Sele-nium (µg/g)	Zinc (µg/g)	Total organic carbon (µg/g)
10.4	3.4	--	26	324	88	--	102	5.1	--	--
12.6	2.5	71	25	331	97	2.92	105	4.0	650	5.3
16.2	.8	90	22	274	115	3.30	85	2.7	530	4.8
12.5	.7	126	19	131	132	12.30	61	1.5	360	2.6
1.6	<0.5	72	15	39	22	1.13	32	1.9	135	2.0
3.3	1.8	69	9	86	31	1.01	44	2.7	200	2.5
3.2	2.1	65	9	82	32	1.04	42	2.6	190	2.6
6.6	1.2	77	16	135	57	2.20	62	2.3	310	3.7
3.5	<.5	68	14	90	31	1.50	46	2.6	180	2.9
1.0	<0.5	67	9	34	18	0.17	33	1.2	129	1.0
1.1	.5	-	6	31	18	.13	35	1.1	144	--
.9	2.8	84	8	32	15	.12	28	1.2	136	<.1
.9	2.1	61	5	37	17	.43	33	1.6	139	2.0
1.1	<.5	65	14	37	20	--	36	--	122	--
1.2	<.5	63	15	39	21	--	38	--	129	--
1.1	1.1	63	15	38	19	--	39	--	126	--
1.0	<0.5	76	2	36	20	0.20	40	1.2	143	1.2
1.1	<.5	76	19	38	12	.18	36	1.3	146	1.0
.9	.5	67	12	31	11	.24	35	1.2	133	1.1
1.0	<.5	91	13	34	15	.24	41	.7	142	<.1
0.9	0.7	60	15	26	13	0.12	23	0.7	121	1.3
1.1	<.5	78	14	31	15	.08	34	1.6	130	<.1
.7	1.3	58	13	27	11	.63	22	1.2	107	2.5
1.0	<.5	81	14	30	16	--	38	--	124	--
1.0	<.5	80	14	30	14	--	38	--	123	--
.7	.9	51	10	31	17	--	23	--	97	--
1.0	<.5	39	13	30	21	--	21	--	119	--
1.0	<.5	39	12	31	21	--	21	--	117	--
1.0	0.6	83	13	25	13	0.10	33	1.2	136	<0.1
.8	<.5	47	11	16	17	.06	14	.6	88	<.1

Table 8.--Total chemical analyses of suspended sediment performed by the U.S. Geological Survey in Denver, Colorado

[Iron, manganese, aluminum, titanium, calcium, magnesium, potassium, and sodium in weight percent; ft^3/s, cubic feet per second; mg/L, milligrams per liter; µg/g; micrograms per gram; <, less than]

Site number in figures 1 and 2	Date	Time	Discharge (ft^3/s)	Sediment concentration (mg/L)	Iron	Manganese	Aluminum	Titanium	Calcium	Magnesium	Potassium	Sodium	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)
Whitewood Creek above Whitewood															
9	03-20-88	1800	36	610	8.2	3,000	4.9	0.20	4.30	1.3	2.00	0.39	870	740	2
9	03-20-88	1805	36	610	7.9	3,000	2.0	.03	4.30	1.1	.45	.10	880	320	2
9	03-21-88	1955	35	184	8.3	3,000	4.9	.20	5.00	1.4	1.90	.46	880	610	2
9	05-02-88	1015	38	26	6.9	2,600	4.2	.16	6.10	1.2	1.60	.42	610	660	2
9	05-09-88	2015	143	[1]156	8.0	2,500	6.2	0.26	3.90	1.6	2.40	0.65	590	130	3
Whitewood Creek above Vale															
14	02-29-88	1215	23	115	5.1	1,500	5.3	0.22	5.20	1.5	1.80	0.62	850	100	2
14	03-21-88	1800	42	180	6.1	1,600	5.9	.25	4.50	1.2	1.90	.32	780	470	2
14	05-09-88	1800	107	377	5.0	1,200	6.1	.29	4.70	1.3	1.90	.37	540	520	2
14	05-09-88	1805	107	377	6.0	1,600	5.8	.25	4.40	1.2	1.80	.33	810	520	2
Belle Fourche River near Sturgis															
24	03-26-88	1550	412	746	4.6	1,200	7.1	0.31	2.90	1.6	1.70	1.30	240	85	2
24	05-10-88	1715	249	286	4.0	1,700	6.4	.29	4.30	1.7	1.70	1.70	230	48	2
24	06-30-88	1625	342	212	4.5	1,500	5.9	.27	4.00	1.4	1.60	.80	320	84	2
Belle Fourche River near Elm Springs															
27	03-29-88	1140	540	2,870	4.4	480	8.6	.38	.93	1.3	2.00	.55	30	560	2
Cheyenne River at Cherry Creek															
30	07-23-87	1135	499		3.4	510	7.1	0.34	3.10	1.7	2.10	0.67	<10	470	2
30	03-29-88	1700	2,480	5,500	4.0	570	7.9	.34	1.90	1.3	2.00	.58	40	610	2
30	05-26-88	1415	297	2,790	3.8	480	7.7	.36	2.00	1.9	1.90	.39	<10	300	3

[1]Average of duplicate analyses.

Table 8.--Total chemical analyses of suspended sediment performed by the U.S. Geological Survey in Denver, Colorado--Continued

Site number in figures 1 and 2	Bismuth (μg/g)	Cadmium (μg/g)	Cerium (μg/g)	Chromium (μg/g)	Cobalt (μg/g)	Copper (μg/g)	Europium (μg/g)	Gallium (μg/g)	Gold (μg/g)	Holmium (μg/g)	Lanthanum (μg/g)	Lead (μg/g)	Lithium (μg/g)	Molybdenum (μg/g)
9	<10	<2	63	71	32	440	<2	16	<8	<4	36	89	31	3
9	<10	<2	57	38	30	440	<2	9	<8	<4	31	92	20	<2
9	<10	<2	67	71	31	470	<2	16	<8	<4	39	92	31	3
9	<10	<2	63	56	28	330	<2	14	<8	<4	36	78	29	3
9	<10	3	81	79	34	280	<2	20	<8	<4	44	80	43	4
14	<10	<2	53	63	14	54	<2	14	<8	<4	31	19	40	3
14	<10	<2	64	73	19	100	<2	17	<8	<4	38	36	45	4
14	<10	<2	60	72	15	66	<2	17	<8	<4	34	25	45	3
14	<10	<2	60	69	19	97	<2	16	<8	<4	35	35	43	3
24	<10	<2	47	80	16	39	<2	19	<8	<4	27	16	54	<2
24	<10	<2	43	71	15	39	<2	17	<8	<4	27	14	57	<2
24	<10	<2	46	62	16	49	<2	16	<8	<4	27	17	42	<2
27	<10	<2	52	91	15	33	<2	22	<8	<4	30	17	62	<2
30	<10	<2	70	45	12	25	<2	20	<8	<4	39	22	54	<2
30	<10	<2	56	83	14	32	<2	21	<8	<4	32	21	58	<2
30	<10	<2	75	42	13	29	<2	21	<8	<4	41	26	57	<2

Table 8.--Total chemical analyses of suspended sediment performed by the U.S. Geological Survey in Denver, Colorado--Continued

Site number in figures 1 and 2	Neo- dymium (μg/g)	Nickel (μg/g)	Nio- bium (μg/g)	Phos- phorus (μg/g)	Scan- dium (μg/g)	Silver (μg/g)	Stron- tium (μg/g)	Tanta- lum (μg/g)	Tho- rium (μg/g)	Tin (μg/g)	Ura- nium (μg/g)	Vana- dium (μg/g)	Ytter- bium (μg/g)	Yttri- um (μg/g)	Zinc (μg/g)
9	30	150	6	0.44	8	15	390	<40	12	<10	<100	110	2	17	610
9	27	150	<4	.45	5	12	220	<40	10	<10	<100	69	1	13	610
9	31	140	7	.45	8	16	490	<40	22	<10	<100	130	2	19	670
9	29	120	5	.42	8	12	430	<40	11	<10	<100	110	2	17	600
9	38	100	8	.27	12	16	380	<40	14	<10	<100	170	2	21	540
14	27	37	6	.13	8	<2	230	<40	10	<10	<100	110	2	16	120
14	30	52	8	.14	10	3	230	<40	11	<10	<100	130	2	18	180
14	30	41	8	.12	10	<2	210	<40	12	<10	<100	130	2	18	130
14	30	48	7	.14	10	3	220	<40	12	<10	<100	130	2	18	170
24	24	34	8	.08	13	<2	240	<40	10	<10	<100	160	2	16	120
24	23	33	8	.08	11	<2	290	<40	11	<10	<100	150	2	15	110
24	23	31	6	.09	10	<2	310	<40	8	<10	<100	130	2	15	120
27	25	40	11	.07	15	<2	160	<40	12	<10	<100	210	2	18	130
30	35	21	9	.07	11	<2	280	<40	17	<10	<100	91	3	25	100
30	27	35	10	.07	13	<2	210	<40	12	<10	<100	180	2	19	90
30	35	24	13	.08	13	<2	210	<40	17	<10	<100	110	3	27	110

Table 9.--Bottom sediment sample from site 17 collected on August 20, 1987, at 1200 and analyzed by the U.S. Geological Survey in Denver, Colorado

[Iron, aluminum, titanium, calcium, magnesium, potassium, and sodium in weight percent; $\mu g/g$, micrograms per gram, --, not determined]

Iron	Manganese	Aluminum	Titanium	Calcium	Magnesium	Potassium	Sodium	Antimony ($\mu g/g$)	Arsenic ($\mu g/g$)	Barium ($\mu g/g$)	Beryllium ($\mu g/g$)	Bismuth ($\mu g/g$)	Boron ($\mu g/g$)	Cadmium ($\mu g/g$)
4.7	0.11	5.7	0.26	4.6	1.1	1.6	0.32	--	670	570	1. 6	--	53	--

Cerium ($\mu g/g$)	Chromium ($\mu g/g$)	Cobalt ($\mu g/g$)	Copper ($\mu g/g$)	Lanthanum ($\mu g/g$)	Lead ($\mu g/g$)	Lithium ($\mu g/g$)	Molybdenum ($\mu g/g$)	Nickel ($\mu g/g$)	Niobium ($\mu g/g$)	Phosphorus ($\mu g/g$)	Strontium ($\mu g/g$)	Tin ($\mu g/g$)	Vanadium ($\mu g/g$)
47	72	13	40	30	36	43	--	56	--	608	185	--	150

Table 10.--Total chemical analysis of bottom sediments performed by the U.S. Geological Survey in Atlanta, Georgia

[Iron, manganese, aluminum, and titanium in weight percent; µg/g, micrograms per gram; <, less than; --, not determined]

Site number in figures 1 and 2	Date	Time	Iron	Manganese	Aluminum	Titnium	Arsenic (µg/g)	Antimony (µg/g)
1	05-12-87	1145	2.6	0.04	5.1	0.32	20	3.1
1	05-12-87	1145	--	--	--	--	--	--
2	05-12-87	1315	16.5	.10	6.2	.35	80	4.2
2	05-12-87	1315	17.0	.10	7.2	.39	85	4.4
3	05-12-87	1535	6.5	.18	5.3	.33	580	17.0
3	05-12-87	1535	7.1	.16	6.1	.33	830	19.0
4	05-12-87	1425	8.6	.20	5.6	.64	520	18.0
4	05-12-87	1425	8.6	.16	6.0	.56	500	19.2
7	05-12-87	1645	8.1	.20	4.7	.27	880	12.4
7	05-12-87	1645	8.1	.18	4.9	.28	910	15.6
9	05-13-87	1045	7.6	.19	5.1	.26	880	10.7
9	05-13-87	1045	7.9	.20	5.3	.28	1,100	14.0
10	05-13-87	1145	8.2	.22	4.5	.27	1,550	5.6
12	05-13-87	1230	32.0	.07	3.2	.12	23,000	2.8
12	05-13-87	1230	31.0	.06	3.2	.12	24,000	3.4
14	05-13-87	1300	5.0	.13	5.1	.30	660	2.4
14	05-13-87	1300	--	--	--	--	--	--
21	05-13-87	1430	5.6	.13	5.8	.32	1,040	1.4
23	05-13-87	1530	4.2	.12	6.8	.32	300	1.1
24	05-14-87	1700	4.7	.12	6.6	.35	600	1.0
24	06-01-87	1200	6.6	.14	5.6	.35	850	1.1
26	05-14-87	1030	4.4	.14	7.1	.35	300	1.1
27	05-14-87	1200	4.4	.10	6.8	.32	180	0.9
27	06-01-87	1630	4.8	.08	8.1	.36	130	0.9
30	05-14-87	1445	3.2	.08	7.0	.32	40	0.9

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)
<0.5	<1	13	14	22	0.19	17	1.2	106	3.5
--	--	--	--	--	--	--	--	--	3.6
1.1	--	32	82	15	--	75	1.5	410	3.4
.7	55	31	80	18	.25	77	1.2	430	3.6
.9	--	30	91	48	--	58	2.1	350	--
.7	69	28	87	52	.72	59	1.8	340	3.6
<.5	--	32	1,790	78	1.60	140	6.9	1240	--
.7	60	24	1,950	86	1.60	141	5.2	1390	3.1
1.4	--	26	402	83	--	95	4.7	700	--
1.1	62	25	388	94	1.73	96	3.2	700	5.3
1.3	--	29	258	80	--	90	3.8	535	5.2
1.5	65	25	255	91	1.66	97	3.0	550	5.1
<.5	59	27	145	44	1.28	52	4.4	260	3.0
<.5	--	13	234	<1	--	14	.3	92	1.3
<.5	32	14	225	<1	.37	13	.6	78	1.3
<.5	58	19	58	20	.55	38	2.7	132	2.3
--	--	--	--	--	.55	--	--	--	--
<.5	63	19	41	9	.42	29	3.2	123	1.3
<.5	65	17	33	11	.24	30	2.1	126	1.5
<.5	65	19	36	14	.38	37	1.9	123	1.1
<.5	80	14	42	15	.53	33	1.6	118	.7
<.5	69	19	34	8	.24	36	1.5	130	1.2
<.5	68	18	33	10	.20	33	1.4	128	1.0
<.5	91	16	34	18	.36	42	1.0	130	.7
<.5	49	17	24	17	.07	28	.8	99	<.1

Table 11.--Total chemical analysis of visually identified unoxidized and oxidized flood-plain sediments

[Iron, manganese, aluminum, and titanium in weight percent; µg/g, micrograms per gram; <, less than; --, not determined]

Site number in figures 1 and 2	Date	Time	Iron	Manganese	Aluminum	Titaninum	Arsenic (µg/g)	Antimony (µg/g)	Cadmium (µg/g)
Unoxidized flood-plain sediments									
12	06-01-87		7.0	0.45	3.5	0.21	4,300	1.8	<0.5
21	06-01-87		15.5	.45	3.0	.19	3,800	1.3	<.5
23	06-01-87		14.5	.40	3.3	.19	2,200	.9	<.5
24	06-01-87		15.0	.40	3.0	.18	3,200	1.0	<.5
26	06-01-87		8.9	.25	4.8	.24	540	1.2	<.5
27	06-01-87		12.5	.35	4.4	.26	1,100	1.0	<.5
Oxidized flood-plain sediments									
12	10-14-87		--	--	--	--	4,100	--	--
21	10-14-87		--	--	--	--	2,700	--	--

Chrom-inum (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Lead (µg/g)	Mer-cury (µg/g)	Nickel (µg/g)	Sele-nium (µg/g)	Zinc (µg/g)	Total organic carbon (µg/g)
46	11	112	5	8.3	12	1.8	129	1.1
38	11	86	<1	4.30	15	2.4	91	2
42	7	69	<1	2.00	13	1.6	105	.9
35	10	73	<1	2.10	14	1.8	85	.9
55	13	53	8	1.60	28	1.6	129	1
60	12	78	5	2.60	24	2.1	124	1.3
--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--

HEAVY MINERAL FRACTIONATION OF SEDIMENTS

Heavy-mineral separations were performed on 5 suspended-sediment, 5 bottom-sediment, 2 unoxidized flood-plain sediment, and 5 oxidized flood-plain sediment samples. The samples that were fractionated were collected between October 1986 and September 1988 with the exception of oxidized flood-plain samples and a suspended-sediment sample from site 6 which were collected in September 1986. Total chemical analyses of the samples are listed in tables 12 to 14. Total chemical analyses of samples collected between October 1984 and September 1986 are in Marron (1988) and Roddy and McKallip (1988).

The procedure for heavy-mineral separations consisted of weighing about 2 g of sediment with a precision of 0.001 g into a 50-mL centrifuge tube containing 20 mL of bromoform. The sample was then dispersed for 1 hour in an ultrasonic bath. Following dispersal the samples were centrifuged at 8,000 rpm for 10 minutes after which the fractionated sample was frozen. The small mass of heavy minerals in the samples was collected without remixing by cutting the centrifuge tube and splitting the frozen bromoform. Heavy- and light-mineral fractions were recovered by melting the bromoform pellets, drawing off the bromoform with a pipet, and rinsing the fractions with ethanol before oven drying at 40 °C for 4 hours. The heavy-mineral fraction was weighed with a precision of 0.0001 g and recorded as a percentage of the total sample. In order to recover as much of the heavy-mineral fraction as possible, the resulting light-mineral fraction was subjected to the above procedure 2 to 5 times. The heavy minerals separated by repetitions of this procedure were aggregated. A heavy-mineral separation was considered complete when the mass of heavy minerals recovered in the last repetition was less than 10 percent of the total mass of heavy minerals collected. Precision of the method of heavy-mineral separations was monitored by the determination of percent of the heavy minerals in replicate samples. Percentages of heavy minerals in 17 samples are listed in table 12.

The heavy- and light-mineral fractions of 8 sediment samples were analyzed chemically at the U.S. Geological Survey laboratory in Georgia. The results of the total chemical analyses are listed in table 13.

Particle sizes were determined by the U.S. Geological Survey in Iowa, following the methods of Guy (1969). The particle size distribution in heavy-mineral fractions of 5 flood-plain samples is listed in table 14.

SCANNING ELECTRON MICROSCOPE ANALYSES

A Phillips 505 scanning electron microscope (SEM) with a Tracor Northern E.D.S. EDAX (energy dispersive x-ray) system was used to analyze the average diameter and arsenic, iron, sulfur, manganese, calcium, barium, silicon, and zircon content of about 200 randomly selected grains from the heavy-mineral fractions of 17 samples and one replicate sample. Analyses were performed at the institute for Ultrastructrual Research at the University of Georgia in Athens, Georgia.

The SEM/EDAX program determines semi-quantitative constituent concentrations on the surfaces of grains in the heavy-mineral fractions. The program scans the entire grain, and its results do not reflect variations of concentrations within grains. Summary statistics of SEM/EDAX analyses are listed in table 15.

Table 12.--Percentages of heavy-minerals in selected alluvial sediment samples

Site number in figures 1 and 2		Date	Time	Percentage of heavy minerals
Suspended				
9		05-20-87	1645	2.2
14		05-23-87	1950	2.7
24		09-25-86		.6, [2](.9)
27		03-07-87	1240	1.1
30		04-01-87	1650	.5
Bottom				
9		05-13-87	1045	6.9, [2](6.0)
16		08-20-87		1.7
24		05-14-87	1700	2.1
27		05-14-87	1200	2.1
30				.8
Oxidized flood plain				
11	[1]WW1B1	--	--	32
11	[1]WW1A2	--	--	32
15	[1]WW2A4	--	--	27
20	[1]BF1B3	--	--	20, [2](22)
25	[1]BF3A1	--	--	39, [2](36)
29	[1]CR1A4	--	--	14
Unoxidized flood plain				
13		10-14-87	1100	56
23		10-14-87	1300	48

[1]Sample designation used by Marron (1988).
[2]Duplicate.

Table 13.--Total chemical analyses of heavy- and light-mineral fractions of alluvial sediments performed at the U.S. Geological Survey in Atlanta, Georgia

[Iron, manganese, aluminum, and titanium in weight percent; H, heavy minerals; L, light minerals; μg/g, micrograms per gram; <, less than]

Site number in figure 1 and 2	Date	Time	Density category	Percent in density fraction	Iron	Manganese	Aluminum
Suspended sediment							
24	09-25-86		H	0.75	35.0	0.99	2.5
24	09-25-86		L	99	4.0	.04	6.2
Bottom sediment							
9	05-13-88	1045	H	6.5	30.0	0.74	3.3
9	05-13-88	1045	L	93.0	5.8	.13	4.7
16	08-20-87		H	1.7	31.0	.43	2.2
16	08-20-87		L	98.3	4.2	.05	5.5
[2]16	08-20-87		L	98.3	4.2	.05	5.3
Flood-plain sediment (oxidized)							
15 [1]WW2A4	--	--	H	26.9	28.0	0.31	5.4
15 [1]WW2A4	--	--	L	73.1	8.0	.05	2.2
20 [1]BF3A1	--	--	H	37.3	28.0	.30	3.2
20 [1]BF3A1	--	--	L	62.7	7.8	.02	2.0
29 [1]CR1A4	--	--	H	14.1	29.0	.95	3.0
29 [1]CR1A4	--	--	L	85.9	3.8	.08	4.6
[2]29 [1]CR1A4	--	--	L	85.9	4.0	.08	4.9
Flood-plain sediment (unoxidized)							
12	10-14-87	1100	H	55.7	25.0	0.90	4.5
12	10-14-87	1100	L	44.3	4.2	.09	2.1
21	10-14-87	1300	H	48.1	22.0	.50	2.7
21	10-14-87	1300	L	51.9	2.3	.03	1.8

[1]Sample designation used by Marron (1988).
[2]Duplicate analyses.

Titanium	Arsenic (μg/g)	Antimony (μg/g)	Cadmium (μg/g)	Chromium (μg/g)	Cobalt (μg/g)	Copper (μg/g)	Lead (μg/g)	Nickel (μg/g)	Zinc (μg/g)
0.83	3,700	8.3	<0.5	66	41	83	73	50	350
.34	300	1.2	<.5	77	11	26	12	31	101
1.03	6,000	50.0	2.5	90	44	232	90	102	530
.17	700	9.5	1.3	59	20	165	74	92	380
1.32	9,900	16.0	.4	132	36	171	17	72	400
.26	600	1.6	.4	62	10	25	11	33	100
.26	600	1.6	.4	63	10	25	14	28	98
0.35	7,700	4.1	<0.5	62	12	167	21	21	230
.09	3,800	2.0	<.5	23	4	81	13	7	64
.25	7,500	3.0	<.5	43	4	66	14	4	109
.11	3,500	1.5	<.5	24	2	34	5	1	33
.71	3,100	2.7	<.5	82	16	101	1	22	160
.18	450	.7	<.5	39	8	25	9	20	79
.19	470	.7	<.5	38	8	25	10	15	76
0.29	8,500	4.0	<0.5	55	17	175	16	11	180
.07	520	1.2	<.5	22	3	14	1	3	49
.18	5,200	3.0	<.5	34	18	122	5	28	109
.08	69	.6	<.5	18	3	13	1	1	34

Table 14.--Particle sizes in selected heavy-mineral fractions of sediment samples

[mm, millimeters]

Site number in tables 1 and 2	Date	Time	Percent finer than 0.02 mm	0.04 mm	0.08 mm	0.16 mm	0.32 mm	0.62 mm	0.125 mm	0.250 mm	0.500 mm	1.00 mm
Oxidized flood-plain sediment												
11 [1]WW1A2	--	--	1	2	--	6	--	17	34	88	98	100
15 [1]WW2A4	--	--	1	2	--	9	--	85	97	100	--	--
20 [1]BF1B3	--	--	3	4	5	12	36	88	100	--	--	--
Unoxidized flood-plain sediment												
12	10-14-87	1100	1	4	13	33	83	100	--	--	--	--
21	10-14-87	1300	2	3	3	5	20	77	91	100	--	--

[1]Sample designation used by Marron (1988).

Table 15.--Summary of results of the scanning electron microscope and energy dispersive x-ray analyses of grains from the heavy-mineral fractions of sediment samples

Site number in figures 1 and 2	Date	Time	Number of analyzed sample grains	Average grain diameter (micrometers)				Percent silica			
				Mean	Standard deviation	Maximum	Minimum	Mean	Standard deviation	Maximum	Minimum
Suspended											
9	05-20-87	1645	213	95.6	60.9	428.4	22.5	19.2	15.9	85	0
14	05-23-87	1950	182	155.8	151.1	787.9	14.6	19.2	15.7	80	0
24	09-25-86		188	215.3	201.2	1644.9	26.1	24.8	22.6	96	0
27	03-07-87	1240	204	157.1	122.9	744.1	19.1	32.5	24.2	96	0
30	04-01-87	1650	183	228.6	137.5	806.1	31.0	25.1	21.7	88	0
Bottom											
10	05-13-87	1045	225	73.0	39.7	258.0	26.5	16.4	15.2	74	0
17	08-20-87		205	80.2	40.2	272.5	27.9	22.4	24.0	96	0
26	05-14-87	1700	222	111.3	49.4	327.0	33.8	13.2	17.6	91	0
29	05-14-87	1200	223	81.8	31.5	228.2	29.8	15.1	18.3	90	0
34	05-14-87		255	93.2	47.3	297.7	33.1	13.7	14.1	95	0
Oxidized flood plain											
12 [1]WW1B1	--	--	172	50.2	23.5	167.7	27.9	8.5	14.3	86	0
16 [1]WW2A4	--	--	171	73.8	54.4	392.9	24.5	22.6	14.6	90	1
22 [1]BF1B3	--	--	253	73.3	44.4	363.8	24.8	24.1	15.6	90	0
27 [1]BF3A1	--	--	192	82.0	61.6	471.3	24.8	16.8	16.4	89	0
[2]27 [1]BF3A1	--	--	228	57.9	34.6	263.3	24.5	13.6	9.7	69	1
31 [1]CR1A4	--	--	227	85.6	48.6	330.7	24.8	20.8	17.5	94	0
Unoxidized flood plain											
13	10-14-87		151	64.0	27.9	181.7	29.5	25.3	17.8	90	0
23	10-14-87	1300	185	95.5	69.9	545.7	24.8	15.6	15.5	93	0

[1]Sample designation used by Marron (1988).
[2]Duplicate.

Table 15.--Summary of results of the scanning electron microscope and energy dispersive x-ray analyses of grains from the heavy-mineral fractions of sediment samples--Continued

Site number in figures 1 and 2	Percent arsenic				Percent calcium			
	Mean	Standard deviation	Maximum	Minimum	Mean	Standard deviation	Maximum	Minimum
Suspended								
9	0.2	1.7	24	0	6.2	14.7	91	0
14	.1	.4	2	0	4.9	14.3	96	0
24	.2	.5	4	0	5.6	15.6	76	0
27	.1	.3	2	0	3.9	11.7	85	0
30	.1	.4	4	0	7.3	17.3	96	0
Bottom								
9	0.3	2.2	25	0	7.8	18.1	96	0
16	.3	1.9	22	0	6.5	17.5	96	0
24	.2	1.7	18	0	8.4	20.9	98	0
27	.1	.4	3	0	5.2	14.4	91	0
33	.1	1.0	15	0	8.7	20.6	98	0
Oxidized flood plain								
11	0.5	0.8	4	0	0.5	1.0	6	0
15	.4	.6	3	0	.2	.5	4	0
20	.2	.5	5	0	.8	1.7	15	0
25	.6	1.0	6	0	.5	1.7	17	0
25	.4	.6	2	0	.7	2.4	25	0
29	.1	.3	1	0	3.9	13.4	96	0
Unoxidized flood plain								
12	0.5	1.7	19	0	3.6	9.4	67	0
21	.3	.8	8	0	8.6	17.9	82	0

Table 15.--Summary of results of the scanning electron microscope and energy dispersive x-ray analyses of grains from the heavy-mineral fractions of sediment samples--Continued

Site number in figures 1 and 2	Percent sulfur				Percent iron			
	Mean	Standard deviation	Maximum	Minimum	Mean	Standard deviation	Maximum	Minimum
Suspended								
9	1.5	5.9	44	0	66.7	21.4	97	1
14	1.1	4.4	36	0	68.2	21.4	96	0
24	2.1	8.6	57	0	60.5	24.2	98	2
27	1.3	4.6	38	0	57.0	24.8	95	1
30	2.2	8.6	55	0	55.0	28.6	98	0
Bottom								
9	1.9	7.2	58	0	67.2	23.1	98	1
16	5.3	13.9	59	0	56.9	28.0	97	0
24	8.4	14.9	57	0	61.3	24.6	96	0
27	8.3	15.5	56	0	61.4	26.3	97	0
30	4.7	10.7	53	0	60.6	27.1	96	0
Oxidized flood plain								
11	7.7	4.9	37	0	77.6	13.7	94	11
15	3.5	5.1	34	0	67.6	14.5	94	2
20	0.3	1.7	25	0	69.6	16.0	98	5
25	5.7	4.6	21	0	70.6	16.6	98	1
25	8.1	5.6	25	0	72.5	10.2	97	26
29	0.7	3.9	41	0	69.2	19.8	95	0
Unoxidized flood plain								
13	3.4	6.9	37	0	61.0	19.1	92	4
23	4.9	10.5	57	0	64.9	19.7	97	5

Table 15.--Summary of results of the scanning electron microscope and energy dispersive x-ray analyses of grains from the heavy-mineral fractions of sediment samples--Continued

Site number in figures 1 and 2	Percent barium				Percent zircon			
	Mean	Standard deviation	Maximum	Minimum	Mean	Standard deviation	Maximum	Minimum
Suspended								
9	2.5	7.6	73	0	0.2	0.4	2	0
14	2.3	7.7	70	0	.2	.5	3	0
24	2.5	12.0	94	0	.3	.7	5	0
27	0.9	1.8	17	0	.1	.5	4	0
30	5.7	14.6	80	0	.7	2.9	29	0
Bottom								
9	4.9	14.1	85	0	0.1	0.6	7	0
16	2.4	8.9	69	0	.2	1.2	17	0
24	3.9	12.4	94	0	.2	1.0	14	0
27	4.7	13.4	65	0	.8	4.5	58	0
30	7.8	18.1	95	0	.4	2.5	27	0
Oxidized flood plain								
11	1.5	2.2	12	0	0.5	0.8	4	0
15	2.0	6.0	61	0	.3	.6	3	0
22	.1	0.5	7	0	1.1	4.8	56	0
25	2.0	4.2	35	0	.4	.8	5	0
25	1.1	1.7	12	0	.2	.6	4	0
29	1.1	4.4	56	0	.2	1.3	19	0
Unoxidized flood plain								
13	1.7	4.2	47	0	0.3	0.8	4	0
23	1.5	4.5	49	0	.3	.8	6	0

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Chapter C. Application of a Sequential Extraction Procedure to Sediments Contaminated with Gold-Mill Tailings, Whitewood Creek

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SAMPLE COLLECTION AND HANDLING PROCEDURES

The study concentrated on oxidized bottom-sediment material collected in the quiet water upstream of the Sheeler Seep site (site 16 in fig. 1 and table 1). This location was chosen for the ease of collecting fine-grained sample material and because of the large amount of interest in and geochemical data already collected at this site. Samples were collected by scooping oxidized material from the top 1 to 3 cm at the sediment-water interface. This was done at several sites in a small area to reduce the effect of any variety in sediment within the study reach. Samples were wet-sieved and homogenized in the field. The samples were sieved through a 63-μm sieve (silt and clay). Approximately 50 g of the size fraction was collected. All samples were packed on ice during transport to the Environmental Engineering laboratory at the South Dakota School of Mines and Technology.

Extractions were performed on three types of samples: fresh, frozen, and freeze-dried. Extractions were performed on fresh samples as soon after collection as possible. All bottom-sediment samples were prepared in the following manner. The sediment slurry that was the result of field sieving was refrigerated overnight, allowing the suspended bottom material to settle to the bottom of the bottle. The following day, most of the river water was decanted and the remaining sediment water slurry was centrifuged at 5,000 rpm for 10 minutes. The supernatant river water was then decanted and saved for analysis of trace metal concentrations. The bottom sediment was removed from the centrifuge bottles and homogenized before splitting into fresh, frozen, and freeze-dried samples. Approximately 1.2 to 1.5 g of wet sediment was measured into 50 mL polypropolene test tubes for the fresh and frozen samples. These samples were washed with 8 to 10 mL of deionized water and agitated for 5 to 10 minutes. The small amount of water and limited agitation was to prevent excess solubilization of solid material. Samples were then centrifuged at 1,500 to 3,000 rpm for 10 minutes, and the supernatant was decanted and analyzed for trace metals. This deionized water wash was conducted to remove or minimize the effect of any traces of river water remaining in the sample. The remaining bottom sediment was placed into 250 mL sample containers and shell frozen in preparation for freeze-drying. The fresh samples were refrigerated overnight until extractions could begin and all the remaining samples were frozen. After completion of the shell freezing, the remaining bottom sediment sample was freeze-dried using the MULTI-DRY freeze-dryer located in the Environmental Engineering laboratory at the South Dakota School of Mines and Technology.

