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# **Environmental Assessment of Water, Sediment, and Biota Collected from the Bear Creek Watershed, Colusa County, California**

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# Conversion Factors

## Inch/Pound to International System of Units

Multiply	By	To obtain
Length		
inch (in)	2.54	centimeter (cm)
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	4,047	square meter (m <sup>2</sup> )
acre	0.004047	square kilometer (km <sup>2</sup> )
square mile (mi <sup>2</sup> )	259.0	hectare (ha)
square mile (mi <sup>2</sup> )	2.590	square kilometer (km <sup>2</sup> )
Volume		
cubic inch (in <sup>3</sup> )	0.01639	cubic centimeter (cm <sup>3</sup> )
cubic foot (ft <sup>3</sup> )	28.32	cubic decimeter (dm <sup>3</sup> )
cubic foot (ft <sup>3</sup> )	0.02832	liter (L)
cubic yard (yd <sup>3</sup> )	0.7646	cubic decimeter (dm <sup>3</sup> )
cubic mile (mi <sup>3</sup> )	4.168	cubic meter (m <sup>3</sup> )
acre-foot (acre-ft)	1,233	cubic meter (m <sup>3</sup> )
acre-foot (acre-ft)	0.001233	cubic kilometer (km <sup>3</sup> )
Mass		
gram (g)	0.03527	ounce, avoirdupois (oz)
Kilogram (kg)	2.205	pound, avoirdupois (lb)
microgram (µg)	0.000000353	ounce, avoirdupois (oz)
milligram (mg)	0.0000353	ounce, avoirdupois (oz)
nanogram (ng)	0.000000000353	ounce, avoirdupois (oz)
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as  $^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32$ .

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as  $^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8$

Concentrations of chemical constituents are given in micrograms per gram (µg /g).

## Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

## Abbreviations

µg	Micrograms
ANCOVA	Analysis of covariance
Au	Gold
B	Boron
BaSO <sub>4</sub>	Barium sulfate (barite)
C	Celsius (degrees)
CaCO <sub>3</sub>	Calcium carbonate
Calcines	Products of roasting ore
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cl <sup>-</sup>	Chloride
CRM	Certified reference material
CVAAS	Cold vapor atomic absorption spectroscopy
CVAFS	Cold vapor atomic fluorescence spectroscopy
CV-GC-AFS	cold vapor-gas chromatography-atomic fluorescence spectrometry
CVRWQCB	Central Valley Regional Water Quality Control Board
DOC	Dissolved organic carbon
Fe	Iron
GC	Gas chromatographic
GMWL	Global meteoric water line
HCl	Hydrochloric acid
HDPE	High-density polyethylene
Hg	Mercury; generic shorthand for mercury; does <i>not</i> denote speciation.
Hg(II)	Mercury salt
Hg <sub>F</sub>	Total mercury (inorganic plus organic) in a filtered sample (either 0.1 µm or 0.45 µm, as specified in text)
HgS	Mercury sulfide (cinnabar)
Hg <sub>T</sub>	Total mercury (inorganic plus organic)
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
HCl	Hydrochloric acid
HNO <sub>3</sub>	Nitric acid
ICP-AES	Inductively couple plasma-atomic emission spectrometry
ICP-MS	Inductively coupled plasma-mass spectrometry
K	Potassium
Li	Lithium
LCS	Laboratory control samples
MDL	Mean detection limit
MMeHg	Monomethylmercury (also known as methylmercury and monomethyl mercury (CH <sub>3</sub> Hg <sup>+</sup> ))
N	Number of samples
Na	Sodium
NAWQA	National Water-Quality Assessment
NBS	National Bureau of Statistics
NIST	National Institute of Standards and Technology

ng/g	Nanogram per gram, equivalent to one (1) part per billion
ng/L	Nanogram per liter, approximately equivalent to one (1) part per billion
ORP	Oxidative-reductive potential
ppm	Parts per million, equivalent to mg/kg or µg/g
QAQC	Quality assurance/Quality Control
Rb	Rubidium
RPD	Relative percent difference
RSI	Removal Site Investigation
S	Sulfur
SC	Specific (electrical) conductivity, reported in units of millisiemens per centimeter (mS/cm) or microsiemens per centimeter (µS/cm).
Sc	Scandium
Se	Selenium
SLAP	Standard Light Antarctic Precipitation
SnCl <sub>2</sub>	Stannous chloride
SO <sub>4</sub>	Sulfate
SOP	Standard Operation Procedure
Sr	Strontium
TSS	Total Suspended Sediment
USBLM	U.S. Bureau of Land Management
USBM	U.S. Bureau of Mines
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VSMOW	Vienna Standard Mean Ocean Water
W	Tungsten
ww	Wet weight

# Environmental Assessment of Water, Sediment, and Biota Collected from the Bear Creek Watershed, Colusa County, California

By James J. Rytuba,<sup>1</sup> Roger L. Hothem,<sup>2</sup> Brianne E. Brussee,<sup>2</sup> Daniel N. Goldstein,<sup>1</sup> and Jason T. May<sup>3</sup>

## Introduction

### Background and Objectives

The Cache Creek watershed lies within California's North Coast Range, an area with abundant geologic sources of mercury (Hg) and a long history of Hg contamination (Rytuba, 2000). Bear Creek, Cache Creek, and the North Fork of Cache Creek are the major streams of the Cache Creek watershed, encompassing 2978 km<sup>2</sup> (fig. 1). The Cache Creek watershed contains soils naturally enriched in Hg as well as natural springs (both hot and cold) with varying levels of aqueous Hg (Domagalski and others, 2004, Suchanek and others, 2004, Holloway and others 2009). All three tributaries are known to be significant sources of anthropogenically derived Hg from historic mines, both Hg and gold (Au), and associated ore storage/processing sites and facilities (Slotton and others, 1995, 2004; CVRWQCB, 2003; Schwarzbach and others, 2001; Gassel and others, 2005; Suchanek and others., 2004, 2008a, 2009) (fig. 2). Historically, two of the primary sources of mercury contamination in the upper part of Bear Creek have been the Rathburn and Petray Hg Mines.

The Rathburn Hg mine was discovered and initially mined in the early 1890s. The Rathburn and the more recently developed Petray open pit mines are localized along fault zones in serpentinite that has been altered and cut by quartz and chalcedony veins (fig. 3). Cold saline-carbonate springs are located peripheral to the Hg deposits and effluent from the springs locally has high concentrations of Hg (Slowey and Rytuba, 2008). Several ephemeral tributaries to Bear Creek drain the mine area which is located on federal land managed by the U.S. Bureau of Land Management (USBLM). The USBLM requested that the U.S. Geological Survey (USGS) measure and characterize Hg and other geochemical constituents in sediment, water, and biota to establish baseline information prior to remediation of the Rathburn and Petray mines. Samples sites were established in Bear Creek upstream and downstream from the mine area. This report is made in response to the USBLM request, the lead agency mandated to conduct a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) - Removal Site Investigation (RSI). The RSI applies to the possible removal of Hg-contaminated mine waste from Bear Creek.

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This report summarizes data obtained from field sampling of water, sediment, and biota in Bear Creek, above input from the mine area and downstream from the Rathburn-Petray mine area to the confluence with Cache Creek. Our results permit a preliminary assessment of the chemical constituents that could elevate levels of monomethyl Hg (MMeHg) in Bear Creek and its uptake by biota and provide baseline information for comparison to conditions after mine remediation is completed.

## **Mining History and Geology**

### **Rathburn-Petray Mine**

The Rathburn Hg mine was discovered and initially mined in the early 1890s. The Rathburn and the more recently developed Petray open pit mines are localized along fault zones in serpentinite that has been altered and cut by quartz and chalcedony veins. Cinnabar is the primary ore mineral, and metacinnabar has been identified in sediment derived from the Petray mine. The Hg ores formed in a hot spring system in the steam-heated environment present above a boiling groundwater table. However, no active hot springs are present in the deposits but cold saline-carbonate springs are present adjacent to the northeast of the Petray Hg mine and may reflect the waning stage of the mercury hydrothermal system (Slowey and Rytuba, 2008). The Rathburn Hg mine is relatively small, having produced 100 flasks of Hg. Mining in the late 1960s and early 1970s recovered about 400 flasks of Hg from the Petray open pit mine (USBM, 1965). At the Rathburn Mine, Hg ores were processed in a brick retort, and small amounts of calcines are present that contain up to 1,020 ppm Hg (Churchill and Clinkenbeard, 2002; Slowey and Rytuba, 2008). Waste rock derived from open cuts (in altered serpentinite) contains less than 39 ppm total Hg (Hg<sub>T</sub>). Ores from the Petray Mine were processed offsite in a rotary furnace at the Abbott Mine, and, as a result, there are no mine tailings at the Petray mine.

## **Sample Locations and Methods**

### **Sample Locations and Conditions: Water and Sediment**

Samples were collected to assess the concentration of Hg and biogeochemically relevant constituents in water and sediment in Bear Creek. Water and sediment were sampled from Bear Creek both upstream and downstream from the Rathburn and Petray mine sites (fig. 4). In addition, samples were collected from Sulphur Creek, a tributary to Bear Creek (fig. 3). Sample-site locations are shown in figures 1 and 4 and listed in table 1. Sample site BC1 is located in Bear Creek at the Brim Road bridge upstream of the tributary input from the mine area and is representative of background conditions in the watershed (figs. 1 and 5). The collection site was under the county road bridge on public land. Sample site BC2 is located in Bear Creek just upstream of the tributary input from the Rathburn-Petray mine area (figs. 4 and 6). Sample sites BC3 (figs. 4 and 7) and BC4 (figs. 1 and 8) are located in Bear Creek downstream from the mine input but upstream from the confluence with Sulphur Creek. Sample sites BC5 and BC6 are located in Sulphur Creek (figs. 1, 9-10). Sample site BC7 is located in Bear Creek, just downstream from the confluence with Sulphur Creek (figs. 1 and 11). Sample sites BC8 (fig. 12), BC9 (fig. 13), and BC10 (fig. 14) are in the lower reach of Bear Creek, with sample site BC10 located just upstream from the confluence with Cache Creek. Water and sediment were collected during five sampling events from 2009 to 2011 (table 1).

Samples were collected under low- and high-flow conditions in 2009, 2010, and 2011 during five separate sampling events. Site numbers in 2009 differed from those in 2010 and 2011. 09BC1 was

the same site as 10BC2, 09BC2 was the same site as 10BC3, and 09BC5 was the same site as 10BC4. Flows in Cache Creek at Rumsey Bridge, just downstream from the confluence with Bear Creek are shown in figure 15. Upper Cache Creek and Bear Creek account for most of the flow in Cache Creek at Rumsey Bridge, thus we use Cache Creek flows as measured at Rumsey Bridge to give an indication of flows in Bear Creek. The first sampling event in this study occurred in January 2009 under low-flow conditions—flows during this sampling event were the lowest of the five events in this study. Flows were high during the second sampling event, in June 2010, as the Cache Creek watershed experienced an extended rainy season from winter 2009 through summer 2010. The third sampling event occurred during September 2010, and flows during this event were considerably lower than flows during the June 2010 event. The fourth sampling event occurred in March of 2011 during a severe storm, and the flows in upper Cache Creek were among the highest recorded since 2006. The fifth and final sampling event took place in June 2011 under high-flow conditions, as the watershed experienced another extended wet period in early summer 2011.

### **Sample Locations and Conditions: Biota**

Samples were collected to assess the concentration of Hg and MMeHg in biological samples collected from Bear Creek, both upstream and downstream from the Rathburn and Petray mine sites, and from Sulphur Creek during June and September 2010. Sample-site locations are shown in figure 1 and listed in table 2. Biological samples were not collected from BC1 because the landowner refused to allow access to the site. Sample site BC2 is co-located with the water and sediment sampling site in Bear Creek at a bridge just upstream of the tributary input from the Rathburn-Petray mine area (fig. 6). Biological sample site BC3 (fig. 7) is co-located with the water and sediment sampling site downstream of the input from the Rathburn and Petray mines and cold saline springs. Biological site BC4 (fig. 8) is located in Bear Creek about 2.9 km downstream from BC3 and about 2.2 km upstream from the confluence with Sulphur Creek. The biota BC4 site was about 800 m upstream from the BC4 site sampled for water and sediment. Biota sample site BC5 is located in Sulphur Creek, about 420 m upstream from the water/sediment site BC5. BCUS is a biota sample site located at a pool on Sulphur Creek about 230 m upstream of biota sample site BC5 (no water or sediment sampled there), and BC6 is a site co-located in Sulphur Creek with a water/sediment site (fig. 10). Sample site BC7 is located in Bear Creek, just downstream from the confluence with Sulphur Creek (fig. 11). Sample sites BC8 (fig. 12), BC9 (fig. 13), and BC10 (fig. 14) are downstream in Bear Creek (fig. 1), and all were within 300 m or less of the water and sediment sites.

## **Field Sampling Methods**

### **Sediments**

Wet-sediment samples were collected from Bear Creek sites and placed in polycarbonate jars (100 ml capacity) for analysis of total Hg ( $Hg_T$ ) and MMeHg. The samples were frozen with dry ice immediately after collection (freezing time approximately 10–20 minutes) and kept frozen until shipped overnight on dry ice to the analytical laboratory. The temperature of samples arriving at the analytical facilities remained below freezing, which is within the limits specified in USEPA Method 1631E. Another sediment sample was collected in a Ziploc<sup>®</sup> bag for analysis of major and minor elements and was stored at ambient temperature.

## Water

Stream-water samples were collected in the field with a peristaltic pump using ultraclean tubing and an inline filter with 0.45  $\mu\text{m}$  openings. Filtered water samples were collected for analysis of anions by ion chromatography, alkalinity by titration, and major and minor elements using inductively coupled plasma-mass spectrometry (ICP-MS) and inductively coupled plasma-atomic emission spectrometry (ICP-AES) analysis. An unfiltered sample also was analyzed using both ICP-MS and ICP-AES.

Samples for major and minor element determinations were acidified to  $\text{pH} < 2$  with trace-metal (*Ultrex*, J.T. Baker)-grade  $\text{HNO}_3$  and were stored in acid-washed, high-density polyethylene (HDPE) bottles. Subsamples for anion and alkalinity measurements were filtered, stored in HDPE bottles, and chilled to approximately 4  $^\circ\text{C}$  until analysis, in accordance with USGS protocols for trace metals (<http://pubs.water.usgs.gov/twri9A>).

Samples for DOC analysis were filtered using 0.45-micron disposable borosilicate filters and stored in 40-mL amber ICHEM glass vials. Shortly after collection, DOC samples were acidified to  $\text{pH}$  less than 2 with HCl and kept on ice and refrigerated until analyzed.

Samples for stable-isotope analysis were collected as a grab sample directly from the stream into clear 40-mL ICHEM glass vials and were stored at ambient temperature until analyzed.

Water variables, including  $\text{pH}$ , conductivity, temperature, dissolved oxygen, and oxidation-reduction potential (ORP), were measured in the field by placing the probe of a battery-powered Hydrolab sonde directly into the flowing stream water.

Samples for  $\text{Hg}_T$  and MMeHg analyses were collected with no headspace in trace-metal-free-certified 250-mL bottles (Nalgene HDPE). The MMeHg bottles contained a preservative of certified ultra-clean HCl provided by the analytical laboratories, Frontier Global Sciences and Brooks Rand Labs. Sampling for  $\text{Hg}_T$  analysis followed ultra-clean sampling and handling protocols (Bloom, 1995; Gill and Fitzgerald, 1987) during the collection of field samples and analysis to avoid introduction of Hg. Samples were kept on ice until shipped. Samples were shipped on ice packs and arrived the next morning at the analytical facilities at temperatures ranging from 1 to 4 $^\circ\text{C}$ , as specified by USEPA Method 1631E to minimize biologically induced phase changes and MMeHg degradation. During every sampling event, a field blank was collected by processing ultra-clean water provided by the analytical laboratories and collecting the same subsamples (except for alkalinity) following the same procedures as used for the field samples. Laboratory blanks and acid blanks were processed periodically to determine whether the equipment, containers, reagents, and procedures introduced any significant contamination.

## Biota

Biological samples were collected similar to procedures outlined by Suchanek and others (2010). Field forms, sample labels, and laboratory submission forms were prepared and printed prior to collecting samples. For examples of such forms, see Scudder and others (2008). California scientific collection permits for collections of invertebrates and fish were obtained from the California Department of Fish and Game. Landowner permissions were obtained for access to sites located on private property or when site access required crossing private property.

Clean techniques were essential to minimize potential contamination, including contact with personnel and equipment. The field methods described here are based on guidelines developed in conjunction with the National Water-Quality Assessment (NAWQA) Program, the Toxic Substances Hydrology Programs, and researchers from other disciplines in the USGS as described by Scudder and others (2008).

Biological samples were collected within a short time period (2 weeks or less for invertebrates and forage fish) to minimize changes that might affect relative Hg concentrations. In addition, sample collection of biota was coordinated with the collection of water and sediment to minimize risk of site disturbance and potential water or sediment sample contamination.

## Invertebrates

Aquatic invertebrates can serve as excellent bioindicators of metals contamination (Cain and others, 1992). The invertebrates sampled for this study (Merritt and Cummins, 1995) were predatory insects, depending on their abundance and availability at sampling sites: larval dragonflies (Order Odonata, Suborder Anisoptera, family Gomphidae, Aeshnidae, and Libellulidae), larval damselflies (Order Odonata, Suborder Zygoptera, family Calopterygidae, Lestidae, and Coenagrionidae), and adult water striders (Order Hemiptera, family Gerridae). Invertebrates were sorted to family and processed as single-taxon composites. Alternate species of invertebrates were collected where available to serve as functionally equivalent substitutes in case adequate numbers of the primary target invertebrates were not available. Field duplicate samples were collected where individuals were sufficiently abundant.

Invertebrate sampling was conducted in June and September to evaluate seasonal differences in Hg bioaccumulation. Invertebrates were collected using dip nets and by hand. Samples were separated by taxon and placed into Ziploc<sup>®</sup> bags with native water on wet ice for later sorting. Within 24 hours, individuals were sorted by family and placed in disposable dishes using Teflon<sup>®</sup>-coated forceps or gloved-hand. Organisms were rinsed with DI water and patted dry with a clean paper towel. The total mass of the composite samples, consisting of 1–120 individuals of the same family, was determined ( $\pm 0.01$  g) with an electronic balance. Samples were placed into chemically cleaned glass jars with Teflon<sup>®</sup>-lined lids, stored frozen for no more than 30 days, and were then shipped to Frontier Global Sciences for analyses. Composites of whole-body aquatic invertebrates were analyzed for both Hg<sub>T</sub> and MMeHg because the ratios of MMeHg to Hg<sub>T</sub> tend to be inconsistent among invertebrate taxa, among sites, and among years (Mason and others, 2000; Haines and others, 2003; Wiener and others, 2007).

## Fish

Fish were collected using backpack electrofishing techniques described elsewhere (Meador and others, 1993; Moulton and others, 2002). Seven to fifteen individual California roach (*Hesperoleucus symmetricus*) of similar length were collected in both spring and fall from the vicinity of sites on Bear Creek also sampled for water, sediments, and invertebrates. After capture, fish were placed in a large plastic bucket in native water until they could be processed. Guidelines for live specimen handling and care are provided in Walsh and Meador (1998); detailed procedures for processing fish are provided by Scudder and others (2008).

Captured fish were held in buckets of native water and were anesthetized using clove oil, placed in clean zip-lock bags on wet ice, and then stored frozen until they could be processed, usually within 24 hours. Individual fish were measured for standard and total length ( $\pm 0.5$  mm) and the total mass determined ( $\pm 0.01$  g) with an electronic balance. The contents of the gastrointestinal tract were removed, and the mass of the remaining sample was determined ( $\pm 0.01$  g). Each sample was then placed in a chemically cleaned glass jar with a Teflon<sup>®</sup>-lined lid and stored frozen. Seven similar-sized fish from each site and both seasons were selected for analysis and sent to the contract laboratory, Frontier Global Sciences in Seattle, Washington for Hg<sub>T</sub> and MMeHg analyses within 30 days of collection. Fish not selected for analysis were stored frozen as potential backups.

## Sample Shipment

Before samples were shipped to the contract laboratory for analysis, all sample data were entered on the appropriate sample chain-of-custody forms (included in the packaging), and the analytical laboratory was notified to ensure that they could receive the samples. Frozen samples were shipped for next-day delivery via FedEx<sup>®</sup>. A sufficient amount of dry ice was included in the packaging so that a 1-day delay would not adversely affect the samples. Samples were shipped on 14 July (June samples) and 7 October (September samples).

## Analytical Methods

### Sediments

Multi-element analyses for all sediments were performed in the laboratories of ALS Chemex. Bulk samples were ground in a zirconia ring mill and subjected to a near-total four-acid digestion. Major elements were determined by ICP-AES. Minor elements, other than Hg, were determined by ICP-MS. Hg was determined by cold vapor atomic absorption spectroscopy (CVAAS) following methods similar to those described by Crock (1996) and O'Leary and others (1996).

Hg and MMeHg analyses for all wet sediments were done at Frontier Global Sciences and Brooks Rand LABS. For total Hg, the sediment was leached with cold aqua regia, followed by stannous chloride (SnCl<sub>2</sub>) reduction, two-stage gold amalgamation, and cold vapor atomic fluorescence spectroscopy (CVAFS) detection. MMeHg was obtained by acid bromide/methyl chloride extraction followed by aqueous phase ethylation, isothermal gas chromatographic (GC) separation, and CVAFS detection (Horvat and others, 1993). Results were reported on both a wet- and dry-weight basis and are listed in table 3.

### Waters

Alkalinity as CaCO<sub>3</sub> was determined in the laboratory by titration with H<sub>2</sub>SO<sub>4</sub>, using Gran's technique (Orion Research, Inc., 1978), within 2–4 days after sample collection. Sulfate, chloride, nitrate, and fluoride concentrations were determined by ion chromatography (Fishman and Pyen, 1979) by the USGS analytical laboratory at the Denver Federal Center. Cations were analyzed by ICP-AES and ICP-MS at USGS laboratories at the Denver Federal Center in Denver, Colorado. Duplicate water samples, blank samples, and USGS Water Resource Division standard reference waters were analyzed with the data set.

At both Frontier Global Sciences and Brooks Rand Labs, samples were handled in a Class-100 clean-air station that was monitored routinely for low levels of total gaseous Hg. An ultra-clean Hg trace-metal protocol was followed, including the use of rigorously cleaned and tested Teflon<sup>®</sup> equipment and sample bottles and prescreened and purified reagents. Laboratory atmosphere and water supply also were routinely monitored for low levels of Hg. Primary standards used in the laboratory were NIST-certified, or traceable to NIST-certified materials. Following USEPA Method 1631, MMeHg standards were made from pure powder and calibrated against an NBS-3133 certified Hg(II) standard. Standards were cross-verified by daily analysis of Certified reference material (CRM) DORM-2 (National Research Council of Canada Institute for National Measurement Standards, 1999). Total Hg was determined by bromine monochloride (BrCl) oxidation followed by tin(II) chloride (SnCl<sub>2</sub>) reduction, two-stage gold amalgamation, and detection by CVAFS (Bloom and others, 1988). MMeHg was liberated from water using an all-Teflon<sup>®</sup> distillation system. Distilled samples were analyzed using

aqueous phase ethylation with purging onto Carbotrap™, isothermal GC separation, and CVAFS detection (Bloom, 1989). To address accuracy and precision, quality assurance measures were employed with the following minimum frequencies: laboratory duplicates, one per ten samples; method blanks, three per analytical batch; filtration blanks, one per ten samples; and spike recovery or standard reference material, one per ten samples.

Since May 1, 1990, hydrogen-isotope-ratio analyses have been performed using a hydrogen equilibration technique (Coplen and others, 1991; Révész and Coplen, 2008a), rather than the zinc technique used prior to that date (Kendall and Coplen, 1985). The hydrogen equilibration technique measures deuterium activity, whereas the zinc technique measures deuterium concentration.

For the majority of the isotopic samples, the difference in reported isotopic compositions between the two techniques is not significant. However, in brines, the difference may be significant (Sofer and Gat, 1972, 1975). Reported delta H-2 values of activity are more positive than delta H-2 values of concentration, and this difference is proportional to molalities of the major dissolved solids. Some examples of the differences between activity ratios and concentration ratios for delta H-2 in 1 molal salt solutions are provided by Horita and others (1993). The data for individual salts may be multiplied by molality to obtain adjustments to delta values based on concentration. Water samples are measured for delta O-18 using the CO<sub>2</sub> equilibration technique of Epstein and Mayeda (1953), which has been automated (Révész and Coplen, 2008b). Therefore, both oxygen and hydrogen isotopic ratio measurements are reported as activities. Oxygen and hydrogen isotopic results are reported in per mil relative to VSMOW (Vienna Standard Mean Ocean Water) and normalized (Coplen, 1994) on scales such that the oxygen and hydrogen isotopic values of SLAP (Standard Light Antarctic Precipitation) are -55.5 per mil and -428 per mil, respectively. The 2-sigma uncertainties of oxygen and hydrogen isotopic results are 0.2 per mil and 2 per mil, respectively, unless otherwise indicated.

## Biota

Samples were analyzed for Hg<sub>T</sub> and MMeHg at Frontier Global Sciences, in Seattle, Washington. Invertebrate samples were rinsed with reagent water, and blotted with clean laboratory wipes prior to being homogenized. Fish were homogenized as whole body fish. Homogenized samples were digested for total mercury analysis with concentrated sulfuric and nitric acids according to method FGS-011, a modified EPA method 1631, Digestion I. Homogenized samples were digested for monomethyl mercury analysis by a heated 25% KOH solution, followed by dilution with methanol, according to FGS-010.

Total mercury in digested tissues was analyzed by SnCl<sub>2</sub> reduction, dual gold amalgamation, and cold vapor atomic fluorescence spectrometry (CVAFS) detection according to FGS-069, a modified EPA1631 method.

Monomethyl mercury in digested tissues was analyzed by gas chromatography-cold vapor-atomic fluorescence spectrometry (GC-CV-AFS) (aqueous phase ethylation, isothermal GC separation, and CVAFS detection) according to Frontier's SOP FGS-070, a modified EPA method 1630.

Duplicate samples were analyzed at a rate of 5%, with at least one duplicate per matrix per analytical run to estimate the precision of the methods. The range of relative percent differences (RPD) for the Hg<sub>T</sub> duplicates (n=8) in spring-season samples was 1.23 to 38.4 percent; one RPD was outside the acceptable criterion (RPD <25%). The range of RPD for the invertebrate MMeHg duplicates (n=8) in spring samples was 9.27 to 38.7 percent; two results fell outside the acceptable criterion of an RPD < 25%. In the fall-season samples, the RPDs for Hg<sub>T</sub> (n=6) ranged from 0.663 to 28.4 percent, with one sample outside the acceptable criterion. The RPDs for MMeHg in the fall samples (n=6) ranged from 7.53 to 34.6 percent, with one sample outside the acceptable criterion. The QA/QC results for those

batches with values outside acceptable limits were deemed acceptable based on matrix spike/matrix spike duplicate (MS/MSD) and/or laboratory control sample/laboratory control sample duplicate (LCS/LCSD) RPD values within control limits.

To assure the accuracy of the methods, procedural blanks, spiked samples, and laboratory control samples were analyzed. To assure that no analyte was added during the processing of the sample, procedural blanks were analyzed at a rate of 5% of the total samples, with at least one per matrix per analytical run. In all blanks for Hg<sub>T</sub> in the spring (n=21) and fall (n=15), and for MMeHg in the spring (n=24) and fall (n=21) the analyte was undetected, although included in the analysis. All blank results were less than the acceptable criterion of twice the method detection limit.

Matrix spikes were used to verify that the matrix characteristics did not interfere with the analytical results. Matrix spike samples and matrix spike duplicates of Hg<sub>T</sub> and MMeHg were analyzed at a rate of 5%, with at least one spike per matrix per analytical run. Spiked samples were fortified with a known quantity of analyte and analyzed as part of the run. The results were compared with an analysis of the original sample with no added spike. If there was no matrix interference, the result of the matrix spike should be equivalent to the result of the parent sample plus the amount of chemical added to the matrix spike sample.

In the spring samples, the Hg<sub>T</sub> matrix spike and matrix spike duplicate recoveries (n=9) ranged from 52.6 to 119 percent, with one sample outside the acceptable criteria of 75-125%. The relative percent differences (RPDs) (n=9) ranged from 0.31 to 54.9 percent, with two exceeding the 25% criterion. In the fall samples, the Hg<sub>T</sub> spike recoveries (n=8) ranged from 13.4 to 201 percent, with six samples outside the acceptable criteria of 75-125%. The RPDs (n=8) ranged from 0.837 to 43.1 percent, with only one exceeding the 25% criterion.

In the spring samples, one of the spike recoveries and one of the RPDs were outside acceptance limits because the spike concentration was less than one-half the sample concentration, the target spike ratio. In the fall samples, the percent recovery for both the matrix and the duplicate were outside the established criteria for three samples. Only one of these sets, however, had an RPD > 25. The other two sets of recoveries were outside acceptance limits because the spike concentrations were less than one-half the sample concentration. The analyses that did not meet the target spike ratio were excluded from the results. The remaining acceptable matrix spike and matrix spike duplicates were sufficient to verify that the matrix did not interfere with the analytical results.

For MMeHg, the matrix spike and matrix spike duplicate recoveries in the spring (n=15) ranged from 12.2 to 2560 percent, with RPDs (n=13) ranging from 4.27 to 179 percent. Nine spike or duplicate recoveries and six RPD values were outside the acceptable limits (65-130%, and < 25%, respectively). The MMeHg spike and matrix duplicate recoveries (n=9) for the fall samples ranged from -1060 to 285 percent, with 7 falling outside the acceptable criteria of 65-135%. RPDs (n=9) ranged from -75.2 to 75.1 percent, with 4 exceeding the acceptable criterion of 25%.

The reason that the matrix spike or duplicates (9 in the spring and 7 in the fall) and the RPDs (6 in the spring and 4 in the fall) were outside the acceptance limits was that spike concentrations were less than one-half the sample concentration. The analyses that did not meet the target spike ratio were excluded from the results. The remaining acceptable matrix spike and matrix spike duplicates were sufficient to verify that the matrix did not interfere with the analytical results.

LCS were analyzed at a rate of 5% to insure that the method worked with naturally incorporated mercury. For spring samples, the recovery for Hg<sub>T</sub> in the LCSs (n=14) was 83.1 to 105 percent, within the criterion of 75 to 125; for MMeHg, recovery was 70 to 128 percent, within the criterion of 70 to 130 percent. LCS duplicates (n=7) ranged from 0.25 to 19.9 percent RPD for Hg<sub>T</sub>, and 0.47 to 5.92 percent for MMeHg, all within the acceptable criterion of less than 25 percent. For fall samples, recovery for

Hg<sub>T</sub> in the LCSs (n=12) was 104 to 114 percent, within the criterion of 75 to 125; for MMeHg, LCS recovery (n=10) was 84.4 to 110 percent, within the criterion of 70 to 130 percent. LCS duplicates ranged from 0.438 to 6.61 percent for Hg<sub>T</sub> (n=6), and 0.264 to 13.9 percent for MMeHg (n=5), all less than the acceptable limit of 25 percent.

## Statistics

Total Hg and MMeHg concentrations in all matrices (water, sediments, invertebrates, and fish) were compared statistically among sites and seasons. Concentrations of MMeHg were compared graphically by site and season for composite samples of invertebrates.

All data for both Hg<sub>T</sub> and MMeHg in California roach from Bear Creek were transformed using Box-Cox transformations. We used a maximum likelihood method for statistically determining the best Box-Cox transformation for a particular dependent variable. Since Hg<sub>T</sub> and MMeHg had different distributions, we chose one family of transformations that was flexible enough to accommodate both.

For the statistical analyses of fish data, we began with a generalized analysis of covariance (ANCOVA) that included site, season, total length (TL), and all possible interaction effects. A backward selection was performed to remove interaction effects that were not significant for either dependent variable. Site, season, TL, and the interaction between TL and site effects were significant. Due to the significance of the TL\*site interaction, the relationship between TL and mercury varied depending on site.

