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Hydrologic and Water-Quality Data at Selected Sites in the Upper Animas River Watershed, Southwestern Colorado, 1997–99

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U.S. Department of the Interior
U.S. Geolgical Survey

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By M. Alisa Mast, Jonathan B. Evans, Kenneth J. Leib, and
Winfield G. Wright

U.S. GEOLOGICAL SURVEY

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Denver, Colorado
2000

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CONVERSION FACTORS AND ABBREVIATIONS

Multiply	By	To obtain
inch	2.54	centimeter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
mile (mi)	1.609	kilometer
liter (L)	0.2641	gallons (US)
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.189	meter per kilometer
square mile (mi^2)	2.59	square kilometer

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) using the following equation:

$$°C = (°F - 32) / 1.8$$

Additional abbreviations used in this report:

micrometer (µm)
microsiemens per centimeter at 25 degrees Celsius (µS/cm)
milligram per liter (mg/L)
microgram per liter (µg/L)
milliliter (mL)
millimeter (mm)

Hydrologic and Water-Quality Data at Selected Sites in the Upper Animas River Watershed, Southwestern Colorado, 1997–99

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Abstract

The water quality and aquatic resources of the upper Animas River watershed are affected by more than1,500 abandoned mines from historical metal-mining activities in the late 1800's and early 1900's. In 1997, the U.S. Geological Survey implemented the Abandoned Mine Lands Initiative to provide scientific information to Federal land-management agencies responsible for remediation of abandoned mine sites on publicly owned land. This report presents hydrologic and water-quality data collected as part of the Abandoned Mine Lands Initiative during water years 1997–99 in the upper Animas River watershed, Colorado. Water-quality samples were collected from four streamflow-gaging stations, nine sites along the main stem and two major tributaries, 55 abandoned mine sites, and 194 selected stream and spring sites. Data include field measurements of streamflow, specific conductance, pH, water temperature, and dissolved oxygen and laboratory analyses of major inorganic and selected trace-element constituents. Daily mean discharge values are tabulated for the four streamflow-gaging stations. A CD-ROM containing hydrologic and water-quality data is in the pocket of this report.

INTRODUCTION

The upper Animas River watershed (UARW) lies in the southwestern part of the Colorado mineral belt and was heavily mined in the late 1800's and early 1900's for gold, silver, zinc, and lead. Numerous prospects, draining mine adits, waste-rock piles, and mill tailings left behind by historical mining activities have severely affected the water quality and aquatic resources of the Animas River and its tributaries. Recently, there has been much interest by local stakeholders, and by State and Federal agencies, in remediating abandoned mine sites in the watershed with the goal of restoring aquatic ecosystems along some reaches of the Animas River. Effective and cost-efficient remediation of abandoned mine lands requires knowledge of the degree of contamination of the environment as well as an understanding of the processes by which abandoned mine lands disturb the natural ecosystem. In 1997, the U.S. Geological Survey (USGS) implemented the Abandoned Mine Lands Initiative (AMLI) to provide this type of scientific information to the Federal land-management agencies responsible for remediation of abandoned mine sites in the UARW (Nimick and von Guerard, 1998). This is part of a larger strategy by the U.S. Department of the Interior and the U.S. Department of Agriculture to coordinate activities between Federal and State agencies and local stakeholders for the cleanup of Federal lands affected by abandoned mine lands. One of the main components of the AMLI is to describe the geological, hydrological, and biological characteristics of the watershed. This information will be used to improve understanding of the processes that control the occurrence and transport of contaminants and to identify mining sites that have the most adverse effect on the water quality and aquatic resources of the Animas River.

Purpose and Scope

The purpose of this report is to present hydrologic and water-quality data and methods of data collection at selected sampling sites in the UARW in southwestern Colorado (fig. 1). Data were collected during water years 1997–99 as part of the AMLI. Bimonthly to weekly water-quality samples were collected at four streamflow-gaging stations and nine sites along the main-stem upper Animas River and two major tributaries to monitor seasonal variations in stream chemistry and solute fluxes in the watershed. The four streamflow-gaging stations are the Animas River below Silverton (station 09359020; A72), Animas River at Silverton (station 09358000; A68), Cement Creek at Silverton (station 09358550; C48), and Mineral Creek at Silverton (station 09359010; M34). One hundred and thirty-eight water-quality samples were collected at 55 selected mine sites during the study period to characterize spatial and seasonal variability in mine-water chemistry and discharge. Water-quality samples at 194 selected streams and springs were sampled throughout the watershed during summer base-flow conditions to help distinguish natural from mining-related sources of metals to surface water. Data presented in this report include field measurements of streamflow, specific conductance, pH, water temperature, and dissolved oxygen and laboratory analyses of concentrations of major inorganic and selected trace-element constituents. Daily mean discharge values for streamflow also are presented for the four streamflow-gaging stations. Supplemental data are on the CD-ROM in the pocket of the report cover.

Acknowledgments

Many aspects of this study would not have been possible without the support of the Upper Animas River Stakeholders Group; the U.S. Department of the Interior, Bureau of Land Management and Bureau of Reclamation; and the U.S. Department of Agriculture Forest Service. The authors are grateful for assistance and guidance from USGS employees Greg Alexander, James Bennett, Mark Gress, Dave Grey, Paul von Guerard, David Roth, Jenny A. Taylor, and Philip Verplanck.

DESCRIPTION OF STUDY AREA

The upper Animas River watershed is in the San Juan Mountains in southwestern Colorado. The river drains 146 mi^2 of rugged mountainous terrain ranging in elevation from 9,200 ft near the town of Silverton, Colorado, to 13,894 ft at the summit of Vermilion Peak (fig. 1). The upper Animas River is a southward-flowing tributary of the San Juan River and has a channel length of about 15.5 mi above the streamflow-gaging station at Animas River below Silverton (A72) and an average stream gradient of about 184 ft/mi. The main channel of the river is perennial, and mean monthly discharge ranges from about 63 ft^3/s in February to 1,196 ft^3/s in June. Snowmelt is the major hydrologic event of the year, and more than 60 percent of the annual streamflow occurs in May, June, and July. Average annual runoff for the watershed was 28 inches from 1992 to 1998 (Crowfoot and others, 1999). The Animas River has two major tributaries, Cement Creek and Mineral Creek, which together account for about 50 percent of the annual discharge from the watershed. Climate of the area is characterized by long, cold winters and short (3–4 months), cool summers. Average monthly air temperature at Silverton, Colorado, ranges from 16.0°F in January to 55.3°F in July (URL http://www.wrcc.sage.dri.edu, accessed March 2000). Precipitation averages 45 inches annually, of which about 70 percent accumulates in a seasonal snowpack between November and April (Wirt and others, 1999). Most of the remaining precipitation falls during monsoonal thundershowers in late summer and early fall. The watershed lies in the Southern Rocky Mountain Forest ecoregion, and much of the area is above treeline, which is at an average elevation of 11,600 ft. The lower slopes are covered by a dense forest of Engelmann spruce and subalpine fir (Bailey and others, 1994).

The UARW lies within the San Juan volcanic field of Tertiary age, which includes the San Juan, Uncompahgre, and Silverton calderas that formed about 28 million years ago (Lipman and others, 1976; Bove and others, 1999). Most of the bedrock in the study area consists of thick sequences of volcanic rocks that are composed of lava flows, ash-flow tuffs, tuff breccias, conglomerates, and mudflow breccias (Lipman and others, 1973; Ringrose, 1982). The lavas and tuffs generally are of intermediate composition and are composed of plagioclase, biotite, augite, quartz, and hornblende. Nearly all the volcanic rocks in the study area were subject to some degree of hydrothermal alteration after deposition (Burbank and Luedke, 1969). Hydrothermal activity related to the Silverton caldera caused regional propylitization of the volcanic rocks, which altered the rocks to chlorite and