Prior to sample collection in the field, all containers, sieves, and equipment used were pretreated to avoid any possible contamination. Pretreatment consisted of soaking sample containers in 20 percent (v/v) nitric acid for 48 hours, followed by soaking for 24 hours in deionized water, and a final rinsing with deionized water. The sieve screen was soaked for 26 hours in 3 percent (v/v) nitric acid, followed by soaking for 24 hours in deionized water. The sieves and other plastic bottles were rinsed with 10 percent (v/v) nitric acid followed by rinsing with deionized water. All laboratory glassware was rinsed with 1 M NaOH, followed by 10 percent HNO_3, and then three rinses with deionized water prior to use.

EXTRACTION PROCEDURE

Step 1. Exchangeables, Solubles, and Carbonates

REAGENT -- 1 M NaOAc at pH 5.0 (adjusted with glacial acetic acid)

PROCEDURE -- A 1-g sediment sample (table 16) is mixed at room temperature with 8 mL of 1 M sodium acetate freshly adjusted to pH 5.0 with glacial acetic acid. Dissolution of the carbonate was complete after 5 hours of leaching with continuous agitation. (The time period varied somewhat depending on the particle size of the carbonate fraction and the amount of carbonate present.) The suspension was centrifuged at 1,500 rpm for 15 minutes and the supernatant decanted. The supernatant was filtered through a 0.1-μm filter and preserved with ultrapure nitric acid for analysis. The residue was then washed with 10 mL of deionized water with continuous agitation for 5 minutes. This suspension was centrifuged at 2,500 rpm for 15 minutes and the wash water decanted. The centrifugation, supernatant preservation, and deionized water wash was the same for each of the following extractions (Tessier and others, 1979).

Step 2. Manganese Oxides

REAGENT -- Hydroxylamine Hydrochloride in 0.01 M nitric acid

PROCEDURE -- 25 mL of 0.1 M hydroxylamine hydrochloride in 0.01 M nitric acid at pH 2.0 was pipetted into the test tube containing the remaining sample from Step 1 and the mixture was shaken for 30 minutes at room temperature. The solution was then centrifuged and the supernatant solution was decanted for analysis (Chao, 1972).

Step 3. Organic Matter

REAGENTS -- a. NaOCl adjusted to pH 9.5
b. 2 percent Sodium Carbonate - Sodium Bicarbonate at pH 9.5

PROCEDURE -- 20 mL of sodium hypochlorite freshly adjusted to pH 9.5 with 6 M hydrochloric acid was pipetted into the test tube containing the remaining sample from Step 2. The test tube was placed in a boiling water bath for 15 minutes, then centrifuged for 10 minutes at 1,500 rpm. The solution was decanted and the procedure was repeated for a total of three treatments. The supernatant from each treatment was combined and preserved for analysis.

A 50-mL aliquot of 2 percent sodium carbonate-sodium bicarbonate adjusted to pH 9.5 was added to the remaining sample in the test tube. This mixture was heated in a boiling water bath for 15 minutes to promote flocculation, and then centrifuged for 10 minutes at 1,500 rpm. The solution was decanted and the procedure was repeated for a total of three treatments. At the end of the third treatment, the mixture was centrifuged for 10 minutes at 2,500 rpm. After the final decantation, the sample was shaken for 12 hours with 10 mL of deionized water (Anderson, 1963). The supernatant from the three treatments was combined and preserved for analysis.

Table 16.--Weights of individual samples used in sequential extraction procedure

[All weights in grams; weights in parentheses are air-dried duplicates]

Sample identifier[1]	Sample type: Fresh	Frozen	Freeze-dried
FA	1.0904 (0.49797)		
FB	1.1654 (0.53223)		
FRA		1.0053 (0.45911)	
FRB		1.2462 (0.56913)	
FRC		1.4549 (0.66444)	
SS1			1.0529
SS2			1.0406
SSEX1			1.0377
SSEX2			1.0063
SSEX3			1.0691
SSEX5			1.0125
SSEX6			1.0349
SSEX7			1.0094
SSTEX2			1.0702
SSTEX4			1.0634
SSTEX5			1.0084
SSTEX6			1.0044
ER1 (1)	1.7146 (0.78304)		
EAS1D100 (4)	1.1295 (0.51583)		
EAS1D200 (5)	1.5111 (0.69010)		
EAS2D100 (11)	1.5945 (0.72819)		
EAS1W100			1.0214
EAFE			1.0350
BFR1 (2)	1.4123 (0.64498)		
BFAS1D100 (6)	1.4080 (0.64302)		
BFAS2D100 (7)	1.4429 (0.65896)		
BFAS2D200 (12)	1.7360 (0.79281)		
BFAS1W100			1.0558
BFAFE			1.0550
CS1 (3)	1.2507 (0.57118)		
CSAS1D100 (8)	1.4192 (0.64813)		
CSAS2D100 (9)	1.5905 (0.72636)		
CSAS1W100			1.0755
CSAFE1			1.0542
CSAFE2			1.0685
AMFE1	1.0474 (0.47834)		
AMFE2	0.9913 (0.45272)		
AMFE3	0.9382 (0.42847)		

[1]Derivation of sample identifier shown in figure 7.

Step 4. Amorphous Iron Oxide

REAGENTS -- Acidified Hydroxylamine Hydrochloride

PROCEDURE -- 25 mL of 0.25 M hydroxylamine hydrochloride - 0.25 M hydrochloric acid was pipetted into the test tube containing the remainder of the sample from Step 3. The test tube was placed in a water-bath shaker at 50 °C for 30 minutes. The mixture was centrifuged at 1,500 rpm for 15 minutes and the supernatant decanted and preserved for later analysis (Chao and Zhou, 1983).

Step 5. Sulfides

REAGENTS -- a. Potassium Chlorate in concentrated HCl
b. 4 N Nitric Acid

PROCEDURE -- 1 g of potassium chlorate was added to the sample remaining in the test tube from Step 4. Ten milliliters of concentrated hydrochloric acid was pipetted into the test tube and the mixture gently stirred. After standing for 30 minutes, the solution was diluted with 10 mL of deionized water, mixed, and then centrifuged. The supernatant was decanted and preserved for later analysis. The remaining sample was gently boiled in 20 mL of 4 N nitric acid in 50 mL beakers. After 20 minutes, 20 mL of deionized water was added to the beaker and the contents transferred back to the test tube (Chao and Sanzolone, 1977).

Step 6. Residuals

The sample remaining in the test tube following Step 5 underwent a "total" digestion using $HF/HClO_4/HNO_3$ acid.

QUALITY ASSURANCE

Ideally, to determine the effectiveness of the extraction procedures on the bottom sediment samples, a known standard must be prepared and analyzed. Several different standards were used to test the extraction procedure. A "total" digestion was also done on all samples to verify the results of the extractions.

An amorphous iron oxide sample was precipitated from ground water collected at the Sheeler Seep site (site 16, fig. 1 and table 1). This sample was used to test the effectiveness of the amorphous iron oxide and manganese oxide extractions. Extractions were analyzed for iron, manganese, and arsenic concentrations, and a split was analyzed by total digestion.

A pure arsenopyrite sample also was used to test the effectiveness of the extraction procedures. A single large crystal of arsenopyrite was obtained from Homestake Mining Company and crushed. The resulting powder underwent extraction steps 5a and 5b (sulfides) and a total digestion.

A native stream sediment study was done on bottom sediment collected from Whitewood Creek above Lead (Englewood) and Belle Fourche River near Nisland. These bottom sediments were collected and preserved using the same methods described previously. A combined sediment sample also was made by mixing 50 percent (w/w) of each sample. This sample simulated the sediment below the confluence of the Whitewood Creek and the Belle Fourche River.

These sediments were used for arsenic adsorption and amorphous iron oxide extraction experiments.

For the arsenic adsorption, an arsenic solution of 250 $\mu g/L$ was made from a stock solution of 1,000 mg/L As by dilution. Wuolo (1986) determined a solid/liquid ratio of 1:20 could be used to model arsenic adsorption in sediments with porosities of 50 percent or less. For these experiments, 10 g of sediment and 200 mL of solution were used. The arsenic adsorption experiments were done at 1 day, 2 days, and 1 week. At the end of each time period, the samples were centrifuged and prepared for the sequential extraction procedure. The supernatant was preserved for arsenic concentration analysis. Extractions were performed on fresh and freeze-dried samples.

Extractions also were performed on the raw sediment samples from the background stations. There were sample splits made for total digestions of these sediments.

As a further quality assurance step, Art Horowitz (NRP, Atlanta, Ga.) suggested that each individual step of the extraction procedure be performed alone on a sample split. This was done on the freeze-dried Sheeler Seep site bottom sediment samples. Along individual extractions, the procedure was done to a particular step and then the remaining sample was subject to total digestion (fig. 7). For example, sample X will only go through Step 1 and then onto Step 6, while sample Y will go through Steps 1 and 2 and then onto Step 6 and sample Z will go through Steps 1, 2, and 3 and then go onto Step 6, etc. (fig. 7).

LABORATORY ANALYSIS

All of the chemical determinations for iron, manganese, copper, and zinc were done by conventional flame atomic absorption spectrophotometry (AAS). Arsenic was determined by graphite furnace atomic absorption spectrophotometry (GFAAS) in the solutions from steps 1, 2, and 4 (Aruscavage, 1977). The sensitivity of GFAAS for arsenic required sufficient dilution that matrix interferences were mostly overcome. The strong oxidizing solutions in steps 3, 5, and 6 produced enough matrix material that arsenic could not be determined directly from these solutions by GFAAS or by hydride generation AAS. In order to determine arsenic in these solutions, an ion exchange procedure was used. The procedure consisted of "catching" the arsenic on an ion exchange column while the matrix of the sample was eluted from the column. After elution of the matrix (major cations), the arsenic was eluted using a dilute acid solution (Walter H. Ficklin, U.S. Geological Survey, personal commun.). Arsenic was determined by GFAAS following matrix modification. Arsenic also was determined at low levels in some samples from step 1 by hydride generation AAS. The data are listed in tables 17, 18, 19, 20, and 21.

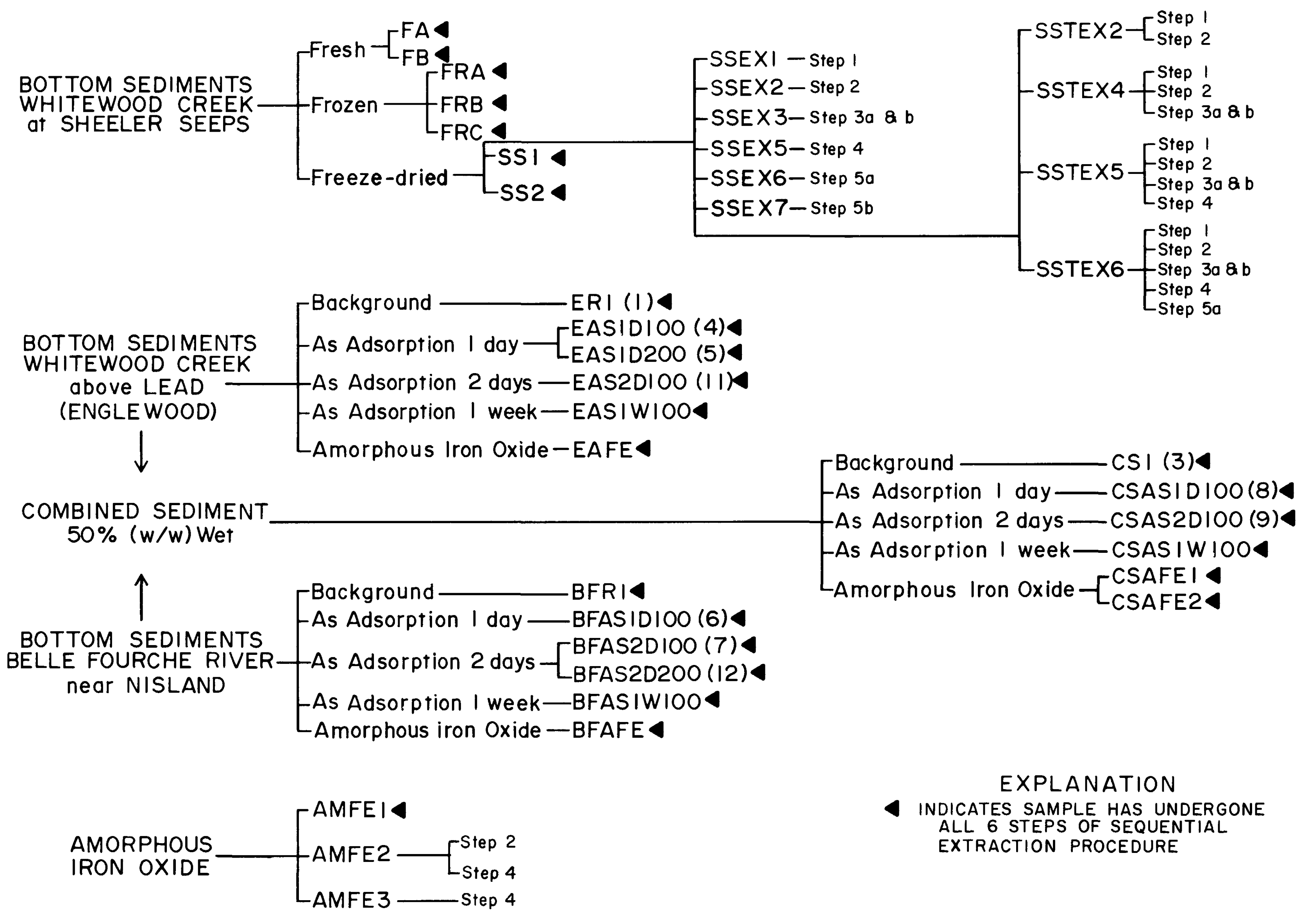

Figure 7.--Flow chart showing the derivation of natural and artificial samples subject to sequential extraction procedure.

Table 17.--Concentration of arsenic measured in extracts, sum of extracts, and total concentration

[All data corrected for sample weight and water content; mg/kg, milligrams per kilograms; µg/L, micrograms per liter; <, less than]

Sample identifier	Sequential extraction (mg/kg)								Water wash (µg/L)	Sum of extracts (mg/kg)	Total digestion (mg/kg)
	Step 1	Step 2	Step 3a	Step 3b	Step 4	Step 5a	Step 5b	Step 6			
FA		38.0	280.0	18.0	36.0	248.0	28.0	7.8		655.80	
FB		36.0	222.0	[1]18.0	26.0	316.0	28.0	8.0		654.00	
FRA	7.00	70.0	204.0	[1]3.2	54.0	320.0	30.0	8.8	0.039	697.04	
FRB	8.60	74.0	114.0	[1]3.4	70.0	304.0	50.0	5.4	0.038	629.44	
FRC	6.00	62.0	104.0	[1]50.0	94.0	364.0	54.0	26	0.040	760.04	
SS1	3.60	55.0	54.0	[1]10.0	64.0	240.0	48.0	7.5	.029	482.13	650
SS2	4.20	55.0	90.0	[1]1.7	67.0	280.0	54.0	7.7	0.031	559.63	
SSEX1	5.30							560.0		565.30	
SSEX2		17.0						590.0		607.00	
SSEX3			57.0	[1]9.2				420.0		486.20	
(RPT)											
SSEX5					126.0			320.0		446.00	
SSEX6						510.0	70.0	12.0		592.00	
SSEX7							940.0	30.0		970.00	
	Combined water from all SSEX extractions								0.094	0.09	
SSTEX2	4.60	34.0						560.0	0.017	598.62	
SSTEX4	5.10	25.0	102.0	[1]135.0				410.0	.034	677.13	
SSTEX5	5.10	33.0	96.0	[1]7.3	57.0			260.0	0.003	458.40	
SSTEX6	4.10	33.0	60.0	[1]9.2	68.0	240.0		26.0	0.056	440.36	
ER1 (1)	[1]0.06	3.4	7.2	[1]<1.0	1.8	14.4	5.6	5	0.028	37.49	30
EAS1D100 (4)	[1]0.06	6.6	9.6	[1]<1.0	1.6	11.2	3.0	3.8	0.030	35.89	38
(RPT)		6.4								6.40	
EAS1D200 (5)		7.6	9.6	[1]<1.0	2.4	5.2	4.2	5.2	0.042	34.24	
EAS2D100 (11)	[1]0.04	6.6	9.6	[1]<1.0	3.6	3.6	6.4	3.8	0.046	33.69	36
EAS1W100	<0.5	3.9	6.1	[1]<1.0	3.6	9.6	4.3	2.6	0.002	30.10	38
EAFE	<0.5	1.3	10.0	[1]<1.0	3.5	10.0	6.7	3.0	0.003	34.50	28
BFR1 (2)	[1]0.02	0.6	<1.0	[1]<1.0	0.6	4.0	1.4	2	0.014	8.63	14
BFAS1D100 (6)	[1]0.02	3.4		[1]<1.0	1.4	12.4	1.4	2	0.014	20.63	6
BFAS2D100 (7)	[1]0.02	3.0	<1.0	[1]<1.0	1.4	4.0	1.4	<1.0	0.014	9.83	16
BFAS2D200 (12)	[1]0.02	5.4	16.8	[1]<1.0	1.8	6.4	0.8	1.8	0.018	33.04	
BFAS1W100	<0.5	1.5	2.4	[1]<1.0	2.4	6.0	1.2	1.9(11)	10	15.40	6
BFAFE	<0.5	0.7	<1.0	[1]<1.0	1.2	4.2	1.0	2.1(11)	10	9.20	29
CS1 (3)	[1]0.02	1.8	<1.0	[1]<1.0	0.8	5.2	2.2	2	0.012	12.03	15
(RPT)											
CSAS1D100 (8)	[1]0.04	4.8	2.4	[1]<1.0	2.2	9.2	2.6	2.6	0.028	23.87	25
CSAS2D100 (9)	[1]0.04	4.6	4.8	[1]<1.0	2.4	9.6	4.0	6.4	0.028	31.87	19
CSAS1W100	<0.5	3.6	6.1	[1]<1.0	2.5	9.4	2.8	2.6	0.002	27.00	
CSAFE1	<0.5	1.4	13.0	[1]<1.0	1.8	8.6	3.4	2.0(16)	14	30.20	24
CSAFE2	<0.5	1.4	11.0	[1]1.2	1.6	7.6	3.7	1.6(13)	16	28.10	
(RPT)		1.4								1.40	
AMFE1	8.40	28.00	72.00	[1]374.00	2,580.00	660.00	18.40	2.8	0.108	3,743.71	1,840
AMFE2	14.80	20.00			6,500.00			420	0.188	6,954.99	
AMFE3					5,760.00			820	0.151	6,580.15	
FeAsS1						150,000	340,000	0.61		490,001	540,000
FeAsS2						150,000	380,000	0.46		530,000	
B	<0.5	<0.2	<1.0		<0.2	<0.5	<0.2				
B4	<0.5	<0.2	<1.0	[1]<1.0	<0.2	<0.5	<0.2				
B5	<0.5	<0.2	<1.0	[1]<1.0	<0.2	<0.5	<0.2				
BLANK (10)	[1]<0.01	<0.2	<1.0	[1]<1.0	<0.2	<0.5	0.3		<0.005		
FC		<1.0	<1.0	3.0	<1.0	1.3	<1.0				
WH-WD-CK									0.006	0.01	

[1]( ) - Hydride generation.

Table 18.--Concentration of copper measured in extracts, sum of extracts, and total concentration

[All data corrected for sample weight and water content; mg/kg, milligrams per kilograms; µg/L, micrograms per liter; <, less than]

Sample identifier	Sequential extraction (mg/kg) Step 1	Step 2	Step 3a	Step 3b	Step 4	Step 5a	Step 5b	Step 6	Water wash (µg/L)	Sum of extracts (mg/kg)	Total digestion (mg/kg)
FA		5.0	<6	<6	8.0	12.6	4.2	6		35.8	
FB		4.6	<6	<6	7.6	13.2	4.2	6		35.6	
FRA	<1.0	11.6	13.2	<2.0	11.0	8.4	5.4	4	<0.01	53.6	
FRB	<1.0	5.6	13.2	<2.0		9.2	5.4	6	<0.01	39.4	
FRC	<1.0	2.0	14.4	<2.0	19.0	12.0	5.4	8	<0.01	60.8	
SS1	<1.0	8.2	5.4	<2.0	10.0	7.4	4.5	4	<0.01	39.5	40
SS2	<1.0	8.8	5.4	<2.0	11.0	8.0	5.4	3	<0.01	41.6	
SSEX1	<1.0							41		41	
SSEX2		0.8						39		39.8	
SSEX3			7.2	<2.0				35		42.2	
(RPT)				<2.0							
SSEX5					16.0			23		39	
SSEX6						28.0	6.0	5		39	
SSEX7							53.0	6		59	
									<0.01		
SSTEX2	<1.0	0.5						40	<0.01	40.5	
SSTEX4	<1.0	0.2	6.6	<2.0				35	<0.01	41.8	
SSTEX5	<1.0	1.3	6.6	<2.0	14.0			18	<0.01	39.9	
SSTEX6	<1.0	0.2	7.8	<2.0	14.0	7.8		6.3	<0.01	36.1	
ER1 (1)	0.2	7.6	14.0	<2.0	7.6	3.6	3.6	8	0.012	44.612	17
EAS1D100 (4)	0.2	4.0	14.0	<2.0	5.0	2.4	2.4	4	<0.01	32	22
(RPT)		5.0								49.412	
EAS1D200 (5)		4.4	18.0	<2.0	6.6	4.4	3.0	8	0.012	ERR	
EAS2D100 (11)	0.2	3.0	12.0	<2.0	5.6	3.6	3.0	6	0.014	33.414	19
EAS1W100	<1.0	1.5	8.4	<2.0	4.2	1.6	2.4	20	<0.01	38.1	20
EAFE	<1.0	<0.1	9.0	<2.0	4.2	1.4	2.7	4	<0.01	21.3	9
BFR1 (2)	0.2	7.0	12.0	<2.0	13.0	4.4	2.4	4	0.014	43.014	23
BFAS1D100 (6)	0.2	8.0	13.0	<2.0	10.4	4.0	3.0	6	0.014	44.614	26
BFAS2D100 (7)	0.2	8.4	12.0	<2.0	10.4	2.4	1.8	5	0.014	40.214	23
BFAS2D200 (12)	<1.0	8.0	12.0	<2.0	10.0	4.0	2.4	4	0.018	40.418	
BFAS1W100	<1.0	4.2	8.4	<2.0	8.0	63.0	12.0	3	<0.01	98.6	61
BFAFE		0.5	7.2	<2.0	10.0	2.2	1.8	3	<0.01	24.7	23
CS1 (3)	0.2	5.0	13.0	<2.0	7.0	0.6	1.2	6	0.012	33.012	23
(RPT)						6.0				6	
CSAS1D100 (8)	0.2	5.6	14.0	<2.0	8.0	2.8	1.8	6	<0.01	38.4	22
CSAS2D100 (9)	0.2	5.0	13.0	<2.0	10.4	2.8	1.8	8	0.012	41.212	23
CSAS1W100	<1.0	2.2	8.4	<2.0	7.0	1.8	2.1	4	<0.01	25.5	
CSAFE1	<1.0		8.4	<2.0	7.2	2.2	2.1	4	<0.01	23.9	21
CSAFE2	<1.0	0.5	6.6	<2.0	7.0	2.0	1.8	4	<0.01	21.9	
(RPT)		0.2				2.0				2.2	
AMFE1	<1.0	7.6	15.6	<2.0	7.6	4.4	0.6	2	<0.01	37.8	16
AMFE2	<1.0	8.4			4.4			8	<0.01	20.8	
AMFE3					13.0			9.6	<0.01	22.6	
FeAsS1						5.7	3.3				
FeAsS2						5.4	3.6				
B	<1.0	<0.1	9.0	<2.0	<0.1	0.6	<0.1		<0.01	9.6	
B4	<1.0	<0.1	8.4	<2.0	0.2	0.4	<0.1			9	
B5	<1.0	<0.1	6.0	<2.0	<0.2	0.0	<0.1			6	
BLANK (10)	0.2	<0.1	5.4	<2.0	0.8	0.4	0.3		<0.01	7.1	
FC		1	<6.0	<6.0	0.8	1.5	0.6				
WH-WD-CK									<0.01		

Table 19.--Concentration of iron measured in extracts, sum of extracts, and total concentration

[All data corrected for sample weight and water content; mg/kg, milligrams per kilograms; µg/L, micrograms per liter; <, less than]

Sample identifier	Sequential extraction (mg/kg) Step 1	Step 2	Step 3a	Step 3b	Step 4	Step 5a	Step 5b	Step 6	Water wash (µg/L)	Sum of extracts (mg/kg)	Total digestion (mg/kg)
FA		1,240	120	440	3,600	13,500	11,400	14,000		44,300.0	
FB		1,160	120	360	3,800	15,900	13,200	14,000		48,540.0	
FRA	40	2,550	120	360	9,800	280	15,840	10,000	20.0	39,010.0	
FRB	230	1,700	120	240		260	18,360	15,400	17.4	36,327.4	
FRC	160	1,600	120	690	13,800	300	17,400	14,400	19.6	48,489.6	
SS1	8	1,425	60	225	9,100	220	13,140	10,800	15.0	34,993.0	46,900
SS2	10	1,325	60	195	10,000	250	16,800	9,000	19.0	37,659.0	
SSEX1	11							39,800		39,811.0	
SSEX2		250						36,700		36,950.0	
SSEX3			60	180				35,000		35,240.0	
(RPT)				150							
SSEX5					9,450			31,700		41,150.0	
SSEX6						440	13,560	12,200		26,200.0	
SSEX7							57,600	10,800		68,400.0	
SSEX									24.0	24.0	
SSTEX2	9	650						38,000	1.3	38,660.3	
SSEX4	11	650	60	90				38,200	2.4	39,013.4	
SSTEX5	15	625	60	255	9,500			28,200	7.5	38,662.5	
SSTEX6	12	750	60	105	10,150	210		18,250	19.0	29,556.0	
ER1 (1)	30	2,300	240	620	5,100	92	8,340	14,000	16.8	30,738.8	25,500
EAS1D100 (4)	30	2,150	120	150	3,650	64	5,220	8,000	12.4	19,396.4	27,000
(RPT)		2,400								2,400.0	
EAS1D200 (5)		2,100	120	180	5,950	92	7,080	13,600	15.4	29,137.4	
EAS2D100 (11)	24	1,700	120	210	4,150	60	7,860	10,000	19.6	24,143.6	26,200
EAS1W100	12	1,050	60	150	4,600	56	7,800	8,500	13.0	22,241.0	25,900
EAFE	13	550	60	90	4,850	50	9,780	8,000	14.0	23,407.0	26,500
BFR1 (2)	30	2,100	120	210	15,600	132	18,840	13,000	26.0	50,058.0	28,900
BFAS1D100 (6)	28	2,656	120	180	12,500	76	11,940	13,600	22.0	41,122.0	38,300
BFAS2D100 (7)	28	1,800	120	180	12,250	88	13,440	11,600	26.0	39,532.0	36,600
BFAS2D200 (12)	26	1,900	120	150	8,600	92	15,600	14,000	24.0	40,512.0	
BFAS1W100	29	900	60	195	9,150	74	11,400	8,800	17.0	30,625.0	33,900
BFAFE	14	550	60	75	9,950	100	13,380	9,500	14.0	33,643.0	34,700
CS1 (3)	36	1,950	120	470	6,150	84	7,080	11,000	15.0	26,905.0	30,100
(RPT)						80					
CSAS1D100 (8)	30	1,850	120	180	8,150	92	10,200	12,400	22.0	33,044.0	31,000
CSAS2D100 (9)	24	1,800	120	180	10,700	108	10,800	10,000	18.0	33,750.0	32,600
CSAS1W100	12	925	60	255	7,850	96	9,600	10,200	17.0	29,015.0	
CSAFE1	10		60	75	8,100	92	10,320	10,000	12.0	28,669.0	34,600
CSAFE2	13	500	60	75	8,250	80	11,580	10,000	14.0	30,572.0	
(RPT)		475				84					
AMFE1	460	22,700	120	840	143,000	152	4,020	4,500	60.0	175,852.0	110,000
AMFE2	540	22,700			170,000			14,000	78.0	207,318.0	
AMFE3					215,000			18,500	60.0	233,560.0	
FeAsS1						150,000	280,000			430,000.0	
FeAsS2						150,000	320,000			470,000.0	
B	0	<1	60	90	<1	0	<10		0.1	150.1	
B4	0	<1	60	75	<1	0	<10			135.0	
B5	0	<1	60	75	50	0	<10			185.0	
BLANK (10)	4	<1	60	75	<1	<1	<10		0.0	139.0	
FC		5	60	16	12	48	70				
WH-WD-CK									0.4	0.4	

Table 20.--Concentration of manganese measured in extracts, sum of extracts, and total concentration

[All data corrected for sample weight and water content; mg/kg, milligrams per kilograms; µg/L, micrograms per liter; <, less than; >, greater than]

Sample identifier	Sequential extraction (mg/kg)								Water wash (µg/L)	Sum of extracts (mg/kg)	Total digestion (mg/kg)
	Step 1	Step 2	Step 3a	Step 3b	Step 4	Step 5a	Step 5b	Step 6			
FA		76	24	<?	66	90.0	102	>0.02		358.0	
FB		74	24	<?	60	96.0	90	>.02		344.0	
FRA	880	136	24	<2.0	76	76.0	90	42	1.6	1,325.6	
FRB	740	96	24	<2.0		66.0	96	32	1.2	1,055.2	
FRC	740	120	24	<2.0	90	80.0	96	62	1.4	1,213.4	
SS1	430	305	12	<2.0	80	64.0	81	88	1.5	1,061.5	940
SS2	430	295	12	<2.0	85	73.0	93	75	1.6	1,064.6	
SSEX1	460							620		1,080.0	
SSEX2		450						480		930.0	
SSEX3			12	<2.0				780		792.0	
(RPT)				<2.0							
SSEX5					750			238		988.0	
SSEX6						1,020.0	137	80		1,237.0	
SSEX7							1,290	92		1,382.0	
SSEX									3.0		
SSTEX2	440	278						370	1.9	1,089.9	
SSEX4	430	270	12	<2.0				360	1.4	1,073.4	
SSTEX5	510	145	12	<2.0	92			220	1.5	980.5	
SSTEX6	500	155	12	<2.0	100	60.0		125	1.9	953.9	
ER1 (1)	260	150	24	<2.0	40	22.0	42	38	0.8	576.8	450
EAS1D100 (4)	220	104	24	<2.0	36	15.2	24	18	0.6	441.8	450
(RPT)		106									
EAS1D200 (5)		136	24	<2.0	44	20.0	36	42	0.6	302.6	
EAS2D100 (11)	200	100	24	<2.0	46	168.0	36	30	0.6	604.6	430
EAS1W100	193	118	12	<2.0	35	13.0	30	48	0.8	449.8	440
EAFE	162	150	12	<2.0	50	13.0	39	50	0.6	476.6	480
BFR1 (2)	260	86	24	<2.0	60	26.0	78	20	0.8	554.8	440
BFAS1D100 (6)	240	80	24	<2.0	56	17.6	72	20	0.6	510.2	460
BFAS2D100 (7)	240	76	24	<2.0	56	17.6	54	18	0.4	486.0	450
BFAS2D200 (12)	220	70	24	<2.0	44	20.0	60	20	0.6	458.6	
BFAS1W100	177	118	12	<2.0	50	15.0	48	25	0.6	445.6	430
BFAFE	172	98	12	<2.0	72	18.0	54	25	0.5	451.5	460
CS1 (3)	220	80	24	<2.0	40	14.8	36	28	0.6	443.4	430
(RPT)		96				15.2					
CSAS1D100 (8)	240	120	24	<2.0	50	19.2	48	25	0.8	527.0	430
CSAS2D100 (9)	260	244	24	<2.0	60	22.0	48	45	0.6	703.6	440
CSAS1W100	185		12	<2.0	50	18.0	39	42	0.6	346.6	
CSAFE1	171		12	<2.0	60	13.0	42	45	0.5	343.5	420
CSAFE2	176	138	12	<2.0	62	16.0	45	42	0.5	491.5	
(RPT)		138				16.0					
AMFE1	780	250	24	<2.0	56	52.0	54	42	2.4	1,260.4	720
AMFE2	900	256			70			98	3.6	1,327.6	
AMFE3					500			110	0.6	610.6	
FeAsS1						45	9			54.0	
FeAsS2						48	12			60.0	
B	0	<1	12	<2.0	<1	0.6	<1		0.0	12.6	
B4	0	<1	12	<2.0	10	1.0	<1			23.0	
B5		<1	12	<2.0	2	0.0	<1			14.0	
BLANK (10)	1	<1	12	<2.0	<1	1.2	<1		0	14.2	
FC		<1	12	<?	10	<1	<1				
WH-WD-CK									0.1	0.1	

Table 21.--Concentration of zinc measured in extracts, sum of extracts, and total concentration

[All data corrected for sample weight and water content; mg/kg, milligrams per kilograms; µg/L, micrograms per liter; <, less than]