To compensate for the various effects of TL on mercury, sites were compared by adjusting the mercury concentrations for TL. A TL of 70 mm was chosen because the median for all the fish was 70.5 mm and the range of fish sizes at all sites and seasons, except site 7 in the fall, captured this value. When all sites were pooled, the mean TL was 71.7 mm, but the site-specific means varied greatly across sites, ranging from 53.6 to 82.7 mm. Although fish from site 7 in the fall were all < 60 mm, the estimates of Hg<sub>T</sub> and MMeHg concentrations were adjusted to project a mercury value for a 70-mm fish. However, since the range of TLs for site-7 data did not capture 70mm, the estimated value is an extrapolation.

## Results and Discussion

### Hg and MMeHg in waters

Hg<sub>T</sub> levels in unfiltered water under high-flow conditions are generally higher than Hg levels in water during low-flow conditions, due to contribution of Hg-contaminated geothermal water and sediment from Sulphur Creek, as well as surface runoff from Rathburn-Petray mine wastes that are enriched in Hg (fig. 15). Hg<sub>T</sub> levels during the high-flow sampling event in March 2011 exceeded low-flow levels by orders of magnitude at all sample sites in Bear Creek (fig. 16). Flows during this high-flow sampling event were unusually high (fig. 15). Hg<sub>T</sub> levels generally increase from a local minimum at the background site (BC1) to a local maximum in Sulphur Creek at sites BC5 and BC6, then decrease downstream in Bear Creek towards the final sample site BC10. However, Hg<sub>T</sub> levels at downstream sample sites (BC7-10) were significantly higher than levels at the upstream sample site (BC1). Hg<sub>T</sub> concentrations in and downstream from Sulphur Creek were orders of magnitude higher than other Hg<sub>T</sub> concentrations measured upstream from Sulphur Creek during low-flows.

Hg<sub>F</sub> levels in water under high-flow conditions are comparable to or lower than Hg<sub>F</sub> levels under low-flow conditions at most of the sample sites (fig. 17). Hg<sub>F</sub> levels were high during the high-flow sampling events in the summer of 2010 and 2011, compared to low-flow Hg<sub>F</sub> levels measured at sites

BC2-4 during the initial sampling event in January 2009. Due to extreme flows and high total suspended sediment in Bear Creek during the highest-flow sampling event in March 2011, Hg present in the waters during this event was predominantly particulate. During both high- and low-flow conditions, Hg<sub>F</sub> levels generally increased from sample site BC1 to a local maximum at sample sites BC4 and BC7, then decreased farther downstream to sample site BC10. Hg<sub>F</sub> levels were significantly higher in Sulphur Creek than in Bear Creek. The value of 44 ng/L of dissolved Hg at sample site BC1 during the Sept. 2010 sampling event is anomalous. Because it is orders of magnitude greater than the result for total Hg at the same site, its reliability is questionable.

MMeHg levels in water under high-flow conditions are comparable to MMeHg levels under low-flow conditions in the upper part of Bear Creek at sample sites BC1-4 (fig. 18). In the lower part of Bear Creek, at sample sites BC7-10, MMeHg levels are considerably higher under high-flow conditions than under low-flow conditions. In the upper reach of the watershed, MMeHg levels tend to increase from sample site BC1 to sample site BC4. During high-flow conditions, MMeHg levels were highest at sample sites BC3 and BC9. Within Sulphur Creek, MMeHg levels are highly elevated at both sample sites BC5 and BC6, and MMeHg levels are also elevated in Bear Creek immediately downstream from the Sulphur Creek input at sample site BC7. As a percentage of Hg<sub>T</sub>, MMeHg levels are highest during low-flow conditions compared to MMeHg levels measured during high-flow conditions. Conditions that favor MMeHg production occur during low-flow, warm conditions. During the high-flow sampling event in March 2011, MMeHg levels were elevated at sample site BC4, just downstream from the Rathburn-Petray mine input.

## Hg and MMeHg in sediments

Hg and MMeHg levels in sediments collected from Bear Creek are listed in table 3 and shown in figs 19-23. Hg levels in sediments are elevated both downstream from the mine input and more so downstream from the confluence with Sulphur Creek. During the low-flow sampling event in January 2009, Hg levels in sediment upstream from the mine area at sample site BC2 were low (80.3 ng/g) (table 3). However, Hg levels in sediment downstream from the mine area, at sample site BC3, were highly elevated (9,290 ng/g for a 0.2 g sample) but decreased downstream in Bear Creek at site BC3. A larger BC3 sample, 20 g, has a lower but still high Hg concentration of 1,780 ng/g (table 5) and indicates that the 0.2 g sample is anomalously high. Downstream to BC4 the Hg concentration decreased to background level.

During the high-flow sampling event in June 2010, Hg levels in sediments collected at sample sites BC1 (Brim Road upstream from mine area) and BC2 (upstream from mine area) were both low (40.6 and 40.1 ng/g, respectively) (fig. 19). However, sediment collected from Bear Creek at sample site BC4, just upstream from the confluence with Sulphur Creek, contained high levels of Hg (2,750 ng/g) (table 3). Sediments collected in the active channel in Sulphur Creek were very highly elevated in Hg. Upstream from the Wilbur hot springs, Hg levels were elevated (2,960 ng/g) in sediments at sample site BC5, but downstream from the hot springs Hg levels were extraordinarily high (332,000 ng/g) in sediments at sample site BC6 (fig. 19). In Bear Creek downstream from the confluence with Sulphur Creek, Hg levels in sediments were elevated at sample sites BC7 and BC8 (1,220 and 1,840 ng/g, respectively), but decreased significantly farther downstream at sites BC9 and BC10 but remained above background concentrations (171 and 355 ng/g, respectively).

During the low-flow sampling event in September 2010, the Hg level in sediments collected at sample site BC1 (Brim Road upstream from mine area) was low (57.2 ng/g), and the Hg level in sediments collected just upstream from the mine area at sample site BC2 were higher but still low (126 ng/g) (fig. 20). Sediment collected from Bear Creek at sample sites BC3 and BC4, downstream from the

tributaries that drain the Rathburn and Petray mines but upstream from the confluence with Sulphur Creek, contained moderately elevated levels of Hg (221 and 254 ng/g, respectively) compared to concentrations upstream from the mine area. At sample site BC5, upstream from the Wilbur hot springs in Sulphur Creek, Hg levels were elevated (1,920 ng/g). Downstream from the hot springs in Sulphur Creek at sample site BC6, the Hg level in sediment was very high (33,500 ng/g), but it was an order of magnitude lower than Hg levels measured under June 2010 high-flow conditions at the same sample site. Downstream from the confluence with Sulphur Creek, Hg levels in sediments in Bear Creek were elevated at sample sites BC7-9 (620-942 ng/g) before decreasing to lower levels at the most downstream sample site, BC10 (228 ng/g) (fig. 20). No data were collected for Hg or MMeHg in sediments during high-flow sampling in 2011.

MMeHg levels were only measured in Bear Creek sediments during two sampling events in 2010. In June 2010, under high-flow conditions, MMeHg levels in sediments in upper Bear Creek at sites BC1 and BC2 were low (0.067 and 0.069 ng/g, respectively, table 3) (fig. 21). MMeHg levels then increased in sediments collected at sample sites BC3 and BC4, downstream from the mine area (0.275 and 0.591 ng/g, respectively, table 3). Within Sulphur Creek, MMeHg levels were highly elevated. At sample site BC5, MMeHg levels in sediment were high (1.52 ng/g), but at sample site BC6, downstream from the hot springs, MMeHg levels were extraordinarily high (145 ng/g). MMeHg levels in sediments collected in Bear Creek downstream from the confluence with Sulphur Creek were highly variable depending on the flow conditions. Immediately downstream from the confluence at sample site BC7 and in one downstream sample at site BC9, MMeHg levels in sediment were low (0.072 and 0.103 ng/g, respectively) (fig. 21). However, at downstream sample sites BC8 and BC10, MMeHg levels in sediments were elevated (1.48 and 0.679 ng/g). Under low-flow conditions in September 2010 when MMeHg production was expected to be at a maximum, MMeHg levels were low in sediments collected at background sample site BC1 upstream from the mine area (0.015 ng/g) (fig. 21). MMeHg levels in sediments just above and downstream from the mine area increased at sites BC2 and BC3 (0.245 and 0.372 ng/g, respectively, table 3) and were highly elevated at sample site BC4 (3.08 ng/g). MMeHg levels were elevated in sediments collected at sample sites BC5 and BC6 in Sulphur Creek (0.774 and 1.17 ng/g respectively), but were orders of magnitude lower than levels measured within Sulphur Creek during high-flow conditions. Downstream from the confluence with Sulphur Creek at sample sites BC7-10, sediments in Bear Creek have moderate to high concentrations of MMeHg (0.222-0.982 ng/g) (fig. 22).

The percentage of MMeHg relative to total Hg (%MMeHg) in sediments is indicative of the overall rate of MMeHg production in the watershed. We calculate %MMeHg as:

$$\%MMeHg = [MMeHg \text{ in sediment in ng/g}] / [Hg \text{ in sediment in ng/g}] \times 100$$

The %MMeHg in samples collected in June 2010 from Bear Creek under high-flow conditions was highly variable (table 3). Because MMeHg was less variable than Hg, the highest %MMeHg values occurred at sample sites where the total Hg in sediment was low. Although MMeHg levels were highly elevated in Sulphur Creek, the %MMeHg in these samples was relatively constant. Downstream from the confluence with Sulphur Creek, the %MMeHg generally trended to higher concentrations downstream to sample site BC10, where %MMeHg was highest during the high-flow sampling event (0.19 percent).

%MMeHg values were similarly variable under low-flow conditions in September 2010. Above the mine area, at sample site BC1, %MMeHg values were low (0.03 percent). %MMeHg values increased significantly downstream from the mine area in Bear Creek at sample sites BC2 to BC4 (0.19 to 1.21 percent). Within Sulphur Creek, Hg levels in sediments were high, and thus, %MMeHg levels remained as low as 0.003 percent. In Bear Creek downstream from the confluence with Sulphur Creek,

%MMeHg values increased downstream from sample sites BC7 to BC9-10 (0.04 to 0.12-0.16 percent, table 3).

## Water Chemistry and Stable Isotopes

Bear Creek waters are predominantly Mg-CO<sub>3</sub> waters with elevated levels of boron (B), chloride (Cl), lithium (Li), sodium (Na), potassium (K), rubidium (Rb), selenium (Se), sulfate (SO<sub>4</sub>), strontium (Sr), and tungsten (W) resulting from input from both hot and cold saline springs from multiple sources (tables 4–7). Waters are slightly alkaline (pH 7.6–8.55) due to buffering from interaction with serpentinite bedrock. Waters are saline in Bear Creek, both above and below the inputs from the mines and saline springs, with conductivity ranging from 822 μS/cm above the mine input to 2,723 μS/cm just below the confluence with the highly saline geothermal waters derived from hot springs in Sulphur Creek (table 1) (figs. 24 and 25).

Cold carbonate springs are present along several faults in the Bear Creek watershed. A large number of these springs are localized along the Bear Fault, which is located to the west of Bear Creek and east of the Rathburn-Petray mines (fig. 4). These springs consist of variable mixtures of meteoric water and saline groundwater derived from connate fluids in sedimentary rocks of the Great Valley Sequence. The cold spring waters have a highly variable proportion of saline groundwater, ranging from 13 to 100 %, with the largest component of saline ground water occurring along the central part of the Bear Fault (Slowey and Rytuba, 2008). The springs have exceptionally high conductivities (9,400 to 19,000 μS). The most saline cold spring waters, 6,065 mg/L Cl<sup>-</sup>, are comparable to saline geothermal hot spring waters located in the Sulphur Creek watershed. The cold springs are characterized by high concentration of the cations Na, K, Rb, Li, Se, Sr, and W, as well as nitrate, sulfate, and DOC. Plots of these cations against Cl<sup>-</sup> for the various cold springs in the Bear Creek watershed define two-component linear mixing lines, indicating that the spring waters are mixtures of meteoric and saline ground water. Chloride, sulfate, and filtered mercury concentrations in waters are shown in figure 24. Alkalinity is relatively high in cold carbonate springs and surface waters that drain the Rathburn-Petray mine area. This results from release of carbonate from saline groundwater, and interaction of groundwater with serpentinite and mafic bedrock of the Coast Range ophiolite and the Franciscan Formation. The presence of alkaline pH ( $\geq 8.0$ ) indicates that the cold carbonate springs, and some surface waters, with a significant component of saline ground water are in aqueous equilibrium with calcium carbonate. At Wilbur Springs, several hot spring vents form a coalescing hot spring terrace along the north bank of Sulphur Creek. The temperature of the Wilbur Hot Springs geothermal waters ranges as high as 56 °C, and the waters have very high concentrations of Cl<sup>-</sup> (approx.. 13,800 ppm) and B (approx. 275,000 ppb). The concentration of Hg<sub>T</sub> in Sulphur Creek are typically very high but variable seasonally, ranging from 3.55 to 11,400 ng/L (fig. 25). However, the value of 3.55 reported for Hg<sub>T</sub> during June 2010 sampling was less than the value reported for Hg<sub>F</sub>, so we disregard this result as erroneous.

Stable-isotope data from samples collected in the 2011 sampling event indicate that stream water in Bear Creek under high-flow conditions is isotopically lighter than under low-flow conditions, measured in summer of 2010 (table 8 and fig. 26) Because meteoric water is light in  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ , stream water dominated by meteoric input under the high-flow conditions will be lighter isotopically. During the dry summer season, the creek receives an influx of isotopically-heavy saline groundwater and minimal runoff of meteoric water. The overall trend of these data represents a two-end-member mixing system between the isotopically-light meteoric water and the isotopically-heavy saline groundwater (figs. 26 and 27). At any given time, the water isotopic chemistry in Bear Creek represents a point along this mixing line, depending on the relative dominance of each input. During the summer

season, saline groundwater input exceeds meteoric input, and the water in Bear Creek is isotopically heavy as a result. During winter and spring, meteoric input dominates the water chemistry of Bear Creek, resulting in isotopically-light water. Under low-flows, Bear Creek appears to receive a gradual input of saline groundwater throughout the study area, with the heaviest waters sampled at downstream site BC10 (fig. 27).

## Biota

Bacteria can convert naturally occurring inorganic Hg to its most toxic form, MMeHg, which is a neurotoxin. MMeHg may affect several physiological functions, including vision, response to stimuli, growth, and reproduction in both vertebrates and invertebrates, and in some cases, can cause mortality. It is important to understand what concentrations of Hg are present, and evaluate whether corrective measures are feasible to lessen the impacts of Hg to wildlife and humans in this region.

## Invertebrates

Aquatic invertebrates were collected during spring (June 16 and 30) and fall (September 15 and 17) of 2010 to evaluate differences in MMeHg bioaccumulation for multiple taxa among sites and between seasons. Forty-four composite samples were collected in spring, and 35 of them were analyzed for Hg<sub>T</sub> and MMeHg, including larval dragonflies (families Aeshnidae, Libellulidae, and Gomphidae) and damselflies (family Coenagrionidae), and adult water striders (family Gerridae), back swimmers (family Notonectidae), and water boatmen (family Corixidae) (table 9). In the fall, we collected 44 composite samples, and analyzed 40, including larval dragonflies (families Aeshnidae, Libellulidae, and Gomphidae) and damselflies (families Calopterygidae and Lestidae), and adult water striders (family Gerridae), back swimmers (family Notonectidae), and water boatmen (family Corixidae) (table 9). The only taxa that could be collected in the fall from site BC6 on Sulphur Creek were larval soldier flies (family Stratiomyidae) and larval horse flies (family Tabanidae).

Only one site (BC2) was sampled for biota upstream from known mining inputs to Bear Creek. All nine composite invertebrate samples collected from site BC2 had MMeHg concentrations <0.10 µg/g, ww. Only one other sample, a composite sample of larval dragonflies (family Gomphidae) from site BC10 collected in spring was less than 0.10 µg/g MMeHg. The Hg<sub>T</sub> concentration in only one of the nine samples from BC2 (water striders from June 2010) exceeded 0.10 µg/g. Water striders were collected at eight of the nine biota sites in the spring, but they were present in sufficient numbers for analysis at only two sites in the fall. MMeHg concentrations ranged from 0.09 µg/g at the reference site (BC2) to a high of 0.618 µg/g at BC6 on Sulphur Creek, about 6.7 times that recorded at the reference. MMeHg concentrations in water striders at sites BC7, BC9, and BC10 were similar in the spring, with all about three times greater than the reference. The MMeHg concentration in water striders at site BC5 in Sulphur Creek in the fall (0.482 µg/g) was about 40% greater than the sample collected from BC5 in the spring. Two composite samples of 25 water striders each were collected from BC9 in the fall. Both samples were nearly identical in mass, percent moisture, Hg<sub>T</sub>, MMeHg, and % MMeHg (table 9). The mean MMeHg concentration was about twice that of the highest sample from the spring, while the mean Hg<sub>T</sub> concentration was only 0.11 µg/g higher than the highest strider concentration in the spring. However, although the percent MMeHg should normally be less than 100%, the average percent MMeHg for these two strider samples was 176%. This discrepancy may be the result of a problem with precision of the analytical method or difficulty in producing a homogeneous sample for analysis.

The taxa most consistently collected at the most sites in both spring and fall were two families of dragonfly larvae, Libellulidae and Aeshnidae, and damselfly larvae, Coenagrionidae in the spring and

Calopterygidae in the fall (fig. 28). In both seasons, MMeHg concentrations in these invertebrates from BC2, above mine inputs, were lower than any other site sampled in the study. Differences between sites BC2 and BC3 were especially great, ranging from 4 to 10 times higher at BC3 located below the mine area than in BC2 for the individual taxa. A trend that was apparent in these taxa was higher site-specific concentrations of MMeHg in the spring above the confluence of Sulphur Creek and Bear Creek and higher concentrations in the fall below Sulphur Creek (fig. 28). This difference is likely related to the relative composition of water entering Bear Creek during each of the seasons. The impact of the Sulphur Creek inflow on lower Bear Creek is apparently more significant in the fall.

Three families of dragonfly larvae, Aeshnidae, Gomphidae, and Libellulidae, were collected at most Bear Creek sites in September. While there was variability among the families in their relative concentrations of MMeHg at each site, the general trends were similar, especially related to the low concentrations at BC2 and the elevated concentrations just downstream from Sulphur Creek at site BC7 (fig. 29).

Slotton and others (1997) found the highest  $Hg_T$  concentrations in the Bear Creek Watershed were from Sulphur Creek, with lower concentrations above the confluence with Sulphur Creek, but with one site about 0.4 km above the confluence of Sulphur Creek with Bear Creek (near sample site BC4) having elevated Hg in invertebrates. Their data also revealed that as soon as Sulphur Creek waters entered Bear Creek, invertebrate Hg concentrations increased. Further studies conducted from 1999-2003 by Slotton and others (2004) provided additional Hg data for invertebrates at three sites in the Bear Creek watershed. As found in the current study, the average MMeHg concentrations in aquatic insects were low at the Upper Bear Creek site, moderately high at the Middle Bear Creek site and especially high at the Sulphur Creek site. Schwarzbach and others (2001) found a pattern of lower  $Hg_T$  concentrations in insects in Bear Creek upstream of Sulphur Creek, but much higher concentrations at sites in Bear Creek downstream of Sulphur Creek and in Sulphur Creek proper. Neither Slotton and others (1997; 2004) nor Schwarzbach and others (2001) sought to evaluate the contribution of the Rathburn and Petray mines to the Hg contamination of Bear Creek.

## Fish

Species of fish that have been collected in previous studies (Slotton and others, 1997, 2004; Schwarzbach and others, 2001) include Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento sucker (*Catostomus occidentalis*), and California roach. Although predatory fish can serve as good bioindicators of metals contamination in the long term (Wiener and Spry, 1996), considering the ephemeral nature of the streams in the Bear Creek watershed, the preferred fish for collection was the California roach, primarily because of its availability and resident status. Smaller fish provide a more short-term representation of changes in Hg concentrations of prey species, which in turn will reflect short-term changes in Hg in water and sediments. Slotton and others (2004) found that only California roach were abundant enough within the Bear Creek watershed to obtain sufficient samples to analyze trends. No fish were found in Sulphur Creek. Total Hg and MMeHg were analyzed in individual whole-body samples of fish, and comparisons were made among sites and between seasons.

Adjusted mean  $Hg_T$  and MMeHg concentrations and 95% confidence limits were calculated for the 7 sites where California roach could be collected (fig. 30 and 31). Comparisons among sites revealed that for both seasons, sites BC4, BC7, BC8, and BC9 were not different from one another. Sites BC3, BC4, BC7, BC9, and BC10 were also not different from one another. However, site BC8 was higher than sites BC3 and BC10, and site BC2 was lower than all other sites.

Previous studies have shown that about 95 percent of  $Hg_T$  in fish muscle tissue is MMeHg (Huckabee and others, 1979; Bloom, 1992; Wiener and Spry, 1996). In this study, however, chemical

analyses from the 98 fish resulted in 58 with MMeHg determinations higher than the Hg<sub>T</sub> determinations in the same fish. Despite this anomaly, the comparisons among sites using Hg<sub>T</sub> and MMeHg produced the same outcomes. There was a significant difference in fish between seasons for Hg (September higher than June), but not for MMeHg. Sampling variation could be a factor, and a larger sample size might have revealed more of a separation.

Back-transformed means (and standard errors, and lower and upper confidence limits]) for each of the 7 sites and 2 seasons are not necessarily good estimates of mean mercury. However, it is fair to call them estimates of median mercury, adjusted for fish length.

## Conclusions

There are three main sources of Hg to Bear Creek: mine wastes from the Rathburn-Petray Hg mines; cold saline springs that occur along the Bear Fault in Bear Valley; and Sulphur Creek where Hg is released from several hot springs along with a minor release from mines. These sources contribute Hg to Bear Creek by means of two processes: surface runoff in which Hg-enriched mine waste is transported from the mine area and released into the tributaries that flow into Bear Creek, and upwelling of groundwater, in which both cold- and hot-spring fluids rise to the surface and enter Bear Creek through its tributaries. The data show that the relative contribution of Hg to Bear Creek by each distinct water source is controlled by several factors; the most important is seasonal variation related to dilution by precipitation.

During the dry season, mine wastes at the Rathburn-Petray mine area do not release Hg to the tributaries that drain the mine area and flow into Bear Creek. The increase in Hg<sub>T</sub> in Bear Creek stream waters downstream from the mine area BC3, compared to upstream sites at BC1 and 2, is measureable but minor compared to the levels of Hg contributed to Bear Creek by Sulphur Creek from the geothermal springs at Wilbur Hot Springs and other thermal springs in the tributary (fig. 16). Under low-flow conditions, these geothermal saline spring waters contribute significant amounts of Hg to Bear Creek, as observed in samples collected downstream from Sulphur Creek in Sept. 2010 (fig. 16). During the storm season, Hg-contaminated waste materials in the Rathburn-Petray mine area are eroded and released into several small tributaries to Bear Creek. Under these high-flow conditions, significant concentrations of Hg are released from the mine area, as indicated by the increase in Hg concentrations in Bear Creek immediately downstream from the mine area at sites BC3 and BC4, as compared to Hg concentrations upstream from the mine area ( sites BC1 and 2, fig16). However Hg concentrations in the March 2011 high flow were comparable above and below the mine area.

However, saline springs, especially those emanating from the Wilbur Springs area in Sulphur Creek, also contribute significant levels of Hg to Bear Creek during high-flow conditions. Under high-flow conditions in June 2010, the highest measured Hg<sub>T</sub> levels in Bear Creek stream water were observed at sample site BC7, just downstream from the confluence with Sulphur Creek and remained elevated downstream to the confluence with Cache Creek. This demonstrates that even during periods of large input of surface runoff, the natural source of Hg emanating from Wilbur Springs and other hot springs in Sulphur Creek dominates the Hg released into the segment of Bear Creek downstream from the confluence with Sulphur Creek. The concentration of Hg in sediment are also very high in this segment of Bear Creek and decrease systematically downstream to site BC10 (figs. 19 and 20). The magnitude of the Hg input from Sulphur Creek far exceeds upstream inputs of Hg from the Rathburn and Petray mines and cold springs along the Bear Fault. As a result, Hg in the Bear Creek watershed below the confluence with Sulphur Creek is dominated by geothermal inputs of Hg from hot springs in

Sulphur Creek. Above the confluence with Sulphur Creek, Hg in Bear Creek is dominated by inputs from the Rathburn and Petray Hg mines and cold springs located along the Bear Fault.

Mercury and MMeHg concentrations in water and sediment were considerably lower at the background sites BC1 and BC2 compared to sites below the mine area, and Hg and MMeHg concentrations in biota were lower at BC2, than sites BC3–4 downstream from the Rathburn and Petray mine areas. Thus, there is a measurable impact on biota in the reach of Bear Creek below the mine area downstream to site BC4, located just above the confluence with Sulphur Creek (figs. 16, 19, and 20). In this reach of Bear Creek, baseline concentrations of Hg<sub>T</sub> and MMeHg in water, sediment, and biota have been established and provide a basis for monitoring changes resulting from the clean-up of the Rathburn and Petray Hg mine areas. However downstream from the confluence of Sulphur Creek with Bear Creek, monitoring of changes of Hg input from the Rathburn and Petray mine areas would not be detectable because of the large input of Hg from the Sulphur Creek tributary. This source of Hg dominates both Hg and MMeHg in water, sediment, and biota in the reach of Bear Creek below its confluence with Sulphur Creek.

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**Table 1.** Sample locations and selected parameters for waters collected from Bear Creek, Colusa County, California.

Field number	Latitude	Longitude	Date	Sample site description	Conductivity mS/cm	pH	Temperature °C	Dissolved O <sub>2</sub> , ppm
Low Flow Jan. 2009								
09BC2	39.09766	-122.41359	1/12/2009	Bear Ck upstream Rathburn Petray Mines	803	8.02	12.19	nr
09BC3	39.08046	-122.41339	1/12/2009	Bear Ck downstream Rathburn Petray Mines	1027	7.92	12.28	nr
09BCA	39.10952	-122.44063	1/13/2009	Spring N of Prater Ranch	224	8.24	17.86	nr
09BCB	39.09733	-122.44911	1/13/2009	Trout Creek Tributary	704	8.16	9.18	nr
09BC4	39.04146	-122.40914	1/13/2009	Bear Ck upstream Sulphur Ck input	1213	8.72	9.21	nr
High Flow Jun. 2010								
10BC1	39.16320	-122.44724	6/15/2010	Brim Road just upstream of bridge	822	8.05	22.75	9.00
10BC2	39.09762	-122.41358	6/15/2010	Upstream of bridge	817	7.98	22.10	7.99
10BC3	39.08030	-122.41329	6/15/2010	In restricted flowing channel	987	8.17	24.19	10.12
10BC4	39.04967	-122.40948	6/15/2010	Fast flowing section between stagnant ponds	1045	8.05	24.59	8.01
10BC5	39.03467	-122.42733	6/15/2010	Upstream of Wilbur Spring, below foot bridge	8430	8.01	28.68	6.55
10BC6	39.03876	-122.41936	6/15/2010	Downstream USGS Gaging Station on Sulphur Creek	10950	8.02	29.40	3.60
10BC7	39.03983	-122.40792	6/15/2010	Downstream confluence w Sulphur Creek	2723	8.20	25.89	7.37
10BC8	39.01247	-122.36462	6/15/2010	300 m upstream from Hwy 20 Bridge	2522	8.43	25.88	8.59
10BC9	38.97247	-122.34123	6/15/2010	Upstream of Thompson Canyon Bridge	2327	8.55	28.00	8.05
10BC10	38.92704	-122.33356	6/15/2010	60 m upstream confluence with Cache Creek	2357	8.55	29.45	8.04
Low Flow Sept. 2010								
10BC1-2	39.16320	-122.44724	9/16/2010	Brim Road just upstream of bridge	913	7.72	22.69	5.14
10BC2-2	39.09762	-122.41358	9/16/2010	At bridge upstream	777	7.62	20.20	4.79
10BC3-2	39.08030	-122.41329	9/16/2010	In restricted flowing channel	1008	7.60	21.47	4.50
10BC4-2	39.04967	-122.40948	9/16/2010	Fast flowing section between stagnant ponds	1050	7.69	20.60	5.20
10BC5-2	39.03467	-122.42733	9/16/2010	Upstream of Wilbur Spring, below foot bridge	32000	7.48	31.52	4.57
10BC6-2	39.03876	-122.41936	9/16/2010	Downstream USGS Gaging Station on Sulphur Creek	33307	7.69	29.88	2.56
10BC7-2	39.03983	-122.40792	9/17/2010	Downstream confluence w Sulphur Creek	3933	7.96	19.62	4.61
10BC8-2	39.01247	-122.36462	9/15/2010	300 m upstream from Hwy 20 Bridge	3730	8.13	23.94	6.36
10BC9-2	38.97247	-122.34123	9/15/2010	Upstream of Thompson Canyon Bridge	3992	8.24	26.16	4.79
10BC10-2	38.92704	-122.33356	9/15/2010	60 m upstream confluence of Cache Creek	3942	8.25	25.38	5.22

**Table 1.—Continued**

<b>Field number</b>	<b>Latitude</b>	<b>Longitude</b>	<b>Date</b>	<b>Sample site description</b>	<b>Conductivity mS/cm</b>	<b>pH</b>	<b>Temperature ° C</b>	<b>Dissolved O<sub>2</sub>, ppm</b>
High Flow Mar. 2011								
11BC1	39.16320	-122.44724	3/23/2011	Brim Road just upstream of bridge	242.9	7.47	22.69	nr
11BC4	39.04967	-122.40948	3/23/2011	Fast flowing section between stagnant ponds	384.8	7.46	20.60	nr
11BC5	39.03467	-122.42733	3/24/2011	Upstream Wilbur Spring, below foot bridge	497.6	7.49	31.52	nr
11BC6	39.03876	-122.41936	3/24/2011	Downstream USGS Gaging Station on Sulphur Creek	469.3	7.39	29.88	nr
11BC7	39.03983	-122.40792	3/24/2011	Downstream confluence w Sulphur Creek	499.2	7.58	19.62	nr
11BC8	39.01247	-122.36462	3/24/2011	300 m upstream from Hwy 20 Bridge	420.6	7.43	23.94	nr
11BC9	38.97247	-122.34123	3/24/2011	Upstream of Thompson Canyon Bridge	320.4	7.42	26.16	nr
11BC10	38.92704	-122.33356	3/24/2011	60 m upstream confluence of Cache Creek	425.0	7.44	25.38	nr
High flow Jun. 2011								
11BC2-2	39.09762	-122.41358	6/6/2011	Upstream of bridge	736	8.35	17.2	nr
11BC3-2	39.08030	-122.41329	6/6/2011	In restricted flowing channel	898	8.45	16.9	nr
11BC4-2	39.04967	-122.40948	6/6/2011	Fast flowing section between stagnant ponds	905	8.23	16.9	nr
11BC10-2	38.92704	-122.33356	6/6/2011	60 m upstream confluence of Cache Creek	1311	8.51	17.2	nr

**Table 2.** Sampling sites for biota within the Bear Creek watershed (NAD 83).

Site no.	Site description	Latitude	Longitude	Sampling dates	Distance from Cache Creek (km)
BC1	<b>Milk Creek at Brim Rd;</b> water and sediment only	39.16320	- 122.44724	Not sampled for biota	34.80
BC2	<b>Bear Creek at bridge;</b> coincides with water/sediment site	39.09761	- 122.41358	6/29, 9/15	25.78
BC3	<b>Bear Creek downstream of BC2;</b> coincides with water/sediment site	39.08063	- 122.41336	6/29, 9/15	23.65
BC4	<b>Bear Creek 2.11 km upstream of Sulphur Creek; 800 m upstream from water/sediment site</b>	39.05667	- 122.41139	6/29, 9/15	20.74
BC5	<b>Sulphur Creek above Wilbur Hot Springs and most mines</b> (stream habitat); 420 m upstream from water/sediment site	39.03344	- 122.43050	6/29, 9/17	21.41
BCUS	<b>Sulphur Creek 230 m above BC5</b> (pool habitat); no water/sediment collected here	39.03436	- 122.43272	9/17	21.64
BC6	<b>Sulphur Creek at USGS Gauge;</b> coincides with water/sediment site	39.03861	- 122.41889	6/29, 9/17	19.92
BC7	<b>Bear Creek downstream of Sulphur Creek;</b> coincides with water/sediment site	39.03972	- 122.40778	6/29, 9/15	18.56
BC8	<b>Bear Creek at Highway 20 Bridge;</b> 300 m downstream from water/sediment site	39.01161	- 122.36121	6/15, 9/15	12.33
BC9	<b>Bear Creek at Thompson Canyon Bridge;</b> 80 m downstream from water/sediment site	38.97183	- 122.34072	6/15, 9/15	6.73
BC10	<b>Bear Creek just upstream of the confluence with Cache Creek;</b> coincides with water/sediment site	38.92694	- 122.33333	6/15, 9/15	0.08

**Table 3.** Mercury and monomethylmercury concentrations in waters and sediment collected from Bear Creek, Colusa County, California.

