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Impact of Mine and Natural Sources of Mercury on Water, Sediment, and Biota in Harley Gulch Adjacent to the Abbott-Turkey Run Mine, Lake County, California

By James J. Rytuba, Roger L. Hothem, Brianne E. Brussee,
and Daniel N. Goldstein

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Abbreviations, Definitions, and Datum Used

µg	micrograms
$BaSO_4$	barium sulfate (barite)
C	Celsius (degrees)
$CaCO_3$	calcium carbonate
CRM	certified reference material
CVAAS	cold vapor atomic absorption spectroscopy
DOC	dissolved organic carbon
DOM	dissolved organic matter
EDAX	energy dispersive spectroscopy
EE/CA	engineering evaluation/cost analysis for “non-time-critical removal actions,” as defined by the U.S. Environmental Protection Agency
FeS	iron sulfide
GC	gas chromatographic
GMWL	global meteoric water line
HDPE	high-density polyethylene
Hg	element symbol in the periodic table for mercury; generic shorthand for mercury; does *not* denote speciation.
Hg(II)	
Hg_F	total mercury (inorganic plus organic) in a filtered sample (either 0.1 µm or 0.45 µm, as specified in the text)
HgS	mercury sulfide (cinnabar)
Hg_T	total mercury (inorganic plus organic)
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
HNO_3	nitric acid
ICP-AES	inductively couple plasma-atomic emission spectrometry
ICP-MS	inductively coupled plasma-mass spectrometry
MMeHg	monomethylmercury (also known as methylmercury and monomethyl mercury (CH_3Hg^+)
N	number of samples
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
pH	
ppb	parts per billion
ppm	parts per million, equivalent to mg/kg or µg/g
pptr	parts per trillion
RPD	relative percent difference
RSI	
SC	specific (electrical) conductivity, reported in units of millisiemens per centimeter (mS/cm) or microsiemens per centimeter (µS/cm).
SEM	scanning electron microscope
$SnCl_2$	stannous chloride
SOP	
SVL	snout-vent length
TSS	Total Suspended Sediment
USEPA	United States Environmental Protection Agency
Ww	Wet weight

Conversion Factors

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^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic inch (in^3)	0.01639	cubic centimeter (cm^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	liter (L)
cubic yard (yd^3)	0.7646	cubic decimeter (dm^3)
cubic mile (mi^3)	4.168	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic kilometer (km^3)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
ton per day (ton/d)	0.9072	metric ton per day
ton per day (ton/d)	0.9072	megagram per day (Mg/d)
ton per day per square mile [(ton/d)/mi^2]	0.3503	megagram per day per square kilometer [(Mg/d)/km^2]
ton per year (ton/yr)	0.9072	megagram per year (Mg/yr)
ton per year (ton/yr)	0.9072	metric ton per year

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

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

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

Impact of Mine and Natural Sources of Mercury on Water, Sediment and Biota in Harley Gulch Adjacent to the Abbott-Turkey Run Mine, Lake County, California

By James J. Rytuba[1], Roger L. Hothem[2], Brianna E. Brussee[2], and Daniel N. Goldstein[1]

Introduction

Background

The Cache Creek watershed covers 2,950 km^2 within the central part of the California Coast Ranges, an area with numerous geologic sources of mercury (Hg). A long history of Hg mining has resulted in environmental Hg contamination (Rytuba, 2000). The major source of Hg exported from the watershed originates from historic Hg mining in the upper watershed (Foe and Croyle, 1998). Studies conducted by the California Regional Water Quality Control Board during 1996-1998 confirmed that Cache Creek was a major source of Hg to the Sacramento-San Joaquin River Delta and San Francisco Bay Estuary (Foe and Croyle, 1998).

Harley Gulch, a tributary to Cache Creek, located in Lake County, California, is listed as impaired by Hg contamination under citation of Section 303(d) of the Clean Water Act (Central Valley Regional Water Quality Control Board, 2003). The Harley Gulch tributary has been identified as a major source of Hg to Cache Creek (Foe and Bosworth, 2008). The primary source of Hg contamination in Harley Gulch has been the Abbott-Turkey Run Hg mine.

Natural sources of Hg also occur in the Cache Creek watershed, including thermal carbonate-chloride springs commonly associated with the Hg deposits, and cold carbonate-chloride springs that discharge connate groundwater. The thermal springs have high concentrations of Hg and are actively depositing Hg and associated trace metals (Donnelly-Nolan and others, 1993). The cold carbonate-chloride springs and associated connate groundwater occur peripherally to the Hg deposits and have variable but often high concentrations of Hg and associated metals (Slowey and Rytuba, 2008).

Information on the concentrations of Hg in water, sediments (Foe and Croyle, 1998; Domagalski, 2001; Domagalski and others, 2004), invertebrates (Slotton and others, 1997, 2004), and fish (Slotton and others, 1995) from the Cache Creek watershed have helped define the sources and magnitude of Hg contamination in the watershed. Where fish are not commonly available to serve as bioindicators of Hg contamination, as in upper Harley Gulch, amphibians can be good surrogates because they occupy a similar trophic level, tend to bioaccumulate Hg, and are sensitive to the effects of Hg (Cooke, 1981). In addition, amphibians have obligate aquatic larval stages, are often able to persist in aquatic systems unsuitable for fish, and are normally less mobile than fish, sometimes spending their entire life cycle in a single pond or

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reach of a stream. Prior to this study, information on Hg concentrations in amphibians in the Harley Gulch was not available.

The Central Valley Regional Water Quality Control Board established a Total Maximum Daily Load (TMDL) for monomethylmercury (MMeHg) in Harley Gulch, based on water, sediment, and biota data, collected by Ichikawa and Jakl (2004). Their data showed high concentrations of Hg in Harley Gulch downstream from the Abbott-Turkey Run mines and low to background concentrations in the East Fork of Harley Gulch where mines are not present. Ichikawa and Jakl also documented high levels of Hg in the Harley Gulch delta at the confluence with Cache Creek. The existing annual load to Harley Gulch was estimated to be 7–10 kg/year of Hg and 1.0 g/year of MMeHg, with an acceptable annual MMeHg load of 0.04 g/yr. The TMDL adopted for Harley Gulch is 0.09 ng/L (ppb) annual, median aqueous (unfiltered) MMeHg, which is needed to attain the target of 0.05 mg/kg (ppm) wet weight MMeHg in trophic level 2 and 3 fish.

Hg was discovered in the Abbott-Turkey Run mine in 1862, and the mine was worked intermittently from the early 1870s until 1971, when mining ceased. During this period, the mine produced more than 50,000 flasks of Hg. Much of Harley Gulch is 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 in Harley Gulch downstream from the Abbott-Turkey Run mine. This report responds to a request from the BLM in support of its Abandoned Mine Lands Program, funded by Congress under the authority of the Clean Water Act.

Hg and MMeHg contamination of water, sediment, and biota downstream from the mine led the Environmental Protection Agency (EPA) to undertake a cleanup of the Abbott-Turkey Run mines. Cleanup at the mine began on October 10, 2006, and was completed on September 6, 2007 at a total cost of $5 million. Hg mine wastes that were judged to be leachable were removed from the mine to a waste site in Nevada. Mine wastes which were considered unleachable were capped with a 2-foot-thick layer of native soil at the mine site. Stabilization of mine wastes and slopes was engineered to withstand a 100-year flood event. Much of the abandoned mining equipment was removed, and the mine entries were filled and capped (Larson, 2007). Thermal water from the Turkey Run adit was diverted such that it did not flow over tailings, but continues to flow into the upper part of Harley Gulch.

Study Objectives

The objectives of this multi-year study were (1) to determine concentrations of Hg in water, sediment, and biota after cleanup of waste material had been completed and (2) to characterize transport of Hg in the watershed post-removal action. Sampling occurred in two phases: first, biota were sampled to determine the amount of overall Hg contamination present post-removal (as compared to reference sites and pre-removal sampling), and second, water, sediment, and biota were jointly sampled to determine more accurately the characteristics of the contamination. In 2007, Hg concentrations in foothill yellow-legged frogs (*Rana boylii*), and their potential invertebrate prey in Harley Gulch, was measured and compared to reference values (Hothem and others, 2010). In 2010–2011, Hg contamination in foothill yellow-legged frogs and invertebrates from sites sampled in 2007were further quantified. Hg contamination upstream of those sites in the wetlands of Harley Gulch and downstream of the sites sampled in 2007 to the confluence of Harley Gulch with Cache Creek also was evaluated. In 2010 and 2011, water and sediment were sampled in Harley Gulch under both low- and high-flow conditions. Natural sources of Hg and MMeHg that previously were unrecognized were studied, and the results are presented in this report.

Executive Summary

Stable-isotope data indicate that there are three sources of water that affect the composition and Hg concentration of waters in Harley Gulch: (1) meteoric water that dominates water chemistry during the wet season; (2) thermal water effluent from the Turkey Run mine that affects the chemistry at sample site HG1; and (3) cold connate groundwater that dominates water chemistry during the dry season as it upwells and reaches the surface. The results from sampling executed for this study suggest four distinct areas in Harley Gulch: (1) the contaminated West Fork of Harley Gulch, consisting of the stream immediately downstream from the mine area and the wetlands upstream from Harley Gulch canyon (sample sites HG1–HG2, (2) the East Fork of Harley Gulch, where no mining has occurred (sample site HG3), (3) sample sites HG4–HG7, where a seasonal influx of saline groundwater alters stream chemistry, and (4) sample sites HG7–HG10, downstream in Harley Gulch towards the confluence with Cache Creek.

West Fork: Mine Area and Wetlands

The concentration of Hg in both storm sediment and active channel sediment was highest at sample site HG1, immediately downstream from the mine. The highest concentrations of total Hg (Hg_T) in water also occurred at site HG1, and they decreased systematically downstream from the mine. The high concentration of Hg_T at site HG1 reflects input of thermal-water effluent from the Turkey Run mine which comprises most of the flow at this site during the dry season. During the May 2011 low-flow sampling, Hg_T concentration was very high at site HG1, but the maximum in Hg_T concentration occurred at sample site HG1.5 in the middle of the wetland area. The high concentration of Hg_T and isotopic chemistry at this site indicates that a significant input of connate groundwater into the creek at this location contributes to the high Hg concentration in water. At site HG1, just downstream from the thermal water input from the Turkey Run mine, water sampled in June 2010 was almost entirely composed of thermal-water effluent. During the storm sampling in March 2011, which resulted in the highest flows of the winter, thermal effluent was virtually undetectable at site HG1, and the water was all meteoric. During the May 2011 sampling event, the input of connate groundwater in the middle of the wetland area at site HG1.5 was dominant. Discharge from the adit and runoff from the mine contributes to the high Hg concentration at site HG1 under both high and low-flow conditions.

East Fork: Background

Hg levels in waters collected from the East Fork of Harley Gulch, where no mining has occurred, were as high as 32.8 parts per trillion (pptr). These levels of Hg in water are significantly higher than regional background Hg concentrations, which range from 4–7 pptr. These anomalous Hg concentrations are partially explained by the abundance of Hg-enriched groundwater in Harley Gulch.

Sites HG4–HG7

Downstream from the wetland, the aqueous concentration of Hg_T decreased, but remained above background levels as another input of connate groundwater occurs in the creek segment between sample sites HG4 and HG7. The input of connate groundwater in this segment of the creek is reflected in the increase in dissolved constituents characteristic of the connate groundwater, such as sulfate (SO_4), chloride (Cl) and magnesium (Mg). Stable-isotope data for heavy isotopes $\delta^{18}O$ and $\delta^{2}D$ also confirm two areas of input of connate groundwater into Harley Gulch: the creek segment in the West Fork near sample site HG1.5 and the segment between sample sites HG4 and HG7. Downstream from the second area of input of connate groundwater, both Hg_F and Hg_T concentrations decrease similarly, but the percentage of Hg in the filtered fraction increases. The decreases in Hg_T and Hg_F between sample sites HG5 and HG7 suggests that this second source of connate groundwater to Harley Gulch is distinct from the Hg-enriched source that enters the middle of the wetlands at sample site HG1.5. During low-flow conditions in June 2010, input of connate groundwater increased from sample site HG4 and reached a maximum near sample site HG7, where it dominated creek water chemistry. Waters collected from sample site HG7 during the June 2010 sampling event were the heaviest isotopically and contained high concentrations of Cl and SO_4, constituents that are characteristically high in the connate groundwater. Both above and below sample site HG7, the amount of connate groundwater in the creek water decreased.

Sites HG8–HG10

Sediment with high Hg concentration is present throughout the West Fork of Harley Gulch below the mine and in the upper part of the Harley Gulch main stem to just above sample site HG10. At the sample site furthest downstream, HG10, Hg concentration is at background levels, as are cobalt (Co), nickel (Ni), and tungsten (W), indicating that the sediment is not significantly contaminated with Hg from the mine.

This report summarizes data obtained from field sampling of water, sediment, and biota in Harley Gulch, downstream from the Abbott-Turkey Run mine. Our results permit an assessment of the chemical constituents that may elevate levels of MMeHg in Harley Gulch and MMeHg uptake by biota, as well as an evaluation of the effectiveness of the clean-up of the Turkey Run and Abbot mines. The authors of this study followed an established sampling protocol adapted for the Cache Creek watershed by the USGS (Suchanek et al, 2010).

Mining History and Geology of the Abbott-Turkey Run Mine

Information about the Abbott-Turkey Run mine is summarized below (Churchill and Clinkenbeard (2003); and other references, as cited).

The Abbott-Turkey Run Mine, located in Lake County along State Highway 20 about 24 miles west of Williams, was discovered in 1862. Production began in the early 1870s and continued intermittently until 1971, when the mine was shut down. Total production during the life of the mine is estimated to be between 50,000 and 60,000 flasks (1,725,000–2,070,000 kg) of Hg (U.S. Bureau of Mines, 1965).

The Abbott mine is within rocks of the early Cretaceous to late Jurassic Great Valley Sequence . The sequence consists of marine shales, mudstones, sandstones, and occasional conglomerates. Lenses of detrital serpentinite also occur in some areas, including at the Abbott mine, where serpentinite is the dominant country rock. The host rock for the Hg ore at the Abbott mine is a silica-rich variety of silica carbonate rock composed of opal, chalcedony, quartz, magnesite, and some calcite (Moisseeff, 1966). Locally, there is a post-mining efflorescence of epsomite ($MgSO_4 \cdot 7H_2O$) (Watts, 1893). Hg is present in the serpentinite country rock at concentrations ranging from 0.1 to 0.2 µg/g, and the background GVS sediments contain 0.05-0.11 µg/g Hg (Holloway et al., 2009).

The ore at the Abbott mine consisted primarily of cinnabar, which occurred as fracture fillings in silicified and altered serpentine breccia (Wiebelt, 1949). Ore occurred in dikes and sills of the altered serpentinite and in tabular ore bodies along contacts, faults, and fault intersections (U.S. Bureau of Mines, 1965). The ores were processed in a rotary furnace and tailings were disposed of in the upper part of Harley Gulch. Hg phases present in the tailings at the Turkey Run mine, which were processed in a retort, include cinnabar and metacinnabar (Kim and others, 2004). Thermal water encountered during underground mining at the Turkey Run mine has resulted in the continuous release of thermal water from the partially collapsed Turkey Run adit. The thermal water contains low Hg and MMeHg water at the mine portal but has very high Hg and MMeHg concentrations after it flows through and reacts with tailings below the adit (Rytuba, 2000). The thermal water flows into the upper part of Harley Gulch, where it accounts for most of the flow during the dry season, even though the flow of thermal water is low at 40 liters/minute (Goff and Janik, 1993). During the dry season, surface flow extends for less than 0.5 km downstream from where the thermal water first enters the West Fork of Harley Gulch.

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 Harley Gulch. Water, sediment, and biota were sampled from Harley Gulch downstream from the mine three years after cleanup of the mine had been completed. Water and sediment samples were collected under low- and high-flow conditions in 2010 and 2011. Water sample site locations are shown in figures 1 and 2 and are listed in table 1. Water flows into Harley Gulch from two separate drainages, termed here the East Fork and the West Fork. Sample site HG1 is in the upper most part of the West Fork of Harley Gulch at the culvert under State Highway 20, immediately downstream from the mine (fig. 3). Biota site HG8-07 is in the wetland downstream from this site (fig. 4). Sample site HG1.5 is in the in the middle of the wetlands in the West Fork along State Highway 20 between the culvert and the headwaters of Harley Gulch Canyon. The biota sites UDUP and UDLW also are located in the wetlands (figs. 5 and 6). Sample site HG3 in the East Fork of Harley Gulch provided data on background concentrations of Hg because there was no mining in this part of the watershed (fig. 7). Sample site HG2 is along State Highway 20 in the West Fork of Harley Gulch at the end of the wetland and 200 m upstream from the confluence of the East and West Forks (fig. 8). Sediment samples 10HG20–23S were collected in the West Fork just above the confluence of the East and West Forks of Harley Gulch (figs. 9 and 10). Sample site HG4 is in the headwaters of Harley Gulch at a pool located just below the confluence of the East and West Forks and (figs. 11 and 12). Sample sites HG5–HG10 are downstream in Harley Gulch where it enters a canyon, and samples were taken at regularly spaced intervals of about 1 km (figs. 13–17).

Water and sediment were collected during five sampling events from 2010 through 2011. Two sampling events occurred under low-flow conditions in 2010 and one in 2011, and two high-flow sampling events occured in 2011, with the March 2011 sampling occurring during the largest storm of the 2010–2011 water year.

Sample Locations and Conditions: Biota

All biota samples collected in 2007, 2008, 2010, and 2011 were within Harley Gulch. Sites sampled within the Harley Gulch wetlands (figs. 1, 3–6) included HG1, 2, and 2a, all sampled in 2008, 2010, and 2011. In addition, one site, HG8-07, was sampled only in 2007, and sites UDLW and UDUP were sampled only in 2010. One site sampled all 4 years was the East Fork of Harley Gulch (HG3) (fig. 7). Site HG4 was sampled in 2007, 2010, and 2011 (fig. 11). Site HG5 (fig. 13) was sampled all four years, HG6 was sampled in 2007 and 2010 (fig. 14), and HG7 was sampled all four years (fig. 15). HG8 was sampled in 2008 and 2010 (fig. 15), but the fish site, HG8A, was sampled only in 2010 (fig. 16). The remaining six sites (HG9–14) were sampled in 2008 and 2010 (table 2, figs. 2, 17, and 18).

As part of a study in 1997 and 1998, foothill yellow-legged frogs were collected from three reference sites: Bear Creek at Brim Road (BRIM), Spanish Creek (SPCR), and East Fork of Middle Creek (EFMC) (fig. 19). Data on frogs from these sites, located in the upper reaches of the Cache Creek watershed, presumably above sources of both anthropogenic and natural Hg (Hothem and others, 2010), are presented for comparison purposes.

Field Sampling Methods

Sediments

Wet-sediment samples were collected from Harley Gulch 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 ranged from 1 to 4 ºC, which is within the limits specified in USEPA Method 1631E.

Another sediment sample was collected in a Ziploc® 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 µm 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 pH<2 with trace-metal (*Ultrex*, J.T. Baker)-grade 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 °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 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 40mL ICHEM glass vials. Stable-isotope samples were stored at ambient temperature until anlyzed.

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

Samples for total Hg (Hg_T) and MMeHg analyses were collected with no headspace in trace-metal-free-certified 250 mL bottles (Nalgene ICHEM). The MMeHg bottles contained a preservative of certified ultra-clean HCl provided by Frontier Global Sciences and Brooks Rand Labs, the analytical laboratories. Sampling for 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 ºC, 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 our equipment, containers, reagents, and procedures introduced any significant contamination.

Invertebrates

The target macroinvertebrates for this study were predatory insects. Depending on their abundance and availability at each sample site, invertebrates collected included larval skimmer and darner dragonflies (Order Odonata, families Libellulidae and Aeshnidae, respectively) and adult water striders (Order Hemiptera, family Gerridae) in 2007. These taxa also were collected at Harley Gulch on October 16, 2002. Taxa collected in 2008, 2010, and 2011 included adult water striders and giant water bugs (Order Hemiptera, family Belostomatidae), two families of Coleoptera [larval water scavenger beetles (family Hydrophilidae), and adult predaceous diving beetles (family Dytiscidae)], two families of larval damselflies [Order Odonata: narrow-winged damselflies (family Coenagrionidae) and spread-winged damselflies (family Lestidae)], two families of larval dragonflies [Order Odonata: skimmer dragonflies (family Libellulidae) and darner dragonflies (family Aeshnidae]), and larval dobsonflies (Order Megaloptera, family Corydalidae).

Invertebrates were collected from all sites, using dip nets and by hand, and placed in Ziploc®plastic bags with native water. Samples were kept in a cooler and allowed to depurate in native water on wet ice for 4–24 hours before processing. Individuals were sorted by family and placed in disposable dishes using Teflon-coated forceps, or by hand while wearing disposable latex gloves. Organisms were rinsed thoroughly with deionized water, patted dry with a clean paper towel, and composited by family, with the goal of obtaining a minimum of 1 g wet biomass per sample. Each sample consisted of 1–40 individuals of the same family (0.39–4.56 g total mass). Sample mass was determined using an electronic balance (± 0.01 g). Samples were placed into chemically cleaned glass jars with Teflon-lined lids and were stored frozen for up to 5 months until they could be shipped to the Brooks Rand Laboratory in Seattle, Wash., for MMeHg and Hg_T analysis.

Frogs

During daylight hours in 2007 and 2008, foothill yellow-legged frogs were collected from Harley Gulch by hand or with a net. Individual frogs were placed in their own plastic Ziploc®bag on wet ice. For each specimen, the site, date, time, and collector were recorded on each specimen bag. Frogs were euthanized humanely on the same day of collection, and were kept frozen until they could be processed within 2 days after collection. Foothill yellow-legged frogs were collected from Harley Gulch and the three reference sites in 1997 and 1998 using the same collection techniques (Hothem and others, 2010).

Each specimen was processed using chemically clean tools, weigh dishes, and disposable latex gloves to avoid cross contamination. Each specimen was thawed, rinsed with tap water to remove debris, and then thoroughly rinsed with deionized water. Excess moisture was removed by patting the specimen dry with a clean paper towel. The total mass (± 0.01 g) for each specimen was determined using an electronic balance. The length from the tip of the snout to the urostyle [snout-vent length (SVL)] (± 0.1 mm) was measured using calipers, and each specimen was examined for gross abnormalities. The digestive tract was removed, and the stomach contents were identified and discarded. The carcass, including the stripped and rinsed digestive tract, was placed in a labeled chemically clean jar (VWR® TraceClean®, which was then sealed with Parafilm® and frozen at –20 ºC, pending chemical analysis. Carcasses of frogs collected in 2008 were analyzed for MMeHg at Brooks Rand Laboratory within 5 months of collection.

Fish

In 2010, California roach (*Hesperoleucus symmetricus*) were collected with a net from site HG8a in Harley Gulch. Fish were placed in a plastic Ziploc® bag on wet ice. Fish were euthanized humanely the same day they were collected and were kept frozen until they could be processed within 2 days after collection. Each specimen was processed using chemically clean tools, weigh dishes, and disposable latex gloves to avoid cross contamination. Each specimen was thawed, rinsed with tap water to remove debris, and then thoroughly rinsed with deionized water. Excess moisture was removed by patting the specimen dry with a clean paper towel. The total mass (± 0.01 g) was determined for each specimen using an electronic balance. The standard length from the tip of the snout to the posterior end of the last vertebra, and total length fromthe tip of the snout to the end of the caudal fin was measured. Each specimen was further examined for gross abnormalities. The digestive tract was removed, and the stomach contents were identified and discarded. The total carcass, including the stripped and rinsed digestive tract, was placed in a labeled chemically clean jar (VWR® TraceClean®), which was then sealed with Parafilm® and frozen at –20 ºC, pending chemical analysis within 30 days.

Analytical Methods

Sediments

Multielement 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 ($SnCl_2$) 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 2.

Waters

Alkalinity as $CaCO_3$ was determined in the laboratory by titration with H_2SO_4, 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. Ion chromatography and alkalinity analyses were performed in USGS laboratories at the Denver Federal Center. 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™ 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 ($SnCl_2$) reduction, two-stage gold amalgamation, and detection by CVAFS (Bloom and others, 1988). MMeHg was liberated from water using an all-Teflon® 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; Revesz 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 Water Resources Division (WRD) 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 as follows (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 CO2 equilibration technique of Epstein and Mayeda (1953), which has been automated (Revesz and Coplen, 2008b). Therefore, both oxygen and hydrogen isotopic ratio measurements are reported as activities. Reporting of Stable Hydrogen and Oxygen Isotope Ratios Oxygen and hydrogen isotopic results are reported in parts per thousand (per mill) 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 mill and -428 per mill, respectively. The 2-sigma uncertainties of oxygen and hydrogen isotopic results are 0.2 per mill and 2 per mill, respectively, unless otherwise indicated. This means that if the same sample were resubmitted for isotopic analysis, the newly measured value would lie within the uncertainty bounds 95 percent of the time.

Frogs, Fish, and Invertebrates

Dry-Weight Correction (percentage Solids) USEPA Method 160.3 (SOP BR-1501)

A solid sample was homogenized and an aliquot was measured into a pre-weighed vessel, dried in an oven overnight, weighed again, and the percentage of dried solid material was calculated. This standard operating procedure (SOP) is analogous to USEPA method 160.3 (Residue, total).

Sample Homogenization (SOP BR-0106)

Once thawed, the samples were homogenized using pre-cleaned commercial-grade homogenization equipment. A homogenization blank was collected after cleaning the equipment and prior to homogenization of the samples. The blank was digested as a tissue sample and analyzed along with the associated homogenates. The result for the homogenization blank was less than one-tenth of the lowest sample result, indicating that no significant contamination occurred during homogenization.

Total Mercury (SOP BR-0002)

Total mercury was analyzed as outlined in EPA method 1631 (SOP BR-0002). Samples were digested in nitric acid (HNO_3) and sulfuric acid (H_2SO_4), and then further oxidized with bromine monochloride (BrCl). Samples were analyzed with stannous chloride ($SnCl_2$) reduction, single gold amalgamation, and CVAFS detection using a BRL Model III CVAFS Mercury Analyzer.

Monomethyl Mercury, USEPA Draft 1630 Modified (SOP BR-0011)

In 2008, all biological samples were analyzed for MMeHg. Samples were prepared by potassium hydroxide (KOH) methanol (CH_3OH) digestion. Samples were analyzed by aqueous-phase ethylation, Tenax trap collection, GC separation, isothermal decomposition, and CVAFS using a BRL Model III CVAFS Mercury Analyzer. All sample results for low-level Hg analysis were blank corrected, as outlined in the calculations section of Brooks Rand SOP BR-0011.

Quality Assurance/Quality Control

At Brooks Rand, duplicate samples were analyzed for Hg at a rate of 5 percent, with at least one duplicate per matrix per analytical run to estimate the precision of the methods. Duplicates were analyzed for MMeHg with relative percent difference between duplicate determinations (RPDs) ranging from 0.7 to 19 percent, all within the allowable criteria of 35 percent. For Hg_T, RPDs ranged from 1 to 21 percent, within the acceptable criterion of less than 30 percent.

To assure that no analyte was added during the processing of the sample, procedural blanks were analyzed at a rate of 5 percent of the total samples, with at least one per matrix per analytical run. The averages for MMeHg blanks ranged from 0.0 to 0.06 ng/g, less than the acceptable criterion of 2.0 ng/g, or twice the minimum detection limit. The averages for Hg_T blanks ranged from 0.004 to 0.04 ng/g, less than the acceptable criterion of 0.08 ng/g.

Spiked samples were analyzed at a rate of 5 percent, with at least one spike per matrix per analytical run. Spikes were samples fortified with a known quantity of analyte and were analyzed as part of the run. Matrix spikes for MMeHg ranged from 97 to 130 percent, and all were within the acceptable criteria (70–130 percent recovery). Duplicate spike RPDs ranged from 0.1 to 22 percent, and all met the criterion of an RPD<35 percent. For Hg_T, matrix spikes ranged from 79 to 115 percent; all were within the acceptable criterion (70–130 percent recovery). Duplicate spike RPDs ranged from 0.3 to 18 percent, and all met the criterion of an RPD < 30 percent.

CRMs were analyzed at a rate of 5 percent to insure that the method worked with naturally incorporated Hg. In 2008, two preparations of CRM-3 produced consistently low recoveries (55–62 percent). Both preparations were analyzed within 28 hours of preparation, and, as demonstrated by further reanalysis, the CRM preparations had not been fully digested to allow for a complete extraction of the MMeHg present. The CRM re-preparations produced acceptable recoveries of 92 percent and 100 percent. In 2010 and 2011, CRMs for MMeHg had recoveries ranging from 78 to 116 percent, within the acceptable criterion of 65 to 135 percent. For Hg_T, recoveries ranged from 97 to 115 percent, within the acceptable criterion of 75 to 135 percent.