Sample identifier	Sequential extraction (mg/kg)								Water wash (µg/L)	Sum of extracts (mg/kg)	Total digestion (mg/kg)
	Step 1	Step 2	Step 3a	Step 3b	Step 4	Step 5a	Step 5b	Step 6			
FA		11.0	<6	<6	20.0	36.0	80.0	26.0		173.0	
FB		9.0	<6	<6	15.6	70.0	68.0	26.0		188.6	
FRA	12.8	16.0	18.0	26.0	40.0	32.0	58.0	20.0	0.2	223.0	
FRB	15.0	12.0	13.2	24.0		30.0	76.0	32.0	0.2	202.4	
FRC	12.4	16.0	14.4	24.0	60.0	50.0	66.0	8.0	0.3	251.1	
SS1	4.8	16.0	7.8	13.0	28.0	27.0	51.0	18.0	0.23	165.8	130.0
SS2	4.5	15.0	6.0	9.0	44.0	31.0	60.0	6.0	0.16	175.7	
SSEX1	6.0							118.0		124.0	
SSEX2		7.0						120.0		127.0	
SSEX3			8.4	9.0				122.0		139.4	
(RPT)				7.5							
SSEX5					32.0			80.0		112.0	
SSEX6						68.0	54.0	21.0		143.0	
SSEX7							170.0	211.0		381.0	
SSEX									0.29		
SSTEX2	6.1	11.0						118.0	0.12	135.2	
SSTEX4	5.6	12.0	7.2	7.5				115.0	0.08	147.4	
SSTEX5	9.6	11.0	9.0	10.0	32.0			52.0	0.15	123.8	
SSTEX6	12.0	10.0	7.8	10.0	35.0	23.0		37.0	0.24	135.0	
ER1 (1)	25.0	56.0	14.8	32.0	28.0	20.0	54.0	28.0	0.18	258.0	100.0
EAS1D100 (4)	19.6	48.0	19.2	26.0	26.0	19.6	34.0	18.0	0.16	210.6	110.0
(RPT)		46.0									
EAS1D200 (5)		44.0	15.6	24.0	28.0	44.0	46.0	28.0	0.18	229.8	
EAS2D100 (11)	20.8	36.0	15.6	24.0	24.0	42.0	58.0	20.0	0.16	240.6	100.0
EAS1W100	8.9	26.0	8.4	9.0	22.0	10.0	51.0	5.0	0.21	140.5	100.0
EAFE	7.5	18.0	8.4	9.0	18.0	10.0	42.0	15.0	0.19	128.1	100.0
BFR1 (2)	19.4	30.0	13.2	26.0	50.0	42.0	80.0	28.0	0.20	288.8	95.0
BFAS1D100 (6)	17.2	26.0	20.0	20.0	42.0	66.0	76.0	26.0	0.50	293.7	40.0
BFAS2D100 (7)	42.6	44.0	14.4	24.0	58.0	24.0	86.0	26.0	0.22	319.2	140.0
BFAS2D200 (12)	26.0	36.0	12.0	18.0	44.0	42.0	66.0	32.0	0.20	276.2	
BFAS1W100	13.0	15.0	7.8	10.0	33.0	44.0	60.0	18.0	0.22	201.0	130.0
BFAFE	12.0	10.0	14.0	9.0	32.0	16.0	52.0	19.0	0.24	164.2	120.0
CS1 (3)	19.4	26.0	16.8	26.0	34.0	26.0	80.0	22.0	0.14	250.3	110.0
(RPT)						26.0					
CSAS1D100 (8)	18.8	32.0	26.0	20.0	36.0	22.0	52.0	24.0	0.16	231.0	120.0
CSAS2D100 (9)	19.4	40.0	12.0	18.0	44.0	22.0	54.0	20.0	0.98	230.4	120.0
CSAS1W100	12.0	20.0	7.8	12.0	28.0	16.0	40.0	20.0	0.17	156.0	
CSAFE1	9.1		8.4	7.5	27.0	14.0	40.0	19.0	0.17	125.2	130.0
CSAFE2	9.5	15.0	6.6	7.5	26.0	13.0	39.0	22.0	0.24	138.8	
(RPT)		15.0				13.0					
AMFE1	18.6	24.0	15.6	24.0	28.0	13.6	24.0	28.0	1.8	177.6	64.0
AMFE2	26.0	26.0			17.0			20.0	0.2	89.2	
AMFE3					104.0			21.0	1.1	126.1	
FeAsS1						8.4	9.0			17.4	
FeAsS2						8.7	12.0			20.7	
B	1.0	0.8	9.0	18.0	4.0	2.8	10.0		0.13	45.7	
B4	5.5	0.5	8.4	10.0	1.3	2.2	9.3			37.2	
B5	1.4	2.2	8.4	10.0	4.0	0.0	12.0			38.0	
BLANK (10)	3.9	2.2	12.0	12.0	21.0	15.0	18.0		0.06	84.2	
FC		2.5	<6	<6	1.5	10.0	15.0			29.0	
WH-WD-CK									0.10	0.1	

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Chapter D. Discharge, Surface-Water Quality, and Streambed Data at Selected Sites on Whitewood Creek and the Belle Fourche and Cheyenne Rivers

By William R. Roddy and Thomas E. McKallip

DISCHARGE DATA

Continuous discharge data were obtained at 5 streamflow-gaging stations, and instantaneous discharge data were obtained at 5 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 subsections along a cross section of the stream. Depths were measured with a graduated wading rod or with a weighted metal cable. Water velocities were determined using either a Price "AA" or a pygmy meter. Widths were measured based on the midpoints between subsections. In a few instances, because of ice effects or fast-rising stages, measurements were made with fewer subsections 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.

Calculations of daily mean discharges (tables 22-26) at continuous-record gages were based on records of water stages recorded every 15 minutes and on water stage-discharge ratings. Water stages were sensed by a bubble-gage manometer and punched on paper tape every 15 minutes 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.

WATER-QUALITY DATA

Water-quality data were obtained at 10 sites during the 1987-88 water years (figs. 1 and 2, table 1). Monthly or bimonthly samples and storm runoff samples were collected at 5 monitoring stations--Whitewood Creek above Whitewood, Whitewood Creek above Vale, Belle Fourche River near Sturgis, Belle Fourche River near Elm Springs, and Cheyenne River at Cherry Creek. Three samples were collected at Cheyenne River near Wasta, three samples were collected at Horse Creek above Vale, and one sample was collected at each of three other sites. Chemical analytical results are listed in tables 26-32.

Normally five field readings--air temperature, water temperature, dissolved oxygen, pH, and specific conductance--were determined at the site. Most often stream readings were determined at the centroid of the stream, while at other times averages were computed from readings determined at 3 to 5 verticals across the channel. Several meters were used in the study: a hand thermometer for air temperatures, a Hydrolab Environmental Data Systems Model 4041 Digital 4-parameter meter, a YSI (Yellow Springs Instrument) Model 54 dissolved oxygen meter, a YSI Model 32 conductance meter, and an Orion SA-250 pH meter. The hand thermometer was checked for calibration the first time it was used, and the other meters were calibrated at each site or at least daily.

Table 22.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Whitewood, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	14	16	16	11	13	11	19	41	53	19	17	15
2	19	16	16	10	13	12	16	39	49	18	16	13
3	23	14	18	10	13	14	19	40	46	20	17	13
4	19	15	20	10	13	16	27	36	44	21	22	16
5	19	16	20	11	12	18	41	34	41	22	16	16
6	17	17	20	12	13	23	49	33	39	23	17	14
7	16	19	20	9.5	13	23	55	31	38	25	26	15
8	15	18	20	9.5	13	25	60	31	37	23	24	14
9	15	16	18	9.5	13	21	63	29	36	22	18	14
10	16	15	15	10	13	18	51	28	35	23	17	14
11	17	16	17	10	13	17	41	27	33	24	16	17
12	15	16	17	13	13	18	38	27	32	22	17	15
13	15	16	16	14	13	19	33	29	30	22	17	15
14	16	15	15	14	14	21	32	29	28	20	18	14
15	15	15	14	14	15	18	39	28	27	21	17	14
16	15	15	13	14	14	19	51	27	26	18	20	14
17	15	16	13	13	13	19	67	32	26	19	16	15
18	15	17	12	13	13	17	82	27	25	19	15	14
19	15	18	12	13	13	18	82	27	29	18	15	14
20	15	18	12	13	14	20	71	52	25	18	16	14
21	15	18	12	13	13	22	61	48	23	17	14	13
22	16	18	12	13	14	26	54	44	22	17	16	13
23	19	17	12	12	13	20	53	66	22	17	15	14
24	17	18	12	12	13	17	54	66	21	17	14	14
25	16	17	12	13	13	17	56	66	21	17	16	14
26	16	18	11	14	12	17	55	61	20	16	20	14
27	16	17	11	15	12	18	52	58	19	15	18	14
28	15	16	12	15	12	17	49	53	18	17	16	14
29	15	16	12	15	---	17	47	55	18	16	15	15
30	16	14	12	13	---	18	43	61	18	16	15	15
31	16	---	12	13	---	19	---	57	---	16	16	---
TOTAL	503	493	454	381.5	366	575	1460	1282	901	598	532	430
MEAN	16.2	16.4	14.6	12.3	13.1	18.5	48.7	41.4	30.0	19.3	17.2	14.3
MAX	23	19	20	15	15	26	82	66	53	25	26	17
MIN	14	14	11	9.5	12	11	16	27	18	15	14	13
AC-FT	998	978	901	757	726	1140	2900	2540	1790	1190	1060	853

CAL YR 1986 TOTAL 9218.6 MEAN 25.3 MAX 152 MIN 6.0 AC-FT 18290
WTR YR 1987 TOTAL 7975.5 MEAN 21.9 MAX 82 MIN 9.5 AC-FT 15820

Table 22.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Whitewood, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	14	14	e14	e12	e11	18	27	34	29	19	14	10
2	14	15	e14	e12	e11	17	27	40	28	20	16	10
3	15	15	14	e13	e12	17	32	39	27	21	17	12
4	14	14	15	e12	e13	18	38	41	27	18	16	13
5	13	14	15	e11	e13	18	35	39	26	17	13	11
6	14	14	14	e11	e13	18	34	41	26	17	12	12
7	14	15	14	e12	e13	19	48	47	24	16	11	12
8	14	15	15	e12	e13	18	51	127	23	17	13	12
9	15	14	14	e12	e13	18	37	130	24	18	12	12
10	16	15	15	e12	e13	22	36	136	24	19	11	13
11	15	15	e14	e13	e14	e19	35	133	24	19	11	13
12	15	15	e14	e12	e15	e10	40	116	26	16	14	15
13	16	15	e13	e12	e16	e8.0	42	100	33	16	13	16
14	15	15	e13	e11	e15	e9.0	40	87	30	20	12	16
15	14	18	e13	e12	e16	e15	38	75	26	16	11	16
16	15	14	e14	e12	e16	e16	36	66	26	14	10	16
17	15	14	e14	e12	e15	e16	38	59	25	15	10	15
18	15	14	e13	e11	15	e16	35	60	24	15	11	16
19	15	14	e13	e11	16	e27	34	55	23	17	10	18
20	15	14	e13	e11	16	e35	33	54	22	15	12	16
21	15	14	e14	e12	17	30	32	47	20	14	12	15
22	15	13	e17	e12	17	32	31	42	20	14	14	13
23	15	13	e14	e13	e16	32	31	40	e22	13	10	13
24	16	13	e14	e13	e17	36	30	38	e20	12	9.5	14
25	15	13	e13	e13	e19	32	30	37	e20	13	11	15
26	15	14	e14	e13	e20	32	31	35	e20	12	11	14
27	15	13	e14	e11	e20	40	30	33	20	11	12	14
28	15	e13	e14	e14	21	37	31	32	18	11	13	35
29	15	e13	e13	e14	19	30	30	31	25	11	14	27
30	15	e13	e13	e13	---	28	32	30	22	11	11	17
31	15	---	e12	e12	---	25	---	31	---	11	14	---
TOTAL	459	425	430	376	445	708.0	1044	1875	724	478	380.5	451
MEAN	14.8	14.2	13.9	12.1	15.3	22.8	34.8	60.5	24.1	15.4	12.3	15.0
MAX	16	18	17	14	21	40	51	136	33	21	17	35
MIN	13	13	12	11	11	8.0	27	30	18	11	9.5	10
AC-FT	910	843	853	746	883	1400	2070	3720	1440	948	755	895

CAL YR 1987 TOTAL 7839.5 MEAN 21.5 MAX 82 MIN 9.5 AC-FT 15550
WTR YR 1988 TOTAL 7795.5 MEAN 21.3 MAX 136 MIN 8.0 AC-FT 15460

e Estimated

Table 23.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Vale, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	20	20	20	15	17	14	70	49	80	18	12	12
2	24	21	20	15	18	18	55	47	69	16	11	11
3	86	20	20	15	18	25	59	50	64	15	12	9.6
4	41	20	21	15	18	39	102	40	58	18	18	12
5	28	21	22	16	17	50	108	37	56	17	13	15
6	26	22	22	16	19	42	99	37	52	16	10	14
7	24	25	22	16	19	36	95	37	49	18	17	14
8	21	19	21	15	19	31	95	36	46	20	39	15
9	22	17	18	16	17	24	101	35	43	17	20	13
10	19	17	18	17	17	24	83	32	43	18	15	12
11	22	17	19	18	17	22	65	29	36	22	12	14
12	20	18	18	21	17	21	60	27	30	25	13	16
13	20	17	17	20	17	23	52	25	26	21	13	13
14	20	18	17	18	20	23	45	24	23	20	14	13
15	19	18	18	17	17	23	53	23	22	18	11	13
16	19	19	17	16	17	23	69	25	20	18	19	11
17	19	19	17	16	18	24	83	34	21	17	13	11
18	19	20	16	18	19	25	102	29	21	21	13	13
19	18	21	14	20	18	25	107	27	24	19	12	12
20	18	21	14	20	17	31	95	45	23	16	12	12
21	18	22	14	18	18	7.8	80	80	21	16	11	11
22	19	43	14	17	16	30	71	57	20	15	12	11
23	24	34	15	16	16	43	70	72	21	13	16	11
24	21	32	15	16	19	28	74	108	19	16	13	11
25	22	34	15	17	17	26	72	116	17	17	13	11
26	21	24	14	18	15	25	72	110	18	16	22	11
27	21	25	14	19	15	24	67	97	17	14	21	9.9
28	21	22	14	19	14	22	64	85	17	15	17	11
29	20	21	15	17	---	20	57	82	17	15	13	12
30	20	19	16	16	---	25	55	85	18	13	12	13
31	19	---	16	17	---	34	---	95	---	12	13	---
TOTAL	731	666	533	530	486	827.8	2280	1675	991	532	462	367.5
MEAN	23.6	22.2	17.2	17.1	17.4	26.7	76.0	54.0	33.0	17.2	14.9	12.2
MAX	86	43	22	21	20	50	108	116	80	25	39	16
MIN	18	17	14	15	14	7.8	45	23	17	12	10	9.6
AC-FT	1450	1320	1060	1050	964	1640	4520	3320	1970	1060	916	729

CAL YR 1986 TOTAL 12020.6 MEAN 32.9 MAX 390 MIN 6.5 AC-FT 23840
WTR YR 1987 TOTAL 10081.3 MEAN 27.6 MAX 116 MIN 7.8 AC-FT 20000

Table 23.--Daily mean discharge, in cubic feet per second, for Whitewood Creek above Vale, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12	14	e16	e9.0	e11	e20	26	32	29	14	4.1	5.5
2	12	14	17	e10	e11	e18	29	45	26	14	7.6	4.7
3	12	15	17	e10	e11	e18	32	40	24	14	7.2	4.6
4	12	13	17	e10	e12	e20	37	40	24	12	12	6.5
5	12	13	17	e9.0	e13	e22	35	40	23	11	11	7.0
6	13	13	16	e9.0	e13	e22	33	40	21	8.4	7.8	5.8
7	14	13	16	e8.0	12	e23	43	42	20	7.0	6.7	5.4
8	14	13	16	e8.0	e13	e22	46	109	19	6.4	7.8	4.6
9	13	13	17	e8.0	e15	e23	38	126	19	6.2	7.6	4.9
10	16	14	17	e8.0	e15	e25	33	123	19	9.9	5.0	5.2
11	16	15	19	e11	e14	e18	33	121	17	12	4.5	5.4
12	15	15	e17	e11	e18	e16	38	113	18	11	4.8	6.6
13	15	15	15	e10	e18	e9.5	40	99	20	8.1	9.3	7.7
14	16	15	15	e10	e17	e8.5	38	88	29	6.9	6.9	7.5
15	15	17	e14	e12	e17	e14	38	77	22	4.4	5.5	7.6
16	16	15	e12	e12	e17	e17	39	67	19	4.2	5.1	7.7
17	16	14	e12	e10	e16	e18	39	63	18	4.5	4.2	7.3
18	15	e15	e13	e10	e16	e20	39	57	15	4.8	5.3	7.1
19	16	13	e13	e10	e16	e27	38	56	14	8.0	5.5	11
20	14	14	e12	e10	e16	e35	36	58	14	8.5	5.0	11
21	13	14	e11	e10	e17	e35	35	51	12	6.9	5.9	9.4
22	12	15	e11	e11	e17	e37	35	46	11	4.7	6.6	8.7
23	12	14	e11	e11	e16	e36	34	44	15	4.8	6.5	7.5
24	13	14	e10	e10	e16	e40	33	42	12	5.7	4.1	7.7
25	14	14	e10	e10	e17	e35	31	39	8.7	5.8	3.7	7.4
26	14	14	e10	e10	e19	e35	34	38	9.0	4.9	3.4	7.4
27	13	15	e10	e11	e22	e40	33	37	8.9	4.6	3.7	6.5
28	13	13	e10	e13	e24	e42	33	36	12	4.2	4.7	14
29	14	e14	e10	e16	e22	e35	32	34	12	2.4	5.7	31
30	14	e15	e10	e16	---	e30	32	30	19	2.8	6.9	17
31	14	---	e9.0	e13	---	e26	---	32	---	3.2	6.0	---
TOTAL	430	425	420.0	326.0	461	787.0	1062	1865	529.6	225.3	190.1	249.7
MEAN	13.9	14.2	13.5	10.5	15.9	25.4	35.4	60.2	17.7	7.27	6.13	8.32
MAX	16	17	19	16	24	42	46	126	29	14	12	31
MIN	12	13	9.0	8.0	11	8.5	26	30	8.7	2.4	3.4	4.6
AC-FT	853	843	833	647	914	1560	2110	3700	1050	447	377	495

CAL YR 1987 TOTAL 9426.3 MEAN 25.8 MAX 116 MIN 7.8 AC-FT 18700
WTR YR 1988 TOTAL 6970.7 MEAN 19.0 MAX 126 MIN 2.4 AC-FT 13830

e Estimated

Table 24.--Daily mean discharge, in cubic feet per second, for Belle Fourche River near Sturgis, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	302	83	80	80	75	50	246	389	538	263	245	245
2	267	84	80	60	65	75	777	377	475	279	230	230
3	346	84	65	60	65	100	1590	407	430	284	256	206
4	847	84	75	70	65	150	1960	430	397	307	299	202
5	601	82	85	80	60	199	2410	482	359	325	314	169
6	411	83	85	80	65	1110	1980	411	301	329	301	197
7	323	75	85	60	70	1390	1660	376	278	332	339	228
8	251	60	80	50	70	991	1080	339	252	351	598	258
9	213	50	55	50	70	300	728	214	231	338	619	290
10	186	40	50	50	75	220	727	226	227	325	544	242
11	167	40	60	65	75	200	906	222	200	314	457	240
12	159	40	80	75	80	187	792	210	163	399	409	227
13	151	35	80	75	75	170	696	182	157	445	437	221
14	140	45	80	65	75	150	601	166	153	436	492	202
15	130	50	80	45	70	139	543	158	152	381	315	185
16	125	65	80	40	75	132	508	150	158	309	277	162
17	121	70	90	35	70	127	491	170	145	257	279	150
18	114	60	70	45	70	126	497	234	141	274	289	171
19	113	60	60	55	75	126	516	260	142	351	249	191
20	109	70	60	55	65	148	528	315	129	365	225	186
21	106	80	60	55	55	270	541	1060	169	357	203	176
22	105	100	60	45	55	280	517	938	160	331	199	179
23	104	150	75	40	55	280	488	670	165	320	221	173
24	101	150	100	35	55	320	467	821	161	310	267	165
25	99	200	100	35	45	326	446	786	155	305	273	165
26	95	200	90	42	30	109	447	777	177	296	272	171
27	90	180	100	50	20	106	435	1070	214	293	270	184
28	90	150	100	60	30	110	429	854	243	285	282	167
29	89	130	100	65	---	100	424	614	237	274	274	176
30	86	100	100	75	---	95	408	655	256	275	240	178
31	83	---	100	75	---	140	---	676	---	269	238	---
TOTAL	6124	2700	2465	1772	1755	8226	23838	14639	6965	9979	9913	5936
MEAN	198	90.0	79.5	57.2	62.7	265	795	472	232	322	320	198
MAX	847	200	100	80	80	1390	2410	1070	538	445	619	290
MIN	83	35	50	35	20	50	246	150	129	257	199	150
AC-FT	12150	5360	4890	3510	3480	16320	47280	29040	13820	19790	19660	11770

CAL YR 1986 TOTAL 122329 MEAN 335 MAX 6520 MIN 35 AC-FT 242600
WTR YR 1987 TOTAL 94312 MEAN 258 MAX 2410 MIN 20 AC-FT 187100

Table 24.--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 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	156	e48	e55	e10	e7.0	e56	95	55	320	1140	223	235
2	157	e48	e58	e9.0	e8.0	e60	87	76	305	562	222	231
3	145	e48	e54	e6.0	e7.0	e55	85	96	285	486	224	226
4	124	e48	e58	e4.5	e7.0	e50	87	111	284	387	273	230
5	99	e47	e65	e3.5	e8.0	e70	89	92	281	357	330	237
6	80	e38	57	e3.0	e10	e90	83	79	256	338	314	255
7	72	e37	53	e3.0	e9.0	e120	78	82	261	297	297	254
8	65	e36	e40	e2.9	e8.0	e160	79	86	246	234	290	224
9	59	e34	e30	e3.1	e7.0	e130	82	153	220	201	309	204
10	59	e34	e29	e5.0	e7.0	e60	78	241	231	193	297	209
11	59	e38	e25	e4.0	e8.0	e50	69	191	228	207	259	250
12	59	e42	e24	e5.0	e11	e60	65	154	243	214	240	250
13	59	e42	e20	e6.0	e18	e60	65	201	260	212	237	282
14	59	e42	e20	e7.0	e19	e70	68	221	323	188	231	291
15	59	e40	e20	e7.5	e19	e70	69	191	329	153	234	287
16	58	e37	e22	e7.5	e19	e70	67	210	309	155	237	264
17	55	e42	e24	e7.5	e19	e80	65	187	292	187	222	226
18	53	e90	e24	e9.0	e20	e110	65	172	261	208	232	146
19	53	e150	e24	e11	e20	e130	65	156	227	233	232	108
20	53	e150	e24	e13	e23	e170	64	173	215	233	256	93
21	53	e140	e23	e13	e20	e400	65	172	209	210	265	82
22	53	e140	e23	e12	e17	e500	69	147	216	220	273	69
23	53	e150	e23	e11	e15	e450	70	161	231	230	293	65
24	53	e160	e20	e11	e18	e400	65	173	246	243	268	61
25	53	e140	e19	e13	e20	e400	65	155	259	225	223	58
26	53	e130	e19	e18	e40	e415	70	182	248	215	222	56
27	53	e110	e19	e26	e55	550	69	187	231	200	233	52
28	53	e70	e18	e33	e65	224	59	200	242	207	232	54
29	53	e40	e12	e29	e60	169	55	211	258	230	253	61
30	53	e38	e8.0	e20	---	140	54	243	489	216	267	77
31	52	---	e9.0	e11	---	115	---	281	---	208	260	---
TOTAL	2165	2209	919.0	324.5	564.0	5484	2146	5039	8005	8589	7948	5137
MEAN	69.8	73.6	29.6	10.5	19.4	177	71.5	163	267	277	256	171
MAX	157	160	65	33	65	550	95	281	489	1140	330	291
MIN	52	34	8.0	2.9	7.0	50	54	55	209	153	222	52
AC-FT	4290	4380	1820	644	1120	10880	4260	9990	15880	17040	15760	10190

CAL YR 1987 TOTAL 88316.0 MEAN 242 MAX 2410 MIN 8.0 AC-FT 175200
WTR YR 1988 TOTAL 48529.5 MEAN 133 MAX 1140 MIN 2.9 AC-FT 96260

e Estimated

Table 25.--Daily mean discharge, in cubic feet per second, for Belle Fourche River near Elm Springs, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	444	81	197	127	65	20	643	410	795	229	228	147
2	372	83	185	115	60	70	1070	405	638	251	199	147
3	389	83	98	120	50	80	2410	422	559	241	226	139
4	829	80	84	124	50	80	3760	435	506	271	213	127
5	992	81	92	128	70	80	4720	456	481	313	244	124
6	709	80	120	127	80	70	3530	473	458	339	270	106
7	511	94	134	110	85	700	2440	426	401	330	277	126
8	401	80	65	100	117	2300	1740	400	355	335	380	174
9	323	40	45	90	112	1080	1200	362	320	343	561	217
10	261	40	40	80	111	627	889	213	330	335	536	256
11	219	40	55	85	98	444	952	205	315	332	478	208
12	192	30	70	100	99	345	936	201	299	306	415	198
13	177	30	80	100	109	279	823	187	193	411	382	185
14	168	35	90	100	94	279	731	153	175	453	443	175
15	156	40	100	90	84	291	665	128	165	428	433	149
16	146	50	100	80	90	226	612	118	158	380	267	142
17	137	50	90	70	95	200	571	187	170	302	209	120
18	128	40	70	50	100	225	549	153	156	240	211	114
19	118	50	60	60	75	308	536	231	136	240	215	124
20	114	60	60	60	73	325	534	531	143	341	163	152
21	111	80	75	50	60	348	542	677	129	357	144	154
22	106	100	85	45	50	474	533	1380	167	347	120	141
23	106	130	112	40	34	207	503	966	167	308	115	138
24	101	150	123	35	26	196	483	2440	161	291	120	132
25	96	200	129	35	24	156	466	2200	145	284	185	134
26	97	218	129	40	20	144	457	2080	136	269	220	128
27	92	272	133	45	16	193	451	4460	153	260	219	131
28	90	291	135	50	18	152	445	3060	178	264	198	124
29	86	251	132	55	---	150	438	1340	217	253	199	131
30	85	207	139	60	---	180	425	1020	214	228	191	137
31	86	---	129	65	---	276	---	914	---	242	155	---
TOTAL	7842	3066	3156	2436	1965	10505	34054	26633	8420	9523	8216	4480
MEAN	253	102	102	78.6	70.2	339	1135	859	281	307	265	149
MAX	992	291	197	128	117	2300	4720	4460	795	453	561	256
MIN	85	30	40	35	16	20	425	118	129	228	115	106
AC-FT	15550	6080	6260	4830	3900	20840	67550	52830	16700	18890	16300	8890

CAL YR 1986 TOTAL 194560 MEAN 533 MAX 13300 MIN 30 AC-FT 385900
WTR YR 1987 TOTAL 120296 MEAN 330 MAX 4720 MIN 16 AC-FT 238600

Table 25.--Daily mean discharge, in cubic feet per second, for Belle Fourche River near Elm Springs, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	136	37	36	e9.0	e9.0	e60	242	56	340	1230	199	257
2	128	38	38	e10	e7.0	e55	217	129	408	1060	226	220
3	133	44	56	e7.0	e8.0	e60	213	197	382	659	242	209
4	124	42	57	e5.0	e8.0	e55	221	177	341	543	248	204
5	107	39	54	e4.0	e7.0	e50	202	153	312	435	299	205
6	90	36	65	e3.0	e9.0	e70	139	131	298	394	363	207
7	76	36	67	e3.0	e10	e90	122	98	271	376	336	222
8	64	34	57	e3.0	e9.0	e130	108	104	285	319	321	219
9	57	33	52	e3.0	e8.0	e170	92	142	276	246	309	196
10	54	34	35	e3.0	e7.0	e70	78	297	243	190	329	178
11	53	35	e30	e5.0	e7.0	e60	76	378	241	166	316	170
12	51	38	e30	e4.0	e9.0	e50	71	283	305	179	265	201
13	51	38	e25	e5.0	e17	e60	64	199	282	200	237	206
14	52	36	e25	e6.0	e18	e60	60	227	336	199	227	237
15	51	34	e20	e8.0	e20	e70	59	241	384	168	217	254
16	50	33	e20	e8.0	e20	e70	62	197	357	132	221	257
17	48	32	e20	e8.0	e20	e70	63	219	326	125	226	239
18	48	26	e25	e8.0	e20	e80	62	203	307	157	205	207
19	49	55	e25	e9.0	e20	e120	63	196	258	205	210	151
20	50	145	e25	e10	e20	e140	62	221	210	237	226	105
21	49	144	e25	e12	e24	e170	60	223	179	247	240	91
22	47	148	e25	e14	e20	e650	60	212	175	206	253	80
23	47	149	e25	e14	e17	e550	63	185	197	210	261	73
24	45	148	e22	e10	e15	e450	66	177	204	223	292	64
25	47	153	e20	e10	e18	e400	65	209	222	259	265	62
26	46	149	e20	e15	e20	426	72	198	227	238	210	56
27	43	150	e20	e20	e40	844	72	215	212	225	203	53
28	44	131	e20	e30	e50	874	69	247	193	210	207	53
29	46	87	e15	e35	e65	525	64	248	237	207	210	54
30	44	59	e10	e20	---	402	56	245	412	228	232	54
31	37	---	e8.0	e15	---	295	---	279	---	212	256	---
TOTAL	1967	2163	972.0	316.0	522.0	7176	2923	6286	8420	9685	7851	4784
MEAN	63.5	72.1	31.4	10.2	18.0	231	97.4	203	281	312	253	159
MAX	136	153	67	35	65	874	242	378	412	1230	363	257
MIN	37	26	8.0	3.0	7.0	50	56	56	175	125	199	53
AC-FT	3900	4290	1930	627	1040	14230	5800	12470	16700	19210	15570	9490

CAL YR 1987 TOTAL 111334.0 MEAN 305 MAX 4720 MIN 8.0 AC-FT 220800
WTR YR 1988 TOTAL 53065.0 MEAN 145 MAX 1230 MIN 3.0 AC-FT 105300

e Estimated

Table 26.--Daily mean discharge, in cubic feet per second, for Cherry Creek at Cherry Creek, S. Dak.