Sample site	Date	Water Hg Total ng/L	Water Hg Filtered ng/L	Water MMeHg ng/L	T.S.S. total mg/L	DOC mg/L	Sediment Hg ng/g	Sediment MMeHg ng/g	% MMeHg (MMeHg/Hg) in sediment
Low Flow Jan. 2009 <sup>1</sup>									
BC2	1/12/2009	0.45	0.42	0.094	nr	nr	80.3	nr	nr
BC3	1/12/2009	2.21	1.74	0.140	nr	nr	9290.0	nr	nr
BCA	1/13/2009	0.81	0.82	0.095	nr	nr	69.7	nr	nr
BCB	1/13/2009	0.26	0.23	0.020	nr	nr	165.0	nr	nr
BC4	1/13/2009	1.83	1.91	0.098	nr	nr	83.9	nr	nr
High Flow June 2010									
BC1	6/15/2010	0.79	0.49	0.036	nr	1.2	40.6	0.067	0.165
BC2	6/15/2010	41.30	1.24	0.242	nr	nr	40.1	0.069	0.172
BC3	6/15/2010	6.11	257.00	0.903	nr	1.9	101.0	0.275	0.272
BC4	6/15/2010	5.10	4.13	1.030	nr	2.2	2750.0	0.591	0.021
BC5	6/15/2010	3.55	250.00	0.627	nr	5.8	2960.0	1.520	0.051
BC6	6/15/2010	496.00	442.00	0.650	nr	5.5	332000.0	145.000	0.044
BC7	6/15/2010	49.60	56.00	0.357	nr	2.7	1220.0	0.072	0.006
BC8	6/15/2010	34.00	20.20	0.690	nr	3.0	1840.0	1.480	0.080
BC9	6/15/2010	26.80	23.40	2.170	nr	3.3	171.0	0.103	0.060
BC10	6/15/2010	10.70	17.00	0.832	nr	3.3	355.0	0.679	0.191
Low Flow Sept. 2010									
BC1	9/16/2010	1.37	44.00	0.080	nr	2.06	57.2	0.015	0.026
BC2	9/16/2010	7.82	1.86	0.146	nr	1.53	126.0	0.245	0.194
BC3	9/16/2010	2.67	1.53	0.302	nr	1.67	221.0	0.372	0.168
BC4	9/16/2010	3.87	1.19	0.259	nr	1.63	254.0	3.080	1.213
BC5	9/16/2010	1360.00	555.00	0.499	nr	6.57	1920.0	0.774	0.040
BC6	9/16/2010	2030.00	517.00	2.250	nr	4.81	33500.0	1.170	0.003
BC7	9/17/2010	47.40	16.40	0.025	nr	3.55	620.0	0.222	0.036
BC8	9/15/2010	36.50	25.80	0.023	nr	3.17	942.0	0.501	0.053
BC9	9/15/2010	10.40	7.97	0.023	nr	4.20	634.0	0.982	0.155
BC10	9/15/2010	2.72	2.34	0.023	nr	4.38	228.0	0.265	0.116

**Table 3.—Continued**

Sample site	Date	Water Hg Total ng/L	Water Hg Filtered ng/L	Water MMeHg ng/L	T.S.S. total mg/L	DOC mg/L	Sediment Hg ng/g	Sediment MMeHg ng/g	% MMeHg (MMeHg/Hg) in sediment
High Flow Mar. 2011									
BC1	3/24/2011	204	3.19	0.157	72.2	5.17	nr	nr	nr
BC4	3/23/2011	104	4.47	0.361	412.0	4.93	nr	nr	nr
BC5	3/23/2011	9590	111.00	2.260	1700.0	4.76	nr	nr	nr
BC6	3/23/2011	11400	91.60	3.220	2440.0	4.75	nr	nr	nr
BC7	3/23/2011	156	4.05	0.411	202.0	4.70	nr	nr	nr
BC8	3/23/2011	1670	16.80	1.130	607.0	5.06	nr	nr	nr
BC9	3/23/2011	927	5.62	0.734	593.0	5.05	nr	nr	nr
BC10	3/23/2011	1750	9.23	0.743	569.0	5.17	nr	nr	nr
High Flow June 2011									
BC2	6/1/2011	1.89	1.24	0.108	nr	2.84	nr	nr	nr
BC3	6/1/2011	8.66	6.56	0.295	nr	4.63	nr	nr	nr
BC4	6/1/2011	6.84	22.80	0.295	nr	3.63	nr	nr	nr
BC10	6/1/2011	49.40	31.10	0.539	nr	4.24	nr	nr	nr

<sup>1</sup>Refer to table 1 for locations of sites BC1–BC5 in 2009.

**Table 4.** Concentration of anions and selected cations in filtered water collected from Bear Creek, Colusa County, California.

Sample site	Cl ppm	F ppm	NO <sub>3</sub> ppm	SO <sub>4</sub> ppm	CaCO <sub>3</sub> ppm	HCO <sub>3</sub> ppm	Ca mg/L	Fe µg/L	K mg/L	Li µg/L	Mg mg/L	Na mg/L
Low Flow Jan. 2009												
BC2	30.2	< 0.08	< 0.08	18.5	405.8	nr	17.2	< 20	0.372	< 5.0	88.7	20.50
BC3	93.8	< 0.08	2.20	17.2	403.1	nr	17.7	< 20	4.940	194.0	88.0	65.30
BCA	1.7	0.25	2.00	4.2	112.0	nr	4.30	< 20	< 0.10	5.4	29.0	1.12
BCB	13.5	< 0.08	< 0.08	13.7	392.7	nr	8.77	< 20	0.341	8.4	96.7	7.27
BC4	150.0	< 0.08	2.50	19.1	415.0	nr	23.4	< 20	4.780	202.0	96.4	83.50
High Flow Jun. 2010												
10BC1	63.5	< 0.08	< 0.08	7.8	403.5	nr	16.3	< 50	0.56	3.6	89.9	29.6
10BC2	40.4	< 0.08	< 0.08	12.5	438.5	nr	17.8	< 50	1.00	20.1	93.0	27.9
10BC3	88.2	< 0.08	< 0.08	11.9	448.0	nr	18.3	< 50	4.26	171.0	91.4	59.6
10BC4	93.0	< 0.08	< 0.08	16.2	463.0	nr	19.8	< 50	4.13	168.0	95.0	64.1
10BC5	1990.0	1.15	50.10	158.3	1240.5	nr	32.8	151	96.40	1560.0	91.1	nr
10BC6	2195.0	< 0.08	< 0.08	180.0	1517.5	nr	31.5	95	132.00	1980.0	90.2	nr
10BC7	518.2	< 0.08	< 0.08	37.0	629.5	nr	23.8	< 50	23.00	572.0	92.2	nr
10BC8	467.1	< 0.08	14.40	37.2	631.5	nr	22.7	< 50	18.70	534.0	96.3	nr
10BC9	463.0	< 0.08	5.20	41.9	621.5	nr	22.3	< 50	16.30	458.0	95.3	nr
10BC10	460.0	< 0.08	4.40	52.7	628.0	nr	24.8	< 50	16.50	457.0	98.9	nr
Low Flow Sept. 2010												
10BC1-2	98.8	0.06	< 0.08	2.6	297.0	362.2	14.9	< 20.0	0.476	< 5.0	90.3	27.90
10BC2-2	37.0	0.06	< 0.08	9.0	278.9	340.1	16.4	37.4	0.862	19.5	88.7	26.00
10BC3-2	121.5	< 0.04	< 0.08	9.0	298.0	363.3	17.1	40.9	3.890	168.0	90.2	57.50
10BC4-2	124.7	< 0.04	< 0.08	9.0	289.5	353.0	17.4	32.0	3.820	163.0	94.4	57.50
10BC5-2	13710.0	< 0.04	< 0.08	460.7	2943.0	3588.2	26.3	136.0	85.800	2180.0	94.6	1520.00
10BC6-2	13934.0	< 0.04	< 0.08	470.1	3347.4	4081.3	10.5	13300.0	1.180	< 5.0	8.23	4.19
10BC7-2	778.3	< 0.04	1.10	46.5	519.9	633.9	< 0.1	< 20.0	0.406	< 5.0	< 0.1	< 0.10
10BC8-2	1032.3	< 0.04	3.50	47.2	473.9	577.8	18.3	< 20.0	16.700	536.0	96.6	337.00
10BC9-2	1178.0	< 0.04	3.40	48.2	541.1	659.8	< 0.1	< 20.0	2.390	< 5.0	< 0.1	0.763
10BC10-2	1228.0	< 0.04	< 0.08	50.2	542.9	661.9	21.6	< 20.0	15.900	504.0	103	325.00

**Table 4.—Continued**

Sample site	Cl ppm	F ppm	NO <sub>3</sub> ppm	SO <sub>4</sub> ppm	CaCO <sub>3</sub> ppm	HCO <sub>3</sub> ppm	Ca mg/L	Fe µg/L	K mg/L	Li µg/L	Mg mg/L	Na mg/L
High Flow Mar. 2011												
11BC1	12.9	<0.04	<0.08	4.8	nr	nr	11.7	120	1.5	< 0.1	17.3	10.5
11BC4	18.8	<0.04	0.40	7.1	nr	nr	10.1	223	1.8	25.5	38.9	16.3
11BC5	42.8	<0.04	0.40	15.8	nr	nr	10.5	697	5.7	69.4	19.6	52.7
11BC6	44.2	<0.04	0.40	17.5	nr	nr	10.3	179	6.2	68.3	18.5	59.8
11BC7	30.6	<0.04	0.40	9.4	nr	nr	11.0	148	2.5	55.4	44.6	25.9
11BC8	22.1	<0.04	0.40	9.0	nr	nr	9.62	207	2.5	33.7	33.5	21.8
11BC9	19.6	<0.04	0.40	11.0	nr	nr	9.86	<20	2.4	29.0	30.7	20.7
11BC10	21.7	<0.04	0.40	14.1	nr	nr	12.6	<20	2.6	34.5	36.1	23.6
High Flow June 2011												
11BC2	34.1	<0.04	<0.08	8.5	339.1	413.4	15.3	<20	1.78	23.3	91.1	24.5
11BC3	29.6	0.40	<0.08	210.2	322.2	392.9	16.2	<20	4.46	141.0	95.5	55.2
11BC4	74.6	<0.04	0.80	12.7	333.5	406.7	15.4	<20	4.64	146.0	88.6	51.3
11BC10	161.5	<0.04	0.80	44.9	373.0	454.2	23.0	22	9.30	264.0	94.2	136.0

**Table 5.** Mercury and associated major and minor elements in sediment, precipitates, Bear Creek, Colusa County, California.

Sample site	Hg ppm	Ag ppm	Al %	As ppm	Ba ppm	Be ppm	Bi ppm	Ca %	Cd ppm	Ce ppm	Co ppm	Cr ppm
Low Flow Jan. 2009												
09BC3S	1.78	0.05	2.61	3.8	210	0.32	0.04	1.01	0.09	8.94	83.6	2150
09BCBS	0.08	0.05	3.38	3.0	230	0.47	0.06	0.86	0.07	12.80	70.0	1630
09BC4S	0.59	0.12	4.86	6.1	370	0.65	0.10	1.35	0.10	18.15	54.1	5510
High Flow June 2010												
10BC1S2	0.06	0.07	3.56	2.0	170	0.30	0.03	2.02	0.07	10.15	86.1	6020
10BC2S2	0.08	0.09	3.64	3.1	280	0.47	0.06	0.79	0.08	13.20	76.3	1780
10BC3S2	1.90	0.12	3.11	3.7	240	0.31	0.04	1.31	0.09	10.45	85.5	4970
10BC4S2	1.20	0.09	5.18	6.7	350	0.63	0.08	1.17	0.10	19.30	60.7	2020
10BC5S2	5.66	0.16	6.69	8.6	510	1.02	0.11	1.46	0.14	27.70	34.8	638
10BC6S2	228.00	0.18	7.00	8.9	580	1.00	0.11	1.59	0.13	28.80	38.4	1850
10BC7S2	9.97	0.11	4.55	6.5	330	0.63	0.09	0.94	0.12	19.30	63.8	1100
10BC8S2	5.47	0.13	4.43	5.1	410	0.65	0.08	1.28	0.10	18.30	54.6	1060
10BC9S2	1.60	0.10	4.09	6.3	290	0.43	0.05	1.78	0.10	15.45	68.7	1630
10BC10S2	0.43	0.17	7.84	16.0	560	1.23	0.17	1.17	0.18	34.10	31.6	345
Low Flow Sept. 2010												
10BC1-2S	0.1	0.07	3.10	3.7	140	0.28	0.04	1.68	0.08	9.15	73.3	3860
10BC2-2S	0.1	0.10	3.76	2.8	260	0.51	0.06	1.18	0.08	14.4	72.1	5010
10BC3-2S	9.5	0.10	3.86	2.9	250	0.41	0.06	1.25	0.09	14.6	77.7	10000
10BC4-2S	2.4	0.10	4.84	4.3	300	0.52	0.07	1.67	0.08	20.6	51.7	8210
10BC5-2S	21.7	0.16	6.09	8.0	480	1.04	0.10	1.31	0.14	26.6	26.9	445
10BC6-2S	33.1	0.27	5.90	5.9	460	0.92	0.11	1.18	0.14	27.3	27.6	681
10BC7-2S	5.9	0.12	4.94	8.1	310	0.82	0.10	0.98	0.15	21.9	45.8	1370
10BC8-2S	23.1	0.14	4.66	9.0	420	0.72	0.09	1.40	0.12	23.1	54.7	1940
10BC9-2S	17.6	0.10	3.83	8.1	480	0.45	0.05	2.95	0.11	15.1	60.4	2610
10BC10-2S	0.5	0.15	7.12	11.9	850	1.11	0.15	4.03	0.15	30.7	23.9	251

**Table 5.—Continued**

<b>Sample site</b>	<b>Cs ppm</b>	<b>Cu ppm</b>	<b>Fe %</b>	<b>Ga ppm</b>	<b>Ge ppm</b>	<b>Hf ppm</b>	<b>In ppm</b>	<b>K %</b>	<b>La ppm</b>	<b>Li ppm</b>	<b>Mg %</b>	<b>Mn ppm</b>
Low Flow Jan. 2009												
09BC3S	9.19	29.0	5.54	5.48	0.16	0.6	0.022	0.33	4.1	31.7	15.50	1025
09BCBS	1.89	28.8	5.32	7.38	0.13	1.0	0.028	0.55	6.2	27.1	14.30	801
09BC4S	8.86	35.9	5.10	10.3	0.13	1.4	0.050	0.68	8.6	43.4	8.93	1035
High Flow June 2010												
10BC1S2	1.58	30.2	6.27	8.12	0.15	1.1	0.030	0.31	4.5	14.8	13.70	1120
10BC2S2	22.50	29.8	5.99	8.28	0.17	1.1	0.030	0.61	6.2	36.1	15.20	803
10BC3S2	10.10	26.3	6.43	6.84	0.16	0.9	0.025	0.36	4.5	27.9	15.50	1000
10BC4S2	10.10	40.2	5.89	11.55	0.16	1.5	0.042	0.75	8.5	50.3	10.55	914
10BC5S2	76.60	51.4	5.71	16.00	0.22	2.3	0.055	1.34	12.6	112.5	4.64	678
10BC6S2	72.10	51.5	5.96	16.45	0.16	2.3	0.057	1.26	13.0	110.0	4.73	739
10BC7S2	14.65	39.2	5.78	9.95	0.18	1.4	0.041	0.76	8.7	49.8	12.60	884
10BC8S2	21.20	36.3	5.30	9.88	0.16	1.5	0.037	0.74	8.4	56.9	11.65	758
10BC9S2	17.25	33.9	6.25	8.95	0.17	1.2	0.036	0.53	6.7	45.9	12.75	1060
10BC10S2	16.65	66.0	5.00	18.15	0.18	2.7	0.060	1.39	16.1	77.5	4.08	622
Low Flow Sept. 2010												
10BC1-2S	1.20	27.7	5.60	6.73	0.24	0.8	0.024	0.30	4.0	15.5	13.35	973
10BC2-2S	22.90	28.4	6.01	8.50	0.25	1.0	0.027	0.57	7.0	43.2	11.70	804
10BC3-2S	14.40	25.8	5.86	8.81	0.24	1.1	0.028	0.48	7.0	38.8	10.45	1250
10BC4-2S	9.61	26.6	5.25	10.30	0.22	1.4	0.036	0.57	9.7	44.7	7.48	846
10BC5-2S	101.00	42.7	5.11	13.75	0.20	1.9	0.048	1.26	12.5	138.5	3.84	672
10BC6-2S	116.00	43.5	4.42	13.40	0.18	1.8	0.047	1.20	12.7	146.0	3.84	496
10BC7-2S	28.20	38.7	5.25	11.25	0.22	1.5	0.041	0.88	10.5	66.1	9.64	636
10BC8-2S	23.60	36.0	5.54	10.65	0.25	1.4	0.039	0.76	11.0	66.3	10.30	827
10BC9-2S	15.85	26.9	6.11	8.24	0.24	1.0	0.031	0.46	6.8	49.2	11.25	1080
10BC10-2S	16.65	52.3	4.20	15.65	0.16	2.1	0.053	1.34	14.6	83.5	2.94	615

**Table 5.—Continued**

Sample site	Mo ppm	Na %	Nb ppm	Ni ppm	P ppm	Pb ppm	Rb ppm	Re ppm	S %	Sb ppm	Sc ppm	Sn ppm
Low Flow Jan. 2009												
09BC3S	0.37	0.54	1.6	1685	220	4.6	20.3	< 0.002	0.08	0.27	14.5	0.5
09BCBS	0.33	0.43	2.6	1325	260	5.0	23.9	< 0.002	0.03	0.35	12.9	0.5
09BC4S	0.49	0.92	3.2	836	430	8.9	31.7	< 0.002	0.05	0.51	16.6	0.6
High Flow June 2010												
10BC1S2	0.22	0.72	2.3	1445	270	2.9	17.9	< 0.002	0.01	0.18	16.9	0.7
10BC2S2	0.27	0.49	2.9	1550	230	5.1	42.5	< 0.002	0.01	0.32	13.6	0.6
10BC3S2	0.26	0.59	2.1	1610	220	4.0	22.8	< 0.002	0.06	0.27	14.4	0.4
10BC4S2	0.43	0.91	3.6	1050	360	6.2	41.5	< 0.002	0.04	0.50	17.2	1.0
10BC5S2	0.64	1.46	5.7	390	780	8.9	64.8	0.002	0.41	5.63	19.8	1.5
10BC6S2	0.63	1.47	5.7	398	650	10.8	71.6	0.002	0.35	6.14	21.0	2.8
10BC7S2	0.46	0.80	3.4	1290	440	6.6	43.0	< 0.002	0.04	0.62	15.3	0.7
10BC8S2	0.51	0.82	3.7	1040	470	6.1	41.9	< 0.002	0.12	2.80	14.8	1.0
10BC9S2	0.44	0.80	2.8	1250	360	5.0	31.1	< 0.002	0.05	0.87	17.2	0.6
10BC10S2	0.92	1.09	5.9	362	560	13.6	68.4	< 0.002	0.22	1.54	20.1	1.3
Low Flow Sept. 2010												
10BC1-2S	0.24	0.73	1.8	1330	200	2.8	13.3	< 0.002	0.01	0.45	15.3	0.6
10BC2-2S	0.20	0.60	3.3	1240	230	4.7	41.2	< 0.002	0.03	0.36	15.3	0.6
10BC3-2S	0.29	0.74	2.9	1065	320	4.3	31.0	< 0.002	0.05	0.42	15.2	0.5
10BC4-2S	0.33	1.19	3.3	684	300	5.3	30.0	< 0.002	0.03	0.38	17.1	0.7
10BC5-2S	0.56	2.13	4.8	322	670	7.3	68.0	< 0.002	0.93	12.55	17.5	1.1
10BC6-2S	0.53	1.95	4.7	324	500	7.9	67.8	< 0.002	0.31	5.95	16.4	1.2
10BC7-2S	0.53	0.90	4.0	871	480	7.1	48.3	< 0.002	0.04	1.00	15.7	3.5
10BC8-2S	0.54	0.91	3.7	947	440	6.7	43.4	< 0.002	0.08	1.29	15.9	0.8
10BC9-2S	0.51	0.85	2.6	1030	370	4.6	24.5	< 0.002	0.10	7.99	15.7	0.5
10BC10-2S	0.80	1.11	5.5	225	470	12.2	60.9	< 0.002	0.22	1.47	16.4	1.1

**Table 5.—Continued**

Sample site	Sr ppm	Ta ppm	Te ppm	Th ppm	Ti %	Tl ppm	U ppm	V ppm	W ppm	Y ppm	Zn ppm	Zr ppm
Low Flow Jan. 2009												
09BC3S	76.4	0.11	0.08	1.0	0.144	0.08	0.4	86	2.9	7.3	65	22.2
09BCBS	44.0	0.17	< 0.05	2.0	0.164	0.15	0.7	87	0.5	7.6	72	30.5
09BC4S	154.5	0.20	0.07	2.4	0.265	0.16	0.8	132	1.9	11.5	112	43.3
High Flow June 2010												
10BC1S2	160.5	0.15	< 0.05	1.0	0.255	0.08	0.4	127	0.4	9.3	98	39.3
10BC2S2	32.0	0.19	< 0.05	2.0	0.170	0.16	0.7	97	7.7	7.6	79	39.5
10BC3S2	61.3	0.14	< 0.05	1.1	0.198	0.09	0.5	117	2.9	7.9	96	32.5
10BC4S2	93.0	0.25	0.06	2.5	0.275	0.18	0.9	131	2.2	11.6	94	54.1
10BC5S2	203.0	0.40	0.06	3.3	0.393	0.39	1.2	166	43.7	17.3	112	83.5
10BC6S2	212.0	0.37	0.06	3.5	0.409	0.37	1.2	173	41.8	18.3	120	85.3
10BC7S2	112.0	0.23	0.06	2.5	0.234	0.21	0.9	116	6.0	11.0	87	50.2
10BC8S2	166.5	0.24	< 0.05	2.4	0.246	0.21	0.9	108	11.0	10.8	83	53.3
10BC9S2	121.5	0.19	< 0.05	1.6	0.239	0.14	0.7	115	10.4	10.8	80	44.5
10BC10S2	181.0	0.42	0.08	5.5	0.370	0.38	2.0	140	6.0	16.9	111	93.2
Low Flow Sept. 2010												
10BC1-2S	134.5	0.11	nr	0.9	0.213	0.05	0.4	107	0.3	8.4	74	31.1
10BC2-2S	49.2	0.20	nr	2.2	0.214	0.14	0.7	109	4.8	9.5	98	37.9
10BC3-2S	89.5	0.17	nr	1.9	0.244	0.12	0.7	146	2.9	10.0	139	39.5
10BC4-2S	124.5	0.20	nr	2.0	0.303	0.12	0.8	140	1.6	11.7	110	46.6
10BC5-2S	189.0	0.30	nr	3.4	0.351	0.31	1.1	138	31.8	16.2	92	66.6
10BC6-2S	222.0	0.28	nr	3.2	0.316	0.27	1.0	121	22.2	14.9	89	65.4
10BC7-2S	128.5	0.25	nr	3.2	0.258	0.23	1.1	121	6.1	12.7	89	56.0
10BC8-2S	146.5	0.23	nr	3.3	0.252	0.20	1.0	117	11.5	13.1	86	54.3
10BC9-2S	446.0	0.16	nr	1.5	0.235	0.11	0.6	115	10.3	11.5	82	38.3
10BC10-2S	1250.0	0.33	nr	5.8	0.333	0.31	2.0	114	6.9	15.4	95	79.0

**Table 6.** Major- and minor-element concentrations in unfiltered waters collected from Bear Creek, Colusa County, California. ICP-MS results (ICP-AES for major elements).

Field number	Ag µg/L	Al µg/L	As µg/L	B µg/L	Ba µg/L	Be µg/L	Bi µg/L	Ca mg/L	Cd µg/L
Sampling Event 1: Jan. 2009									
BC2	< 1	18.2	1	77.60	99.9	< 0.05	< 0.2	17.20	< 0.02
BC3	< 1	5.3	2	2830.00	184.0	< 0.05	< 0.2	17.60	< 0.02
BCA	< 1	123.0	2	8.05	23.0	< 0.05	< 0.2	4.04	< 0.02
BCB	< 1	< 2.0	< 1	98.60	18.3	< 0.05	< 0.2	8.17	< 0.02
BC4	< 1	13.5	2	3270.00	200.0	< 0.05	< 0.2	23.70	< 0.02
Sampling Event 2: Jun. 2010									
10BC1A	< 1	7.3	1.0	132	65.5	< 0.05	< 0.2	13.8	< 0.02
10BC2A	< 1	10900.0	2.0	339	206.0	0.30	< 0.2	19.9	0.08
10BC3A	< 1	25.3	2.0	1910	185.0	< 0.05	< 0.2	16.6	< 0.02
10BC4A	< 1	18.3	2.0	2000	204.0	< 0.05	< 0.2	17.7	< 0.02
10BC5A	< 1	82.9	13.8	43300	384.0	< 0.05	< 0.2	25.1	< 0.02
10BC6A	< 1	40.8	16.1	65300	496.0	< 0.05	< 0.2	23.9	< 0.02
10BC7A	< 1	35.8	4.5	13500	259.0	< 0.05	< 0.2	21.4	< 0.02
10BC8A	< 1	31.0	4.5	12300	244.0	< 0.05	< 0.2	21.3	< 0.02
10BC9A	< 1	10.6	4.1	10400	230.0	< 0.05	< 0.2	20.9	< 0.02
10BC10A	< 1	10.1	3.8	9350	205.0	< 0.05	< 0.2	21.3	< 0.02
Sampling Event 3: Sep. 2010									
10BC1A	< 1	9.2	< 1.0	183	74.2	< 10	< 0.2	16.3	< 0.02
10BC2A	< 1	20.5	< 1.0	138	127.0	< 10	< 0.2	15.6	< 0.02
10BC3A	< 1	42.8	< 1.0	2850	222.0	< 10	< 0.2	17.2	< 0.02
10BC4A	< 1	136.0	< 1.0	2630	228.0	< 10	< 0.2	17.4	< 0.02
10BC5A	< 1	197.0	10.9	204000	1770.0	< 10	< 0.2	17.0	0.05
10BC6A	< 1	29.8	9.5	250000	1620.0	< 10	< 0.2	14.3	0.02
10BC7A	< 1	32.0	1.4	19800	335.0	< 10	< 0.2	18.9	< 0.02
10BC8A	< 1	33.4	2.4	20500	333.0	< 10	< 0.2	20.4	< 0.02
10BC9A	< 1	10.5	2.8	21100	325.0	< 10	< 0.2	21.6	< 0.02
10BC10A	< 1	5.8	2.6	19400	171.0	< 10	< 0.2	16.6	< 0.02
Sampling Event 4: Mar. 2011									
11BC1A	< 1	4850	< 1.0	25.9	146	0.13	< 0.2	13.1	0.05
11BC4A	< 1	6470	< 1.0	435.0	144	0.12	< 0.2	12.2	0.05
11BC5A	< 1	50800	3.4	1740.0	769	1.00	< 0.2	49.2	0.52
11BC6A	< 1	38600	2.3	1640.0	674	0.78	< 0.2	31.7	0.33
11BC7A	< 1	2980	4.5	897.0	146	0.07	< 0.2	11.5	0.03
11BC8A	< 1	10100	< 1.0	612.0	222	0.26	< 0.2	15.0	0.09
11BC9A	< 1	10100	1.0	553.0	189	0.22	< 0.2	14.8	0.07
11BC10A	< 1	12100	1.4	655.0	203	0.21	< 0.2	17.6	0.08
Sampling Event 5: Jun. 2011									
11BC2A	< 1	115.0	< 1.0	220	87.4	< 0.05	< 0.2	14.6	< 0.02
11BC3A	< 1	11.6	< 1.0	966	94.4	< 0.05	< 0.2	62.5	< 0.02
11BC4A	< 1	23.1	< 1.0	1810	144.0	< 0.05	< 0.2	16.0	< 0.02
11BC10A	< 1	54.6	1.6	4260	153.0	< 0.05	< 0.2	22.0	< 0.02

**Table 6.—Continued**

Field number	Ce µg/L	Co µg/L	Cr µg/L	Cs µg/L	Cu µg/L	Dy µg/L	Er µg/L	Eu µg/L
Sampling Event 1: Jan. 2009								
BC2	0.03	0.18	7.9	< 0.02	0.59	0.009	0.005	0.030
BC3	0.02	0.15	8.9	2.02	0.68	0.010	0.007	0.052
BCA	0.16	0.30	7.6	< 0.02	0.91	0.040	0.009	0.020
BCB	<0.01	0.03	22.0	< 0.02	0.56	0.006	< 0.005	0.008
BC4	0.03	0.11	9.0	0.56	0.89	0.010	0.010	0.058
Sampling Event 2: Jun. 2010								
10BC1A	0.01	0.13	7.9	< 0.02	< 0.50	< 0.005	0.005	0.007
10BC2A	5.66	61.5	807.0	10.70	27.20	0.880	0.390	0.300
10BC3A	0.02	0.29	5.1	1.97	0.59	0.006	0.005	0.030
10BC4A	0.02	0.17	4.6	1.55	0.74	0.006	0.005	0.020
10BC5A	0.08	0.43	11.1	140.00	3.00	0.030	0.020	0.052
10BC6A	0.09	0.44	15.0	262.00	2.40	0.040	0.020	0.050
10BC7A	0.05	0.26	6.0	26.20	1.40	0.020	0.020	0.020
10BC8A	0.04	0.30	6.0	26.20	1.40	0.020	0.010	0.030
10BC9A	0.03	0.24	6.5	19.60	1.40	0.020	0.010	0.020
10BC10A	0.02	0.21	5.2	15.70	1.40	0.007	0.009	0.020
Sampling Event 3: Sep. 2010								
10BC1A	0.01	0.23	< 1.0	< 0.02	< 0.50	0.030	< 0.005	< 0.005
10BC2A	0.02	0.19	< 1.0	0.04	< 0.50	0.020	< 0.005	< 0.005
10BC3A	0.04	0.28	1.4	2.70	< 0.50	0.020	0.009	< 0.005
10BC4A	0.09	0.43	2.2	1.40	0.71	0.030	0.010	< 0.005
10BC5A	0.24	0.61	4.8	905.00	1.80	0.130	0.110	< 0.005
10BC6A	0.17	0.37	4.8	1000.00	1.50	0.097	0.068	< 0.005
10BC7A	0.04	0.17	1.1	68.70	0.77	0.020	0.010	< 0.005
10BC8A	0.04	0.26	< 1.0	55.80	1.10	0.020	0.020	0.010
10BC9A	0.02	0.26	< 1.0	37.00	1.50	< 0.005	0.008	0.010
10BC10A	0.01	0.26	< 1.0	21.70	1.50	0.009	0.008	0.008
Sampling Event 4: Mar. 2011								
11BC1A	4.2	13.0	81	0.37	13.9	0.64	0.35	0.25
11BC4A	4.1	23.7	149	2.10	17.7	0.69	0.38	0.23
11BC5A	53.6	115.0	635	56.20	141.0	7.70	3.60	2.50
11BC6A	36.6	87.2	421	33.20	106.0	5.10	2.40	1.70
11BC7A	2.6	11.0	67.8	2.10	9.6	0.43	0.24	0.15
11BC8A	9.1	36.5	220	6.60	31.3	1.40	0.68	0.46
11BC9A	7.9	33.9	202	4.80	28.3	1.20	0.64	0.43
11BC10A	8.7	32.9	194	7.00	30.8	1.40	0.67	0.47
Sampling Event 5: Jun. 2011								
11BC2A	0.31	11.80	15.7	0.64	1.1	0.094	0.066	0.30
11BC3A	0.27	0.83	< 1.0	< 0.02	1.8	0.099	0.064	0.30
11BC4A	0.26	6.70	6.5	3.80	1.0	0.094	0.064	0.29
11BC10A	0.30	7.10	5.1	6.50	1.6	0.098	0.066	0.29