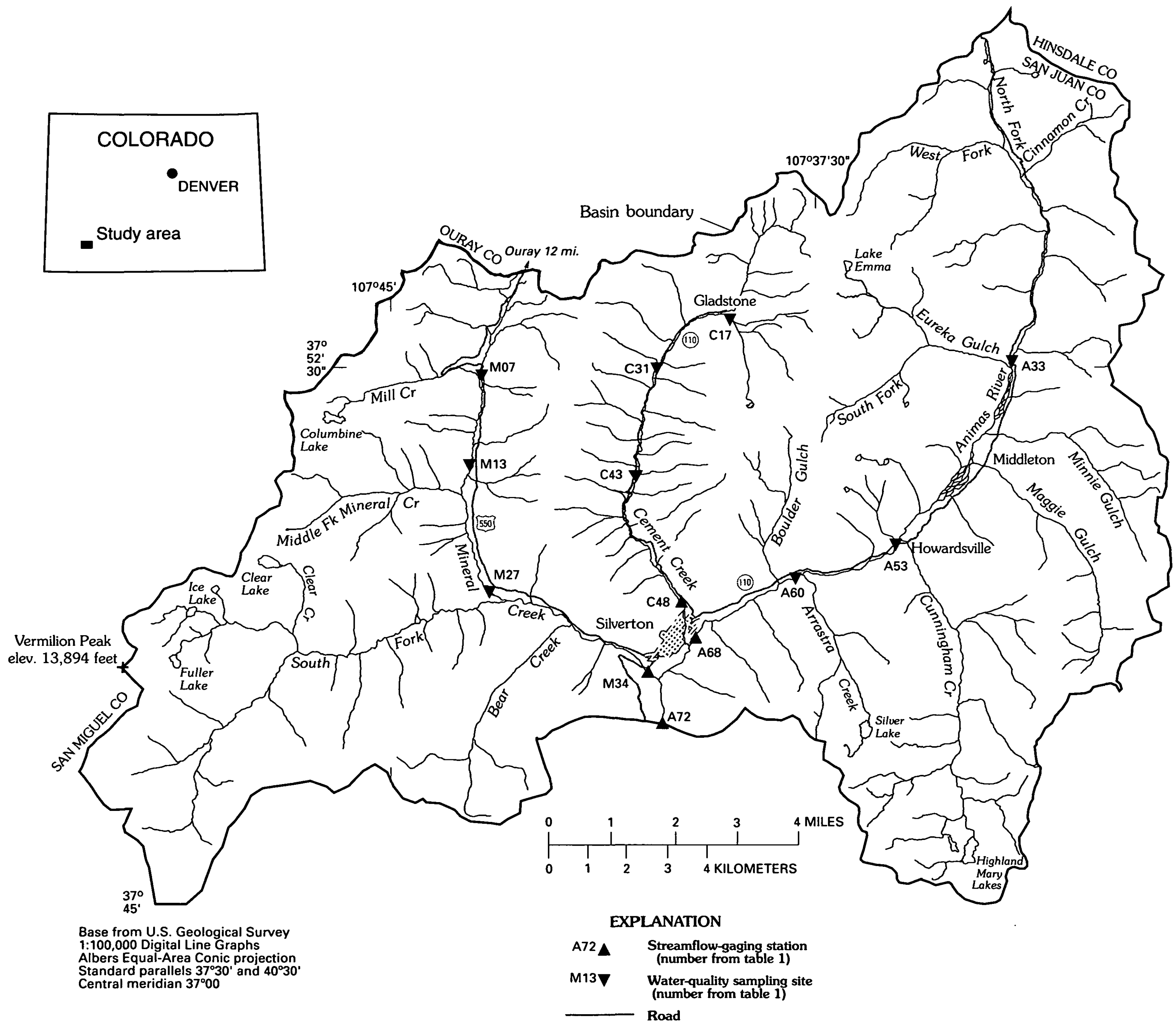

Figure 1. Upper Animas River watershed and locations of four USGS streamflow-gaging stations and nine water-quality sampling sites along the main stem and major tributaries.

epidote with calcite and pyrite often disseminated throughout the groundmass. The propylitized rocks were subsequently mineralized and hydrothermally altered during three later episodes of magmatism (11–23 million years ago), which were the source of most ore deposition in the area (Casadevall and Ohmoto, 1977). Most economic ore deposits occur in polymetallic vein systems that follow structures formed during subsidence and resurgence of the San Juan, Uncompahgre, and Silverton calderas (Burbank and Luedke, 1969; Ringrose, 1982). The area was first prospected for precious metals in 1860, and most mining activities occurred in the late 1800's and early 1900's. Production was primarily from vein type deposits that yielded gold, silver, zinc, and lead. Over 1,500 prospect pits, abandoned mines, and dismantled mill sites are now scattered throughout the watershed as a result of past mining activities.

METHODS OF STUDY

This section includes a description of the methods used to collect and analyze water-quality samples collected in the UARW as part of the AMLI. Methods of operation for streamflow-gaging stations are standardized within the USGS (Rantz and others, 1982) and will not be included in this report. Daily mean streamflow values at the four streamflow-gaging stations for 1997–99 are presented in the "Hydrologic and Water-Quality Data" section of this report and also are in Crowfoot and others (1998), Crowfoot and others (1999), and Crowfoot and others (U.S. Geological Survey, written commun., 2000).

Water-Quality Sampling

Water-quality samples were collected seasonally (weekly to bimonthly) at the four streamflow-gaging stations and at nine upstream sites along the main stem Animas River and major tributaries. The sites are listed in table 1 and locations shown in figure 1. Seasonal (monthly to bimonthly) samples also were collected at seven mine sites: the Avalanche Mine, Bandora Mine, Bonner Mine, Elk Tunnel, Evelyn Mine, Forest Queen Mine, and Mighty Monarch Mine. The mine sites are listed in table 2 and locations shown in figure 2. Field measurements at the sampling sites included stream discharge, specific conductance, pH, water temperature, and dissolved oxygen. Water-quality measurements were made using methods

Table 1. Streamflow-gaging stations and water-quality sampling sites on the main stem and major tributaries in the upper Animas River watershed

[Site locations are shown in figure 1; identification number is USGS downstream order number; elevation in feet; watershed area in square miles; --, not reported]

Site number	Site name	Identification number	Latitude	Longitude	Elevation	Watershed area
A72	Animas River below Silverton, Colorado	09359020	37°47'25"	107°40'01"	9,200	146
A68	Animas River at Silverton, Colorado	09358000	37°48'40"	107°39'31"	9,290	70.6
C48	Cement Creek at Silverton, Colorado	09358550	37°49'11"	107°39'47"	9,380	20.1
M34	Mineral Creek at Silverton, Colorado	09359010	37° 48'10"	107°40'20"	9,245	52.5
A33	Animas River at Eureka	--	37°52'45"	107°33'55"	9,852	18.2
A53	Animas River at Howardsville	--	37°50'07"	107°35'52"	9,642	57.7
A60	Animas River below Arrastra Gulch	--	37°49'38"	107°37'34"	9,475	60.0
C17	South Fork Cement Creek at Gladstone	--	37°53'21"	107°39'10"	10,469	3.1
C31	Cement Creek at Fairview Gulch Bridge	--	37°52'30"	107°40'16"	10,206	9.4
C43	Cement Creek near Yukon Mine	--	37°50'56"	107°40'35"	9,894	14.8
M07	Mineral Creek at Chattanooga	--	37°52'27"	107°43'26"	10,240	4.4
M13	Mineral Creek at Burro Bridge	--	37°51'02"	107°43'31"	10,006	10.4
M27	Mineral Creek above South Fork	--	37°49'16"	107°13'08"	9,534	20.0

Table 2. Water-quality sampling sites at selected mines in the upper Animas River watershed

[Site locations are shown in figure 2; elevation in feet; site MS24 eliminated from this report]