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1986 TO SEPTEMBER 1987
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1340	425	530	350	430	260	5270	800	3820	399	319	366
2	2050	427	518	350	370	300	7580	760	2990	401	316	343
3	3620	430	465	350	360	700	7230	750	2400	402	368	325
4	7650	431	400	340	370	1550	8980	1000	2070	408	364	316
5	5050	437	350	340	390	3080	13600	1500	1640	423	348	302
6	1140	439	340	330	400	6340	15700	1450	1390	429	327	293
7	920	445	340	320	380	6650	11500	1030	1250	422	339	291
8	654	468	330	300	350	5500	8560	996	859	480	436	280
9	560	472	320	300	340	4000	6650	932	763	497	466	302
10	539	397	300	320	350	3000	4710	846	723	476	528	322
11	519	340	340	340	500	4900	3810	711	671	519	673	369
12	469	330	380	300	700	3810	3330	566	819	471	620	374
13	441	320	400	250	850	2810	3130	567	1130	453	762	339
14	422	350	420	200	1000	1700	2770	506	784	465	861	328
15	422	380	450	186	950	1130	2450	472	752	513	600	316
16	441	400	430	180	600	1730	2220	427	760	502	735	317
17	370	450	400	190	500	1990	2030	399	663	469	561	306
18	387	450	400	200	392	1910	1830	386	592	729	483	301
19	396	450	385	200	399	1850	1670	411	563	453	433	282
20	390	470	385	190	372	4240	1540	427	536	403	415	269
21	380	500	385	190	353	14300	1490	1090	565	396	376	270
22	370	550	400	190	344	18000	1480	5710	544	930	350	288
23	362	1000	400	190	357	8790	1410	4010	452	524	330	293
24	370	1200	400	190	379	8070	1220	3080	436	423	311	282
25	400	1100	385	200	358	6950	1080	10900	415	391	298	277
26	420	700	370	240	353	6330	1150	8180	404	385	313	271
27	430	600	370	300	286	5660	1100	6610	402	369	391	267
28	427	600	370	350	270	5110	1020	13500	399	362	399	258
29	420	550	360	380	---	4260	950	7920	399	357	408	253
30	422	550	360	420	---	3050	900	5220	399	342	406	253
31	425	---	360	450	---	2100	---	4490	---	325	394	---
TOTAL	32206	15661	12043	8636	12703	140070	126360	85646	29590	14118	13930	9053
MEAN	1039	522	388	279	454	4518	4212	2763	986	455	449	302
MAX	7650	1200	530	450	1000	18000	15700	13500	3820	930	861	374
MIN	362	320	300	180	270	260	900	386	399	325	298	253
AC-FT	63880	31060	23890	17130	25200	277800	250600	169900	58690	28000	27630	17960

CAL YR 1986 TOTAL 620415 MEAN 1700 MAX 21400 MIN 90 AC-FT 1231000
WTR YR 1987 TOTAL 500016 MEAN 1370 MAX 18000 MIN 180 AC-FT 991800

Table 26.--Daily mean discharge, in cubic feet per second, for Cherry Creek at Cherry Creek, S. Dak.--Continued

DISCHARGE, CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1987 TO SEPTEMBER 1988
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	255	162	190	e100	e40	e300	809	228	252	1280	214	250
2	257	163	162	e90	e35	e260	633	239	279	3170	205	266
3	264	170	137	e80	e30	e280	533	1180	309	1800	205	257
4	263	172	174	e60	e28	e300	528	1070	324	778	238	238
5	256	175	178	e45	e25	e350	530	549	299	1370	294	230
6	244	174	194	e42	e27	e380	608	414	280	1020	862	227
7	234	174	210	e38	e30	e400	596	363	271	590	573	231
8	215	173	221	e35	e28	e420	504	339	256	492	443	233
9	203	170	204	e38	e25	e460	446	379	241	428	387	250
10	193	165	184	e42	e22	e500	411	310	245	351	338	252
11	191	165	174	e41	e20	e450	363	339	236	285	320	238
12	190	163	170	e40	e23	e360	324	412	222	236	320	228
13	189	163	158	e39	e27	e320	296	390	218	209	309	229
14	186	165	135	e38	e32	e280	281	336	273	204	277	252
15	183	165	132	e42	e37	e240	257	292	259	198	253	262
16	182	165	e130	e41	e45	e220	238	296	270	197	229	286
17	182	165	e125	e40	e51	e210	219	303	329	180	207	295
18	182	165	e115	e39	e60	e210	211	285	322	151	218	290
19	180	162	e125	e38	e58	e220	215	297	294	141	218	274
20	178	163	e135	e38	e55	e260	216	320	262	168	205	255
21	178	177	e145	e38	e66	e300	202	1780	226	197	205	220
22	176	240	e140	e39	e64	326	198	2510	201	266	204	191
23	176	251	e138	e40	e60	889	197	683	300	273	226	178
24	174	258	e130	e37	e70	1130	196	442	211	237	268	177
25	174	260	e135	e33	e90	1200	203	345	187	225	260	175
26	174	261	e140	e36	e120	1430	219	310	204	225	267	167
27	171	263	e135	e42	e160	1110	234	292	236	241	247	162
28	167	263	e130	e50	e200	2070	234	271	221	229	223	169
29	168	270	e125	e60	e240	2550	253	267	219	233	221	168
30	163	248	e120	e70	---	1780	275	263	995	216	227	162
31	160	---	e110	e55	---	1100	---	255	---	210	233	---
TOTAL	6108	5830	4701	1466	1768	20305	10429	15759	8441	15800	8896	6812
MEAN	197	194	152	47.3	61.0	655	348	508	281	510	287	227
MAX	264	270	221	100	240	2550	809	2510	995	3170	862	295
MIN	160	162	110	33	20	210	196	228	187	141	204	162
AC-FT	12120	11560	9320	2910	3510	40270	20690	31260	16740	31340	17650	13510

CAL YR 1987 TOTAL 456745 MEAN 1251 MAX 18000 MIN 110 AC-FT 906000
WTR YR 1988 TOTAL 106315 MEAN 290 MAX 3170 MIN 20 AC-FT 210900

e Estimated

The Hydrolab instrument was used most often during 1987 to determine water readings. 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 4-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 other 3 meters were used during most of 1988. The YSI meter uses a Clark polarographic probe and is temperature and pressure compensated. The Beckman meter is equipped with a glass conductivity probe containing platinum electrodes; meter readings were standardized to 25 °C using a temperature-compensation chart. The Orion pH meter is equipped with pH and reference electrodes and is temperature compensated and auto-calibrating.

Water 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). In the field, except for organic carbon, samples normally were obtained by wading the stream and collecting depth-integrated aliquots with a sampling rod that held two 2-liter bottles equipped with sampling nozzles. Normally aliquots of stream water were collected at from 10 to 25 verticals across the channel.

Water to be analyzed for suspended-sediment concentration was collected in 2-L bottles and shipped to the U.S. Geological Survey sediment lab in Iowa City, Iowa. Water to be analyzed for suspended-sediment chemistry concentrations was composited in plastic containers, placed on ice, and transported back to Rapid City for concentration (see chapter F). Water to be analyzed for inorganic constituents was composited in a sample-splitting churn and processed on site.

Subsamples to be analyzed for total concentrations of inorganic constituents were withdrawn from the churn while the water and sediment were being mixed. Subsamples to be analyzed for dissolved concentrations were filtered from the churn using a peristaltic pump. Prior to April 1987, dissolved samples were filtered through a 0.45-μm cellulose filter; beginning in April 1987, dissolved samples were filtered through a 0.1-μm filter. Subsamples to be analyzed for nitrogen species and phosphorus were placed in brown polyethelene bottles, preserved with mercuric chloride, and put on ice. Subsamples to be analyzed for dissolved trace elements and major cations were preserved with nitric acid. Subsamples to be analyzed for dissolved mercury were placed in glass bottles and preserved with chromic acid. Subsamples to be analyzed for cyanide were preserved with NaOH and put on ice. Subsamples were then shipped to the U.S. Geological Survey's Central Laboratory in Arvada, Colorado, for analysis.

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 and filtered through 0.45-μm silver filters, pressurized with nitrogen gas, into similar small glass bottles. The bottles were then put on ice and shipped to the Central Laboratory for analysis.

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 10- or 25-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, 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 covered with thick ice and weather conditions were dangerous.

Two water-chemical samples and several suspended-sediment samples were collected by Manning automatic samplers (Model S-4050). With these samplers, a tube runs from the sampler, housed in a shelter near the stream, to an intake submerged in the stream. The sampler is connected electronically to a stream-stage sensor and starts pumping water from the stream when the gage height reaches storm-runoff stage. When the sampler turns on, it pumps air back through the tube to flush the tube, pumps an initial aliquot of water to rinse the sampling bowl, pumps the rinse back out the tube, pumps a second aliquot of water, and dumps this water into a sample bottle. The sampler holds 24 bottles which may be filled in a number of combinations of groups and time. The water samples were stored in a chest-type refrigerator in the shelter and picked up and preserved within 12 hours of collection. Results of water-chemical samples, collected by the Manning samplers on May 9 and 10, 1988, at Whitewood Creek above Whitewood, are listed in table 27 and are footnoted.

Results of analysis of additional suspended-sediment samples collected on Whitewood Creek above Whitewood and the Belle Fourche River near Sturgis are listed in table 33. The suspended-sediment samples for the Belle Fourche River near Sturgis were collected by an observer. These samples were collected from April 21 through September 26, 1988, to help define the relation between discharge and suspended-sediment concentration. During this period, the observer collected weekly and high-flow samples from the bridge at a single vertical near the centroid of flow. Samples were collected in pint glass bottles using a cable-suspended sampler and then shipped to the Iowa sediment lab for analysis.

STREAMBED DATA

Three types of streambed data were collected: bedload discharge, particle sizes of bulk bed material, and particle sizes of material on the surface of the streambed.

Bedload is "the sediment that moves by sliding, rolling, or bouncing along on or within a few grain diameters of the streambed" (Edwards and Glysson, 1988, p. 308). Four samples of bedload discharge were collected at the Belle Fourche River near Sturgis using Helley-Smith bedload samplers and field techniques published by the U.S. Geological Survey (Edwards and Glysson, 1988). Samplers had a 3-inch by 3-inch opening and a 1.4 flare ratio and were equipped with nylon bags with a mesh size of 0.25 mm. During sample collection, the sampler rested on the bottom of the stream, and bed material that rolled through the opening was collected in the bag. The hand-held sampler weighed 4 pounds, and the cable-suspended sampler weighed 65 pounds.

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.

[<, less than; E, estimated]

WATER QUALITY DATA

DATE	TIME	TEMPER-ATURE WATER (DEG C) (00010)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)	PH (STAND-ARD UNITS) (00400)	PH LAB (STAND-ARD UNITS) (00403)	NITRO-GEN, TOTAL (MG/L AS N) (00600)
OCT 1986											
21...	1340	10.5	668	15	876	828	11.2	115	9.70	9.20	--
NOV											
24...	1050	3.5	665	17	828	773	11.1	97	8.71	8.40	--
DEC											
05...	1114	0.0	--	22	850	--	--	--	--	--	--
22...	1451	-0.5	668	14	850	855	12.8	99	8.53	8.20	--
JAN 1987											
09...	1515	-0.5	670	9.4	871	881	13.0	100	8.55	8.19	--
FEB											
11...	1355	3.5	670	13	901	899	13.1	113	8.88	8.51	--
MAR											
05...	1520	8.0	--	17	--	--	--	--	9.17	--	--
14...	0950	E3.0	--	17	--	--	--	--	--	--	--
19...	1230	6.0	657	21	852	--	12.0	113	9.00	--	--
19...	1640	7.5	659	20	755	756	11.2	108	9.06	8.65	--
APR											
06...	1320	--	--	41	--	--	--	--	--	--	--
07...	1900	--	--	<60	--	--	--	--	--	--	3.8
08...	2005	9.0	660	E70	470	--	9.5	95	8.41	--	3.9
10...	2045	--	--	49	--	--	--	--	--	--	--
15...	1650	13.0	--	36	--	--	--	--	--	--	--
21...	1530	11.0	674	58	425	444	9.6	98	8.88	8.70	--
MAY											
19...	1615	15.5	664	27	680	696	9.8	113	9.44	9.30	--
20...	1645	8.5	672	79	510	--	9.9	96	8.45	--	--
23...	1950	10.0	--	83	417	--	--	--	8.36	--	5.0
JUN											
26...	1520	23.0	--	23	787	798	7.8	--	8.88	8.90	--
JUL											
15...	1420	24.0	665	22	904	892	9.4	129	9.33	9.20	--
AUG											
30...	1145	15.5	676	15	947	927	8.8	100	9.04	8.80	--
30...	1150	15.5	676	15	947	927	8.8	100	9.04	8.80	--
SEP											
28...	1115	9.5	674	14	911	918	11.1	110	8.86	8.60	--
OCT											
20...	1555	5.0	675	15	920	906	10.8	96	9.60	9.10	--
NOV											
17...	1410	2.0	669	13	1020	1040	12.2	100	9.25	8.80	--

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	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)	PHOSPHOROUS TOTAL (MG/L AS P) (00665)	PHOSPHOROUS 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)
OCT 1986										
21...	--	2.5	--	6.40	--	0.178	2.5	2.4	0.03	707
NOV										
24...	--	0.60	--	5.30	--	0.187	1.6	1.6	0.05	550
DEC										
05...	--	--	--	--	--	--	--	--	--	--
22...	--	1.1	--	6.40	--	0.260	2.9	1.9	0.05	614
JAN 1987										
09...	--	1.5	--	7.90	--	0.435	1.9	1.7	0.04	602
FEB										
11...	--	2.4	--	8.80	--	0.236	2.3	2.2	<0.01	634
MAR										
05...	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
19...	--	0.90	--	6.90	--	0.009	1.7	2.3	0.03	526
APR										
06...	--	--	--	--	--	--	--	--	--	--
07...	1.2	--	2.60	--	0.590	--	8.0	--	--	--
08...	1.5	--	2.40	--	0.560	--	8.4	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
21...	--	0.60	--	1.70	--	0.076	3.3	2.7	0.03	252
MAY										
19...	--	0.80	--	4.10	--	0.150	1.9	2.4	0.02	456
20...	--	--	--	--	--	--	--	--	--	--
23...	3.2	--	1.80	--	2.10	--	33	--	--	--
JUN										
26...	--	1.1	--	5.60	--	<0.005	2.2	2.0	0.02	522
JUL										
15...	--	1.1	--	8.40	--	<0.005	2.8	3.7	0.20	651
AUG										
30...	--	1.1	--	8.70	--	0.310	2.5	1.9	<0.01	648
30...	--	1.2	--	8.70	--	0.160	2.5	4.2	0.02	648
SEP										
28...	--	0.80	--	6.20	--	0.232	2.7	2.2	<0.01	612
OCT										
20...	--	0.70	--	7.10	--	0.194	2.2	3.1	<0.01	620
NOV										
17...	--	0.50	--	8.00	--	0.280	2.0	2.0	<0.01	751

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (00932)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)
OCT 1986										
21...	595	380	148	82	43	47	1	21	7.8	16
NOV										
24...	552	360	175	75	41	42	1	20	7.3	18
DEC										
05...	--	--	--	--	--	--	--	--	--	--
22...	607	390	176	81	45	48	1	21	8.4	10
JAN 1987										
09...	524	390	--	84	43	46	1	20	8.2	17
FEB										
11...	620	390	148	85	43	53	1	22	8.9	14
MAR										
05...	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
19...	533	340	159	77	35	43	1	21	7.3	16
APR										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--
08...	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
21...	286	180	136	44	17	18	0.6	18	3.6	12
MAY										
19...	450	290	146	65	30	33	0.9	20	6.5	12
20...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
JUN										
26...	519	330	161	76	35	38	0.9	19	7.0	10
JUL										
15...	630	370	151	83	40	54	1	23	9.2	14
AUG										
30...	643	390	158	85	42	51	1	22	9.5	12
30...	644	390	156	87	42	51	1	22	9.6	12
SEP										
28...	625	390	178	86	43	48	1	21	1.3	16
OCT										
20...	641	400	148	88	44	50	1	21	8.9	14
NOV										
17...	721	460	159	94	54	55	1	20	9.2	18

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	CADMIUM DIS- SOLVED (UG/L AS CD) (01025)	COPPER, DIS- SOLVED (UG/L AS CU) (01040)	IRON, DIS- SOLVED (UG/L AS FE) (01046)	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)	ZINC, DIS- SOLVED (UG/L AS ZN) (01090)
OCT 1986										
21...	280	0.70	1.5	29	2	6	13	17	<0.1	5
NOV										
24...	230	0.80	9.1	25	<1	5	16	96	<0.1	7
DEC										
05...	--	--	--	--	--	--	--	--	--	--
22...	270	0.80	10	33	<1	5	20	97	<0.1	11
JAN 1987										
09...	280	0.90	10	27	<1	5	14	110	<0.1	3
FEB										
11...	280	1.0	7.4	18	<1	8	10	95	<0.1	10
MAR										
05...	--	--	--	--	--	--	--	--	--	--
14...	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--
19...	220	0.80	8.0	20	1	8	7	58	<0.1	8
APR										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--
08...	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
21...	91	0.50	11	<1	<1	<1	5	35	<0.1	6
MAY										
19...	190	0.60	7.6	29	<1	8	7	14	<0.1	15
20...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
JUN										
26...	220	0.80	11	24	<1	5	6	6	<0.1	12
JUL										
15...	290	0.70	11	31	<1	10	32	5	0.3	8
AUG										
30...	300	0.90	9.3	29	<1	6	10	6	<0.1	7
30...	300	0.90	9.5	31	<1	7	10	5	<0.1	7
SEP										
28...	290	0.90	6.0	32	<1	5	20	7	<0.1	<3
OCT										
20...	310	0.80	5.1	34	<1	6	5	7	<0.1	6
NOV										
17...	350	0.90	9.6	28	<1	7	6	22	<0.1	6

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	ANTI- MONY, DIS- SOLVED (UG/L AS SB) (01095)	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)
OCT 1986										
21...	2	7	85	--	--	--	--	--	--	--
NOV										
24...	<1	9	100	--	--	--	--	--	--	--
DEC										
05...	--	7	94	--	--	--	--	--	--	--
22...	1	4	80	--	--	--	--	--	--	--
JAN 1987										
09...	1	7	94	--	--	--	--	--	--	--
FEB										
11...	<1	12	85	--	--	--	--	--	--	--
MAR										
05...	--	18	82	--	--	--	--	--	--	--
14...	--	11	81	--	--	--	--	--	--	--
19...	--	10	78	--	--	--	--	--	--	--
19...	1	7	98	--	--	--	--	--	--	--
APR										
06...	--	64	94	--	--	--	--	--	--	--
07...	--	101	90	--	--	--	--	--	--	--
08...	--	131	89	--	--	--	--	--	--	--
10...	--	27	94	--	--	--	--	--	--	--
15...	--	9	85	--	--	--	--	--	--	--
21...	<1	23	91	--	--	--	--	--	--	--
MAY										
19...	6	14	88	--	--	--	--	--	--	--
20...	--	519	--	46	61	73	82	96	98	100
23...	--	1640	100	45	60	74	92	--	--	--
JUN										
26...	2	13	98	--	--	--	--	--	--	--
JUL										
15...	11	8	94	--	--	--	--	--	--	--
AUG										
30...	5	--	--	--	--	--	--	--	--	--
30...	3	--	--	--	--	--	--	--	--	--
SEP										
28...	6	4	100	--	--	--	--	--	--	--
OCT										
20...	4	12	64	--	--	--	--	--	--	--
NOV										
17...	4	--	--	--	--	--	--	--	--	--

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPER- ATURE WATER (DEG C) (00010)	BARO- METRIC PRES- SURE (MM OF HG) (00025)	STREAM- FLOW, INSTAN- TANEOUS (CFS) (00061)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	SPE- CIFIC CON- DUCT- ANCE LAB (US/CM) (90095)	OXYGEN, DIS- SOLVED (MG/L) (00300)	OXYGEN, DIS- SOLVED (PER- CENT SATUR- ATION) (00301)	PH (STAND- ARD UNITS) (00400)	PH LAB (STAND- ARD UNITS) (00403)	NITRO- GEN, TOTAL (MG/L AS N) (00600)
DEC 1987											
22...	0930	0.0	663	17	1000	975	--	--	8.35	8.20	--
JAN 1988											
27...	1235	0.0	669	11	893	921	12.2	95	8.41	8.30	--
FEB											
29...	1550	4.0	668	17	819	827	10.8	94	8.61	8.40	--
MAR											
19...	1655	0.0	--	5.0	--	--	--	--	--	--	--
20...	1800	1.0	--	36	750	--	--	--	8.76	--	--
21...	1955	6.0	--	35	728	722	--	--	8.58	8.50	5.0
21...	2025	5.5	--	37	728	--	--	--	--	--	--
30...	1805	3.0	672	27	775	722	11.2	95	8.99	8.50	--
APR											
11...	1550	11.0	668	30	620	639	9.8	102	9.23	9.10	--
MAY											
02...	1015	5.0	666	38	546	--	12.8	116	9.00	--	3.2
09...	2012	9.5	670	143	393	--	10.1	101	8.20	--	--
[1]09...	2015	9.5	670	160	393	400	10.1	101	8.20	8.00	1.4
[1]10...	1045	8.0	--	135	356	--	--	--	8.38	--	--
31...	1225	18.5	664	31	617	627	9.8	120	9.32	9.10	--
JUN											
27...	1500	27.0	667	21	881	869	7.2	104	8.89	8.90	--
JUL											
22...	1230	23.0	670	14	950	906	10.7	142	9.36	9.20	--
AUG											
25...	1545	22.0	673	12	1010	973	9.8	128	9.55	9.50	--
SEP											
06...	1255	17.5	665	E12	1080	1050	--	--	9.31	9.10	--
06...	1300	17.5	665	12	1080	1050	--	--	9.31	9.10	--

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	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)	PHOSPHOROUS TOTAL (MG/L AS P) (00665)	PHOSPHOROUS 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)
DEC 1987										
22...	--	0.40	--	8.50	--	0.310	1.6	1.9	0.02	738
JAN 1988										
27...	--	0.50	--	6.50	--	0.280	3.4	1.7	<0.01	618
FEB										
29...	--	0.60	--	4.80	--	0.209	--	2.5	0.01	--
MAR										
19...	--	--	--	--	--	--	--	--	--	--
20...	--	4.4	--	4.60	0.192	0.148	62	2.2	<0.01	486
21...	1.5	0.50	3.50	3.90	1.00	0.161	9.7	2.3	<0.01	--
21...	--	--	--	--	--	--	--	--	--	--
30...	--	0.50	--	3.90	--	0.161	--	2.3	<0.01	--
APR										
11...	--	0.40	--	2.60	--	0.110	--	2.4	<0.01	--
MAY										
02...	0.80	--	2.40	--	0.110	--	3.7	--	--	--
09...	--	--	--	--	--	--	--	--	--	--
[1]09...	0.30	0.30	1.10	1.10	0.100	0.061	7.5	3.5	<0.01	244
[1]10...	--	--	--	--	--	--	--	--	--	--
31...	--	0.40	--	2.20	--	0.099	--	3.9	<0.01	--
JUN										
27...	--	1.0	--	5.00	--	0.230	--	4.2	<0.01	--
JUL										
22...	--	0.90	--	7.50	--	0.200	--	3.2	<0.01	--
AUG										
25...	--	1.3	--	8.60	--	0.247	--	2.3	0.01	--
SEP										
06...	--	0.90	--	8.70	--	0.247	--	1.8	0.02	--
06...	--	1.1	--	9.00	--	0.269	--	2.2	0.01	--

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	SOLIDS, SUM OF CONSTI- TUENTS, DIS- SOLVED (MG/L) (70301)	HARD- NESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (00932)	POTAS- SIUM, DIS- SOLVED (MG/L AS K) (00935)	CHLO- RIDE, DIS- SOLVED (MG/L AS CL) (00940)
DEC 1987										
22...	741	450	166	93	54	56	1	21	10	19
JAN 1988										
27...	632	390	189	82	45	48	1	21	9.2	14
FEB										
29...	--	--	169	--	--	--	--	--	--	--
MAR										
19...	--	--	--	--	--	--	--	--	--	--
20...	474	290	150	65	32	43	1	24	6.7	28
21...	--	--	163	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
30...	--	--	163	--	--	--	--	--	--	--
APR										
11...	--	--	147	--	--	--	--	--	--	--
MAY										
02...	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--
[1]09...	251	180	97	42	18	13	0.4	13	3.3	11
[1]10...	--	--	--	--	--	--	--	--	--	--
31...	--	--	146	--	--	--	--	--	--	--
JUN										
27...	--	--	201	--	--	--	--	--	--	--
JUL										
22...	694	430	157	91	49	54	1	21	10	18
AUG										
25...	--	--	158	--	--	--	--	--	--	--
SEP										
06...	--	--	171	--	--	--	--	--	--	--
06...	--	--	170	--	--	--	--	--	--	--

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	CADMIUM DIS- SOLVED (UG/L AS CD) (01025)	COPPER, DIS- SOLVED (UG/L AS CU) (01040)	IRON, DIS- SOLVED (UG/L AS FE) (01046)	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)	ZINC, DIS- SOLVED (UG/L AS ZN) (01090)
DEC 1987										
22...	360	0.90	11	23	<1	3	8	57	<0.1	4
JAN 1988										
27...	280	0.80	11	20	<1	14	34	47	<0.1	6
FEB										
29...	--	--	--	19	--	14	230	44	0.1	5
MAR										
19...	--	--	--	--	--	--	--	--	--	--
20...	180	0.70	8.2	20	<1	7	15	27	<0.1	5
21...	--	--	--	16	--	6	10	54	<0.1	45
21...	--	--	--	--	--	--	--	--	--	--
30...	--	--	--	16	--	6	10	54	<0.1	45
APR										
11...	--	--	--	20	--	8	28	27	<0.1	74
MAY										
02...	--	--	--	--	--	--	--	--	--	--
09...	--	--	--	--	--	--	--	--	--	--
[1]09...	88	0.40	12	14	<1	4	15	60	<0.1	36
[1]10...	--	--	--	--	--	--	--	--	--	--
31...	--	--	--	24	--	11	24	14	<0.1	5
JUN										
27...	--	--	--	70	--	8	48	12	<0.1	<3
JUL										
22...	340	--	4.6	43	<1	8	42	5	<0.1	180
AUG										
25...	--	--	--	44	--	8	16	5	<0.1	<3
SEP										
06...	--	--	--	41	--	6	12	<1	<0.1	21
06...	--	--	--	40	--	5	25	1	<0.1	9

Table 27.--Chemical analyses of surface-water samples collected at Whitewood Creek above Whitewood, S. Dak.--Continued

WATER QUALITY DATA

DATE	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	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 .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)
DEC 1987										
22...	4	9	59	--	--	--	--	--	--	--
JAN 1988										
27...	3	41	75	--	--	--	--	--	--	--
FEB										
29...	3	--	--	--	--	--	--	--	--	--
MAR										
19...	--	140	94	--	--	--	--	--	--	--
20...	1	610	--	22	36	66	94	97	99	100
21...	2	184	95	--	--	--	--	--	--	--
21...	--	259	98	--	--	--	--	--	--	--
30...	2	9	99	--	--	--	--	--	--	--
APR										
11...	<1	8	92	--	--	--	--	--	--	--
MAY										
02...	--	26	93	--	--	--	--	--	--	--
09...	--	149	96	--	--	--	--	--	--	--
[1]09...	4	162	93	--	--	--	--	--	--	--
[1]10...	--	89	96	--	--	--	--	--	--	--
31...	2	--	--	--	--	--	--	--	--	--
JUN										
27...	4	--	--	--	--	--	--	--	--	--
JUL										
22...	2	--	--	--	--	--	--	--	--	--
AUG										
25...	2	--	--	--	--	--	--	--	--	--
SEP										
06...	2	--	--	--	--	--	--	--	--	--
06...	2	--	--	--	--	--	--	--	--	--

[1]Sample collected by Manning automatic sampler.

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.

[<, less than]

WATER QUALITY DATA

DATE	TIME	TEMPER-ATURE WATER (DEG C) (00010)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)	PH (STAND-ARD UNITS) (00400)	PH LAB (STAND-ARD UNITS) (00403)	NITRO-GEN, TOTAL (MG/L AS N) (00600)
OCT 1986											
22...	1309	11.0	689	18	1200	1180	9.3	94	8.18	8.20	--
NOV											
24...	1510	6.0	683	32	1080	1020	9.9	90	8.34	8.20	--
DEC											
19...	1535	-0.5	688	12	1330	1420	14.4	108	8.25	8.00	--
JAN 1987											
08...	1555	-0.5	690	15	1320	1410	13.3	100	8.30	8.03	--
FEB											
13...	1615	6.5	684	17	879	1170	14.2	130	8.62	7.98	--
MAR											
05...	1740	7.5	--	70	--	--	--	--	8.20	--	--
24...	1245	0.0	687	28	1170	1110	12.0	91	8.23	7.68	--
APR											
06...	1500	11.5	697	88	855	--	9.1	91	8.23	--	17
07...	2005	--	--	88	--	--	--	--	--	--	--
10...	1950	--	--	79	--	--	--	--	--	--	--
15...	1510	16.5	--	56	--	--	--	--	--	--	--
23...	1540	16.0	690	80	675	698	8.6	96	8.43	8.40	--
MAY											
19...	1235	14.5	684	30	1010	1030	8.9	98	8.42	8.30	--
20...	1100	13.0	--	40	959	--	--	--	8.35	--	--
21...	1230	9.0	693	76	894	--	10.0	95	8.38	--	--
23...	2207	13.0	--	115	880	--	--	--	8.23	--	6.7
23...	2225	--	--	112	--	--	--	--	--	--	--
JUN											
18...	1335	24.0	690	23	1060	1060	10.0	132	8.72	8.30	--
JUL											
14...	1400	25.0	690	13	1200	1150	10.2	137	8.44	8.30	--
AUG											
30...	1355	21.0	695	13	1190	1160	9.2	114	8.60	8.30	--
SEP											
28...	1330	15.0	694	12	1180	1180	9.9	108	8.40	8.30	--
OCT											
20...	1200	3.5	698	15	1150	1160	12.1	100	8.30	8.30	--
NOV											
18...	1315	2.0	690	20	1230	1240	11.8	94	8.30	8.20	--
18...	1320	2.0	690	20	1230	1230	11.8	94	8.30	8.20	--
DEC											
22...	1355	0.0	683	11	1310	1310	12.1	92	8.29	8.20	--

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO- GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N) (00631)	PHOS- PHOROUS TOTAL (MG/L AS P) (00665)	PHOS- PHOROUS 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 DIS- SOLVED (MG/L AS CN) (00723)	SOLIDS, RESIDUE AT 180 DEG. C DIS- SOLVED (MG/L) (70300)
OCT 1986										
22...	--	1.1	--	1.90	--	<0.005	4.9	2.2	0.01	903
NOV										
24...	--	0.50	--	2.60	--	0.035	2.8	2.7	0.02	811
DEC										
19...	--	0.50	--	2.70	--	<0.005	2.5	1.4	<0.01	1090
JAN 1987										
08...	--	0.70	--	3.50	--	<0.005	1.9	1.7	0.02	919
FEB										
13...	--	1.0	--	4.50	--	0.006	1.7	2.3	<0.01	904
MAR										
05...	--	--	2.00	--	0.390	--	15	--	--	--
24...	--	0.40	--	4.30	--	0.012	3.0	2.0	<0.01	858
APR										
06...	15	--	1.70	--	0.450	--	9.6	--	--	--
07...	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
23...	--	0.40	--	1.50	--	0.023	3.9	2.5	0.01	442
MAY										
19...	--	0.50	--	2.40	--	0.008	4.1	2.1	0.01	723
20...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
23...	3.5	--	3.20	--	1.40	--	23	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
JUN										
18...	--	0.70	--	2.20	--	0.020	2.2	3.7	0.01	773
JUL										
14...	--	0.80	--	2.40	--	<0.005	2.4	2.3	0.01	890
AUG										
30...	--	0.40	--	2.50	--	0.005	2.3	2.3	<0.01	871
SEP										
28...	--	0.40	--	2.10	--	<0.005	2.1	2.3	<0.01	872
OCT										
20...	--	0.40	--	3.10	--	<0.005	1.6	2.2	<0.01	851
NOV										
18...	--	0.40	--	4.30	--	0.005	1.6	1.6	<0.01	918
18...	--	0.30	--	4.20	--	<0.005	1.5	1.5	0.01	922
DEC										
22...	--	0.30	--	4.50	--	<0.005	1.4	1.7	0.02	1030

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	SOLIDS, SUM OF CONSTITUENTS, DISSOLVED (MG/L) (70301)	HARDNESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (00932)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	CHLORIDE, DISSOLVED (MG/L AS CL) (00940)
OCT 1986										
22...	884	590	169	130	65	46	0.8	14	9.6	20
NOV										
24...	805	530	176	120	55	50	1	17	8.4	18
DEC										
19...	1030	690	201	150	77	56	1	15	9.9	18
JAN 1987										
08...	1010	680	212	150	75	56	1	15	9.4	11
FEB										
13...	876	580	170	130	62	52	1	16	9.7	16
MAR										
05...	--	--	--	--	--	--	--	--	--	--
24...	874	560	182	130	57	55	1	17	7.7	18
APR										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
23...	425	310	105	73	30	24	0.6	14	4.8	13
MAY										
19...	666	470	183	110	48	39	0.8	15	7.8	14
20...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
JUN										
18...	760	490	121	110	53	42	0.8	15	8.1	14
JUL										
14...	847	560	145	120	63	52	1	17	10	26
AUG										
30...	809	550	104	120	61	50	1	16	10	15
SEP										
28...	754	550	103	120	61	51	1	17	4.0	19
OCT										
20...	795	570	118	130	59	50	0.9	16	9.0	16
NOV										
18...	831	590	164	130	65	54	1	16	9.1	18
18...	820	620	128	140	65	54	1	16	9.1	19
DEC										
22...	949	660	165	150	69	55	1	15	10	19

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
OCT 1986										
22...	500	0.70	3.2	28	<1	1	15	180	<0.1	8
NOV										
24...	430	0.70	5.6	23	<1	2	8	190	<0.1	8
DEC										
19...	580	0.70	5.6	21	1	1	7	360	<0.1	5
JAN 1987										
08...	560	0.70	5.3	17	<1	2	9	320	<0.1	3
FEB										
13...	480	0.70	3.2	22	<1	2	12	180	<0.1	11
MAR										
05...	--	--	--	--	--	--	--	--	--	--
24...	470	0.60	7.7	20	<1	2	8	200	<0.1	4
APR										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--
10...	--	--	--	--	--	--	--	--	--	--
15...	--	--	--	--	--	--	--	--	--	--
23...	200	0.50	9.6	13	<1	<1	3	100	<0.1	8
MAY										
19...	320	0.60	6.2	44	<1	3	18	150	<0.1	80
20...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--
JUN										
18...	440	0.70	9.5	55	<1	5	7	94	0.2	44
JUL										
14...	470	0.70	6.9	43	<1	5	11	54	<0.1	55
AUG										
30...	470	0.70	8.4	64	1	2	9	59	<0.1	6
SEP										
28...	420	0.80	7.2	48	<1	3	5	71	<0.1	4
OCT										
20...	440	0.80	6.1	35	<1	2	3	91	0.6	3
NOV										
18...	430	0.60	7.1	36	<1	1	7	84	<0.1	<3
18...	430	0.70	7.1	37	<1	1	7	85	<0.1	18
DEC										
22...	520	0.70	6.1	23	<1	4	6	120	<0.1	10