**Table 6.—Continued**

<b>Field number</b>	<b>Fe µg/L</b>	<b>Ga µg/L</b>	<b>Gd µg/L</b>	<b>Ge µg/L</b>	<b>Ho µg/L</b>	<b>K mg/L</b>	<b>La µg/L</b>	<b>Li µg/L</b>
Sampling Event 1: Jan. 2009								
BC2	43.8	< 0.05	0.010	< 0.05	< 0.005	0.43	0.01	4.8
BC3	< 20.0	< 0.05	0.010	< 0.05	< 0.005	5.78	0.01	206.0
BCA	249.0	< 0.05	0.052	< 0.05	0.006	0.08	0.05	4.5
BCB	< 20.0	< 0.05	0.005	< 0.05	< 0.005	0.42	0.01	7.2
BC4	30.0	< 0.05	0.008	< 0.05	< 0.005	5.67	0.02	220.0
Sampling Event 2: Jun. 2010								
10BC1A	< 20.0	< 0.05	< 0.005	< 0.05	< 0.005	0.52	< 0.01	2.8
10BC2A	37.4	2.90	1.130	1.30	0.170	1.45	3.16	52.3
10BC3A	40.9	< 0.05	0.009	< 0.05	< 0.005	3.95	0.02	170.0
10BC4A	32.0	< 0.05	0.006	< 0.05	< 0.005	3.94	0.02	173.0
10BC5A	136.0	0.05	0.030	3.10	0.010	88.20	0.04	1,560.0
10BC6A	13,300.0	< 0.05	0.040	6.40	0.009	121.00	0.04	2,020.0
10BC7A	< 20.0	< 0.05	0.010	0.94	< 0.005	23.90	0.03	610.0
10BC8A	< 20.0	< 0.05	0.020	0.58	< 0.005	18.00	0.03	551.0
10BC9A	< 20.0	< 0.05	0.010	0.28	< 0.005	16.20	0.02	494.0
10BC10A	< 20.0	< 0.05	0.009	0.20	< 0.005	15.80	0.01	469.0
Sampling Event 3: Sep. 2010								
10BC1A	20	< 0.05	< 0.005	nr	0.006	0.462	< 0.01	< 5
10BC2A	50	< 0.05	0.006	nr	0.006	0.498	0.01	14
10BC3A	110	< 0.05	< 0.005	nr	< 0.005	5.570	0.01	218
10BC4A	293	0.05	0.010	nr	0.009	4.760	0.04	193
10BC5A	884	0.39	0.096	nr	0.030	394	0.07	10,400
10BC6A	253	0.43	0.072	nr	0.020	486	0.05	12,700
10BC7A	75	0.09	0.020	nr	0.020	33.5	0.02	908
10BC8A	65	0.07	< 0.005	nr	0.010	33.4	0.02	939
10BC9A	< 20	0.10	0.020	nr	< 0.005	32.2	< 0.01	934
10BC10A	< 20	0.07	0.020	nr	0.020	29.1	< 0.01	876
Sampling Event 4: Mar. 2011								
11BC1A	9,490	1.8	0.85	nr	0.120	1.9	1.90	5.8
11BC4A	13,900	2.4	0.84	nr	0.130	2.5	1.70	35.9
11BC5A	102,000	21.8	9.50	nr	1.400	12.5	21.10	254.0
11BC6A	73,200	16.2	6.50	nr	0.940	11.6	14.30	197.0
11BC7A	6230	1.2	0.54	nr	0.084	2.9	0.96	65.5
11BC8A	21,400	4.3	1.80	nr	0.260	3.7	3.50	59.1
11BC9A	20,800	3.9	1.70	nr	0.220	3.4	3.10	47.1
11BC10A	23,800	4.3	1.60	nr	0.250	3.8	3.40	56.6
Sampling Event 5: Jun. 2011								
11BC2A	218.0	< 0.05	< 0.005	nr	0.02	1.12	< 0.01	18.6
11BC3A	< 20.0	< 0.05	< 0.005	nr	0.02	2.49	< 0.01	68.3
11BC4A	56.6	< 0.05	< 0.005	nr	0.02	4.21	< 0.01	141.0
11BC10A	99.7	< 0.05	< 0.005	nr	0.02	8.60	< 0.01	244.0

**Table 6.—Continued**

<b>Field number</b>	<b>Lu µg/L</b>	<b>Mg mg/L</b>	<b>Mn µg/L</b>	<b>Mo µg/L</b>	<b>Na mg/L</b>	<b>Nb µg/L</b>	<b>Nd µg/L</b>	<b>Ni µg/L</b>
Sampling Event 1: Jan. 2009								
BC2	< 0.1	91.1	39.8	< 2	21.2	< 0.2	0.03	3.8
BC3	< 0.1	87.0	32.6	< 2	66.5	< 0.2	0.02	3.8
BCA	< 0.1	27.4	6.2	< 2	1.23	< 0.2	0.15	4.2
BCB	< 0.1	92.8	0.4	< 2	7.6	< 0.2	0.03	2.2
BC4	< 0.1	98.1	7.3	< 2	86.6	< 0.2	0.03	3.8
Sampling Event 2: Jun. 2010								
10BC1A	< 0.1	90.3	5.1	< 2	27.9	< 0.2	< 0.01	2.6
10BC2A	< 0.1	88.7	842.0	< 2	26.0	< 0.2	4.27	1,400
10BC3A	< 0.1	90.2	31.5	< 2	57.5	< 0.2	0.02	4.9
10BC4A	< 0.1	94.4	13.6	< 2	57.5	< 0.2	0.02	4.2
10BC5A	< 0.1	94.6	47.6	< 2	1520.0	< 0.2	0.06	5.9
10BC6A	< 0.1	8.23	57.2	< 2	4.19	< 0.2	0.08	5.6
10BC7A	< 0.1	< 0.10	15.5	< 2	< 0.10	< 0.2	0.05	5.2
10BC8A	< 0.1	96.6	13.8	< 2	337.0	< 0.2	0.04	5.1
10BC9A	< 0.1	< 0.10	9.2	< 2	0.763	< 0.2	0.03	4.8
10BC10A	< 0.1	103.0	4.9	< 2	325.0	< 0.2	0.02	3.8
Sampling Event 3: Sep. 2010								
10BC1A	nr	103.0	33.6	< 2	32.4	< 0.2	< 0.01	2.4
10BC2A	nr	88.2	33.5	< 2	21.1	< 0.2	0.02	2.4
10BC3A	nr	91.0	41.8	< 2	66.8	< 0.2	0.01	4.3
10BC4A	nr	89.3	28.9	< 2	63.8	< 0.2	0.07	6.9
10BC5A	nr	78.5	185.0	< 2	5,060.0	0.27	0.20	9.3
10BC6A	nr	80.1	108.0	< 2	5,560.0	< 0.2	0.11	8.0
10BC7A	nr	93.9	20.3	< 2	624.0	< 0.2	0.04	3.9
10BC8A	nr	104.0	9.0	< 2	627.0	< 0.2	0.04	4.3
10BC9A	nr	115.0	10.2	< 2	644.0	< 0.2	< 0.01	4.9
10BC10A	nr	120.0	8.1	< 2	631.0	0.27	0.02	3.6
Sampling Event 4: Mar. 2011								
11BC1A	nr	28.0	237	< 2	10.1	< 0.2	2.9	192
11BC4A	nr	58.4	380	< 2	15.8	< 0.2	2.9	359
11BC5A	nr	142.0	2,600	< 2	57.8	< 0.2	35.6	1,440
11BC6A	nr	101.0	1,930	< 2	56.9	< 0.2	24.1	1,040
11BC7A	nr	50.5	196	< 2	24.9	< 0.2	1.8	162
11BC8A	nr	67.2	665	< 2	21.2	< 0.2	6.2	531
11BC9A	nr	62.4	590	< 2	20.1	< 0.2	5.4	480
11BC10A	nr	68.3	621	< 2	22.7	< 0.2	5.8	465
Sampling Event 5: Jun. 2011								
11BC2A	nr	86.8	226.0	< 2	22.3	< 0.2	0.50	5.8
11BC3A	nr	140.0	< 0.2	< 2	64.1	< 0.2	0.48	< 0.4
11BC4A	nr	92.3	34.8	< 2	53.2	< 0.2	0.47	0.4
11BC10A	nr	89.2	94.5	< 2	130.0	< 0.2	0.48	< 0.4

**Table 6.—Continued**

Field number	P mg/L	Pb µg/L	Pr µg/L	Rb µg/L	Sb µg/L	Sc µg/L	Se µg/L	SiO <sub>2</sub> mg/L
Sampling Event 1: Jan. 2009								
BC2	0.04	< 0.05	< 0.01	0.14	< 0.3	5.5	1.3	24.4
BC3	0.04	< 0.05	< 0.01	10.30	< 0.3	5.3	2.2	25.4
BCA	0.03	0.09	0.03	0.10	< 0.3	8.9	< 1.0	44.4
BCB	< 0.01	< 0.05	< 0.01	0.28	< 0.3	6.5	< 1.0	32.2
BC4	0.02	0.91	< 0.01	6.90	< 0.3	4.6	2.7	23.0
Sampling Event 2: Jun. 2010								
10BC1A	< 0.01	1.6	< 0.01	0.30	< 0.3	2.8	1.3	32.8
10BC2A	0.20	5.8	0.94	7.67	< 0.3	15.3	1.2	100.0
10BC3A	0.01	1.5	< 0.01	8.94	< 0.3	2.3	2.1	29.1
10BC4A	< 0.01	1.5	< 0.01	8.34	< 0.3	2.4	1.9	29.5
10BC5A	< 0.01	1.2	0.01	189.0	5.39	1.4	36.5	23.0
10BC6A	0.02	0.6	0.01	262.0	6.22	2.3	47.0	39.9
10BC7A	< 0.01	2.0	0.01	55.2	0.85	2.1	9.6	30.9
10BC8A	< 0.01	1.6	< 0.01	40.1	0.84	1.8	8.7	24.0
10BC9A	< 0.01	1.5	< 0.01	35.2	0.75	1.6	7.9	22.1
10BC10A	< 0.01	1.4	< 0.01	33.2	0.68	1.2	7.5	16.2
Sampling Event 3: Sept. 2010								
10BC1A	< 0.01	< 0.05	< 0.01	0.28	< 0.3	1.1	< 1.0	31
10BC2A	0.03	< 0.05	< 0.01	0.46	< 0.3	1.1	1.1	28
10BC3A	0.03	< 0.05	< 0.01	12.6	< 0.3	0.9	5.0	29
10BC4A	0.04	1.87	0.01	10.1	< 0.3	1.1	3.9	30
10BC5A	0.40	0.40	0.04	899.0	31.1	4.4	611.0	58
10BC6A	0.40	0.09	0.02	919.0	20.2	6.3	686.0	96
10BC7A	0.07	< 0.05	< 0.01	70.4	1.3	2.5	76.3	35
10BC8A	0.03	< 0.05	0.01	65.4	1.3	1.9	65.9	29
10BC9A	0.04	< 0.05	< 0.01	61.3	1.2	1.4	75.6	21
10BC10A	0.04	< 0.05	< 0.01	50.6	1.0	1.2	71.4	10
Sampling Event 4: Mar. 2011								
11BC1A	0.2	1.64	0.66	3.0	< 0.3	8.1	< 1.0	55
11BC4A	0.2	1.83	0.62	6.2	< 0.3	11.5	< 1.0	82
11BC5A	1.7	23.5	8.0	77.8	0.46	44.8	2.0	190
11BC6A	1.1	16.80	5.4	60.4	0.39	34.5	2.4	180
11BC7A	0.1	1.24	0.4	6.1	< 0.3	5.6	< 1.0	46
11BC8A	0.3	4.21	1.4	12.3	< 0.3	14.3	1.0	100
11BC9A	0.3	3.55	1.2	10.4	< 0.3	12.8	< 1.0	100
11BC10A	0.3	3.96	1.3	12.3	< 0.3	14.4	< 1.0	110
Sampling Event 5: Jun. 2011								
11BC2A	0.04	0.14	0.22	2.2	< 0.3	3.4	1.2	33
11BC3A	0.03	0.17	0.22	1.2	< 0.3	2.0	1.8	17
11BC4A	0.02	0.13	0.22	9.2	< 0.3	3.6	1.9	32
11BC10A	0.02	0.14	0.22	16.4	0.39	3.1	4.8	26

**Table 6.—Continued**

Field number	Sm µg/L	SO <sub>4</sub> mg/L	Sr µg/L	Ta µg/L	Tb µg/L	Th µg/L	Ti µg/L	Tl µg/L
Sampling Event 1: Jan. 2009								
BC2	< 0.01	18	320.0	< 0.02	< 0.005	< 0.2	< 0.5	< 0.1
BC3	< 0.01	17	428.0	< 0.02	< 0.005	< 0.2	< 0.5	< 0.1
BCA	0.03	3	34.6	< 0.02	0.008	< 0.2	< 0.5	< 0.1
BCB	0.01	9	97.4	< 0.02	< 0.005	< 0.2	< 0.5	< 0.1
BC4	< 0.01	18	768.0	< 0.02	< 0.005	< 0.2	< 0.5	< 0.1
Sampling Event 2: Jun. 2010								
10BC1A	< 0.01	4	450	< 0.02	< 0.005	< 0.2	0.6	< 0.1
10BC2A	1.12	11	395	< 0.02	0.170	0.34	231.0	< 0.1
10BC3A	< 0.01	11	428	< 0.02	< 0.005	< 0.2	1.0	< 0.1
10BC4A	< 0.01	12	518	< 0.02	< 0.005	< 0.2	0.8	< 0.1
10BC5A	0.02	107	915	0.03	0.006	< 0.2	4.3	< 0.1
10BC6A	0.03	134	1,000	0.04	0.006	< 0.2	5.0	< 0.1
10BC7A	< 0.01	29	690	< 0.02	< 0.005	< 0.2	2.0	< 0.1
10BC8A	0.01	29	679	< 0.02	< 0.005	< 0.2	1.7	< 0.1
10BC9A	0.01	33	678	< 0.02	< 0.005	< 0.2	1.2	< 0.1
10BC10A	< 0.01	45	664	< 0.02	< 0.005	< 0.2	1.6	< 0.1
Sampling Event 3: Sep. 2010								
10BC1A	< 0.01	< 2.0	510	0.04	< 0.005	< 0.2	< 0.5	< 0.1
10BC2A	< 0.01	5.9	328	0.03	< 0.005	< 0.2	< 0.5	< 0.1
10BC3A	< 0.01	2.9	418	0.03	< 0.005	< 0.2	< 0.5	< 0.1
10BC4A	0.03	6.2	460	0.03	< 0.005	< 0.2	3.2	< 0.1
10BC5A	0.07	240.0	1,460	0.42	0.020	< 0.2	13.6	< 0.1
10BC6A	0.09	280.0	1,600	0.22	0.006	< 0.2	14.4	< 0.1
10BC7A	< 0.01	31.0	640	0.04	< 0.005	< 0.2	3.6	< 0.1
10BC8A	< 0.01	32.0	689	0.03	< 0.005	< 0.2	2.0	< 0.1
10BC9A	0.03	41.0	767	0.04	< 0.005	< 0.2	2.7	< 0.1
10BC10A	0.04	49.0	498	0.09	< 0.005	< 0.2	3.4	< 0.1
Sampling Event 4: Mar. 2011								
11BC1A	0.65	2.7	256	< 0.02	0.13	0.31	91.4	< 0.10
11BC4A	0.72	4.4	210	< 0.02	0.14	0.32	136.0	< 0.10
11BC5A	8.80	15.0	690	< 0.02	1.40	3.23	1070.0	0.53
11BC6A	6.30	14.0	530	< 0.02	0.98	1.81	483.0	0.34
11BC7A	0.42	5.6	239	< 0.02	0.088	0.25	37.9	< 0.10
11BC8A	1.60	6.2	275	< 0.02	0.28	0.40	120.0	0.11
11BC9A	1.40	7.2	255	< 0.02	0.25	0.42	152.0	0.10
11BC10A	1.50	11.0	279	< 0.02	0.27	0.62	226.0	0.12
Sampling Event 5: Jun. 2011								
11BC2A	0.35	9.9	350	< 0.02	0.006	0.38	2.7	0.28
11BC3A	0.34	220.0	940	< 0.02	< 0.005	0.39	3.5	0.43
11BC4A	0.34	13.0	397	< 0.02	< 0.005	0.37	1.0	0.29
11BC10A	0.36	51.0	540	< 0.02	< 0.005	0.38	3.7	0.30

**Table 6.—Continued**

<b>Field number</b>	<b>Tm µg/L</b>	<b>U µg/L</b>	<b>V µg/L</b>	<b>W µg/L</b>	<b>Y µg/L</b>	<b>Yb µg/L</b>	<b>Zn µg/L</b>	<b>Zr µg/L</b>
Sampling Event 1: Jan. 2009								
BC2	< 0.005	< 0.1	4.3	< 0.50	0.10	0.005	2.3	< 0.2
BC3	< 0.005	< 0.1	5.2	3.06	0.12	0.006	2.0	< 0.2
BCA	< 0.005	< 0.1	3.7	< 0.50	0.15	< 0.005	2.4	< 0.2
BCB	< 0.005	< 0.1	1.7	< 0.50	0.06	< 0.005	2.4	< 0.2
BC4	< 0.005	< 0.1	5.1	1.47	0.14	0.007	2.2	< 0.2
Sampling Event 2: Jun. 2010								
10BC1A	< 0.005	< 0.10	5.0	< 0.50	0.04	< 0.005	0.6	< 0.2
10BC2A	0.053	0.18	36.7	0.88	3.54	0.280	52.6	0.2
10BC3A	< 0.005	< 0.10	4.0	2.66	0.08	0.005	1.5	< 0.2
10BC4A	< 0.005	< 0.10	3.8	2.61	0.08	< 0.005	1.0	< 0.2
10BC5A	< 0.005	0.31	12.5	509.0	0.30	0.020	1.7	0.2
10BC6A	< 0.005	0.28	12.4	782.0	0.30	0.020	1.9	0.3
10BC7A	< 0.005	< 0.10	6.4	136.0	0.15	0.009	3.0	< 0.2
10BC8A	< 0.005	< 0.10	5.4	105.0	0.14	0.007	1.2	< 0.2
10BC9A	< 0.005	< 0.10	5.8	87.1	0.12	0.008	1.4	< 0.2
10BC10A	< 0.005	0.11	5.6	84.6	0.10	0.010	2.0	< 0.2
Sampling Event 3: Sep. 2010								
10BC1A	0.005	< 0.10	1.9	nr	0.04	0.01	< 3	nr
10BC2A	< 0.005	< 0.10	< 0.5	nr	0.05	< 0.01	< 3	nr
10BC3A	< 0.005	< 0.10	1.4	nr	0.08	< 0.01	< 3	nr
10BC4A	< 0.005	< 0.10	1.8	nr	0.13	0.04	< 3	nr
10BC5A	0.010	0.19	5.0	nr	1.00	0.10	3.5	nr
10BC6A	0.010	0.13	2.2	nr	0.60	0.06	< 3	nr
10BC7A	0.007	< 0.10	1.7	nr	0.11	0.04	< 3	nr
10BC8A	< 0.005	< 0.10	2.2	nr	0.14	0.02	< 3	nr
10BC9A	0.005	< 0.10	4.3	nr	0.11	0.05	< 3	nr
10BC10A	0.006	0.11	5.0	nr	0.04	0.04	< 3	nr
Sampling Event 4: Mar. 2011								
11BC1A	0.070	< 0.10	19.9	< 0.5	35.1	2.60	295.0	nr
11BC4A	0.077	< 0.10	27.2	< 0.5	24.4	1.60	230.0	nr
11BC5A	0.440	0.62	263.0	2.0	1.9	0.14	20.4	nr
11BC6A	0.310	0.41	169.0	1.2	6.4	0.47	65.5	nr
11BC7A	0.052	< 0.10	15.1	< 0.5	5.8	0.45	57.1	nr
11BC8A	0.120	0.14	47.5	< 0.5	6.1	0.40	60.5	nr
11BC9A	0.110	0.14	43.3	< 0.5	nr	nr	nr	nr
11BC10A	0.110	0.17	47.7	0.56	nr	nr	nr	nr
Sampling Event 5: Jun. 2011								
11BC2A	0.03	< 0.10	3.9	1.9	0.10	< 0.01	< 3	nr
11BC3A	0.03	0.88	3.3	2.0	0.13	< 0.01	< 3	nr
11BC4A	0.03	< 0.10	4.0	3.8	0.09	< 0.01	< 3	nr
11BC10A	0.03	< 0.10	4.9	20.0	0.12	< 0.01	< 3	nr

**Table 7.** Major- and minor-element concentrations in filtered waters collected from Bear Creek, Colusa County California. ICP-MS results (ICP-AES for major elements).

Field number	Ag µg/L	Al µg/L	As µg/L	B µg/L	Ba µg/L	Be µg/L	Bi µg/L	Ca mg/L
Sampling Event 1: Jan. 2009								
BC2	< 1	< 2	1	77.7	100	< 0.05	< 0.2	17.2
BC3	< 1	< 2	2	2,790	179	< 0.05	< 0.2	17.7
BCA	< 1	< 2	2	6.21	20.5	< 0.05	< 0.2	4.30
BCB	< 1	< 2	< 1	96.7	18.0	< 0.05	< 0.2	8.77
BC4	< 1	< 2	2	3,100	195	< 0.05	< 0.2	23.4
Sampling Event 2: Jun. 2010								
10BC1B	< 1	< 2.0	1.0	116	66	< 0.05	< 0.2	14.9
10BC2B	< 1	14.3	1.0	273	111	< 0.05	< 0.2	16.4
10BC3B	< 1	15.0	2.0	1,920	176	< 0.05	< 0.2	17.1
10BC4B	< 1	13.4	2.0	2,030	193	< 0.05	< 0.2	17.4
10BC5B	< 1	84.1	14.8	46,600	375	< 0.05	< 0.2	26.3
10BC6B	< 1	38.7	16.6	< 5	488	< 0.05	< 0.2	10.5
10BC7B	< 1	10.7	4.7	< 5	249	< 0.05	< 0.2	< 0.1
10BC8B	< 1	< 2.0	4.0	10,600	248	< 0.05	< 0.2	18.3
10BC9B	< 1	8.6	3.4	90.5	220	< 0.05	< 0.2	< 0.1
10BC10B	< 1	< 2.0	3.9	9,990	203	< 0.05	< 0.2	21.6
Sampling Event 3: Sep. 2010								
10BC1B	< 1	< 2.0	3.2	96.7	98.3	< 10	< 0.2	14.6
10BC2B	< 1	< 2.0	2.8	90.1	175	< 10	< 0.2	15.4
10BC3B	< 1	< 2.0	3.2	2,660	299	< 10	< 0.2	16.3
10BC4B	< 1	< 2.0	3.3	2,660	307	< 10	< 0.2	17.4
10BC5B	< 1	45.6	20.5	198,000	2,320	< 10	< 0.2	16.8
10BC6B	< 1	7.4	15.1	275,000	2,110	< 10	< 0.2	15.4
10BC7B	< 1	< 2.0	5.4	19,800	429	< 10	< 0.2	18.9
10BC8B	< 1	2.7	4.3	19,600	435	< 10	< 0.2	19.2
10BC9B	< 1	< 2.0	3.2	21,000	407	< 10	< 0.2	21.3
10BC10B	< 1	< 2.0	5.8	19,500	223	< 10	< 0.2	16.5
Sampling Event 4: Mar. 2011								
11BC1B	< 1	80.9	< 1	26.7	56.7	< 0.05	< 0.2	11.7
11BC4B	< 1	155.0	< 1	449	51.8	< 0.05	< 0.2	10.1
11BC5B	< 1	485.0	< 1	1,560	33.7	< 0.05	< 0.2	10.5
11BC6B	< 1	115.0	< 1	1,620	32.1	< 0.05	< 0.2	10.3
11BC7B	< 1	96.9	< 1	868	71.3	< 0.05	< 0.2	11.0
11BC8B	< 1	134.0	< 1	593	49.8	< 0.05	< 0.2	9.62
11BC9B	< 1	3.7	< 1	537	44.6	< 0.05	< 0.2	9.86
11BC10B	< 1	3.1	< 1	679	47.5	< 0.05	< 0.2	12.6
Sampling Event 5: Jun. 2011								
11BC2B	< 1	< 2	< 1.0	252	88.2	< 0.05	< 0.2	15.3
11BC3B	< 1	< 2	< 1.0	1,820	143	< 0.05	< 0.2	16.2
11BC4B	< 1	< 2	< 1.0	1,870	145	< 0.05	< 0.2	15.4
11BC10B	< 1	< 2	1.6	4,480	156	< 0.05	< 0.2	23.0

**Table 7.—Continued**

Field number	Cd µg/L	Ce µg/L	Co µg/L	Cr µg/L	Cs µg/L	Cu µg/L	Dy µg/L	Er µg/L
Sampling Event 1: Jan. 2009								
BC2	< 0.02	< 0.01	0.13	7.8	< 0.02	0.63	0.007	0.006
BC3	< 0.02	0.01	0.14	9.6	1.95	0.67	0.008	0.007
BCA	< 0.02	0.03	0.12	6.4	< 0.02	0.54	0.009	< 0.005
BCB	< 0.02	< 0.01	0.03	23.4	< 0.02	0.53	0.008	< 0.005
BC4	< 0.02	0.02	0.07	9.4	0.53	0.85	0.010	0.009
Sampling Event 2: Jun. 2010								
10BC1B	< 0.02	< 0.01	0.12	6.5	< 0.02	0.50	< 0.005	< 0.005
10BC2B	< 0.02	0.01	0.20	4.3	0.20	0.62	0.010	0.005
10BC3B	< 0.02	0.02	0.24	4.8	1.90	0.66	< 0.005	< 0.005
10BC4B	< 0.02	0.02	0.16	4.2	1.46	0.81	< 0.005	0.007
10BC5B	< 0.02	0.07	0.48	10.8	143.0	3.0	0.020	0.020
10BC6B	< 0.02	0.09	0.50	10.2	259.0	2.5	0.040	0.020
10BC7B	< 0.02	0.02	0.22	4.7	35.6	1.2	0.010	0.010
10BC8B	< 0.02	0.02	0.22	4.0	26.8	1.2	0.009	0.007
10BC9B	< 0.02	0.02	0.29	3.5	19.1	1.4	0.010	0.010
10BC10B	< 0.02	0.01	0.19	3.3	15.8	1.5	0.008	0.009
Sampling Event 3: Sep. 2010								
10BC1B	0.03	< 0.01	0.15	1.1	0.02	< 0.5	0.02	0.020
10BC2B	0.06	0.01	0.15	1.4	0.12	< 0.5	0.02	0.010
10BC3B	0.06	< 0.01	0.14	1.5	3.20	< 0.5	0.02	0.008
10BC4B	0.04	0.01	0.10	1.2	1.60	0.54	0.02	0.009
10BC5B	0.04	0.15	0.38	4.6	1,070	1.3	0.11	0.079
10BC6B	0.03	0.12	0.26	4.6	1,220	1.3	0.06	0.040
10BC7B	0.03	0.01	0.15	1.5	81.7	0.9	0.01	0.020
10BC8B	0.04	0.02	0.20	1.3	66.2	1.1	0.01	0.020
10BC9B	0.03	0.01	0.20	1.2	42.1	1.3	0.03	0.020
10BC10B	0.03	< 0.01	0.21	1.3	26.1	1.4	0.008	0.020
Sampling Event 4: Mar. 2011								
11BC1B	< 0.02	0.18	1.40	1.9	< 0.02	1.7	0.073	0.072
11BC4B	< 0.02	0.15	3.40	6.2	0.14	1.8	0.078	0.063
11BC5B	< 0.02	0.48	4.60	7.5	0.74	2.8	0.110	0.084
11BC6B	< 0.02	0.27	0.41	3.5	0.54	2.0	0.074	0.066
11BC7B	< 0.02	0.12	1.40	5.7	0.33	1.4	0.063	0.056
11BC8B	< 0.02	0.18	3.80	6.3	0.30	2.1	0.071	0.067
11BC9B	< 0.02	0.07	0.22	3.5	0.16	1.5	0.052	0.063
11BC10B	< 0.02	0.07	0.24	3.6	0.22	1.6	0.056	0.061
Sampling Event 5: Jun. 2011								
11BC2B	< 0.02	0.25	4.9	6.6	0.55	0.89	0.089	0.064
11BC3B	< 0.02	0.25	5.4	6.2	4.10	0.96	0.088	0.063
11BC4B	< 0.02	0.25	5.6	6.1	3.80	1.20	0.097	0.063
11BC10B	0.11	0.26	5.8	4.8	6.60	1.60	0.097	0.065

**Table 7.—Continued**

Field number	Eu µg/L	Fe µg/L	Ga µg/L	Gd µg/L	Ge µg/L	Ho µg/L	K mg/L	La µg/L
Sampling Event 1: Jan. 2009								
BC2	0.030	< 20	< 0.05	0.006	< 0.05	< 0.005	0.44	< 0.01
BC3	0.061	< 20	< 0.05	0.008	< 0.05	< 0.005	5.58	0.01
BCA	0.009	< 20	< 0.05	0.010	< 0.05	< 0.005	0.06	0.01
BCB	0.007	< 20	< 0.05	0.007	< 0.05	< 0.005	0.41	0.01
BC4	0.059	< 20	< 0.05	0.008	< 0.05	< 0.005	5.58	0.01
Sampling Event 2: Jun. 2010								
10BC1B	0.01	< 20	< 0.05	< 0.005	< 0.05	< 0.005	0.56	< 0.01
10BC2B	0.02	37.4	< 0.05	0.006	< 0.05	< 0.005	1.00	0.02
10BC3B	0.04	40.9	< 0.05	0.010	< 0.05	< 0.005	4.26	0.01
10BC4B	0.02	32.0	< 0.05	0.006	< 0.05	< 0.005	4.13	0.01
10BC5B	0.04	136	< 0.05	0.040	3.40	0.008	96.4	0.03
10BC6B	0.051	13,300	< 0.05	0.030	6.60	0.008	132.0	0.05
10BC7B	0.03	< 20	< 0.05	0.010	1.10	< 0.005	23.0	0.02
10BC8B	0.05	< 20	< 0.05	0.007	0.52	< 0.005	18.7	0.02
10BC9B	0.02	< 20	< 0.05	0.006	0.32	< 0.005	16.3	0.01
10BC10B	0.02	< 20	< 0.05	0.005	0.10	< 0.005	16.5	< 0.01
Sampling Event 3: Sep. 2010								
10BC1B	0.010	< 20	0.10	0.02	nr	< 0.005	0.373	< 0.01
10BC2B	0.007	< 20	0.10	0.02	nr	0.009	0.510	0.01
10BC3B	< 0.005	< 20	0.09	0.03	nr	0.005	5.330	< 0.01
10BC4B	0.010	< 20	0.10	0.01	nr	0.005	5.130	< 0.01
10BC5B	< 0.005	301	0.46	0.087	nr	0.020	385.0	0.04
10BC6B	0.009	241	0.48	0.067	nr	0.020	539.0	0.03
10BC7B	0.010	< 20	0.10	0.03	nr	0.008	32.5	< 0.01
10BC8B	< 0.005	< 20	0.20	0.02	nr	0.007	32.7	0.01
10BC9B	< 0.005	< 20	0.20	0.02	nr	0.009	32.6	< 0.01
10BC10B	0.007	< 20	0.20	0.02	nr	0.009	29.9	< 0.01
Sampling Event 4: Mar. 2011								
11BC1B	0.04	120	< 0.05	0.092	nr	0.01	1.5	0.10
11BC4B	0.04	223	< 0.05	0.072	nr	0.01	1.8	0.06
11BC5B	0.04	697	0.10	0.130	nr	0.02	5.7	0.18
11BC6B	0.04	179	< 0.05	0.094	nr	0.01	6.2	0.10
11BC7B	0.04	148	< 0.05	0.062	nr	0.01	2.5	0.05
11BC8B	0.03	207	< 0.05	0.071	nr	0.01	2.5	0.07
11BC9B	0.03	< 20	< 0.05	0.056	nr	0.01	2.4	0.02
11BC10B	0.04	< 20	< 0.05	0.053	nr	0.01	2.6	0.03
Sampling Event 5: Jun. 2011								
11BC2B	0.3	< 20	< 0.05	< 0.005	nr	0.02	1.78	< 0.01
11BC3B	0.3	< 20	< 0.05	< 0.005	nr	0.02	4.46	< 0.01
11BC4B	0.3	< 20	< 0.05	< 0.005	nr	0.02	4.64	< 0.01
11BC10B	0.3	22	< 0.05	< 0.005	nr	0.02	9.30	< 0.01