Site number	Site name	Latitude	Longitude	Elevation
MS1	Anglo Saxon Mine	37°51'32"	107°40'36"	10,080
MS2	Avalanche Mine	37°52'24"	107°40'07"	10,540
MS3	Bagley Tunnel	37°55'59"	107°34'50"	11,440
MS4	Bandora Mine	37°47'12"	107°48'04"	10,784
MS5	Big Colorado Mine	37°52'37"	107°38'46"	11,060
MS6	Black Hawk Mine	37°52'56"	107°38'05"	11,600
MS7	Bonner Mine	37°50'41"	107°44'09"	10,040
MS8	Brooklyn Mine	37°51'37"	107°42'54"	11,348
MS9	Bullion King Mine	37°53'19"	107°44'32"	12,400
MS10	Burbank Mine	37°48'43"	107°46'37"	10,480
MS11	Elk Tunnel	37°52'13"	107°40'29"	10,200
MS12	Esmeralda Mine	37°50'54"	107°31'57"	11,490
MS13	Evelyn Mine	37°53'17"	107°39'53"	10,580
MS14	Ferricrete Mine	37°52'05"	107°43'35"	10,300
MS15	Forest Queen Mine	37°51'58"	107°33'54"	9,860
MS16	Grand Mogul Mine	37°54'36"	107°37'49"	11,760
MS17	Imogene Mine	37°51'45"	107°43'41"	10,360
MS18	Independence Mine	37°50'41"	107°44'23"	10,180
MS19	Joe and Johns Mine	37°53'31"	107°40'42"	11,200
MS20	Kittimac Mine	37°51'54"	107°32'12"	11,600
MS21	Lark Mine	37°53'34"	107°40'50"	11,320
MS22	London Mine	37°56'57"	107°35'01"	11,920
MS23	Lucky Jack Mine	37°57'14"	107°34'21"	12,000
MS25	Mighty Monarch Mine	37°48'29"	107°39'24"	9,477
MS26	Mine in upper Cement Creek	37°54'39"	107°38'00"	11,680
MS27	Mine in Bighorn Gulch	37°52'28"	107°41'43"	12,400
MS28	Mine east of Chattanooga beaver ponds	37°52'15"	107°43'07"	10,600
MS29	Mine in South Fork Eureka Gulch	37°52'35"	107°36'06"	11,015
MS30	Mine in Georgia Gulch	37°53'03"	107°41'13"	11,900
MS31	Mine in gulch south of Hancock Gulch	37°50'12"	107°39'46"	10,440
MS32	Mine in Middle Fork Cement Creek	37°53'04"	107°38'28"	11,060
MS33	Mine in Minnie Gulch	37°51'47"	107°33'09"	10,480
MS34	Mine near Paradise Portal	37°50'32"	107°45'52"	10,600
MS35	Mine in Prospect Gulch	37°53'27"	107°41'17"	11,640
MS36	Mine in upper Animas River	37°53'56"	107°33'27"	10,400
MS37	Mine in upper Browns Gulch	37°51'46"	107°42'22"	11,840
MS38	Mine in upper Cement Creek	37°54'27"	107°38'22"	11,280

Table 2. Water-quality sampling sites at selected mines in the upper Animas River watershed—Continued

[Site locations are shown in figure 2; elevation in feet; site MS24 eliminated from this report]

Site number	Site name	Latitude	Longitude	Elevation
MS39	Mine in upper Minnie Gulch	37°50'17"	107°31'33"	12,000
MS40	Mine in upper North Fork Cement Creek	37°53'50"	107°37'37"	12,650
MS41	Mine above Brooklyn #6	37°51'53"	107°42'35"	11,890
MS42	Mine near Horseshoe Bend	37°52'26"	107°43'58"	10,420
MS43	Mine near Hwy 550 south of Middle Fork Mineral Creek	37°50'25"	107°43'31"	10,080
MS44	Mine northwest of Burro Bridge	37°51'20"	107°43'27"	10,440
MS45	Mine near McMillan Peak	37°52'46"	107°41'43"	12,450
MS46	Mine west of Burro Bridge	37°51'02"	107°43'45"	10,200
MS47	Mine near Eureka Gulch	37°53'07"	107°35'28"	10,680
MS48	Mine near Burro Bridge	37°51'01"	107°43'30"	10,040
MS49	Old Hundred Mine	37°49'24"	107°35'04"	9,980
MS50	Queen Anne Mine	37°54'52"	107°37'47"	12,200
MS51	Silver Crown Mine	37°52'18"	107°44'35"	11,800
MS52	Silver Ledge Mine	37°52'36"	107°38'38"	10,970
MS53	Silver Wing Mine	37°54'12"	107°33'19"	10,440
MS54	Treasure Mountain Mine	37°54'49"	107°34'11"	11,640
MS55	Vermilion Mine	37°56'10"	107°36'01"	12,400
MS56	Yukon Mine	37°50'58"	107°40'32"	9,985

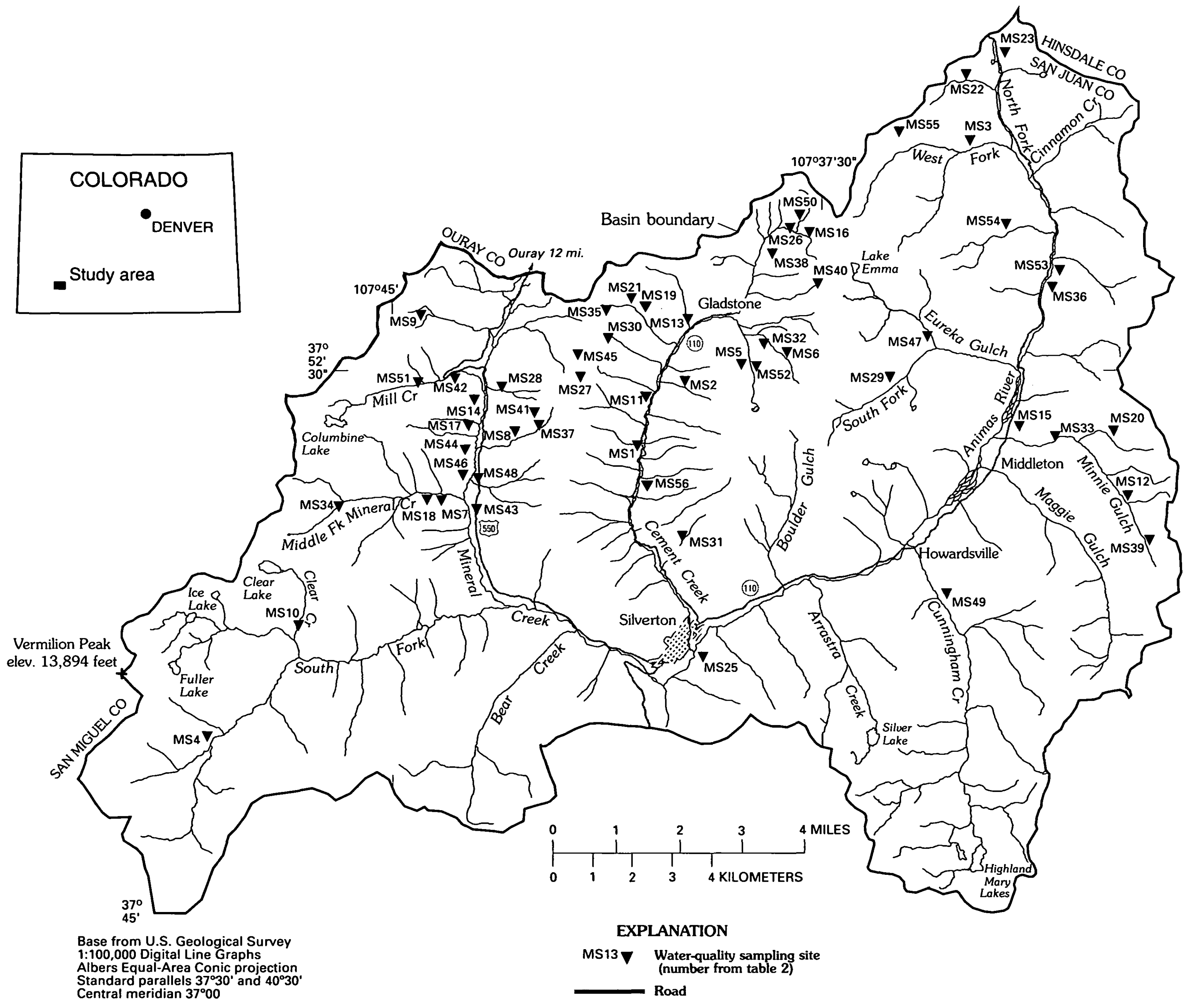

Figure 2. Upper Animas River watershed and locations of water-quality sampling sites at selected mines.

similar to those described by Wilde and Radtke (1998). Field meters were calibrated in the morning on the day of the sample collection. The pH meters were calibrated with pH-2 and pH-4 buffers or pH-4 and pH-7 buffers to bracket the range of pH values measured in the field. Specific-conductance (SC) meters were calibrated with two standards that bracketed the range of values expected at the sampling sites. Dissolved oxygen (DO) meters were calibrated to the saturated DO of water according to the water temperature and barometric pressure at each sampling site. The DO meters also were checked against a solution with a DO concentration of 0 mg/L. Instantaneous discharge at the time of sampling was determined from the stage reading and stage-discharge-rating table at the four streamflow-gaging stations. At the nine upstream sites and seven mine sites, instantaneous discharge was measured using a current meter according to methods described by Rantz and others (1982). Standard USGS sampling techniques as described in Ward and Hair (1990) and Shelton (1994) were used to collect water-quality samples. Water-quality samples at the stream sites were collected using depth-integrating samplers utilizing the equal-width-increments (EWI) method (Edwards and Glysson, 1988) then transferred into precleaned 2-L or 3-L polyethylene bottles. Mine-site samples were collected in precleaned polyethylene bottles by using the dip method.