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	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)
OCT 1986										
22...	1	6	87	--	--	--	--	--	--	--
NOV										
24...	<1	21	99	--	--	--	--	--	--	--
DEC										
19...	<1	11	95	--	--	--	--	--	--	--
JAN 1987										
08...	<1	22	88	--	--	--	--	--	--	--
FEB										
13...	<1	10	86	--	--	--	--	--	--	--
MAR										
05...	--	448	96	41	49	--	70	--	--	--
24...	<1	101	91	--	--	--	--	--	--	--
APR										
06...	--	244	91	--	--	--	--	--	--	--
07...	--	172	91	--	--	--	--	--	--	--
10...	--	92	89	--	--	--	--	--	--	--
15...	--	40	90	--	--	--	--	--	--	--
23...	2	61	87	--	--	--	--	--	--	--
MAY										
19...	5	15	91	--	--	--	--	--	--	--
20...	--	62	96	--	--	--	--	--	--	--
21...	--	147	92	--	--	--	--	--	--	--
23...	--	894	--	43	53	63	76	94	97	100
23...	--	912	--	45	56	66	78	96	98	100
JUN										
18...	4	28	95	--	--	--	--	--	--	--
JUL										
14...	13	7	75	--	--	--	--	--	--	--
AUG										
30...	6	--	--	--	--	--	--	--	--	--
SEP										
28...	8	9	67	--	--	--	--	--	--	--
OCT										
20...	3	10	59	--	--	--	--	--	--	--
NOV										
18...	8	--	--	--	--	--	--	--	--	--
18...	6	--	--	--	--	--	--	--	--	--
DEC										
22...	4	32	88	--	--	--	--	--	--	--

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPER-ATURE WATER (DEG C) (00010)	BARO-METRIC PRES-SURE (MM OF HG) (00025)	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	OXYGEN, DIS-SOLVED (MG/L) (00300)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION) (00301)	PH (STAND-ARD UNITS) (00400)	PH LAB (STAND-ARD UNITS) (00403)
JAN 1988										
26...	1240	-0.5	694	2.7	1240	1240	11.6	86	8.16	7.90
FEB										
29...	1215	1.0	690	23	1060	1050	11.8	92	8.21	8.10
MAR										
19...	1815	0.0	--	25	--	--	--	--	--	--
21...	1800	8.5	--	42	1030	1020	--	--	8.42	8.30
31...	1550	9.5	693	26	1050	1020	12.8	124	8.90	8.30
APR										
15...	1650	15.0	689	41	744	752	11.9	131	9.09	8.50
MAY										
09...	1800	14.0	681	107	494	598	8.8	96	8.23	7.90
30...	1540	27.0	676	28	867	852	7.7	109	8.48	8.30
JUN										
27...	1800	26.5	684	8.5	992	987	7.2	101	8.30	8.40
JUL										
22...	0935	20.0	689	6.0	1120	1080	8.6	106	8.17	8.10
AUG										
25...	1115	19.0	694	3.6	1260	1210	9.9	118	8.40	8.40
SEP										
06...	0925	14.5	687	5.7	1230	1190	--	--	8.30	8.20

DATE	NITRO-GEN, TOTAL (MG/L AS N) (00600)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHOROUS TOTAL (MG/L AS P) (00665)	PHOS-PHOROUS 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 DIS-SOLVED (MG/L AS CN) (00723)
JAN 1988										
26...	--	--	0.30	--	4.20	--	0.009	--	1.7	<0.01
FEB										
29...	4.1	0.70	0.40	3.40	3.30	0.050	0.024	3.8	2.0	<0.01
MAR										
19...	--	--	--	--	--	--	--	--	--	--
21...	3.5	0.70	0.20	2.80	2.50	0.200	0.004	4.9	2.4	<0.01
31...	--	--	0.20	--	2.50	--	0.004	--	2.4	<0.01
APR										
15...	--	--	0.30	--	1.60	--	0.015	--	2.5	<0.01
MAY										
09...	1.5	0.40	0.40	1.10	1.10	0.056	0.028	10	3.7	<0.01
30...	--	--	0.30	--	1.30	--	0.008	--	3.0	<0.01
JUN										
27...	--	--	0.50	--	0.760	--	0.005	--	3.7	<0.01
JUL										
22...	--	--	0.50	--	0.730	--	0.006	--	2.3	<0.01
AUG										
25...	--	--	0.40	--	0.790	--	<0.001	--	0.2	<0.01
SEP										
06...	--	--	0.30	--	1.70	--	0.002	--	1.9	0.01

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L) (70300)	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)
JAN 1988										
26...	929	860	620	166	140	65	50	0.9	15	9.6
FEB										
29...	751	727	480	184	110	50	45	0.9	17	8.3
MAR										
19...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	148	--	--	--	--	--	--
31...	--	--	--	148	--	--	--	--	--	--
APR										
15...	--	--	--	122	--	--	--	--	--	--
MAY										
09...	336	384	270	119	64	26	20	0.5	14	4.9
30...	--	--	--	150	--	--	--	--	--	--
JUN										
27...	--	--	--	112	--	--	--	--	--	--
JUL										
22...	--	--	--	139	--	62	52	--	--	11
AUG										
25...	--	--	--	148	--	--	--	--	--	--
SEP										
06...	--	--	--	159	--	--	--	--	--	--

DATE	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)	CADMIUM DIS-SOLVED (UG/L AS CD) (01025)	COPPER, DIS-SOLVED (UG/L AS CU) (01040)	IRON, DIS-SOLVED (UG/L AS FE) (01046)	MANGA-NESE, DIS-SOLVED (UG/L AS MN) (01056)	MERCURY DIS-SOLVED (UG/L AS HG) (71890)
JAN 1988										
26...	17	450	0.70	9.2	26	<1	2	15	150	<0.1
FEB										
29...	21	360	0.60	7.1	30	2	5	9	150	<0.1
MAR										
19...	--	--	--	--	--	--	--	--	--	--
21...	--	--	--	--	38	--	4	7	120	<0.1
31...	--	--	--	--	38	--	4	7	120	<0.1
APR										
15...	--	--	--	--	46	--	4	9	50	<0.1
MAY										
09...	11	170	0.50	11	40	<1	2	11	110	<0.1
30...	--	--	--	--	56	--	4	4	74	<0.1
JUN										
27...	--	--	--	--	79	--	3	16	14	<0.1
JUL										
22...	17	460	--	4.4	61	<1	2	10	54	<0.1
AUG										
25...	--	--	--	--	76	--	2	8	76	<0.1
SEP										
06...	--	--	--	--	41	--	1	6	84	<0.1

Table 28.--Chemical analyses of surface-water samples collected at Whitewood Creek above Vale, S. Dak.--Continued

WATER QUALITY DATA

DATE	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	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 .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)
JAN 1988										
26...	6	3	10	66	--	--	--	--	--	--
FEB										
29...	6	4	115	92	--	--	--	--	--	--
MAR										
19...	--	--	152	90	--	--	--	--	--	--
21...	46	3	180	96	--	--	--	--	--	--
31...	46	3	30	98	--	--	--	--	--	--
APR										
15...	3	1	54	94	--	--	--	--	--	--
MAY										
09...	40	2	377	--	35	45	63	88	96	100
30...	7	3	--	--	--	--	--	--	--	--
JUN										
27...	43	4	--	--	--	--	--	--	--	--
JUL										
22...	14	3	--	--	--	--	--	--	--	--
AUG										
25...	19	2	--	--	--	--	--	--	--	--
SEP										
06...	<3	3	--	--	--	--	--	--	--	--

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.

[<, less than; E, estimated]

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 TOTAL (MG/L AS N) (00625)
OCT 1986												
27...	1434	12.5	691	91	2860	2760	9.8	103	8.36	8.10	2.5	0.60
NOV												
25...	1200	-0.5	699	197	3030	3070	11.9	89	8.23	8.10	9.1	1.0
DEC												
30...	1700	0.0	694	108	2960	3110	12.3	93	8.23	7.70	4.4	0.60
JAN 1987												
27...	1405	0.0	695	49	2790	2950	13.2	100	8.08	7.80	--	--
FEB												
12...	1430	E0.0	--	80	--	--	--	--	--	--	--	--
MAR												
02...	1245	-0.5	698	79	2900	3030	12.9	96	8.36	7.86	--	--
06...	1640	2.5	--	1270	--	--	--	--	8.13	--	--	--
07...	1450	5.0	--	1350	--	--	--	--	8.02	--	--	--
23...	1350	--	--	E224	--	--	--	--	--	--	--	--
26...	1345	6.0	688	110	2510	2340	12.0	108	8.40	8.04	4.2	0.50
APR												
06...	1720	8.5	--	1960	1130	--	9.5	--	8.50	--	81	80
27...	1435	17.0	704	434	1330	1250	9.3	105	8.40	8.21	1.3	0.90
MAY												
20...	1540	12.5	693	319	1960	2030	10.2	107	8.66	8.20	1.9	0.80
27...	1120	--	--	957	--	--	--	--	--	--	--	--
JUN												
01...	1925	20.0	--	684	1250	--	--	--	8.31	--	3.1	2.5
29...	1150	22.0	700	232	2000	2250	8.4	106	8.38	8.30	1.6	1.1
JUL												
30...	1225	28.0	692	272	1860	1830	8.4	119	8.32	8.20	--	--
AUG												
30...	1630	22.5	702	243	1900	1890	8.7	110	8.60	8.20	--	--
SEP												
28...	1600	15.5	701	156	1960	1980	10.0	110	8.44	8.30	--	--
OCT												
23...	1345	8.0	698	48	2320	2440	11.9	111	8.40	8.10	--	--
NOV												
17...	1035	0.0	696	42	2560	2670	12.1	92	8.38	8.20	3.2	0.20
JAN 1988												
29...	1420	0.0	687	28	2820	2840	8.8	67	7.71	7.70	--	--
29...	1425	0.0	687	28	2820	2840	8.8	67	7.71	7.70	--	--
MAR												
26...	1550	0.5	695	412	--	4010	10.6	81	8.34	7.90	--	--

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHOROUS TOTAL (MG/L AS P) (00665)	PHOS-PHOROUS 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 TOTAL (MG/L AS CACO3) (00900)
OCT 1986												
27...	0.30	1.90	1.90	<0.010	0.020	4.3	4.2	--	<0.01	2570	2250	1300
NOV												
25...	1.0	8.10	7.80	0.030	0.024	5.3	5.6	--	<0.01	2900	2630	1300
DEC												
30...	0.60	3.80	3.80	<0.010	0.010	3.7	3.6	--	<0.01	2840	2640	1500
JAN 1987												
27...	1.0	--	4.30	0.010	0.010	3.9	3.8	--	<0.01	2550	2350	1400
FEB												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
02...	2.3	--	1.60	0.010	0.030	4.3	4.3	<0.010	<0.01	2750	2500	1200
06...	--	5.30	--	0.450	--	39	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
26...	0.40	3.70	3.70	0.040	0.009	4.4	4.6	--	0.02	2020	1870	940
APR												
06...	--	0.800	--	3.10	--	37	--	--	--	--	--	--
27...	0.60	0.400	0.400	0.020	0.006	6.9	3.1	--	<0.01	1040	1000	640
MAY												
20...	0.90	1.10	1.10	0.100	<0.005	5.5	4.2	--	<0.01	1690	1450	810
27...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
01...	--	0.600	--	0.830	--	15	--	--	--	--	--	--
29...	0.80	0.500	0.480	0.182	0.046	5.8	5.2	--	<0.01	1640	1500	800
JUL												
30...	0.70	--	0.220	0.030	<0.005	6.9	5.7	<0.010	<0.01	1550	1430	860
AUG												
30...	0.40	--	0.560	<0.010	0.006	5.8	4.5	<0.010	<0.01	1610	1510	850
SEP												
28...	0.20	--	1.00	0.010	<0.005	4.6	4.3	--	<0.01	1680	1520	900
OCT												
23...	0.20	--	1.60	<0.010	<0.005	3.7	3.4	<0.010	<0.01	2160	1840	1100
NOV												
17...	0.20	3.00	2.90	<0.010	<0.005	3.4	3.4	--	<0.01	2440	2190	1100
JAN 1988												
29...	0.60	--	3.00	0.010	<0.005	--	4.6	--	<0.01	2600	2260	1300
29...	0.60	--	3.00	--	<0.005	--	3.6	--	<0.01	2600	2170	1200
MAR												
26...	--	--	5.40	0.050	0.017	17	--	<0.010	<0.01	3470	3180	1100

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	SODIUM PERCENT (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)
OCT 1986												
27...	109	250	160	220	3	27	11	27	1500	0.50	4.2	9
NOV												
25...	173	260	170	310	4	33	10	30	1700	0.70	6.4	7
DEC												
30...	282	290	180	250	3	27	14	19	1700	0.50	4.1	13
JAN 1987												
27...	--	300	150	230	3	27	10	33	1600	0.60	4.6	5
FEB												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
02...	256	240	150	290	4	34	10	46	1600	0.50	3.4	5
06...	--	--	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
26...	138	180	120	210	3	32	8.7	46	1200	0.50	3.6	6
APR												
06...	--	--	--	--	--	--	--	--	--	--	--	--
27...	179	160	58	60	1	17	5.2	13	590	0.50	8.0	15
MAY												
20...	167	180	88	150	2	28	7.6	21	890	0.50	2.9	8
27...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
01...	--	--	--	--	--	--	--	--	--	--	--	--
29...	131	180	85	130	2	26	9.5	17	990	0.40	3.6	11
JUL												
30...	139	200	86	110	2	22	9.1	13	920	0.50	3.4	13
AUG												
30...	113	200	85	130	2	25	8.6	15	990	0.50	3.7	31
SEP												
28...	95	210	91	130	2	24	3.3	18	1000	0.50	3.0	10
OCT												
23...	110	230	120	180	2	27	7.7	23	1200	0.60	4.4	8
NOV												
17...	116	230	130	210	3	29	7.7	30	1500	0.50	2.8	6
JAN 1988												
29...	252	300	140	190	2	24	10	42	1400	0.60	8.4	5
29...	218	260	130	190	2	26	10	26	1400	0.50	8.1	5
MAR												
26...	176	180	150	550	7	53	10	55	2100	0.40	4.1	5

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	BORON, DIS-SOLVED (UG/L AS B) (01020)	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)
OCT 1986												
27...	--	<1	--	<1	20	--	260	<0.1	--	--	<10	1
NOV												
25...	--	<1	--	2	20	--	400	<0.1	--	--	<10	<1
DEC												
30...	--	<1	--	2	360	--	520	<0.1	--	--	10	<1
JAN 1987												
27...	430	<1	--	2	20	--	520	<0.1	--	--	10	<1
FEB												
12...	--	--	--	--	--	--	--	--	--	--	--	--
MAR												
02...	370	<1	<1	5	60	<5	410	1.1	<0.10	<1.0	<10	<1
06...	--	--	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--	--	--
23...	--	--	--	--	--	--	--	--	--	--	--	--
26...	290	<1	--	2	10	--	420	<0.1	--	--	<10	<1
APR												
06...	--	--	--	--	--	--	--	--	--	--	--	--
27...	150	<1	--	1	3	--	8	<0.1	--	--	9	1
MAY												
20...	280	<1	--	1	10	--	30	<0.1	--	--	120	2
27...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
01...	--	--	--	--	--	--	--	--	--	--	--	--
29...	--	<1	--	5	<10	--	10	<0.1	--	--	<10	2
JUL												
30...	290	<1	<1	2	7	<5	7	0.1	--	<1.0	14	1
AUG												
30...	80	<1	1	<1	8	<5	7	<0.1	<0.10	<1.0	6	1
SEP												
28...	290	<1	--	2	3	--	17	<0.1	--	--	<3	2
OCT												
23...	390	<1	3	2	20	<5	60	--	0.10	1.0	<10	<1
NOV												
17...	400	<1	--	<1	10	--	50	<0.1	--	--	<10	<1
JAN 1988												
29...	400	<1	--	2	20	--	220	<0.1	--	--	10	1
29...	--	<1	--	2	20	--	220	<0.1	--	--	10	<1
MAR												
26...	230	<1	2	4	230	<5	50	<0.1	0.20	<1.0	10	1

Table 29.--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)
OCT 1986											
27...	--	15	96	--	--	--	--	--	--	--	--
NOV											
25...	--	40	93	--	--	--	--	--	--	--	--
DEC											
30...	--	131	63	--	--	--	--	--	--	--	--
JAN 1987											
27...	--	7	84	--	--	--	--	--	--	--	--
FEB											
12...	--	49	91	--	--	--	--	--	--	--	--
MAR											
02...	12	20	94	--	--	--	--	--	--	--	--
06...	--	3960	--	50	59	67	74	90	96	99	100
07...	--	4460	--	66	77	84	89	97	99	100	--
23...	--	120	97	--	--	--	--	--	--	--	--
26...	--	22	93	--	--	--	--	--	--	--	--
APR											
06...	--	3920	--	59	70	79	88	96	97	100	--
27...	--	153	94	--	--	--	--	--	--	--	--
MAY											
20...	--	115	96	--	--	--	--	--	--	--	--
27...	--	1630	--	68	79	87	93	99	99	100	--
JUN											
01...	--	684	--	65	79	90	97	99	99	100	--
29...	--	45	95	--	--	--	--	--	--	--	--
JUL											
30...	3	46	93	--	--	--	--	--	--	--	--
AUG											
30...	4	49	96	--	--	--	--	--	--	--	--
SEP											
28...	--	23	91	--	--	--	--	--	--	--	--
OCT											
23...	3	15	63	--	--	--	--	--	--	--	--
NOV											
17...	--	--	--	--	--	--	--	--	--	--	--
JAN 1988											
29...	--	10	61	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
MAR											
26...	34	396	99	62	74	83	89	--	--	--	--

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	TIME	TEMPER- ATURE WATER (DEG C) (00010)	BARO- METRIC PRES- SURE (MM OF HG) (00025)	STREAM- FLOW, INSTAN- TANEOUS (CFS) (00061)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	SPE- CIFIC CON- DUCT- ANCE LAB (US/CM) (90095)	OXYGEN, DIS- SOLVED (MG/L) (00300)	OXYGEN, DIS- SOLVED (PER- CENT SATUR- ATION) (00301)	PH (STAND- ARD UNITS) (00400)	PH LAB (STAND- ARD UNITS) (00403)	NITRO- GEN, TOTAL (MG/L AS N) (00600)
APR 1988											
27...	1430	13.5	693	61	1870	1880	10.9	116	8.45	8.30	--
27...	1440	13.5	693	61	1870	1870	10.9	116	8.45	8.20	--
MAY											
10...	1715	20.0	701	249	2750	2790	9.0	108	8.31	7.90	12
JUN											
30...	1625	20.5	699	342	1790	1120	8.9	109	8.48	8.30	--
JUL											
01...	2115	--	--	799	1620	--	--	--	--	--	--
21...	1310	25.0	702	214	1930	1940	9.4	125	8.40	8.00	--
SEP											
22...	1435	17.0	696	66	2240	2230	9.2	105	8.34	8.30	--

DATE	NITRO- GEN,AM- MONIA + ORGANIC TOTAL (MG/L AS N) (00625)	NITRO- GEN,AM- MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO- GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITRO- GEN, NO2+NO3 DIS- SOLVED (MG/L AS N) (00631)	PHOS- PHOROUS TOTAL (MG/L AS P) (00665)	PHOS- PHOROUS 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 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)
APR 1988											
27...	--	--	--	1.00	--	--	--	--	--	1560	1440
27...	--	0.20	--	1.00	--	0.004	--	3.5	--	--	1430
MAY											
10...	1.1	0.90	11.0	11.0	0.020	0.008	9.0	5.8	<0.01	2290	2200
JUN											
30...	--	--	--	--	--	--	--	--	--	--	--
JUL											
01...	--	--	--	--	--	--	--	--	--	--	--
21...	--	0.60	--	0.270	0.040	0.005	--	5.2	--	--	1490
SEP											
22...	--	0.40	--	0.790	--	0.003	--	3.9	--	--	1830

DATE	HARD- NESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (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)
APR 1988											
27...	790	166	160	96	130	2	26	7.9	24	920	--
27...	770	166	160	91	130	2	27	7.0	17	920	0.60
MAY											
10...	870	136	150	120	350	5	46	9.6	40	1400	0.50
JUN											
30...	--	148	--	--	--	--	--	--	--	--	--
JUL											
01...	--	--	--	--	--	--	--	--	--	--	--
21...	820	132	180	89	110	2	22	8.7	16	1000	0.40
SEP											
22...	1000	166	230	110	150	2	24	11	21	1200	--

Table 29.--Chemical analyses of surface-water samples collected at Belle Fourche River near Sturgis, S. Dak.--Continued

WATER QUALITY DATA

DATE	SILICA, DIS-SOLVED (MG/L AS SIO2) (00955)	ARSENIC DIS-SOLVED (UG/L AS AS) (01000)	BORON, DIS-SOLVED (UG/L AS B) (01020)	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)	ZINC, DIS-SOLVED (UG/L AS ZN) (01090)
APR 1988											
27...	--	7	250	<1	<1	3	--	<5	--	<0.1	5
27...	1.5	8	250	--	--	--	3	--	78	--	6
MAY											
10...	4.3	11	250	<1	--	3	10	--	50	<0.1	<10
JUN											
30...	--	1	--	--	--	--	--	--	10	--	<10
JUL											
01...	--	--	--	--	--	--	--	--	--	--	--
21...	3.8	12	270	--	--	--	9	--	11	--	17
SEP											
22...	--	10	--	--	--	--	20	--	10	--	20

DATE	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)	SED. SUSP. FALL DIAM. % FINER THAN .062 MM (70342)	SED. SUSP. FALL DIAM. % FINER THAN .125 MM (70343)
APR 1988										
27...	--	3	--	--	--	--	--	--	--	--
27...	--	--	--	--	--	--	--	--	--	--
MAY										
10...	1	--	286	98	--	--	--	--	--	--
JUN										
30...	--	--	212	--	41	49	--	71	95	100
JUL										
01...	--	--	2910	--	67	77	87	91	99	100
21...	--	--	--	--	--	--	--	--	--	--
SEP										
22...	--	--	--	--	--	--	--	--	--	--

Table 30.--Chemical analyses of surface-water samples collected at Belle Fourche River near Elm Springs, S. Dak.

[<, less than; >, greater than; E, estimated]

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 TOTAL (MG/L AS N) (00625)
MAR 1987												
07...	1240	1.0	--	1210	--	--	--	--	8.03	--	--	--
APR												
16...	1230	12.0	703	624	1590	1630	8.7	88	8.55	8.20	1.6	0.90
MAY												
27...	1425	16.0	696	4920	1140	1160	7.7	86	8.08	7.90	14	13
27...	1520	16.0	696	5020	1140	--	7.7	86	8.08	--	--	--
JUN												
24...	1300	22.5	708	228	2300	--	8.0	100	8.42	--	1.4	0.50
29...	1445	24.0	700	207	2290	2240	8.7	114	8.40	8.30	--	1.0
29...	1455	24.0	708	207	2290	2260	8.7	112	8.38	8.20	1.0	0.80
JUL												
30...	1525	31.0	E705	254	1860	1840	7.9	--	8.32	7.90	--	<0.20
30...	1530	31.0	E705	254	1860	1830	7.9	--	8.32	8.20	--	<0.20
AUG												
31...	1435	22.5	711	165	1960	1970	9.0	112	8.34	7.90	--	--
31...	1445	22.5	711	165	1960	1990	9.0	112	8.34	8.20	--	0.70
SEP												
29...	1115	12.0	715	136	2130	2050	11.2	112	8.40	8.20	--	--
29...	1120	12.0	--	136	2130	2050	--	--	8.40	8.30	--	--
OCT												
21...	1310	4.0	703	52	2500	2480	12.4	104	8.30	8.30	--	--
21...	1315	4.0	703	52	2500	2450	12.4	104	8.30	8.10	--	0.40
NOV												
19...	1445	1.0	715	33	2650	2750	12.5	94	8.33	8.10	--	--
JAN 1988												
28...	1050	0.0	706	20	4700	4690	12.0	90	7.79	7.70	--	--
MAR												
29...	1140	2.5	705	540	2040	1950	11.2	90	8.70	7.90	--	--
APR												
19...	0915	10.5	701	62	2380	2390	11.4	112	8.40	8.20	--	0.30
19...	0920	--	701	62	--	2390	11.4	--	--	8.10	--	--
19...	0925	--	--	62	--	2400	--	--	--	8.10	--	--
MAY												
26...	1015	23.0	701	261	2230	--	8.6	111	8.33	--	--	--
JUL												
19...	1515	24.0	713	210	2020	--	8.9	114	8.41	--	--	--
SEP												
07...	1520	18.0	696	225	2030	1980	8.8	103	8.35	8.10	--	--

Table 30.--Chemical analyses of surface-water samples collected at Belle Fourche River near Elm Springs, S. Dak.--Continued

WATER QUALITY DATA

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)	PHOSPHOROUS TOTAL (MG/L AS P) (00665)	PHOSPHOROUS 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 TOTAL (MG/L AS CACO3) (00900)	ALKALINITY LAB (MG/L AS CACO3) (90410)
MAR 1987												
07...	--	6.50	--	1.00	--	48	--	--	--	--	--	--
APR												
16...	0.60	0.700	0.760	0.040	0.012	8.0	4.2	<0.01	1310	1250	670	165
MAY												
27...	1.3	0.600	0.530	>1.00	0.055	110	7.9	<0.01	803	781	300	82
27...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
24...	--	0.900	--	0.030	--	4.7	--	--	--	--	--	--
29...	--	--	0.170	0.170	0.040	--	--	--	1930	1780	870	137
29...	1.1	0.200	0.190	0.026	0.024	4.5	4.6	0.01	1880	1770	860	133
JUL												
30...	0.70	<0.100	<0.100	0.043	<0.005	6.2	5.4	<0.01	1590	1490	860	114
30...	1.1	<0.100	<0.100	0.038	0.008	6.2	5.4	<0.01	1590	1460	830	116
AUG												
31...	0.40	--	1.10	--	0.005	5.5	4.3	<0.01	1670	1560	880	134
31...	--	--	1.10	0.340	0.210	--	--	--	1710	1510	840	96
SEP												
29...	0.20	--	0.440	--	<0.005	4.5	4.7	<0.01	1750	1620	890	105
29...	<0.20	--	0.440	--	<0.005	4.5	4.3	<0.01	1760	1630	880	128
OCT												
21...	<0.20	--	1.10	--	<0.005	3.6	3.6	<0.01	2240	1970	1200	110
21...	--	--	1.00	<0.010	<0.010	--	--	--	2230	2010	1200	148
NOV												
19...	0.70	--	1.90	--	<0.005	3.6	3.6	<0.01	2520	2190	1100	147
JAN 1988												
28...	0.60	--	1.80	--	<0.005	--	5.3	<0.01	4750	4190	2000	368
MAR												
29...	--	4.70	2.50	0.017	0.014	27	7.2	<0.01	1440	1510	550	121
APR												
19...	--	--	0.970	0.020	<0.010	--	--	--	2100	1970	970	160
19...	0.30	--	--	--	0.010	--	3.4	--	--	--	--	159
19...	0.30	--	<0.100	--	<0.010	--	3.5	--	--	--	--	160
MAY												
26...	0.40	--	0.830	--	0.020	--	4.3	--	--	--	--	147
JUL												
19...	0.30	--	--	--	<0.010	--	4.8	--	--	--	--	--
SEP												
07...	0.60	--	1.00	--	<0.010	--	4.0	--	--	--	--	128

Table 30.--Chemical analyses of surface-water samples collected at Belle Fourche River near Elm Springs, 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)	SODIUM PERCENT (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 1987												
07...	--	--	--	--	--	--	--	--	--	--	--	--
APR												
16...	160	66	130	2	29	6.9	22	750	0.50	7.6	6	210
MAY												
27...	76	27	120	3	46	7.3	11	480	0.40	7.6	2	--
27...	--	--	--	--	--	--	--	--	--	--	--	--
JUN												
24...	--	--	--	--	--	--	--	--	--	--	--	--
29...	190	95	170	3	30	10	21	1200	0.40	2.5	5	--
29...	180	100	170	3	30	10	22	1200	0.10	7.5	6	--
JUL												
30...	200	87	120	2	23	2.3	15	990	0.50	2.8	8	--
30...	190	87	120	2	24	1.0	16	970	0.60	2.9	8	--
AUG												
31...	200	92	150	2	27	8.9	18	1000	0.50	3.7	8	--
31...	190	88	140	2	26	8.8	18	970	0.50	3.6	--	--
SEP												
29...	190	100	140	2	--	<0.10	20	1100	0.50	2.4	7	--
29...	190	99	140	2	26	1.5	19	1100	0.50	2.5	7	--
OCT												
21...	260	140	170	2	23	7.1	24	1300	0.50	2.3	6	--
21...	260	130	170	2	24	7.0	24	1300	0.50	2.3	7	--
NOV												
19...	220	130	200	3	28	7.6	32	1500	0.50	1.8	4	--
JAN 1988												
28...	430	220	550	6	38	12	38	2700	0.50	7.2	6	--
MAR												
29...	120	60	300	6	54	8.7	24	910	0.40	1.3	2	--
APR												
19...	190	120	230	3	34	9.8	23	1300	0.50	0.70	4	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
MAY												
26...	--	--	--	--	--	--	--	--	--	--	--	--
JUL												
19...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
07...	--	--	--	--	--	--	--	--	--	--	9	--

Table 30.--Chemical analyses of surface-water samples collected at Belle Fourche River near Elm Springs, 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)	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)	ALUM-INUM, DIS-SOLVED (UG/L AS AL) (01106)
MAR 1987											
07...	--	--	--	--	--	--	--	--	--	--	--
APR											
16...	<1	--	<1	<3	--	6	<0.1	--	5	<1	--
MAY											
27...	<1	--	8	9	--	2	<0.1	--	84	2	--
27...	--	--	--	--	--	--	--	--	--	--	--
JUN											
24...	--	--	--	--	--	--	--	--	--	--	--
29...	<1	<1	1	<10	<5	10	<0.1	<1.0	<10	--	<10
29...	<1	--	3	<10	--	10	--	--	30	1	--
JUL											
30...	<1	--	1	<3	--	4	<0.1	--	6	1	--
30...	<1	--	1	4	--	6	<0.1	--	52	1	--
AUG											
31...	<1	--	1	<3	--	5	<0.1	--	5	1	--
31...	--	--	--	--	--	--	--	--	--	--	--
SEP											
29...	<1	--	2	20	--	10	<0.1	--	20	1	--
29...	<1	--	2	20	--	20	<0.1	--	20	1	--
OCT											
21...	1	--	1	10	--	40	<0.1	--	<10	<1	--
21...	<1	2	2	20	<5	40	<0.1	<1.0	<10	--	10
NOV											
19...	<1	--	3	10	--	40	<0.1	--	<10	1	--
JAN 1988											
28...	<1	--	2	60	--	10	<0.1	--	10	<1	--
MAR											
29...	<1	--	3	<10	--	10	<0.1	--	<10	2	--
APR											
19...	<1	1	<1	20	<5	30	<0.1	<1.0	<10	--	10
19...	--	--	--	20	--	30	--	--	<10	--	--
19...	--	--	--	20	--	40	--	--	<10	--	--
MAY											
26...	--	--	--	<10	--	20	--	--	<10	--	--
JUL											
19...	--	--	--	--	--	--	--	--	--	--	--
SEP											
07...	--	--	--	18	--	6	--	--	33	--	--

Table 30.--Chemical analyses of surface-water samples collected at Belle Fourche River near Elm Springs, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	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 1987											
07...	--	7960	--	55	65	74	83	95	98	100	100
APR											
16...	--	534	--	65	77	86	92	96	98	99	100
MAY											
27...	--	12900	--	64	75	85	91	97	98	99	100
27...	--	12600	--	66	77	87	92	98	99	100	100
JUN											
24...	--	56	98	--	--	--	--	--	--	--	--
29...	4	122	99	--	--	--	--	--	--	--	--
29...	--	49	98	--	--	--	--	--	--	--	--
JUL											
30...	--	45	89	--	--	--	--	--	--	--	--
30...	--	50	92	--	--	--	--	--	--	--	--
AUG											
31...	--	51	98	--	--	--	--	--	--	--	--
31...	--	86	98	--	--	--	--	--	--	--	--
SEP											
29...	--	31	76	--	--	--	--	--	--	--	--
29...	--	--	--	--	--	--	--	--	--	--	--
OCT											
21...	--	15	73	--	--	--	--	--	--	--	--
21...	3	5	69	--	--	--	--	--	--	--	--
NOV											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1988											
28...	--	13	64	--	--	--	--	--	--	--	--
MAR											
29...	--	2870	100	73	85	94	99	--	--	--	--
APR											
19...	4	58	96	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--
MAY											
26...	--	45	98	--	--	--	--	--	--	--	--
JUL											
19...	--	--	--	--	--	--	--	--	--	--	--
SEP											
07...	--	--	--	--	--	--	--	--	--	--	--

Table 31.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.