**Table 7.—Continued**

Field number	Li µg/L	Lu µg/L	Mg mg/L	Mn µg/L	Mo µg/L	Na mg/L	Nb µg/L	Nd µg/L
Sampling Event 1: Jan. 2009								
BC2	4.2	< 0.1	88.7	24.8	< 2	20.50	< 0.2	0.01
BC3	203.0	< 0.1	88.0	28.5	< 2	65.30	< 0.2	0.02
BCA	3.9	< 0.1	29.0	5.2	< 2	1.12	< 0.2	0.03
BCB	7.2	< 0.1	96.7	0.2	< 2	7.27	< 0.2	0.02
BC4	217.0	< 0.1	96.4	5.5	< 2	83.50	< 0.2	0.02
Sampling Event 2: Jun. 2010								
10BC1B	3.6	< 0.1	90.3	3.2	< 2	27.9	< 0.2	< 0.01
10BC2B	20.1	< 0.1	88.7	26.6	< 2	26.0	< 0.2	0.02
10BC3B	171	< 0.1	90.2	27.0	< 2	57.5	< 0.2	0.02
10BC4B	168	< 0.1	94.4	12.8	< 2	57.5	< 0.2	0.02
10BC5B	1,560	< 0.1	94.6	50.8	< 2	1,520	< 0.2	0.06
10BC6B	1,980	< 0.1	8.23	60.5	< 2	4.19	< 0.2	0.08
10BC7B	572	< 0.1	< 0.10	19.3	< 2	< 0.1	< 0.2	0.02
10BC8B	534	< 0.1	96.6	7.7	< 2	337	< 0.2	0.02
10BC9B	458	< 0.1	< 0.10	7.7	< 2	0.763	< 0.2	0.03
10BC10B	457	< 0.1	103	3.4	< 2	325	< 0.2	0.01
Sampling Event 3: Sep. 2010								
10BC1B	8	nr	91.0	19.9	< 2	33.0	< 0.2	0.02
10BC2B	10	nr	86.2	14.6	< 2	20.7	< 0.2	0.04
10BC3B	200	nr	85.9	22.0	< 2	65.5	< 0.2	0.02
10BC4B	196	nr	88.3	3.8	< 2	70.1	< 0.2	0.03
10BC5B	10,100	nr	77.6	140	< 2	< 0.1	< 0.2	0.14
10BC6B	14,000	nr	85.9	84.8	< 2	< 0.1	< 0.2	0.09
10BC7B	880	nr	90.7	12.3	< 2	596.0	< 0.2	0.05
10BC8B	915	nr	101.0	3.3	< 2	633.0	< 0.2	0.02
10BC9B	939	nr	115.0	3.1	< 2	648.0	< 0.2	0.01
10BC10B	890	nr	122.0	2.7	< 2	654.0	< 0.2	0.01
Sampling Event 4: Mar. 2011								
11BC1B	< 0.1	nr	17.3	3.6	< 2	10.5	< 0.2	0.22
11BC4B	25.5	nr	38.9	11.7	< 2	16.3	< 0.2	0.18
11BC5B	69.4	nr	19.6	24.7	< 2	52.7	< 0.2	0.43
11BC6B	68.3	nr	18.5	10.9	< 2	59.8	< 0.2	0.24
11BC7B	55.4	nr	44.6	6.8	< 2	25.9	< 0.2	0.17
11BC8B	33.7	nr	33.5	12.6	< 2	21.8	< 0.2	0.21
11BC9B	29.0	nr	30.7	3.3	< 2	20.7	< 0.2	0.14
11BC10B	34.5	nr	36.1	3.1	< 2	23.6	< 0.2	0.14
Sampling Event 5: Jun. 2011								
11BC2B	23.3	nr	91.1	< 0.2	< 2	24.5	< 0.2	0.45
11BC3B	141.0	nr	95.5	< 0.2	< 2	55.2	< 0.2	0.46
11BC4B	146.0	nr	88.6	< 0.2	< 2	51.3	< 0.2	0.46
11BC10B	264.0	nr	94.2	< 0.2	< 2	136.0	< 0.2	0.46

**Table 7.—Continued**

<b>Field number</b>	<b>Ni µg/L</b>	<b>P mg/L</b>	<b>Pb µg/L</b>	<b>Pr µg/L</b>	<b>Rb µg/L</b>	<b>Sb µg/L</b>	<b>Sc µg/L</b>	<b>Se µg/L</b>
Sampling Event 1: Jan. 2009								
BC2	3.0	0.03	0.4	< 0.01	0.14	< 0.3	5.5	1.2
BC3	3.4	0.04	0.3	< 0.01	10.10	< 0.3	5.5	2.2
BCA	2.1	0.02	< 0.05	< 0.01	0.03	< 0.3	9.8	< 1.0
BCB	2.1	< 0.01	0.2	< 0.01	0.27	< 0.3	6.8	< 1.0
BC4	3.4	0.02	0.4	< 0.01	6.82	< 0.3	5.1	2.8
Sampling Event 2: Jun. 2010								
10BC1B	1.9	0.02	0.8	< 0.01	0.29	< 0.3	3.1	1.3
10BC2B	3.9	0.04	0.5	< 0.01	1.28	< 0.3	2.8	1.2
10BC3B	4.3	0.05	0.7	< 0.01	9.16	< 0.3	2.6	2.0
10BC4B	3.9	0.04	0.6	< 0.01	8.52	< 0.3	2.6	1.9
10BC5B	6.4	0.09	0.8	0.01	199	5.37	1.7	38.0
10BC6B	5.9	0.04	0.4	0.01	275	6.18	2.4	45.8
10BC7B	4.3	< 0.01	1.4	< 0.01	51.7	0.88	2.1	9.2
10BC8B	3.9	< 0.01	1.1	< 0.01	41.4	0.86	1.7	8.3
10BC9B	4.5	0.02	0.9	< 0.01	34.8	0.72	1.5	7.2
10BC10B	3.7	< 0.01	0.9	< 0.01	33.8	0.74	1.1	7.5
Sampling Event 3: Sep. 2010								
10BC1B	1.8	0.03	< 0.05	< 0.01	0.22	< 0.3	3.6	42.2
10BC2B	1.5	0.04	0.06	< 0.01	0.43	< 0.3	3.5	44.1
10BC3B	2.2	0.03	< 0.05	< 0.01	11.8	< 0.3	3.2	40.1
10BC4B	1.7	0.03	< 0.05	< 0.01	9.7	< 0.3	3.0	36.9
10BC5B	5.1	0.10	0.12	0.02	873	48.2	4.3	624.0
10BC6B	4.6	0.07	0.07	0.01	896	31.1	5.8	662.0
10BC7B	2.6	0.04	0.08	< 0.01	67.8	2.1	3.4	92.1
10BC8B	3.2	0.03	0.05	< 0.01	63.1	2.0	2.9	86.3
10BC9B	4.0	0.02	< 0.05	< 0.01	57.9	1.6	2.7	95.0
10BC10B	3.4	0.03	0.05	< 0.01	47.8	1.5	2.4	84.7
Sampling Event 4: Mar. 2011								
11BC1B	4.4	0.07	< 0.05	0.07	0.17	< 0.30	1.6	< 1.0
11BC4B	10.3	0.08	0.39	0.05	1.8	0.86	2.4	< 1.0
11BC5B	18.5	0.07	0.34	0.09	8.5	1.30	2.3	2.3
11BC6B	8.1	0.06	0.10	0.07	8.9	0.47	1.9	2.2
11BC7B	7.9	0.07	0.18	0.05	3.2	< 0.30	2.4	1.5
11BC8B	27.1	0.07	0.47	0.06	3.1	2.10	2.3	1.1
11BC9B	6.6	0.07	< 0.05	0.04	2.6	< 0.30	2.0	1.3
11BC10B	6.6	0.07	< 0.05	0.04	3.0	< 0.30	2.1	1.1
Sampling Event 5: Jun. 2011								
11BC2B	< 0.4	0.02	0.11	0.22	2.3	< 0.30	3.5	< 1.0
11BC3B	< 0.4	0.02	0.12	0.22	9.5	< 0.30	3.5	2.7
11BC4B	< 0.4	0.04	0.12	0.22	9.3	< 0.30	3.5	1.8
11BC10B	< 0.4	0.01	0.13	0.22	16.9	0.36	2.9	4.8

**Table 7.—Continued**

<b>Field number</b>	<b>SiO<sub>2</sub> mg/L</b>	<b>Sm µg/L</b>	<b>SO<sub>4</sub> mg/L</b>	<b>Sr µg/L</b>	<b>Ta µg/L</b>	<b>Tb µg/L</b>	<b>Th µg/L</b>	<b>Ti µg/L</b>
Sampling Event 1: Jan. 2009								
BC2	23.2	< 0.01	16	331	< 0.02	< 0.005	< 0.2	< 0.5
BC3	24.1	< 0.01	16	417	< 0.02	< 0.005	< 0.2	< 0.5
BCA	42.3	< 0.01	3	33.7	< 0.02	< 0.005	< 0.2	< 0.5
BCB	31.2	< 0.01	8	94	< 0.02	< 0.005	< 0.2	< 0.5
BC4	23.6	< 0.01	19	755	< 0.02	< 0.005	< 0.2	< 0.5
Sampling Event 2: Jun. 2010								
10BC1B	34.6	< 0.01	6	469	< 0.02	< 0.005	< 0.2	< 0.5
10BC2B	30.7	< 0.01	11	393	< 0.02	< 0.005	< 0.2	0.8
10BC3B	30.6	< 0.01	12	445	< 0.02	< 0.005	< 0.2	0.8
10BC4B	30.4	< 0.01	13	517	< 0.02	< 0.005	< 0.2	0.6
10BC5B	25.5	0.02	108	963	0.04	0.005	< 0.2	4.6
10BC6B	39.7	0.03	133	1,040	0.04	0.007	< 0.2	4.8
10BC7B	31.6	< 0.01	27	676	< 0.02	< 0.005	< 0.2	1.2
10BC8B	23.8	< 0.01	25	692	< 0.02	< 0.005	< 0.2	0.9
10BC9B	20.7	< 0.01	28	653	< 0.02	< 0.005	< 0.2	1.1
10BC10B	15.2	< 0.01	43	667	0.02	< 0.005	< 0.2	1.0
Sampling Event 3: Sept. 2010								
10BC1B	15	0.03	13	504	0.04	0.005	< 0.2	4.3
10BC2B	14	0.04	18	343	< 0.02	< 0.005	< 0.2	5.2
10BC3B	15	0.05	14	440	< 0.02	< 0.005	< 0.2	4.3
10BC4B	15	0.05	12	486	< 0.02	0.006	< 0.2	3.8
10BC5B	28	0.07	110	1,550	0.29	0.020	< 0.2	12.2
10BC6B	49	0.07	130	1,690	0.20	0.010	< 0.2	11.9
10BC7B	17	0.04	19	676	0.03	0.006	< 0.2	5.4
10BC8B	15	0.04	21	728	0.03	< 0.005	< 0.2	5.2
10BC9B	10	0.02	22	773	0.02	0.007	< 0.2	5.2
10BC10B	5.4	0.04	26	510	0.03	0.005	< 0.2	5.5
Sampling Event 4: Mar. 2011								
11BC1B	16	< 0.01	4.2	231	< 0.02	0.03	< 0.2	3.3
11BC4B	23	< 0.01	5.4	161	< 0.02	0.02	0.20	3.4
11BC5B	22	0.03	15.0	195	< 0.02	0.03	0.21	7.2
11BC6B	19	< 0.01	16.0	190	< 0.02	0.03	< 0.2	2.6
11BC7B	23	< 0.01	8.2	216	< 0.02	0.02	< 0.2	1.9
11BC8B	23	< 0.01	7.5	192	< 0.02	0.03	< 0.2	2.9
11BC9B	20	< 0.01	9.5	189	< 0.02	0.02	< 0.2	< 0.5
11BC10B	21	< 0.01	13.0	219	< 0.02	0.02	< 0.2	< 0.5
Sampling Event 5: Jun. 2011								
11BC2B	32	0.34	10	345	< 0.02	< 0.005	0.37	< 0.5
11BC3B	32	0.35	11	393	< 0.02	< 0.005	0.37	< 0.5
11BC4B	32	0.34	14	394	< 0.02	< 0.005	0.38	< 0.5
11BC10B	27	0.34	52	554	< 0.02	< 0.005	0.38	1.1

**Table 7.—Continued**

Field number	Tl µg/L	Tm µg/L	U µg/L	V µg/L	W µg/L	Y µg/L	Yb µg/L	Zn µg/L	Zr µg/L
Sampling Event 1: Jan. 2009									
BC2	< 0.1	< 0.005	< 0.1	4.4	< 0.5	0.09	0.005	3.0	< 0.2
BC3	< 0.1	< 0.005	< 0.1	5.3	3.01	0.11	< 0.005	2.2	< 0.2
BCA	< 0.1	< 0.005	< 0.1	3.5	< 0.5	0.05	< 0.005	1.8	< 0.2
BCB	< 0.1	< 0.005	< 0.1	2.2	< 0.5	0.06	< 0.005	2.6	< 0.2
BC4	< 0.1	< 0.005	< 0.1	5.2	1.74	0.13	0.008	2.6	< 0.2
Sampling Event 2: Jun. 2010									
10BC1B	< 0.1	< 0.005	< 0.1	5.1	< 0.5	0.03	< 0.005	0.6	< 0.2
10BC2B	< 0.1	< 0.005	< 0.1	3.6	< 0.5	0.07	< 0.005	0.8	< 0.2
10BC3B	< 0.1	< 0.005	< 0.1	4.1	2.07	0.07	< 0.005	0.7	< 0.2
10BC4B	< 0.1	< 0.005	< 0.1	4.1	2.09	0.07	0.006	0.7	< 0.2
10BC5B	< 0.1	< 0.005	0.30	12.8	506	0.29	0.020	1.6	0.3
10BC6B	< 0.1	< 0.005	0.28	12.3	779	0.30	0.020	2.9	0.2
10BC7B	< 0.1	< 0.005	< 0.1	5.4	122	0.13	0.010	1.0	< 0.2
10BC8B	< 0.1	< 0.005	< 0.1	5.2	105	0.12	< 0.005	1.3	< 0.2
10BC9B	< 0.1	< 0.005	< 0.1	5.1	83.5	0.12	0.005	0.9	< 0.2
10BC10B	< 0.1	< 0.005	0.1	5.2	81.2	0.10	< 0.005	1.0	< 0.2
Sampling Event 3: Sept. 2010									
10BC1B	< 0.1	0.007	< 0.1	4.3	nr	0.05	0.03	< 3	nr
10BC2B	< 0.1	0.007	< 0.1	3.4	nr	0.07	0.04	< 3	nr
10BC3B	< 0.1	0.006	< 0.1	3.4	nr	0.07	0.02	< 3	nr
10BC4B	< 0.1	0.010	< 0.1	4.2	nr	0.08	0.03	< 3	nr
10BC5B	< 0.1	0.010	0.26	4.9	nr	1.10	0.07	3.2	nr
10BC6B	< 0.1	0.010	0.19	4.5	nr	0.65	0.05	< 3	nr
10BC7B	< 0.1	0.010	< 0.1	3.7	nr	0.12	0.02	< 3	nr
10BC8B	< 0.1	0.009	< 0.1	4.2	nr	0.15	0.02	< 3	nr
10BC9B	< 0.1	0.010	0.11	4.8	nr	0.14	0.04	< 3	nr
10BC10B	< 0.1	0.010	0.17	6.6	nr	0.04	0.01	< 3	nr
Sampling Event 4: Mar. 2011									
11BC1B	< 0.1	0.04	< 0.1	2.9	< 0.5	0.20	0.03	< 3	nr
11BC4B	< 0.1	0.04	< 0.1	3.4	0.52	0.14	0.03	< 3	nr
11BC5B	< 0.1	0.04	< 0.1	4.7	7.7	0.34	0.04	4.5	nr
11BC6B	< 0.1	0.04	< 0.1	4.0	9.9	0.22	0.02	< 3	nr
11BC7B	< 0.1	0.03	< 0.1	3.0	1.1	0.14	0.02	< 3	nr
11BC8B	< 0.1	0.04	< 0.1	3.6	1.5	0.18	0.03	< 3	nr
11BC9B	< 0.1	0.04	< 0.1	3.3	2.0	0.10	0.02	< 3	nr
11BC10B	< 0.1	0.03	< 0.1	3.2	2.2	0.10	0.02	< 3	nr
Sampling Event 5: Jun. 2011									
11BC2B	0.28	0.03	< 0.1	3.6	2.0	0.06	< 0.01	< 3	nr
11BC3B	0.28	0.03	< 0.1	4.0	4.0	0.07	< 0.01	< 3	nr
11BC4B	0.28	0.03	< 0.1	4.0	4.1	0.08	< 0.01	< 3	nr
11BC10B	0.29	0.03	< 0.1	4.9	20	0.10	< 0.01	< 3	nr

**Table 8.** Enrichment of stable isotopes in unfiltered waters collected from Bear Creek, Colusa County, California.

Sample site	$\delta^{18}\text{H}$ per mil	$\delta^2\text{H}$ per mil
Low Flow Sept. 2010		
BC1	-8.12	-58.68
BC2	-7.92	-57.12
BC3	-7.75	-57.99
BC4	-7.64	-55.74
BC5	-5.21	-48.65
BC6	-4.20	-45.84
BC7	-7.02	-55.29
BC8	-6.88	-53.79
BC9	-6.65	-52.64
BC10	-6.48	-51.80
High Flow Mar. 2011		
BC1	-10.04	-71.06
BC4	-8.94	-61.38
BC5	-10.03	-67.00
BC6	-9.79	-66.00
BC7	-8.96	-61.76
BC8	-9.10	-61.45
BC9	-9.17	-62.48
BC10	-9.11	-62.30
High Flow June 2011		
BC2	-8.80	-63.42
BC3	-8.73	-61.92
BC4	-8.73	-62.32
BC10	-8.47	-61.48

**Table 9.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in invertebrates from sites in the Bear Creek Watershed, June and September 2010.

Sample code										
Collection site- Collection date- Sample number	Common name	Order	Family	Sample size	Mass (g)	Ave. mass (g)	% Moisture	Hg <sub>T</sub> (µg/g ww)	MMeHg (µg/g ww)	% MMeHg
BC2-062910-002	Larval dragonflies	Odonata	Aeshnidae	3	5.79	1.930	78.2	0.072	0.067	93.1
BC2-062910-001	Larval damselflies	Odonata	Coenagrionidae	30	1.15	0.038	80.8	0.058	0.073	126.9
BC2-062910-005	adult water striders	Hemiptera	Gerridae	25	1.38	0.055	67.1	0.121	0.091	75.2
BC2-062910-004	Larval dragonflies	Odonata	Gomphidae	4	1.45	0.363	71.5	0.045	0.040	89.7
BC2-062910-003	Larval dragonflies	Odonata	Libellulidae	7	3.83	0.547	81.6	0.059	0.068	115.7
BC3-062910-003	Larval dragonflies	Odonata	Aeshnidae	1	2.17	2.170	53.7	0.442	0.543	122.9
BC3-062910-002	Larval damselflies	Odonata	Coenagrionidae	30	1.37	0.046	NA	0.237	0.365	154.0
BC3-062910-007	Adult water striders	Hemiptera	Gerridae	20	1.01	0.051	55.9	0.139	0.157	112.9
BC3-062910-005	Larval dragonflies	Odonata	Libellulidae	4	2.33	0.583	80.1	0.351	0.397	113.1
BC4-062910-001	Larval dragonflies	Odonata	Aeshnidae	2	3.51	1.755	78.6	0.293	0.344	117.4
BC4-062910-003	Larval damselflies	Odonata	Coenagrionidae	30	1.13	0.038	NA	0.376	0.472	125.5
BC4-062910-004	Adult water striders	Hemiptera	Gerridae	13	0.58	0.045	NA	0.385	0.259	67.3
BC4-062910-002	Larval dragonflies	Odonata	Libellulidae	3	1.67	0.557	80.0	0.271	0.339	125.1
BC5-062910-002	Larval damselflies	Odonata	Coenagrionidae	30	1.32	0.044	NA	0.429	0.248	57.8
BC5-062910-006	Adult water boatmen	Hemiptera	Corixidae	28	1.24	0.044	71.5	0.235	0.124	52.8
BC5-062910-003	Adult water striders	Hemiptera	Gerridae	20	1.02	0.051	NA	0.317	0.344	108.5
BC5-062910-001	Larval dragonflies	Odonata	Libellulidae	4	1.97	0.493	80.5	0.334	0.170	50.9
BC5-062910-004	Adult backswimmers	Hemiptera	Notonectidae	17	1.73	0.102	NA	0.298	0.255	85.6
BC6-062910-001	Larval damselflies	Odonata	Coenagrionidae	17	0.74	0.044	NA	4.660	0.331	7.1
BC6-062910-002	Adult water striders	Hemiptera	Gerridae	24	1.16	0.048	NA	0.597	0.618	103.5
BC7-062910-002	Larval dragonflies	Odonata	Aeshnidae	1	2.18	2.180	73.7	0.353	0.205	58.1
BC7-062910-003	Larval damselflies	Odonata	Coenagrionidae	30	1.41	0.047	80.4	0.284	0.185	65.1
BC7-062910-004	Adult water striders	Hemiptera	Gerridae	30	1.58	0.053	71.9	0.327	0.298	91.1
BC7-062910-001	Larval dragonflies	Odonata	Gomphidae	7	2.07	0.296	72.6	0.253	0.140	55.3
BC8-061510-002	Larval dragonflies	Odonata	Aeshnidae	3	4.97	1.657	77.7	0.286	0.207	72.4
BC8-061510-005	Larval damselflies	Odonata	Coenagrionidae	40	1.79	0.045	64.4	0.239	0.201	84.1
BC8-061510-003	Larval dragonflies	Odonata	Libellulidae	5	2.91	0.582	79.6	0.278	0.282	101.4
BC9-061510-001	Larval damselflies	Odonata	Coenagrionidae	30	1.35	0.045	84.0	0.264	0.238	90.2

**Table 9.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in invertebrates from sites in the Bear Creek Watershed, June and September 2010.—Continued

Sample code										
Collection site- Collection date- Sample number	Common name	Order	Family	Sample size	Mass (g)	Ave. mass (g)	% Moisture	Hg <sub>T</sub> (µg/g ww)	MMeHg (µg/g ww)	% MMeHg
BC9-061510-004	Adult water striders	Hemiptera	Gerridae	25	1.23	0.049	NA	0.260	0.281	108.1
BC9-061510-003	Larval dragonflies	Odonata	Libellulidae	4	2.25	0.563	80.7	0.270	0.181	67.0
BC10-061510-004	Larval dragonflies	Odonata	Aeshnidae	2	4.47	2.235	77.7	0.257	0.299	116.3
BC10-061510-005	Larval damselflies	Odonata	Coenagrionidae	50	2.15	0.043	82.3	0.171	0.140	81.9
BC10-061510-006	Adult water striders	Hemiptera	Gerridae	19	0.88	0.046	NA	0.152	0.290	190.8
BC10-061510-002	Larval dragonflies	Odonata	Gomphidae	5	1.89	0.378	74.6	0.100	0.086	86.2
BC10-061510-001	Larval dragonflies	Odonata	Libellulidae	3	1.88	0.627	77.4	0.132	0.142	107.6
BC2-091510-003	Larval dragonflies	Odonata	Aeshnidae	2	1.15	0.575	NA	0.019	0.020	107.0
BC2-091510-005	Larval damselflies	Odonata	Calopterygidae	10	1.07	0.107	87.1	0.023	0.020	87.7
BC2-091510-001	Larval dragonflies	Odonata	Gomphidae	5	1.66	0.332	77.0	0.064	0.040	62.0
BC2-091510-002	Larval dragonflies	Odonata	Libellulidae	7	1.90	0.271	84.6	0.082	0.052	63.4
BC3-091510-001	Larval dragonflies	Odonata	Aeshnidae	10	3.50	0.350	80.4	0.186	0.216	116.1
BC3-091510-004	Larval damselflies	Odonata	Calopterygidae	14	1.05	0.075	84.5	0.095	0.083	87.0
BC3-091510-003	Larval dragonflies	Odonata	Gomphidae	3	0.49	0.163	NA	0.372	0.308	82.8
BC3-091510-002	Larval dragonflies	Odonata	Libellulidae	7	3.38	0.483	87.6	0.304	0.240	78.9
BC4-091510-001	Larval dragonflies	Odonata	Aeshnidae	16	5.11	0.319	85.0	0.387	0.338	87.3
BC4-091510-004	Larval damselflies	Odonata	Calopterygidae	13	1.33	0.102	84.4	0.132	0.108	81.8
BC4-091510-003	Larval dragonflies	Odonata	Gomphidae	8	1.80	0.225	75.7	0.248	0.200	80.6
BC4-091510-002	Larval dragonflies	Odonata	Libellulidae	9	2.65	0.294	85.9	0.272	0.273	100.4
BC5-091710-004	Adult water boatmen	Hemiptera	Corixidae	9	0.45	0.050	NA	0.401	0.220	54.9
BC5-091710-005	Adult water striders	Hemiptera	Gerridae	17	0.98	0.058	NA	0.482	0.482	100.0
BC5-091710-006	Larval damselflies	Odonata	Lestidae	120	1.14	0.010	85.7	0.182	0.245	134.6
BC5-091710-003	Larval dragonflies	Odonata	Libellulidae	3	0.98	0.327	NA	0.175	0.144	82.3
BC5-091710-001	Adult backswimmers	Hemiptera	Notonectidae	20	2.17	0.109	68.6	0.373	0.344	92.2
BCUS-091710-002	Larval dragonflies	Odonata	Aeshnidae	5	0.95	0.190	NA	0.199	0.259	130.2
BCUS-091710-001	Larval dragonflies	Odonata	Libellulidae	10	1.21	0.121	85.4	0.054	0.052	95.6
BC6-091710-002	Larval soldier flies	Diptera	Stratiomyidae	10	2.43	0.243	74.5	1.110	0.072	6.5
BC6-091710-001	Larval horse flies	Diptera	Tabanidae	5	0.89	0.178	NA	0.670	0.100	14.9

**Table 9.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in invertebrates from sites in the Bear Creek Watershed, June and September 2010.—Continued

<b>Sample code</b>										
<b>Collection site- Collection date- Sample number</b>	<b>Common name</b>	<b>Order</b>	<b>Family</b>	<b>Sample size</b>	<b>Mass (g)</b>	<b>Ave. mass (g)</b>	<b>% Moisture</b>	<b>Hg<sub>T</sub> (µg/g ww)</b>	<b>MMeHg (µg/g ww)</b>	<b>% MMeHg</b>
BC7-091510-003	Larval dragonflies	Odonata	Aeshnidae	15	4.58	0.305	NA	1.010	0.369	36.5
BC7-091510-005	Larval damselflies	Odonata	Calopterygidae	15	1.62	0.108	88.3	1.090	0.591	54.2
BC7-091510-004	Larval dragonflies	Odonata	Gomphidae	9	3.06	0.340	76.3	0.583	0.599	102.7
BC7-091510-001	Larval dragonflies	Odonata	Libellulidae	4	1.76	0.440	84.0	1.200	0.347	28.9
BC8-091510-001	Larval dragonflies	Odonata	Aeshnidae	4	2.38	0.595	78.6	0.240	0.216	90.0
BC8-091510-002	Larval dragonflies	Odonata	Aeshnidae	10	3.14	0.314	79.8	0.286	0.179	62.6
BC8-091510-005	Larval damselflies	Odonata	Calopterygidae	19	1.89	0.099	81.7	0.183	0.128	69.9
BC8-091510-003	Larval dragonflies	Odonata	Libellulidae	9	3.59	0.399	82.7	0.573	0.504	88.0
BC9-091510-002	Larval dragonflies	Odonata	Aeshnidae	14	4.17	0.298	81.4	0.236	0.271	114.8
BC9-091510-005	Larval damselflies	Odonata	Calopterygidae	20	0.91	0.046	83.9	0.212	0.224	105.7
BC9-091510-006	Adult water striders	Hemiptera	Gerridae	25	1.25	0.050	63.1	0.718	1.250	174.1
BC9-091510-007	Adult water striders	Hemiptera	Gerridae	25	1.22	0.049	62.7	0.694	1.230	177.2
BC9-091510-001	Larval dragonflies	Odonata	Gomphidae	3	1.04	0.347	NA	0.477	0.534	111.9
BC9-091510-003	Larval dragonflies	Odonata	Libellulidae	10	4.39	0.439	82.9	0.537	0.589	109.7
BC9-091510-004	Larval dragonflies	Odonata	Libellulidae	13	2.37	0.182	85.2	0.288	0.291	101.0
BC10-091510-001	Larval dragonflies	Odonata	Aeshnidae	14	3.40	0.243	79.0	0.299	0.330	110.4
BC10-091510-004	Larval damselflies	Odonata	Calopterygidae	6	0.36	0.060	NA	0.129	0.149	115.5
BC10-091510-003	Larval dragonflies	Odonata	Gomphidae	5	1.70	0.340	78.0	0.106	0.131	123.6
BC10-091510-002	Larval dragonflies	Odonata	Libellulidae	15	2.86	0.191	82.6	0.103	0.145	140.8

**Table 10.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in California roach (*Hesperoleucus symmetricus*) from sites in the Bear Creek Watershed, June and September 2010.