Filtering and processing of water samples was done in a field laboratory in Silverton, Colorado, within 5 hours of sample collection. Standard USGS equipment (Horowitz and others, 1994) was used. Samples requiring filtered water were passed through a 0.45-µm cellulose filter housed in a 47-mm polycarbonate filtering unit using a peristaltic pump. The filter housing and pump tubing were soaked in dilute nitric acid and rinsed six times with deionized water between samples. Occasionally samples containing substantial amounts of sediment or colloids, were filtered using a 0.45-µm capsule filter instead of the plate filter. Filtered and unfiltered aliquots for dissolved and total major inorganic and trace-element constituents were preserved with concentrated ultrapure nitric acid (1 mL per 250 mL of sample). A filtered unpreserved aliquot was collected for sulfate analysis, and an unfiltered unpreserved aliquot was collected for the alkalinity determination. For selected samples, a filtered aliquot was preserved with 6 molar hydrochloric acid for ferrous iron analysis. Collection and processing procedures similar to those described above were used for the remaining mine sites listed in table 2 and the selected spring and stream sites listed in table 3 and shown in plate 1, except that samples were filtered and processed at the sampling site rather than in the laboratory.

Analytical Techniques

Analytical techniques used for water-quality analyses and the corresponding analytical detection limits are listed in table 4. Alkalinity was determined by incremental titration on unfiltered samples with pH greater than 4.5. The analysis was conducted at the sampling site or within 5 hours of sample collection at a USGS field laboratory in Silverton, Colorado. Major inorganic and selected trace-element constituents were analyzed on filtered and unfiltered (raw) samples by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) and potassium was analyzed by atomic absorption spectroscopy (AA) at a USGS research laboratory in Boulder, Colorado. The unfiltered samples were digested in the laboratory with concentrated hydrochloride acid at 60 C for 8 hours according to the method of Hoffman and others (1996). The digested samples were filtered through 0.45-µm polycarbonate filters into acid-washed polyethylene bottles prior to ICP-AES and AA analysis. Sulfate was determined by a turbidimetric method using a Hach SulfoVer reagent and ferrous iron (Fe^{+2}) was determined by a colorimetric method using a Hach 1, 10-phenanthroline reagent. The sulfate and Fe^{+2} determinations were measured on filtered samples using a Hach DR2000 spectrophotometer with a 25-mL sample cell. The quality of all laboratory analyses was assessed through the analysis of laboratory blanks, sample duplicates, USGS standard reference water samples (Long and Farrar, 1995), and calculated ion balances.

QUALITY ASSURANCE

Quality-assurance procedures used during the study period included daily calibration of water-quality meters, cleaning of sampling equipment and rinsing of sample bottles, and collection of quality-control samples (field equipment blanks and replicate samples). Results of 15 field equipment blanks and

Table 3. Water-quality sampling sites at selected springs and streams in the upper Animas River watershed (grouped according to three major subbasins of the watershed)

[UA, upper Animas River above Silverton; CC, Cement Creek; MC, Mineral Creek; site locations are shown on plate 1]

Site number	Site name	Latitude	Longitude	Elevation (feet)
UA1	Boulder Gulch near mouth	37°49'44"	107°38'09"	9,680
UA2	Burrows Gulch above North Fork Animas River	37°56'44"	107°34'29"	11,640
UA3	Burrows Gulch below London Mine	37°56'51"	107°35'02"	11,850
UA4	Burrows Gulch below wetland	37°56'49"	107°34'39"	11,800
UA5	California Gulch above Vermillion Mine	37°55'52"	107°35'58"	11,760
UA6	California Gulch above Mountain Queen Mine	37°54'55"	107°36'48"	12,400
UA7	California Gulch below Mountain Queen Mine	37°54'59"	107°36'46"	12,300
UA8	Cinnamon Creek near mouth	37°55'29"	107°33'49"	10,850
UA9	Cunningham Gulch near mouth	37°50'10"	107°35'48"	9,642
UA10	Eureka Gulch above mines	37°54'19"	107°36'51"	12,480
UA11	Eureka Gulch above sink holes	37°53'42"	107°36'30"	11,900
UA12	Eureka Gulch below cut dike	37°53'59"	107°36'56"	12,210
UA13	Eureka Gulch below Terry Tunnel	37°53'28"	107°35'52"	11,190
UA14	Eureka Gulch near mouth	37°52'48"	107°34'10"	9,890
UA15	Grouse Gulch near mouth	37°55'02"	107°33'15"	11,000
UA16	Hematite Gulch near mouth	37°50'09"	107°35'52"	9,648
UA17	Horseshoe Creek near mouth	37°57'00"	107°34'18"	11,750
UA18	California Gulch below mines	37°55'54"	107°35'37"	11,640
UA19	Maggie Gulch near mouth	37°51'18"	107°34'31"	9,711
UA20	Maggie Gulch above mines	37°48'47"	107°32'10"	11,840
UA21	McCarty Basin	37°53'32"	107°36'14"	11,560
UA22	Minnie Gulch above Esmeralda Mine	37°50'52"	107°31'56"	11,550
UA23	Minnie Gulch near mouth	37°51'44"	107°34'19"	9,760
UA24	Niagara Gulch near mouth	37°52'57"	107°33'41"	10,000
UA25	North Fork Animas River above Burrows Gulch	37°56'46"	107°34'27"	11,630
UA26	North Fork Animas River above West Fork	37°55'57"	107°34'08"	11,200
UA27	North Fork below Burrows Gulch	37°56'43"	107°34'26"	11,600
UA28	North Fork Minnie Gulch	37°51'44"	107°32'48"	11,720
UA29	Picayne Gulch near mouth	37°54'42"	107°33'21"	10,640
UA30	Placer Gulch above Gold Prince Mine	37°54'30"	107°36'06"	12,280
UA31	Placer Gulch above Sunbank Mine	37°54'56"	107°35'29"	11,660
UA32	Placer Gulch below Gold Prince Mine	37°54'35"	107°35'57"	12,120
UA33	Placer Gulch below Sunbank Mine	37°55'02"	107°35'26"	11,610
UA34	South Fork Eureka Gulch	37°52'54"	107°35'37"	10,600
UA35	Spring below London Mine Dump	37°56'53"	107°35'00"	11,950
UA36	Spring in Burns Gulch	37°54'08"	107°32'43"	11,400
UA37	Spring in California Gulch	37°55'09"	107°36'40"	12,190
UA38	Spring in Placer Gulch	37°54'32"	107°35'47"	12,090

Table 3. Water-quality sampling sites at selected springs and streams in the upper Animas River watershed (grouped according to three major subbasins of the watershed)

[UA, upper Animas River above Silverton; CC, Cement Creek; MC, Mineral Creek; site locations are shown on plate 1]