Statistical Analyses

Because collection of one composite sample of each invertebrate taxon per site precluded statistical comparisons, only qualitative comparisons were made with previous data and with results from a reference site. Total Hg concentrations in frogs from different sites sampled in 2007 were compared using one-way analysis of variance (ANOVA). When differences among sites were significant, the Tukey pairwise multiple comparison procedure was used. Hg concentrations in frogs were compared using $\log_{10}$-transformed Hg concentrations (wet-weight basis), and where more than one sample was collected per site, geometric means were calculated. With the exception of HG8, only one frog was collected from each site sampled in 2008; therefore, statistical comparisons between sites were not made. Frogs collected in 2008 were analyzed only for MMeHg. To compare Hg_T concentrations in frogs collected in 2008 with frogs from previous years and from reference sites, the MMeHg concentrations in the 2008 frogs were estimated. Since frogs collected in 2007 were found to contain about 50 percent MMeHg, Hg_T in frogs in 2008 was calculated by multiplying the MMeHg concentration by 1.98. The body mass and SVL of the frogs were compared, separated by year and by sex using one-way ANOVA. Where normality failed, Kruskal-Wallis one-way analysis of variance on ranks was used. The relationship between both SVL and body mass and Hg_T concentration was evaluated using linear regression. The significance level for all tests was α=0.05.

Results

Hg and MMeHg in Waters

Concentrations of Hg and MMeHg in waters collected from Harley Gulch are listed in table 3 and shown in figures 20, 21, and 22. Concentrations of Hg_T measured during the high-flow sampling event in March 2011 exceeded levels measured during all other sampling events by several orders of magnitude (fig. 20). This high-flow event was the largest storm of the 2010–2011 winter season. Hg_T concentrations measured during the second high-flow sampling event in June 2011 are lower and comparable to levels measured during low-flow conditions. Runoff during this event was minimal as rainfall was relatively low, and the surface soils in the watershed had dried during the dry period before this late-season storm. Concentrations of Hg_T follow a similar trend moving downstream during both low- and high-flow conditions. Hg_T levels are highest at sample sites HG1, HG1.5 and HG2, in the west fork of Harley Gulch, immediately downstream from the Abbott-Turkey Run mine. Hg_T levels at sample site HG1 under high-flow conditions were extremely high, 429,000 ng/L, but during all other sampling events Hg_T levels were lower (301–825 ng/L), but still highly elevated. During the May 2011 sampling event, Hg_T levels measured at sample site HG1.5 in the middle of the wetland area were very high (2,300 ng/L), and were higher than Hg_T levels at site HG1 immediately downstream from the mine (624 ng/L). In the east fork of Harley Gulch (sample site HG3), where no mining occurred, Hg_T levels (4.08-32.8 ng/L) for all sampling events were several orders of magnitude lower than levels measured in the West Fork and reflect background concentrations (fig. 20). Downstream from the confluence of the highly contaminated West Fork and the relatively clean East Fork, Hg_T levels in waters were elevated, but declined systematically downstream to site HG10, where the lowest concentration (18.3 ng/L) was measured (fig. 20).

Filtered Hg (Hg_F) concentrations in waters sampled under high-flow conditions were generally higher or comparable to Hg_F concentrations in water sampled under low-flow conditions (fig. 21). Concentrations of Hg_F were highest in the West Fork of Harley Gulch at sample sites HG1, HG1.5, and HG2. Hg_F levels were slightly elevated in the East Fork of Harley Gulch at sample site HG3 under high-flow conditions in the March 2011 sampling event. In general, the concentration of Hg_F systematically decreases downstream from the confluence of the East and West Forks of Harley Gulch at site HG4, to the most downstream site sampled, HG10 (fig. 21). During the May 2011 sampling event, Hg_F concentration at sample site HG1.5 was considerably higher than at sample site HG1, and the percentage of dissolved Hg (Hg_F/Hg_T) increased downstream from sample site HG1 to HG1.5. Under low-flow conditions at site HG1, the percentage of dissolved Hg was very high in June of 2010 (78.4 percent), and considerably less in May of 2011 (28.8 percent). During the high-flow sampling event of March 2011, when meteoric input dominated Harley Gulch water chemistry, the percentage of dissolved Hg at site HG1 was extremely low (0.79 percent) indicating that essentially all of the Hg was being transported in the particulate phase. During low-flow conditions in June 2010, Hg_F decreased systematically downstream from sample site HG5 to HG10, mirroring the decline of Hg_T (fig. 21).

Concentrations of MMeHg in unfiltered water varied considerably depending on flow conditions and distance downstream from the mine (fig. 22). The highest MMeHg concentration measured(15.8 ng/L) was at sample site HG1, just below the mine, during the March 2011 high-flow event. The highest MMeHg concentrations were measured at site HG1 for all sampling events, except for the June 2010 sampling, when the highest concentration occurred at the end of the wetland area at site HG2. For all sampling events, the lowest MMeHg concentrations measured always occurred in the East Fork of Harley Gulch at sample site HG3, the East Fork Harley Gulch reference site. Concentrations of MMeHg levels were highest in the West Fork of Harley Gulch and declined downstream from sample site HG1 to sample site HG4, located below the confluence of the East and West Forks of Harley Gulch. Downstream from the confluence, MMeHg concentration increased from sample site HG5 to sample site HG7 during the low-flow sampling events (fig. 22). Further downstream from sample site HG7, MMeHg levels declined systematically to sample site HG10. As a percentage of Hg_T, MMeHg levels are higher during low-flow conditions (table 3).

Hg and MMeHg in Sediments

Previous work in 2003 indicated Hg concentrations as high as 100 ppm in sediments collected from the West Fork of Harley Gulch prior to cleanup of the mine (Ichikawa and Jakl, 2004). Sediment from the active channel of Harley Gulch was collected during two low-flow sampling events in 2010 and one in 2011, four and five years respectively after cleanup of the mine had been completed in 2007. For this study, sediment was analyzed for Hg and MMeHg; the results are listed in table 2 and shown in figs. 23 and 24. Storm sediment deposited outside and above the active channel of Harley Gulch during high-flow events in the winter of 2011 also was sampled and analyzed. The results for storm sediment and sediment from the active channel are listed in table 5 and shown in fig. 24.

The Hg concentrations in sediment from the active channel remain elevated and consistent across sampling events (fig. 23). Hg concentrations in sediment are highest at sample site HG1, immediately downstream from the mine. At sample site HG1, Hg concentrations in sediment in the active channel ranged from 44,700 –78,300 ng/g (ppb) the concentration was greater than 100,000 ng/g in storm sediment (table 4). Concentrations of Co, Ni, and W also are elevated and indicate that tailings or mineralized rock comprise a significant portion of the sediment (table 5). Sediment samples from the active channel collected during the first low-flow sampling event in June 2010 showed a decrease in Hg downstream from sample site HG1 (fig. 23). Sediment collected at sample site HG4 during the second low-flow sampling event in September 2010 contained Hg concentration that was considerably lower, but still elevated. Sediment samples collected during the third low-flow sampling event in May 2011 showed an irregular trend, with highly elevated Hg levels downstream from the confluence of the East and West Forks at sample sites HG5 and HG7. Samples collected from sample site HG3, the reference site in the East Fork of Harley Gulch, had much lower levels of Hg than did samples collected from the West Fork. In the active channel, Hg concentration ranges from 213–420 ng/g (table 3). In the East Fork, where there are no mines, waters contained lower concentrations of Hg, Co, Ni, and W (table 5); however, Hg concentrations in the East Fork were elevated relative to regional background Hg levels. At the sample site furthest downstream, HG10, sediment in the active channel primarily is derived from Great Valley Sequence siltstone and sandstone present in bedrock exposed along the creek bank. Low concentrations of Co, Ni, and W, as well as near-background Hg levels (60–190 ng/g) indicate that the sediment in the East Fork is not contaminated with tailings (table 5).

Unlike Hg levels in sediments, concentrations of MMeHg are high in sediment samples collected at several downstream sites in Harley Gulch (fig. 23). During the first low-flow sampling event in June 2010, MMeHg concentrations were low at sample site HG1 (0.098 ng/g), immediately downstream from the mine. At sample site HG2, downstream from the input from the wetlands, MMeHg concentration in sediment was elevated (3.79 ng/g). MMeHg levels in sediment collected below the confluence of the East and West Forks of Harley Gulch at sample site HG4 were very high (36.3 ng/g), but declined to 0.89 ng/g downstream from the confluence at sample site HG5. From sample sites HG5 to HG7, MMeHg concentrations increased systematically downstream. MMeHg levels remained high downstream from sample sites HG7 to HG9.5, but declined at sample site HG10 (fig. 23). Sediment samples collected during the second low-flow sampling event in September 2010 at site HG4 were elevated, but were considerably lower than the results of June 2010. During the third low-flow sampling event, in May 2011, MMeHg levels were lower than concentrations at the same site during previous sampling events. During this sampling event, MMeHg concentrations increased from sample site HG1 to sample site HG1.5 in the middle of the wetland area, where connate groundwater enters the wetland. MMeHg levels also were elevated in sediment collected at sample site HG4 during this sampling event, but decreased to lower levels further downstream (fig. 23).

During two low-flow sampling events, sediment samples were collected to assess the concentrations of Hg storm sediment deposited during the winter high-flow events as compared to sediment in the active stream channel. Hg concentrations were considerably higher in storm sediment than in active-stream channel sediment at all sample sites, except HG7 (table 5, fig. 24). The highest concentrations of Hg in storm sediment (136,000 ng/g) occurred at site HG20 (about 25m upstream from sample site HG4) (table 5), and the lowest concentration (210 ng/g) occurred in storm sediment in the East Fork of Harley Gulch (table 4).

Water Chemistry

Major- and minor-element concentrations in waters collected from Harley Gulch are listed in tables 4, 6, and 7. Waters in Harley Gulch are predominantly Mg-CO_3-SO_4 waters that have elevated concentrations of Ca, Cl, Fe, Na, Hg, Ti and W. Stream water in Harley Gulch is alkaline as a result of interaction with the serpentinite country rock.

There are three water sources in the Harley Gulch watershed. Meteoric water dominates flows in the wet season, while connate groundwater dominates flows in the dry season. These dry-season flows of connate groundwater support the abundant riparian vegetation between sample sites HG4 and HG7 (fig. 25). The third source of water, thermal water from the Turkey Run adit, dominates flows only in the upper most part of the watershed during the dry season (sample site HG1). Meteoric water is isotopically light, (δ^{18}O=-8.7, δ^{2}H=-61.49) and has low concentrations of chloride and sulfate. The thermal water at the Turkey Run adit is isotopically heavy (δ^{18}O=-5.8, δ^{2}H=-52.2) and has high concentrations of SO_4 (2,020 µg/L) (ppm), Cl (1,150 µg/L), and CO_3 (1,938 µg/L), as well as elevated concentrations of B (37.6 µg/L), Li (1.5 µg/L), and Mg (224 µg/L) (Goff and Janik, 1993). The connate groundwater is isotopically distinct and has the heaviest δ^{18}O (-5.43) and δ^{2}H (-48.5) of waters sampled in the Harley Gulch watershed (fig. 26, table 7). The connate groundwater has high concentrations of SO_4 (1,424 µg/L), Cl (874 µg/L), and CO_3 (907 µg/L), as well as elevated concentrations of B (21.8 µg/L), Li (0.67 µg/L), and Mg (309 µg/L) (sample 10HG7, tables 3 and 7). The thermal water and the connate groundwater have similar suites of elements that are elevated, indicating that both are derived from the same geological source, water lodged in the Great Valley Sequence; however, the two waters can be distinguished based on isotopes and chemical concentration of selected elements. The thermal water has much higher concentrations of SO_4, Cl, and CO_3 than the connate groundwater. The concentration of Hg_F in the thermal water is very low, ranging from 2–7 ng/L. The connate groundwater has much higher concentrations of Hg_F, ranging from 40 to 811 ng/L, and as mentioned above, is isotopically heavier than the thermal water.

Thermal-water effluent from the Turkey Run mine contributes only to the flow in the upper most part of Harley Gulch and it becomes a minor component farther downstream from site HG1 owing to its relatively small volume. During the dry season, the thermal water does not flow into the lower reach of Harley below site HG2. Depending on several factors, including seasonality, temperature, and rainfall, the creek water at site HG1, located just downstream from the input of thermal water, is a variable mixture of meteoric water and thermal effluent. During the dry season, thermal water dominates water chemistry at sample site HG1; meteoric water dominates this section of the creek during the wet season. Farther downstream, at site HG1.5, thermal water is not a significant component of creek water, and instead the waters are a mixture of meteoric water and connate groundwater. The connate groundwater first enters Harley Gulch at sample site HG1.5, and then again in the stream segment between sample sites HG4 and HG7. During the dry summer season, Harley Gulch stream water is dominated by input from connate groundwater, resulting in creek water with high levels of Mg, SO_4, and Hg_F and enrichment in the stable-isotopes δ^{18}O and δ^{2}H. During the rainy season, meteoric water dominates Harley Gulch, and waters are isotopically light and contain high levels of particulate Hg.

Stable-isotope levels in water collected from Harley Gulch provide evidence for a complex system of connate groundwater input and mixing with meteoric water. Each sampling event produced a distinct trend line of waters moving away from the global meteoric water line (GMWL) (table 8, figs. 26 and 25). During the first low-flow sampling event in 2010 (fig. 26, data highlighted in red), waters collected at sample site HG1 were isotopically heavy from input thermal-water effluent from the Turkey Run Mine. The creek water became isotopically lighter towards the confluence of the East and West Forks of Harley Gulch at sample site HG4 as it mixed with meteoric water (fig. 27). Then waters became isotopically heavier downstream from site HG4 reaching a maximum value at site HG7 as the connate groundwater input increased in this segment of the creek (fig. 27). Downstream from site HG7, waters became isotopically lighter as meteoric water increased in the segment of the creek to sample site HG10. During the low-flow sampling event in May 2011, waters were heaviest in the middle of the wetlands at sample site HG1.5, and waters were light downstream from the confluence in Harley Gulch, indicating that meteoric water dominated downstream water chemistry. Waters collected during the high-flow sampling event of March 2011 were isotopically light, with all samples plotting above the GMWL (fig. 26). These samples were collected during a major storm, during which flow rates in Harley Gulch were at an annual peak. Waters collected during the high-flow sampling event of June 2011 were influenced by connate groundwater input, plotting below the GMWL, with the isotopically heaviest water occurring at sample site HG2, downstream from the wetlands (fig. 26), indicating that connate groundwater was actively entering the creek in the central part of the wetlands in the area of site HG1.5. Waters collected in the East Fork of Harley Gulch at sample site HG3 typically were among the lightest isotopically in the watershed for all sampling events, and they reflect the dominance of meteoric water and the lower amounts of connate groundwater in this section of the watershed. These patterns suggest two main inputs of isotopically-heavy connate groundwater—one in the middle of the wetland area, and a second area farther downstream between sample site HG4 to HG7.

The composition of waters in Harley Gulch reflect the three end-member water sources, and the contribution of each can be calculated based on the isotopic and chemical composition of each source. For the meteoric water source, the isotopic and chemical composition of surface water in a nearby watershed, the Fresh Water Branch of Sulphur Creek, was used. This watershed does not contain thermal or connate groundwater. The isotopic and chemical composition of the thermal-water source is from waters sampled at the Turkey Run adit. For the connate groundwater source, the isotopic and chemical composition of Harley Gulch creek water at sample site HG7 was used. However, in 2011, the hydrology of the watershed had changed such that the isotopically heaviest connate groundwater emanated at site HG1.5, and the water chemistry at this site was used for the connate-groundwater source for the 2011 sampling events. The percentage of thermal-water and connate-groundwater source contribution to Harley Gulch stream water was calculated using data from thermal-water effluent sampled in 1997 and connate-groundwater sampled in 2010 and 2011. These calculations are listed in table 8.

The calculations of water composition demonstrate the dominance of each source of fluid to Harley Gulch based on flow conditions and seasonality. During the low-flow sampling event in June 2010, mine effluent was dominant in the upper section of the West Fork of Harley Gulch, and the connate-groundwater source near sample site HG7 also contributed significantly to stream chemistry. During the low-flow sampling event in May 2011, mine-effluent was less of a contributor to stream chemistry, and connate-groundwater from the springs in the wetlands near site HG1.5 was dominant. Under high-flow conditions in both March and June 2011, meteoric water was more dominant, with only minor signals of mine-effluent and connate-groundwater influence. In the East Fork of Harley Gulch at sample site HG3, connate groundwater is a significant component of the creek water under low-flow conditions, but it decreased to about 20 percent under high-flow conditions because meteoric water diluted the groundwater source (table 8). The difference in isotopic composition of waters collected at sample site HG3 in the East

Fork during two low-flow sampling events in June 2010 and May 2011 indicates the complexity of water sources to Harley Gulch and suggests that evaporation may contribute to isotopic composition of stream waters.

Biogenic Sediment

Biogenic sediment accumulates in the upper part of Harley Gulch between sample sites HG2 and HG10 during the dry seasons. The biogenic sediment covers the creek bed with a tan 1–2 cm thick layer of sediment that consists of living and recently expired diatoms (figs. 28 and 29). Below this surface layer, the biogenic sediment has a black color owing tothe presence of iron sulfide (FeS) (figs. 12 and 30). The black biogenic sediment consists of diatom fragments and minor amounts of clay and bioclastic carbonate grains. X-ray diffraction of the biogenic sediment shows that a silica phase is the primary component of the sediment, and it indicates that silica shells of diatoms are the primary component of the sediment. During the low-flow conditions in the dry season, particulate transport is minimal and the diatoms accumulate essentially in place. The thickness of the biogenic sediment is variable, with deep pools in the creek containing up to several tens of centimeters of sediment. In seasonally dry segments of the creek, the biogenic sediment is light gray and has the consistency of diatomite (fig. 31). The concentration of Hg in the biogenic sediment typically is high and ranges from 0.39 to 50.3 μg/g (table 4). The highest Hg concentrations in biogenic sediment occur upstream from, and at site HG4, and decrease systematically downstream to site HG9.5 (in between sites HG9 and HG10).

Several types of diatoms occur in the biogenic sediment (fig. 32) and the species that predominate change in differenct segments of the creek. At sample site HG6 a diverse assemblage of *Nitzschia* species and a number of *Rhopalodia* are present. These benthic species prefer neutral to alkaline pH and can tolerate backish water. At sample site HG7 the most common species is *Mastogloia smithii*, but a number of other species are also present. The abundance of a number of diatom species likely reflects the high carbonate and chloride concentration of the water but the presence of species more typically found in deeper water is unusual.

Carbonates

The biogenic sediment contains variable amounts of calcite ($CaCO_3$) that occurs as aggregates and individual grains. The waters in the upper part of Harley Gulch have high alkalinity and Ca content (table 3). Calcite precipitates in the creek water when oversaturation occurs, with respect to Ca and CO_3, as the creek water evaporates during the dry season.

Sulfides

Micron to submicron grains of HgS occur in the biogenic sediment as individual grains and aggregates in association with the diatoms in the black biogenic sediment. Scanning electron microscopy (SEM) has documented the presence of HgS grains, and EDAX (Energy Dispersive Spectroscopy) has demonstrated that Hg and S are the only two elements in the phase (fig. 33). The HgS typically occurs as aggregates of framboids amidst fragments of diatom shells (fig. 34). Submicron grains of FeS are the most abundant sulfide visible under the SEM, and they occur as aggregates and individual grains in association with the fragments of diatom shells (fig. 35). EDAX spectra confirm that the FeS grains contain only Fe and S.

Sulfates

Barite, barium sulfate ($BaSO_4$), forming hexagonal-appearing crystals and aggregates of acicular crystals, is common in the biogenic sediment (fig. 36). Barite spheres with dissolution pits also have been observed. Microbially mediated precipitation of barite results in crystal forms other than the more typical orthorhombic tabular crystals (Bonny and Jones, 2008). The Ba and SO_4 concentrations of creek water in the upper part of Harley Gulch are high because of the input of connate groundwater in this segment of the creek. The exact mechanism of barite precipitation in Harley Gulch waters is unknown. However, it is likely that the precipitation of barite is mediated by bacteria (Baldi et al, 1996; Bonny and Jones, 2008; González and others, 2003; Senko and others, 2004), and that the sulfate-reducing bacteria present in Harley Gulch are involved in the precipitation and dissolution of batire. Less commonly, a magnesium-sulfate phase, likely epsomite, occurs in the dry biogenic sediment (fig. 37). The precipitation of this phase reflects the high Mg and sulfate concentrations that occur in the creek water, which becomes concentrated as portions of the creek cease to flow and dry completely in the summer months.

Oxides

Less common phases in the black biogenic sediment include a tungsten (W) oxide and a titanium (Ti) oxide phase. Both W and Ti concentrations are elevated in the connate groundwater that occurs in the upper part of Harley Gulch, and this likely causes the precipitation of the W and Ti phases (fig. 39).

Invertebrates

Composite samples of aquatic invertebrates were collected from 13 sites in 2008, from 16 sites in 2010, and from 7 sites in 2011 for comparison with samples analyzed in 2002 and 2007 at Harley Gulch. Invertebrates that might be consumed by frogs were also collected. Based on food habits analyses, two of the 15 frogs from 2007 and one of the 7 frogs from 2008 had consumed water striders; three frogs from 2007 had consumed damselflies.

Trends similar to those observed in 2007 were evident in the 2008, 2010, and 2011 samples. Concentrations of MMeHg in invertebrates appear to decrease with increasing distance from the Abbott-Turkey Run Hg mines, with the exception of the predaceous diving beetles (fig. 40), which were highly variable. Concentrations of MMeHg in water striders and larval dragonflies collected in 2007 were higher than in similar taxa collected from similar sites in 2008, 2010, and 2011. However, samples collected at comparable sites in 2011, while mostly lower in MMeHg than 2007 samples, generally were higher in MMeHg than samples from 2008 and 2010 (figs. 40–44).

Concentrations observed in samples collected from the East Fork site (HG3) were considered background values because the site is above contamination from the Abbott-Turkey Run mines. In 2008, however, the highest MMeHg concentration found in Harley Gulch was found in Belostomatidae from HG3 (1.71 µg/g) (table 9). These predatory insects feed on aquatic insects, as well as frogs (Benard, 2007) and small fish, and it is common for them to bioaccumulate high concentrations of MMeHg (Alpers and others, 2005). Another Belostomatid collected from HG5 had the second highest concentration of MMeHg in 2008 (1.45 µg/g) (table 9). The lowest MMeHg concentration in 2008 was found in damselflies (Lestidae) from the most downstream site in the watershed, HG14 (0.0039 µg/g) (table 9, fig. 43). In 2010, the highest

MMeHg concentration was found in Dytiscidae from HG6 (0.235 µg/g) (fig. 40), and the lowest concentration was found in Lestidae from HG14 (0.0029 µg/g) (fig. 43). In 2011, fewer sites, all located in the upper part of Harley Gulch, were sampled (fig. 2). The sample with the highest concentration of MMeHg was Coenagrionidae from site HG2 in the wetlands (0.604 µg/g). That sample also had a high concentration of Hg_T (4.5 µg/g), but the percentage of MMeHg was only 13.4. The samples with the five highest concentrations of Hg_T in 2011 were from wetlands sites (HG1 and HG2: 1.24–9.94 µg/g) (fig. 45). The samples with five of the seven highest MMeHg concentrations also were from sites HG1 and HG2 (0.228–0.604 µg/g);however, six of the nine samples with the lowest MMeHg: Hg_T ratios were from the two wetlands sites. At HG1, the percentage of MMeHg in the three collected samples ranged from 1.90 to 2.61. For comparison, all samples from HG3, the reference site, had >30 percent MMeHg (fig. 46). Total Hg concentrations for taxa collected from the wetlands sites (HG1, HG2, and HG2a) increased from 2010 to 2011, but the percentage MMeHg tended not to change (fig. 45). During 2007–2011, the percentage MMeHg declined for water striders (Gerridae) and dragonflies (Libellulidae) at the reference site (HG3) as well as at downstream sites (HG4, HG5, HG6, and HG7), apparently in relation to availability of the HgT and MMeHg in the system those years (fig. 46).

Slotton and others (2004) collected invertebrates from the Cache Creek watershed and found that MMeHg was present at higher concentrations in aquatic invertebrates from Harley Gulch than at any other site sampled in the watershed. Samples of damselflies (Coenagrionidae), dobsonflies (Corydalidae), net-spinning caddisflies (Hydropsychidae), and creeping water bugs (Naucoridae) were collected on May 8, 2000, 13–27 days earlier than the 2008 collections. Those samples had average MMeHg concentrations of 0.296, 0.582, 0.274, and 0.937 µg/g, respectively, for the four taxa. Although the taxa were not identical, the mean concentrations of MMeHg in the invertebrates collected in 2002 were higher, those collected in 2007 were similar, and those collected in 2008, 2010, and 2011 were generally lower than those collected by Slotton and others (2004).

Frogs

On May 16, 2007, two foothill yellow-legged frogs were collected from the East Fork (HG3) and 13 more were collected from four lower Harley Gulch sites (HG4 through HG7). On June 4, 2008, seven yellow-legged frogs were collected from lower Harley Gulch (one each from HG5, HG9, HG10, HG11, and HG13, and two from HG8) (table 10).

Adult frog sizes within and between 2007 and 2008 were compared. There were no differences between genders for mass (H=0.102; P=0.805) or SVL (F=1.064; P=0.323) in 2007 or in 2008 for mass (F=1.187; P=0.326) or SVL (F=1.605; P=0.261). In addition, neither the mass nor the SVL for either the males or the females differed by year (P >0.23). Although the mean mass (10.54 g) and the mean SVL (45.77 mm) of the females from both years combined were greater than the mean mass (7.71 g) and SVL (39.45 mm) of the males, neither difference was significant (H=1.269; P=0.260 and F=2.504; P=0.130, respectively). The correlation between SVL and body mass (R^2=0.947) for all 21 of the Harley Gulch frogs collected in 2007 and 2008 was significant (F=359.3; P <0.001).

Neither the correlation between SVL and Hg_T in frogs from 2007 (F=1.84; P=0.202) nor between SVL and MMeHg in frogs from 2008 (F=2.716; P=0.160) was significant. There was no significant correlation between body mass and Hg_T in frogs collected from Harley Gulch in 2007 (F=1.33; P=0.274), or between mass and MMeHg in frogs collected in 2008 (F=3.084; P=0.139). There was no significant difference between geometric mean Hg_T concentrations in males (0.800

μg/g) and females (0.830 μg/g) (F=0.034; P=0.856) from lower Harley Gulch collected in 2007, nor between MMeHg concentrations in males (0.365 μg/g) and females (0.255 μg/g) (F=0.958; P=0.373) collected in 2008. These low correlations between size and gender and Hg concentration in frogs from Harley Gulch, indicate that the differences in Hg_T and MMeHg concentrations are related to site differences in Hg contamination.

Geometric-mean concentrations of Hg_T in frogs collected from four lower Harley Gulch sites in 2007 (table 10) were not significantly different from one another (F=0.238; P=0.868), or from frogs collected from Harley Gulch in 1997 (table 11; fig. 47). All lower Harley Gulch frogs collected in 2007 had significantly higher geometric-mean concentrations of Hg_T than did the three reference sites (table 11) and the East Fork of Harley Gulch site (HG3) (fig. 47). In 2008, all frogs were collected from below the confluence of the two forks of Harley Gulch and were analyzed for MMeHg only. MMeHg concentrations ranged from 0.135 μg/g to 0.468 μg/g, with the highest concentration found in the frog from HG5. To compare Hg concentration in 2008 with previous years, Hg_T concentrations in 2008 were estimated based on the percentage MMeHg in frogs analyzed for both Hg_T and MMeHg in 2007 (see statistics section). Estimated Hg_T values found in frogs from sites HG5 and HG8 in 2008 were comparable to values found in frogs from nearby sites (HG4–HG7) in 2007 (fig. 48). However, as was found for the invertebrates, the concentrations of MMeHg in frogs tended to decrease going downstream (fig. 49). The MMeHg concentration in the frog from site HG5 (0.468 μg/g) was about 3 times higher than the concentration of MMeHg in the frog collected about 5,000 m further downstream at site HG13 (0.152 μg/g). Based on linear regression analysis, there was a significant decrease in MMeHg concentration in foothill yellow-legged frogs with distance from the mines (R^2=0.708; P=0.036).

For comparison, the overall mean Hg_T concentration for the lower Harley Gulch frogs in 2007 (0.814 μg/g) was similar to the mean observed for leg muscle in pig frogs (*Rana grylio*) (0.911 μg/g) from a highly contaminated site in the Florida Everglades (Ugarte and others, 2005). The estimated mean Hg_T of the three frogs collected in the same general area of lower Harley Gulch was 0.902 μg/g, a value similar to both the 2007 mean and the mean from the Everglades.