Sample code										
Collection site- Collection date- Sample number	Total length (mm)	Standard length (mm)	Fresh mass (g)	Sample mass (g)	% moisture	Hg <sub>T</sub> (µg/g, ww)	Geometric mean Hg <sub>T</sub> (µg/g)	MMeHg (µg/g, ww)	Geometric mean MMeHg (µg/g)	% MMeHg
BC2-062910-005F	104	90	14.83	13.03	73.8	0.273	0.161	0.384	0.204	140.7
BC2-062910-007F	93	80	9.98	8.41	74.4	0.238		0.280		117.6
BC2-062910-010F	76	65	5.96	4.89	74.3	0.124		0.135		108.9
BC2-062910-011F	85	71	7.17	6.11	75.6	0.107		0.093		86.7
BC2-062910-012F	70	59	4.62	4.01	72.8	0.277		0.374		135.0
BC2-062910-013F	66	56	3.13	2.58	75.6	0.104		0.161		154.8
BC2-062910-019F	55	46	2.08	1.70	67.2	0.113		0.181		160.2
BC3-062910-001F	82	70	8.35	6.67	76.3	0.220	0.326	0.375	0.413	170.5
BC3-062910-003F	79	67	6.97	5.23	77.0	0.245		0.410		167.3
BC3-062910-006F	75	64	6.09	4.79	74.4	0.424		0.503		118.6
BC3-062910-007F	71	61	5.19	4.11	75.9	0.309		0.281		90.9
BC3-062910-008F	67	56	4.32	3.62	69.6	0.355		0.372		104.8
BC3-062910-010F	71	60	3.87	3.38	76.8	0.475		0.558		117.5
BC3-062910-015F	56	48	2.34	1.82	69.8	0.326		0.455		139.6
BC4-062910-001F	77	65	6.31	4.93	74.6	0.479	0.482	0.628	0.505	131.1
BC4-062910-002F	80	67	6.34	5.20	75.2	0.617		0.761		123.3
BC4-062910-004F	75	65	5.42	4.34	73.3	0.523		0.531		101.5
BC4-062910-007F	71	60	4.65	3.59	74.5	0.327		0.324		99.1
BC4-062910-008F	68	57	3.96	3.19	72.8	0.392		0.475		121.2
BC4-062910-009F	65	54	3.26	2.69	72.1	0.494		0.442		89.5
BC4-062910-014F	60	50	2.67	2.10	66.9	0.614		0.483		78.7

**Table 10.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in California roach (*Hesperoleucus symmetricus*) from sites in the Bear Creek Watershed, June and September 2010.—Continued

<u>Sample code</u>										
Collection site- Collection date- Sample number	Total length (mm)	Standard length (mm)	Fresh mass (g)	Sample mass (g)	% moisture	Hg <sub>T</sub> (µg/g, ww)	Geometric mean Hg <sub>T</sub> (µg/g)	MMeHg (µg/g, ww)	Geometric mean MMeHg (µg/g)	% MMeHg
BC7-062910-001F	80	67	7.19	5.80	68.2	0.436	0.457	0.463	0.481	106.2
BC7-062910-002F	71	60	5.29	4.01	74.9	0.407		0.407		100.0
BC7-062910-004F	67	56	4.36	3.40	74.1	0.488		0.453		92.8
BC7-062910-005F	68	56	4.06	3.20	75.2	0.532		0.393		73.9
BC7-062910-009F	62	54	3.26	2.65	75.6	0.577		0.575		99.7
BC7-062910-012F	60	51	2.97	2.25	74.8	0.410		0.610		148.8
BC7-062910-015F	57	49	2.29	1.63	81.0	0.383		0.505		131.9
BC8-061510-003F	75	65	5.66	4.40	75.4	0.501	0.523	0.390	0.554	77.8
BC8-061510-005F	67	56	3.91	3.14	78.1	0.427		0.628		147.1
BC8-061510-006F	61	52	3.13	2.63	75.4	0.405		0.504		124.4
BC8-061510-007F	59	49	2.61	2.04	78.1	0.488		0.639		130.9
BC8-061510-009F	50	42	1.62	1.22	77.7	0.461		0.441		95.7
BC8-062910-001F	72	62	5.68	4.38	75.9	0.820		0.602		73.4
BC8-062910-002F	69	59	4.79	3.59	75.4	0.672		0.767		114.1
BC9-061510-001F	67	57	4.14	3.19	75.8	0.363	0.437	0.457	0.456	125.9
BC9-061510-003F	51	43	1.86	1.49	74.3	0.359		0.397		110.6
BC9-062910-001F	96	81	11.08	9.39	72.5	0.663		0.587		88.5
BC9-062910-002F	71	60	4.84	3.84	75.1	0.407		0.519		127.5
BC9-062910-003F	70	60	4.59	3.45	74.0	0.660		0.568		86.1
BC9-062910-007F	62	54	3.29	2.36	75.9	0.357		0.355		99.4
BC9-062910-008F	62	52	2.88	2.31	76.7	0.367		0.369		100.5

**Table 10.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in California roach (*Hesperoleucus symmetricus*) from sites in the Bear Creek Watershed, June and September 2010.—Continued

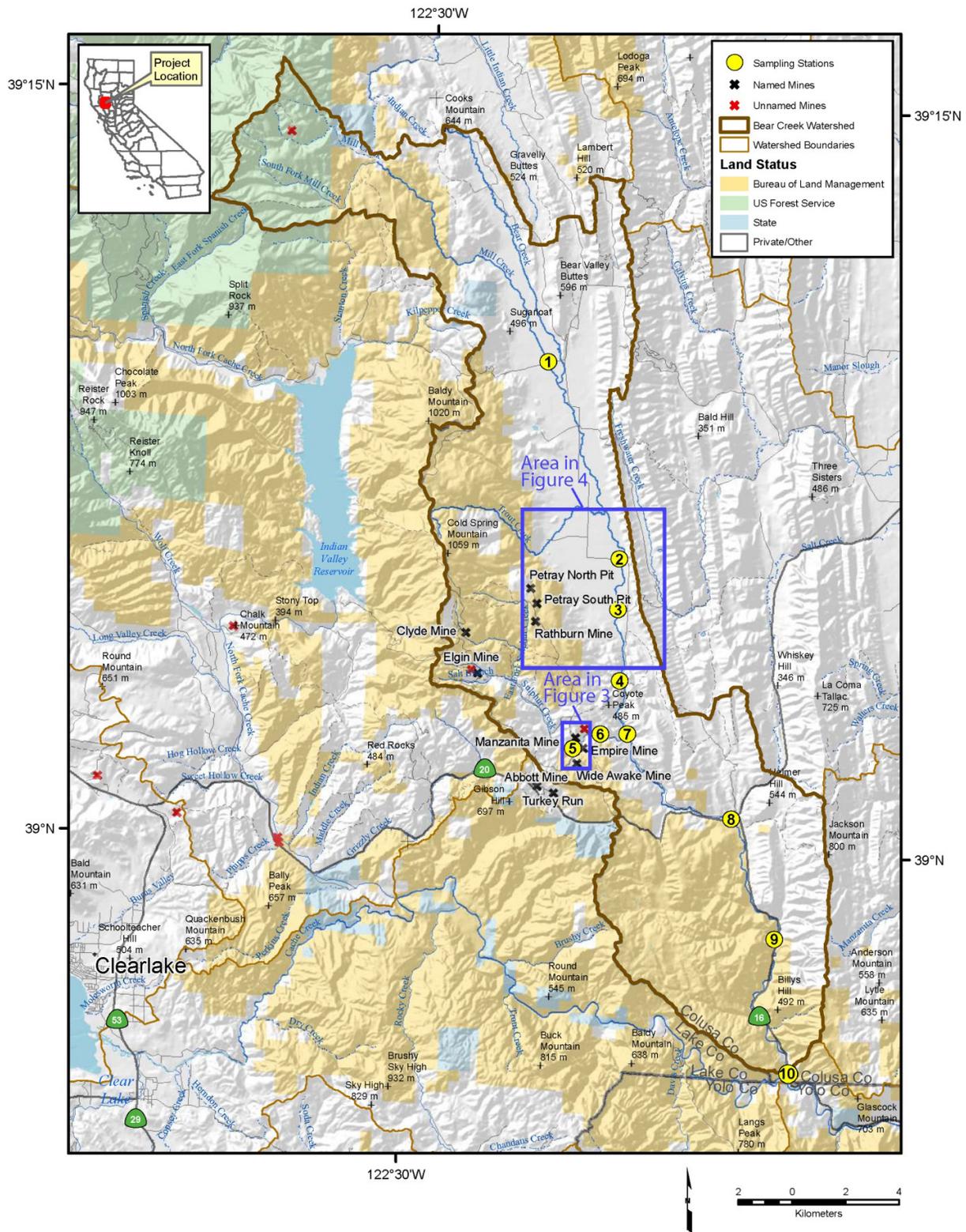
<b>Sample code</b>										
<b>Collection site- Collection date- Sample number</b>	<b>Total length (mm)</b>	<b>Standard length (mm)</b>	<b>Fresh mass (g)</b>	<b>Sample mass (g)</b>	<b>% moisture</b>	<b>Hg<sub>T</sub> (µg/g, ww)</b>	<b>Geometric mean Hg<sub>T</sub> (µg/g)</b>	<b>MMeHg (µg/g, ww)</b>	<b>Geometric mean MMeHg (µg/g)</b>	<b>% MMeHg</b>
BC10-062910-001F	96	81	11.41	9.96	76.0	0.750	0.433	0.879	0.521	117.2
BC10-062910-002F	88	75	8.64	7.26	74.3	0.436		0.551		126.4
BC10-062910-004F	84	70	8.19	6.59	74.0	0.454		0.585		128.9
BC10-062910-007F	83	71	7.12	5.92	77.6	0.365		0.447		122.5
BC10-062910-008F	80	65	6.21	5.33	75.8	0.449		0.584		130.1
BC10-062910-010F	67	55	3.48	2.88	78.5	0.376		0.402		106.9
BC10-062910-011F	62	51	3.20	2.57	77.8	0.314		0.352		112.1
BC2-091510-001F	80	66	5.21	4.43	75.7	0.184	0.164	0.301	0.213	163.6
BC2-091510-003F	78	65	5.05	4.55	74.0	0.114		0.165		144.7
BC2-091510-004F	75	62	4.26	3.68	74.7	0.109		0.204		187.2
BC2-091510-005F	68	56	3.40	2.92	73.8	0.177		0.168		94.9
BC2-091510-006F	66	55	3.03	2.62	74.9	0.285		0.280		98.2
BC2-091510-008F	66	56	3.40	2.81	73.2	0.281		0.384		136.7
BC2-091510-009F	65	54	3.18	2.71	75.4	0.100		0.109		109.0
BC3-091510-001F	76	64	4.72	4.17	73.5	0.485	0.571	0.601	0.419	123.9
BC3-091510-002F	72	61	3.80	3.29	74.4	0.548		0.636		116.1
BC3-091510-003F	67	56	3.93	3.16	72.8	0.816		0.774		94.9
BC3-091510-004F	68	57	3.69	3.12	74.8	0.551		0.580		105.3
BC3-091510-005F	69	57	3.32	2.91	74.8	0.646		0.605		93.7
BC3-091510-006F	63	53	2.60	2.31	71.2	0.363		0.390		107.4
BC3-091510-007F	63	52	2.62	2.15	76.0	0.704		0.056		7.9

**Table 10.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in California roach (*Hesperoleucus symmetricus*) from sites in the Bear Creek Watershed, June and September 2010.—Continued

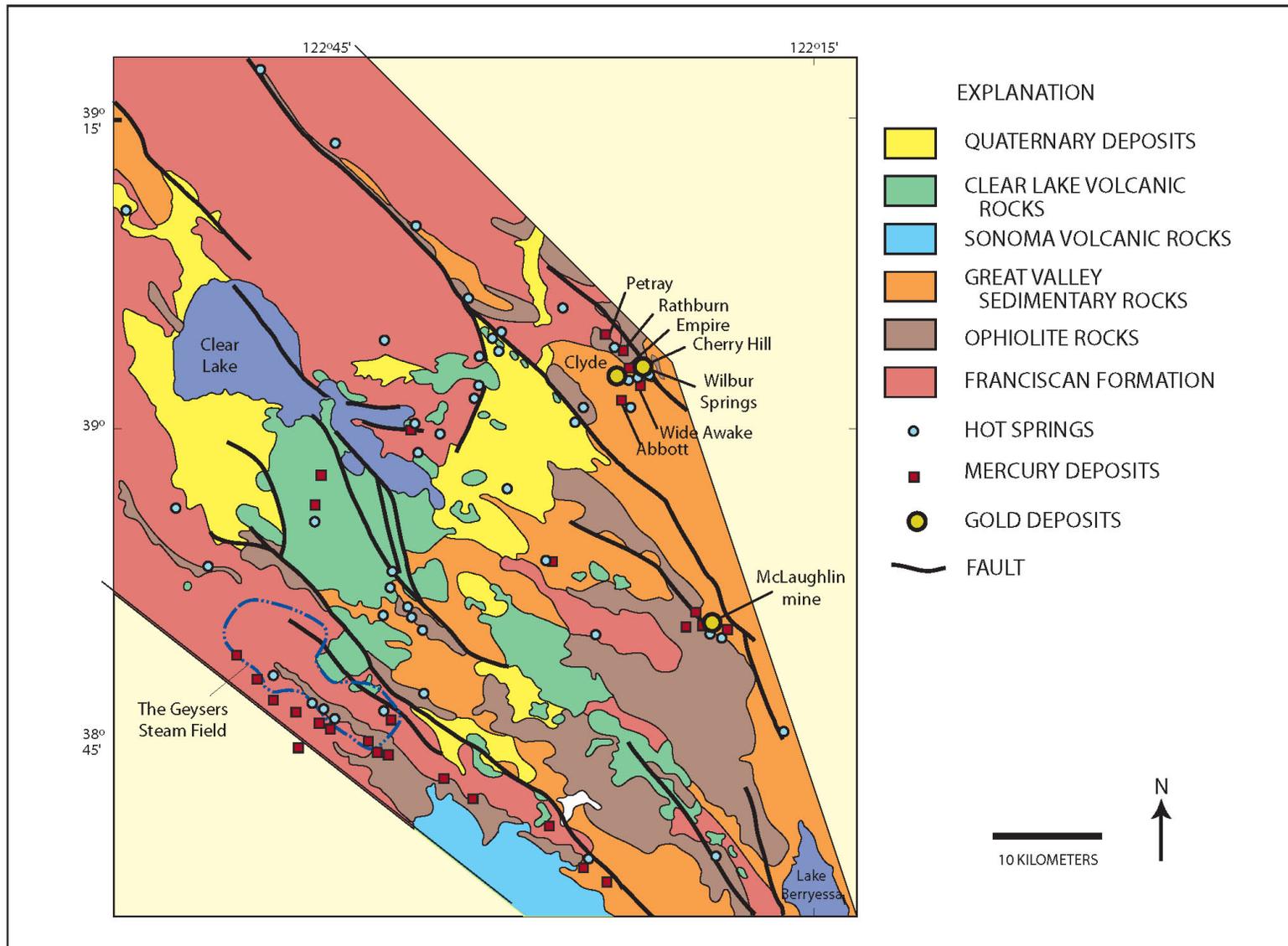
<b>Sample code</b>										
<b>Collection site- Collection date- Sample number</b>	<b>Total length (mm)</b>	<b>Standard length (mm)</b>	<b>Fresh mass (g)</b>	<b>Sample mass (g)</b>	<b>% moisture</b>	<b>Hg<sub>T</sub> (µg/g, ww)</b>	<b>Geometric mean Hg<sub>T</sub> (µg/g)</b>	<b>MMeHg (µg/g, ww)</b>	<b>Geometric mean MMeHg (µg/g)</b>	<b>% MMeHg</b>
BC4-091510-001F	91	76	9.26	8.02	69.3	0.744	0.599	0.744	0.483	100.0
BC4-091510-003F	85	73	6.17	5.25	74.2	0.638		0.599		93.9
BC4-091510-004F	75	63	5.05	4.49	72.2	0.532		0.462		86.8
BC4-091510-005F	71	60	4.35	3.58	72.4	0.542		0.613		113.1
BC4-091510-006F	75	62	3.59	3.14	74.4	0.757		0.149		19.7
BC4-091510-007F	73	62	3.25	2.91	73.2	0.548		0.567		103.5
BC4-091510-009F	62	53	2.60	2.14	73.1	0.490		0.571		116.5
BC7-0091510-001F	54	45	1.99	1.63	73.7	1.030	0.999	0.704	0.769	68.3
BC7-0091510-002F	57	48	1.89	1.58	71.1	0.697		0.563		80.8
BC7-0091510-003F	55	45	1.62	1.37	74.3	0.743		0.750		100.9
BC7-0091510-004F	53	44	1.53	1.37	76.9	1.670		0.962		57.6
BC7-0091510-005F	54	44	1.56	1.29	74.9	1.030		0.877		85.1
BC7-0091510-007F	51	42	1.30	1.15	76.2	0.791		0.720		91.0
BC7-0091510-008F	51	42	1.23	1.00	72.7	1.370		0.880		64.2
BC8-091510-001F	112	95	15.12	13.24	74.4	1.410	0.807	1.350	0.733	95.7
BC8-091510-003F	95	80	10.83	9.28	72.5	1.110		1.130		101.8
BC8-091510-005F	86	71	7.35	6.15	73.4	1.110		1.200		108.1
BC8-091510-008F	74	63	5.70	4.59	75.8	0.566		0.309		54.6
BC8-091510-009F	76	64	5.13	4.35	72.2	0.686		0.775		113.0
BC8-091510-011F	67	55	3.64	3.12	72.9	0.532		0.476		89.5
BC8-091510-014F	69	55	3.21	2.68	76.2	0.620		0.544		87.7

**Table 10.** Wet weight concentrations of total mercury (Hg<sub>T</sub>) and monomethyl mercury (MMeHg) in California roach (*Hesperoleucus symmetricus*) from sites in the Bear Creek Watershed, June and September 2010.—Continued

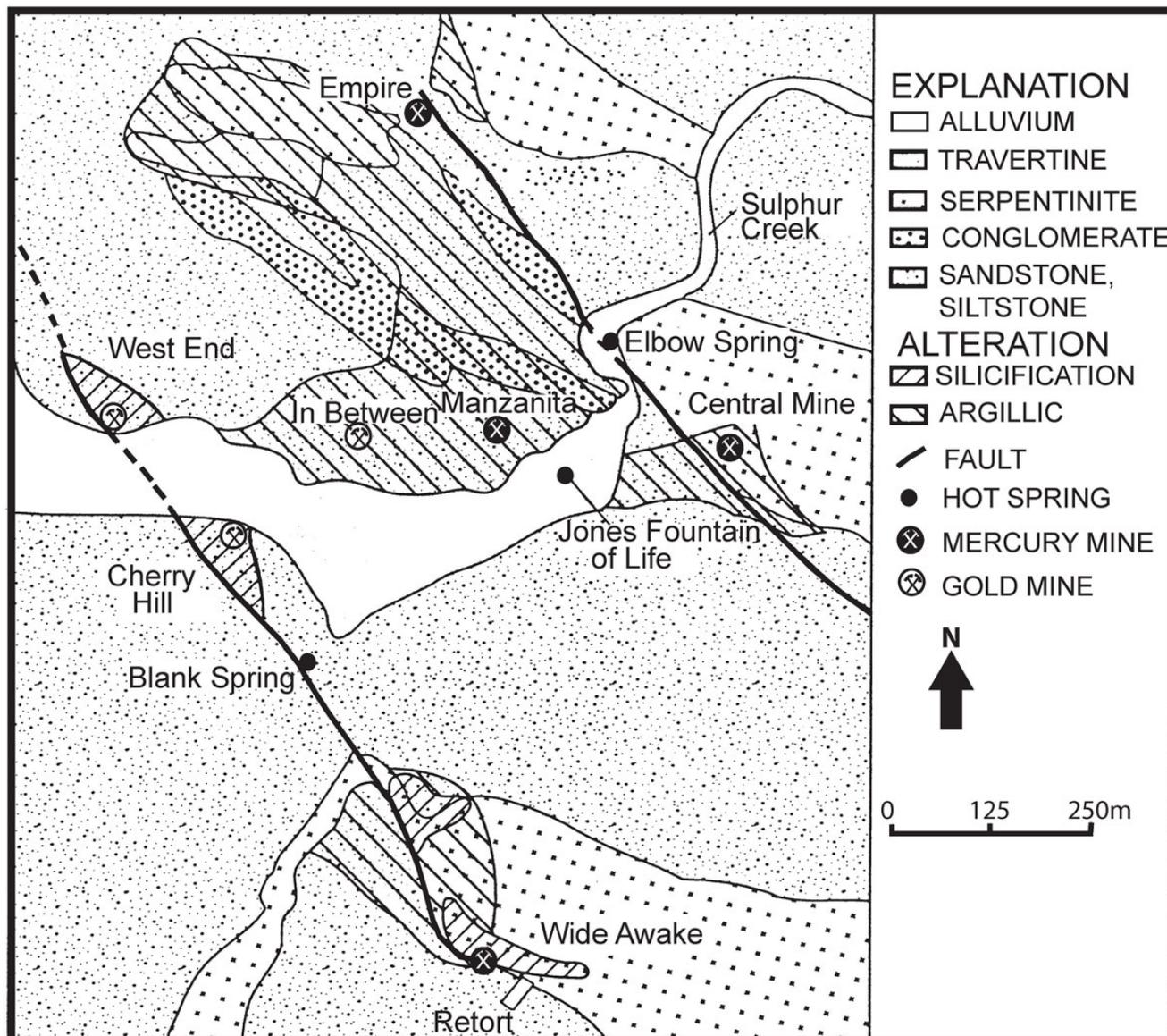
<u>Sample code</u>										
Collection site- Collection date- Sample number	Total length (mm)	Standard length (mm)	Fresh mass (g)	Sample mass (g)	% moisture	Hg <sub>T</sub> (µg/g, ww)	Geometric mean HgT (µg/g)	MMeHg (µg/g, ww)	Geometric mean MMeHg (µg/g)	% MMeHg
BC9-091510-002F	96	83	11.53	10.19	74.6	1.340	0.657	0.536	0.583	40.0
BC9-091510-005F	94	80	8.37	7.03	74.5	0.748		1.140		152.4
BC9-091510-006F	67	56	3.73	3.08	72.7	0.524		0.449		85.7
BC9-091510-007F	73	62	4.21	3.69	74.6	0.986		0.727		73.7
BC9-091510-009F	65	55	3.46	2.67	73.1	0.377		0.395		104.8
BC9-091510-011F	62	51	2.95	2.44	73.7	0.545		0.524		96.1
BC9-091510-012F	55	45	2.00	1.59	74.6	0.496		0.552		111.3
BC10-091510-001F	92	76	8.91	7.47	75.1	0.672	0.508	0.890	0.513	132.4
BC10-091510-002F	88	73	7.25	5.93	75.9	0.360		0.389		108.1
BC10-091510-003F	87	73	7.45	6.15	75.4	0.492		0.467		94.9
BC10-091510-004F	85	70	6.07	5.18	77.2	0.675		0.697		103.3
BC10-091510-005F	80	66	5.62	4.78	76.9	0.648		0.604		93.2
BC10-091510-006F	75	61	4.62	3.93	75.4	0.494		0.466		94.3
BC10-091510-007F	40	33	0.64	0.47	NA	0.339		0.296		87.3



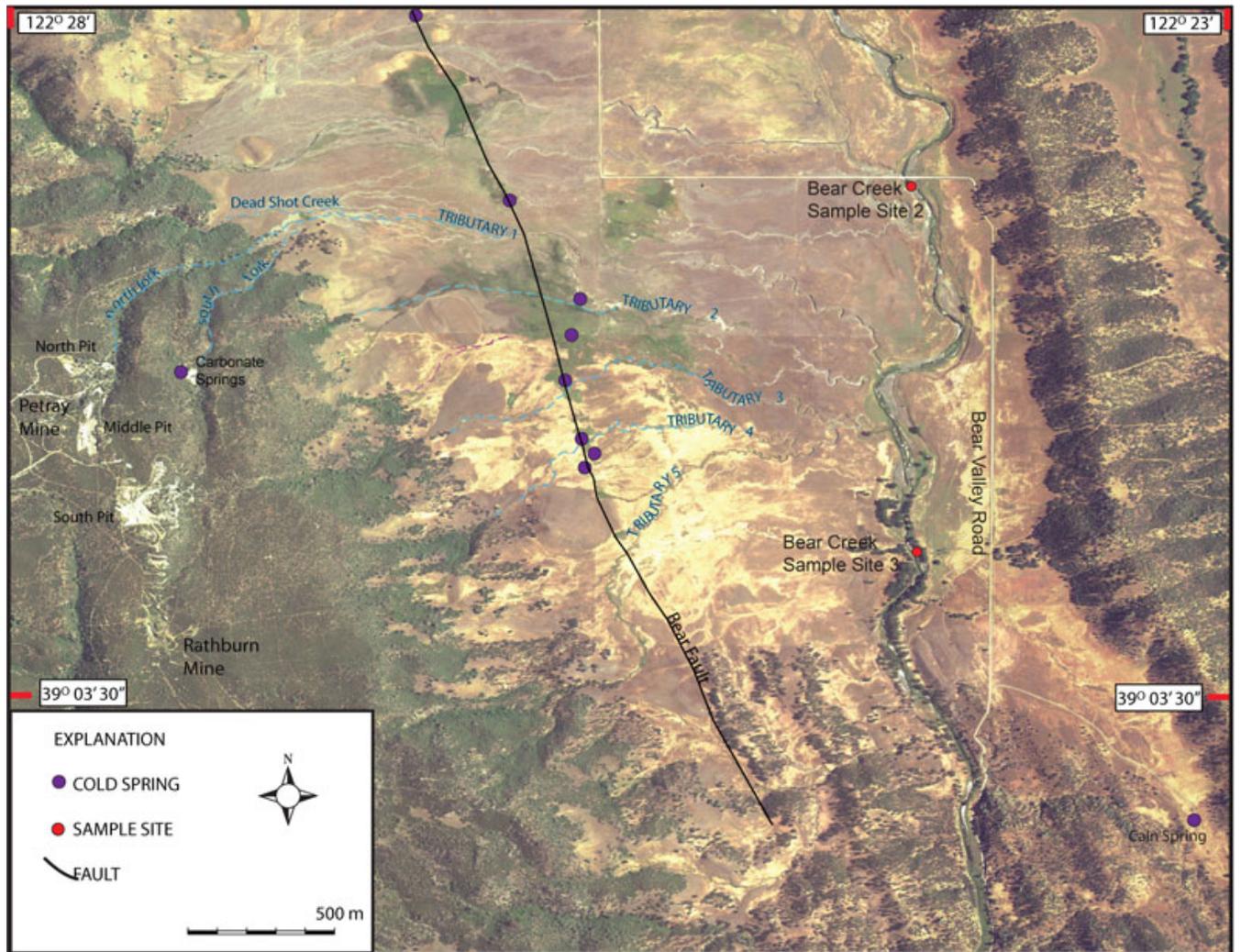
**Figure 1.** Bear Creek Watershed with locations of mines, springs, and locations of samples sites for water, sediment, and biota. Locations of figures 3 and 4 are indicated on this figure.



**Figure 2.** Geological map and ore deposits and geothermal springs located in the Clear Lake volcanic field, including the Bear Creek watershed. Wilbur Springs and adjacent Hg and Au deposits and geothermal springs in the Sulphur Creek tributary are significant sources of Hg to Bear Creek.



**Figure 3.** Geology and Hg and Au deposits located in the Sulphur Creek tributary to Bear Creek. Geothermal springs adjacent to the ore deposits are actively depositing Hg and Au and are sources of Hg-enriched sediment to Bear Creek.



**Figure 4.** Location of the Rathburn and Petray Hg mines and tributaries 1–5 that drain the mine area and release Hg-enriched sediment into Bear Creek. Some saline cold springs along the Bear Fault release Hg into Bear Creek. Cold carbonate springs east of the Petray Mine have relatively low concentrations of Hg as does the saline Cain Spring located east of Bear Creek. Sample site 2 located upstream of the mine input and sample site 3 located downstream from the mine area are shown by red dots.



**Figure 5.** View of sample site BC1 located under Brim Road bridge during low flow conditions sampling on September 16, 2010. Biota were not collected at this site in 2010.



**Figure 6.** View of sample site BC2 located at the bridge upstream from the Rathburn and Petray mines. Samples were collected under this bridge during low conditions during the September 16, 2010 sampling event. Biota were collected here on June 29 and September 15, 2010.



**Figure 7.** View of Bear Creek during low conditions on September 16, 2010 of sample site BC3 located downstream from the Rathburn and Petray mines. Biota were collected here on June 29 and September 15, 2010.



**Figure 8.** View of Bear Creek at water/sediment site BC4 (left photo) during low conditions on September 16, 2010. The biota site BC4 (right photo), located about 800 m upstream of the water/sediment site, was sampled on June 29 and September 15, 2010. Both sites are downstream from the Rathburn and Petray mines and upstream from Sulphur Creek.



**Figure 9.** Water/sediment sample site BC5 located in Sulphur Creek where several hot spring vents occur in and adjacent to the creek. The white material is elemental sulfur, and the black sediment is fine grained iron sulfide that contains HgS, which is deposited from the thermal water. View is during low conditions on September 16, 2010. Note Teflon® tubing used to sample water from the creek.



**Figure 10.** Biota sites BC5 (left photo) and BC6 (right photo), sampled on June 29 and September 17, 2010. The water/sediment site BC5 was 420 m downstream of biota site BC5. The water/sediment site BC6 coincided with biota site BC6.



**Figure 11.** View of Bear Creek downstream during low conditions on September 16, 2010 at sample site BC7 located downstream from the confluence with Sulphur Creek. Biota were collected at this site on June 29 and September 15, 2010.



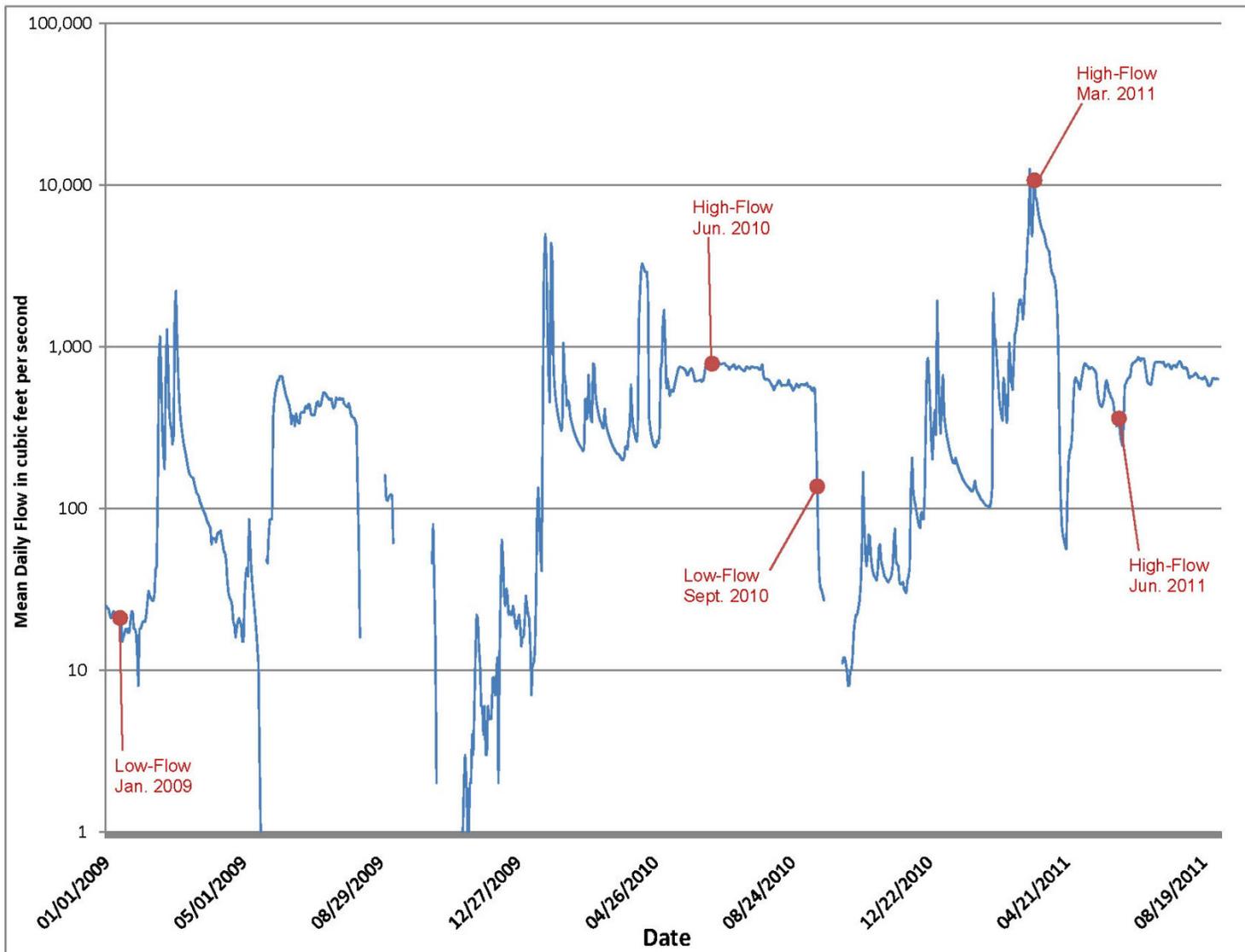
**Figure 12.** View of Bear Creek during low conditions on June 15, 2010 at the water/sediment sample site BC8 (left photo), located 300 m upstream from Highway 20 bridge crossing. The biota BC8 sample site (right photo) is located at the bridge and was sampled on June 15 and September 15, 2010.