Site number	Site name	Latitude	Longitude	Elevation (feet)
UA39	Spring in South Fork Eureka Gulch	37°52'50"	107°36'03"	11,300
UA40	Spring near Houghton Mountain	37°56'47"	107°35'09"	11,840
UA41	Spring near Silver Wing Mine	37°54'12"	107°33'20"	10,360
UA42	Stream below Denver Lake	37°57'00"	107°34'21"	11,750
UA43	Stream below Lucky Jack Mine	37°57'10"	107°34'21"	11,760
UA44	Stream in Placer Gulch	37°54'39"	107°36'03"	12,220
UA45	Upper Animas River above Cinnamon Creek	37°55'31"	107°33'50"	10,850
UA46	Upper Animas River above Silver Wing Mine	37°54'15"	107°33'21"	10,380
UA47	Upper Burns Gulch	37°54'04"	107°32'35"	11,600
UA48	Burns Gulch	37°54'18"	107°32'55"	11,240
UA49	Upper Picayne Creek	37° 54'34"	107°34'32"	11,830
UA50	West Fork Animas River below Placer Gulch	37°55'51"	107°34'55"	11,370
UA51	West Fork Animas River near Animas Forks	37°55'53"	107°34'13"	11,120
CC1	Bogwan Spring	37°52'45"	107°40'11"	10,265
CC2	Cascade Gulch near mouth	37°51'56"	107°40'26"	10,100
CC3	Cement Creek above Mogul Mine	37°54'37"	107°38'23"	11,360
CC4	Cement Creek below Ross Basin	37°54'34"	107°37'49"	11,760
CC5	Dry Gulch above Evelyn Mine	37°53'19"	107°39'51"	10,500
CC6	East Queen Anne Creek	37°54'48"	107°37'48"	12,200
CC7	Fairview Gulch near mouth	37°52'23"	107°40'38"	10,540
CC8	Georgia Gulch near mouth	37°52'42"	107°40'21"	10,400
CC9	Hancock Gulch near mouth	37°50'08"	107°40'34"	9,720
CC10	Stream south of Hancock Gulch above adit	37°50'12"	107°39'46"	10,440
CC11	Stream south of Hancock Gulch near mouth	37°49'46"	107°40'10"	9,649
CC12	Illinois Gulch above Yukon Mine	37°51'01"	107°40'29"	9,960
CC13	Middle Fork Cement Creek near mouth	37°53'08"	107°38'50"	10,710
CC14	Minnesota Gulch near mouth	37°51'47"	107°40'33"	10,800
CC15	Minnehaha near mouth	37°53'14"	107°38'49"	10,640
CC16	Niagara Gulch below Irene Mine	37°50'28"	107°42'04"	11,600
CC17	Niagara Gulch near mouth	37°50'23"	107°40'47"	9,800
CC18	North Fork Cement Creek above upper Gold King Mine	37°53'44"	107°37'49"	12,090
CC19	North Fork Cement Creek above upper Gold King Mine	37°53'38"	107°38'15"	11,430
CC20	Porcupine Gulch above mines	37°51'35"	107°41'03"	10,920
CC21	Porcupine Gulch near mouth	37°51'31"	107°40'35"	10,080
CC22	Prospect Gulch above mouth	37°53'04"	107°40'23"	10,600
CC23	Prospect Gulch above Red Chemotroph Spring	37°53'00"	107°40'17"	10,470
CC24	Prospect Gulch below Henrietta Mine	37°53'20"	107°40'37"	10,920
CC25	Prospect Gulch below Red Chemotroph Spring	37°52'59"	107°40'03"	10,440

Table 3. Water-quality sampling sites at selected springs and streams in the upper Animas River watershed (grouped according to three major subbasins of the watershed)

[UA, upper Animas River above Silverton; CC, Cement Creek; MC, Mineral Creek; site locations are shown on plate 1]

Site number	Site name	Latitude	Longitude	Elevation (feet)
CC26	Prospect Gulch near mouth	37°52'58"	107°40'02"	10,360
CC27	Queen Anne Creek above Queen Anne Mine	37°54'51"	107°37'47"	12,200
CC28	Queen Anne Creek near mouth	37°54'37"	107°37'56"	11,720
CC29	Red Chemotroph Spring	37°53'00"	107°40'14"	10,450
CC30	South Fork Cement Creek above Silver Ledge Mine	37°52'33"	107°38'38"	10,974
CC31	South Fork Cement Creek below Big Colorado Mine	37°52'41"	107°38'42"	10,912
CC32	South Fork Cement Creek below Velocity Lake	37°52'08"	107°38'37"	11,305
CC33	South Fork Cement Creek at Gladstone	37°53'21"	107°39'10"	10,469
CC34	Spring near Big Colorado Mine	37°52'36"	107°38'40"	10,950
CC35	Spring below Red Mountain #3	37°53'53"	107°41'08"	12,120
CC36	Spring below Red Mountain #3	37°53'54"	107°41'08"	12,120
CC37	Spring in Cement Creek	37°53'18"	107°39'41"	10,436
CC38	Spring in Dry Gulch	37°54'01"	107°40'25"	11,690
CC39	Spring in Prospect Gulch	37°53'23"	107°40'20"	11,120
CC40	Spring in Middle Fork Cement Creek below mine	37°52'53"	107°38'15"	11,400
CC41	Spring in Minnehaha Basin	37°53'20"	107°37'57"	11,780
CC42	Spring in Niagara Gulch	37°50'28"	107°42'11"	11,720
CC43	Spring in Prospect Gulch	37°53'21"	107°41'31"	12,070
CC44	Spring in Prospect Gulch	37°53'21"	107°41'25"	12,020
CC45	Spring in Prospect Gulch	37°53'43"	107°41'22"	11,860
CC46	Spring in Prospect Gulch	37°53'48"	107°40'39"	11,915
CC47	Spring in Prospect Gulch	37°53'46"	107°40'57"	11,910
CC48	Spring in Prospect Gulch	37°53'36"	107°41'15"	11,730
CC49	Spring in Prospect Gulch	37°53'25"	107°41'34"	12,050
CC50	Spring in Ross Basin	37°54'13"	107°37'32"	12,240
CC51	Spring in Ross Basin	37°54'15"	107°37'43"	12,200
CC52	Spring in South Fork Cement Creek	37°53'02"	107°38'46"	10,695
CC53	Spring near Corkscrew Pass	37°54'12"	107°39'32"	11,840
CC54	Spring near Dry Gulch	37°53'18"	107°39'39"	10,390
CC55	Spring near Gladstone	37°53'22"	107°39'20"	10,400
CC56	Spring near Queene Anne Creek	37°54'48"	107°37'43"	12,200
CC57	Stream below Henrietta #3 Mine	37°53'20"	107°40'40"	11,000
CC58	Stream below Kansas City Mine	37°52'55"	107°40'59"	11,400
CC59	Stream below Lead Carbonate Mill	37°53'24"	107°37'59"	11,750
CC60	Stream in Middle Fork Cement Creek	37°52'51"	107°38'09"	11,570
CC61	Stream in Minnesota Gulch	37°52'03"	107°41'08"	10,840
CC62	Stream in Minnesota Gulch	37°52'02"	107°41'00"	10,680
CC63	Stream in Niagara Gulch	37°50'28"	107°41'50"	11,240
CC64	Stream in Niagara Gulch	37°50'32"	107°41'48"	11,300

Table 3. Water-quality sampling sites at selected springs and streams in the upper Animas River watershed (grouped according to three major subbasins of the watershed)

[UA, upper Animas River above Silverton; CC, Cement Creek; MC, Mineral Creek; site locations are shown on plate 1]

Site number	Site name	Latitude	Longitude	Elevation (feet)
CC65	Stream in Porcupine Gulch	37°51'40"	107°41'03"	11,000
CC66	Stream in Prospect Gulch	37°53'37"	107°41'20"	11,920
CC67	Stream in Prospect Gulch	37°53'35"	107°41'02"	11,320
CC68	Stream in Prospect Gulch	37°53'29"	107°41'10"	11,550
CC69	Stream in Prospect Gulch	37°53'28"	107°41'11"	11,550
CC70	Stream in Prospect Gulch	37°53'30"	107°41'21"	11,700
CC71	Stream in Prospect Gulch	37°53'28"	107°41'13"	11,570
CC72	Stream in Prospect Gulch	37°53'35"	107°41'19"	11,720
CC73	Stream in Prospect Gulch	37°53'37"	107°41'31"	11,960
CC74	Stream in Prospect Gulch	37°53'30"	107°41'34"	11,960
CC75	Stream in Prospect Gulch	37°53'24"	107°41'28"	11,850
CC76	Stream in Prospect Gulch	37°53'29"	107°41'23"	11,820
CC77	Stream in Prospect Gulch	37°53'31"	107°41'22"	11,740
CC78	Stream near Adams Mine	37°54'00"	107°38'29"	11,200
CC79	Telephone Gulch above adit	37°52'24"	107°40'06"	10,560
CC80	Telephone Gulch at mouth	37°52'25"	107°40'17"	10,220
CC81	Tirbutary of upper Cement Creek	37°54'49"	107°38'26"	11,900
CC82	Topeka Gulch near mouth	37°50'46"	107°40'43"	9,895
CC83	Tributary of Queen Anne Creek	37°54'51"	107°37'41"	12,220
CC84	Tributary of upper Cement Creek	37°54'50"	107°38'13"	12,080
CC85	Upper Cement Creek below upper Ross Basin	37°54'32"	107°37'41"	12,000
CC86	Upper Georgia Gulch	37°53'03"	107°41'18"	11,840
MC1	Bear Creek near mouth	37°48'46"	107°41'54"	9,560
MC2	Browns Gulch above Brooklyn Mine	37°51'37"	107°42'35"	11,200
MC3	Browns Gulch near mouth	37°51'24"	107°43'23"	10,260
MC4	Browns Gulch below Brooklyn Mine	37°51'26"	107°42'56"	10,800
MC5	Crystal Creek near mouth	37°50'33"	107°45'51"	10,640
MC6	Iron bog in South Fork Mineral Creek	37°48'58"	107°43'49"	9,590
MC7	Middle Fork Mineral Creek above Paradise Portal	37°50'27"	107°45'56"	10,680
MC8	Middle Fork Mineral Creek below Paradise Portal	37°50'33"	107°45'50"	10,660
MC9	Mill Creek near mouth	37°52'21"	107°44'08"	10,500
MC10	Mineral Creek near Red Mountain Pass	37°53'32"	107°43'00"	10,980
MC11	Moss bog in South Fork Mineral Creek	37°48'50"	107°44'16"	9,662
MC12	North tributary to Bighorn Gulch above mines	37°53'16"	107°42'29"	11,440
MC13	North tributary to Bighorn Gulch below mines	37°53'13"	107°42'36"	11,290
MC14	Porphyry Gulch above Bullion King Mine	37°53'16"	107°44'28"	12,340
MC15	Porphyry Gulch below Bullion King Mine	37°53'17"	107°44'27"	12,000
MC16	Porphyry Gulch below Highway 550	37°53'05"	107°43'20"	10,780
MC17	Red Tributary of Middle Fork Mineral Creek	37°50'25"	107°44'57"	10,460