Based on the mean Hg_T concentration in the frogs from East Fork of Harley Gulch in 2007, there do not appear to be significant sources of Hg contamination east of the confluence of the two forks. The Abbott-Turkey Run Hg mines upstream of the West Fork of Harley Gulch (fig. 1) appear to be important sources of mercury to the West Fork and further downstream in Harley Gulch.

The Hg_T concentration in 31 percent of the 13 frogs collected from lower Harley Gulch in 2007 exceeded the FDA criterion (1.0 μg/g) for regulation of commercial fish (U.S. Food and Drug Administration, 2001), while none of the seven frogs collected in 2008 exceeded that criterion. In addition, the Hg concentrations in 100 percent of the 2007 frogs and 43 percent of the 2008 frogs exceeded the USEPA Hg criterion (0.3 μg/g) for issuance of health advisories for human fish consumption (U.S. Environmental Protection Agency, 2001). The Hg_T in the 13 frogs collected in 2007, the estimated Hg_T in the seven frogs collected in 2008, and the Hg_T in the frogs collected from Harley Gulch in 1997–1998 all exceeded the Hg criterion for the protection of piscivorous wildlife (0.077 μg/g: the no-effect level) (U.S. Environmental Protection Agency, 1997). Therefore, Hg concentrations in foothill yellow-legged frogs from all years were high enough to pose a potential hazard to their predators.

Fish

Seven fish were collected from site HG8a in Harley Gulch (table 12, fig. 16). Hg_T concentrations in fish ranged from 0.264 µg/g, ww to 0.414 µg/g, ww. MMeHg in fish ranged from 0.173 µg/g, ww to 0.356 µg/g, ww. Percent MMeHg in fish ranged from 65 percent to 125 percent.

Conclusions

Concentrations of MMeHg in water exceed the Harley Gulch TMDL aqueous annual median concentration of 0.09 ng/L at all sample sites and flow conditions, except in the East Fork of Harley Gulch (HG3). High aqueous concentrations of MMeHg were measured under both high and low conditions, and the highest concentrations occurred in the West Fork of Harley Gulch downstream from the mine. Under high-flow conditions at site HG1 in March 2011, the aqueous MMeHg concentration was the highest measured (15.8 ng/L) indicating export of MMeHg from the mine. Under low-flow conditions in June 2010 at site HG2 downstream from the wetland the MMeHg aqueous concentration also was high (12.1 ng/L) indicating export of MMeHg from the wetland area. During the low-flow conditions in June 2010, the input of connate groundwater between sample sites HG4 and HG7 correlated with an increase in aqueous MMeHg concentration in that segment of the creek, despite a corresponding decrease in Hg_T in the creek segment. The data indicate that connate groundwater contributes to MMeHg production in the upper part of Harley Gulch between sites HG4 and HG7. However, at the entry area of groundwater to the wetland at site HG1.5, aqueous MMeHg is low despite very high filtered and Hg_T concentrations, indicating that several factors, other than just connate groundwater input, play an important role in the methylation of Hg in Harley Gulch.

MMeHg levels in active stream-channel sediment in Harley Gulch show a complex pattern. MMeHg levels in sediment are low at sample site HG1, immediately downstream from the mine, and increase to elevated levels in the middle of the wetland area (sample site HG1.5 and immediately downstream at sample site HG2). The wetland environment is, therefore, favorable for the methylation of Hg. The systematic increase in MMeHg concentration in sediments from sample sites HG5 to HG7 (June 2010 sampling event) corresponds to the input of connate groundwater in this segment of the creek. Thus, the connate groundwater contributes to MMeHg production. However, the high concentrations of MMeHg in sediments collected in Harley Gulch are largely caused by the unusual abundance of diatoms in the biogenic sediment that occurs between sample sites HG2 and HG 9.5. Because the diatoms in the biogenic sediment bioaccumulate Hg and MMeHg, the concentrations of Hg and MMeHg in the biogenic sediment are much higher than in clastic sediment.

Phytoplankton are important in the Hg cycle because they are the entry point of Hg and MMeHg into the food web (fig. 50). The bioaccumulation factor between phytoplankton and water is the highest for any of the Hg and MMeHg trophic transfers. Bioaccumulation factors between phytoplankton and water are highly variable and can range from 26,000 to 50,000 for Hg, and 19,000 to 1,460,000 for MMeHg (Kuwabara and others, 2005; Pickhardt and Fisher, 2007). As a result, phytoplankton, such as diatoms, can have high concentrations of Hg and MMeHg. In the upper part of Harley Gulch where connate groundwater with high concentrations of Hg enters the creek, the creek water has high concentrations of Hg and this results in high bioaccumulation of Hg and MMeHg in the diatoms

The bioaccumulation factor between phytoplankton in the biogenic sediment in Harley Gulch and total Hg (Hg_T) and filtered Hg (Hg_F) in water is high: 37,500 for Hg_T and 60,000 for Hg_F (fig. 51). The linear relationship between both Hg_T and Hg_F in water and the concentration of Hg in the biogenic sediment demonstrates a positive relationship between Hg concentration in streamwater and Hg concentration in the diatoms in the biogenic sediment. Based on this relationship and association of HgS with the reduced black biogenic sediment, a two-step model for the formation of Hg enriched biogenic sediment is proposed (fig. 52). In the first step, Hg and MMeHg are bioaccumulated in living diatoms. Because the concentration of Hg in the connate groundwater in the upper part of Harley Gulch is elevated, the diatoms initially have a high concentration of Hg and MMeHg. In the second step of the process, the expired diatoms release Hg and MMeHg to pore fluids of the biogenic sediment. Because the creek water has high SO_4 and Fe concentrations, SO_4-reducing bacteria reduce SO_4 to sulfide which then reacts with the Hg in the pore fluids to precipitate submicron-size grains of HgS. The Fe in the pore fluids also reacts with the sulfide, and precipitates as FeS, which gives the sediment its black color. High barium and sulfate concentrations in the pore waters result in microbially mediated precipitation of unusual crystal forms of barite, though the exact mechanism of this precipitation is not completely understood. The high concentration of W and Ti in the pore fluid leads to precipitation of W and Ti oxide phases. The resulting biogenic sediment is enriched in HgS, FeS, barite, W, and Ti oxides. The biogenic sediment also has extremely high MMeHg concentrations ranging from 11.1 to 36.3 ng/g because of the high bioaccumulation factor for MMeHg between water and diatoms. This natural Hg and MMeHg trap has not been previously documented, and it is a continuing source of Hg- and MMeHg-enriched material in sediment in Harley Gulch. The biogenic sediment is very fine grained and is transported downstream to the Harley Gulch delta and into Cache Creek during the first high-flow events in the early part of the winter wet season. The relative magnitude of Hg and MMeHg released to Harley Gulch from this natural biogenic source as compared to the mining source needs to be documented further. However, the concentrations of Hg in waters sampled during high-flow events and in storm sediment bring significant amounts of Hg into Harley Gulch from the Abbott-Turkey Run mine 4 years after clean up.

MMeHg levels in biota are highest immediately downstream from the mine at site HG1. The high levels of Hg_T and MMeHg in biota at site HG1 correlate with high levels of Hg and MMeHg in water from the mine areaconsisting of meteoric runoff and release of thermal water. Below site HG1, levels of Hg_T and MMeHg remain elevated in all trophic levels downstream to site HG7. Connate groundwater with elevated concentrations of Hg and biogenic sediment enriched in Hg and MMeHg are present and contribute to the elevated levels of Hg_T and MMeHg in biota in this segment.

The source of Hg_T and MMeHg in biota probably is not only the Abbott-Turkey Run mine, but also connate groundwater and biogenic sediment present in Harley Gulch. These natural sources of Hg and MMeHg in the upper part of Harley Gulch significantly contribute to uptake of Hg and MMeHg by biota. If release of Hg and MMeHg from the mine can be controlled in the future with further remediation, the natural sources will still contribute to elevated levels of Hg and MMeHg in biota. Presently, both natural and mining sources of Hg and MMeHg continue to impact biota in Harley Gulch.

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References Cited

Alpers, C.N., M.P. Hunerlach, J.T. May, R.L. Hothem, H.E. Taylor, R.C. Antweiler, J.F. DeWild, and D.A. Lawler. 2005. Geochemical characterization of water, sediment, and biota affected by mercury contamination and acidic drainage from historical gold mining, Greenhorn Creek, Nevada County, California, 1999–2001. U.S. Geological Survey, Scientific Investigations Report 2004-5251, 278 pp.

Baldi, F., Pepi, M., Burrini, D., Kniewald, G., Scali, D., and Lanciotti, E., 1996, Dissolution of barium from barite in sewage sludges and cultures of *Desulfobibrio desulfuricans*: Applied and Environmental Microbiology, v. 62, p. 2398–2404.

Benard, M.F., 2007, Predators and mates—conflicting selection on the size of male Pacific treefrogs (*Pseudacris regilla*): Journal of Herpetology, v. 41, p. 317–320.

Bloom, N.S., 1989, Determination of picogram levels of methylmercury by aqueous phase ethylation, followed by cryogenic gas chromatography with cold vapour atomic fluorescence detection: Canadian Journal of Fisheries and Aquatic Sciences, v. 46, p. 1131–1140.

Bloom, N.S., 1995, Mercury as a case study of ultra-clean sample handling and storage in aquatic trace metal research: Environmental Laboratory, v. 3–4, p. 20–25.

Bloom, N.S., Crecelius, E.A., and Fitzgerald, W.F., 1988, Determination of volatile mercury species at the picogram level by low temperature gas chromatography with cold vapor atomic fluorescence detection: Analytica Chimica Acta, v. 208, p. 151–161.

Bonny, S.M., and Jones, B., 2008, Experimental precipitation of barite among streamers of sulphur-oxidizing bacteria: Journal of Sedimentary Research, v. 78, p. 357-365.

Central Valley Regional Water Quality Control Board. 2003. 2003 CWA section 303(d) list of water quality limited segment, accessed 9/17/11 at www.watercoards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml.

Churchill, R., and Clinkenbeard, J., 2003, Assessment of the feasibility of remediation of mercury mine sources in the Cache Creek watershed–CALFED final report and appendices, accessed 9/17/11 at *http://loer.tamug.tamu.edi/calfed/Report/Final/Calfed_Mercury_Final_Report_Task5C1_091503.pdf*.

Cooke, A.S. 1981. Tadpoles as indicators of harmful levels of pollution in the field: Environmental Pollution (Serial A), v. 25, p. 123–133.

Coplen, T. B., 1994. Reporting of Stable Hydrogen, Carbon, and Oxygen Isotopic Abundances, Pure and Applied Chemistry, v. 66, p. 273-276.

Coplen, T. B., Wildman, J. D. and Chen, J., 1991. Improvements in the Gaseous Hydrogen-Water Equilibration Technique for Hydrogen Isotope Ratio Analysis, Analytical Chemistry, v. 63, p. 910-912.

Crock, J.G., 1996, Mercury—Chapter 29 *in* Sparks, D.L., ed., Methods of soil analysis, part 3, chemical methods: Soil Science Society of America Book Series, no. 5, p. 769–791.
Domagalski, J., 2001, Mercury and methylmercury in water and sediment of the Sacramento River Basin, Ca: Applied Geochemistry, v. 16, p. 1677–1691.
Domagalski, J.L., Alpers, C.N., Slotton, D.G., Suchanek, T.H., and Ayers, S.M., 2004,Mercury and methylmercury concentrations and loads in the Cache Creek watershed, California: Science of the Total Environment, v. 327, p. 215–237.
Donnelly-Nolan, J.M., Burns, M.G., Goff, F.E., Peters, E.K., and Thompson, J.M., 1993, The Geysers-Clear Lake area, CA—Thermal waters, mineralization, volcanism, and geothermal potential: Economic Geology, v. 88, p. 301–316.
Epstein, S. and Mayeda, T., 1953. Variation of O-18 content of water from natural sources. Geochim. Cosmochim. Acta, v. 4, p. 213-224.
Foe, C.G., and Croyle, B., 1998, Mercury concentration and loads from the Sacramento River and from Cache Creek to the Sacramento-San Joaquin Delta Estuary: Staff report, California Regional Water Quality Control Board, Central Valley Region, Sacramento, Calif. 81 p., 2 appendices.
Foe, C. and Bosworth, D., 2008, Mercury inventory in the Cache Creek Canyon: California Environmental Protection Agency, Regional Water Quality Control Board, Central Valley Region, 48 p.
Fishman, M.J. and Pyen, G., 1979, Determination of selected anions in water by ion chromatography: U.S. Geological Survey Water Resources Investigations 79–101, 30 p.
Gill, G.A., and Fitzgerald, W.F., 1987, Picomolar mercury measurements in seawater and other materials using stannous chloride reduction and two-stage gold amalgamation with gas phase detection: Marine Chemistry, v. 20, p. 227–243.
Goff, F., and Janik, C.J., 1993, Gas geochemistry and guide for geothermal features in the Clear Lake region, California, *in* Rytuba, J. J. ed., Active geothermal systems and gold-mercury deposits in the Sonoma-Clear Lake volcanic fields: California, Society of Economic Geologists Guidebook 16, p. 207–261.
González-Muñoz, M.T., Fernández-Luque, B., Martínez-Ruiz, F., Chekroun, K.B., Arias, J.M., Rodríguez-Ballego, M., Martínez-Cañamero, M., De Linares, C., and Paytan, A., 2003, Precipitation of barite by Myxococcus Xanthus—possible implications for the biogeochemical cycle of barium: Applied and Environmental Microbiology, v. 69, p. 5722–5725.
Holloway, J.M., Goldhaber, M.B., and Morrison, J.M., 2009, Geomorphic controls on mercury accumulation in soils from a historically mined watershed, Central California Coast Range, USA: Applied Geochemistry, v. 24, p. 1538–1548.
Horita, J., Wesolowski, D., and Cole, D., 1993. The activitycomposition relationship of oxygen and hydrogen isotopes in aqueous salt solutions: I. Vapor-liquid water equilibration of single salt solutions from 50 to 100ø C, Geochim. Cosmochim. Acta, v. 57, p. 2797-2817.
Horvat, M., Bloom, N.S., and Liang, L., 1993, Comparison of distillation with other current isolation methods for the determination of methyl mercury compounds in low level environmental samples, part 1 sediments: Analytica Chimica Acta, v. 281, p. 135–152.
Hothem, R.L., M.R. Jennings, and J.J. Crayon. 2010. Mercury contamination in three species of Anuran amphibians from the Cache Creek Watershed, California, USA: Environmental Monitoring and Assessment, v. 163 p. 433–448.

Ichikawa, G., and Jakl, B., 2004, Data and quality assurance/quality control report for Harley Gulch maximum daily load (TMDL) project: Prepared for Water Quality Control Board, Central Valley Region, Sacramento, Calif., 20 p.

Kendall, C. and Coplen, T.B., 1985. Multisample Conversion of Water to Hydrogen by Zinc for Stable Isotope Determination. Anal. Chem. v. 57, p. 1437-1440.

Kim, C.S., Brown Jr., G.E., and Rytuba, J.J., 2004, Geological and anthropogenic factors influencing mercury speciation in mine wastes—an EXAFS spectroscopy study: Applied Geochemistry, v. 19, no. 3, p. 379–393.

Kuwabara, J.S., Topping, B.R., and others, 2005, Mercury accumulation by lower trophic-level organisms in lentic systems within the Guadalupe River Watershed, California: U.S. Geological Survey Scientific Investigations Report 2005–5037, 59 p.

Larson, E., 2007, Abbott, Turkey Run mine cleanup project completed: Lake County News, accessed 9/28/11 at *http://lakeconews.com/content/view/1715/919/.*

Moisseeff, A.N., 1966, The geology and geochemistry of the Wilbur Springs quicksilver district, Colusa and Lake counties, California: Stanford University, unpublished Ph.D. dissertation, 214 p.

National Research Council of Canada Institute for National Measurement Standards, 1999, DORM-2, DOLT-2, Dogfish muscle and liver certified reference materials for trace metals: INMS Certified Reference Materials Data Sheet, 4 p. (Also available at *http://www.ems.nrc.ca/ems1.htm*, last accessed January 28, 2009.)

O'Leary, R.M., Hageman, P.L., and Crock, J.G., 1996, Determination of mercury in water, geologic, and plant materials by continuous flow-cold vapor-atomic absorption spectrophotometry, *in* Arbogast, B.F., ed., Quality assurance manual for the branch of geochemistry—United States Geological Survey: United States Geological Survey Open-File Report 96–525, p. 42–55.

Orion Research, Inc., 1978, Analytical methods guide, 9th ed.: Cambridge, Mass., 48 p.

Pickhardt, P.C., and Fisher, N.S., 2007, Accumulation of inorganic and methylmercury by freshwater phytoplankton in two contrasting water bodies: Environmental Science and Technology, no. 41, p. 125–131.

Révész, Kinga, and Coplen, T.B., 2008a, Determination of the delta (2H/1H) of water: RSIL lab code 1574, chap. C1 of Révész, Kinga, and Coplen, T.B., eds., Methods of the Reston Stable Isotope Laboratory: U.S. Geological Survey Techniques and Methods 10–C1, 27 p.

Révész, Kinga, and Coplen, Tyler, B., 2008b, Determination of the delta (18O/16O) of water: RSIL lab code 489, chap. C2 of Révész, Kinga, and Coplen, Tyler B., eds., Methods of the Reston Stable Isotope Laboratory: U.S. Geological Survey Techniques and Methods, 10–C2, 28 p.

Rytuba, J.J., 2000, Mercury mine drainage and processes that control its environmental impact. Science of the Total Environment, v. 260, p. 57–71.

Senko, J.M., Campbell, B.S., Henriksen, J.R., Elshahed, M.S., Dewers, T.A., and Krumholz, L.R., 2004, Barite deposition resulting from phototrophic sulfide-oxidizing bacterial activity: Geochimica et Cosmochimica Acta, v. 68, p. 773–780.

Slotton, D.G., Reuter, J.E., and Goldman, C.R., 1995, Mercury uptake patterns of biota in a seasonally anoxic northern California reservoir. Water Air and Soil Pollution, v. 80, p. 841–850.

Slotton, D.G., Ayers, S.M., Reuter, J.E., and Goldman, C.R., 1997, Cache Creek watershed preliminary mercury assessment, using benthic macro-invertebrates: Final report for the Central Valley Regional Water Quality Control Board and the National Science Foundation, June 1997.

Slotton, D.G., Ayers, S.M., Suchanek, T.H., Weyand, R.D., and Liston, A.M., 2004, Mercury bioaccumulation and trophic transfer in the Cache Creek Watershed of California, in relation to diverse aqueous mercury exposure conditions—Component 5B of the multi-institution directed action research project: Assessment of ecological and human health impacts of mercury in the San Francisco Bay-Delta Watershed, a Cal-Fed Bay-Delta Program Project, Final report, January 25, 2004, 74 p., 63-p. appendix, accessed 9/17/11 at *http://loer.tamug.tamu.edu/calfed/Report/Final/UCDavis_Cache_Bio_Final.pdf*.

Slowey, A.J., and Rytuba, J.J., 2008, Mercury release from the Rathburn mine, Petray mine, and Bear Valley saline springs, Colusa County, California 2004–2006: U.S. Geological Survey Open-File Report 2008–1179, 49 p., accessed 9/17/11 at *http://pubs.usgs.gov/of/2008/1179/*.

Sofer, Z. and Gat, J. R., 1972. Activities and concentrations of oxygen-18 in concentrated aqueous salt solutions: analytical and geophysical implications. Earth Planetary Science Letters, v. 15, p. 232-238.

Sofer, Z. and Gat, J. R., 1975. The isotope composition of evaporating brines: Effect of the isotopic activity ratio in saline solutions. Earth Planetary Science Letters, v. 26, p. 179-186.

Suchanek, T.H., Hothem, R.L., Rytuba, J.J., and Yee, J.L., 2010, Mercury assessment and monitoring protocol for the Bear Creek Watershed, Colusa County, California: U.S. Geological Survey Scientific Investigations Report 2010-5018, 34 p.

Ugarte, C.A., Rice, K.G., and Donnelly, M.A., 2005, Variation of total mercury concentrations in pig frogs (*Rana grylio*) across the Florida Everglades, USA: Science of the Total Environment, v. 345 p. 51–59.

U.S. Bureau of Mines, 1965, Mercury potential of the United States: U.S. Department of the Interior, Bureau of Mines, Information Circular 8252, 376 p.

U.S. Environmental Protection Agency, 1997, Mercury study report to Congress—U.S. Environmental Protection Agency, vol. VII—Characterization of human health and wildlife risks from mercury exposure in the United States, Washington, DC, EPA-452/R-97-009, accessed 9/17/11 at: *http://www.epa.gov/ttn/oarpg/t3/reports/volume7.pdf*.

U.S. Environmental Protection Agency, 2001, Water quality criterion for the protection of human health—Methylmercury: U.S. Environmental Protection Agency, Washington, DC, EPA-823-R-01-001, accessed 9/17/11 at: *http://www.epa.gov/waterscience/criteria/methylmercury/merctitl.pdf*

U.S. Food and Drug Administration, 2001, Consumer advisory—An important message for pregnant women and women of child-bearing age who may become pregnant about the risks of mercury in fish: U.S. Food and Drug Administration, accessed 9/17/11 at: *http://vm.cfsan.fda.gov/ ~dms/admehg.html*.

Watts, W.L., 1893, Colusa County, eleventh feport of the State Mineralogist: Sacramento, California State Mining Bureau, p. 183–184.

Wiebelt, F.J., 1949, Investigation of the Abbott quicksilver mine, Lake County, California: U.S. Bureau of Mines, Report of Investigations 4558, 11 p., 3 figures.

Table 1. Sample locations and physical parameters from waters collected from Harley Gulch, Lake County, California.

Field number	Latitude	Longitude	Collection date	Location Description	Water conductivity µS/cm	Water pH	Water temperature deg C	Water dissolved O_2
	Low-flow June 2010							
10HG1	39.0154	-122.44023	6/16/10	Below Highway 20 culvert downstream from Turkey Run	7,820	8.06	19.82	7.04
10HG2	39.0134	-122.43625	6/16/10	West Fork Harley Gulch downstream from end of wetland	6,850	7.91	22.72	5.31
10HG3	39.01037	-122.43344	6/16/10	East Fork Harley Gulch	1,438	8.33	29.31	9.67
10HG4	39.01994	-122.43426	6/17/10	Pool at water fall downstream from confluence East and West Fork	3,560	7.50	16.78	7.15
10HG5	39.00911	-122.43530	6/17/10	Harley Gulch	4,355	8.16	23.35	10.62
10HG6	39.0084	-122.4365	7/1/10	Harley Gulch area with biogenic sediment	4,613	8.16	23.41	7.93
10HG7	39.00743	-122.43896	7/1/10	Upstream from biota site #7	4,715	8.49	34.40	12.49
10HG8	39.00675	-122.44736	7/1/10	Pool near biota sample site #8	4,150	7.94	23.35	9.34
10HG9	39.00439	-122.45496	7/1/10	Downstream from biota site #9	3,488	7.56	25.93	6.7
10HG9.5	39.0032	-122.45886	7/1/10	Between sites #9 and #10 - sediment sample only				
10HG10	39.00238	-122.46398	7/1/10	Downstream from biota site #10, intermittent pools	3,280	7.63	22.16	7.63
	Low-flow Sept. 2010							
10HG4-2	39.01994	-122.43426	9/16/10	Pool at water fall downstream from confluence East and West Fork	5,174	6.99	17.21	2.7
	Low-flow May 2011							
11HG1	39.01627	-122.44001	5/25/11	Below Highway 20 culvert downstream from Turkey Run	2,270	8.20	19.82	
11HG1.5	39.01402	-122.43709	5/25/11	Middle of Harley Gulch wetland	5,560	8.26	17.00	
11HG2	39.01068	-122.43380	5/25/11	West Fork Harley Gulch downstream from end of wetland	5,380	8.23	15.40	
11HG3	39.01023	-122.43330	5/25/11	East Fork Harley Gulch	1,156	8.38	18.10	
11HG4	39.0098	-122.43419	5/25/11	Pool at water fall downstream from confluence East and West Fork	3,200	8.32	17.40	
11HG5	39.00904	-122.43515	5/25/11	Harley Gulch	3,040	8.39	16.70	
11HG7	39.00732	-122.43953	5/25/11	Upstream from biota site #7	3,040	8.49	19.40	
	High-flow March 2011							
11HG1	39.0154	-122.44023	3/24/11	Below Highway 20 culvert downstream from Turkey Run	725.1	6.91	19.62	
11HG2	39.0134	-122.43625	3/24/11	West Fork Harley Gulch downstream from end of wetland	1,318	7.75	23.94	
11HG3	39.01037	-122.43344	3/24/11	East Fork Harley Gulch	540.1	7.68	26.16	
11HG4	39.01994	-122.43426	3/24/11	Pool at water fall downstream from confluence East and West Fork	1,060	7.75	25.38	
	High-flow June 2011							
11HG1	39.01627	-122.44001	6/7/11	Below Highway 20 culvert downstream from Turkey Run	3,160	8.23	18.20	
11HG2	39.01068	-122.43380	6/7/11	West Fork Harley Gulch downstream from end of wetland	5,290	8.37	15.90	
11HG3	39.01023	-122.43330	6/7/11	East Fork Harley Gulch	1,356	8.50	16.10	

Table 2. Collection sites, for biological samples from Harley Gulch, Lake County, California, in 2007, 2008, 2010, and 2011.