[<, less than; >, greater than; E, estimated]

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 TOTAL (MG/L AS N) (00625)
OCT 1986												
28...	1240	12.0	722	130	2270	2240	--	--	8.34	7.80	1.1	0.60
DEC												
02...	1310	0.0	720	521	2550	2630	13.3	97	8.24	8.20	6.0	1.2
02...	1400	0.0	--	518	2550	2640	13.3	--	8.49	7.90	--	1.0
18...	1630	-0.5	718	400	2570	2650	13.6	99	8.41	8.10	2.4	0.70
JAN 1987												
11...	1410	-0.5	--	340	2570	2650	16.4	--	8.49	8.10	--	--
FEB												
12...	1230	0.0	--	E100	--	--	--	--	--	--	--	--
19...	1225	1.0	725	400	2330	2270	14.0	104	8.48	8.19	3.3	1.1
19...	1305	1.0	725	400	2230	2290	14.0	104	8.48	8.20	--	1.2
APR												
01...	1650	3.5	719	5460	1480	1410	11.6	93	8.18	8.20	4.7	4.2
28...	1255	18.0	717	1020	1890	1980	10.0	113	8.37	8.04	--	0.90
JUN												
01...	1425	22.0	714	3520	1800	1830	8.2	101	8.41	8.20	2.6	2.1
01...	1500	22.0	--	3380	--	--	--	--	--	--	--	--
19...	1200	23.5	719	530	2250	2290	8.0	101	8.32	8.20	--	1.1
24...	1800	24.0	720	425	2280	--	6.8	86	8.28	--	2.0	1.7
JUL												
23...	1120	26.5	--	530	--	--	--	--	--	--	--	--
23...	1135	26.5	716	522	--	1590	6.8	90	8.24	8.00	11	10
AUG												
31...	1040	17.0	726	405	1950	1970	8.6	94	8.24	7.90	1.9	1.0
31...	1045	--	--	405	--	--	--	--	--	--	--	--
SEP												
30...	1115	14.0	725	253	2350	2450	10.1	103	8.22	8.00	--	--
30...	1120	14.0	--	253	--	--	--	--	--	--	--	--
OCT												
22...	1145	5.5	772	182	2570	2590	13.0	103	8.36	8.20	--	--
22...	1200	5.5	729	174	2570	2600	13.0	109	8.62	8.00	--	<0.20
NOV												
19...	1140	1.0	728	167	2440	2520	12.1	90	8.32	8.10	--	--
JAN 1988												
28...	1510	0.0	715	40	3110	3150	>20.0	--	8.34	8.10	--	--
MAR												
29...	1700	5.5	--	2480	2390	2240	11.1	--	8.39	7.90	4.1	1.4
APR												
21...	1320	7.0	714	194	--	2820	12.0	106	--	8.10	--	--

Table 31.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	NITRO-GEN,AM-MONIA + ORGANIC DIS. (MG/L AS N) (00623)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N) (00630)	NITRO-GEN, NO2+NO3 DIS-SOLVED (MG/L AS N) (00631)	PHOS-PHOROUS TOTAL (MG/L AS P) (00665)	PHOS-PHOROUS 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 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 TOTAL (MG/L AS CACO3) (00900)	ALKA-LINITY LAB (MG/L AS CACO3) (90410)
OCT 1986												
28...	0.80	0.500	0.470	0.048	<0.005	3.2	3.1	<0.01	1910	1770	870	151
DEC												
02...	0.90	4.80	4.80	0.195	<0.005	5.1	5.0	<0.01	2260	2080	980	127
02...	--	--	4.90	0.330	0.060	--	--	--	2290	2170	1100	213
18...	0.70	1.70	1.70	0.068	0.040	5.3	3.7	<0.01	2280	2180	1100	229
JAN 1987												
11...	0.40	--	1.70	--	0.070	3.3	3.3	<0.01	2220	2040	1100	235
FEB												
12...	--	--	--	--	--	--	--	--	--	--	--	--
19...	1.2	2.20	2.30	0.185	<0.005	4.0	3.1	<0.01	1890	1800	840	191
19...	--	--	2.30	0.210	0.060	--	--	--	1910	1920	840	191
APR												
01...	0.80	0.500	0.510	--	0.061	60	6.2	<0.01	978	972	380	107
28...	0.70	<0.100	<0.100	0.019	<0.005	7.0	3.5	<0.01	1510	1450	680	150
JUN												
01...	0.80	0.500	0.460	0.920	0.040	18	5.0	<0.01	1380	1260	550	17
01...	--	--	--	--	--	--	--	--	--	--	--	--
19...	0.80	<0.100	<0.100	<0.005	<0.005	7.3	5.5	<0.01	1820	1740	740	112
24...	--	0.300	--	2.10	--	9.8	--	--	--	--	--	--
JUL												
23...	--	--	--	--	--	--	--	--	--	--	--	--
23...	1.1	1.00	0.970	0.050	0.100	66	5.6	<0.01	1190	1230	380	248
AUG												
31...	<0.20	0.900	0.900	2.50	<0.005	14	3.7	<0.01	1580	1510	740	126
31...	--	--	--	--	--	15	--	--	--	--	--	--
SEP												
30...	<0.20	--	0.360	--	<0.005	4.0	4.0	<0.01	2040	1710	890	96
30...	--	--	--	--	--	--	--	--	--	--	--	--
OCT												
22...	<0.20	--	0.420	--	<0.005	3.7	3.3	<0.01	2180	1890	960	114
22...	--	--	0.430	0.010	<0.010	--	--	--	2210	2000	1000	153
NOV												
19...	<0.20	--	0.510	--	<0.005	3.7	3.7	<0.01	2120	1860	800	140
JAN 1988												
28...	0.60	--	1.40	--	0.046	--	3.8	<0.01	2710	2350	1100	98
MAR												
29...	--	2.70	4.00	0.014	0.011	41	4.5	<0.01	1460	1570	600	79
APR												
21...	<0.20	--	<0.100	--	<0.002	--	3.7	--	--	--	--	155

Table 31.--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)	SODIUM PERCENT (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)
OCT 1986											
28...	190	95	220	3	35	12	55	1100	0.40	6.0	3
DEC											
02...	210	110	280	4	38	10	68	1300	0.50	8.0	6
02...	240	110	290	4	37	11	65	1300	0.50	9.0	5
18...	250	110	270	4	35	11	80	1300	0.60	8.7	4
JAN 1987											
11...	250	110	250	3	33	10	69	1200	0.50	7.0	4
FEB											
12...	--	--	--	--	--	--	--	--	--	--	--
19...	200	83	220	3	36	8.8	62	1100	0.40	5.3	3
19...	190	87	240	4	38	8.9	62	1200	0.50	5.4	3
APR											
01...	100	31	160	4	47	7.7	21	580	0.30	5.9	3
28...	160	69	180	3	36	7.8	59	880	0.40	6.0	4
JUN											
01...	130	54	190	4	42	10	30	820	0.40	9.6	7
01...	--	--	--	--	--	--	--	--	--	--	--
19...	170	76	240	4	41	12	66	1100	0.50	7.0	5
24...	--	--	--	--	--	--	--	--	--	--	--
JUL											
23...	--	--	--	--	--	--	--	--	--	--	--
23...	110	26	210	5	54	10	19	670	0.60	27	9
AUG											
31...	180	70	180	3	34	12	6.1	970	0.50	13	5
31...	--	--	--	--	--	--	--	--	--	--	--
SEP											
30...	200	96	200	3	32	10	42	1100	0.50	3.4	4
30...	--	--	--	--	--	--	--	--	--	--	--
OCT											
22...	220	100	210	3	32	9.8	80	1200	0.50	4.0	2
22...	250	100	250	3	34	11	82	1200	0.50	3.9	3
NOV											
19...	190	79	220	3	37	9.7	78	1200	0.50	1.5	1
JAN 1988											
28...	270	100	300	4	37	13	100	1500	0.60	4.2	3
MAR											
29...	140	60	280	5	50	0.70	23	1000	0.80	4.3	2
APR											
21...	--	--	--	--	--	--	--	--	--	--	--

Table 31.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, 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)	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)	ALUM- INUM, DIS- SOLVED (UG/L AS AL) (01106)
OCT 1986											
28...	<1	--	1	20	--	20	<0.1	--	<10	<1	--
DEC											
02...	<1	--	1	20	--	50	<0.1	--	<10	<1	--
02...	<1	<1	6	20	<5	50	<0.1	<1.0	30	--	<10
18...	<1	--	2	10	--	<10	<0.1	--	10	<1	--
JAN 1987											
11...	<1	--	2	20	--	50	<0.1	--	<10	<1	--
FEB											
12...	--	--	--	--	--	--	--	--	--	--	--
19...	<1	--	1	20	--	40	<0.1	--	<10	<1	--
19...	<1	<1	3	20	<5	40	<0.1	<1.0	<10	--	20
APR											
01...	<1	--	5	3	--	4	<0.1	--	<3	<1	--
28...	<1	--	1	4	--	2	<0.1	--	20	<1	--
JUN											
01...	<1	--	5	5	--	2	0.3	--	30	1	--
01...	--	--	--	--	--	--	--	--	--	--	--
19...	<1	--	3	20	--	20	<0.1	--	20	<1	--
24...	--	--	--	--	--	--	--	--	--	--	--
JUL											
23...	--	--	--	--	--	--	--	--	--	--	--
23...	<1	--	4	<3	--	1	--	--	62	2	--
AUG											
31...	<1	--	2	4	--	2	<0.1	--	10	1	--
31...	--	--	--	--	--	--	--	--	--	--	--
SEP											
30...	<1	--	3	20	--	20	<0.1	--	20	<1	--
30...	--	--	--	--	--	--	--	--	--	--	--
OCT											
22...	<1	--	1	10	--	60	<0.1	--	<10	<1	--
22...	1	1	7	20	<5	70	<0.1	1.0	20	--	<10
NOV											
19...	<1	--	2	10	--	60	<0.1	--	10	<1	--
JAN 1988											
28...	1	--	3	20	--	100	<0.1	--	10	<1	--
MAR											
29...	<1	--	2	5	--	10	<0.1	--	<3	<1	--
APR											
21...	--	--	--	30	--	30	--	--	<10	--	--

Table 31.--Chemical analyses of surface-water samples collected at Cheyenne River at Cherry Creek, S. Dak.--Continued

WATER QUALITY DATA

DATE	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)	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 1986											
28...	--	19	95	--	--	--	--	--	--	--	--
DEC											
02...	--	300	93	--	--	--	--	--	--	--	--
02...	11	--	--	--	--	--	--	--	--	--	--
18...	--	91	99	--	--	--	--	--	--	--	--
JAN 1987											
11...	--	21	97	--	--	--	--	--	--	--	--
FEB											
12...	--	E464	--	--	--	--	--	--	--	--	--
19...	--	247	97	53	60	--	71	77	79	93	100
19...	6	436	92	--	--	--	--	--	--	--	--
APR											
01...	--	8270	--	49	59	68	75	94	98	100	100
28...	--	160	83	--	--	--	--	--	--	--	--
JUN											
01...	--	1460	--	54	65	74	82	92	96	99	100
01...	--	1420	--	58	68	78	86	95	98	99	100
19...	--	232	99	--	--	--	--	--	--	--	--
24...	--	2810	100	78	89	96	98	--	--	--	--
JUL											
23...	--	27700	--	66	79	92	98	100	--	--	--
23...	--	27900	100	69	80	93	98	--	--	--	--
AUG											
31...	--	3520	99	73	81	94	97	--	--	--	--
31...	--	3270	100	74	85	94	98	--	--	--	--
SEP											
30...	--	54	100	--	--	--	--	--	--	--	--
30...	--	63	100	--	--	--	--	--	--	--	--
OCT											
22...	--	21	84	--	--	--	--	--	--	--	--
22...	2	--	--	--	--	--	--	--	--	--	--
NOV											
19...	--	--	--	--	--	--	--	--	--	--	--
JAN 1988											
28...	--	9	59	--	--	--	--	--	--	--	--
MAR											
29...	--	5500	--	59	70	81	88	97	98	100	--
APR											
21...	--	26	96	--	--	--	--	--	--	--	--

Table 31.--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)	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)
MAY 1988												
26...	1415	25.5	702	297	2020	2000	7.9	106	8.28	8.10	0.80	0.20
JUL												
19...	1145	24.5	726	139	2000	--	8.0	102	8.28	--	--	--
19...	1150	24.5	--	139	2000	--	--	--	8.28	--	--	--
SEP												
07...	1210	18.0	708	237	2300	2270	8.4	96	8.36	8.20	--	--

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)	PHOSPHOROUS TOTAL (MG/L AS P) (00665)	PHOSPHOROUS 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 TOTAL (MG/L AS CACO3) (00900)	ALKALINITY LAB (MG/L AS CACO3) (90410)
MAY 1988												
26...	0.50	0.600	0.570	0.024	0.012	7.6	3.6	<0.01	1550	1520	610	159
JUL												
19...	0.30	--	--	--	<0.010	--	4.1	--	--	--	--	--
19...	0.30	--	5.80	--	<0.010	--	4.0	--	--	--	--	--
SEP												
07...	0.50	--	0.160	--	<0.010	--	3.8	--	--	--	--	117

DATE	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)	SODIUM PERCENT (00932)	POTASSIUM, DISSOLVED (MG/L AS K) (00935)	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)
MAY 1988												
26...	150	57	220	4	43	11	40	930	0.60	14	8	<1
JUL												
19...	--	--	--	--	--	--	--	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
07...	--	--	--	--	--	--	--	--	--	--	5	--

DATE	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)	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)
MAY 1988												
26...	2	6	3	<0.1	8	1	2790	100	84	91	93	95
JUL												
19...	--	--	--	--	--	--	34	--	--	--	--	--
19...	--	--	--	--	--	--	--	--	--	--	--	--
SEP												
07...	--	<10	<10	--	10	--	--	--	--	--	--	--

Table 32.--Chemical analysis of surface-water samples collected at miscellaneous sites

[<, less than; E, estimated]

DATE	TIME	TEMPERATURE WATER (DEG C) (00010)	BAROMETRIC PRESSURE (MM OF HG) (00025)	DISCHARGE, INST. CUBIC FEET PER SECOND (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 DISSOLVED (MG/L AS N) (00602)
452023103451901 YELLOW CREEK NEAR KIRK POWER PLANT (LAT 45 20 23N LONG 103 45 19W)											
MAY 1987											
12...	1315	15.5	--	0.85	284	298	7.9	--	7.90	7.80	0.56
442135103442001 GOLD RUN CREEK AT MOUTH (LAT 44 21 35N LONG 103 44 20W)											
MAY 1987											
12...	1425	20.5	636	7.6	1050	1530	--	--	8.38	8.30	21
442322103423701 LEAD DEAD MUNICIPAL S.T.P. OUTFLOW (LAT 44 23 22N LONG 103 42 37W)											
MAY 1987											
12...	1720	11.5	643	3.9	647	684	6.8	74	7.50	7.60	6.9
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)											
MAR 1987											
07...	1015	5.0	--	3460	--	--	--	--	8.43	--	--
JUN											
23...	1300	22.5	701	125	2130	--	8.2	104	8.22	--	--
AUG											
31...	1640	24.5	--	112	2110	--	--	--	8.64	--	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)											
NOV 1986											
25...	1625	--	--	34	--	--	--	--	--	--	--
MAR 1987											
06...	1930	--	--	E200	--	--	--	--	--	--	--
07...	1650	3.0	--	615	--	--	--	--	8.00	--	--

Table 32.--Chemical analysis of surface-water samples collected at miscellaneous sites--Continued

DATE	NITROGEN, AMMONIA + ORGANIC TOTAL (MG/L AS N) (00625)	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)	PHOSPHOROUS TOTAL (MG/L AS P) (00665)	PHOSPHOROUS 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)
452023103451901 YELLOW CREEK NEAR KIRK POWER PLANT (LAT 45 20 23N LONG 103 45 19W)										
MAY 1987										
12...	--	0.30	--	0.260	--	<0.005	4.8	2.5	<0.01	165
442135103442001 GOLD RUN CREEK AT MOUTH (LAT 44 21 35N LONG 103 44 20W)										
MAY 1987										
12...	--	1.7	--	19.0	--	0.240	9.5	1.7	0.23	1110
442322103423701 LEAD DEAD MUNICIPAL S.T.P. OUTFLOW (LAT 44 23 22N LONG 103 42 37W)										
MAY 1987										
12...	--	1.5	--	5.40	--	0.320	12	4.0	0.01	382
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)										
MAR 1987										
07...	--	--	0.500	--	0.110	--	41	--	--	--
JUN										
23...	0.90	--	<0.100	--	0.270	--	6.1	--	--	--
AUG										
31...	--	--	--	--	--	--	--	--	--	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
NOV 1986										
25...	--	--	--	--	--	--	--	--	--	--
MAR 1987										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--

Table 32.--Chemical analysis of surface-water samples collected at miscellaneous sites--Continued

DATE	SOLIDS, SUM OF CONSTI-TUENTS, DIS-SOLVED (MG/L) (70301)	HARD-NESS TOTAL (MG/L AS CACO3) (00900)	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)	SODIUM PERCENT (00932)	POTAS-SIUM, DIS-SOLVED (MG/L AS K) (00935)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL) (00940)
	452023103451901 YELLOW CREEK NEAR KIRK POWER PLANT (LAT 45 20 23N LONG 103 45 19W)									
MAY 1987										
12...	177	140	84	35	12	2.8	0.1	4	3.3	2.9
	442135103442001 GOLD RUN CREEK AT MOUTH (LAT 44 21 35N LONG 103 44 20W)									
MAY 1987										
12...	1140	550	94	110	68	110	2	29	18	8.7
	442322103423701 LEAD DEAD MUNICIPAL S.T.P. OUTFLOW (LAT 44 23 22N LONG 103 42 37W)									
MAY 1987										
12...	378	250	213	63	22	37	1	24	3.9	48
	06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)									
MAR 1987										
07...	--	--	--	--	--	--	--	--	--	--
JUN										
23...	--	--	--	--	--	--	--	--	--	--
AUG										
31...	--	--	--	--	--	--	--	--	--	--
	06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)									
NOV 1986										
25...	--	--	--	--	--	--	--	--	--	--
MAR 1987										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--

Table 32.--Chemical analysis of surface-water samples collected at miscellaneous sites--Continued

DATE	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)	CADMIUM DIS- SOLVED (UG/L AS CD) (01025)	COPPER, DIS- SOLVED (UG/L AS CU) (01040)	IRON, DIS- SOLVED (UG/L AS FE) (01046)	MANGA- NESE, DIS- SOLVED (UG/L AS MN) (01056)	MERCURY DIS- SOLVED (UG/L AS HG) (71890)	ZINC, DIS- SOLVED (UG/L AS ZN) (01090)
452023103451901 YELLOW CREEK NEAR KIRK POWER PLANT (LAT 45 20 23N LONG 103 45 19W)										
MAY 1987										
12...	56	0.20	13	<1	<1	1	380	54	<0.1	12
442135103442001 GOLD RUN CREEK AT MOUTH (LAT 44 21 35N LONG 103 44 20W)										
MAY 1987										
12...	670	1.2	11	28	<1	16	63	68	<0.1	72
442322103423701 LEAD DEAD MUNICIPAL S.T.P. OUTFLOW (LAT 44 23 22N LONG 103 42 37W)										
MAY 1987										
12...	38	0.90	14	20	<1	8	20	19	0.6	65
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)										
MAR 1987										
07...	--	--	--	--	--	--	--	--	--	--
JUN										
23...	--	--	--	--	--	--	--	--	--	--
AUG										
31...	--	--	--	--	--	--	--	--	--	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
NOV 1986										
25...	--	--	--	--	--	--	--	--	--	--
MAR 1987										
06...	--	--	--	--	--	--	--	--	--	--
07...	--	--	--	--	--	--	--	--	--	--

Table 32.--Chemical analysis of surface-water samples collected at miscellaneous sites--Continued

DATE	ANTI-MONY, DIS-SOLVED (UG/L AS SB) (01095)	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)
452023103451901 YELLOW CREEK NEAR KIRK POWER PLANT (LAT 45 20 23N LONG 103 45 19W)										
MAY 1987										
12...	<1	--	--	--	--	--	--	--	--	--
442135103442001 GOLD RUN CREEK AT MOUTH (LAT 44 21 35N LONG 103 44 20W)										
MAY 1987										
12...	5	57	90	--	--	--	--	--	--	--
442322103423701 LEAD DEAD MUNICIPAL S.T.P. OUTFLOW (LAT 44 23 22N LONG 103 42 37W)										
MAY 1987										
12...	2	--	--	--	--	--	--	--	--	--
06423500 CHEYENNE RIVER NEAR WASTA,SD (LAT 44 04 52N LONG 102 24 03W)										
MAR 1987										
07...	--	15400	--	--	--	--	--	95	--	--
JUN										
23...	--	475	100	--	--	--	--	--	--	--
AUG										
31...	--	451	100	--	--	--	--	--	--	--
06436760 HORSE CR ABOVE VALE SD (LAT 44 39 08N LONG 103 21 59W)										
NOV 1986										
25...	--	55	97	--	--	--	--	--	--	--
MAR 1987										
06...	--	E1730	--	--	--	--	--	--	--	--
07...	--	3510	--	50	58	69	80	98	100	100

Table 33.--Sediment concentrations and particle sizes of samples collected by depth integration at the centroid of flow

[E, estimated]

DATE	TIME	TEMPER- ATURE WATER (DEG C) (00010)	STREAM- FLOW, INSTAN- TANEOUS (CFS) (00061)	SPE- CIFIC CON- DUCT- ANCE (US/CM) (00095)	SPE- CIFIC CON- DUCT- ANCE LAB (US/CM) (90095)	SEDI- MENT, SUS- PENDED (MG/L) (80154)
06436180 WHITEWOOD CR ABOVE WHITEWOOD SD (LAT 44 26 32N LONG 103 37 44W)						
MAY 1988						
09...	1035	--	136	--	--	242
09...	2015	9.5	160	393	400	162
10...	0035	--	149	--	450	409
10...	0230	--	147	--	380	189
10...	0435	--	141	--	680	378
10...	0635	--	140	--	410	485
10...	0835	--	139	--	480	155
10...	1044	--	138	--	280	127
JUN						
13...	1555	--	60	--	--	1090
13...	1625	--	91	--	660	899
13...	1655	--	85	--	650	593
13...	1725	--	81	--	640	624
06437000 BELLE FOURCHE R NEAR STURGIS SD (LAT 44 30 47N LONG 103 08 11W)						
MAR 1988						
26...	1530	1.5	E400	2910	--	746
27...	1610	4.0	E450	3280	--	1510
28...	0710	2.0	E236	3190	--	439
29...	0630	0.0	E186	2760	--	238
30...	0715	3.5	E148	2630	--	120
APR						
11...	0715	5.5	E69	2080	--	22
21...	1000	8.0	65	1880	1900	32
25...	0730	6.0	66	1800	1800	12
MAY						
02...	0730	7.0	78	1980	2000	140
09...	0615	6.5	99	2630	250	77
10...	0625	10.0	255	1980	1900	354
11...	0620	14.0	199	2250	2200	115
17...	0625	15.0	206	1640	1600	117
24...	0605	16.5	169	2100	2000	114
30...	0610	20.0	225	1990	1800	252
JUN						
06...	0810	20.0	259	1870	1800	171
13...	0555	19.0	251	1900	1900	233
20...	0610	23.5	214	1870	1800	95
28...	0530	23.5	251	1900	1800	107

Table 33.--Sediment concentrations and particle sizes of samples collected by depth integration at the centroid of flow--Continued

DATE	TIME	TEMPER-ATURE WATER (DEG C) (00010)	STREAM-FLOW, INSTAN-TANEOUS (CFS) (00061)	SPE-CIFIC CON-DUCT-ANCE (US/CM) (00095)	SPE-CIFIC CON-DUCT-ANCE LAB (US/CM) (90095)	SEDI-MENT, SUS-PENDED (MG/L) (80154)
06437000 BELLE FOURCHE R NEAR STURGIS SD--Continued						
JUL						
01...	0645	17.0	1180	1480	1400	6520
02...	0625	18.0	585	1670	1600	1890
03...	0620	20.5	528	1620	1700	848
04...	0600	23.0	393	1520	1600	990
11...	0700	20.0	199	1850	1900	54
18...	0645	19.0	199	1900	2000	46
25...	0640	19.0	232	1800	1800	30
AUG						
01...	0640	21.0	217	1900	1800	54
05...	0725	19.0	334	1880	1900	32
08...	0720	20.0	283	1830	1800	74
15...	0700	20.0	229	1900	1900	88
29...	0645	14.0	251	2060	1900	84
SEP						
19...	0720	9.0	113	1920	1950	65
26...	0745	12.0	57	2110	2050	74

Of the 4 bedload samples, the first three were collected by wading the stream using a hand-held sampler. The first two samples were single-equal-width-increment samples, collected by compositing subsamples from 20 sections sampled in two successive passes of the cross section. The third sample was a 6-vertical unequal-width-increment sample and was collected an hour after the second sample. The fourth sample was an 8-vertical unequal-width-increment sample collected from a bridge. Subsamples were collected from the bridge using the cable-suspended sampler, and particle-size distributions were determined for each vertical. Samples were sent to the U.S. Geological Survey's sediment lab in Iowa City for analysis, and results are listed in table 34.

During September to October 1988, 16 bulk samples of bed material were collected at the 5 main-stem sites using techniques described by T. R. Yuzyk (1986). At each site, 3 or 4 locations spaced from 5 to 20 channel widths apart were selected for sampling (table 35). Samples were collected by scraping off the top layer of material from a gravel bar and scooping the underlying material from a hole that was 1.5 to 2.5 ft deep and 0.5 ft in diameter. Most of the sample holes were cored with a concentric-pipe sampler, and bulk material was scooped by hand from the smaller pipe into the larger pipe. There were many larger-sized rocks at 6 sampling points and a shovel was used to dig and scoop up a sample. Samples were placed in plastic-lined canvas bags, and wet weights of the bags ranged from about 35 to 175 pounds.

Four of the 16 samples were selected to be analyzed by the U.S. Geological Survey. Large particle sizes were determined by personnel in Rapid City, and a split of the sample remainder was sent to the U.S. Geological Survey laboratory in Iowa City, Iowa (table 36). The remaining 12 samples were sent to Travis Labs, Rapid City, South Dakota, for analyses. Results of the analyses are listed in table 37.

Particle-size samples of the streambed surface were collected near each of the bulk-material sampling locations, in cross sections which are described in table 34. At each location, one or two cross sections were selected for sampling, and about 50 particles were collected within each. Normally the cross section passes were made across the active stream channel, but in 3 cases the second pass was across a gravel bar. U.S. Geological Survey personnel determined the particle sizes of the samples and results of the analyses are listed in table 38.

Table 34.--Bedload data collected at station 06437000 Belle Fourche River near Sturgis, S. Dak.

Date	Begin time	End time	Streamflow discharge (cubic feet per second)	Stream-width (feet)	Number of verticals sampled	Number of subsamples	Sampling time (seconds)	Bedload discharge (tons per day)
05-09-88	1420	1510	(195)	91	20	40	800	0.91
05-10-88	1335	1350	(260)	95	20	40	600	.87
05-10-88	1455	1525	(295)	95	6	6	720	.94
07-01-88	1825	2050	(1,000)	120	8	16	840	23.8

Date	Bedload (tons per day)	Station (in feet from left edge of water)	Size distribution									Weight of sample (grams)
			16	8	4	2	1	0.5	0.25	0.125	0.062	
05-09-88[1]	0.91	--	100	100	98.6	98.1	97.1	94.7	79.0	57.4	42.1	20.9
05-10-88[1]	.87	--	100	100	97.9	96.5	93.0	71.3	20.3	14.6	10.5	14.3
05-10-88[2]	.94	--	--	--	--	--	--	--	--	--	--	--
07-01-88	23.8	--										
07-01-88[3]		20	100	92.5	71.8	42.2	19.5	4.8	1.1	.7	.4	81.5
07-01-88[3]		35	100	96.4	80.9	61.7	45.2	19.5	1.8	.6	.3	262.9
07-01-88[3]		45	100	100	100	98.8	96.2	87.5	47.5	17.5	10.0	8.0
07-01-88[3]		55	100	95.9	93.3	90.2	85.7	68.1	18.1	3.0	1.4	129.0
07-01-88[3]		65	100	95.6	89.8	85.0	80.9	66.7	11.3	2.9	1.9	355.8
07-01-88[3]		80	100	99.0	85.5	69.8	57.5	42.4	21.9	4.1	1.5	142.4
07-01-88[3]		95	100	100	100	100	98.2	91.2	72.6	28.3	16.8	11.3
07-01-88[3]		110	100	100	100	100	83.3	75.0	54.2	29.2	16.7	2.4

[1]Composited sample.
[2]No size distribution for second sample on 5-10-88.
[3]Each of the eight subsamples was analyzed separately.

Table 35.--Locations and descriptions of bed-material sampling points

Station number	Cross-section number	Distance from gage (river miles)	Description of streambed sampling points	
			Bulk samples[1]	Surface
06436180	1	0.05 upstream	right side bar	streambed
	2	.05 downstream	left side bank	streambed
	3	.2 downstream	right side bank	streambed
06436198	1	.08 upstream	right side bar	streambed
	2	.2 upstream	left side bar	streambed
	3	.3 upstream	right side bar	streambed
06437000	1	.2 upstream	mid-channel bar	streambed
	2	.3 upstream	right point bar	streambed
	3	1.2 upstream	mid-channel bar	streambed
	4	1.6 upstream	left point bar	streambed
06438000	1	.02 downstream	mid-channel bar	streambed, bar
	2	.7 upstream	left point bar	streambed, bar
	3	1.1 upstream	mid-channel bar	streambed
06439300	1	.2 downstream	right point bar	streambed, bar
	2	.4 downstream	left point bar	streambed, bar
	3	.6 downstream	right point bar	streambed, bar

[1]Right and left refer to the sides of the channel when looking downstream.

Table 36.--Size distributions of bulk-material streambed samples from Whitewood Creek, and the Belle Fourche and Cheyenne Rivers (analyses performed at Travis Laboratory, Rapid City, South Dakota)

Station number	Cross-section number	millimeters 0.045	0.075	0.15	0.18	0.25	0.30	0.60	0.85	1.4	2.0	2.36	4.75	12.7	19.0	25.4	50.8	120	680
06436180	1a	0.3	0.4	0.6	0.7	1.1	1.6	6.5	12	20	24	26	33	48	55	62	82	93	100
	1b	.3	.5	.7	.9	1.5	2.0	7.5	14	21	25	27	34	47	56	61	81	93	100
	2	.3	.5	1.1	1.4	2.0	2.4	4.4	5.8	7.9	9.3	9.9	12	16	18	21	35	42	100
	3	1.1	1.3	2.0	2.6	3.9	4.7	7.8	9.0	10	11	11	14	18	20	22	27	82	100
06437000	3	.7	.8	.9	1.3	2.4	3.6	17	27	35	39	41	49	70	80	85	98	98	100
	4	1.9	2.1	2.6	3.8	6.6	8.0	12	15	20	23	25	34	53	60	68	97	97	100
06438000	1	1.2	1.3	1.5	2.2	4.3	6.3	24	31	36	39	40	49	76	89	96	100	100	100
	2	1.2	1.3	1.8	2.7	5.6	7.7	17	20	26	30	33	43	66	78	84	93	96	100
	3	1.0	1.1	1.3	1.6	2.3	2.7	4.2	5.6	8.5	12	14	24	43	55	65	92	96	100
06439300	1	.6	.7	.8	1.2	2.0	2.5	5.0	11	21	28	31	41	62	71	80	97	97	100
	2	.4	.5	.6	.9	2.2	4.0	18	26	35	40	44	57	80	87	91	97	97	100
	3	1.2	1.3	1.4	1.8	2.7	3.5	7.5	10	16	21	24	40	65	76	87	100	100	100

Table 37.--Size distributions of bulk-material streambed samples from Whitewood Creek, and the Belle Fourche and Cheyenne Rivers (analyses performed by U.S. Geological Survey, Iowa City, Iowa)

Station number	Cross-section number	millimeters 0.062	0.125	0.25	0.5	1.0	2.0	4.0	7.5	17	34	70	120
06436198	1	1.3	2.3	3.3	3.9	4.2	4.7	7.1	9.3	33	71	71	100
	2	1.5	2.8	6.9	13	16	20	28	30	53	86	86	100
	3	2.2	3.9	7.2	12	17	21	26	28	45	77	77	100
06437000	2a	11	12	15	21	26	32	45	46	66	84	84	100
	2b	8.6	9.2	11	14	18	23	33	34	59	80	80	100

Table 38.--Size distributions of particles collected from the surface of channel beds at 5 main-stem sampling sites

Site number	Cross-section sampling location[1]	Number of particles	Distribution of particles sizes (millimeters along b-axis)						
			Mininum	P.10[2]	P.25[2]	P.50[2]	P.75[2]	P.90[2]	Maximum
06436180	1a	40	8	13.0	18.00	32.5	44.50	78.6	98
	1b	60	17	27.2	36.50	54.0	79.75	106.8	240
	2	79	9	13.0	21.00	34.0	66.00	127.0	162
	3a	51	12	24.2	32.00	40.0	76.00	108.6	241
	3b	52	15	21.6	31.00	51.5	75.75	111.1	189
06436198	1a	50	14	24.3	33.75	47.0	63.00	71.0	114
	1b	50	7	21.2	36.75	51.0	69.50	85.8	218
	2	50	9	14.1	17.75	26.0	34.50	44.0	111
	3	50	11	15.3	27.00	36.0	45.00	61.0	132
06437000	1a	57	9	17.0	23.00	36.0	48.00	70.2	166
	1b	50	15	18.0	33.00	46.0	64.00	86.5	128
	2a	50	12	28.1	40.50	53.0	67.25	108.6	135
	2b	50	9	12.1	15.00	31.5	59.25	84.6	210
	3a	55	15	17.6	32.00	44.0	61.00	65.8	104
	3b	53	12	15.4	24.50	38.0	55.50	66.8	78
	4a	54	11	16.0	25.00	37.0	62.00	84.5	192
	4b	48	9	16.9	30.25	47.5	72.50	91.0	140
06438000	1a	56	15	26.1	32.50	41.5	56.00	81.9	148
	1b	54	11	17.5	24.75	34.0	44.00	59.5	171
	2a	51	17	25.2	36.00	45.0	58.00	64.8	85
	2b	62	10	19.3	30.00	39.0	52.00	64.7	151
	3a	56	14	21.0	29.25	38.0	54.50	66.2	97
	3b	49	13	23.0	30.00	44.0	68.50	105.0	141
06439300	1a	54	8	9.5	12.00	14.5	18.00	24.5	32
	1b	50	3	3.0	3.00	3.0	58.50	103.9	149
	2a	54	8	11.0	12.75	19.5	30.50	40.5	64
	2b	50	3	3.0	3.00	3.0	11.25	27.5	68
	3	51	8	12.0	14.00	20.0	23.00	26.8	45

[1]See table 35 for explanation and description of sampling cross sections.
[2]Respective percentiles.