Table 3. Water-quality sampling sites at selected springs and streams in the upper Animas River watershed (grouped according to three major subbasins of the watershed)

[UA, upper Animas River above Silverton; CC, Cement Creek; MC, Mineral Creek; site locations are shown on plate 1]

Site number	Site name	Latitude	Longitude	Elevation (feet)
MC18	Red Tributary of Middle Fork Mineral Creek	37°50'23"	107°44'59"	10,500
MC19	Red Tributary of Middle Fork Mineral Creek	37°50'15"	107°45'08"	10,700
MC20	Red Tributary of Middle Fork Mineral Creek	37°50'13"	107°45'11"	10,750
MC21	Red Tributary of Middle Fork Mineral Creek	37°49'55"	107°45'34"	11,360
MC22	Red Tributary of Middle Fork Mineral Creek	37°50'38"	107°44'49"	10,360
MC23	Spring in Red Tributary of Middle Fork Mineral Creek	37°50'14"	107°45'10"	10,720
MC24	Spring in Red Tributary of Middle Fork Mineral Creek	37°50'17"	107°44'52"	10,800
MC25	Spring in Red Tributary of Middle Fork Mineral Creek	37°50'15"	107°45'03"	10,720
MC26	Spring in Red Tributary of Middle Fork Mineral Creek	37°49'59"	107°45'30"	11,300
MC27	Spring in Red Tributary of Middle Fork Mineral Creek	37°49'43"	107°45'37"	11,660
MC28	Spring in Battleship Slide	37°50'01"	107°43'49"	10,040
MC29	Spring in Battleship Slide	37°50'00"	107°43'54"	10,180
MC30	Spring in Battleship Slide	37°50'00"	107°43'51"	10,200
MC31	Spring near Burro Bridge	37°51'06"	107°43'30"	10,040
MC32	Spring near Chattanooga	37° 52'15"	107°43'34"	10,280
MC33	Spring near Chattanooga	37°52'14"	107°43'45"	10,600
MC34	Spring near Mount Moly	37°49'18"	107°44'10"	10,690
MC35	Spring near Paradise Portal	37°50'35"	107°45'42"	10,640
MC36	Spring northwest of Burro Bridge	37°51'20"	107°43'52"	10,760
MC37	Spring northwest of Chattanooga beaver bogs	37°52'16"	107°43'38"	10,310
MC38	Spring southwest of Ohio Peak	37°50'58"	107°42'06"	11,840
MC39	Stream below Congress Mine	37°53'26"	107°42'27"	11,430
MC40	Stream below mine in U S Basin	37°52'28"	107°41'46"	12,260
MC41	Stream in Cemetary Slide	37°52'14"	107°43'13"	10,420
MC42	Stream in Cemetary Slide	37°52'14"	107°43'07"	10,620
MC43	Stream in Red Tributary of Middle Fork Mineral Creek	37°50'23"	107°44'58"	10,500
MC44	Stream in Red Tributary of Middle Fork Mineral Creek	37°50'13"	107°45'09"	10,760
MC45	Stream in Battleship Slide	37°50'05"	107°43'39"	9,730
MC46	Stream in Cemetary Slide	37°52'14"	107°43'01"	10,680
MC47	Stream near Mount Moly	37°49'02"	107°44'29"	10,050
MC48	Stream near Mount Moly	37°50'14"	107°43'39"	9,740
MC49	Stream near Mount Moly	37°48'51"	107°44'28"	9,680
MC50	Stream south of Browns Gulch	37°50'51"	107°43'25"	10,110
MC51	Stream south of Browns Gulch	37°50'48"	107°43'15"	10,200
MC52	Stream south of Browns Gulch	37°50'50"	107°43'14"	10,200
MC53	Stream southwest of Ohio Peak	37°50'57"	107°42'12"	11,800
MC54	Upper Zuni Gulch	37°49'50"	107°42'17"	11,020
MC55	Upper Zuni Gulch	37°49'49"	107°42'15"	11,020
MC56	Zuni Gulch near mouth	37°49'09"	107°42'24"	9,580
MC57	Spring below mine northwest of Burro Bridge	37°51'19"	107°43'42"	10,270

Table 4. Analytical techniques and corresponding detection limits used for water-quality analyses

[ICP-AES, inductively coupled plasma-atomic emission spectroscopy; AA, atomic absorption spectroscopy; mg/L, milligrams per liter; µg/L, micrograms per liter]

Constituent	Analytical method	Detection limit
Calcium	ICP-AES	0.15 mg/L
Magnesium	ICP-AES	0.01 mg/L
Sodium	ICP-AES	0.10 mg/L
Potassium	AA	0.01 mg/L
Alkalinity	Incremental titration	0.5 mg/L
Sulfate	Turbidimetric method	1.0 mg/L
Silica	ICP-AES	0.20 mg/L
Aluminum	ICP-AES	40 µg/L
Barium	ICP-AES	2 µg/L
Beryllium	ICP-AES	1 µg/L
Cadmium	ICP-AES	2 µg/L
Chromium	ICP-AES	15 µg/L
Copper	ICP-AES	4 µg/L
Iron, total	ICP-AES	30 µg/L
Ferrous iron	Colorimetric method	30 µg/L
Lead	ICP-AES	6 µg/L
Lithium	ICP-AES	3 µg/L
Manganese	ICP-AES	10 µg/L
Molybdenum	ICP-AES	20 µg/L
Nickel	ICP-AES	30 µg/L
Strontium	ICP-AES	3 µg/L
Vanadium	ICP-AES	4 µg/L
Zinc	ICP-AES	20 µg/L

18 replicate samples collected during the study period are presented in tables 5–7 and are discussed below.

Field Equipment Blanks

A field equipment blank is a sample prepared using blank (deionized) water that is passed through all the sampling and processing equipment (Spahr and Boulger, 1997). This type of sample is used to check for potential contamination of the environmental samples during sampling collection, processing, handling, and analysis. Analytical results for the 15 field equipment blanks collected during the study period are listed in table 5. The measured concentrations for most constituents were at or below the detection limits of the analytical methods. Several samples did have detectable concentrations of molybdenum, although most concentrations were less than twice the analytical detection limit.

Concurrent and Sequential Replicates

Concurrent and sequential replicate samples are collected to estimate variability in the environmental data. In the concurrent replicate, one sample is collected concurrently with the environmental sample by a second collection team or by using a second set of collection equipment. In the sequential replicate, a replicate is collected as close in time as possible to the environmental sample. Each sample is processed through all the normal steps of a regular water-quality sample (Spahr and Boulger, 1997). For each step of sample processing, the environmental sample is processed before the replicate sample. The replicate samples were processed using a clean filter and equipment.