Site	Site description	Sample dates	Latitude	Longitude
HG1	Wetlands at culvert	5/21/08, 6/8/10, 6/2/11	39° N 00' 55.3"	122° W 26' 25.0"
UDUP	Wetlands-Upper unnamed drainage	6/8/10	39° N 00' 53.2"	122° W 26' 19.9"
HG8-07	Harley Gulch Pond	5/16/07	39° N 00' 48.5"	122° W 26' 10.9"
HG2	Mid point wetlands	5/21/08, 6/8/10, 6/2/11	39° N 00' 47.8"	122° W 26' 11.1"
UDLW	Wetlands-Lower unnamed drainage	6/8/10	39° N 00' 42.0"	122° W 26' 6.0"
HG2a	Wetlands above confluence	5/21/08, 6/8/10, 6/2/11	39° N 00' 38.5"	122° W 26' 01.7"
HG3	East Fork Harley Gulch (Reference)	5/16/07, 5/21/08, 6/8/10, 6/2/11	39° N 00' 37.2"	122° W 26' 01.5"
HG4	Just below confluence	5/16/07, 6/8/10, 6/2/11, 6/10/11	39° N 00' 36.1"	122° W 26' 03.9"
HG5	200 m below confluence	5/16/07, 5/21/08, 6/10/10, 6/2/11, 6/10/11	39° N 00' 32.4"	122° W 26' 08.4"
HG6	320 m below confluence	5/16/07, 6/10/10	39° N 00' 30.1"	122° W 26' 11.2"
HG7	600 m below confluence	5/16/07, 6/4/08, 6/10/10, 6/2/11	39° N 00' 26.3"	122° W 26' 21.9"
HG8	740 m below site HG7	6/4/08, 6/10/10	39° N 00' 24.4"	122° W 26' 50.6"
HG8a	Fish pond	6/10/10, 6/17/10	39° N 00' 21.0"	122° W 27' 00.6"
HG9	650 m below site HG8	6/4/08, 6/10/10	39° N 00' 16.0"	122° W 27' 13.6"
HG10	740 m below site HG9	6/4/08, 6/10/10	39° N 00' 10.5"	122° W 27' 41.6"
HG11	830 m below site HG10	6/4/08, 6/17/10	38° N 59' 56.7"	122° W 28' 02.2"
HG12	840 m below site HG11	6/4/08, 6/17/10	38° N 59' 39.2"	122° W 28' 13.5"
HG13	840 m below site HG12	6/4/08, 6/17/10	38° N 59' 21.5"	122° W 28' 30.7"
HG14	390 m below site HG13, 220 m above Cache Creek	6/4/08, 6/17/10	38° N 59' 14.8"	122° W 28' 35.2"

Table 3. Mercury and monomethylmercury concentrations in waters and sediment collected in Harley Gulch, Lake County, California

Field number	Water Hg_T in ng/L	Water Hg_F in ng/L	percentDissolved (Hg_F/Hg_T) in water	Water MMeHg in ng/L	percent MMeHg (MMeHg/Hg) in water	T.S.S., in mg/L	D.O.C., in mg/L	Sediment Hg in ng/g	Sediment MMeHg in ng/g	percent MMeHg (MMeHg/Hg) in sediment
Low-flow June 2010										
10HG1	825	647	78.42	0.168	0.02		2.7	57,800	0.098	0.000
10HG2	552	100	18.12	12.1	2.19		11	35,900	3.79	0.011
10HG3	7.36	4.4	59.78	0.552	7.50		3.2	213	0.565	0.265
10HG4	234	90.3	38.59	2.14	0.91		2.9	16,800	36.3	0.216
10HG5	142	96.5	67.96	0.52	0.37		3.7	13,300	0.89	0.007
10HG6	101	56.4	55.84	0.881	0.87		4.0	3,650	4.03	0.110
10HG7	58	40.9	70.52	2.35	4.05		5.1	2,510	19.4	0.773
10HG8	48.8	34.8	71.31	0.947	1.94		3.9	1,170	19.5	1.667
10HG9	23.9	15.5	64.85	0.511	2.14		2.5	769	11.1	1.443
10HG9.5								565	15.2	2.690
10HG10	18.3	12.8	69.95	0.176	0.96		2.6	147	0.082	0.056
Low-flow Sept. 2010										
10HG4	168	110	65.48	1.03	0.61		2.85	719	5.2	0.723
Low-flow May 2011										
11HG1	624	180	28.85	7.43	1.19		9.23	78,300	0.744	0.001
11HG1.5	2,300	811	35.26	1.54	0.07		4.66	11,000	6.83	
11HG2	2,100	283	13.48	1.38	0.07		6.38	14,700	0.388	0.003
11HG3	5.24	2.68	51.15	0.054	1.03		4.04	420	0.153	0.036
11HG4	214	118	55.14	0.62	0.29		5.33	2760	1.49	0.054
11HG5	137	102	74.45	0.621	0.45		4.68	18,800	0.774	0.004
11HG7	102	84.5	82.84	0.804	0.79		5.57	11,900	0.163	0.001
High-flow March 2011										
11HG1	429,000	3390	0.79	15.8	0.00	1010	5.39			
11HG2	32,800	266	0.81	2.29	0.01	101	4.26			
11HG3	32.8	15.7	47.87	0.153	0.47	40	4.09			
11HG4	11,000	2410	21.91	0.481	0.00	85.7	4.19			
High-flow June 2011										
11HG1	301	151	50.17	2.82	0.94		3.25			
11HG2	312	269	86.22	1.39	0.45		5.04			
11HG3	4.08	3.11	76.23	0.058	1.42		3.44			

Table 4. Concentration of anions and selected cations in filtered water from Harley Gulch sample sites

Field number	Cl in µg/L	F in µg/L	NO_3 in µg/L	SO_4 in µg/L	Alkalinity as $CaCO_3$ in µg/L	Ca in mg/L	Fe in µg/L	K in mg/L	Li in µg/L	Mg in mg/L	Na in mg/L
Low-flow June 2010											
10HG1	1,131.8	<.08	20.6	1,068	1,988.0	42.8	<20	34.1	1,520	617	1080
10HG2	1,021	<.08	<.08	1,409	1,586.7	50.8	84.2	21.9	1,080	552	855
10HG3	43.6	<.08	<.08	321	913.8	53.1	<20	4.41	171	119	101
10HG4	403.4	<.08	<.08	751.4	474.6	46.7	<20	9.35	522	276	430
10HG5	572.6	<.08	<.08	959.3	807.1	43.8	<20	10.8	626	330	522
10HG6	748.5	<.04	<.08	1,196	934.8	39.5	23.8	12.1	670	294	542
10HG7	874.5	<.04	<.08	1,424	907.3	24.7	<20	11.1	677	309	562
10HG8	511	<.04	<.08	942	780.5	54.5	21.8	9.1	508	271	457
10HG9	484.1	<.04	<.08	1,015	623.9	76.9	<20	7.8	386	213	355
10HG10	431.9	<.04	<.08	1,034.4	573.6	69.5	<20	7.22	330	197	345
Low-flow Sept. 2010											
10HG4	862	<.04	<.08	813.5	769.0	43.3	43	12.8	678	360	612
Low-flow May 2011											
11HG1	60.4	<0.04	<0.08	964.56	355.8	59	<50	4.4	166	296	nr
11HG1.5	762.6	<0.04	51.6	1,275.5	1,113.5	59.8	<50	18.9	1,070	457	nr
11HG2	752.6	<0.04	<0.08	1,260.3	1,030.0	58.1	<50	16	934	442	nr
11HG3	29.6	<0.04	<0.08	201.6	428.6	53.9	<50	2.2	76.7	146	70.9
11HG4	354.2	<0.04	<0.08	684.6	659.3	53.5	<50	8.6	530	279	nr
11HG5	320.5	<0.04	<0.08	660	681.7	55.8	<50	7.5	462	262	nr
11HG7	391.9	<0.04	<0.08	759	682.1	50.4	<50	7.9	503	269	nr
High-flow March 2011											
11HG1	10.9	0.4	0.6	228.1	591.8	29	327	2	27.1	61.5	28.1
11HG2	67.5	<0.04	1.1	285	1,034.3	23	62.7	4.5	127	80.1	101
11HG3	4.8	<0.04	<0.08	30.2		15.7	114	1.3	8.9	27.5	12.1
11HG4	25.8	<0.04	1.1	111		17.9	646	2.4	51.5	45.5	41
High-flow June 2011											
11HG1	101.6	<0.04	<0.08	1,379							
11HG2	758.6	<0.04	<0.08	1,251.3							
11HG3	73.3	<0.04	<0.08	11							

Table 5. Mercury and associated major and minor elements in active stream channel, biogenic, and storm sediment, Harley Gulch

Field number	Type	Hg in µg/g	Ag in µg/g	Al percent	As in µg/g	Ba in µg/g	Be in µg/g	Bi in µg/g	Ca percent	Cd in µg/g	Ce in µg/g	Co in µg/g	Cr in µg/g
	Low-flow June 2011												
10HG1S2	Active Stream Channel	44.7	0.09	6.68	13.1	440	1.26	0.17	0.87	0.11	42.5	43	511
10HG2S2	Biogenic Sediment	10.95	0.11	6.52	12.8	470	1.07	0.18	1.12	0.14	38.2	49.3	341
10HG3S2	Active Stream Channel	0.31	0.17	8.41	15.2	800	1.2	0.19	0.86	0.14	36.7	18.2	111
10HG4-2S	Biogenic Sediment	23.1	0.29	7.27	12.7	1,020	1.06	0.19	1.24	0.14	31.5	18.9	171
10HG4S2	Biogenic Sediment	9.83	0.15	6.64	9.8	600	0.96	0.13	4.62	0.13	29.5	14.4	173
10HG4-2-2S	Biogenic Sediment	17.7	0.19	5.66	6.9	550	0.78	0.12	6.54	0.11	24.3	12.3	127
10HG5S2	Active Stream Channel	6.84	0.13	7.72	17.2	2,390	1.26	0.18	1.44	0.14	39.8	30.3	392
10HG6S	Biogenic Sediment	15.6	0.16	6.59	12.1	1,210	0.89	0.16	3.59	0.13	33.4	23	249
10HG7S	Biogenic Sediment	5.6	0.06	2.96	<5	580	0.4	0.06	19.7	0.05	13.15	7.5	80
10HG7S2	Active Stream Channel	6.13	0.11	6.5	9	1,110	0.85	0.12	7.51	0.11	32.3	23.3	182
10HG8S2	Biogenic Sediment	1.95	0.11	6.68	11.3	610	0.74	0.12	6.26	0.09	24.7	17.8	132
10HG9S	Active Stream Channel	1.7	0.08	3.79	6	430	0.31	0.09	13.6	0.05	12.4	8.4	95
10HG9.5S	Biogenic Sediment	0.39	0.24	8.98	17	690	1.34	0.21	0.54	0.12	36	18.4	107
10HG9.5S2	Active Stream Channel	0.33	0.19	8.46	14.8	660	1.23	0.21	0.49	0.13	38.7	16.4	97
10 HG10S	Active Stream Channel	0.06	0.2	9.19	16.4	410	1.16	0.15	0.68	0.09	30.2	18.1	107
10HG10S2	Active Stream Channel	0.19	0.16	8.29	15.1	400	1.09	0.15	0.75	0.11	30.1	15.9	94
10HG17S2	Biogenic Sediment	1.87	0.13	7.6	10.8	420	0.89	0.16	4.33	0.11	25.6	16.8	100
10HG20S	Storm Sediment	136	0.2	6.68	14.4	2,680	1.08	0.19	1.12	0.15	35.3	28.2	2,200
10HG21S	Biogenic Sediment	16.1	0.24	6.67	10.8	650	1.02	0.17	1.51	0.13	30	17	207
10HG22S	Storm Sediment	23.9	0.28	6.8	14.5	2,200	1.19	0.19	1.18	0.17	36.6	24.2	689
10HG23S	Biogenic Sediment	50.3	0.13	3.96	8.8	590	0.63	0.1	4.14	0.11	18.6	16.1	681
	Low-flow May 2011												
11HG1S1-2	Active Stream Channel	78.3	0.16	6.2	9.2	460	0.95	0.16	2.08	0.08	34.2	36.7	516
11HG1S2-2	Storm Sediment	>100	0.16	6.16	10.3	490	0.91	0.16	1.43	0.08	33.3	37	3,160
11HG1.5S1-2	Active Stream Channel	11	0.07	7.46	19.1	470	1.18	0.17	1.79	0.13	39.6	29.5	368
11HG1.5S2-2	Storm Sediment	14.4	0.19	7.33	14.8	1,400	1.17	0.17	0.96	0.11	34.9	23.8	682
11HG2S1-2	Active Stream Channel	14.7	0.25	7.5	13.7	2,320	1.09	0.18	0.94	0.13	33	22.3	449
11HG2S2-2	Storm Sediment	24.2	0.28	7.33	12.8	1,600	0.97	0.19	1.05	0.11	31.2	24.3	281
11HG3S1-2	Active Stream Channel	0.42	0.23	7.79	15.5	620	1.03	0.19	0.68	0.11	31.2	16.8	128
11HG3S2-2	Storm Sediment	0.21	0.25	8.28	13.5	640	1.03	0.19	0.69	0.1	29.8	17.7	110
11HG4S1-2	Active Stream Channel	2.76	0.19	7.39	12.8	670	0.91	0.15	1.26	0.1	25	18.8	110
11HG4S2-2	Storm Sediment	48.5	0.26	7.54	13.7	2,450	1.02	0.19	0.82	0.1	35.3	24	1,080
11HG5S1-2	Active Stream Channel	18.8	0.21	7.38	14	1,260	0.96	0.17	1.32	0.1	32.4	23.4	341
11HG5S2-2	Storm Sediment	31.2	0.18	6.05	12.5	450	1.09	0.16	2.13	0.09	34.1	39.7	336
11HG6S1-2	Active Stream Channel	11.9	0.19	7.21	13.8	980	0.91	0.16	1.01	0.08	29.7	20.8	254
11HG6S2-2	Storm Sediment	8.9	0.19	7.19	13	1,140	0.9	0.15	1.47	0.09	30.5	25.8	251

Table 5 (cont'd).

Field number	Type	Cs in µg/g	Cu in µg/g	Fe percent	Ga in µg/g	Ge in µg/g	Hf in µg/g	In in µg/g	K percent	La in µg/g	Li in µg/g	Mg percent	Mn in µg/g
	Low-flow June 2011												
10HG1S2	Active Stream Channel	28.2	45	5.05	15.4	0.2	2.7	0.062	1.35	18.6	72.8	5.15	957
10HG2S2	Biogenic Sediment	13.3	50.2	4.97	14.6	0.2	2.5	0.054	1.26	17.8	80	4.21	1,280
10HG3S2	Active Stream Channel	5.83	69.4	5.22	17.95	0.16	2.5	0.071	1.28	16.1	87.6	1.47	631
10HG4-2S	Biogenic Sediment	7.74	79.8	4.83	15.55	0.15	1.8	0.061	1.2	13.1	108	1.75	397
10HG4S2	Biogenic Sediment	8.06	53.8	3.73	13.6	0.13	2	0.058	1.05	13.4	73.8	1.37	408
10HG4-2-2S	Biogenic Sediment	6.89	45	3.28	12.1	0.13	1.6	0.044	0.93	11.1	89.1	1.34	359
10HG5S2	Active Stream Channel	12.9	65.1	5.71	16.5	0.15	2.2	0.067	1.27	16.4	86.1	2.49	994
10HG6S	Biogenic Sediment	9.84	49.8	4.17	13.95	0.16	2	0.056	1.12	14.3	94.1	1.74	657
10HG7S	Biogenic Sediment	3.66	21.6	1.7	5.76	0.05	0.8	0.023	0.48	5.9	43.6	0.88	169
10HG7S2	Active Stream Channel	9.62	47.4	3.89	13.4	0.15	1.9	0.054	1.04	12.9	72.9	1.87	568
10HG8S2	Biogenic Sediment	5.39	47.1	4.13	13.7	0.13	1.7	0.063	0.93	10.8	69.1	1.57	381
10HG9S	Active Stream Channel	2.35	27.7	2.1	7.16	0.06	1	0.036	0.53	6	44.3	0.89	239
10HG9.5S	Biogenic Sediment	4.68	78.5	5.56	19.55	0.15	2.6	0.068	1.4	15.7	110.5	1.16	695
10HG9.5S2	Active Stream Channel	4.99	69.5	5.1	18.2	0.16	2.5	0.077	1.33	17.8	87	1.1	656
10 HG10S	Active Stream Channel	3.3	70.6	5.52	20.5	0.15	2.2	0.068	1.29	13.3	116	1.45	450
10HG10S2	Active Stream Channel	3.77	62.7	4.65	18.95	0.14	2.2	0.078	1.15	14.4	90	1.31	407
10HG17S2	Biogenic Sediment	4.1	52.9	4.12	15.75	0.13	1.9	0.064	1.03	11.7	73.2	1.35	377
10HG20S	Storm Sediment	15.8	55.8	5.27	15.3	0.18	2.1	0.058	1.23	15.5	101	2.29	721
10HG21S	Biogenic Sediment	7.39	58.4	4.18	14.6	0.16	1.9	0.056	1.11	13.1	103.5	1.38	296
10HG22S	Storm Sediment	12.05	63.8	5.04	15.9	0.19	2.3	0.062	1.22	15.8	101	1.97	792
10HG23S	Biogenic Sediment	9.62	37.8	2.75	8.85	0.13	1.2	0.032	0.78	8.4	74.2	2.22	325
	Low-flow May 2011												
11HG1S1-2	Active Stream Channel	9.99	43.7	4.89	13.95	0.17	2.2	0.053	1.18	15.7	65	3.16	692
11HG1S2-2	Storm Sediment	7.98	41.5	5.17	12.95	0.19	2.1	0.054	1.16	15.5	58.4	2.71	680
11HG1.5S1-2	Active Stream Channel	17.25	57.5	5.86	17	0.19	2.4	0.061	1.4	16.5	107.5	3.17	783
11HG1.5S2-2	Storm Sediment	11.1	64.2	5.12	17.45	0.14	2	1.23	15	107	1.76	658	1.49
11HG2S1-2	Active Stream Channel	16	62.6	4.94	16.85	0.18	2.2	0.071	1.29	14.4	90.2	1.98	720
11HG2S2-2	Storm Sediment	16.35	61.7	4.89	15.6	0.19	2.2	0.072	1.25	13.9	81.1	2.09	760
11HG3S1-2	Active Stream Channel	5.28	68.6	5.09	17.05	0.17	2.2	0.073	1.22	13.9	86.4	1.38	632
11HG3S2-2	Storm Sediment	5.33	67.9	5.13	17.4	0.19	2.2	0.077	1.25	13.8	83.2	1.43	588
11HG4S1-2	Active Stream Channel	6.39	59.8	4.83	15.8	0.17	1.8	0.065	1.12	10.8	84.1	1.71	553
11HG4S2-2	Storm Sediment	17.95	62	5.02	15.8	0.21	2.3	0.069	1.34	16.1	80.5	2.08	678
11HG5S1-2	Active Stream Channel	12.3	60.7	5.1	15.45	0.2	2.2	0.067	1.21	14.4	81.5	2.12	706
11HG5S2-2	Storm Sediment	10.2	48.3	4.95	15	0.16	2.2	0.057	1.15	15.6	88.2	3.75	785
11HG6S1-2	Active Stream Channel	10.8	57.3	4.95	14.95	0.2	2	0.065	1.18	13.1	77.3	1.82	592
11HG6S2-2	Storm Sediment	11.6	59.4	5.17	15.05	0.22	2.1	0.069	1.14	13.7	81.4	2.47	675

Table 5 (cont'd).

Field number	Type	Mo in µg/g	Na percent	Nb in µg/g	Ni in µg/g	P in µg/g	Pb in µg/g	Rb in µg/g	Re in µg/g	S percent	Sb in µg/g	Sc in µg/g	Se in µg/g	Sn in µg/g
	Low-flow June 2011													
10HG1S2	Active Stream Channel	1.02	0.76	7.6	552	440	12.8	62.8	<0.002	0.07	3.99	16.8	1	1.4
10HG2S2	Biogenic Sediment	1	0.88	6.9	582	540	12.6	56.5	<0.002	0.35	2.36	17.2	2	1.4
10HG3S2	Active Stream Channel	1.88	0.81	5.7	64.4	400	11.8	53.6	<0.002	0.07	1.21	20.4	2	1.3
10HG4-2S	Biogenic Sediment	1.5	0.81	5.3	116.5	500	11.1	51.2	<0.002	0.29	2.45	17.9	2	1.2
10HG4S2	Biogenic Sediment	1.14	0.79	4.9	90.8	800	9	46	<0.002	0.31	1.17	16	3	1
10HG4-2-2S	Biogenic Sediment	0.96	0.83	4.6	75.6	730	7.6	52.1	<0.002	0.42	0.89	13.5	2	1
10HG5S2	Active Stream Channel	1.51	0.82	5.4	206	500	13.2	53	<0.002	0.1	1.74	19.5	2	1.2
10HG6S	Biogenic Sediment	1.02	0.94	4.8	143.5	530	10.9	60	<0.002	0.57	1.47	18	3	6.6
10HG7S	Biogenic Sediment	0.57	0.65	1.9	44.2	390	4.1	24.8	<0.002	0.43	0.46	7.5	3	1.6
10HG7S2	Active Stream Channel	0.74	0.78	4.4	155	470	9.1	42.9	<0.002	0.13	1.37	15.7	2	1
10HG8S2	Biogenic Sediment	0.72	0.82	3.7	97.8	500	7.5	36.3	<0.002	0.41	1.13	17	2	0.9
10HG9S	Active Stream Channel	2.05	0.7	1.9	41.8	440	4.6	25.8	<0.002	0.66	0.47	10	4	3.6
10HG9.5S	Biogenic Sediment	2.17	0.68	7.2	68.6	410	12.9	62.2	<0.002	0.04	1.33	21.8	2	1.4
10HG9.5S2	Active Stream Channel	2.1	0.66	6.3	62.2	380	12.1	59	<0.002	0.04	1.23	20.5	2	1.3
10 HG10S	Active Stream Channel	0.84	0.88	6.1	55.3	530	9.5	49	0.002	0.05	1	25.2	2	1.2
10HG10S2	Active Stream Channel	0.93	0.85	5.2	51.4	380	9.1	47.6	<0.002	0.07	1.04	22.6	2	1.2
10HG17S2	Biogenic Sediment	0.68	0.89	3.9	59.7	380	7.2	39.6	<0.002	0.1	0.92	19.7	2	1.2
10HG20S	Storm Sediment	1.48	0.88	6	260	380	12.5	61.5	<0.002	0.14	1.94	16.8	2	1.3
10HG21S	Biogenic Sediment	1.54	0.86	5.3	109	520	10.2	52.7	<0.002	0.64	1.47	16.7	2	1.1
10HG22S	Storm Sediment	2.01	0.8	6.3	206	400	13.2	60.6	<0.002	0.13	1.75	17.5	2	1.2
10HG23S	Biogenic Sediment	0.98	1.42	3.5	179.5	1,340	7	40.1	<0.002	0.98	1.49	9.9	2	0.7
	Low-flow May 2011													
11HG1S1-2	Active Stream Channel	0.45	0.73	6.3	528	340	10.9	63.3	<0.002	0.05	2.41	14.4	2	1.9
11HG1S2-2	Storm Sediment	0.5	0.76	6	413	340	11.4	56.2	<0.002	0.09	2.4	13.4	1	1.3
11HG1.5S1-2	Active Stream Channel	1.01	0.83	6.7	336	570	13.1	79.6	<0.002	0.05	2.56	21.2	2	1.4
11HG1.5S2-2	Storm Sediment	0.83	6.2	155.5	420	12.6	60.3	<0.002	0.06	1.53	20.1	2	2.9	246
11HG2S1-2	Active Stream Channel	1.43	0.7	6	178	400	14.2	62.6	<0.002	0.1	1.84	17.6	2	1.4
11HG2S2-2	Storm Sediment	1.28	0.64	6	228	380	14.1	50.3	<0.002	0.06	1.98	16	2	1.3
11HG3S1-2	Active Stream Channel	1.62	0.73	5.6	70.3	400	11.4	57.4	<0.002	0.03	1.18	18.2	2	1.3
11HG3S2-2	Storm Sediment	1.23	0.91	5.6	70	380	10.3	54.9	<0.002	0.04	1.09	18.7	2	1.3
11HG4S1-2	Active Stream Channel	0.91	0.82	4.6	93.6	400	9.9	41.2	<0.002	0.04	1.07	17.3	2	1.1
11HG4S2-2	Storm Sediment	1.32	0.81	6.3	197.5	380	12.9	65.9	<0.002	0.1	1.72	16.7	2	1.3
11HG5S1-2	Active Stream Channel	1.23	0.83	5.4	187.5	430	11.4	60.1	<0.002	0.06	1.61	16.6	2	1.2
11HG5S2-2	Storm Sediment	0.75	0.73	6.1	537	450	12.6	63.5	<0.002	0.06	3.82	16.2	2	1.3
11HG6S1-2	Active Stream Channel	1.06	0.88	5.1	151.5	370	10.6	52.9	<0.002	0.04	1.58	16.2	2	1.2
11HG6S2-2	Storm Sediment	0.88	0.8	5	236	410	10.2	54.5	<0.002	0.05	1.87	16.9	2	1.2

Table 5 (cont'd).

Field number	Type	Sr in µg/g	Ta in µg/g	Te in µg/g	Th in µg/g	Ti percent	Tl in µg/g	U in µg/g	V in µg/g	W in µg/g	Y in µg/g	Zn in µg/g	Zr in µg/g
	Low-flow June 2011												
10HG1S2	Active Stream Channel	305	0.55	0.11	6.5	0.323	0.98	1.8	128	10.3	15.3	158	80.4
10HG2S2	Biogenic Sediment	257	0.53	0.13	6	0.321	1	1.8	120	18.4	15.2	196	75.6
10HG3S2	Active Stream Channel	208	0.42	0.15	5.1	0.398	0.33	1.7	162	1.8	16.1	128	67.6
10HG4-2S	Biogenic Sediment	325		0.34	4.6	0.353	0.44	1.6	143	7.2	14.3	124	62.8
10HG4S2	Biogenic Sediment	1,215	0.36	0.11	4	0.32	0.46	1.6	115	3.4	12.5	204	59.8
10HG4-2-2S	Biogenic Sediment	1,590		0.29	4.1	0.276	0.38	1.7	98	3	11.2	152	57.4
10HG5S2	Active Stream Channel	409	0.4	0.16	5	0.355	0.59	1.6	158	20.2	16.2	145	63.2
10HG6S	Biogenic Sediment	1,065	0.34	0.11	4.4	0.319	0.48	1.5	119	12.3	13.5	127	59.3
10HG7S	Biogenic Sediment	5,660	0.13	0.1	1.7	0.141	0.21	1.5	50	8.9	6.4	59	24
10HG7S2	Active Stream Channel	2,000	0.32	0.13	3.7	0.298	0.53	1.6	117	10.7	13	107	53.5
10HG8S2	Biogenic Sediment	1,555	0.27	0.1	3	0.3	0.43	1.3	116	3.7	12	102	48.1
10HG9S	Active Stream Channel	3,110	0.14	0.08	1.7	0.171	0.16	1.5	63	43.8	6.8	55	26.9
10HG9.5S	Biogenic Sediment	102	0.52	0.13	6.2	0.431	0.37	1.8	174	1.1	16.2	132	80.6
10HG9.5S2	Active Stream Channel	93.5	0.47	0.15	5.9	0.402	0.37	2	162	1.2	17	130	74.9
10 HG10S	Active Stream Channel	139.5	0.41	0.1	4.8	0.453	0.31	1.4	190	1.2	15.2	132	68.4
10HG10S2	Active Stream Channel	157	0.37	0.11	4.4	0.396	0.34	1.5	165	1.5	13.6	119	61.8
10HG17S2	Biogenic Sediment	913	0.28	0.11	3.4	0.341	0.35	1.4	138	2.7	12.6	109	53.7
10HG20S	Storm Sediment	337	<0.2	0.38	5.3	0.345	0.68	1.7	141	22.6	15.6	124	75
10HG21S	Biogenic Sediment	355	<0.2	0.35	4.5	0.324	0.46	1.7	125	5.2	13.6	153	63.1
10HG22S	Storm Sediment	354	<0.2	0.4	5.4	0.341	0.61	1.8	135	21.6	17.6	127	76.7
10HG23S	Biogenic Sediment	1,515	<0.2	0.22	2.9	0.196	0.81	1.3	79	5	8.7	419	44.4
	Low-flow May 2011												
11HG1S1-2	Active Stream Channel	387	0.47	0.09	5.3	0.325	0.99	1.6	121	6.1	13.7	132	69.1
11HG1S2-2	Storm Sediment	259	0.44	0.09	4.9	0.322	0.92	1.4	134	5.3	12.6	118	63.4
11HG1.5S1-2	Active Stream Channel	493	0.46	0.13	5.6	0.37	1.06	1.8	160	7.8	15.7	154	79.6
11HG1.5S2-2	Storm Sediment	0.41	0.1	5	0.372	0.53	1.6	157	12.9	16.1	128	65.4	
11HG2S1-2	Active Stream Channel	336	0.44	0.13	4.9	0.367	0.72	1.6	152	24.5	14.2	134	66.7
11HG2S2-2	Storm Sediment	338	0.45	0.12	4.6	0.36	0.68	1.6	147	32.9	13.5	119	64.1
11HG3S1-2	Active Stream Channel	157.5	0.42	0.14	4.7	0.388	0.34	1.6	159	1.8	14.5	123	63.2
11HG3S2-2	Storm Sediment	143.5	0.41	0.13	4.5	0.406	0.33	1.6	169	1.9	13.8	125	62.4
11HG4S1-2	Active Stream Channel	303	0.33	0.11	3.7	0.368	0.38	1.3	156	4.6	12	122	54.3
11HG4S2-2	Storm Sediment	284	0.47	0.14	5.4	0.377	0.64	1.7	153	24.3	14	124	67.2
11HG5S1-2	Active Stream Channel	351	0.4	0.12	4.7	0.366	0.54	1.5	148	17.4	14.5	120	66.2
11HG5S2-2	Storm Sediment	525	0.45	0.11	5.3	0.305	1.5	1.6	123	9.5	15.3	127	68.8
11HG6S1-2	Active Stream Channel	263	0.38	0.12	4.2	0.36	0.5	1.4	146	13.5	12.7	112	57.9
11HG6S2-2	Storm Sediment	404	0.35	0.13	4.1	0.348	0.64	1.4	149	17.7	13.8	116	61.7

Table 6. Unfiltered water, major and minor element concentrations from ICP-MS results (ICP-AES for major elements), Harley Gulch, Lake County, California.