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Chapter E. Field Investigations of the Effect of Stream pH on Dissolved Arsenic Concentrations

by Christopher C. Fuller, Kimball E. Goddard, and James A. Davis

INTRODUCTION

An understanding of the processes controlling partitioning of reactive solutes between dissolved and solid phases is required in order to develop adequate models to describe solute transport in hydrologic systems. The role of adsorption processes on oxide surfaces in controlling dissolved inorganic solutes at concentrations below the solubilities of pure phases has been the focus of numerous field and laboratory investigations (Morel, 1983; Dreaver, 1982). The inverse pH dependence of adsorption on oxide surfaces has been demonstrated for the oxyanions of several elements (Davis and Leckie, 1980) and has been observed for oxyanions of arsenic (Anderson and others, 1976; Pierce and Moore, 1982; Goldberg, 1986). In the Whitewood Creek basin, field studies have suggested the importance of abundant iron oxides in the control of dissolved arsenic in stream water (Goddard, 1989; Fuller and others, 1987; Cherry and others, 1986). A laboratory study by Wuolo (1986) indicated the partitioning of arsenic between solutions and flood-plain sediments was strongly pH dependent. To elucidate the role of adsorption-desorption processes in controlling dissolved arsenic in Whitewood Creek, field investigations of temporal fluctuations in dissolved arsenic in response to diurnal stream-water pH fluctuations were conducted. This chapter contains field data collected during these studies. Interpretive reports utilizing these results along with results of laboratory experiments and additional field measurements are published elsewhere (Fuller and others, 1989; Fuller and Davis, in press).

Data previously collected from sites on lower Whitewood Creek indicate pH varies more than two units seasonally (Goddard, 1987) and as much as 0.7 units diurnally in August 1986, and June 1987 (Fuller, unpublished data on file at U.S. Geological Survey office, Menlo Park, California). To determine if this natural pH variation resulted in a corresponding variation in dissolved arsenic concentration in Whitewood Creek, two diurnal sampling studies were conducted. A preliminary sample set was collected on July 7 and 8, 1987, at Whitewood Creek above Vale (site 14). A second, more comprehensive sample set was collected on August 11, 12, and 13, 1987, at the sites Whitewood Creek above Gold Run (site 3), Gold Run at mouth (site 4), Whitewood Creek above Whitewood (site 9), Whitewood Creek at Custer Camp (site 13), and Whitewood Creek at the Sheeler site (site 16).

SAMPLE COLLECTION AND HANDLING PROCEDURES

Samples for pH measurement and arsenic analysis were collected either in a single container from the center of flow, or, at the Sheeler site, were composited from 4 subsamples collected across the channel. Concurrent measurements of water temperature, specific conductance, and dissolved oxygen are available for the first sample set and concurrent measurements of water temperature are available for the second set. Measurement of pH was made using an Orion model SA-250 digital meter. Samples in the first set were filtered through a 0.1-μm filter and preserved with nitric acid. Samples in the second set were filtered through a 0.1 μm filter and preserved with hydrochloric acid to 1 percent (V/V).

ANALYTICAL PROCEDURES AND RESULTS

Samples from the preliminary study were analyzed for total inorganic arsenic concentration by the U.S. Geological Survey Central Laboratory in Arvada, Colorado, by hydride generation and atomic absorption spectrophotometry (Skougstad and others, 1979). More than 90 percent of the dissolved arsenic in Whitewood Creek has been reported to exist in the +5 oxidation state (Fuller and others, in press). Field data and analytical results are listed in table 39. Samples from the comprehensive study were analyzed by C. Fuller at the U.S. Geological Survey National Research Program office at Menlo Park, California, by hydride generation atomic absorption spectrophotometry. Field data and analytical results are listed in tables 40, 41, 42, 43, and 44. Graphical presentations of the pH and dissolved arsenic concentration data for Whitewood Creek at Custer Camp (site 13), and Whitewood Creek at the Sheeler site (site 16), are shown in figures 8 and 9.

Table 39.--Water temperature, pH, conductivity, and dissolved-oxygen and arsenic concentrations measured at Whitewood Creek above Vale, July 7-8, 1987

[μS/cm, microsiemens per centimeter at 25 °C; μg/L, micrograms per liter]

Date	Time	Temperature (°C)	pH (units)	Specific conductance (μS/cm)	Dissolved oxygen (mg/L)	Dissolved arsenic (μg/L)	Comments
July 7	1500	24.9	8.49	1,180	11.1	43	Clear and sunny. Air temperature 31 °C.
	1600	26.0	8.52	1,190	11.0	--	Clear and sunny.
	1700	25.8	8.50	1,190	9.8	51 (47)	Duplicate samples. Cloudy since 1630.
	1800	24.5	8.40	1,090	6.4	41	Very heavy rain starting at 1740. Air temperature 22 °C.
	1900	23.5	8.30	1,180	5.3	44	Rain ends at 1820.
	2000	22.4	8.21	1,180	4.9	--	
	2100	21.6	8.14	1,180	4.6	41	Dusk.
	2200	21.4	8.10	1,190	4.4	--	Dark.
	2300	20.4	8.06	1,180	4.9	42	
	2400	19.7	8.02	1,170	5.3	--	Air temperature 18 °C.
July 8	0100	19.1	8.03	1,170	5.6	35 (33)	Duplicate samples. Water slightly turbid.
	0200	18.6	8.06	1,160	5.6	--	Water still slightly turbid.
	0300	18.3	8.04	1,150	5.8	35	
	0400	18.0	8.04	1,150	5.8	--	Early light; fog.
	0500	17.8	8.04	1,150	5.9	34	Heavy fog. Air temperature 13.5 °C.
	0600	17.4	8.06	1,150	6.2	--	Fog.
	0700	17.5	8.10	1,160	7.0	35	Fog.
	0800	17.6	8.18	1,170	8.0	--	Fog.
	0900	18.3	8.25	1,160	9.4	38	Sunny since 0830. Air temperature 22.5 °C.
	1000	19.6	8.34	1,160	10.5	--	Full sun.
	1100	21.2	8.39	1,170	11.1	45(?)[1]	Duplicate samples.
	1200	23.0	8.43	1,160	11.8	--	Clear and hot.
	1300	24.5	8.46	1,160	11.8	(?)[1]	Clear and hot. Air temperature 31.5 °C.

[1]Samples collected but data not received from NWQL.

Table 40.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek above Gold Run, August 12-13, 1987

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-12-87	1000	13.0	8.51	0.05	0.01
	1400	15.0	8.49	.07	.01
	1800	15.0	8.47	.07	.01
	2400	12.0	8.36	.05	.02
8-13-87	0600	11.5	8.37	.06	.01

Table 41.--Water temperature, pH, and dissolved-arsenic concentration measured at Gold Run at Mouth, August 12-13, 1987

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-12-87	1200	22.0	8.34	0.28	0.02
	2000	21.5	8.31	.22	.01
8-13-87	0400	20.5	8.27	.27	.02
	1000	21.5	8.23	.27	.01

Table 42.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek above Whitewood, August 12-13, 1987

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-12-87	0900	17.0	8.11	--	--
	0930	17.5	7.92	--	--
	1000	17.0	8.51	0.44	0.01
	1030	17.0	8.74	--	--
	1100	17.5	8.36	--	--
	1115	17.5	8.61	--	--
	1130	17.5	8.75	--	--
	1145	18.0	8.93	--	--
	1200	18.5	8.95	.40	.02
	1230	19.0	8.98	--	--
	1300	19.5	8.88	--	--
	1330	19.0	8.75	--	--
	1345	19.5	8.77	--	--
	1400	19.0	8.69	.43	.01
	1430	19.0	8.52	--	--
	1500	19.0	8.33	--	--
	1530	19.0	8.63	--	--
	1545	18.8	8.77	--	--
	1600	18.8	8.93	.40	.01
	1630	18.8	8.90	--	--
	1700	18.8	8.90	--	--
	1730	18.8	8.91	--	--
	1800	18.5	8.84	.44	.03
	1830	18.5	8.97	--	--
	1900	18.0	8.92	--	--
	1915	18.0	8.91	--	--
	1930	17.5	8.84	--	--
	1945	17.5	8.74	--	--
	2000	17.5	8.71	.43	.02
	2015	17.5	8.55	--	--
	2030	17.5	8.71	--	--
	2100	17.5	8.71	.47	.03
	2200	17.0	8.73	.47	.01
	2300	16.5	8.73	.48	.01
8-13-87	--	16.5	8.76	.46	.02
	0100	16.0	8.62	.48	.01
	0200	15.5	8.61	.43	.01
	0300	15.5	8.65	.42	.01
	0400	15.5	8.66	.37	.01
	0500	15.0	8.63	--	--
	0530	15.0	8.62	--	--
	0545	15.0	8.56	--	--
	0600	15.0	8.57	--	--
	0615	15.0	8.62	--	--
	0630	15.0	8.69	--	--
	0645	15.0	8.72	--	--
	0700	15.0	8.68	.39	.01
	0715	15.0	8.75	--	--

Table 42.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek above Whitewood, August 12-13, 1987--Continued

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-13-87	0730	15.0	8.73	--	--
	0745	15.0	8.72	--	--
	0800	15.0	8.73	--	--
	0830	15.0	8.75	--	--
	0900	15.5	8.75	0.41	0.01
	0930	16.0	8.76	--	--
	1004	16.0	8.72	--	--
	1030	17.0	8.64	.42	.01
	1100	18.0	8.82	--	--
	1130	19.0	8.87	--	--
	1200	19.5	8.92	.40	.01
	1230	20.3	8.96	--	--
	1300	21.5	8.97	--	--
	1330	22.0	8.96	--	--
	1400	22.0	8.96	.42	.01
	1430	23.8	9.06	--	--
	1500	24.5	8.96	.42	.03
	1530	24.0	9.07	--	--
	1600	24.5	9.05	.40	.01
	1700	24.0	9.01	.40	.01
	1730	23.5	8.98	--	--
	1800	23.0	8.98	.43	.01
	1830	23.0	8.92	--	--
	1900	23.0	8.92	.42	.02
	1915	22.0	8.91	--	--
	1930	22.0	8.88	--	--
	1945	21.5	8.85	--	--
	2000	21.5	8.84	.43	.01
	2015	21.0	8.78	--	--
	2030	21.0	8.73	--	--
	2045	21.0	8.68	--	--
	2100	21.0	8.66	.42	.02

Table 43.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek at Custer, August 12-13, 1987

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-12-87	--	18.0	8.54	0.92	0.01
	0930	18.0	8.56	--	--
	1000	18.0	8.57	.89	.03
	1030	18.0	8.59	--	--
	1045	18.0	8.58	--	--
	1100	19.0	8.60	1.00	.01
	1130	19.0	8.63	--	--
	1145	20.0	8.63	--	--
	1200	20.0	8.66	1.02	.04
	1215	20.5	8.66	--	--
	1230	20.5	8.66	--	--
	1245	21.0	8.66	--	--
	1300	21.0	8.66	1.03	.02
	1315	21.0	--	--	--
	1330	22.0	8.65	--	--
	1400	23.0	8.67	.98	.01
	1430	23.0	8.61	--	--
	1445	23.0	8.61	--	--
	1500	22.0	8.60	.99	.04
	1530	22.5	8.58	--	--
	1545	22.5	8.58	--	--
	1600	22.0	8.55	1.03	.04
	1615	22.0	8.54	--	--
	1630	21.5	8.53	--	--
	1645	21.5	8.53	--	--
	1700	21.5	8.54	1.03	.03
	1730	21.5	8.56	--	--
	1800	21.5	8.54	1.03	.04
	1845	21.0	8.55	--	--
	1900	21.0	8.48	1.03	.01
	1930	20.0	8.42	--	--
	1945	20.0	8.38	--	--
	2000	19.5	8.38	.97	.01
	2015	19.0	8.32	--	--
	2030	19.0	8.33	--	--
	2045	19.0	8.30	--	--
	2100	19.0	8.28	.87	.01
	2115	19.0	8.30	--	--
	2130	18.5	8.27	--	--
	2145	18.5	8.30	--	--
	2200	18.5	8.25	.97	.12
	2215	18.0	8.23	--	--
	2300	17.5	8.23	.92	.01
	2400	17.0	8.19	.88	.01
8-13-87	0100	17.0	8.32	.83	.01
	0130	17.0	8.20	--	--
	0200	17.0	8.20	.81	.01
	0300	16.5	8.21	.80	.01
	0400	16.0	8.26	.81	.01

Table 43.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek at Custer, August 12-13, 1987--Continued

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-13-87	0500	16.0	8.23	0.80	0.02
	0545	16.0	8.27	--	--
	0600	16.0	8.24	.77	.01
	0630	16.0	8.26	--	--
	0700	16.0	8.32	.81	.03
	0730	16.0	8.34	--	--
	0745	16.5	8.43	--	--
	0800	16.5	8.39	.80	.01
	0815	16.5	8.53	--	--
	0830	16.5	8.52	--	--
	0845	17.0	8.56	--	--
	0900	17.0	8.48	.82	.01
	0915	17.0	8.48	--	--
	0930	17.5	8.55	--	--
	0945	18.0	8.57	--	--
	1000	18.5	8.60	.88	.03
	1030	19.2	8.61	--	--
	1045	20.0	8.66	--	--
	1100	20.0	8.70	.96	.04
	1115	20.0	8.68	--	--
	1130	20.0	8.68	--	--
	1145	21.5	8.69	--	--
	1200	22.5	8.64	.95	.02
	1215	23.0	8.64	--	--
	1230	26.5	8.66	--	--
	1300	24.0	8.63	.99	.01
	1330	25.0	8.65	--	--
	1400	25.5	8.63	1.03	.04
	1430	25.5	8.64	--	--
	1500	26.0	8.64	1.02	.04
	1530	26.0	8.61	--	--
	1600	26.0	8.59	1.10	.01
	1700	26.0	8.55	1.01	.14
	1730	25.5	8.48	--	--
	1800	25.0	8.51	.97	.03
	1830	24.0	8.42	--	--
	1845	24.0	8.39	--	--
	1900	24.0	8.38	.92	.01
	1915	24.0	8.31	--	--
	1930	24.0	8.28	--	--
	1945	23.5	8.26	--	--
	2000	23.0	8.24	.96	.02
	2015	23.0	8.21	--	--
	2030	22.5	8.19	--	--
	2100	22.0	8.17	.85	.07

Table 44.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek at Sheeler site, August 11-13, 1987

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-11-87	1027	22.6	7.88	0.60	0.03
	1124	23.2	8.20	.64	.04
	1143	23.7	8.28	--	--
	1211	24.5	8.28	.60	.02
	1235	25.6	8.30	--	--
	1304	26.4	8.33	.65	.04
	1331	27.2	8.33	--	--
	1401	28.4	8.41	.71	.06
	1433	28.4	8.34	--	--
	1501	28.9	8.32	.78	.01
	1531	29.3	8.31	--	--
	1601	29.1	8.31	.72	.01
	1631	29.4	8.30	--	--
	1701	29.3	8.30	.69	.07
	1730	28.2	8.28	--	--
	1801	27.8	8.27	.70	.03
	1831	27.0	--	--	--
	1901	26.3	8.24	.69	.04
	2004	24.0	8.25	.68	.02
	2010	24.0	8.16	--	--
	2035	23.9	8.22	--	--
	2100	23.5	8.18	.52	.03
	2130	23.3	8.08	--	--
	2200	23.0	8.05	.65	.04
	2234	22.5	8.11	--	--
	2259	22.4	8.12	.65	.01
08-12-87	0145	20.7	8.12	.64	.01
	0235	20.1	8.20	.58	.03
	0307	19.9	8.21	--	--
	0327	19.9	8.17	.57	.01
	0419	19.4	8.18	.55	.01
	0511	19.0	8.21	.57	.01
	0539	18.6	8.21	--	--
	0607	18.6	8.20	.58	.01
	0644	18.0	8.17	--	--
	0645	18.1	8.22	--	--
	0654	18.1	8.16	.61	.01
	0825	18.1	8.17	.56	.02
	0850	18.2	8.21	--	--
	0915	18.3	8.21	.60	.03
	1000	18.7	8.24	.58	.03
	1028	19.1	8.27	--	--
	1059	19.4	8.27	.62	.02
	1129	19.6	8.30	--	--
	1200	20.2	8.30	.60	.01
	1255	22.1	8.33	.63	.01
	1331	23.3	8.36	--	--
	1400	23.4	8.36	.63	.01
	1431	23.7	8.36	--	--

Table 44.--Water temperature, pH, and dissolved-arsenic concentration measured at Whitewood Creek at Sheeler site, August 11-13, 1987--Continued

Date	Time	Water temperature (°C)	pH (units)	Dissolved-arsenic concentration (micromoles per liter)	Precision of analysis (micromoles per liter)
8-12-87	1502	24.4	8.35	0.64	0.02
	1530	24.2	8.34	--	--
	1600	24.1	8.34	.63	.01
	1632	23.9	8.33	--	--
	1702	23.4	8.34	.64	.01
	1731	23.2	8.33	--	--
	1800	22.6	8.31	.70	.01
	1840	22.0	8.29	--	--
	1702	21.7	8.27	.74	.01
	1930	21.2	8.27	--	--
	2009	20.6	8.25	.72	.05
	2034	20.1	8.24	--	--
	2058	19.9	8.24	.74	.02
	2132	19.6	8.20	--	--
	2203	19.3	8.21	.73	.03
	2234	18.9	8.22	--	--
	2300	18.7	8.20	.70	.04
	2400	18.5	8.13	.69	.02
8-13-87	0141	18.0	8.20	.67	.03
	0228	17.8	8.19	.64	.02
	0326	17.5	8.21	.63	.02
	0417	17.4	8.21	.58	.02
	0620	16.8	8.10	.57	.02
	0716	16.6	8.10	.60	.04
	0844	17.0	8.20	.56	.01
	0918	17.4	8.25	--	--
	0948	18.1	8.30	.53	.01
	1030	19.3	8.28	--	--
	1100	20.3	8.28	.60	.04
	1113	20.6	8.32	--	--
	1128	21.1	8.32	--	--
	1204	22.4	8.34	.63	.03
	1228	23.1	8.34	--	--
	1306	24.6	8.35	.68	.04
	1334	25.2	8.34	--	--
	1406	26.0	8.34	.70	.02
	1501	27.0	8.33	.68	.01
	1605	27.5	8.32	.68	.03
	1705	27.3	8.31	.69	.02
	1803	26.3	8.28	.73	.03
	1827	24.0	--	--	--

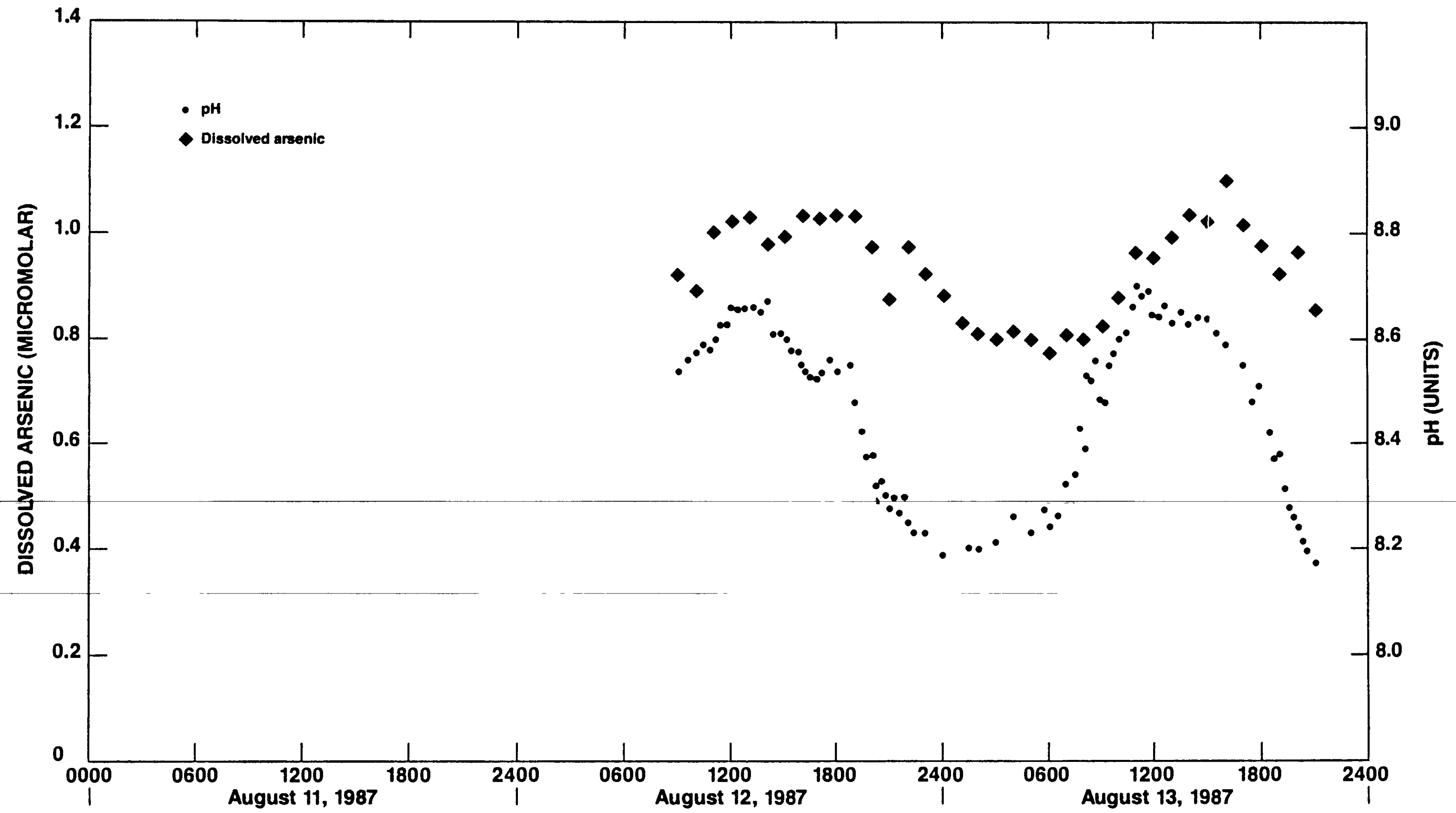

Figure 8.--Diurnal fluctuation of dissolved arsenic concentration and pH in Whitewood Creek at Custer Camp.

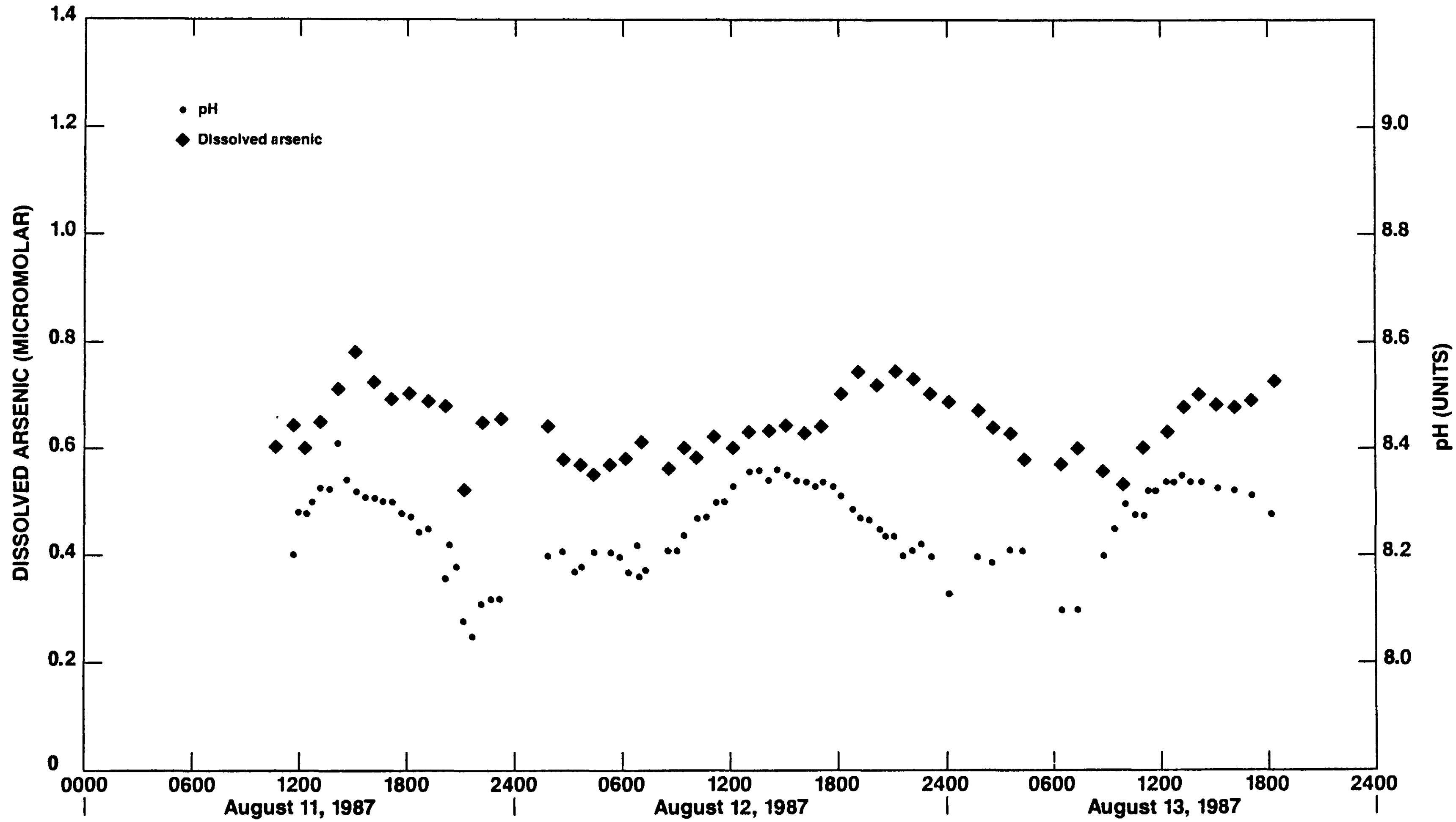

Figure 9.--Diurnal fluctuation of dissolved arsenic concentration and pH in Whitewood Creek at Sheeler Seep.

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Chapter F. Laboratory Investigation of the Effect of Solution pH on the Concentration of Dissolved Arsenic and Trace Metals

by Kimball E. Goddard

PROCEDURES AND RESULTS

An attempt to duplicate the effect of solution pH on the corresponding concentration of dissolved arsenic was made by conducting a set of laboratory experiments. The experiments were qualitative and used natural alluvial sediments rather than more precisely quantified artificial materials. The three sediment samples used were collected previously by Wuolo from the flood plain of Whitewood Creek at site 12 (fig. 1, table 1) and have been analyzed extensively for mineral and chemical composition, and adsorption/desorption characteristics (Wuolo, 1986; Goddard, 1988). Two of the samples were contaminated by mill tailings (TC-1; TC-3), while the third sample was an uncontaminated alluvial sediment (AC-1).

The experiments consisted of placing a 1,400-g sample of sediment into a polycarbonate jar, adding 4,000 mL of deionized water, and continuously pumping the water through the sediment in a circuit open to the atmosphere. Water samples were collected from the circuit after pH stabilization, and small volumes of 1 m NaOH were added to incrementally change the pH. Specific conductance was measured by a Yellow Springs Model 32 conductance meter with glass probe, and pH was measured by an Orion Model SA-250 digital pH meter with combination probe. Samples for arsenic and metal analysis were filtered through 0.1-μm filters and preserved with nitric acid. Laboratory analysis was conducted by the U.S. Geological Survey Central Laboratory in Arvada, Colorado, using standard procedures (Skougstad and others, 1979). Experimental and analytical data for the three samples are listed in table 45.

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Table 45.--Experimental and analytical data from a laboratory study of the effect of pH on arsenic and selected metal concentration in a mixture of sediment and deionized water

[mL, milliliters; µS/cm, microsiemens per centimeter at 25 °C; mg/L, milligrams per liter; µg/L, micrograms per liter]

Date	Time	Sodium hydroxide (mL)	Specific conductance (µS/cm)	pH (units)	Sodium (mg/L)	Calcium (mg/L)	Arsenic (µg/L)	Copper (µg/L)	Iron (µg/L)	Manganese (µg/L)	Zinc (µg/L)
AC-1											
10/14/88	1530	--	--	7.80	--	--	--	--	--	--	--
10/18/88	1100	0	2,380	8.06	7.8	470	1	30	20	230	20
10/24/88	1015	14	2,010	8.03	83	360	2	20	10	800	10
11/03/88	0845	19	2,310	8.13	98	370	1	20	10	250	20
11/08/88	0900	39	2,310	8.74	190	280	1	20	10	20	10
TC-1											
10/14/88	1530	--	--	3.97	--	--	--	--	--	--	--
10/18/88	1345	0	3,450	4.16	3.6	530	41	90	270	88,000	480
10/22/88	1230	17	3,360	5.61	92	520	24	30	40	42,000	130
10/23/88	1515	22	3,460	6.18	120	520	24	20	20	30,000	60
10/26/88	1400	37	3,270	6.94	170	470	6	20	9	8,400	20
10/31/88	1345	49.5	3,310	7.43	210	450	10	20	9	3,200	20
11/03/88	1430	54.5	3,070	8.42	240	410	16	10	3	730	10
11/08/88	1000	74.5	3,040	9.34	280	350	12	10	20	40	10
TC-3											
10/13/88	1600	--	--	3.37	--	--	--	--	--	--	--
10/17/88	1315	0	2,930	3.11	2.7	550	5	290	910	22,000	470
10/20/88	1330	15	3,020	3.66	74	560	3	180	160	19,000	400
10/21/88	1315	25	3,010	4.02	120	520	3	100	30	14,000	300
10/23/88	1500	45	3,280	4.58	230	530	2	30	40	6,400	100
10/27/88	1100	65	3,450	5.24	280	500	1	20	7	2,400	30
10/29/88	1215	75	3,600	5.72	300	480	1	20	10	1,000	20
11/02/88	1330	95	3,610	6.82	370	460	2	20	9	210	10
11/05/88	1100	115	3,730	7.54	410	430	3	20	10	80	10
11/06/88	1500	125	3,770	8.23	450	410	8	20	8	30	10
11/08/88	1315	145	3,750	8.67	520	380	11	20	20	7	10

Chapter G. Biological Investigations - Surface-Water Toxics Program, Whitewood Creek

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

INTRODUCTION

Previous studies have shown that biological processes can play an important role in water-quality modeling and monitoring (Kuwabara and others, 1984; Cain and others, 1988; Kuwabara and others 1988). Two research projects involved in biological studies were continued from the 1986 water year. One project examined the potential importance of periphyton growth on arsenic stream transport. The other project examined arsenic accumulation in benthic invertebrates as a tool for determining the fate of arsenic within the Cheyenne River system. Data from the two studies are presented in two subsections. In each subsection, the study objectives and experimental methods are briefly described prior to presentation of tabular data. Additional results and some interpretation of these data have been presented at the 1988 Toxic Substances Hydrology Program Technical Meeting (Cain and others, 1989; Kuwabara and others, 1989).

WORK ON PERIPHYTON

Attempting to model the role of periphyton effects on arsenic (As) transport within an aquatic environment is complicated by biological and chemical interactions (Button and others, 1973; Sanders, 1979) and a lack of understanding of the effects of physical parameters (for example, light and temperature) on As metabolism. A field and laboratory integrated approach has been used to estimate As transport parameters for periphyton under various dissolved arsenate and orthophosphate concentrations. A first order equation was assumed for this periphyton component (Kuwabara and others, 1988). Methods for parameter determination have also been reported (Kuwabara and others, 1989).

In addition to these studies, diurnal variations in biologically significant parameters (for example, photosynthetically reactive irradiance, pH, water temperature, and specific conductivity) have been examined using data-logging systems. Data loggers (Campbell, Model CR-10) were set up at four sampling sites along Whitewood Creek: (1) A site 7 km upstream of the Homestake Mining activities (1,800 m altitude) (site 1, fig. 1 and table 1); (2) 15 km downstream of the first site and within the town of Deadwood 0.25 km downstream of municipal water treatment discharge (1,350 m altitude) (site 7, fig. 1 and table 1); (3) 39 km further downstream at a U.S. Geological Survey gaging station (870 m altitude) (site 14, fig. 1 and table 1); and (4) approximately 1 km upstream of the confluence of Whitewood Creek and the Belle Fourche River (850 m altitude) (site 16, fig. 1 and table 1). Data from logging experiments for the four sampling sites are shown in tables 46 to 49.