Ten sequential and eight concurrent replicates were collected during the study period. Comparison of analytical results between environmental samples and sequential replicates and between environmental samples and concurrent replicates for major inorganic and trace-element constituents are listed in tables 6 and 7. The sequential replicates were collected using the same sampling team and the same collection procedures and analytical methods discussed previously in this report. The concurrent replicates were collected as part of another USGS data-collection program, and samples were analyzed at the USGS National Water Quality Laboratory in Lakewood, Colorado (Crowfoot and others, 1998; Crowfoot and others, 1999; Crowfoot and others, written commun., 2000). The majority of the differences between the environmental and the sequential replicates agree

Table 5. Chemical analyses of field equipment blanks collected during the study period

[concentrations in micrograms per liter except calcium, magnesium, sodium, potassium, sulfate, and silica in milligrams per liter; diss., dissolved; --, no data; <, less than]

Date	Calcium		Magnesium		Sodium		Potas-sium	Sulfate	Silica		Aluminum		Barium		Beryllium		Cadmium		Chromium	
	diss.	total	diss.	total	diss.	total	diss.	diss.	diss.	total	diss.	total	diss.	total	diss.	total	diss.	total	diss.	total
10/18/96	<0.15	--	<0.01	--	<0.10	--	--	--	0.22	--	<40	--	<2	--	<1	--	<2	--	<15	--
02/26/97	<0.15	<0.15	<0.01	<0.01	<0.10	<0.10	--	<1	<0.20	<0.20	50	<40	<2	<2	<1	<1	2	<2	<15	<15
06/17/97	<0.15	--	<0.01	--	<0.10	--	--	--	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
10/01/97	<0.15	--	<0.01	--	<0.10	--	--	--	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
12/29/97	<0.15	<0.15	<0.01	<0.01	<0.10	<0.10	<0.01	<1	<0.20	<0.20	<40	<40	<2	<2	<1	<1	<2	<2	<15	<15
06/24/98	<0.15	--	<0.01	--	<0.10	--	<0.01	<1	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
07/17/98	<0.15	<0.15	<0.01	<0.01	<0.10	<0.10	<0.01	--	<0.20	<0.20	<40	<40	<2	<2	<1	<1	2	2	<15	<15
07/23/98	0.02	--	<0.01	--	<0.10	--	<0.01	<1	0.42	--	<40	--	<2	--	<1	--	<2	--	<15	--
08/10/98	<0.15	--	<0.01	--	<0.10	--	<0.01	<1	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
09/17/98	<0.15	--	<0.01	--	<0.10	--	<0.01	<1	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
09/29/98	<0.15	--	<0.01	--	<0.10	--	<0.01	<1	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
12/29/98	<0.15	--	<0.01	--	<0.10	--	0.01	--	<0.20	--	<40	--	<2	--	<1	--	2	--	<15	--
07/29/99	<0.15	--	<0.01	--	<0.10	--	<0.01	--	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--
08/27/99	<0.15	--	<0.01	--	<0.10	--	<0.01	--	<0.20	--	62	--	<2	--	<1	--	<2	--	--	--
09/19/99	<0.15	--	0.04	--	0.40	--	<0.01	--	<0.20	--	<40	--	<2	--	<1	--	<2	--	<15	--

Date	Copper		Iron		Lead		Lithium		Manganese		Molybdenum		Nickel		Strontium		Vanadium		Zinc	
	diss.	total	diss.	total	diss.	diss.	diss.	total	diss.	total	diss.	total	diss.	total	diss.	total	diss.	total	diss.	total
10/18/96	<4	--	<30	--	<30	--	<6	--	<3	--	<10	--	<20	--	<3	--	<4	--	<20	--
02/26/97	4	<4	<30	<30	<30	<30	<6	<6	<3	<3	<10	<10	<20	<20	<3	<3	<4	<4	<20	<20
06/17/97	<4	--	39	--	<30	--	<6	--	<3	--	<10	--	<20	--	<3	--	<4	--	<20	--
10/01/97	<4	--	<30	--	<30	--	<6	--	<3	--	<10	--	<20	--	<3	--	<4	--	<20	--
12/29/97	<4	<4	<30	<30	<30	<30	<6	<6	<3	<3	19	<10	<20	<20	<3	<3	<4	<4	<20	<20
06/24/98	<4	--	<30	--	<30	--	<6	--	<3	--	<10	--	<20	--	<3	--	<4	--	<20	--
07/17/98	<4	<4	37	<30	<30	<30	<6	<6	<3	<3	<10	<10	<20	<20	<3	<3	<4	<4	<20	<20
07/23/98	<4	--	<30	--	<30	--	<6	--	<3	--	24	--	<20	--	<3	--	<4	--	<20	--
08/10/98	<4	--	<30	--	<30	--	<6	--	<3	--	27	--	<20	--	<3	--	<4	--	<20	--
09/17/98	<4	--	<30	--	<30	--	<6	--	<3	--	14	--	<20	--	<3	--	5	--	<20	--
09/29/98	<4	--	<30	--	<30	--	<6	--	<3	--	<10	--	<20	--	<3	--	<4	--	<20	--
12/29/98	<4	--	<30	--	<30	--	<6	--	<3	--	16	--	<20	--	<3	--	<4	--	<20	--
07/29/99	<4	--	<30	--	<30	--	<6	--	<3	--	15	--	20	--	<3	--	<4	--	<20	--
08/27/99	<4	--	<30	--	<30	--	<6	--	<3	--	11	--	<20	--	<3	--	<4	--	<20	--
09/19/99	<4	--	<30	--	<30	--	<6	--	<3	--	22	--	<20	--	<3	--	<4	--	33	--

Table 6. Comparison of chemical analyses of environmental samples and sequential replicates collected during the study period

[diss., dissolved; Env., environmental sample; Rep., replicate sample; R, river; Cr, creek; mg/L, milligrams per liter; µg/L, micrograms per liter]

Sampling site	Date	Calcium, diss.		Calcium, total		Magnesium, diss.		Magnesium, total		Sodium, diss.		Sodium, total		Potassium, diss.		Potassium, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	210	220	--	--	9.0	9.1	--	--	3.9	4.0	--	--	--	--	--	--
Animas R below Silverton	02/26/97	110	110	100	95	6.8	6.6	6.3	6.2	4.1	3.9	4.1	3.3	--	--	--	--
Avalanche Mine	07/01/98	46	51	53	46	8.3	9.0	8.8	8.7	2.1	2.2	2.3	2.2	2.0	2.0	--	--
Crystal Creek	08/27/98	32	33	--	--	2.0	2.1	--	--	1.9	2.0	--	--	0.2	0.2	--	--
North Fork Animas River	09/06/98	15	14	--	--	1.8	1.8	--	--	0.59	0.57	--	--	0.5	0.5	--	--
Animas R at Howardsville	09/23/98	39	41	41	41	2.4	2.4	2.4	2.4	1.6	1.7	1.8	1.8	0.6	0.6	0.6	0.6
Animas River at Eureka	05/10/99	19	19	--	--	1.4	1.4	--	--	0.60	0.65	--	--	0.4	0.4	--	--
Mineral Cr at Chattanooga	06/09/99	8.2	8.4	--	--	0.97	0.96	--	--	.72	.76	--	--	0.3	0.3	--	--
Animas R at Eureka	07/16/99	16	17	--	--	1.5	1.5	--	--	.45	.48	--	--	0.4	0.4	--	--
Bonner Mine	08/25/99	76	74	--	--	5.7	5.5	--	--	5.8	5.5	--	--	--	--	--	--

Sampling site	Date	Sulfate, diss.		Alkalinity, field		Silica, diss.		Silica, total		Aluminum, diss.		Aluminum, total		Barium, diss.		Barium, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	520	480	30	30	28	28	--	--	900	900	--	--	9	13	--	--
Animas R below Silverton	02/26/97	285	--	2.0	--	23	22	--	18	1,500	1,400	3,500	3,200	22	23	20	19
Avalanche Mine	07/01/98	300	300	--	--	50	53	58	52	7,700	8,400	8,600	8,700	3	3	8	4
Crystal Creek	08/27/98	77	80	6.0	6.0	11	11	--	--	60	80	--	--	22	24	--	--
North Fork Animas River	09/06/98	45	45	2.0	2.0	4.0	4.0	--	--	60	60	--	--	13	14	--	--
Animas R at Howardsville	09/23/98	97	97	33	35	6.1	6.3	6.5	6.5	<40	<40	46	58	24	23	26	25
Animas River at Eureka	05/10/99	--	--	21	23	4.2	4.3	--	--	<40	<40	--	--	9	9	--	--
Mineral Cr at Chattanooga	06/09/99	--	--	8	8	3.1	2.9	--	--	195	88	--	--	20	17	--	--
Animas R at Eureka	07/16/99	--	--	16	16	3.2	3.2	--	--	<40	62	--	--	11	12	--	--
Bonner Mine	08/25/99	--	--	--	--	46	45	--	--	7,300	7,000	--	--	22	21	--	--

Table 6. Comparison of chemical analyses of environmental samples and sequential replicates collected during the study period--Continued

[diss., dissolved; Env., environmental sample; Rep., replicate sample; R, river; Cr, creek; mg/L, milligrams per liter; µg/L, micrograms per liter]