Field Number	Ag in µg/L	Al in µg/L	As in µg/L	B in µg/L	Ba in µg/L	Be in µg/L	Bi in µg/L	Ca in mg/L	Cd in µg/L	Ce in µg/L	Co in µg/L	Cr in µg/L	Cs in µg/L	Cu in µg/L	Dy in µg/L
	Low-flow June 2010														
10HG1	<1	47.8	8.3	40,600	82.6	<0.05	< 0.2	40.7	<0.02	0.12	0.61	15.8	35.9	3.7	0.03
10HG2	<1	2830	15.5	33,300	176	0.08	< 0.2	51.7	0.02	2.21	9.73	39.1	0.97	9.1	0.28
10HG3	<1	84.5	1	2,400	92.7	<0.05	< 0.2	51.5	<0.02	0.1	0.12	5	0.03	2	0.03
10HG4	<1	7.7	3.8	14,300	52.4	<0.05	< 0.2	43.7	<0.02	0.02	0.1	9.1	0.21	2.9	0.009
10HG5	<1	15.1	4.6	17,900	50	<0.05	< 0.2	42.8	<0.02	0.03	0.08	10	0.22	3.1	0.01
10HG6	<10	35	<10	20,700	46.8	<0.5	< 2	39.5	<0.2	<0.1	<0.2	<10	0.31	5.4	<0.05
10HG7	<10	<20	<10	21,600	29.3	<0.5	< 2	24.7	<0.2	<0.1	<0.2	<10	0.21	<5	< 0.05
10HG8	<10	<20	<10	17,400	56.4	<0.5	< 2	54.5	<0.2	<0.1	<0.2	<10	<0.2	<5	<0.05
10HG9	<10	<20	<10	13,800	49	<0.5	< 2	76.9	<0.2	<0.1	<0.2	<10	<0.2	<5	<0.05
10HG10	<10	<20	<10	10,900	69.1	<0.5	< 2	69.5	<0.2	<0.1	<0.2	<10	<0.2	<5	<0.05
	Low-flow Sept. 2010														
10HG4	<1	14.8	1.6	18,900	40.6	<10	< 0.2	39.9	<0.02	0.03	0.1	<1	0.45	3.2	0.03
	Low-flow May 2011														
11HG1	<1	124	1.6		45.3	<0.05	nr	60.7	<0.02	< 0.01	0.31	8	0.12	4.5	0.15
11HG1.5	<1	153	5.7		85.9	<0.05	nr	62.7	<0.02	< 0.01	1.1	18.4	19.2	3.7	0.17
11HG2	<1	79.1	6.4		89.7	<0.05	nr	58.5	<0.02	< 0.01	0.68	15.5	1.4	4.8	0.17
11HG3	<1	135	<1		90.8	<0.05	nr	53.4	<0.02	< 0.01	0.13	4.8	0.03	2.2	0.16
11HG4	<1	152	3.4		89	<0.05	nr	54	<0.02	< 0.01	0.34	8.5	0.51	3.5	0.18
11HG5	<1	46.7	3		88.5	<0.05	nr	57.7	<0.02	< 0.01	0.18	7.8	0.26	3.1	0.17
11HG6	<1	35.7	3.2		87.9	<0.05	nr	49.9	<0.02	< 0.01	0.17	5.9	0.2	3	0.16
	High-flow March 2011														
11HG1	<1	35700	6.1	448	488	1.1	< 0.2	35.9	0.16	34.6	102	400	3.5	100	3.7
11HG2	<1	7400	3.2	3,540	161	0.22	< 0.2	25.3	0.04	6.3	14.8	72	1.7	21.5	0.67
11HG3	<1	2280	<1	178	57.2	0.06	< 0.2	15.2	<0.02	1.7	2.2	12.7	0.18	6.9	0.25
11HG4	<1	3180	1.2	978	75.8	0.08	< 0.2	16.4	<0.02	2.8	5	26	0.53	9.9	0.34

Table 6 (cont'd)

Field Number	Er in µg/L	Eu in µg/L	Fe in µg/L	Ga in µg/L	Gd in µg/L	Ge in µg/L	Ho in µg/L	K in mg/L	La in µg/L	Li in µg/L	Lu in µg/L	Mg in mg/L	Mn in µg/L	Mo in µg/L
	Low-flow June 2010													
10HG1	0.02	0.02	79.6	< 0.05	0.04	6	0.009	34.6	0.04	1,500	< 0.1	588	77.4	< 2
10HG2	0.15	0.1	7210	0.83	0.36	1.4	0.052	21.9	0.89	1,090	< 0.1	553	726	3.2
10HG3	0.01	0.02	136	< 0.05	0.04	0.05	0.006	4.36	0.05	176	< 0.1	118	11.4	< 2
10HG4	0.009	0.009	<20	< 0.05	< 0.005	0.05	< 0.005	9.36	< 0.01	532	< 0.1	265	24.2	2.1
10HG5	0.006	0.009	23.7	< 0.05	0.01	< 0.05	< 0.005	10.6	< 0.01	608	< 0.1	322	6.4	2.4
10HG6	<0.05	<0.05	23.8	< 0.5	<0.05	<0.5	< 0.05	12.1	<0.1	670	< 1	294	7.9	<20
10HG7	< 0.05	< 0.05	<20	< 0.5	<0.05	<0.5	< 0.05	11.1	< 0.1	677	< 1	309	<2	<20
10HG8	<0.05	< 0.05	21.8	< 0.5	<0.05	<0.5	< 0.05	9.1	< 0.1	508	< 1	271	23.1	< 20
10HG9	< 0.05	< 0.05	<20	< 0.5	< 0.05	<0.5	< 0.05	7.8	< 0.1	386	< 1	213	<2	< 20
10HG10	< 0.05	< 0.05	<20	< 0.5	<0.05	<0.5	< 0.05	7.22	< 0.1	330	< 1	197	<2	< 20
	Low-flow Sept. 2010													
10HG4	0.01	0.008	62	0.06	0.02		0.008	11.6	0.02	624		333	35.8	2.4
	Low-flow May 2011													
11HG1	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	4.5	< 0.01	171		291	17.6	< 2
11HG1.5	< 0.005	0.05	146	0.05	< 0.005		< 0.005	19.7	< 0.01	1,090		467	136	< 2
11HG2	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	16.4	< 0.01	919		455	27.6	2.4
11HG3	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	2.1	< 0.01	73.5		142	5.1	< 2
11HG4	< 0.005	0.051	<50	< 0.05	< 0.005		< 0.005	9	< 0.01	529		274	14.4	< 2
11HG5	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	7.7	< 0.01	461		269	7.4	< 2
11HG6	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	7.8	< 0.01	476		263	5.4	< 2
	High-flow March 2011													
11HG1	1.7	1.2	65,800	15.8	4.7		0.68	7.3	12.3	116		115	1740	< 2
11HG2	0.34	0.23	12,700	3.1	0.85		0.12	6	2.1	170		92.9	263	< 2
11HG3	0.15	0.094	3,240	0.87	0.34		0.05	1.7	0.68	22.5		27.4	59	< 2
11HG4	0.2	0.14	5,200	1.4	0.41		0.067	2.7	1	55.6		40.6	103	< 2

Table 6 (cont'd)

Field Number	Na in mg/L	Nb in µg/L	Nd in µg/L	Ni in µg/L	P in mg/L	Pb in µg/L	Pr in µg/L	Rb in µg/L	Sb in µg/L	Sc in µg/L	Se in µg/L	SiO2 in mg/L	Sm in µg/L	SO4 in mg/L	Sr in µg/L
	Low-flow June 2010														
10HG1	1,030	< 0.2	0.07	6.5	0.2	1.7	0.01	65.5	0.83	4.5	22.9	58.7	0.02	1,310	2,250
10HG2	828	< 0.2	1.36	92.4	0.5	2.5	0.29	9.93	0.45	3.8	18.9	48	0.32	1,400	1,850
10HG3	97.6	< 0.2	0.09	<0.4	< 0.01	1.6	0.02	2.42	<0.3	1.6	1.8	18.1	0.02	336	908
10HG4	419	< 0.2	0.02	0.6	< 0.01	2	< 0.01	7.56	0.46	1.6	8.7	20.3	< 0.01	838	1,170
10HG5	509	< 0.2	0.01	1.1	< 0.01	1.9	< 0.01	8.36	0.49	1.5	10.9	20	< 0.01	962	1,190
10HG6	542	< 2	<0.1	<4	<0.1	<0.5	< 0.1	7.52	<3	<6	<10	14.2	< 0.1	904	1,020
10HG7	562	< 2	< 0.1	<4	<0.1	<0.5	< 0.1	7.1	<3	<6	<10	13.4	< 0.1	977	516
10HG8	457	< 2	< 0.1	<4	<0.1	<0.5	< 0.1	2.93	<3	<6	<10	14.2	< 0.1	890	1,150
10HG9	355	< 2	< 0.1	<4	<0.1	<0.5	< 0.1	3.01	<3	<6	<10	12.2	< 0.1	790	1,300
10HG10	345	< 2	<0.1	<4	<0.1	<0.5	< 0.1	1.59	<3	<6	<10	9.6	< 0.1	776	1,340
	Low-flow June 2010														
10HG4	561	< 0.2	0.03	<0.4	0.2	<0.05	< 0.01	10.5	0.65	1.4	63.5	20	0.04	1,000	1,220
	Low-flow May 2011														
11HG1	nr	< 0.2	< 0.01	11.5	0.1	<0.05	< 0.01	2.1	1	1.8	1.7	20	< 0.01	900	887
11HG1.5	nr	< 0.2	< 0.01	12.4	0.2	<0.05	< 0.01	29	1.1	4	14.7	43	< 0.01	1,100	1,940
11HG2	nr	< 0.2	< 0.01	14.3	0.2	<0.05	< 0.01	8.2	1.7	2.2	15.7	27	< 0.01	1,100	1,690
11HG3	66.8	< 0.2	< 0.01	<0.4	0.04	<0.05	< 0.01	1.1	<0.3	1.7	1.5	20	< 0.01	190	850
11HG4	nr	< 0.2	< 0.01	6.1	0.09	<0.05	< 0.01	4.4	0.85	1.8	8.3	21	< 0.01	630	1,170
11HG5	nr	< 0.2	< 0.01	4.1	0.07	<0.05	< 0.01	3.7	0.76	1.9	7.2	22	< 0.01	590	1,180
11HG6	nr	< 0.2	< 0.01	3.6	0.07	<0.05	< 0.01	3.4	0.8	1.6	7.1	19	< 0.01	600	1,030
	High-flow March 2011														
11HG1	26.7	< 0.2	18.6	1560	0.4	19.2	4.3	25	0.52	37.8	< 1	240	4.7	200	435
11HG2	103	< 0.2	3.3	233	0.2	3.27	0.78	8.8	0.63	9.9	2.3	79	0.79	270	440
11HG3	11.2	< 0.2	1.1	28	0.08	0.75	0.28	2.3	<0.3	3.1	< 1	27	0.23	25	170
11HG4	32	< 0.2	1.6	76	0.1	1.28	0.38	3.8	<0.3	4.8	1.3	37	0.39	80	238

Table 6 (cont'd)

Field Number	Ta in µg/L	Tb in µg/L	Th in µg/L	Ti in µg/L	Tl in µg/L	Tm in µg/L	U in µg/L	V in µg/L	W in µg/L	Y in µg/L	Yb in µg/L	Zn in µg/L	Zr in µg/L
	Low-flow June 2010												
10HG1	0.04	< 0.005	< 0.2	20.4	0.1	< 0.005	0.91	9.6	261	0.33	0.02	22.4	< 0.2
10HG2	0.06	0.055	0.2	44.1	<0.1	0.02	2.69	14.6	26.8	1.37	0.08	28.6	0.7
10HG3	0.02	0.006	< 0.2	6.4	<0.1	< 0.005	0.71	4.3	1.82	0.17	< 0.005	1.7	< 0.2
10HG4	0.02	< 0.005	< 0.2	13.3	<0.1	< 0.005	1.7	5.2	7.06	0.08	0.007	3.2	< 0.2
10HG5	0.02	< 0.005	< 0.2	15.5	<0.1	< 0.005	2.12	5.7	8.5	0.09	0.008	4.4	< 0.2
10HG6	< 0.2	< 0.05	< 2	10.6	<1	< 0.05	<1	<5	48.5	<0.1	<0.05	495	< 2
10HG7	< 0.2	< 0.05	< 2	10.6	<1	< 0.05	<1	<5	25.3	<0.1	<0.05	<5	< 2
10HG8	< 0.2	< 0.05	< 2	10.2	<1	< 0.05	<1	<5	14.4	<0.1	< 0.05	<5	< 2
10HG9	< 0.2	< 0.05	< 2	7.2	<1	< 0.05	<1	<5	11.3	<0.1	< 0.05	<5	< 2
10HG10	< 0.2	< 0.05	< 2	9.5	<1	< 0.05	<1	<5	8.24	<0.1	< 0.05	<5	< 2
	Low-flow Sept. 2010												
10HG4	0.1	< 0.005	< 0.2	25.3	<0.1	0.007	2.32	1.8		0.07	0.02	<3	
	Low-flow May 2011												
11HG1	0.29	< 0.005	0.4	18.2	<0.1	< 0.005	1.39	4.6	1.5	0.11	< 0.01	19	
11HG1.5	0.3	< 0.005	0.41	19.8	<0.1	< 0.005	1.55	8.5	110	0.22	< 0.01	10.8	
11HG2	0.29	< 0.005	0.39	18.7	<0.1	< 0.005	2.55	9.9	35	0.23	< 0.01	16.1	
11HG3	0.28	< 0.005	0.36	5.3	<0.1	< 0.005	1.05	3.7	1.6	0.17	< 0.01	<3	
11HG4	0.28	< 0.005	0.37	12.5	<0.1	< 0.005	1.67	6.2	15	0.22	< 0.01	8.2	
11HG5	0.28	< 0.005	0.36	10.6	<0.1	< 0.005	1.77	5.9	11	0.18	< 0.01	4.9	
11HG6	0.28	< 0.005	0.37	10.7	<0.1	< 0.005	1.68	5.3	12	0.14	< 0.01	3.3	
	High-flow March 2011												
11HG1	< 0.02	0.71	3.41	66.3	1.31	0.25	0.77	141	0.72	17.4	1.2	234	234
11HG2	< 0.02	0.14	0.81	74.3	0.26	0.075	0.48	32.2	2	3.1	0.25	50	50
11HG3	< 0.02	0.064	0.26	22.2	<0.1	0.05	0.13	12.2	< 0.5	1.1	0.08	13.4	13.4
11HG4	< 0.02	0.078	0.35	31.6	0.12	0.051	0.21	16.5	0.5	1.5	0.12	20.4	20.4

Table 7. Filtered water, major and minor element concentrations from ICP-MS (ICP-AES for major elements), Harley Gulch, Lake County, California.

Field number	Ag in µg/L	Al in µg/L	As in µg/L	B in µg/L	Ba in µg/L	Be in µg/L	Bi in µg/L	Ca in mg/L	Cd in µg/L	Ce in µg/L	Co in µg/L	Cr in µg/L	Cs in µg/L
	Low-flow June 2010												
10HG1	<1	7.6	8.3	42,500	80.7	<0.05	< 0.2	42.8	<0.02	0.09	0.6	19.9	34.8
10HG2	<1	6.4	12.8	33,300	126	<0.05	< 0.2	50.8	<0.02	0.03	2.03	17.7	0.14
10HG3	<1	<2	1	2,410	88.3	<0.05	< 0.2	53.1	<0.02	0.04	0.08	4.9	< 0.02
10HG4	<1	<2	3.8	14,800	52.7	<0.05	< 0.2	46.7	<0.02	0.01	0.09	9.6	0.2
10HG5	<1	2.8	4.6	18,200	51.2	<0.05	< 0.2	43.8	<0.02	0.02	0.08	10	0.22
10HG6	<10	<20	<10	21,100	48.1	<0.5	< 2	<20	<0.2	< 0.1	<0.2	<10	0.35
10HG7	<10	<20	<10	21,800	28	<0.5	< 2	<20	<0.2	< 0.1	0.2	<10	0.25
10HG8	<10	<20	<10	16,900	58.6	<0.5	< 2	<20	<0.2	< 0.1	<0.2	<10	< 0.2
10HG9	<10	<20	<10	13,900	48.6	<0.5	< 2	<20	<0.2	< 0.1	<0.2	<10	< 0.2
10HG10	<10	<20	<10	10,900	70.7	<0.5	< 2	<20	<0.2	< 0.1	<0.2	<10	< 0.2
	Low-flow Sept. 2010												
10HG4-2	<1	<2	5	20,600	54.3	nr	< 0.2	43.3	0.05	0.02	0.08	1.2	0.77
	Low-flow May 2011												
11HG1-2	<1	3	1.3		39.6	<0.05	nr	59	<0.02	< 0.01	0.31	4.2	0.08
11HG1.5-2	<1	3	5.4		79.5	<0.05	nr	59.8	<0.02	< 0.01	0.27	14.6	18.7
11HG2-2	<1	2.7	6.6		84.9	<0.05	nr	58.1	<0.02	< 0.01	0.6	12.1	1.3
11HG3-2	<1	6.4	<1		89.7	<0.05	nr	53.9	<0.02	< 0.01	0.25	6.2	< 0.02
11HG4-2	<1	7	3.2		86.3	<0.05	nr	53.5	<0.02	< 0.01	0.53	7.9	0.47
11HG5-2	<1	11	3.2		86	<0.05	nr	55.8	<0.02	< 0.01	0.15	7.2	0.24
11HG6-2	<1	20.7	3.1		87.6	<0.05	nr	50.4	<0.02	< 0.01	0.17	5.3	0.2
	High-flow March 2011												
11HG1	<1	176	<1	476	72.2	<0.05	< 0.2	29	<0.02	0.24	4.5	3.3	0.06
11HG2	<1	49.5	1.5	3,400	61.1	<0.05	< 0.2	23	<0.02	0.13	3.2	2.4	0.04
11HG3	<1	59.5	<1	196	30.1	<0.05	< 0.2	15.7	<0.02	0.15	0.13	1.6	< 0.02
11HG4	<1	399	<1	1,340	44.1	<0.05	< 0.2	17.9	<0.02	0.38	0.67	4.5	0.11

Table 7 (cont'd)

Field number	Cu in µg/L	Dy in µg/L	Er in µg/L	Eu in µg/L	Fe in µg/L	Ga in µg/L	Gd in µg/L	Ge in µg/L	Ho in µg/L	K in mg/L	La in µg/L	Li in µg/L	Lu in µg/L
	Low-flow June 2010												
10HG1	3.6	0.03	0.02	0.01	<20	< 0.05	0.01	5.5	0.008	34.1	0.02	1,520	< 0.1
10HG2	3.1	0.02	0.01	0.01	84.2	< 0.05	0.02	1.2	< 0.005	21.9	0.02	1,080	< 0.1
10HG3	1.8	0.01	0.01	0.01	<20	< 0.05	0.02	< 0.05	< 0.005	4.41	0.02	171	< 0.1
10HG4	2.7	< 0.005	0.005	0.005	<20	< 0.05	0.005	< 0.05	< 0.005	9.35	< 0.01	522	< 0.1
10HG5	3	0.005	0.007	< 0.005	<20	< 0.05	0.009	< 0.05	< 0.005	10.8	< 0.01	626	< 0.1
10HG6	<5	< 0.05	< 0.05	< 0.05	<20	< 0.5	< 0.05	< 0.5	< 0.05	12.6	< 0.1	657	< 1
10HG7	<5	< 0.05	< 0.05	< 0.05	<20	< 0.5	< 0.05	< 0.5	< 0.05	11.1	< 0.1	663	< 1
10HG8	<5	< 0.05	< 0.05	< 0.05	<20	< 0.5	< 0.05	< 0.5	< 0.05	8.6	< 0.1	484	< 1
10HG9	<5	< 0.05	< 0.05	< 0.05	<20	< 0.5	< 0.05	< 0.5	< 0.05	6.76	< 0.1	381	< 1
10HG10	<5	< 0.05	< 0.05	< 0.05	<20	< 0.5	< 0.05	< 0.5	< 0.05	5.78	< 0.1	339	< 1
	Low-flow Sept. 2010												
10HG4-2	2.2	0.01	0.04	0.02	43	0.1	0.01		0.005	12.8	0.01	678	
	Low-flow May 2011												
11HG1-2	3.5	0.15	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	4.4	< 0.01	166	
11HG1.5-2	3.3	0.15	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	18.9	< 0.01	1,070	
11HG2-2	4.3	0.16	< 0.005	0.04	<50	< 0.05	< 0.005		< 0.005	16	< 0.01	934	
11HG3-2	2	0.16	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	2.2	< 0.01	76.7	
11HG4-2	3.2	0.17	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	8.6	< 0.01	530	
11HG5-2	3	0.16	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	7.5	< 0.01	462	
11HG6-2	3.2	0.17	< 0.005	0.05	<50	< 0.05	< 0.005		< 0.005	7.9	< 0.01	503	
	High-flow March 2011												
11HG1	3	0.072	0.07	0.04	327	0.06	0.077		0.01	2	0.09	27.1	
11HG2	3.3	0.065	0.063	0.03	62.7	< 0.05	0.063		0.01	4.5	0.05	127	
11HG3	2.9	0.076	0.064	0.04	114	< 0.05	0.082		0.01	1.3	0.06	8.9	
11HG4	3.7	0.11	0.072	0.04	646	0.2	0.1		0.02	2.4	0.14	51.5	

Table 7 (cont'd)

Field number	Mg in mg/L	Mn in µg/L	Mo in µg/L	Na in mg/L	Nb in µg/L	Nd in µg/L	Ni in µg/L	P in mg/L	Pb in µg/L	Pr in µg/L	Rb in µg/L	Sb in µg/L	Sc in µg/L
	Low-flow June 2010												
10HG1	617	75.5	< 2	1080	< 0.2	0.06	5.4	0.07	1	< 0.01	65.6	0.8	4.1
10HG2	552	210	3.6	855	< 0.2	0.02	11.3	0.2	0.8	< 0.01	7.81	0.35	2.2
10HG3	119	7.4	< 2	101	< 0.2	0.03	<0.4	< 0.01	1.3	< 0.01	2.36	<0.3	1.5
10HG4	276	24.6	2	430	< 0.2	< 0.01	<0.4	< 0.01	1.6	< 0.01	7.43	0.45	1.6
10HG5	330	4.3	2.4	522	< 0.2	0.01	0.8	< 0.01	1.6	< 0.01	8.69	0.49	1.5
10HG6	302	<2	< 20	557	< 2	< 0.1	<4	< 0.1	<0.5	< 0.1	7.45	<3	< 6
10HG7	309	<2	< 20	573	< 2	< 0.1	<4	< 0.1	<0.5	< 0.1	7.02	<3	< 6
10HG8	269	19.5	< 20	439	< 2	< 0.1	<4	< 0.1	<0.5	< 0.1	2.78	<3	< 6
10HG9	211	<2	< 20	372	< 2	< 0.1	<4	< 0.1	<0.5	< 0.1	2.97	<3	< 6
10HG10	202	<2	< 20	343	< 2	< 0.1	<4	< 0.1	<0.5	< 0.1	1.65	<3	< 6
	Low-flow Sept. 2010												
10HG4-2	360	27.2	2.5	612	< 0.2	0.04	0.5	0.1	<0.05	< 0.01	10.5	1.1	2.4
	Low-flow May 2011												
11HG1-2	296	10.7	< 2	nr	< 0.2	< 0.01	8.9	0.1	<0.05	< 0.01	1.9	0.95	1.5
11HG1.5-2	457	32.3	< 2	nr	< 0.2	< 0.01	7.1	0.1	<0.05	< 0.01	28.5	0.96	3.5
11HG2-2	442	17.7	2.3	nr	< 0.2	< 0.01	11.4	0.2	<0.05	< 0.01	7.9	1.7	2.1
11HG3-2	146	3.1	< 2	70.9	< 0.2	< 0.01	<0.4	0.04	<0.05	< 0.01	1.1	<0.3	1.6
11HG4-2	279	9.6	< 2	nr	< 0.2	< 0.01	5.4	0.1	<0.05	< 0.01	4.2	0.9	1.7
11HG5-2	262	5.5	< 2	nr	< 0.2	< 0.01	4	0.08	<0.05	< 0.01	3.6	0.71	1.8
11HG6-2	269	3.1	< 2	nr	< 0.2	< 0.01	3.5	0.07	<0.05	< 0.01	3.4	0.76	1.5
	High-flow March 2011												
11HG1	61.5	12.8	< 2	28.1	< 0.2	0.23	10.8	0.06	0.3	0.06	0.5	0.46	1.8
11HG2	80.1	7.3	< 2	101	< 0.2	0.18	6.7	0.07	0.27	0.05	1.5	1.5	1.9
11HG3	27.5	4.9	< 2	12.1	< 0.2	0.2	3.3	0.05	<0.05	0.05	0.22	<0.3	1.7
11HG4	45.5	12.9	< 2	41	< 0.2	0.34	12.7	0.06	0.17	0.08	0.94	<0.3	2

Table 7(cont'd)

Field number	Se in µg/L	SiO2 in mg/L	Sm in µg/L	SO4 in mg/L	Sr in µg/L	Ta in µg/L	Tb in µg/L	Th in µg/L	Ti in µg/L	Tl in µg/L	Tm in µg/L	U in µg/L	V in µg/L
	Low-flow June 2010												
10HG1	22.2	59.9	0.01	1,290	2,220	0.03	< 0.005	< 0.2	18.8	0.1	< 0.005	0.96	10.6
10HG2	17.5	31.3	< 0.01	1,370	1,870	0.03	< 0.005	< 0.2	20.4	<0.1	< 0.005	2.64	7
10HG3	2.1	18	0.01	340	896	< 0.02	< 0.005	< 0.2	5.4	<0.1	< 0.005	0.68	4.1
10HG4	8.3	20.1	< 0.01	829	1,180	< 0.02	< 0.005	< 0.2	12.8	<0.1	< 0.005	1.76	5.3
10HG5	11.1	19.6	< 0.01	1,020	1,220	< 0.02	< 0.005	< 0.2	15.8	<0.1	< 0.005	2.1	6
10HG6	< 10	13.8	< 0.1	892	1,060	< 0.2	< 0.05	< 2	10	<1	< 0.05	< 1	<5
10HG7	< 10	12.6	< 0.1	932	492	< 0.2	< 0.05	< 2	10.2	<1	< 0.05	< 1	<5
10HG8	< 10	13.8	< 0.1	880	1,150	< 0.2	< 0.05	< 2	10.5	<1	< 0.05	< 1	<5
10HG9	< 10	11.8	< 0.1	770	1,280	< 0.2	< 0.05	< 2	9.4	<1	< 0.05	< 1	<5
10HG10	< 10	9.5	< 0.1	777	1,350	< 0.2	< 0.05	< 2	8.3	<1	< 0.05	< 1	<5
	Low-flow Sept. 2010												
10HG4-2	68.2	10	< 0.01	450	1,190	0.03	< 0.005	< 0.2	20.3	<0.1	0.006	3.08	4.2
	Low-flow May 2011												
11HG1-2	2	19	< 0.01	870	876	0.28	< 0.005	0.37	14.2	<0.1	< 0.005	1.37	3.5
11HG1.5-2	15.3	40	< 0.01	1,100	1,890	0.28	< 0.005	0.36	17.1	<0.1	< 0.005	1.54	7.2
11HG2-2	14.7	25	< 0.01	1,000	1,640	0.28	< 0.005	0.37	17	<0.1	< 0.005	2.55	8.8
11HG3-2	1.1	20	< 0.01	190	874	0.27	< 0.005	0.36	3.4	<0.1	< 0.005	1.08	3.8
11HG4-2	7.9	21	< 0.01	600	1,180	0.28	< 0.005	0.37	9.8	<0.1	< 0.005	1.69	5.8
11HG5-2	6.4	21	< 0.01	570	1,150	0.27	< 0.005	0.36	9.9	<0.1	< 0.005	1.73	5.5
11HG6-2	8	20	< 0.01	600	1,050	0.28	< 0.005	0.36	10.4	<0.1	< 0.005	1.68	5
	High-flow March 2011												
11HG1	1.3	17	< 0.01	210	320	< 0.02	0.03	0.21	6.3	<0.1	0.04	0.38	3.6
11HG2	3.3	18	< 0.01	270	410	< 0.02	0.02	< 0.2	5.8	<0.1	0.04	0.39	3.5
11HG3	< 1	16	< 0.01	30	171	< 0.02	0.03	< 0.2	1.8	<0.1	0.03	0.12	2.6
11HG4	1.6	19	0.04	100	249	< 0.02	0.03	0.21	6.9	<0.1	0.04	0.21	4.3

Table 7 (cont'd)

Field number	W in µg/L	Y in µg/L	Yb in µg/L	Zn in µg/L	Zr in µg/L
	Low-flow June 2010				
10HG1	279	0.3	0.01	14.4	< 0.2
10HG2	37.4	0.2	0.008	5.5	0.5
10HG3	2.12	0.12	0.008	1.3	< 0.2
10HG4	7.28	0.08	0.005	3	< 0.2
10HG5	8.47	0.08	< 0.005	3.8	< 0.2
10HG6	48.8	< 0.1	< 0.05	<5	< 2
10HG7	26	< 0.1	< 0.05	6.5	< 2
10HG8	15.2	< 0.1	< 0.05	<5	< 2
10HG9	10.8	< 0.1	< 0.05	5.9	< 2
10HG10	8.03	< 0.1	< 0.05	<5	< 2
	Low-flow Sept. 2010				
10HG4-2		0.09	0.02	<3	
	Low-flow May 2011				
11HG1-2	1.5	0.07	< 0.01	17.2	
11HG1.5-2	110	0.14	< 0.01	7.9	
11HG2-2	36	0.18	< 0.01	11.6	
11HG3-2	1.6	0.12	< 0.01	<3	
11HG4-2	16	0.17	< 0.01	5.5	
11HG5-2	11	0.16	< 0.01	4.5	
11HG6-2	12	0.14	< 0.01	3.7	
	High-flow March 2011				
11HG1	< 0.5	0.2	0.03	3.1	
11HG2	6.7	0.17	0.03	3.8	
11HG3	< 0.5	0.2	0.03	<3	
11HG4	1.8	0.3	0.04	3.4	

Table 8. Stable-isotope levels and calculated percent effluent in stream waters collected from Harley Gulch*, Lake County, California.