Table 46.--Parameters monitored with a data logger at Whitewood Creek above Lead (site 1)

[μS/cm, microsiemens per centimeter; (μE/m^2)/s, microeinsteins per square meter per second]

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m^2)/s)
8-29-88	1645	0	16.9	8.8	216	160.5
	1700	15	16.8	8.8	222	184.5
	1715	30	16.8	8.8	228	160.7
	1730	45	16.8	8.7	232	139.8
	1745	60	16.7	8.7	236	151.9
	1800	75	16.6	8.7	236	150.8
	1815	90	16.6	8.7	242	123.6
	1830	105	16.6	8.7	248	66.8
	1845	120	16.3	8.7	252	42.1
	1900	135	16.1	8.6	255	31.6
	1915	150	15.8	8.6	252	22.4
	1930	165	15.5	8.6	255	9.7
	1945	180	15.4	8.5	248	3.4
	2000	195	15.0	8.5	255	1.5
	2015	210	14.7	8.5	255	1.5
	2030	225	14.4	8.4	265	1.6
	2045	240	14.2	8.4	261	1.7
	2100	255	14.0	8.4	268	1.5
	2115	270	13.6	8.4	268	1.6
	2130	285	13.4	8.4	271	1.5
	2145	300	13.2	8.3	268	1.6
	2200	315	12.8	8.3	274	1.4
	2215	330	12.6	8.3	271	1.4
	2230	345	12.4	8.3	284	1.4
	2245	360	12.2	8.3	278	1.4
	2300	375	12.0	8.3	274	1.4
	2315	390	11.7	8.3	281	1.4
	2330	405	11.5	8.3	278	1.4
	2345	420	11.3	8.3	281	1.4
8-30-88	0000	435	11.1	8.3	281	1.4
	0015	450	10.9	8.3	287	1.4
	0030	465	10.8	8.3	287	1.4
	0045	480	10.7	8.3	281	1.4
	0100	495	10.6	8.3	284	1.4
	0115	510	10.4	8.3	290	1.4
	0130	525	10.3	8.3	281	1.4
	0145	540	10.0	8.3	287	1.4
	0200	555	9.9	8.3	300	1.4
	0215	570	9.8	8.3	300	1.4
	0230	585	9.8	8.3	284	1.4
	0245	600	9.7	8.3	294	1.4
	0300	615	9.4	8.3	303	1.4
	0315	630	9.4	8.3	300	1.4
	0330	645	9.3	8.3	290	1.4
	0345	660	9.2	8.3	294	1.4
	0400	675	9.0	8.3	310	1.4
	0415	690	9.0	8.3	307	1.4
	0430	705	9.1	8.3	294	1.4

Table 46.--Parameters monitored with a data logger at Whitewood Creek above Lead (site 1)--Continued

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
8-30-88	0445	720	9.0	8.3	313	1.4
	0500	735	8.9	8.3	297	1.4
	0515	750	8.9	8.3	300	1.4
	0530	765	8.8	8.3	307	1.4
	0545	780	8.7	8.3	316	1.4
	0600	795	8.7	8.3	316	1.4
	0615	810	8.6	8.3	313	1.7
	0630	825	8.5	8.3	303	3.3
	0645	840	8.5	8.3	303	6.5
	0700	855	8.5	8.3	307	9.7
	0715	870	8.3	8.4	310	14.1
	0730	885	8.3	8.4	313	19.4
	0745	900	8.3	8.4	317	25.4
	0800	915	8.3	8.4	318	34.5
	0815	930	8.4	8.4	320	55.3
	0830	945	8.5	8.4	307	76.5
	0845	960	8.5	8.4	317	107.9
	0900	975	8.8	8.5	307	111.3
	0915	990	9.0	8.5	314	112.6
	0930	1,005	9.1	8.5	317	136.8
	0945	1,020	9.4	8.6	317	146.4
	1000	1,035	9.7	8.6	304	159.5
	1015	1,050	10.0	8.6	310	173.9
	1030	1,065	10.5	8.6	301	189.0
	1045	1.080	10.9	8.6	310	210.2
	1100	1,095	11.5	8.7	294	240.7
	1115	1,110	12.0	8.7	290	318.0
	1130	1,125	12.5	8.7	291	348.6
	1145	1,140	13.1	8.7	278	465.3
	1200	1,155	13.6	8.7	271	641.8
	1215	1,170	14.2	8.7	261	421.8
	1230	1,185	14.8	8.7	261	327.3
	1245	1,200	15.4	8.7	252	594.7
	1300	1,215	15.9	8.8	248	762.3
	1315	1,230	16.4	8.8	236	831.7
	1330	1,245	16.7	8.8	232	535.4
	1345	1,260	17.1	8.8	232	626.4
	1400	1,275	17.5	8.8	232	925.9
	1415	1,290	17.8	8.8	229	1,026.6
	1430	1,305	18.2	8.8	229	987.1
	1445	1,320	18.4	8.8	226	402.5
	1500	1,335	18.5	8.8	223	451.6
	1515	1,350	18.6	8.8	223	212.4
	1530	1,365	18.8	8.8	223	198.8
	1545	1,380	18.8	8.8	226	91.7
	1600	1,395	18.6	8.8	223	113.3
	1615	1,410	18.5	8.8	232	138.9
	1630	1,425	18.5	8.8	232	156.0
	1645	1,440	18.3	8.8	226	166.3
	1700	1,455	18.2	8.8	232	153.3

Table 47.--Parameters monitored with a data logger at Whitewood Creek below Deadwood STP (site 7)

[$\mu S/cm$, microsiemens per centimeter; $(\mu E/m^2)/s$, microeinsteins per square meter per second]

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance ($\mu S/cm$)	Irradiance ($(\mu E/m^2)/s$)
8-30-88	0845	0	12.4	8.3	820	152.5
	0900	15	12.6	8.3	817	172.3
	0915	30	12.6	--	817	195.9
	0930	45	12.7	8.3	814	210.6
	0945	60	12.9	--	812	241.0
	1000	75	13.0	8.3	813	255.9
	1015	90	13.3	--	807	338.3
	1030	105	13.3	8.3	811	384.8
	1045	120	13.6	--	806	412.9
	1100	135	13.6	8.4	802	393.9
	1115	150	13.8	--	794	443.8
	1130	165	14.2	8.4	787	478.0
	1145	180	14.4	--	777	454.0
	1200	195	14.6	8.4	776	419.4
	1215	210	14.9	--	771	393.9
	1230	225	14.9	8.4	763	422.4
	1245	240	15.3	--	758	429.4
	1300	255	15.3	8.5	761	387.9
	1315	270	15.5	--	761	301.4
	1330	285	15.7	8.5	762	260.4
	1345	300	16.0	--	757	258.1
	1400	315	16.0	8.5	751	248.3
	1415	330	16.2	--	745	243.3
	1430	345	16.3	8.5	744	239.7
	1445	360	16.4	--	739	229.9
	1500	375	16.6	8.5	733	229.0
	1515	390	17.1	--	722	225.5
	1530	405	17.1	8.6	723	224.9
	1545	420	17.1	--	723	188.4
	1600	435	17.1	8.6	726	209.0
	1615	450	17.1	--	720	164.0
	1630	465	17.0	8.5	724	146.3
	1645	480	16.7	--	730	143.8
	1700	495	16.7	8.5	732	128.3
	1715	510	16.6	--	734	131.2
	1730	525	16.5	8.5	733	95.0
	1745	540	16.7	--	728	93.6
	1800	555	16.4	8.5	734	103.3
	1815	570	16.7	--	729	101.2
	1830	585	16.5	8.5	735	60.4
	1845	600	16.4	--	734	37.7
	1900	615	16.3	8.4	730	21.8
	1915	630	16.3	--	722	17.0
	1930	645	16.1	8.4	724	7.4
	1945	660	16.0	--	728	1.1
	2000	675	16.0	8.4	734	.1
	2015	690	15.8	--	736	.1

Table 47.--Parameters monitored with a data logger at Whitewood Creek below Deadwood STP (site 7)--Continued

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
8-30-88	2030	705	15.6	8.4	740	0.1
	2045	720	15.6	--	738	.1
	2100	735	15.3	8.3	745	.1
	2115	750	15.3	--	748	.1
	2130	765	15.2	8.3	752	.1
	2145	780	15.0	--	757	.1
	2200	795	14.9	8.3	762	.1
	2215	810	14.9	--	754	.1
	2230	825	14.6	8.2	755	.1
	2245	841	14.6	--	752	.1
	2300	856	14.6	8.3	753	.1
	2315	871	14.4	--	753	.1
	2330	886	14.2	8.3	756	.1
	2345	901	14.2	--	757	.1
8-31-88	0000	916	14.0	8.2	762	.1
	0015	931	13.8	--	766	.1
	0030	946	13.6	8.2	774	.1
	0045	961	13.6	--	775	.1
	0100	976	13.6	8.2	775	.1
	0115	991	13.5	--	766	.1
	0130	1,006	13.2	8.2	761	.1
	0145	1,021	13.2	--	755	.1
	0200	1,036	13.2	8.2	759	.1
	0215	1,051	13.0	--	762	.1
	0230	1,066	12.9	8.2	771	.1
	0245	1,081	12.8	--	775	.0
	0300	1,096	12.6	8.2	783	.1
	0315	1,111	12.6	--	784	.0
	0330	1,126	12.6	8.2	784	.0
	0345	1,141	12.4	--	783	.2
	0400	1,156	12.3	8.2	793	.2
	0415	1,171	12.3	--	792	.3
	0430	1,186	12.3	8.1	789	.4
	0445	1,201	12.1	--	783	.3
	0500	1,216	12.0	8.2	786	.3
	0515	1,231	12.0	--	786	.5
	0530	1,246	12.0	--	789	.5
	0545	1,261	12.0	--	789	.6
	0600	1,276	12.0	8.2	791	.6
	0615	1,291	12.0	--	791	1.3
	0630	1,306	12.0	--	795	1.7
	0645	1,321	12.0	--	796	4.4
	0700	1,336	12.0	8.2	805	7.9
	0715	--	--	--	804	10.8
	0730	--	--	--	799	15.7
	0745	--	--	--	794	20.7
	0800	--	--	--	791	24.7
	0815	--	--	--	787	35.1
	0830	--	--	--	791	55.4
	0845	--	--	--	789	80.9

Table 47.--Parameters monitored with a data logger at Whitewood Creek below Deadwood STP (site 7)--Continued

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
8-31-88	0900	--	--	--	792	75.9
	0915	--	--	--	795	116.2
	0930	--	--	--	802	144.2
	0945	--	--	--	817	153.6
	1000	--	--	--	830	166.2
	1015	--	--	--	830	308.9
	1030	--	--	--	819	474.6
	1045	--	--	--	814	517.8
	1100	--	--	--	810	529.0
	1115	--	--	--	812	552.3
	1130	--	--	--	814	631.6
	1145	--	--	--	821	686.0
	1200	--	--	--	816	816.9
	1215	--	--	--	808	941.1
	1230	--	--	--	803	931.4
	1245	--	--	--	804	808.8
	1300	--	--	--	800	711.9
	1315	--	--	--	780	388.2
	1330	--	--	--	762	134.9
	1345	--	--	--	748	90.8
	1400	--	--	--	741	91.5
	1415	--	--	--	737	102.2
	1430	--	--	--	736	102.4
	1445	--	--	--	730	91.4
	1500	--	--	--	730	79.7
	1515	--	--	--	727	92.0
	1530	--	--	--	728	121.2
	1545	--	--	--	729	130.2
	1600	--	--	--	735	127.9
	1615	--	--	--	731	123.8
	1630	--	--	--	726	120.8

Table 48.--Parameters monitored with a data logger at Whitewood Creek above Vale (site 14)

[μS/cm, microsiemens per centimeter; $(\mu E/m^2)/s$, microeinsteins per square meter per second]

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance $((\mu E/m^2)/s)$
8-31-88	0700	0	15.1	8.4	1,180	9.7
	0715	15	15.1	8.4	1,180	19.8
	0730	30	15.1	8.4	1,180	32.3
	0745	45	15.1	8.4	1,180	43.4
	0800	60	14.9	8.4	1,180	53.5
	0815	75	14.8	8.4	1,180	69.7
	0830	90	14.9	8.5	1,180	75.9
	0845	105	14.8	8.5	1,180	92.2
	0900	120	14.9	8.5	1,180	129.8
	0915	135	15.0	8.6	1,180	175.3
	0930	150	15.1	8.6	1.180	286.2
	0945	165	15.1	8.6	1,180	376.3
	1000	180	15.3	8.7	1,180	423.6
	1015	195	15.4	8.7	1,170	486.0
	1030	210	15.7	8.7	1,170	531.5
	1045	225	16.0	8.8	1,170	580.1
	1100	240	16.2	8.8	1,170	599.6
	1115	255	16.4	8.8	1,170	646.8
	1130	270	16.7	8.9	1,160	675.1
	1145	285	17.1	8.9	1,160	685.3
	1200	300	17.3	8.9	1,160	698.3
	1215	315	17.6	8.9	1,160	723.2
	1230	330	18.0	9.0	1,150	732.5
	1245	345	18.4	9.0	1,150	781.6
	1300	360	18.7	9.0	1,150	831.5
	1315	375	19.0	9.0	1,140	450.1
	1330	390	19.4	9.0	1,140	354.4
	1345	405	19.8	9.0	1,140	252.1
	1400	420	20.1	9.0	1,140	281.9
	1415	435	20.5	9.0	1,130	799.8
	1430	450	20.9	9.0	1,130	813.5
	1445	465	21.1	9.0	1,130	655.1
	1500	480	21.4	9.0	1,130	429.7
	1515	495	21.7	9.0	1,130	361.5
	1530	510	22.1	9.0	1,120	348.9
	1545	525	22.2	9.0	1,120	211.6
	1600	540	22.5	8.9	1,120	172.8
	1615	555	22.6	8.9	1,120	179.1
	1630	570	22.8	8.9	1,120	182.4
	1645	585	22.9	8.9	1,120	204.4
	1700	600	23.0	8.9	1,120	254.8
	1715	615	23.2	8.8	1,120	232.4
	1730	630	23.1	8.8	1,120	157.7
	1745	645	23.0	8.8	1,120	127.1
	1800	660	22.9	8.8	1,120	117.6
	1815	675	22.8	8.8	1,120	80.9
	1830	690	22.6	8.7	1,120	45.8

Table 48.--Parameters monitored with a data logger at Whitewood Creek above Vale (site 14)--Continued

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
8-31-88	1845	705	22.5	8.7	1,120	37.6
	1900	720	22.3	8.7	1,120	27.9
	1915	735	22.1	8.7	1,130	22.7
	1930	750	22.1	8.7	1,130	11.2
	1945	765	21.9	8.7	1,130	3.3
	2000	780	21.5	8.7	1,130	1.4
	2015	795	21.4	8.7	1,130	1.3
	2030	810	21.1	8.7	1,130	1.4
	2045	826	21.1	8.7	1,130	1.4
	2100	841	20.8	8.7	1,130	1.6
	2115	856	20.6	8.7	1,140	1.9
	2130	871	20.4	8.6	1,140	1.6
	2145	886	20.2	8.6	1,140	1.7
	2200	901	10.0	8.6	1,140	2.0
	2215	916	19.7	8.6	1,140	1.9
	2230	931	19.7	8.6	1,140	1.8
	2245	946	19.4	8.6	1,140	1.8
	2300	961	19.4	8.6	1,140	1.7
	2315	976	19.1	8.6	1,140	1.5
	2330	991	18.8	8.5	1,140	1.7
	2345	1,006	18.7	8.5	1,150	1.4
9-01-88	0000	1,021	18.5	8.5	1,150	1.5
	0015	1,036	18.5	8.5	1,150	1.4
	0030	1,051	18.3	8.5	1,150	1.4
	0045	1,066	18.2	8.5	1,150	1.5
	0100	1,081	18.0	8.5	1,150	1.4
	0115	1,096	17.9	8.5	1,150	1.4
	0130	1,111	17.7	8.5	1,150	1.4
	0145	1,126	17.4	8.5	1,160	1.4
	0200	1,141	17.4	8.5	1,160	1.3
	0215	1,156	17.2	8.5	1,160	1.3
	0230	1,171	17.2	8.5	1,160	1.3
	0245	1,186	17.1	8.5	1,160	1.3
	0300	1,201	16.9	8.5	1,160	1.3
	0315	1,216	16.6	8.5	1,160	1.6
	0330	1,231	16.6	8.5	1,160	1.6
	0345	1,246	16.5	8.5	1,160	1.7

Table 49.--Parameters monitored with a data logger at the Sheeler site (site 16)

[μS/cm, microsiemens per centimeter; (μE/m²)/s, microeinsteins per square meter per second]

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
9-01-88	0645	0	15.3	7.9	1,370	34.3
	0700	15	15.3	7.9	1,370	45.8
	0715	30	15.2	7.9	1,370	62.4
	0730	45	15.2	7.9	1,370	78.9
	0745	60	15.2	8.0	1,380	97.5
	0800	75	15.2	8.0	1,380	135.2
	0815	90	15.2	8.0	1,380	186.9
	0830	105	15.2	8.0	1,380	133.3
	0845	120	15.3	8.0	1,380	366.0
	0900	135	15.3	8.0	1,390	485.9
	0915	150	15.5	8.0	1,380	549.7
	0930	165	15.6	8.0	1,390	624.8
	0945	180	15.9	8.1	1,390	696.7
	1000	195	16.2	8.1	1,390	771.1
	1015	210	16.5	8.1	1,380	850.5
	1030	225	16.8	8.1	1,380	935.1
	1045	240	17.3	8.1	1,380	980.9
	1100	255	17.7	8.1	1,380	1,018.7
	1115	270	18.1	8.1	1,380	1,091.0
	1130	285	18.6	8.2	1,370	1,122.9
	1145	300	19.3	8.2	1,370	1,146.0
	1200	315	19.8	8.2	1,370	1,177.4
	1215	330	20.3	8.2	1,360	490.7
	1230	345	21.0	8.2	1,360	663.8
	1245	360	21.5	8.2	1,360	1,152.1
	1300	375	22.1	8.2	1,360	1,218.8
	1315	390	22.6	8.2	1,350	1,237.5
	1330	405	23.0	8.3	1,350	1,256.4
	1345	420	23.5	8.3	1,350	1,246.7
	1400	435	24.0	8.3	1,340	1,214.4
	1415	450	24.6	8.3	1,340	1,189.8
	1430	465	24.9	8.3	1,340	1,167.1
	1445	480	25.1	8.3	1,340	1,128.1
	1500	495	25.4	8.3	1,340	1,071.4
	1515	510	25.7	8.3	1,330	1,045.5
	1530	525	25.8	8.3	1,320	986.5
	1545	540	25.8	8.3	1,320	907.8
	1600	555	26.1	8.3	1,320	838.3
	1615	570	26.2	8.3	1,320	781.0
	1630	585	26.2	8.3	1,320	717.5
	1645	600	26.0	8.3	1,330	619.2
	1700	615	25.8	8.3	1,320	545.4
	1715	630	25.8	8.2	1,330	483.7
	1730	645	25.5	8.2	1,330	279.4
	1745	660	25.3	8.2	1,330	137.4
	1800	675	25.0	8.2	1,330	82.6
	1815	690	24.9	8.2	1,330	73.9

Table 49.--Parameters monitored with a data logger at the Sheeler site (site 16)--Continued

Date	Time	Elapsed time (minutes)	Water temperature (°C)	pH	Specific conductance (μS/cm)	Irradiance ((μE/m²)/s)
9-01-88	1830	705	24.6	8.2	1,330	60.5
	1845	720	24.2	8.1	1,330	38.5
	1900	735	23.9	8.1	1,330	33.9
	1915	750	23.7	8.1	1,330	26.1
	1930	765	23.5	8.1	1,330	10.8
	1945	780	23.4	8.1	1,340	2.7
	2000	795	23.0	8.1	1,340	1.7
	2015	810	22.8	8.0	1,340	1.5
	2030	825	22.5	8.0	1,340	1.4
	2045	840	22.3	8.0	1,340	1.3
	2100	855	22.0	8.0	1,340	1.3
	2115	870	21.8	8.0	1,340	1.4
	2130	885	21.4	8.0	1,340	1.3
	2145	900	21.2	8.0	1,340	1.3
	2200	915	20.9	8.0	1,340	1.3
	2215	930	20.7	8.0	1,350	1.3
	2230	945	20.3	8.0	1,350	1.3
	2245	960	20.1	7.9	1,350	1.3
	2300	975	19.8	7.9	1,350	1.3
	2315	990	19.7	7.9	1,350	1.3
	2330	1,005	19.4	7.9	1,350	1.3
	2345	1,020	19.2	7.9	1,350	1.3
9-02-88	0000	1,035	19.0	7.9	1,350	1.3
	0015	1,050	18.7	7.9	1,350	1.3
	0030	1,065	18.5	7.9	1,350	1.3
	0045	1,080	18.2	7.9	1,360	1.3
	0100	1,095	18.2	7.9	1,360	1.3
	0115	1,110	18.0	7.9	1,360	1.3
	0130	1,125	17.7	7.9	1,360	1.3
	0145	1,140	17.6	7.9	1,360	1.3
	0200	1,155	17.4	7.9	1,360	1.3
	0215	1,170	17.4	7.9	1,360	1.3
	0230	1,185	17.2	7.9	1,360	1.2
	0245	1,200	17.1	7.9	1,360	1.3
	0300	1,215	16.9	7.9	1,360	1.3
	0315	1,230	16.7	7.9	1,350	1.3

ARSENIC IN BENTHIC INSECTS

The development of biological indicators includes the identification of intrinsic variables that complicate the interpretation of spatial and temporal differences in the bioavailability to environmental contaminants (Phillips, 1980). Spatial variability in the arsenic concentration of benthic insects in Whitewood Creek, South Dakota, was assessed in relation to total sediment arsenic concentration. Trophic level, taxonomic relation, and the body size of the insects also were examined as sources of variability in the arsenic concentrations of these animals (Cain and others, 1988).

Insect and sediment samples were collected from six stations on Whitewood Creek and one station on Spearfish Creek. A station on Whitewood Creek upstream of Lead (site 1) and the station on Spearfish Creek (site 17) were outside the arsenic-contaminated area, and served to represent background concentrations of arsenic in the watershed. Stations above Gold Run (site 3) and below Gold Run (site 5) were approximately 1 km above and 100 m below the confluence of Gold Run Creek, respectively. Whitewood Creek above Whitewood (site 9) was near the town of Whitewood. Two sampling sites were located at the Berger site (site 12). Site 12 above seep, was in Whitewood Creek roughly 100 m upstream of a visible ground-water seep; and site 12 below seep, was at the point of discharge of this seep into Whitewood Creek.

Insects were collected by hand and kick net and sorted initially in the field to the taxonomic levels of order and family. Collections focused upon immature stages of the species, although pupae and adults of some taxa also were collected. Specimens of all species were initially preserved in formalin, then later permanently transferred to 85 percent ethanol. These samples were used for taxonomic identifications. After collection and sorting, samples for arsenic determination were kept in closed plastic bags in stream water cooled with ice for about 6 hours to allow some evacuation of the gut cavity. The samples were then frozen. In the laboratory, the samples were thawed, then sorted to the family, genus, and species level, based upon identifications of the preserved samples. Individuals within the same taxon were further sorted by size and pooled into samples with enough biomass (ca. 100 mg dry weight) for the determination of As. The numbers of individuals within a sample ranged from 3 to greater than 100 depending upon the taxon. The samples were prepared and then analyzed by hydride-generation atomic absorption spectroscopy (Cain and others, 1988).

The upper 5 to 10 mm of sediment was collected with a polypropylene scoop in shallow water from several locations along the left and right edges of the stream and composited into a single sample by sieving with stream water, on site, through a 63-μm nylon screen into acid-washed polypropylene jars. The sediment was allowed to settle in the jars for 24 hours, and then the water was decanted and the sediment was frozen. In the laboratory, sediments were freeze-dried for analysis. Total arsenic was determined by inductively coupled plasma spectroscopy (Moore and others, 1988).

Insects also were transferred from the background sites (site 1 and 19) to Whitewood Creek above Whitewood (site 10) to determine short-term rates of As accumulation within the contaminated zone of Whitewood Creek. Specimens of <u>Hesperophylax</u> <u>occidentalis</u> were collected from site 1, and <u>Hydropsyche</u> <u>oslari</u>, <u>Hesperoperla</u> <u>pacifica</u>, and <u>Rhyacophila</u> sp. were collected from site 19. Collections of each taxa were split into three equal groups. The first group was immediately processed for As determination to establish the As concentration of the insects from the control stations at the start of the experiment (0 hour). A second and a third group were sealed in plastic (nitex) bags (500-μm mesh). The second group was placed back into the control stream for the duration of the experiment to determine if confinement in the bag affected the As concentrations in the insects. The third group was placed in aerated stream water and transferred to Whitewood Creek above Whitewood (site 10) within 2 hours of collection. The control and transferred insects were recovered after 48 hours.

The average dry weight and arsenic concentration of individual insects within samples are given in table 50. The arsenic concentrations of sediments and insect taxa are summarized in table 51. The results of the transfer experiment are given in table 52.

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Table 50.--Dry tissue weight and arsenic concentration per individual insect for taxa collected from Spearfish Creek and Whitewood Creek in May and June 1986

[Values are the averages of similar sized individuals pooled into single samples.]

Site	Taxon	Dry weight (milligrams)	Arsenic (micrograms per gram)
17	Hydropsyche oslari	2.4	9
	Hydropsyche oslari	6.3	8
	Hesperoperla pacifica	--	2
	Hesperoperla pacifica	--	2
	Rhyacophila acropedes gr.	--	2
	R. acropedes gr. (pupae)	--	2
1	Baetis tricaudatus	.5	10
	Ephemerella inermis	1.0	16
	Ephemerella inermis	.6	16
	Hesperophylas occidentalis	7.2	8
	H. occidentalis (pupae)	10.3	4
	Hesperoperla pacifica	58.3	3
	Hesperoperla pacifica	29.2	3
	Hesperoperla pacifica	15.7	4
3	Baetis tricaudatus	.9	83
	Baetis tricaudatus	1.0	64
	Baetis tricaudatus	1.1	69
	Baetis tricaudatus	1.2	46
	Ephemerella inermis	2.5	41
	Ephemerella inermis	1.0	39
	Hydropsyche slossonae & oslari	2.3	66
	Hydropsyche slossonae & oslari	4.1	46
	Hydropsyche slossonae & oslari	4.3	61
	Limnephilus sp. & Hesperophylax sp.	17.6	8
	Limnephilus sp. & Hesperophylax sp. (pupae)	21.8	2
	Rhyacophila sp.	10.8	4
	Hesperoperla pacifica	16.8	6
	Hesperoperla pacifica	35.3	5
	Hesperoperla pacifica	73.3	4
5	Baetis tricaudatus	.5	81
	Baetis tricaudatus	.6	93
	Baetis tricaudatus	.7	64
	Ephemerella inermis	1.1	78
	Ephemerella inermis	4.1	39
	Limnephilus sp. & Hesperophylax occidentalis	42.8	10
	Limnephilus sp. & Hesperophylax occidentalis	44.5	10
	Hydropsyche slossonae & oslari	7.6	30
	Hydropsyche slossonae & oslari	6.1	31
	Hydropsyche slossonae & oslari	6.5	40
	Hydropsyche slossonae & oslari	4.9	42
	Hydropsyche slossonaie & oslari	2.5	44

Table 50.--Dry tissue weight and arsenic concentration per individual insect for taxa collected from Spearfish Creek and Whitewood Creek in May and June 1986--Continued

Site	Taxon	Dry weight (milligrams)	Arsenic (micrograms per gram)
	Hydropsyche bronta	8.5	20
	Rhyacophila acropedes gr.	9.5	64
19	Baetis tricaudatus	1.6	26
	Baetis tricaudatus	1.7	23
	Hydropsyche slossonae & oslari	4.1	120
	Hydropsyche slossonaie & oslari	3.4	103
	Hydropsyche slossonaie & oslari	5.6	70
	Hydropsyche bronta	4.7	83
	Hydropsyche bronta	4.0	77
	Hydropsyche sp. (adults)	1.5	3
	Hydropsyche sp. (adults)	1.6	3
	Cheumatopsyche spp.	3.5	62
	Cheumatopsyche spp.	3.6	58
	Cheumatopsyche spp.	3.2	47
	Isoperla quinquepunctata	4.9	13
	Isoperla quinquepunctata	6.0	8
	Isoperla quinquepunctata (adults)	4.7	5
	Isoperla quinquepunctata (adults)	5.4	4
12	Choroterpes sp.	--	172
(above	Choroterpes sp.	1.1	165
seep)	Choroterpes sp.	1.4	169
	Choroterpes sp.	1.6	122
	Choroterpes sp.	1.3	118
	Choroterpes sp.	1.3	167
	Choroterpes sp.	1.3	162
	Choroterpes sp.	1.3	132
	Choroterpes sp.	1.1	205
	Tricorythodes sp.	1.3	71
	Tricorythodes sp.	1.1	93
	Tricorythodes sp.	1.4	112
	Hydropsyche bronta	9.8	54
	Hydropsyche sp.	7.6	64
	Hydropsyche sp.	5.5	48
	Hydropsyche sp.	--	39
	Hydropsyche sp.	7.4	59
	Hydropsyche sp.	8.4	77
	Hydropsyche sp.	3.2	113
	Hydropsyche sp.	2.7	44
	Hydropsyche sp.	2.2	95
	Hydropsyche sp.	2.4	29
	Cheumatopsyche spp.	4.7	59
	Ambrysus sp.	21.2	17
	Ambrysus sp.	29.7	21
	Ambrysus sp.	7.8	32
	Ambrysus sp.	7.4	32
	Ambrysus sp.	8.4	24
	Ambrysus sp.	18.7	25
	Ambrysus sp.	21.8	24

Table 50.--Dry tissue weight and arsenic concentration per individual insect for taxa collected from Spearfish Creek and Whitewood Creek in May and June 1986--Continued

Site	Taxon	Dry weight (milligrams)	Arsenic (micrograms per gram)
12	*Choroterpes* sp.	1.4	209
(at	*Choroterpes* sp.	1.2	252
seep)	*Choroterpes* sp.	1.3	374
	Tricorythodes sp.	1.6	702
	Tricorythodes sp.	1.4	633
	Tricorythodes sp.	1.3	542
	Hydropsyche sp.	9.9	85
	Hydropsyche sp.	5.0	60
	Hydropsyche sp.	2.6	88
	Ambrysus sp.	17.7	55
	Ambrysus sp.	27.1	43
	Ambrysus sp.	6.6	121

Table 51.--Arsenic concentrations of sediments (<63 micrometer) and benthic insects collected from Whitewood Creek and Spearfish Creek in May-June 1987

[Values are in micrograms per gram dry weight. Standard deviation of the mean concentration shown. Sample size given in parentheses. The caddisflies *Limnephilus* sp. and *Hesperophylax* sp. were not separated prior to As determination]

	Site						
	1	3	5	9	12 (above seep)	12 (below seep)	17
Sediment	15 (1)	440 (1)	460±14 (2)	610±198 (2)	930 (1)	1100 (1)	90 (1)
Trophic taxon level							
Herbivore							
Baetis tricaudatus	10 (1)	65±15 (4)	80±15 (3)	24±2 (2)			
Choroterpes sp. (=*Neochoroterpes*)					156±28 (9)	278±86 (3)	
Ephemerella inermis	16±0.2 (2)	40±1 (2)	59±28 (2)				
Tricorythodes sp.					90±20 (3)	625±80 (3)	
Hesperophylax occidentalis	6±3 (2)						
Limnephilus sp. & *Hesperophylax* sp.		8 (1)	10±0.03 (2)				
Herbivore/Omnivore							
Cheumatopsyche spp.				56±8 (3)	59 (1)		
Omnivore							
Hydropsyche bronta			20 (1)	80±4 (2)	29 (1)		
Hydropsyche oslari							7±3 (2)
Hydropsyche slossonae & *oslari*		58±10 (3)	37±6 (5)	98±26 (3)			
Hydropsyche sp.					66±25 (9)	77±15 (3)	
Predator							
Rhyacophila acropedes gr.		4 (1)	64 (1)				2 (1)
Isoperla quinquepunctata				10±4 (2)			
Hesperoperla pacifica	3±0.5 (3)	5±1 (3)					2±0.2 (2)
Ambrysus sp.					25±5 (7)	73±42 (3)	

Table 52.--Arsenic concentrations in controls and insects transferred to Whitewood Creek above Whitewood (site 9) for 2 days

[Values are the mean and 1 standard error of the mean in micrograms per gram dry weight; sample sizes are given in parentheses]

Taxon	Control (unbagged)	Control (bagged)	Transfer (bagged)	Resident
Hydropsyche oslari	6.69±1.96 (3)	5.92±1.40 (3)	42.0±5.0 (3)	98±15 (3)
Hesperophylax occidentalis	11.9±0.4 (2)	5.4 (1)	40.9±18.0 (2)	
Hesperoperla pacifica	1.86±0.12 (2)	1.36±0.31 (6)	6.63±1.10 (3)	
Rhyacophila acropedes gr.	2.12 (1)	2.30 (1)	3.12±0.22 (2)	