Sampling site	Date	Beryllium, diss.		Beryllium, total		Cadmium, diss.		Cadmium, total		Chromium, diss.		Chromium, total		Copper, diss.		Copper, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	<1	<1	--	--	6	5	--	--	<15	<15	--	--	10	8	--	--
Animas R below Silverton	02/26/97	<1	<1	<1	<1	<2	<2	<2	<2	<15	<15	<15	<15	30	30	30	30
Avalanche Mine	07/01/98	<1	<1	<1	<1	3	<2	<2	6	<15	<15	<15	<15	50	50	60	50
Crystal Creek	08/27/98	<1	<1	--	--	<2	<2	--	--	<15	<15	--	--	<4	<4	--	--
North Fork Animas River	09/06/98	1	<1	--	--	6	5	--	--	<15	<15	--	--	10	10	--	--
Animas R at Howardsville	09/23/98	<1	<1	<1	<1	<2	<2	3	<2	<15	<15	<15	<15	<4	<4	<4	<4
Animas River at Eureka	05/10/99	<1	<1	--	--	3	4	--	--	20	<15	--	--	30	30	--	--
Mineral Cr at Chattanooga	06/09/99	<1	<1	--	--	<2	<2	--	--	<15	<15	--	--	54	34	--	--
Animas R at Eureka	07/16/99	<1	<1	--	--	3	<2	--	--	<15	<15	--	--	<4	<4	--	--
Bonner Mine	08/25/99	<1	<1	--	--	33	16	--	--	<15	<15	--	--	120	120	--	--

Sampling site	Date	Iron, diss.		Iron, total		Lead, diss.		Lead, total		Lithium, diss.		Lithium, total		Manganese, diss.		Manganese, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	10	10	--	--	<30	<30	--	--	40	50	--	--	2,400	2,500	--	--
Animas R below Silverton	02/26/97	2,700	2,700	5,000	4,900	<30	<30	<30	<30	<6	<6	7	7	1,500	1,400	1,300	1,300
Avalanche Mine	07/01/98	41,000	45,000	44,000	44,000	<30	<30	<30	<30	30	40	50	30	670	730	770	700
Crystal Creek	08/27/98	<30	<30	--	--	<30	<30	--	--	<6	<6	--	--	38	38	--	--
North Fork Animas River	09/06/98	<30	<30	--	--	<30	40	--	--	<6	<6	--	--	660	660	--	--
Animas R at Howardsville	09/23/98	40	50	80	90	<30	<30	<30	<30	8	8	<6	<6	250	260	270	270
Animas River at Eureka	05/10/99	<30	<30	--	--	<30	<30	--	--	<6	<6	--	--	210	210	--	--
Mineral Cr at Chattanooga	06/09/99	800	200	--	--	<30	<30	--	--	<6	<6	--	--	89	76	--	--
Animas R at Eureka	07/16/99	<30	<30	--	--	<30	<30	--	--	<6	<6	--	--	770	770	--	--
Bonner Mine	08/25/99	3,600	3,500	--	--	<30	<30	--	--	<6	<6	--	--	3,400	3,300	--	--

Table 6. Comparison of chemical analyses of environmental samples and sequential replicates collected during the study period--Continued

[diss., dissolved; Env., environmental sample; Rep., replicate sample; R, river; Cr, creek; mg/L, milligrams per liter; µg/L, micrograms per liter]

Sampling site	Date	Molybdenum, diss.		Molybdenum, total		Nickel, diss.		Nickel, total		Strontium, diss.		Strontium, total		Vanadium, diss.		Vanadium, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	<10	<10	--	--	<20	<20	--	--	2,600	2,600	--	--	<4	<4	--	--
Animas R below Silverton	02/26/97	<10	22	<10	<10	<20	<20	<20	<20	1,200	1,200	1,100	1,100	<4	<4	<4	<4
Avalanche Mine	07/01/98	<10	<10	<10	<10	40	<20	50	30	600	660	690	600	<4	<4	<4	5
Crystal Creek	08/27/98	<10	<10	--	--	<20	<20	--	--	240	250	--	--	<4	<4	--	--
North Fork Animas River	09/06/98	<10	17	--	--	<20	<20	--	--	40	40	--	--	<4	<4	--	--
Animas R at Howardsville	09/23/98	<10	<10	11	<10	<20	<20	<20	<20	380	390	390	400	<4	<4	<4	<4
Animas River at Eureka	05/10/99	25	<10	--	--	20	<20	--	--	120	120	--	--	<4	<4	--	--
Mineral Cr at Chattanooga	06/09/99	<10	<10	--	--	20	31	--	--	160	170	--	--	<4	<4	--	--
Animas R at Eureka	07/16/99	18	28	--	--	20	<20	--	--	100	100	--	--	<4	<4	--	--
Bonner Mine	08/25/99	<10	38	--	--	20	<20	--	--	350	340	--	--	<4	<4	--	--

Sampling site	Date	Zinc, diss.		Zinc, total	
		Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
Silver Ledge Mine	10/18/96	700	700	--	--
Animas R below Silverton	02/26/97	750	760	720	710
Avalanche Mine	07/01/98	190	200	210	210
Crystal Creek	08/27/98	<20	<20	--	--
North Fork Animas River	09/06/98	770	770	--	--
Animas R at Howardsville	09/23/98	230	250	240	240
Animas River at Eureka	05/10/99	460	460	--	--
Mineral Cr at Chattanooga	06/09/99	300	310	--	--
Animas R at Eureka	07/16/99	360	340	--	--

Table 7. Comparison of chemical analyses of environmental samples and concurrent replicates collected at the Animas River below Silverton during the study period

[diss., dissolved; Env., environmental sample; Rep., replicate sample; mg/L, milligrams per liter; µg/L, micrograms per liter]

Date	Calcium, diss.		Magnesium, diss.		Sodium, diss.		Potassium, diss.		Alkalinity, field		Sulfate, diss.		Silica, diss.		Aluminum, diss.		Aluminum, total	
	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (mg/L)	Rep. (mg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
11/19/96	75	77	4.5	4.3	2.9	3.0	--	0.8	10	10	200	200	15	13	98	59	1,800	1,700
04/28/97	50	53	3.4	3.6	2.1	2.3	--	0.6	9.0	9.0	130	140	12	11	80	31	1,300	1,200
06/16/97	21	21	1.6	1.5	1.1	1.1	--	0.4	16	16	39	43	7.1	6.6	<40	42	370	470
08/13/97	33	33	2.3	2.3	1.5	1.5	--	0.5	18	--	72	74	8.2	7.2	<40	31	350	550
10/22/97	51	52	3.2	3.2	2.0	2.1	--	0.6	14	14	140	130	9.2	10	<40	22	740	1,100
05/05/98	40	37	2.5	2.5	2.2	1.7	0.6	0.5	9.0	11	98	91	9.6	8.8	70	17	870	960
06/02/98	22	19	1.5	1.4	1.2	1.0	0.4	0.4	11	13	44	42	6.4	5.7	77	26	640	700
07/22/98	36	36	2.4	2.5	1.5	1.6	0.5	0.5	14	20	90	86	7.7	7.7	62	27	660	710

Date	Cadmium, diss.		Copper, diss.		Copper, total		Iron, diss.		Iron, total		Lead, diss.		Manganese, diss.		Manganese, total		Zinc, diss.	
	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)	Env. (µg/L)	Rep. (µg/L)
11/19/96	<2	2	12	12	34	20	1,600	1,600	2,700	2,900	<30	<1	880	840	860	810	530	560
04/28/97	<2	2	9	10	42	62	810	870	2,100	2,000	<30	<1	1,100	1,100	1,100	1,100	650	690
06/16/97	<2	<1	8	8	19	19	98	150	670	840	<30	<1	260	250	280	320	280	300
08/13/97	<2	<1	<4	3	12	12	130	140	560	700	<30	<1	430	430	370	400	250	250
10/22/97	<2	2	5	5	41	30	760	850	1,490	1,800	<30	<1	650	670	530	620	380	420
05/05/98	<2	2	6	8	37	<10	580	550	2,100	2,400	<30	<1	720	710	760	710	520	530
06/02/98	<2	<1	<4	6	27	26	120	140	1,700	2,000	<30	<1	240	230	340	360	240	230
07/22/98	<2	1	<4	2	15	<10	160	190	980	960	<30	<1	460	470	490	470	220	230

within ±10 percent. Many of the trace-element concentrations were less than the analytical detection limit.

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