Sample	$\delta^{18}O$ (percentD) x1000	δD (percentD) x1000	Cl in µg/g	SO_4 in µg/g	percent Effluent δ18O	percent Effluent δD	percent Effluent Cl	percent Effluent SO_4
	Low-flow Jun. 2010							
10HG1	-5.77	-49.66	1,131.8	1,068	101.03	127.34	98.40	52.61
10HG2	-6.47	-51.51	1,021	1,409	68.20	76.89	88.68	69.59
10HG3	-6.82	-52.17	43.6	321	57.49	71.80	2.93	15.43
10HG4	-7.05	-54.08	403.4	751.4	50.46	57.09	34.50	36.85
10HG5	-6.84	-53.76	572.6	959.3	56.88	59.55	49.34	47.20
10HG6	-6.54	-52.1	748.5	1,196	66.06	72.34	64.77	58.98
10HG7	-5.43	-48.51	874.5	1,424	100.00	100.00	75.83	70.33
10HG8	-5.75	-49.13	511	942	90.21	95.22	43.94	46.34
10HG9	-5.97	-50.65	484.1	1,015	83.49	83.51	41.58	49.98
10HG10	-6.56	-51.46	431.9	1,034.4	65.44	77.27	37.00	50.94
	Low-flow Sept. 2010							
10HG4-2	-7.01	-53.23	862	813.5	51.68	63.64	74.73	39.95
	Low-flow May 2011							
11HG1	-7.49	-53.56	60.4	964.56	55.76	85.36	4.40	47.46
11HG1.5	-6.53	-52.38	762.6	1,275.5	100.00	70.18	66.01	62.94
11HG2	-6.82	-52.88	752.6	1,260.3	86.64	66.33	65.13	62.19
11HG3	-7.69	-53.93	29.6	201.6	46.54	58.24	1.70	9.49
11HG4	-7.23	-53.34	354.2	684.6	67.74	62.79	30.18	33.53
11HG5	-7.24	-53.66	320.5	660	67.28	60.32	27.22	32.30
11HG7	-7.13	-52.94	391.9	759	72.35	65.87	33.49	37.23
	High-flow Mar. 2011							
11HG1-2	-9.7	-65.58	10.9	228.1	0.63	0.00	0.06	10.81
11HG2-2	-9.35	-63.75	67.5	285	11.60	10.72	5.03	13.64
11HG3-2	-9.72	-65.29	4.8	30.2	0.00	1.70	-0.47	0.96
11HG4-2	-9.54	-64.45	25.8	111	5.64	6.62	1.37	4.98
	High-flow Jun. 2011							
11HG1-3	-8.1	-57.85	101.6	1,379	20.69	39.18	8.02	68.09
11HG2-3	-7.06	-55.81	758.6	1,251.3	50.15	43.76	65.66	61.74
11HG3-3	-8.04	-58.51	73.3	11	20.18	22.96	5.54	0.00

*Percentages of effluent fluid are calculated using a two-end member system in which meteoric water from the nearby Clyde mine is treated as the background, meteoric end-member 1, and either effluent collected from the adit in 1997 or water sampled from sample sites HG1.5 or HG7 are used as end-member 2. Which sample is used as the second end member depends on the conditions during the specific sampling event.

Table 9. Total mercury (Hg_T) and monomethyl mercury (MMeHg) (μg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, and 2010, and at a reference site, Bear River at Highway 20 (BR 20), during 1999–2002, Lake County, California.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (μg/g, wet wt)	MMeHg (μg/g, wet wt)	percent MMeHg
BR20-99	10/1/1999	BY-BH20-100199-001	Hemiptera	Gerridae	adult	21	1.07	0.051	57.20	NA1	0.027	NA
BR20-00	9/12/2000	BY-BH20-091200-001	Hemiptera	Gerridae	adult	26	1.3	0.050	76.10	0.028	0.027	95.00
BR20-01	9/15/2001	BY-BH20-091501-009	Odonata	Aeshnidae	larvae	7	3.89	0.556	81.90	0.022	0.014	64.20
BR20-01	9/15/2001	BY-BH20-091501-003	Hemiptera	Gerridae	adult	25	1.25	0.050	64.70	0.070	0.050	71.60
BR20-02	8/23/2002	BY-BR20-082302-005	Odonata	Aeshnidae	larvae	8	3.63	0.454	79.90	0.024	0.026	107.60
BR20-02	8/23/2002	BY-BR20-082302-001	Hemiptera	Gerridae	adult	25	1.37	0.055	63.00	0.045	0.041	91.80
HGDS-02	10/16/2002	CA02G001	Hemiptera	Gerridae	adult	25	1.34	0.054	56.40	1.308	1.443	110.30
HGDS-02	10/16/2002	CA02A001	Odonata	Aeshnidae	larvae	9	2.3	0.256	80.60	3.996	3.162	79.10
HGDS-02	10/16/2002	CA02A002	Odonata	Libellulidae	larvae	9	4.56	0.507	80.70	3.783	2.548	67.30
HG3	5/16/2007	HAR-SITE3-51607-001	Hemiptera	Gerridae	adult	25	1.56	0.062	75.30	0.159	0.146	91.80
HG3	5/16/2007	HAR-SITE3-51607-002	Odonata	Libellulidae	larvae	5	2.29	0.458	82.90	0.191	0.218	114.10
HG4	5/16/2007	HAR-SITE4-51607-001	Hemiptera	Gerridae	adult	17	1.13	0.066	65.20	0.302	0.241	79.80
HG4	5/16/2007	HAR-SITE4-51607-002	Odonata	Aeshnidae	larvae	3	4.1	1.367	79.30	1.180	0.855	72.50
HG4	5/16/2007	HAR-SITE4-51607-003	Odonata	Libellulidae	larvae	9	2.41	0.268	82.20	0.961	0.357	37.10
HG5	5/16/2007	HAR-SITE5-51607-001	Odonata	Libellulidae	larvae	4	1.69	0.423	83.90	0.581	0.540	92.90
HG6	5/16/2007	HAR-SITE6-51607-001	Hemiptera	Gerridae	adult	25	1.71	0.068	67.70	0.701	0.690	98.40
HG6	5/16/2007	HAR-SITE6-51607-002	Odonata	Libellulidae	larvae	5	3.03	0.606	79.70	1.920	1.570	81.80
HG6	5/16/2007	HAR-SITE6-51607-004	Odonata	Aeshnidae	larvae	4	2.83	0.708	83.40	0.492	0.445	90.40
HG7	5/16/2007	HAR-SITE7-51607-001	Hemiptera	Gerridae	adult	25	1.46	0.058	73.70	0.546	0.547	100.20
HG7	5/16/2007	HAR-SITE7-51607-002	Odonata	Libellulidae	larvae	5	1.8	0.360	87.70	0.961	0.915	95.20
HG8-07	5/16/2007	HAR-SITE8-51607-001	Odonata	Aeshnidae	larvae	5	3.61	0.722	81.90	0.863	0.498	57.70
HG8-07	5/16/2007	HAR-SITE8-51607-002	Odonata	Libellulidae	larvae	2	0.82	0.410	89.80	0.640	0.443	69.20
HG1	5/21/2008	CR-HG1-052108-001	Coleoptera	Hydrophilidae	larvae	6	1.86	0.310	86.50	NA	0.036	NA
HG1	5/21/2008	CR-HG1-052108-002	Coleoptera	Hydrophilidae	larvae	6	1.45	0.242	79.43	NA	0.029	NA
HG1	5/21/2008	CR-HG1-052108-003	Odonata	Libellulidae	larvae	2	0.66	0.330	83.83	NA	0.186	NA
HG1	5/21/2008	CR-HG1-052108-006	Odonata	Coenagrionidae	larvae	8	0.39	0.049	83.46	NA	0.204	NA
HG1	5/21/2008	CR-HG1-052180-004	Coleoptera	Hydrophilidae	adult	4	1.08	0.270	70.25	NA	0.097	NA
HG1	5/21/2008	CR-HG1-052180-005	Coleoptera	Dytiscidae	adult	16	0.75	0.047	71.63	NA	0.195	NA
HG2	5/21/2008	CR-HG2-052108-001	Coleoptera	Dytiscidae	adult	15	0.81	0.054	83.67	NA	0.069	NA
HG2	5/21/2008	CR-HG2-052108-002	Odonata	Coenagrionidae	larvae	16	1.03	0.064	84.78	NA	0.059	NA
HG2	5/21/2008	CR-HG2-052108-003	Odonata	Coenagrionidae	larvae	23	1.11	0.048	83.88	NA	0.114	NA
HG2a	5/21/2008	CR-HG2A-052108-001	Hemiptera	Gerridae	adult	27	1.81	0.067	74.34	NA	0.056	NA
HG2a	5/21/2008	CR-HG2A-052108-002	Odonata	Libellulidae	larvae	2	0.84	0.420	86.41	NA	0.087	NA

Table 9 (continued). Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, 2010 and 2011, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (µg/g, wet wt)	MMeHg (µg/g, wet wt)	percent MMeHg
HG2a	5/21/2008	CR-HG2A-052108-003	Coleoptera	Hydrophilidae	larvae	5	1.12	0.224	90.36	NA	0.054	NA
HG2a	5/21/2008	CR-HG2A-052108-004	Odonata	Coenagrionidae	larvae	19	1.06	0.056	80.75	NA	0.131	NA
HG2a	5/21/2008	CR-HG2A-052108-005	Odonata	Coenagrionidae	larvae	24	1.11	0.046	84.43	NA	0.110	NA
HG3	5/21/2008	CR-HG3-052108-001	Odonata	Coenagrionidae	larvae	21	0.82	0.039	87.98	NA	0.101	NA
HG3	5/21/2008	CR-HG3-052108-002	Odonata	Libellulidae	larvae	5	0.99	0.198	94.23	NA	0.057	NA
HG3	5/21/2008	CR-HG3-052108-003	Hemiptera	Gerridae	adult	20	1.11	0.056	82.29	NA	0.035	NA
HG3	5/21/2008	CR-HG3-052108-004	Hemiptera	Gerridae	adult	18	0.99	0.055	85.41	NA	0.031	NA
HG3	5/21/2008	CR-HG3-052108-005	Coleoptera	Dytiscidae	adult	20	1.18	0.059	80.04	NA	0.123	NA
HG3	5/21/2008	CR-HG3-052108-006	Hemiptera	Belostomatidae	adult	5	1.56	0.312	73.48	NA	1.710	NA
HG3	5/21/2008	CR-HG3-052108-007	Megaloptera	Corydalidae	larvae	1	0.65	0.650	80.00	NA	0.023	NA
HG5	5/21/2008	CR-HG5-052108-001	Hemiptera	Gerridae	adult	25	1.87	0.075	79.22	NA	0.063	NA
HG5	5/21/2008	CR-HG5-052108-002	Odonata	Coenagrionidae	larvae	35	1.27	0.036	84.60	NA	0.154	NA
HG5	5/21/2008	CR-HG5-052108-003	Hemiptera	Belostomatidae	adult	3	1.18	0.393	73.76	NA	1.450	NA
HG5	5/21/2008	CR-HG5-052108-004	Odonata	Aeshnidae	larvae	3	1.41	0.470	84.57	NA	0.169	NA
HG5	5/21/2008	CR-HG5-052108-005	Odonata	Libellulidae	larvae	6	2.60	0.433	84.59	NA	0.254	NA
HG5	5/21/2008	CR-HG5-052108-006	Odonata	Libellulidae	larvae	7	1.12	0.160	85.17	NA	0.357	NA
HG7	6/4/2008	CR-HG7-060408-001	Odonata	Libellulidae	larvae	3	1.32	0.440	90.02	NA	0.103	NA
HG7	6/4/2008	CR-HG7-060408-002	Odonata	Libellulidae	larvae	13	1.58	0.122	89.35	NA	0.109	NA
HG7	6/4/2008	CR-HG7-060408-003	Odonata	Coenagrionidae	larvae	40	1.33	0.033	85.22	NA	0.125	NA
HG7	6/4/2008	CR-HG7-060408-004	Hemiptera	Gerridae	adult	30	1.77	0.059	78.67	NA	0.130	NA
HG8-08	6/4/2008	CR-HG8-060408-001	Hemiptera	Gerridae	adult	30	1.78	0.059	75.18	NA	0.091	NA
HG8-08	6/4/2008	CR-HG8-060408-002	Coleoptera	Hydrophilidae	adult	1	1.45	1.450	62.43	NA	0.059	NA
HG8-08	6/4/2008	CR-HG8-060408-003	Odonata	Libellulidae	larvae	10	2.49	0.249	84.25	NA	0.144	NA
HG8-08	6/4/2008	CR-HG8-060408-004	Odonata	Lestidae	larvae	25	1.51	0.060	91.38	NA	0.066	NA
HG8-08	6/4/2008	CR-HG8-060408-005	Odonata	Coenagrionidae	larvae	22	0.84	0.038	85.69	NA	0.126	NA
HG9	6/4/2008	CR-HG9-060408-001	Hemiptera	Gerridae	adult	25	1.35	0.054	77.37	NA	0.046	NA
HG9	6/4/2008	CR-HG9-060408-002	Odonata	Libellulidae	larvae	4	1.17	0.293	87.32	NA	0.055	NA
HG9	6/4/2008	CR-HG9-060408-003	Odonata	Lestidae	larvae	7	0.67	0.096	91.06	NA	0.016	NA
HG9	6/4/2008	CR-HG9-060408-004	Odonata	Coenagrionidae	larvae	21	0.77	0.037	88.34	NA	0.034	NA
HG10	6/4/2008	CR-HG10-060408-001	Hemiptera	Gerridae	adult	30	1.86	0.062	80.89	NA	0.039	NA
HG10	6/4/2008	CR-HG10-060408-002	Odonata	Libellulidae	larvae	5	1.09	0.218	86.71	NA	0.072	NA
HG10	6/4/2008	CR-HG10-060408-003	Odonata	Coenagrionidae	larvae	30	0.93	0.031	87.44	NA	0.046	NA
HG11	6/4/2008	CR-HG11-060408-001	Hemiptera	Gerridae	adult	30	2.31	0.077	74.01	NA	0.034	NA
HG11	6/4/2008	CR-HG11-060408-002	Odonata	Coenagrionidae	larvae	30	0.93	0.031	91.34	NA	0.025	NA

Table 9 (continued). Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, 2010 and 2011, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (µg/g, wet wt)	MMeHg (µg/g, wet wt)	percent MMeHg
HG11	6/4/2008	CR-HG11-060408-003	Megaloptera	Corydalidae	larvae	2	1.03	0.515	84.94	NA	0.081	NA
HG11	6/4/2008	CR-HG11-060408-004	Odonata	Aeshnidae	larvae	3	2.53	0.843	83.93	NA	0.093	NA
HG11	6/4/2008	CR-HG11-060408-005	Odonata	Libellulidae	larvae	6	2.19	0.365	82.96	NA	0.106	NA
HG11	6/4/2008	CR-HG11-060408-006	Coleoptera	Dytiscidae	adult	9	0.62	0.069	72.49	NA	0.087	NA
HG12	6/4/2008	CR-HG12-060408-001	Hemiptera	Gerridae	adult	20	1.33	0.067	77.09	NA	0.037	NA
HG12	6/4/2008	CR-HG12-060408-002	Hemiptera	Gerridae	adult	20	1.42	0.071	78.64	NA	0.037	NA
HG12	6/4/2008	CR-HG12-060408-003	Odonata	Lestidae	larvae	10	0.6	0.060	92.81	NA	0.009	NA
HG12	6/4/2008	CR-HG12-060408-004	Megaloptera	Corydalidae	larvae	2	1.03	0.515	80.58	NA	0.056	NA
HG13	6/4/2008	CR-HG13-060408-001	Hemiptera	Gerridae	adult	25	1.92	0.077	76.89	NA	0.025	NA
HG13	6/4/2008	CR-HG13-060408-002	Odonata	Lestidae	larvae	10	1.05	0.105	87.44	NA	0.004	NA
HG14	6/4/2008	CR-HG!4-060408-001	Odonata	Lestidae	larvae	7	0.82	0.117	85.56	NA	0.004	NA
HG14	6/4/2008	CR-HG!4-060408-002	Hemiptera	Gerridae	adult	30	1.96	0.065	78.93	NA	0.023	NA
UDLW	6/8/2010	CR-UDLW-060810-001	Odonata	Coenagrionidae	larvae	25	1.33	0.053	86.18	0.461	0.021	4.56
UDLW	6/8/2010	CR-UDLW-060810-002	Coleoptera	Dytiscidae	adult	21	0.8	0.038	85.62	0.232	0.063	26.94
UDLW	6/8/2010	CR-UDLW-060810-003	Hemiptera	Gerridae	adult	30	1.83	0.061	75.44	0.163	0.062	38.28
UDUP	6/8/2010	CR-UDUP-060810-001	Coleoptera	Hydrophilidae	larvae	7	1.9	0.271	85.72	1.570	0.049	3.13
UDUP	6/8/2010	CR-UDUP-060810-002	Odonata	Coenagrionidae	larvae	38	2.18	0.057	83.01	1.990	0.048	2.43
UDUP	6/8/2010	CR-UDUP-060810-003	Coleoptera	Dytiscidae	adult	24	1.22	0.051	78.51	0.828	0.070	8.48
UDUP	6/8/2010	CR-UDUP-060810-004	Hemiptera	Gerridae	adult	10	0.62	0.062	NA	0.112	0.060	53.13
HG1	6/8/2010	CR-HG1-060810-001	Coleoptera	Hydrophilidae	larvae	3	0.68	0.227	87.82	0.503	0.021	4.08
HG1	6/8/2010	CR-HG1-060810-002	Odonata	Coenagrionidae	larvae	30	1.51	0.050	85.31	2.340	0.067	2.86
HG1	6/8/2010	CR-HG1-060810-003	Odonata	Coenagrionidae	larvae	30	1.45	0.048	86.03	2.050	0.062	3.00
HG1	6/8/2010	CR-HG1-060810-004	Coleoptera	Dytiscidae	adult	32	1.34	0.042	69.50	0.295	0.111	37.63
HG2	6/8/2010	CR-HG2-060810-001	Coleoptera	Dytiscidae	adult	25	1.02	0.041	84.32	0.406	0.188	46.31
HG2a	6/8/2010	CR-HG2a-060810-001	Coleoptera	Hydrophilidae	larvae	4	1.21	0.303	88.06	0.171	0.020	11.64
HG2a	6/8/2010	CR-HG2a-060810-002	Coleoptera	Hydrophilidae	larvae	4	1.4	0.350	88.48	0.186	0.022	11.72
HG2a	6/8/2010	CR-HG2a-060810-003	Coleoptera	Dytiscidae	adult	20	1.13	0.057	87.14	0.440	0.018	4.00
HG2a	6/8/2010	CR-HG2a-060810-004	Hemiptera	Gerridae	adult	22	1.54	0.070	75.72	0.139	0.074	52.88
HG3	6/8/2010	CR-HG3-060810-001	Coleoptera	Hydrophilidae	larvae	9	1.93	0.214	89.11	0.025	0.010	40.40
HG3	6/8/2010	CR-HG3-060810-002	Odonata	Lestidae	larvae	20	1.48	0.074	90.21	0.048	0.035	71.93
HG3	6/8/2010	CR-HG3-060810-003	Odonata	Coenagrionidae	larvae	11	0.45	0.041	NA	0.062	0.031	50.49
HG3	6/8/2010	CR-HG3-060810-005	Coleoptera	Dytiscidae	adult	16	1.08	0.068	77.85	0.129	0.040	30.70
HG3	6/8/2010	CR-HG3-060810-007	Hemiptera	Gerridae	adult	26	1.66	0.064	68.58	0.057	0.044	77.89
HG4	6/8/2010	CR-HG4-060810-001	Coleoptera	Hydrophilidae	larvae	4	0.64	0.160	95.55	0.217	0.021	9.63

Table 9 (continued). Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, 2010 and 2011, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (µg/g, wet wt)	MMeHg (µg/g, wet wt)	percent MMeHg
HG4	6/8/2010	CR-HG4-060810-002	Odonata	Libellulidae	larvae	3	0.65	0.217	94.76	0.094	0.041	43.74
HG4	6/8/2010	CR-HG4-060810-003	Odonata	Coenagrionidae	larvae	23	0.91	0.040	86.84	0.443	0.095	21.53
HG4	6/8/2010	CR-HG4-060810-004	Odonata	Lestidae	larvae	30	1.79	0.060	85.37	0.204	0.130	63.73
HG4	6/8/2010	CR-HG4-060810-005	Hemiptera	Gerridae	adult	25	1.91	0.076	75.85	0.116	0.078	66.90
HG5	6/10/2010	CR-HG5-061010-001	Odonata	Libellulidae	larvae	7	3.08	0.440	81.55	0.201	0.094	46.52
HG5	6/10/2010	CR-HG5-061010-002	Odonata	Aeshnidae	larvae	1	0.68	0.680	90.60	0.098	0.038	38.35
HG5	6/10/2010	CR-HG5-061010-003	Hemiptera	Gerridae	adult	21	1.5	0.071	70.48	0.106	0.065	61.70
HG5	6/10/2010	CR-HG5-061010-004	Coleoptera	Dytiscidae	adult	19	1.92	0.101	72.90	0.200	0.132	66.00
HG6	6/10/2010	CR-HG6-061010-002	Odonata	Libellulidae	larvae	5	2.63	0.526	86.46	0.253	0.127	50.20
HG6	6/10/2010	CR-HG6-061010-003	Odonata	Coenagrionidae	larvae	23	1.11	0.048	89.59	0.374	0.087	23.18
HG6	6/10/2010	CR-HG6-061010-004	Hemiptera	Gerridae	adult	19	1.3	0.068	82.19	0.066	0.040	60.61
HG6	6/10/2010	CR-HG6-061010-005	Coleoptera	Dytiscidae	adult	15	1.48	0.099	69.77	0.246	0.165	67.07
HG6	6/10/2010	CR-HG6-061010-006	Coleoptera	Dytiscidae	adult	14	1.6	0.114	69.45	0.236	0.235	99.58
HG7	6/10/2010	CR-HG7-061010-001	Odonata	Libellulidae	larvae	4	1.93	0.483	83.33	0.157	0.081	51.72
HG7	6/10/2010	CR-HG7-061010-002	Odonata	Libellulidae	larvae	3	1.37	0.457	90.02	0.118	0.082	69.66
HG7	6/10/2010	CR-HG7-061010-003	Odonata	Coenagrionidae	larvae	40	1.38	0.035	84.97	0.244	0.070	28.65
HG7	6/10/2010	CR-HG7-061010-004	Hemiptera	Gerridae	adult	25	1.6	0.064	73.18	0.151	0.105	69.54
HG8	6/10/2010	CR-HG8-061010-001	Odonata	Libellulidae	larvae	3	1.41	0.470	87.70	0.133	0.093	69.77
HG8	6/10/2010	CR-HG8-061010-002	Odonata	Coenagrionidae	larvae	35	1.13	0.032	85.81	0.283	0.074	26.11
HG8	6/10/2010	CR-HG8-061010-003	Odonata	Lestidae	larvae	25	1.62	0.065	89.29	0.113	0.054	47.70
HG8	6/10/2010	CR-HG8-061010-004	Odonata	Lestidae	larvae	25	1.17	0.047	86.87	0.136	0.075	54.85
HG8	6/10/2010	CR-HG8-061010-006	Hemiptera	Gerridae	adult	25	1.7	0.068	69.92	0.068	0.066	97.35
HG8a	6/10/2010	CR-HG8a-061010-001	Odonata	Aeshnidae	larvae	3	2.61	0.870	67.17	0.081	0.041	50.25
HG8a	6/10/2010	CR-HG8a-061010-002	Odonata	Libellulidae	larvae	2	1.19	0.595	86.00	0.159	0.140	88.05
HG8a	6/10/2010	CR-HG8a-061010-003	Odonata	Coenagrionidae	larvae	30	1.85	0.062	82.46	0.203	0.066	32.41
HG8a	6/10/2010	CR-HG8a-061010-004	Odonata	Lestidae	larvae	35	1.18	0.034	87.70	0.074	0.032	43.03
HG8a	6/17/2010	CR-HG8a-061710-001	Hemiptera	Gerridae	adult	24	1.41	0.059	83.58	0.105	0.088	84.19
HG9	6/10/2010	CR-HG9-061010-001	Coleoptera	Hydrophilidae	larvae	5	1.02	0.204	89.93	0.048	0.005	9.87
HG9	6/10/2010	CR-HG9-061010-003	Odonata	Lestidae	larvae	17	1	0.059	90.49	0.031	0.006	17.57
HG9	6/10/2010	CR-HG9-061010-004	Odonata	Coenagrionidae	larvae	18	0.56	0.031	89.42	0.080	0.010	12.28
HG9	6/10/2010	CR-HG9-061010-005	Hemiptera	Gerridae	adult	25	1.41	0.056	77.88	0.052	0.026	49.23
HG10	6/10/2010	CR-HG10-061010-002	Odonata	Libellulidae	larvae	2	0.68	0.340	91.63	0.036	0.023	63.33
HG10	6/10/2010	CR-HG10-061010-003	Coleoptera	Hydrophilidae	larvae	8	0.39	0.049	NA	0.019	0.003	15.63
HG10	6/10/2010	CR-HG10-061010-005	Coleoptera	Dytiscidae	adult	16	0.84	0.053	80.43	0.069	0.028	40.55

Table 9 (continued). Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, 2010 and 2011, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (µg/g, wet wt)	MMeHg (µg/g, wet wt)	percent MMeHg
HG10	6/10/2010	CR-HG10-061010-006	Hemiptera	Gerridae	adult	25	1.48	0.059	79.82	0.033	0.021	63.64
HG10	6/10/2010	CR-HG10-061010-007	Hemiptera	Gerridae	adult	25	1.45	0.058	84.47	0.026	0.020	78.68
HG11	6/17/2010	CR-HG11-061710-001	Odonata	Libellulidae	larvae	2	0.71	0.355	NA	0.061	0.039	64.27
HG11	6/17/2010	CR-HG11-061710-002	Coleoptera	Dytiscidae	adult	13	0.68	0.052	69.60	0.150	0.148	98.67
HG11	6/17/2010	CR-HG11-061710-003	Odonata	Lestidae	larvae	26	1.59	0.061	87.05	0.023	0.008	33.48
HG11	6/17/2010	CR-HG11-061710-004	Odonata	Coenagrionidae	larvae	16	0.64	0.040	85.60	0.091	0.018	19.30
HG11	6/17/2010	CR-HG11-061710-005	Hemiptera	Gerridae	adult	25	1.53	0.061	68.59	0.045	0.034	74.44
HG12	6/17/2010	CR-HG12-061710-001	Coleoptera	Hydrophilidae	larvae	4	1.25	0.313	86.61	0.022	0.007	31.36
HG12	6/17/2010	CR-HG12-061710-003	Odonata	Lestidae	larvae	17	0.95	0.056	87.23	0.018	0.007	37.08
HG12	6/17/2010	CR-HG12-061710-005	Hemiptera	Gerridae	adult	25	1.57	0.063	66.89	0.037	0.040	107.26
HG13	6/17/2010	CR-HG13-061710-002	Odonata	Lestidae	larvae	14	0.74	0.053	87.85	0.010	0.003	35.68
HG13	6/17/2010	CR-HG13-061710-003	Odonata	Coenagrionidae	larvae	15	0.61	0.041	NA	0.079	0.018	22.04
HG13	6/17/2010	CR-HG13-061710-004	Hemiptera	Gerridae	adult	24	1.4	0.058	79.81	0.029	0.023	79.04
HG14	6/17/2010	CR-HG14-061710-001	Hemiptera	Gerridae	adult	24	1.54	0.064	80.49	0.015	0.013	82.47
HG14	6/17/2010	CR-HG14-061710-003	Odonata	Lestidae	larvae	16	2.21	0.138	85.62	0.009	0.003	33.22
HG1	6/2/2011	CR-HG1-060211-001	Coleoptera	Hydrophilidae	larvae	5	0.53	0.106	NA	5.960	0.113	1.90
HG1	6/2/2011	CR-HG1-060211-002	Odonata	Coenagrionidae	larvae	30	1.46	0.049	80.11	8.800	0.230	2.61
HG1	6/2/2011	CR-HG1-060211-003	Odonata	Coenagrionidae	larvae	30	1.59	0.053	80.08	9.940	0.228	2.29
HG1	6/2/2011	CR-HG1-060211-004	Coleoptera	Dytiscidae	adult	35	1.29	0.037	56.35	1.240	0.267	21.53
HG2	6/2/2011	CR-HG2-060211-001	Coleoptera	Dytiscidae	adult	20	1.13	0.057	83.70	2.490	0.491	19.72
HG2	6/2/2011	CR-HG2-060211-002	Odonata	Coenagrionidae	larvae	25	1.59	0.064	78.44	4.500	0.604	13.42
HG2a	6/2/2011	CR-HG2a-060211-001	Hemiptera	Gerridae	adult	24	1.66	0.069	70.38	0.165	0.079	47.94
HG2a	6/2/2011	CR-HG2a-060211-002	Coleoptera	Hydrophilidae	larvae	4	1.1	0.275	81.30	0.840	0.078	9.26
HG2a	6/2/2011	CR-HG2a-060211-003	Coleoptera	Hydrophilidae	larvae	8	1.13	0.141	87.26	0.685	0.046	6.72
HG2a	6/2/2011	CR-HG2a-060211-004	Coleoptera	Dytiscidae	adult	16	1.11	0.069	63.41	0.839	0.213	25.39
HG3	6/2/2011	CR-HG3-060211-001	Odonata	Coenagrionidae	larvae	14	0.62	0.044	80.57	0.053	0.024	44.01
HG3	6/2/2011	CR-HG3-060211-002	Odonata	Lestidae	larvae	29	1.13	0.039	86.52	0.020	0.014	71.50
HG3	6/2/2011	CR-HG3-060211-003	Coleoptera	Hydrophilidae	larvae	10	1.09	0.109	83.22	0.019	0.010	50.52
HG3	6/2/2011	CR-HG3-060211-004	Odonata	Aeshnidae	larvae	4	3.96	0.990	72.72	0.038	0.023	60.37
HG3	6/2/2011	CR-HG3-060211-005	Odonata	Libellulidae	larvae	5	2.47	0.494	77.61	0.039	0.027	68.48
HG3	6/2/2011	CR-HG3-060211-006	Coleoptera	Dytiscidae	adult	20	1.47	0.074	62.63	0.242	0.109	45.04
HG3	6/2/2011	CR-HG3-060211-007	Hemiptera	Gerridae	adult	26	1.66	0.064	71.05	0.051	0.034	66.21
HG4	6/2/2011	CR-HG4-060211-001	Odonata	Aeshnidae	larvae	2	1.99	0.995	72.82	0.814	0.520	63.88
HG4	6/2/2011	CR-HG4-060211-002	Odonata	Libellulidae	larvae	8	3.87	0.484	80.25	0.355	0.129	36.34

Table 9 (continued). Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in individual composites of invertebrates collected at Harley Gulch in 2002, 2007, 2008, 2010 and 2011, and at a reference site, Bear River at Highway 20 (BR 20), during 1999-2002.