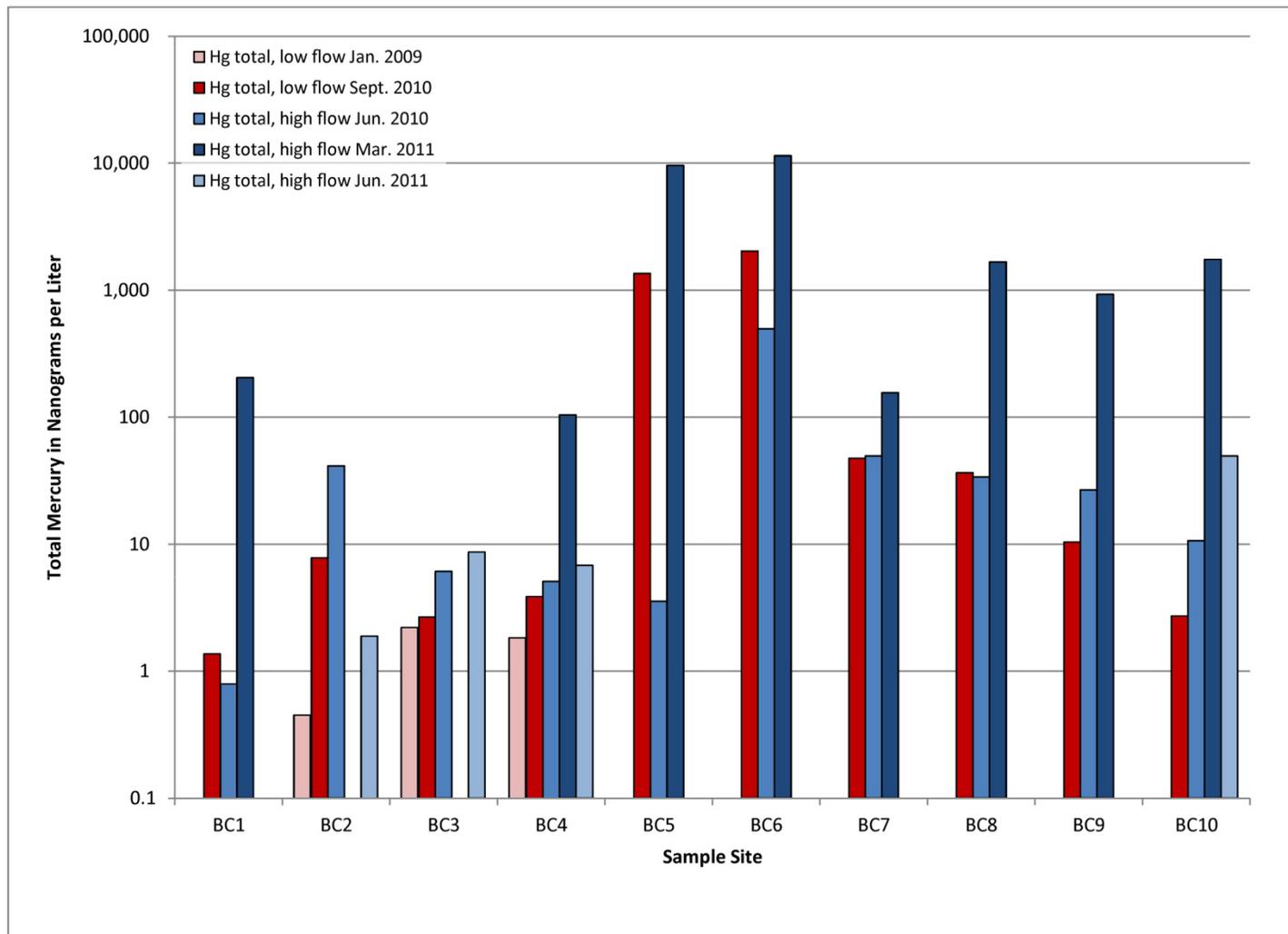
**Figure 13.** View of Bear Creek during low flow conditions on June 15, 2010 at water/sediment sample site BC9. Biota were sampled at a site about 80 m downstream near the Thompson Canyon bridge on June 15 and September 15, 2010.



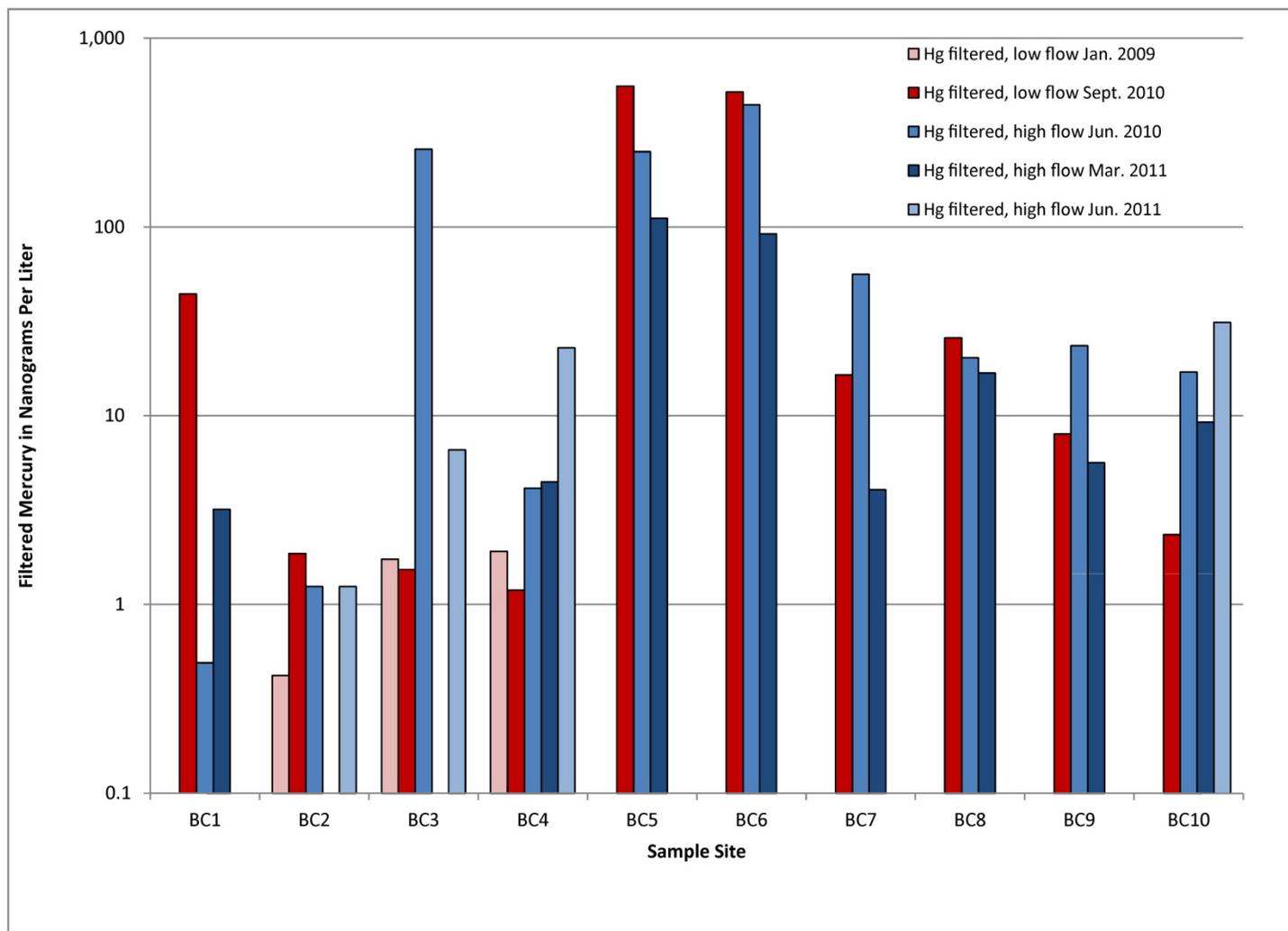
**Figure 14.** View of Bear Creek during low conditions on September 16, 2010 at sample site BC10 about 60 m upstream from confluence with Cache Creek. Exposures of bedded siltstone and shale of the Great Valley Sequence occur in the creek. Biota were also collected at this site and further upstream on June 15 and September 15, 2010.



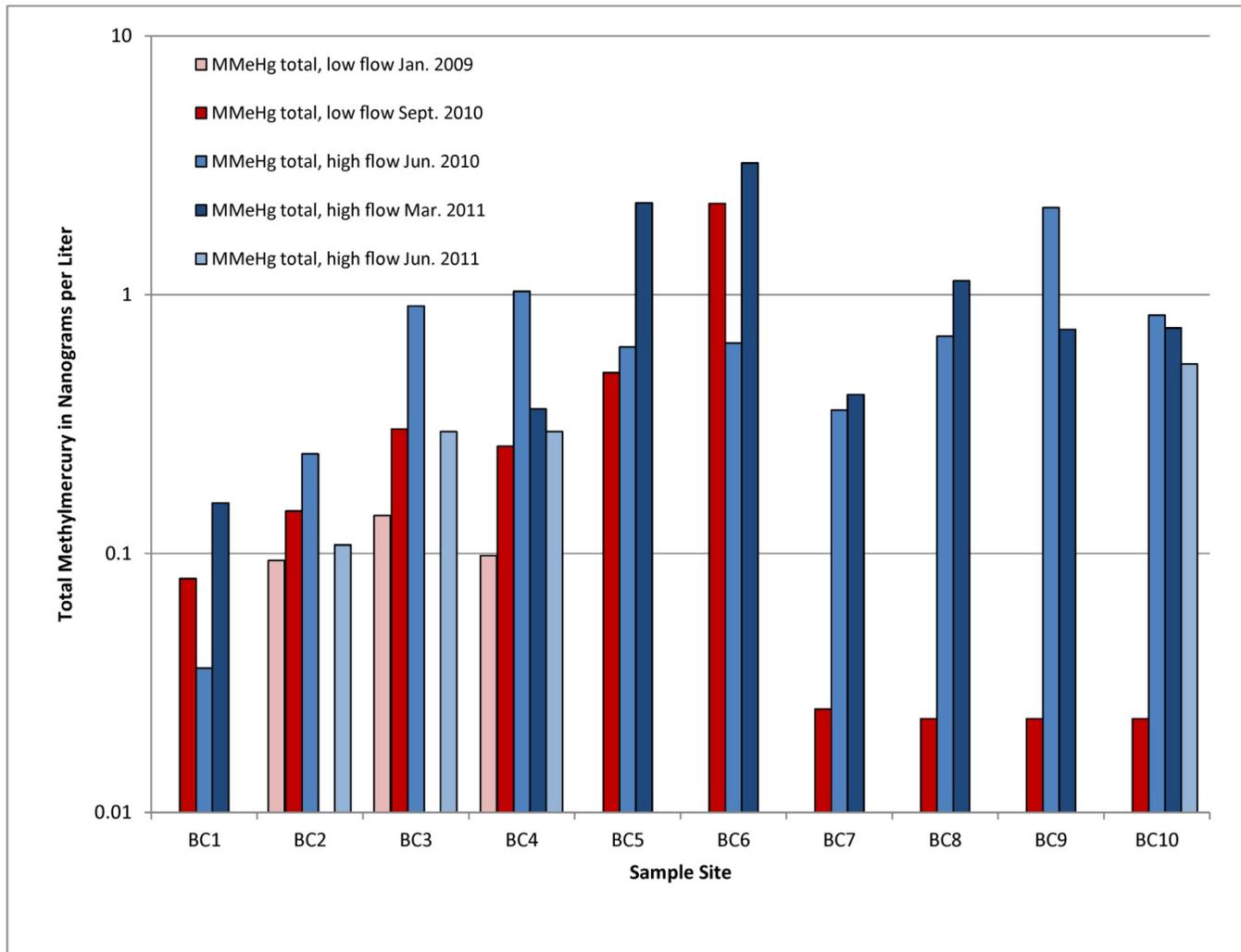
**Figure 15.** Plot showing Mean daily flows in Cache Creek in cubic feet per second over a three-year period beginning in January 2009. Flows were measured at the USGS Gaging Station in Cache Creek, downstream of Bear Creek at the Rumsey Bridge.



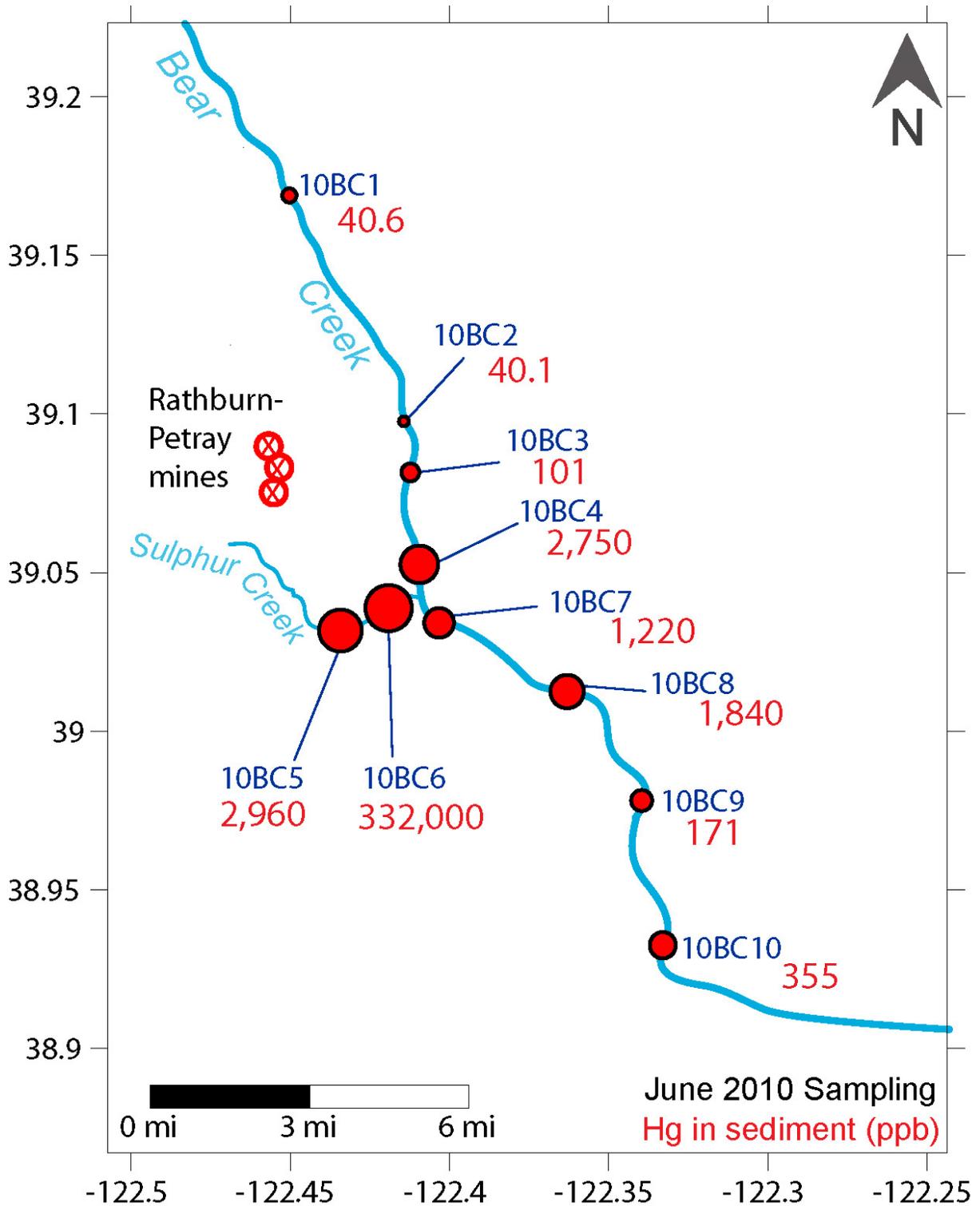
**Figure 16.** Logarithmic-scale plot showing concentrations of total mercury (HgT) in water collected from sample sites in Bear Creek watershed, Colusa County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.



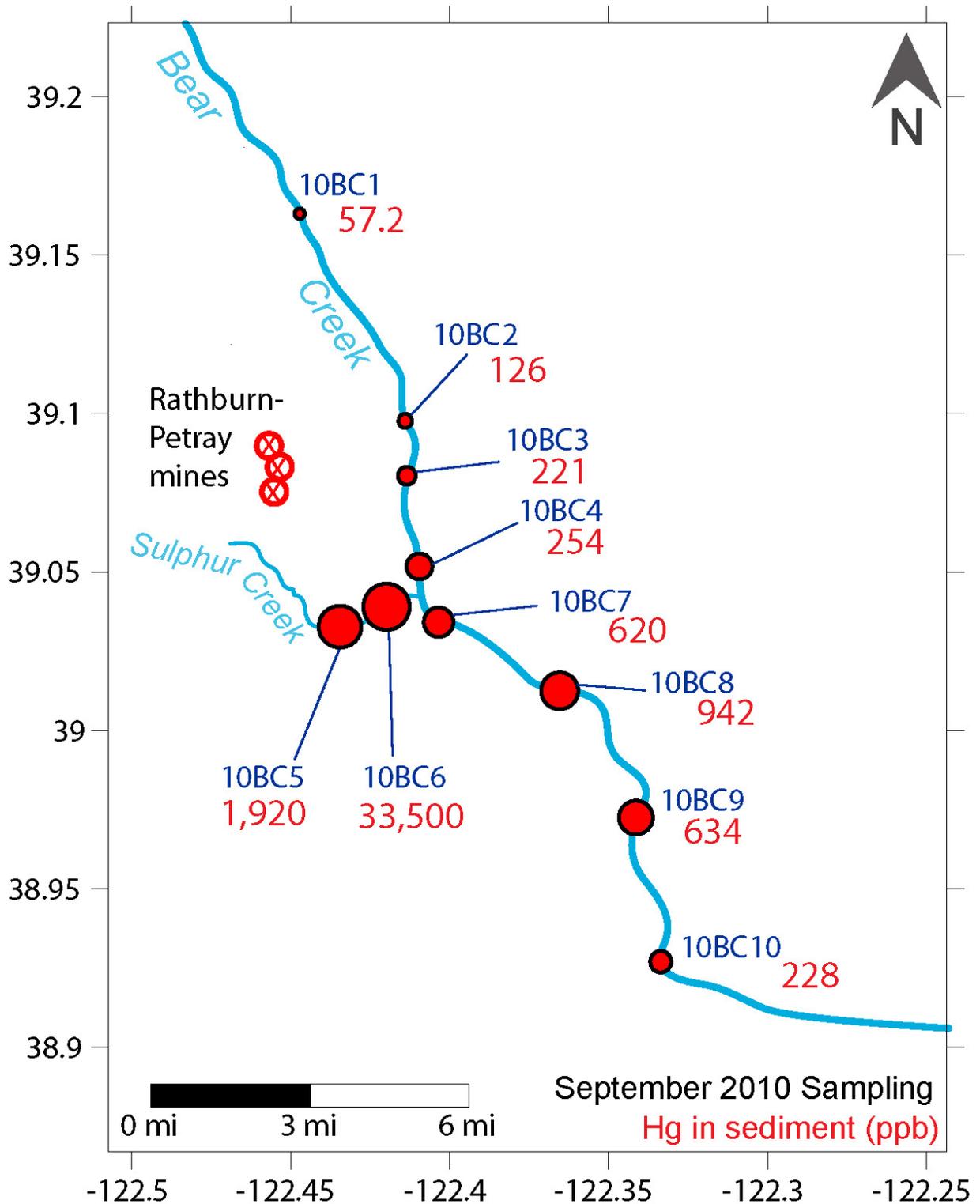
**Figure 17.** Logarithmic-scale plot showing concentrations of filtered mercury (HgF) in water collected from sample sites in Bear Creek watershed, Colusa County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.



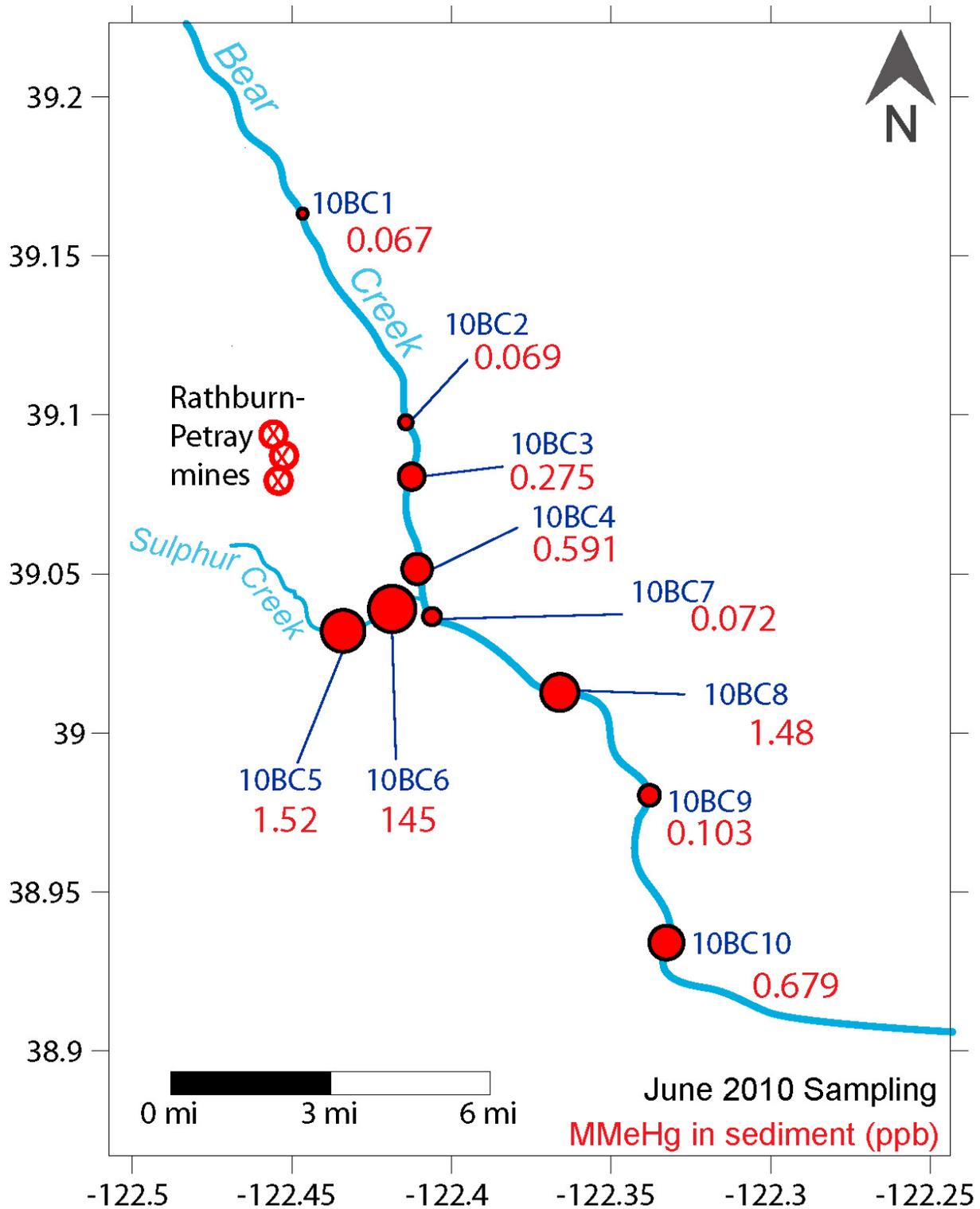
**Figure 18.** Logarithmic-scale plot showing concentrations of MMeHg in water collected from sample sites in Bear Creek watershed, Colusa County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.



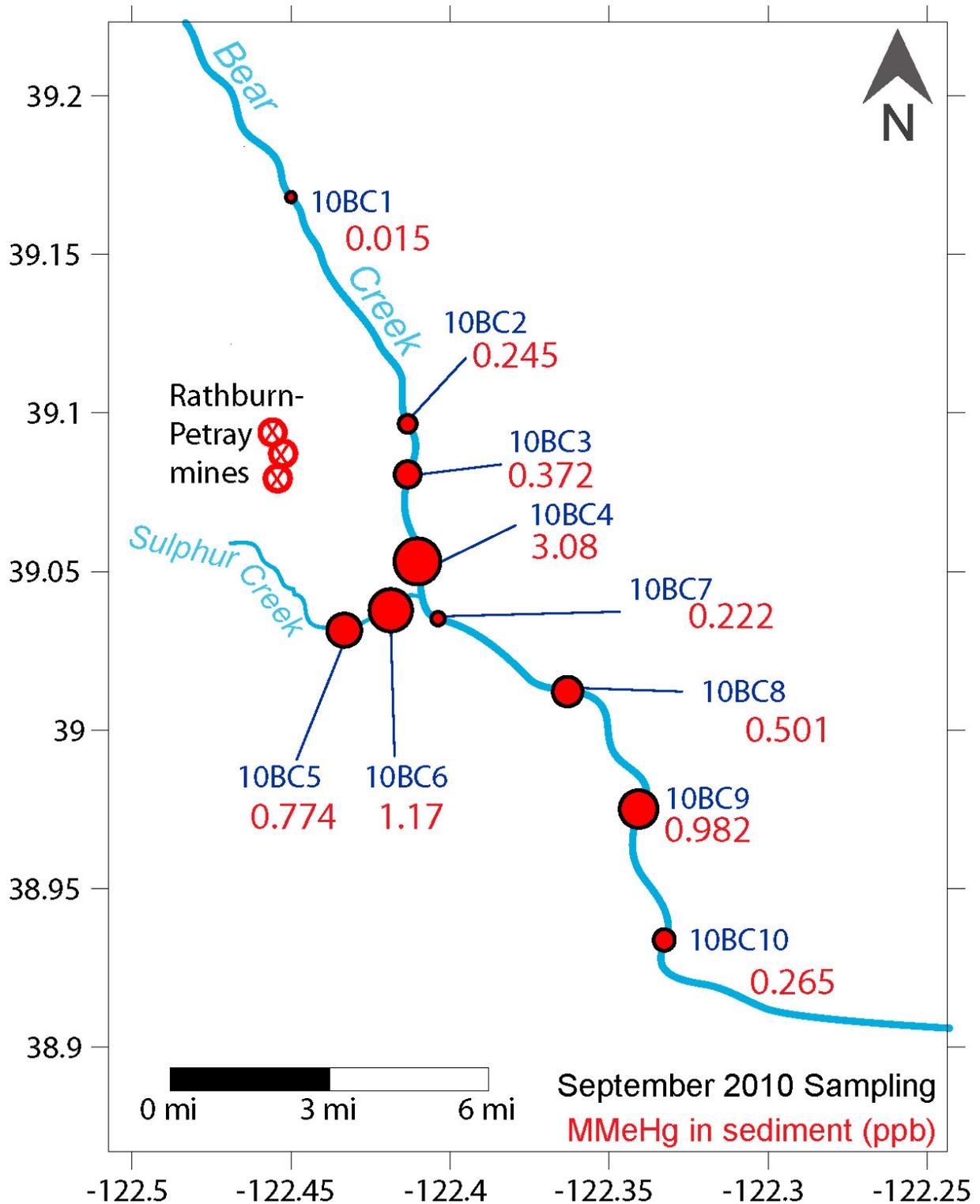
**Figure 19.** Map showing concentrations of Hg in sediment collected from Bear Creek and Sulphur Creek, Colusa County, California, in June 2010. The increase in Hg in Bear Creek sediment downstream from Sulphur Creek is about five times greater than the increase in Hg in sediment downstream from the Rathburn-Petray Input.



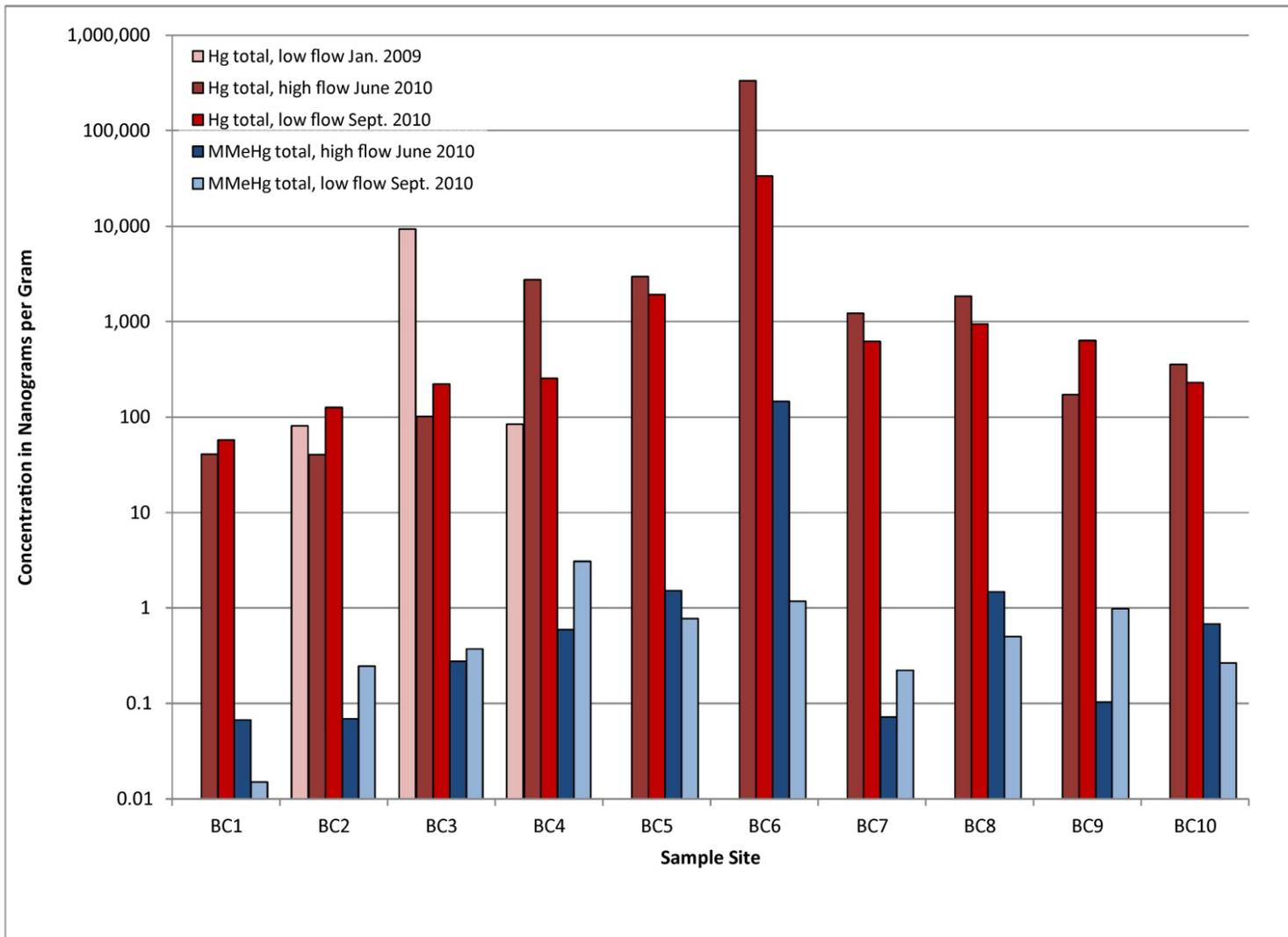
**Figure 20.** Map showing concentrations of Hg in sediment collected from Bear Creek and Sulphur Creek, Colusa County, California, in September 2010. The increase in Hg in sediment is significantly greater after the Sulphur Creek saline input enters Bear Creek than the increase associated with the mine input at sample site BC3.