Site-Year	Date collected	Sample number	Order	Family	Age	N	Mass (g)	Ave. Mass (g)	Moisture (percent)	Hg_T (µg/g, wet wt)	MMeHg (µg/g, wet wt)	percent MMeHg
HG4	6/2/2011	CR-HG4-060211-003	Odonata	Coenagrionidae	larvae	20	1.09	0.055	79.86	0.870	0.101	11.61
HG4	6/2/2011	CR-HG4-060211-004	Odonata	Lestidae	larvae	25	1.39	0.056	81.33	0.363	0.094	25.81
HG4	6/2/2011	CR-HG4-060211-005	Coleoptera	Dytiscidae	adult	19	1.74	0.092	66.96	0.667	0.275	41.23
HG4	6/10/2011	CR-HG4-061011-006	Hemiptera	Gerridae	adult	25	1.62	0.065	67.88	0.246	0.132	53.66
HG5	6/2/2011	CR-HG5-060211-001	Odonata	Coenagrionidae	larvae	25	1.45	0.058	82.04	0.747	0.214	28.65
HG5	6/2/2011	CR-HG5-060211-002	Odonata	Coenagrionidae	larvae	25	1.58	0.063	81.21	0.710	0.225	31.69
HG5	6/2/2011	CR-HG5-060211-003	Odonata	Aeshnidae	larvae	4	2.95	0.738	79.01	0.435	0.170	39.08
HG5	6/2/2011	CR-HG5-060211-004	Odonata	Libellulidae	larvae	4	1.64	0.410	79.55	0.308	0.114	37.01
HG5	6/2/2011	CR-HG5-060211-005	Coleoptera	Dytiscidae	adult	14	1.31	0.094	70.76	0.326	0.169	51.84
HG5	6/10/2011	CR-HG5-061011-006	Hemiptera	Gerridae	adult	25	1.64	0.066	71.87	0.228	0.131	57.46
HG5	6/10/2011	CR-HG5-061011-007	Hemiptera	Gerridae	adult	25	1.73	0.069	69.14	0.282	0.146	51.77
HG7	6/2/2011	CR-HG7-060211-001	Odonata	Libellulidae	larvae	7	3.15	0.450	82.65	0.290	0.147	50.69
HG7	6/2/2011	CR-HG7-060211-002	Odonata	Libellulidae	larvae	8	1.77	0.221	83.86	0.285	0.137	48.07
HG7	6/2/2011	CR-HG7-060211-003	Odonata	Libellulidae	larvae	30	1.66	0.055	82.99	0.539	0.166	30.80
HG7	6/2/2011	CR-HG7-060211-004	Hemiptera	Gerridae	adult	25	1.73	0.069	72.94	0.215	0.133	61.86

[1] NA = not analyzed.

Table 10. Total mercury (Hg_T) and monomethyl mercury (MMeHg) (μg/g, wet wt) in foothill yellow-legged frogs from Harley Gulch, Lake county, California, in 2007–2008.

Site	Sample number	Year	Age	Sex	Length, in millimeters	Mass, in grams	Hg_T (μg/g ww)	MMeHg (μg/g ww)
HG3	2056	2007	Adult	Female	30.2	3.31	0.045	0.059
HG3	2057	2007	Juvenile	Female	29.7	2.65	0.059	NA
HG4	2052	2007	Adult	Male	42.2	9.42	0.525	NA
HG4	2053	2007	Adult	Female	32.4	4.61	0.785	0.403
HG4	2054	2007	Adult	Male	36.6	6.11	0.795	NA
HG4	2055	2007	Adult	Female	63.3	28.03	1.13	NA
HG5	2049	2007	Adult	Male	49.9	14.86	1.66	NA
HG5	2050	2007	Adult	Male	36.3	7.18	0.733	0.351
HG5	2051	2007	Adult	Male	32.4	5.04	0.525	NA
HG6	2043	2007	Adult	Female	58.9	27.12	0.895	NA
HG6	2044	2007	Adult	Male	33.2	4.26	0.734	0.4
HG6	2045	2007	Adult	Female	42.6	8.91	0.568	NA
HG7	2046	2007	Adult	Female	44.1	10.54	0.616	NA
HG7	2047	2007	Adult	Male	37.1	5.65	1.07	0.523
HG7	2048	2007	Adult	Female	35.1	4.55	1.18	NA
HG5	2075	2008	Adult	Female	44.40	10.98	NA[1]	0.468
HG8	2076	2008	Adult	Male	44.06	10.19	NA	0.467
HG8	2077	2008	Adult	Male	38.05	8.23	NA	0.432
HG9	2078	2008	Adult	Female	44.19	10.41	NA	0.263
HG10	2079	2008	Adult	Female	45.98	14.12	NA	0.135
HG11	2080	2008	Adult	Male	44.73	12.34	NA	0.189
HG13	2081	2008	Adult	Female	62.29	31.28	NA	0.152

[1] NA = Not analyzed.

Table 11. Total mercury (Hg_T) (µg/g, wet wt) in foothill yellow-legged frogs from Harley Gulch and reference sites, 1997-1998.

Site/ sample no.	Collection date	Latitude/ Longitude	Age	Sex	Length, in millimeters	Mass, in grams	Site Description	Hg_T
EFMC/1005	5/14/97	39° N 15' 09"/ 122° W 57' 00"	Adult	Female	74.7	47.1	East Fork Middle Creek	0.120
EFMC/1004	5/14/97	39° N 15' 09"/ 122° W 57' 00"	Adult	Female	60.9	30.3	East Fork Middle Creek	0.079
EFMC/1003	5/14/97	39° N 15' 09"/ 122° W 57' 00"	Adult	Male	53.7	19.3	East Fork Middle Creek	0.055
BRIM/927	4/11/97	39° N 09' 45"/ 122° W 26' 59"	Adult	Female	61.7	33.8	Mill Creek at Brim Road	0.103
BRIM/929	4/11/97	39° N 09' 45"/ 122° W 26' 59"	Adult	Female	50.7	17.0	Mill Creek at Brim Road	0.081
BRIM/928	4/11/97	39° N 09' 45"/ 122° W 26' 59"	Adult	Female	54.2	18.1	Mill Creek at Brim Road	0.066
SPCR/1001	5/12/97	39° N 10' 17"/ 122° W 37' 05"	Adult	Female	56.4	20.7	Spanish Creek	0.089
SPCR/1002	5/12/97	39° N 10' 17"/ 122° W 37' 05"	Adult	Female	57.1	26.7	Spanish Creek	0.068
SPCR/1000	5/12/97	39° N 10' 17"/ 122° W 37' 05"	Adult	Female	43.2	7.6	Spanish Creek	0.057
TRKY/926	3/27/97	39° N 00' 57"/ 122° W 26' 26"	Adult	Female	47.8	13.4	Turkey Run Mine	0.793
HGDS/963	4/25/97	39° N 00' 34"/ 122° W 26' 05"	Adult	Female	47.2	11.8	Lower Harley Gulch	0.583
HGDS/961	4/25/97	39° N 00' 34"/ 122° W 26' 05"	Adult	Male	41.9	9.4	Lower Harley Gulch	0.419
HGDS/962	4/25/97	39° N 00' 34"/ 122° W 26' 05"	Adult	Male	36.4	6.2	Lower Harley Gulch	0.355
ABBT/1201	3/16/98	39° N 00' 56"/ 122° W 26' 29"	Adult	Male	56.0	23.4	Abbott Drain	1.680
HGDS/1190	3/11/98	39° N 00' 34"/ 122° W 26' 05"	Adult	Male	54.3	23.1	Lower Harley Gulch	1.130

Table 12. Total mercury (Hg_T) and monomethyl mercury (MMeHg) (µg/g, wet wt) in California Roach (Hesperoleucus symmetricus) frogs from site HG8a, fish pond, collected on June 10, 2010, Harley Gulch, Lake County, California.

Sample ID	Total Length, in millimeters	Standard Length, in millimeters	Mass, in grams	Sample mass, in grams	Hg_T (µg/g, ww)	MMeHg (µg/g, ww)	percent Moisture	percent MMeHg
CR-HG8a-061010-001F	76	61	5.2	4.01	0.362	0.352	81.74	97.2
CR-HG8a-061010-002F	64	51	3.12	2.55	0.414	0.356	82.45	86.0
CR-HG8a-061010-003F	63	51	3.25	2.75	0.28	0.237	80.28	84.6
CR-HG8a-061010-004F	62	50	2.36	1.86	0.335	0.307	83.68	91.6
CR-HG8a-061010-005F	58	46	2.5	1.49	0.275	0.343	86.05	124.7
CR-HG8a-061010-006F	55	44	2.26	1.48	0.264	0.173	86.30	65.5
CR-HG8a-061010-007F	60	49	2.03	1.71	0.382	0.334	84.29	87.4

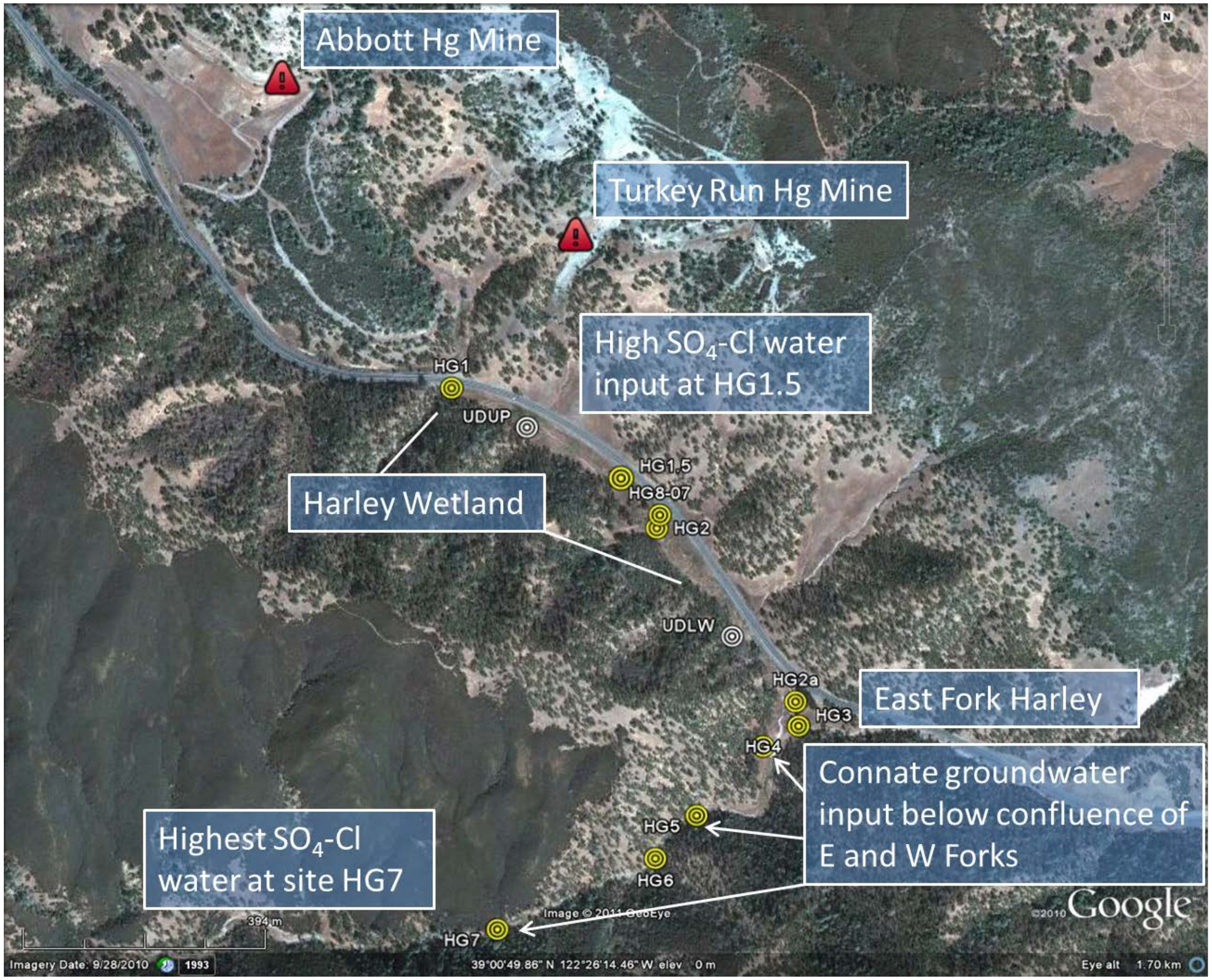

Figure 1. Location of sample sites in the Harley Gulch wetland and upper part of Harley Gulch downstream from the Abbott-Turkey Run mine, Lake County, California. Connate groundwater input occurs in the central part of the wetland at sample site HG1.5 and in the upper part of Harley Gulch between sample sites HG 4 and HG7.

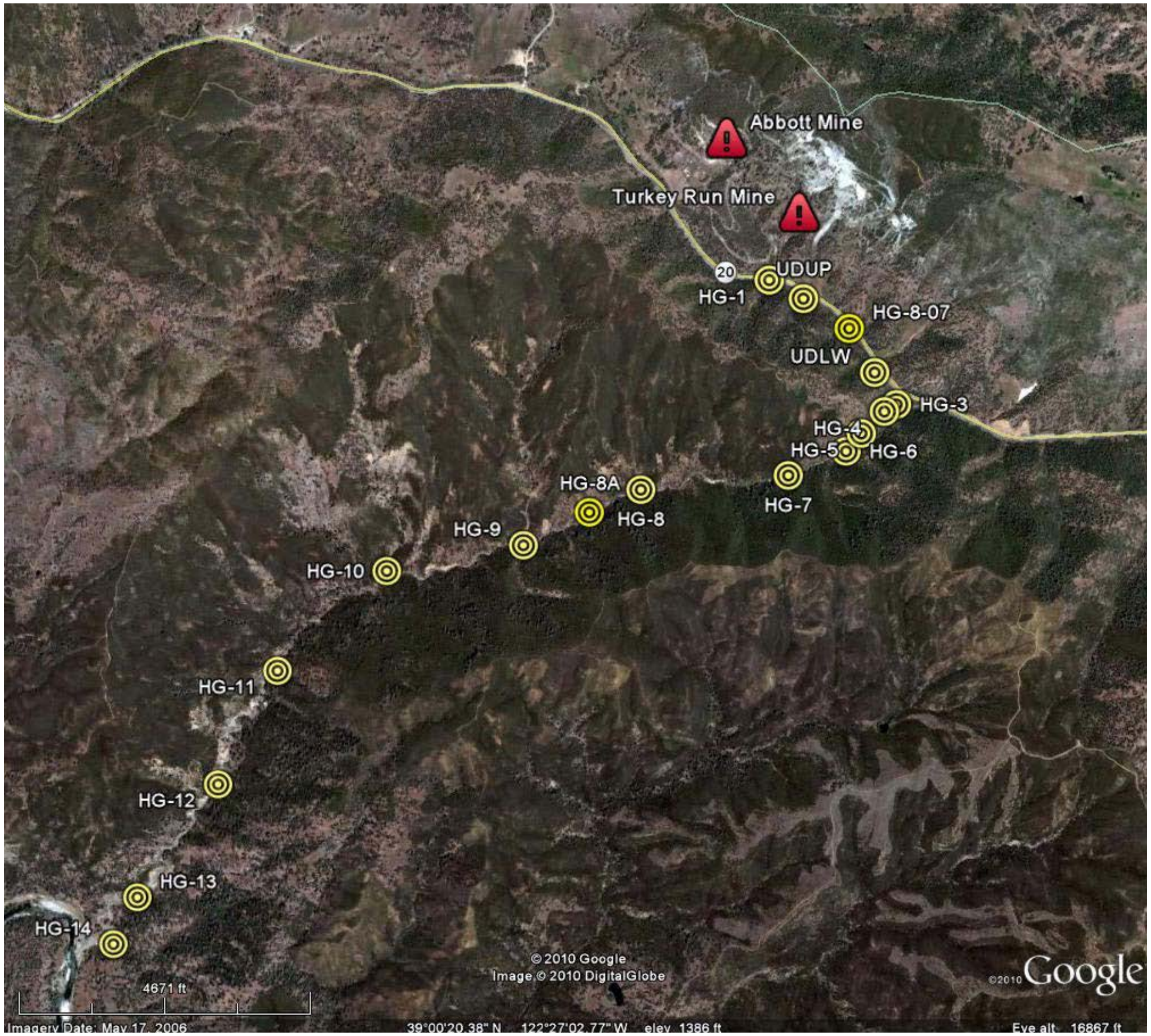

Figure 2. Location of sample sites in the lower part of Harley Gulch, Lake County, California. Sample site HG10 is the most downstream water and sediment site sampled; see fig. 1 for locations of sites 2 and 2a.

Figure 3. Sample site HG1, Harley Gulch, Lake County, California, just downstream from Highway 20.

Figure 4. Sample site HG8-07, Harley Gulch Pond, Lake County, California, sampled only for biota on May 16, 2007.

Figure 5. Harley Gulch Wetlands, between Highway 20 and the confluence with East Fork Harley Gulch, Lake County, California.

Figure 6. Harley Gulch Wetlands sites, UDLW (left) and UDUP (right) sampled for biota only on June 10, 2010, Lake County, California.

Figure 7. Sample site HG3, East Fork of Harley Gulch, Lake County, California, upstream from the confluence with West Fork Harley Gulch.

Figure 8. West Fork of Harley Gulch, Lake County, California at sample site HG 2 downstream from wetland area. Sediment in creek bed is cemented by $CaCO_3$.

Figure 9. West Fork of Harley Gulch looking downstream from sample site HG2 toward sample site HG4 (location of geologist), Lake County, California. Creek bed is covered by efflorescent salts (white area) and sediment deposited from a high-flow event.

Figure 10. Coarse pebble sand at site HG2, deposited during high-flow events in the winter of 2010, has high Hg concentration(136 µg/g) because of erosion of tailings and Hg-enriched soils from the Abbott-Turkey Run mine, Lake County, California.

Figure 11. Pool at sample site HG4, Harley Gulch, Lake County, California with high $S0_4$-Cl-CO_3 water derived from connate ground water. Water has high total mercury (Hg_T) and filtered mercury (Hg_F).

Figure 12. Black reduced sediment at bottom of pool at site HG4, Harley Gulch, Lake County, California, consisting of biogenic and clastic sediment with high Hg concentration (23.9 µg/g).

Figure 13. Sample site HG5 in the West Fork of Harley Gulch, Lake County, California.

Figure 14. Sample site HG6 in the West Fork of Harley Gulch, Lake County, California.

Figure 15. Sample sites HG7 (left) and sample site HG8 (right) in the West Fork of Harley Gulch, Lake County, California.

Figure 16. Sample site HG8a, Fish Pond, Harley Gulch, Lake County, California, sampled only in 2010 (June 10 and June 17).

Figure 17. Sample sites HG9 and HG10 in the West Fork of Harley Gulch, Lake County, California.

Figure 18. Sample sites HG11, HG12, HG13, and HG14 (clockwise from top left), Lake County, California sampled for biota only on June 4, 2008, and June 17, 2010.

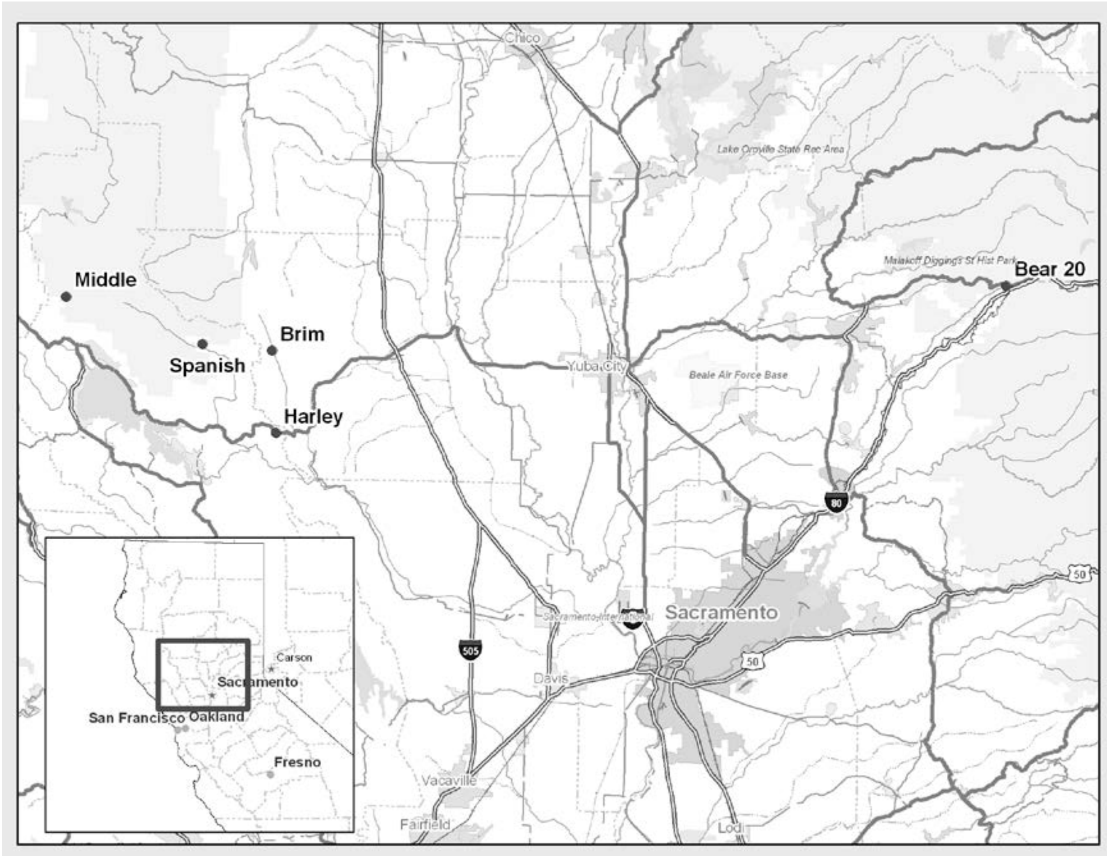

Figure 19. Locations of reference sites for studies at Harley Gulch, Lake County, California. [Foothill yellow-legged frog reference sites in 1997 were East Fork of Middle Creek (Middle), Spanish Creek (Spanish), and Bear Creek at Brim Road (Brim)] (Hothem and others, 2010).

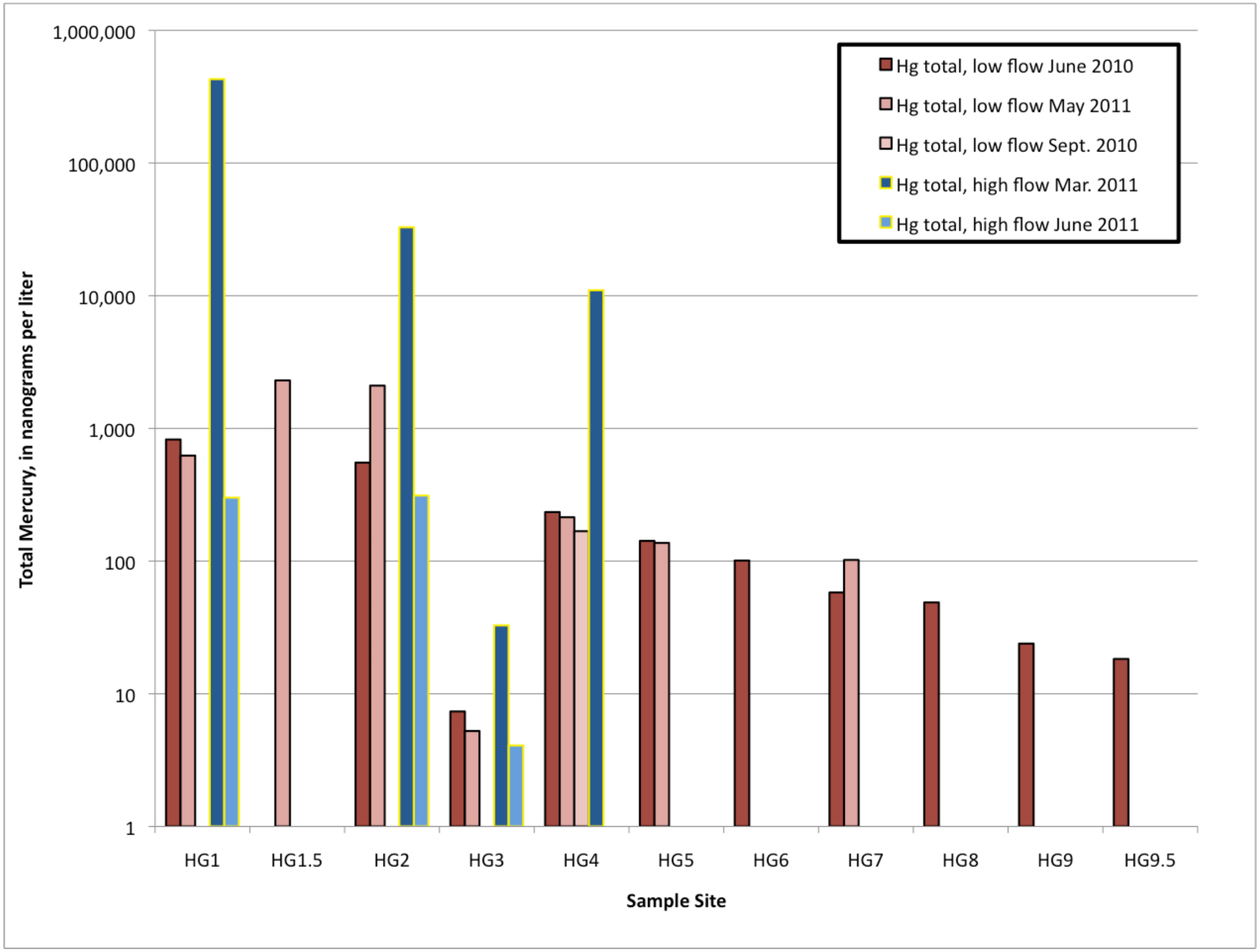

Figure 20. Logarithmic-scale plot showing concentrations of total mercury (Hg_T) in water collected from sample sites in Harley Gulch, Lake County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.