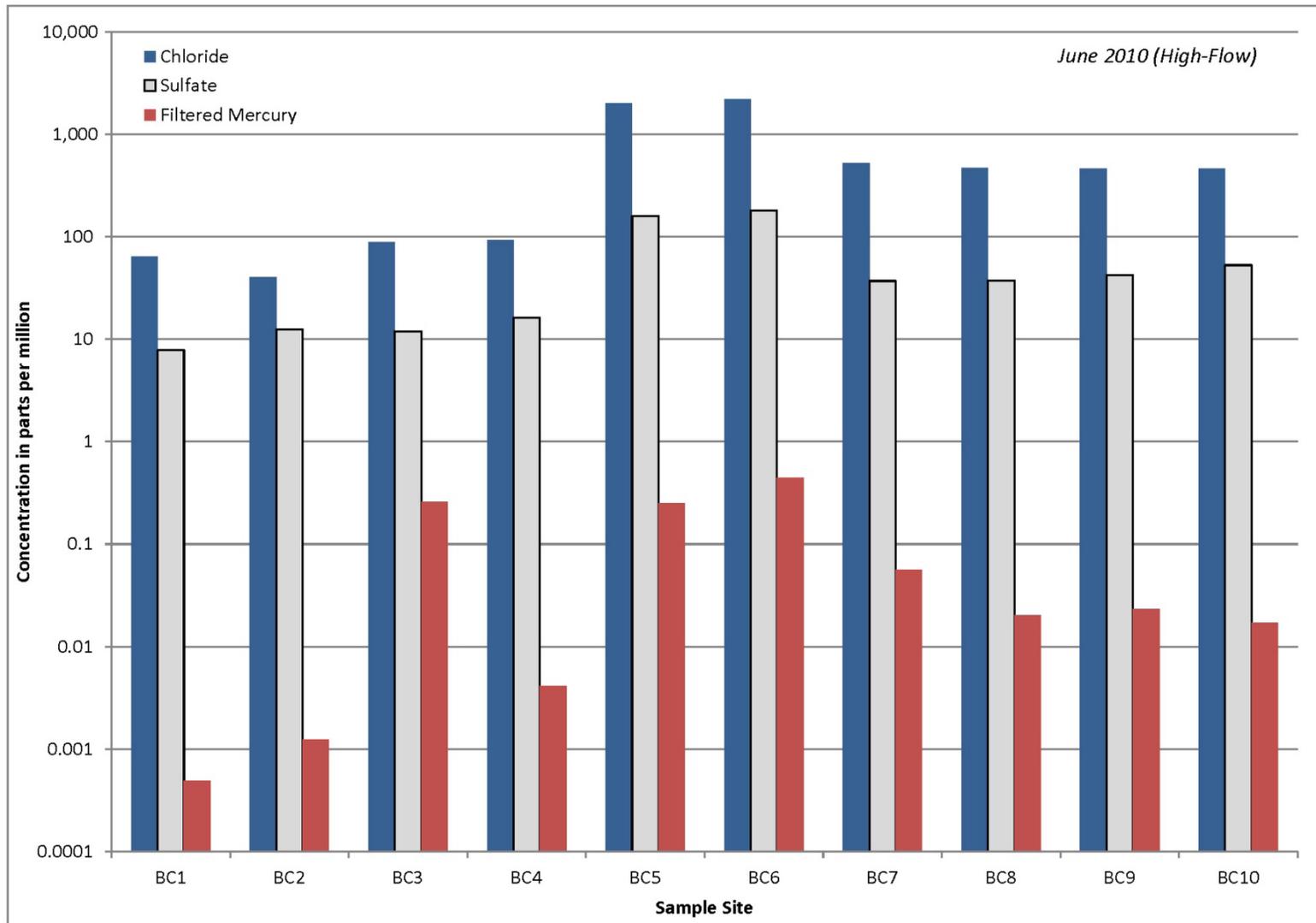
**Figure 21.** Map showing MMeHg levels in sediments collected from Bear Creek and Sulphur Creek, Colusa County, California, in June 2010. Figure shows high rates of methylation occurring downstream from the mine, and further downstream in Bear Creek at sites BC8 and 9.



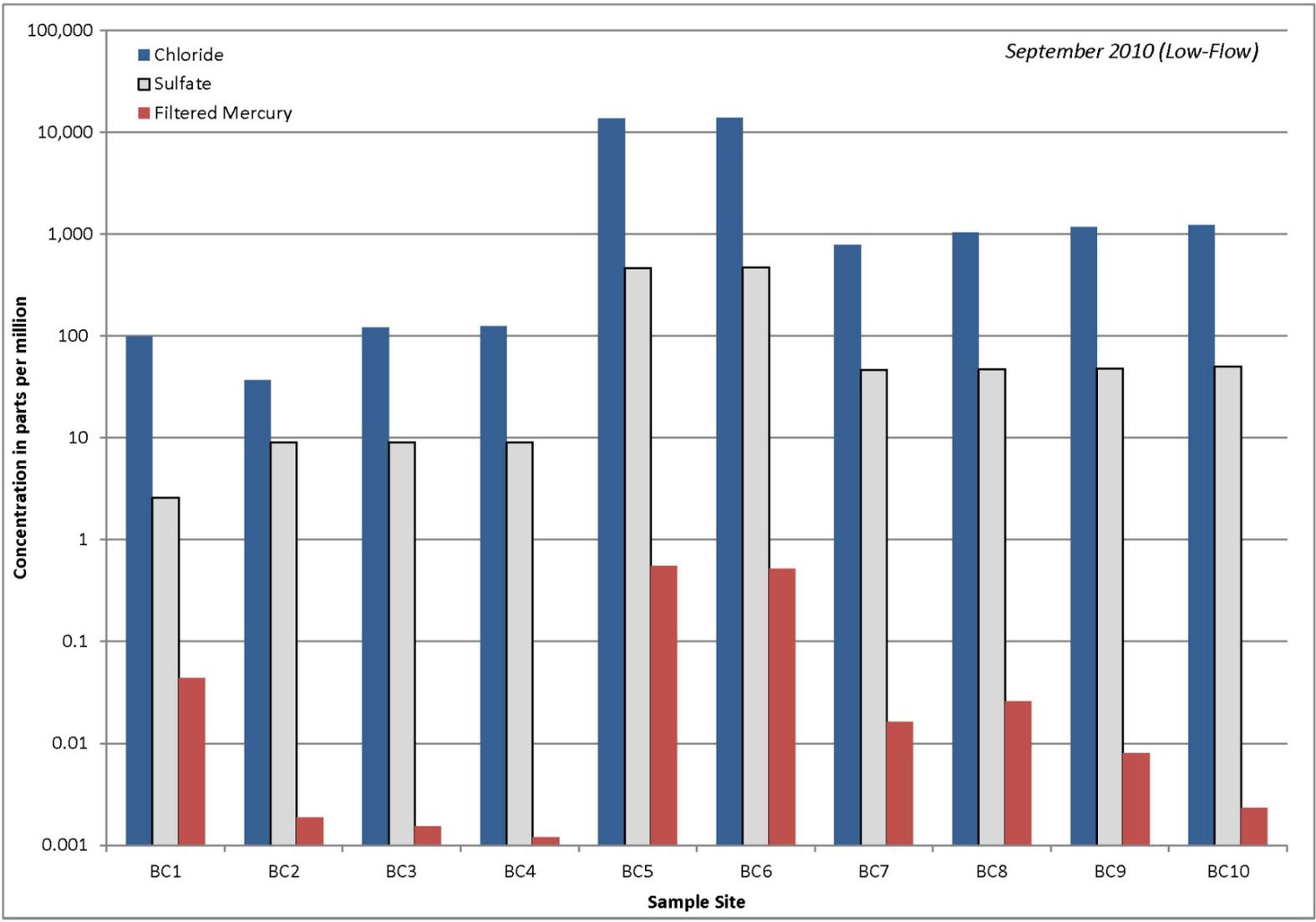
**Figure 22.** Map showing MMeHg levels in sediments collected from Bear Creek and Sulphur Creek, Colusa County, California, in September 2010. Figure shows high rates of methylation at sample site BC4 downstream from the mine input, as well as at sample site BC9 in downstream Bear Creek.



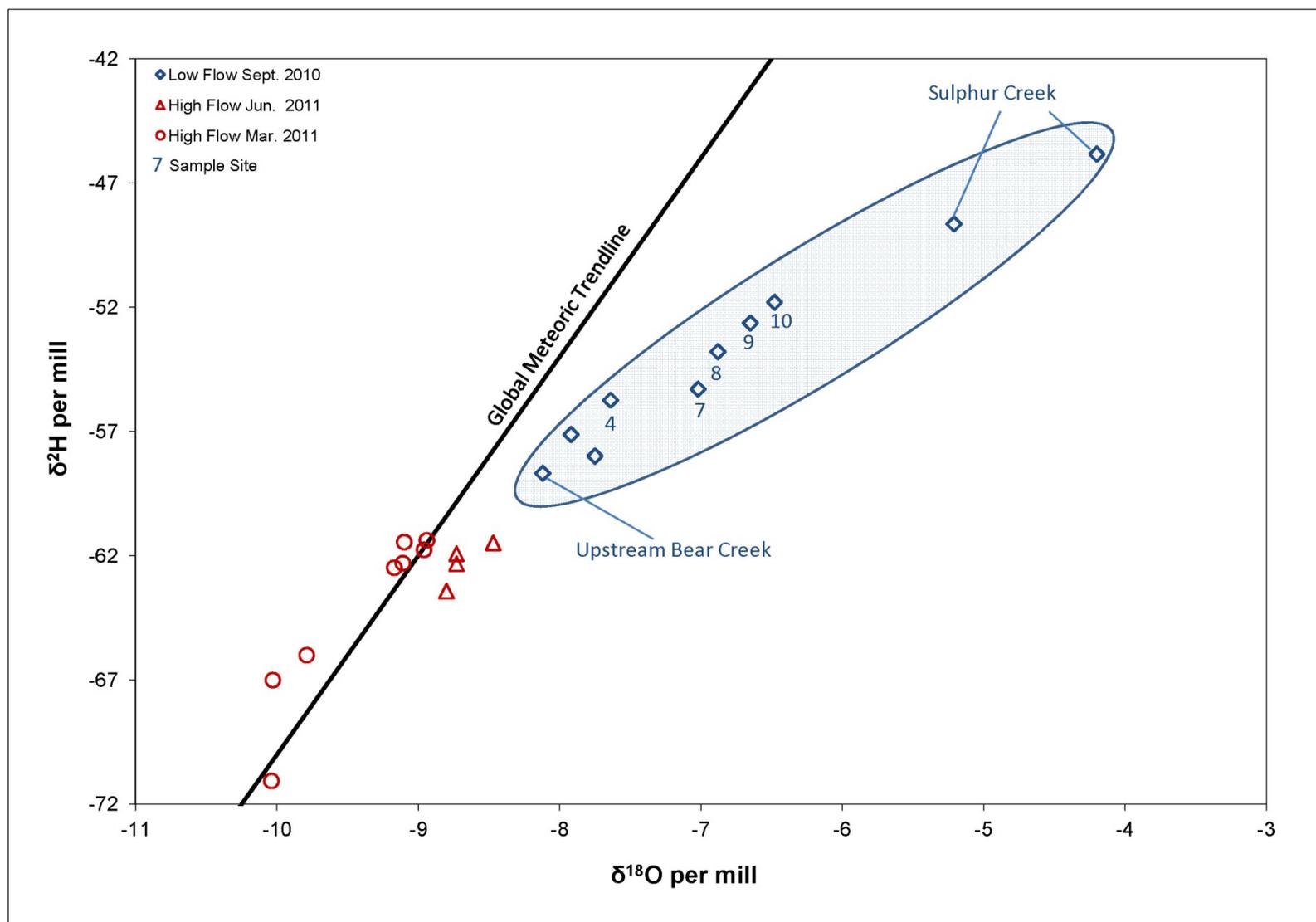
**Figure 23.** Logarithmic-scale plot showing concentrations of Hg and MMeHg in sediment collected from sample sites in Bear Creek watershed, Colusa County, California, moving downstream to the right on the x-axis. Hg concentrations are shown by red bars, and MMeHg concentrations with blue bars.



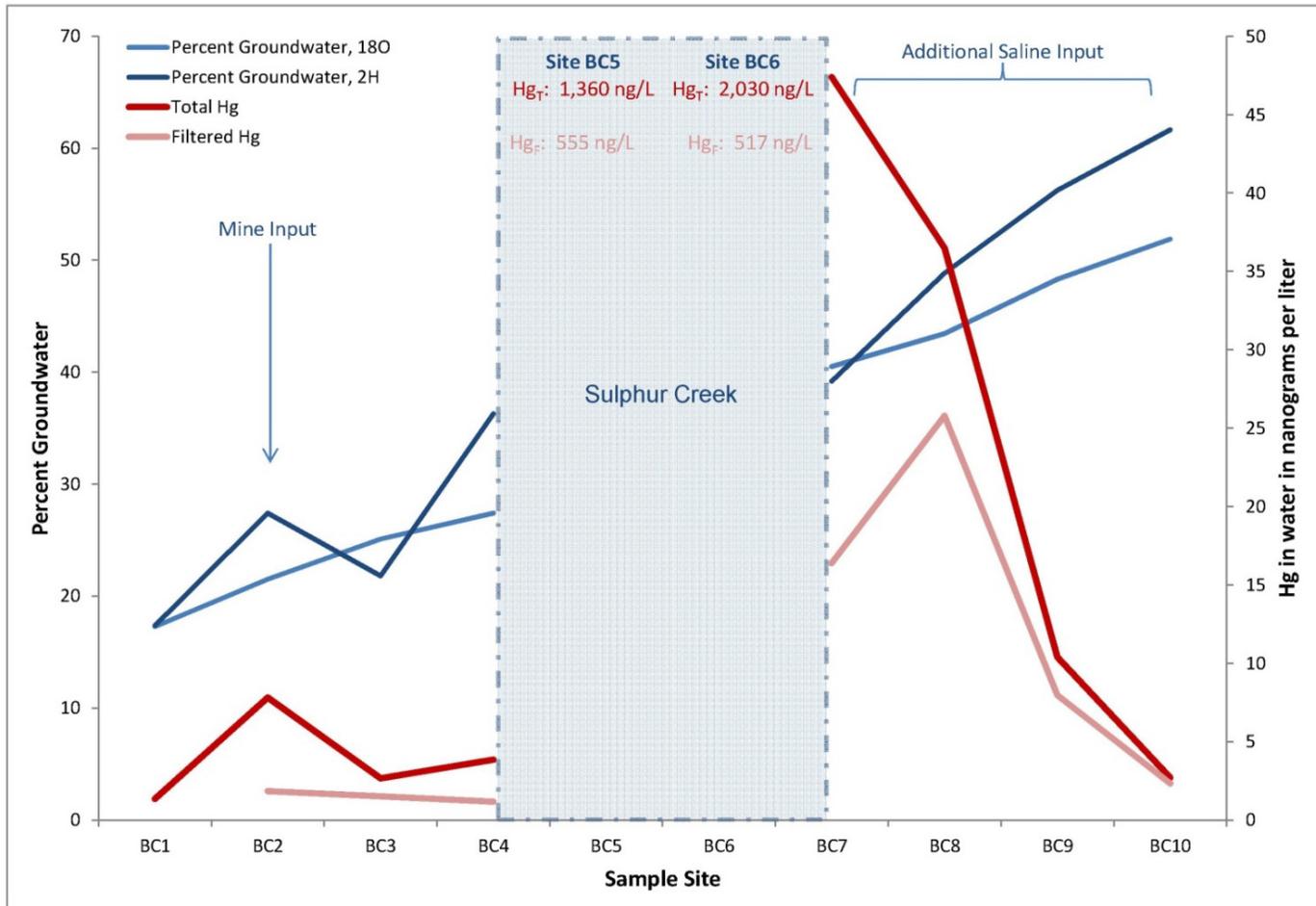
**Figure 24.** Logarithmic scale plot showing concentrations of Chloride (blue bars), Sulfate (grey bars), and Filtered Mercury (red bars) moving downstream in Bear Creek and Sulphur Creek, Colusa County, California. Data was collected in June 2010 under moderate high-flow conditions.



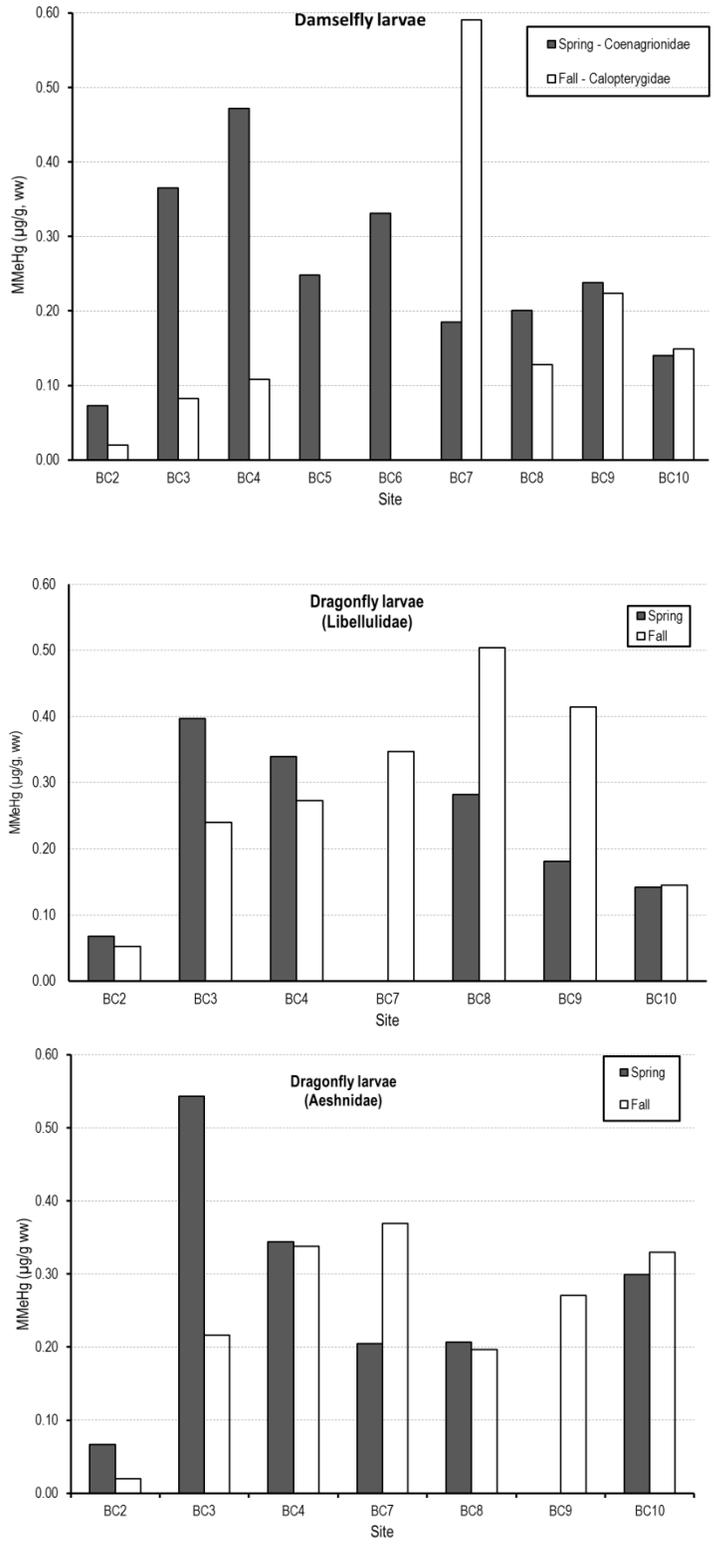
**Figure 25.** Logarithmic scale plot showing concentrations of Chloride (blue bars), Sulfate, (grey bars), and Filtered Mercury (red bars) moving downstream in Bear Creek and Sulphur Creek, Colusa County, California. Data was collected in September 2010 under low-flow conditions.



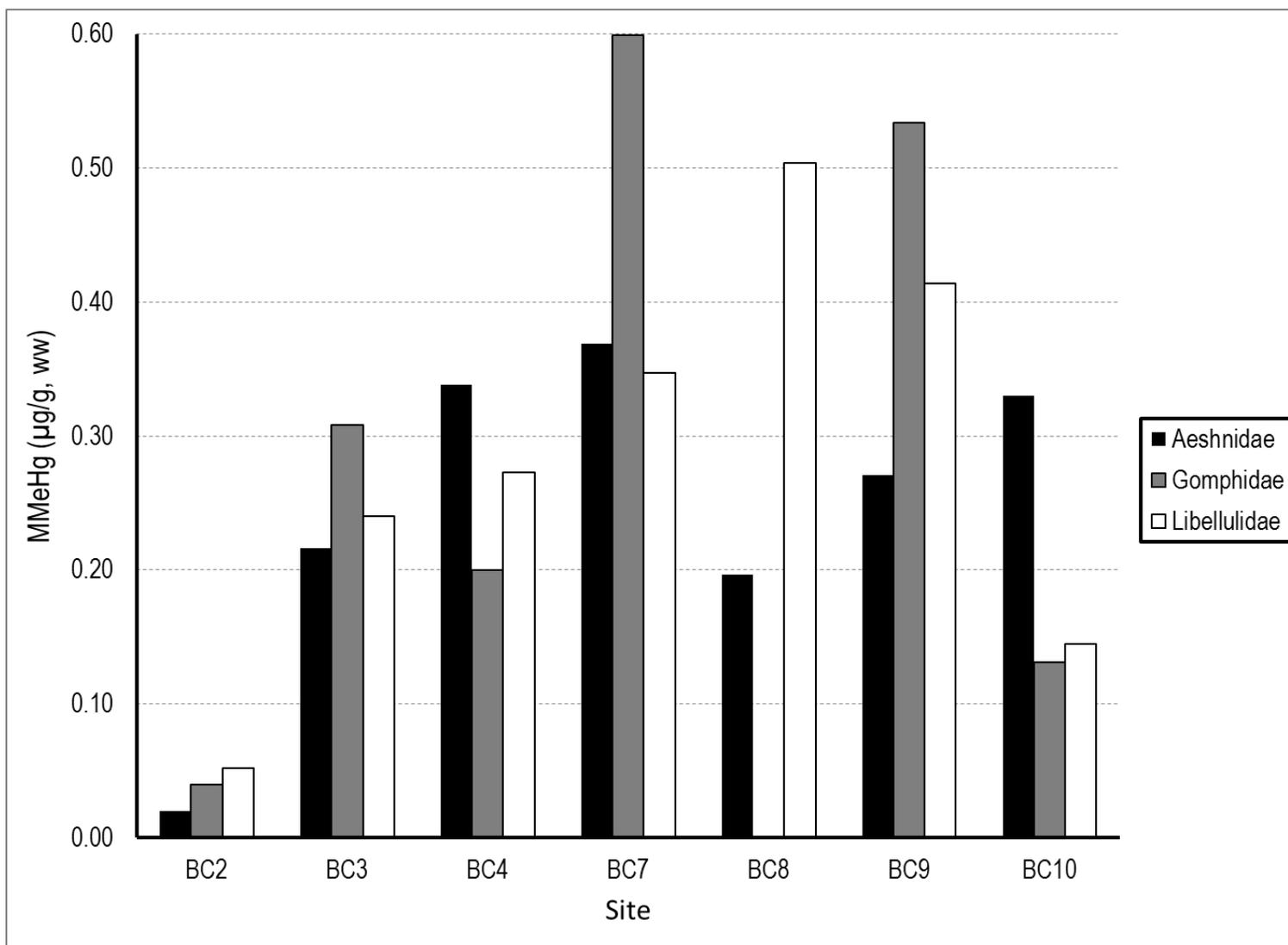
**Figure 26.** Plot of isotopic composition of waters in Bear Creek and Sulphur Creek, Colusa County, California, which shows that the waters do not fall along the meteoric water line and are, thus, a mixture of connate water, thermal water, and meteoric water.



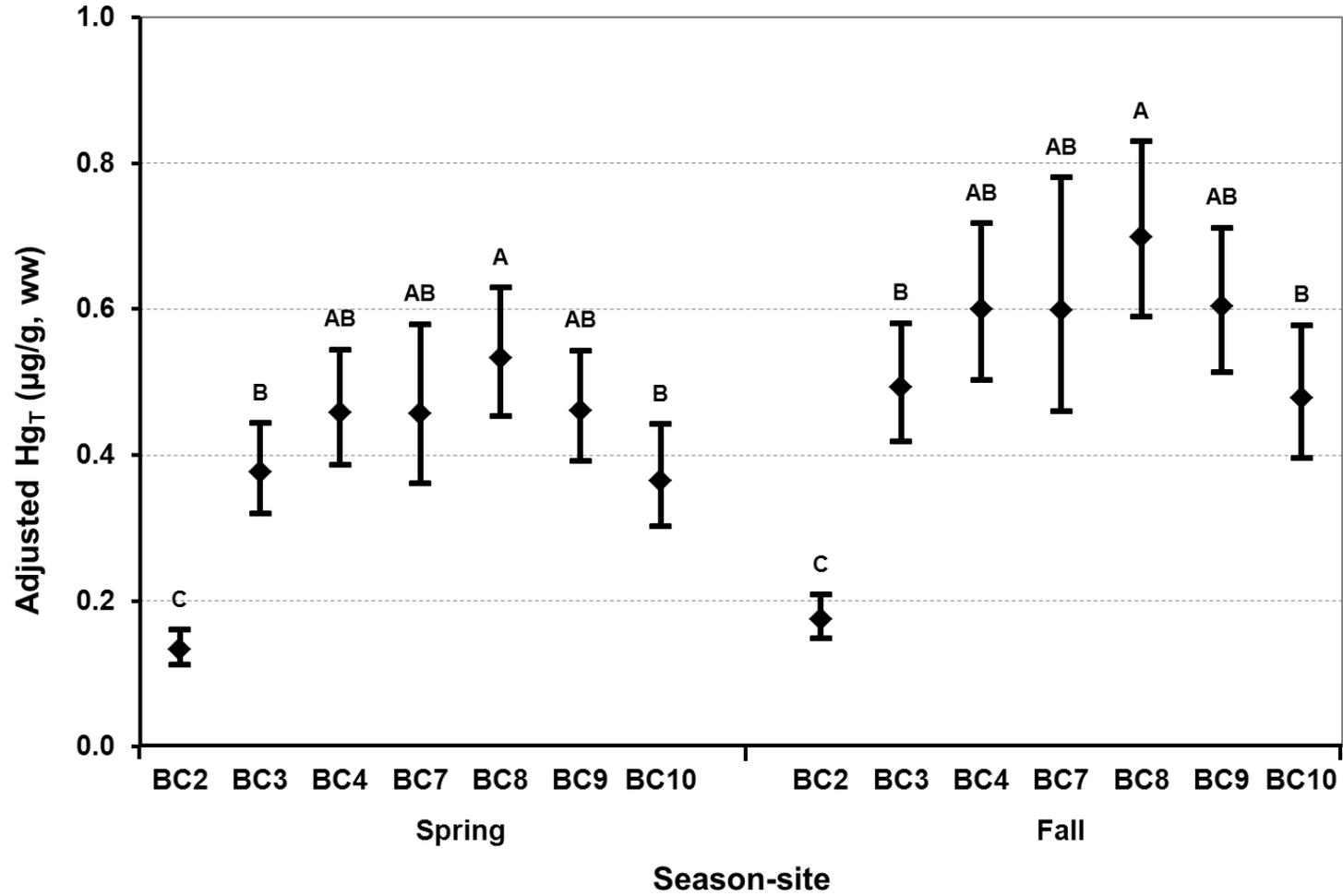
**Figure 27.** Plot showing changes in groundwater input and HgT and HgF concentration in low-flow condition waters collected from Bear Creek, Colusa County, California. Percent groundwater was calculated using a two endmember system in which high-flow waters collected from upstream Bear Creek sites were treated as background meteoric water, and low-flow waters collected from Sulphur Creek were treated as pure saline groundwater. Thus, at any given point in Bear Creek, stream water is a variable mixture of each endmember. Plot shows a linear increase in saline groundwater influence moving downstream in Bear Creek. The input of saline, isotopically-heavy groundwater from Sulphur Creek is also associated with large increases in HgT and HgF. High concentrations of HgT and HgF in Sulphur Creek samples are shown at the top of the blue area.



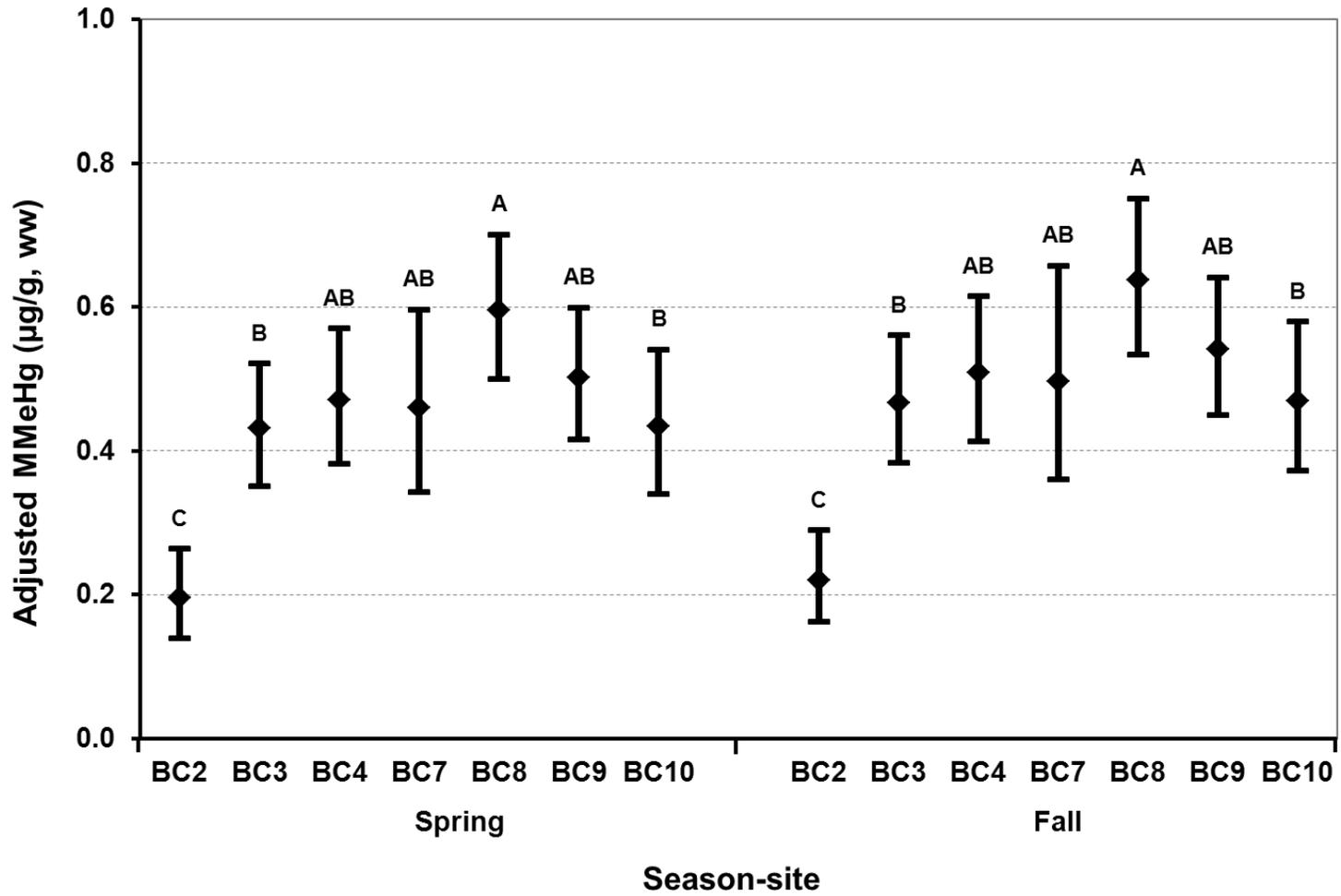
**Figure 28.** Seasonal comparisons for damselfly and dragonfly larvae collected from Bear Creek during June and September 2010.



**Figure 29.** Monomethyl mercury concentrations in three families of dragonflies collected from Bear Creek in September 2010.



**Figure 30.** Adjusted mean HgT concentrations and 95% confidence limits by site and season for California Roach collected from the Bear Creek Watershed during 2010. Within season, sites with the same letter are not significantly different.



**Figure 31.** Adjusted mean MMeHg concentrations and 95% confidence limits by site and season for California Roach collected from the Bear Creek Watershed during 2010. Within seasons, sites with the same letter are not significantly different.