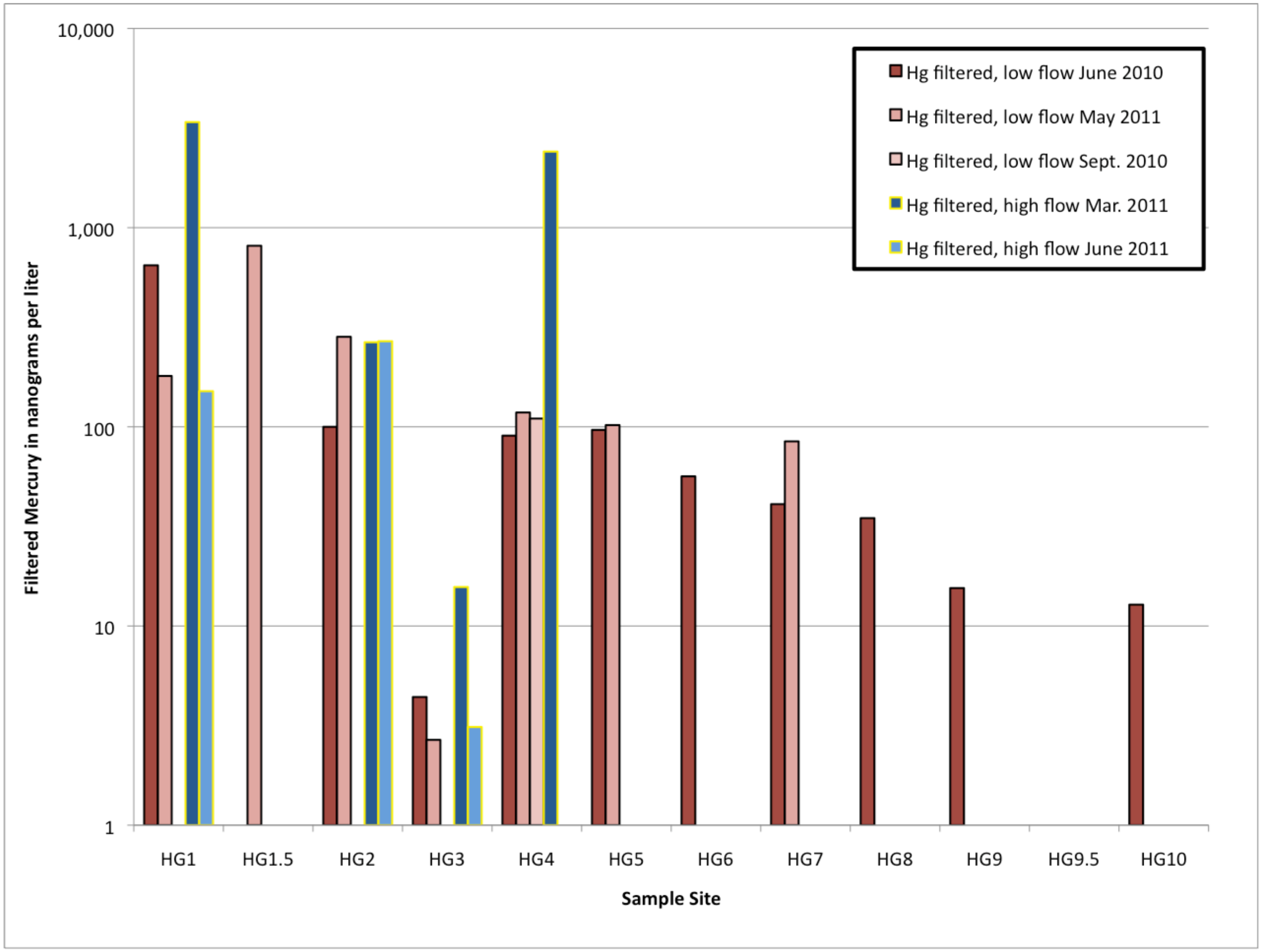

Figure 21. Logarithmic-scale plot showing concentrations of filtered mercury (Hg_F) in water collected from sample sites in Harley Gulch, Lake County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.

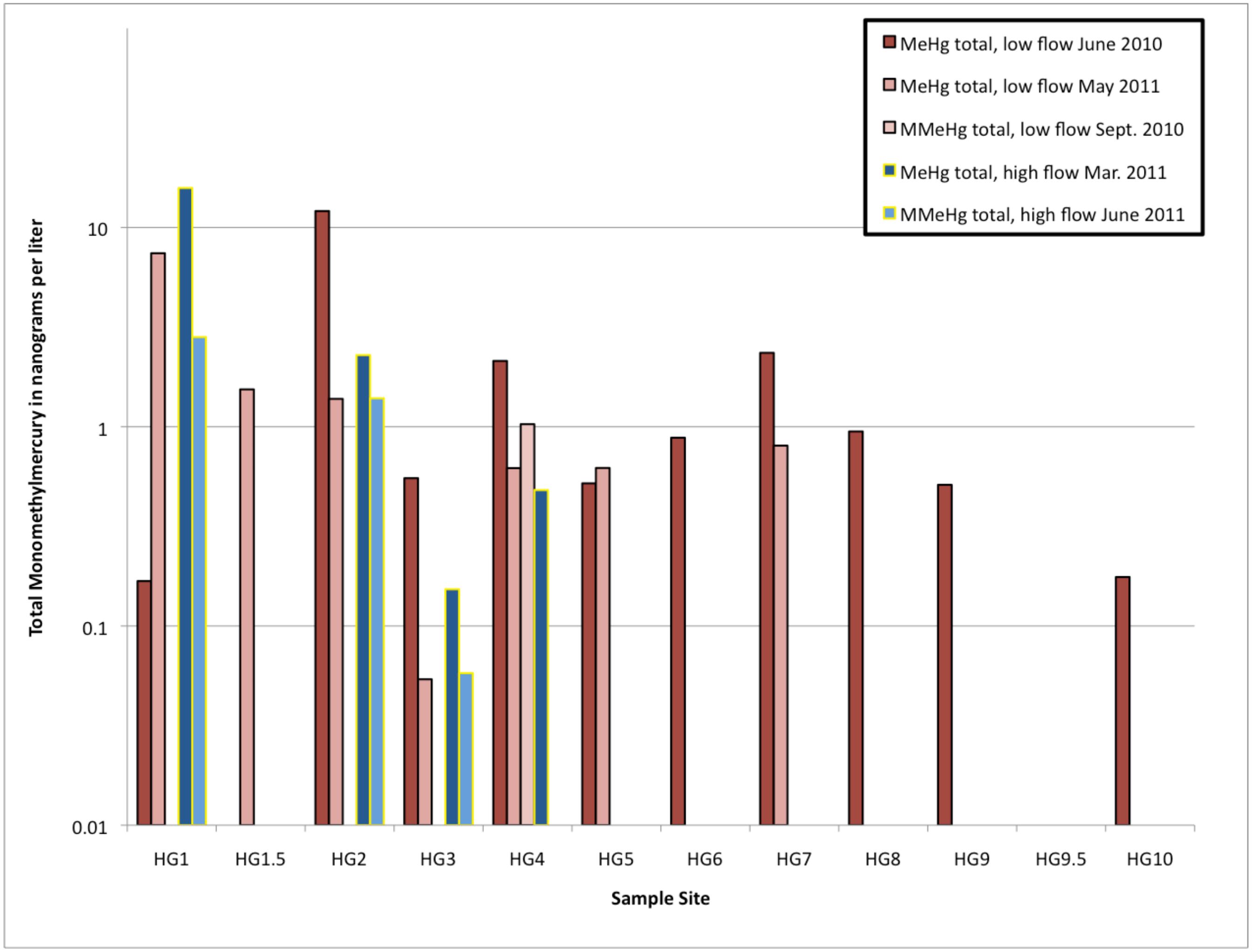

Figure 22. Logarithmic-scale plot showing concentrations of MMeHg in water collected from sample sites in Harley Gulch, Lake County, California, moving downstream to the right on the x-axis. Low-flow sampling events are shown with red bars; high-flow sampling events are shown with blue bars.

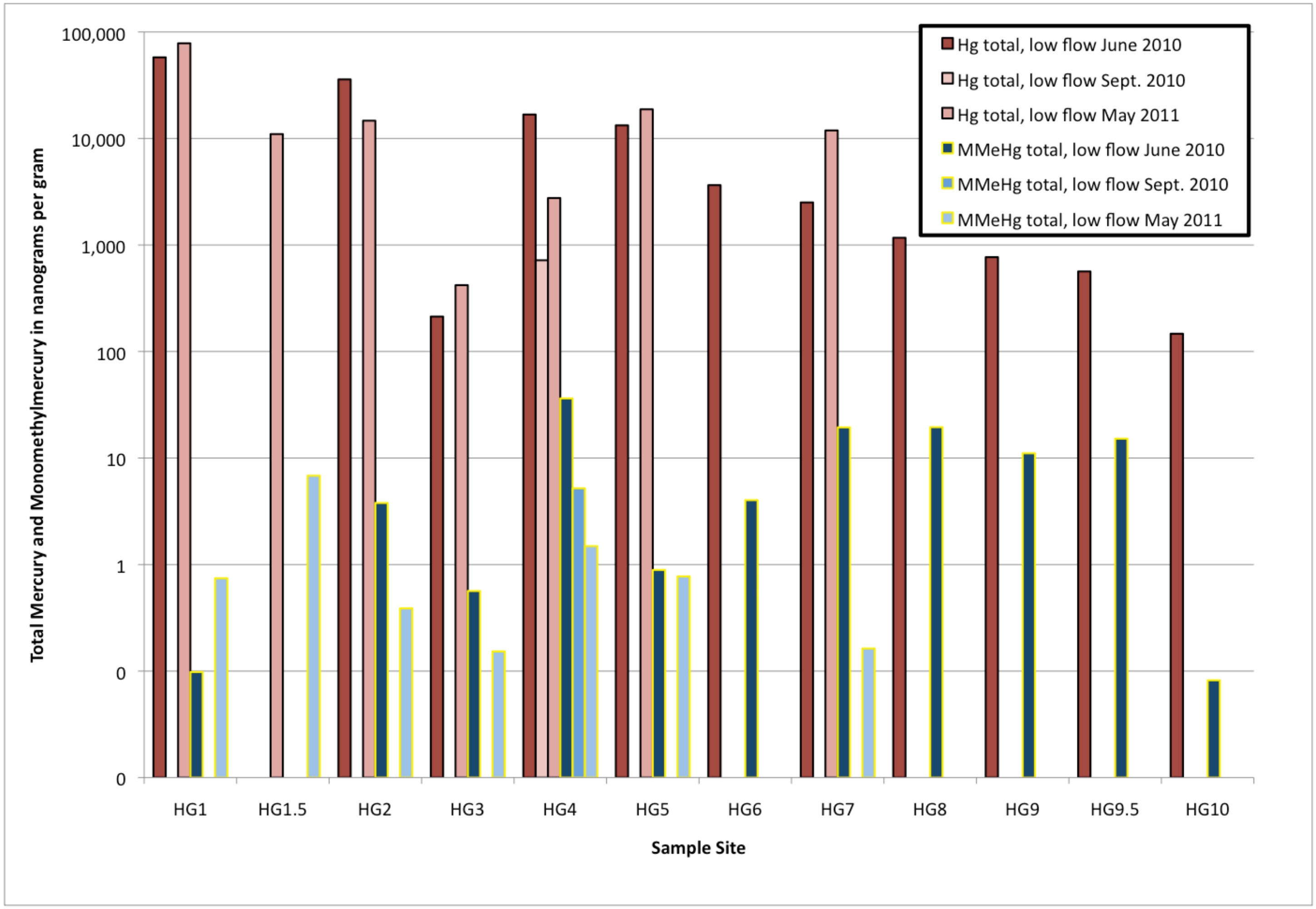

Figure 23. Logarithmic-scale plot showing concentrations of Hg and MMeHg in sediment collected from sample sites in Harley Gulch, Lake County, California, moving downstream to the right on the x-axis. Hg concentrations are shown by red bars, and MMeHg concentrations with blue bars.

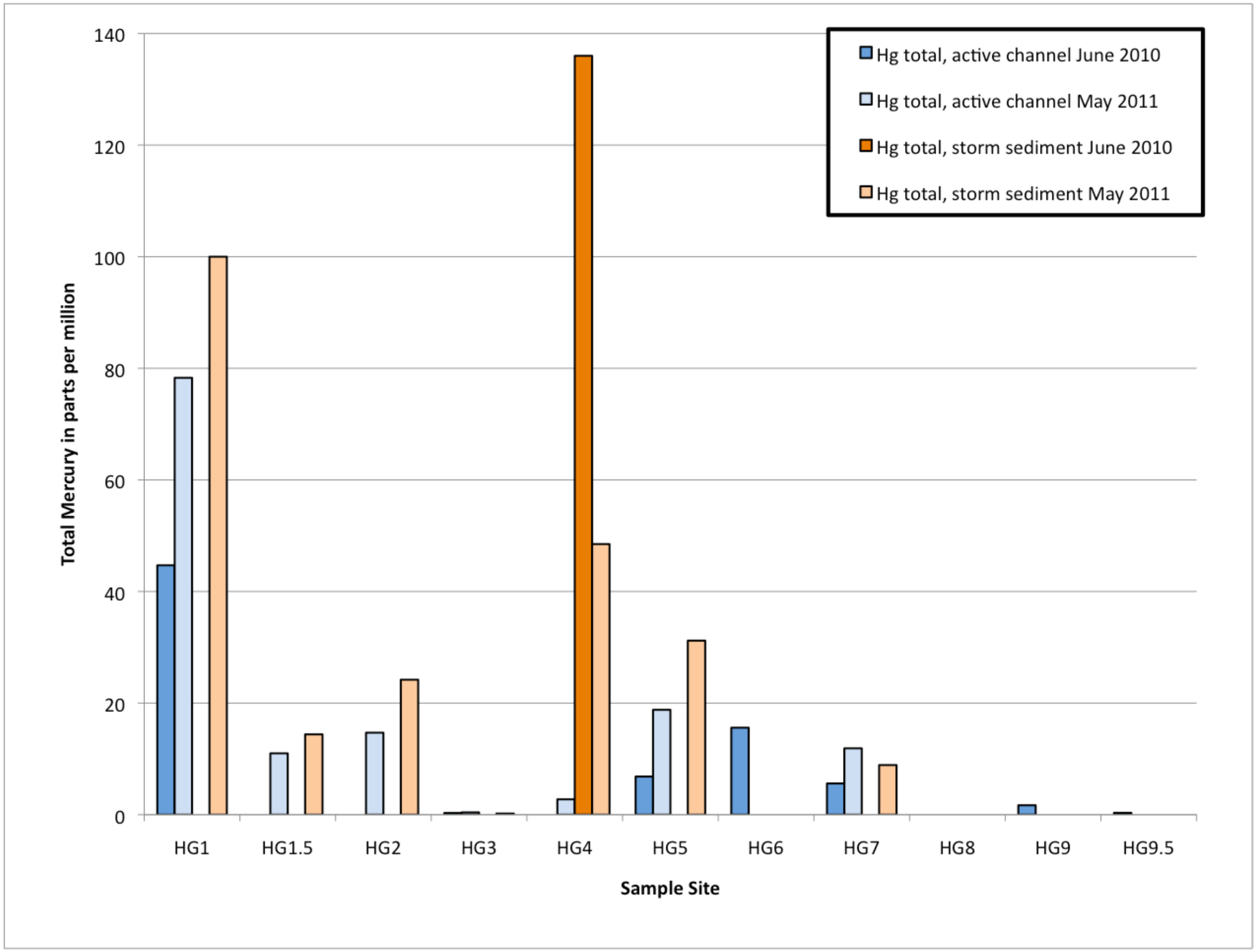

Figure 24. Plot showing concentration of Hg in sediments collected from Harley Gulch, Lake County, California. Samples collected from the active stream channel of Harley Gulch are shown with blue bars; samples collected from the banks of Harley Gulch where storm sediment is deposited are shown with orange bars.

Figure 25. Harley Gulch, Lake County, California, downstream from sample site HG4 has abundant riparian vegetation because of input of connate groundwater in the segment of the creek between sample sites HG4 and HG7.

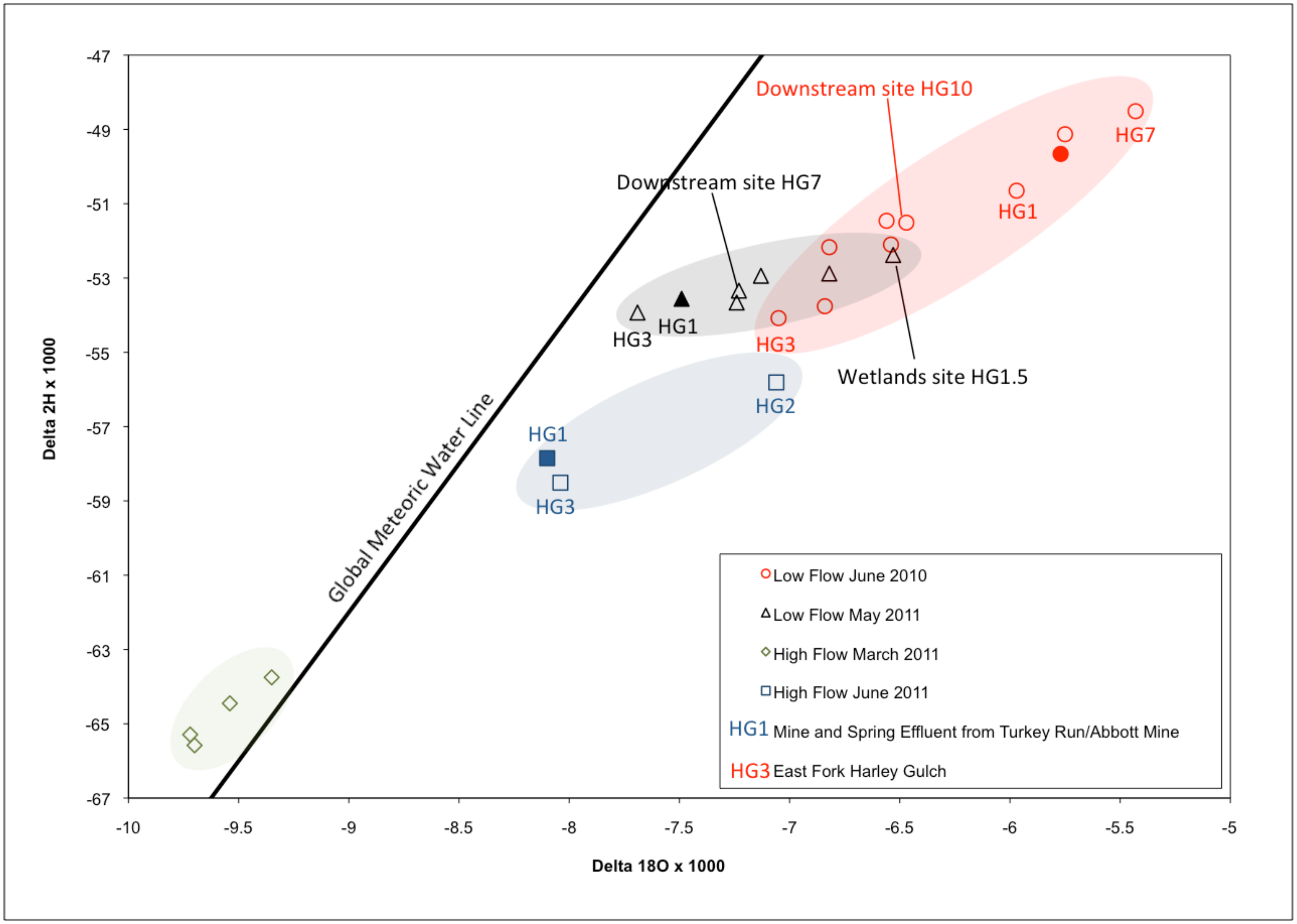

Figure 26. Plot of isotopic composition of waters in Harley Gulch, Lake County, California, which shows that the waters do not fall along the meteoric water line and are, thus, a mixture of connate water, thermal water, and meteoric water.

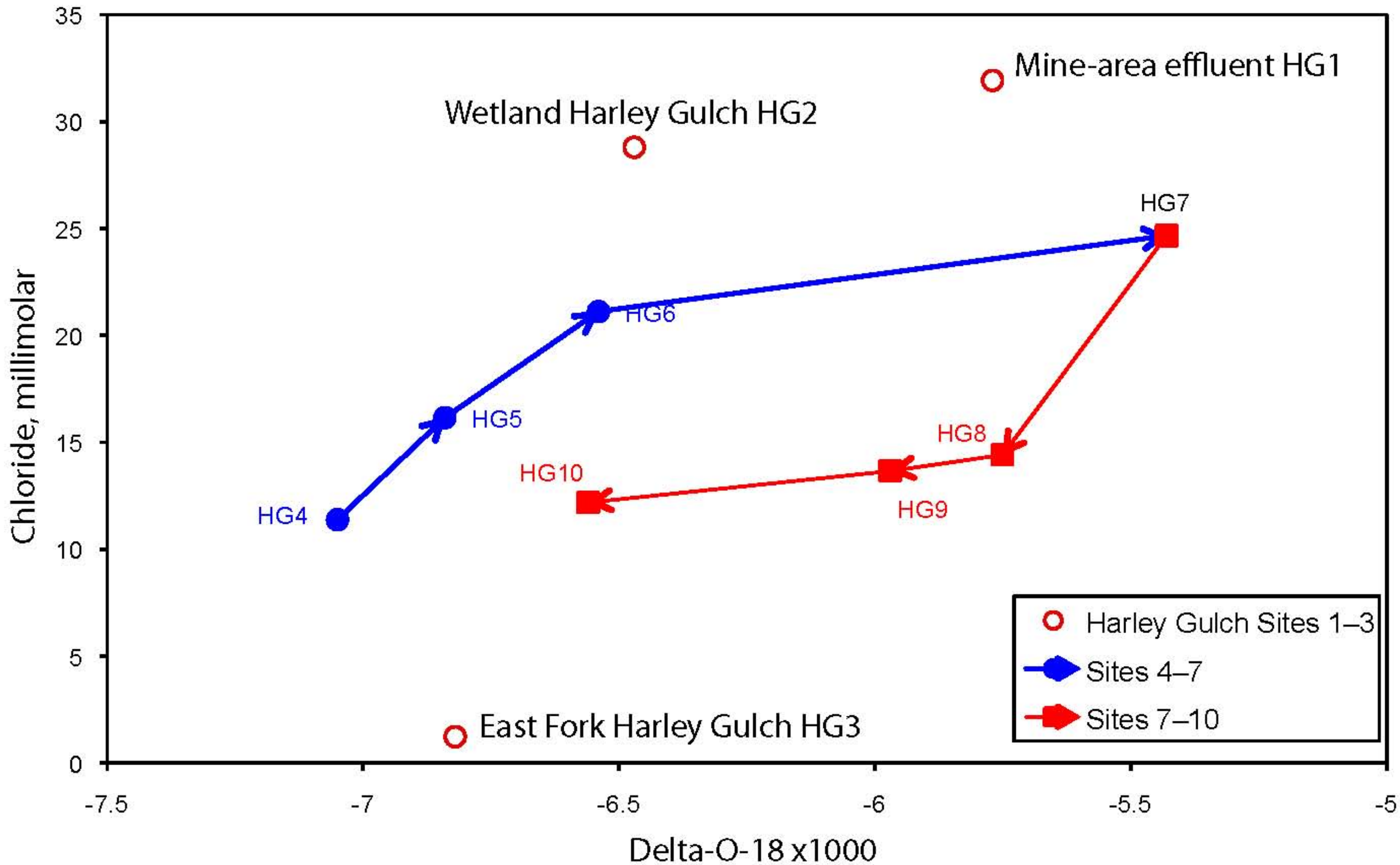

Figure 27. Plot of chloride (Cl) and $\delta^{18}O$ of water in Harley Gulch, Lake County, California. The creek water becomes systematically heavier with higher Cl concentration downstream from site HG4, reaching a maximum in $\delta^{18}O$ and Cl concentration at site HG7. The creek water then decreases in $\delta^{18}O$ and Cl concentration owing to mixing with isotopically-light meteoric water.

Figure 28. Tan biogenic sediment at sample site HG8 forms in the upper part of Harley Gulch, Lake County, California, in the area between sample sites HG2A and HG9, where connate groundwater high in $S0_4$-Cl-CO_3 enters the creek and dominates the water chemistry.

Figure 29. Tan biogenic sediment accumulating on creek bed at sample site HG7, Harley Gulch, Lake County, California, consists of living and recently expired diatoms with high concentrations of Hg [5.6 μg/g (ppm)], and MMeHg (0.5 ng/g).

Figure 30. Black reduced sulfidic biogenic sediment below tan surface layer of biogenic sediment at sample site HG7, Harley Gulch, Lake County, California. The sediment consists of expired diatoms and FeS that gives the sediment a black color.

Figure 31. Biogenic sediment accumulates to a thickness of several 10s of cm in Harley Gulch, Lake County, California. Above site HG4, during the dry season, biogenic sediment with high Hg concentration [23.9 μg/g (ppm)] locally becomes dry and has the consistency of diatomite.

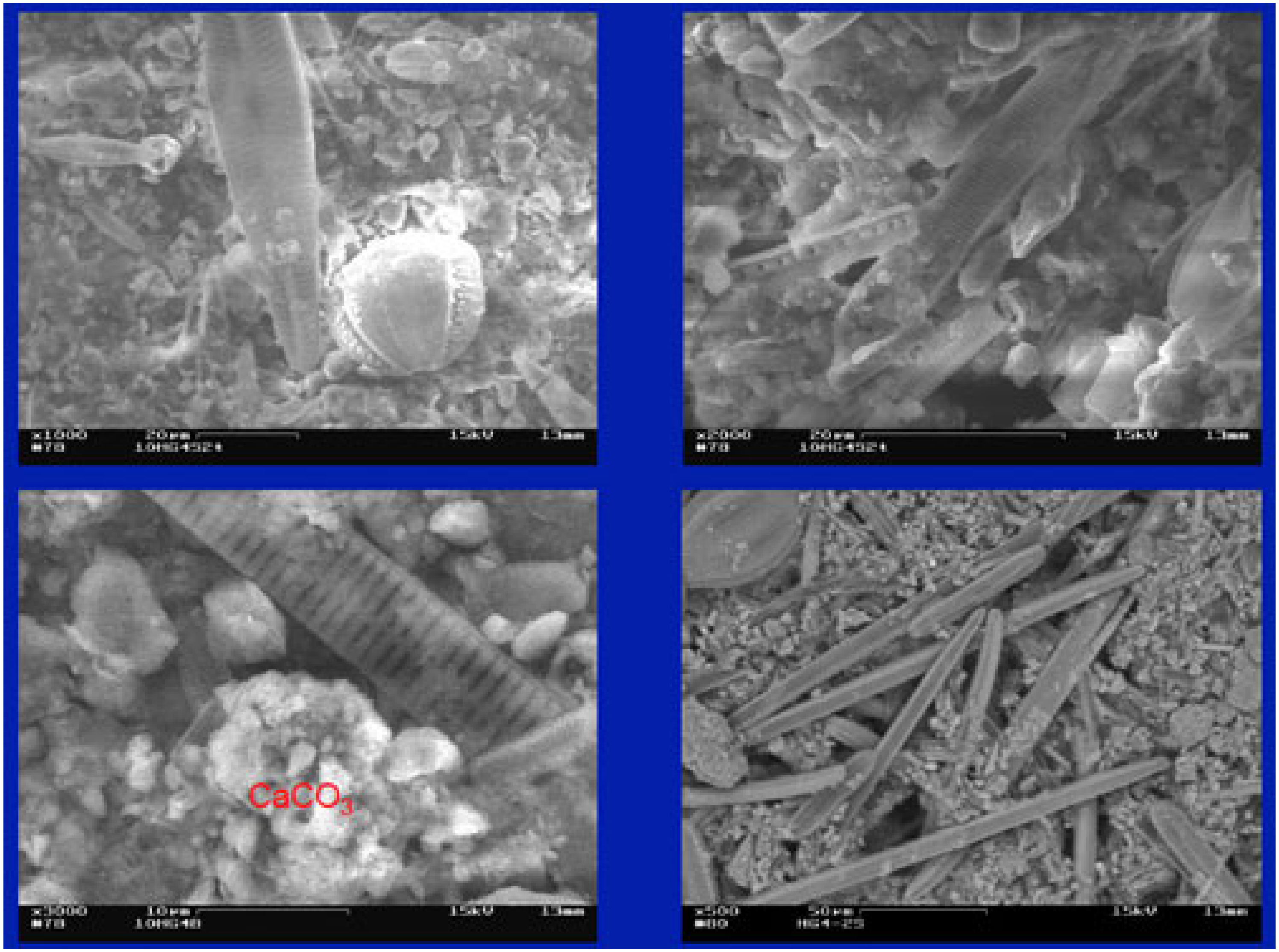

Figure 32. Biogenic sediment composed primarily of a variety of diatoms and diatom fragments and minor $CaCO_3$ and clay minerals.

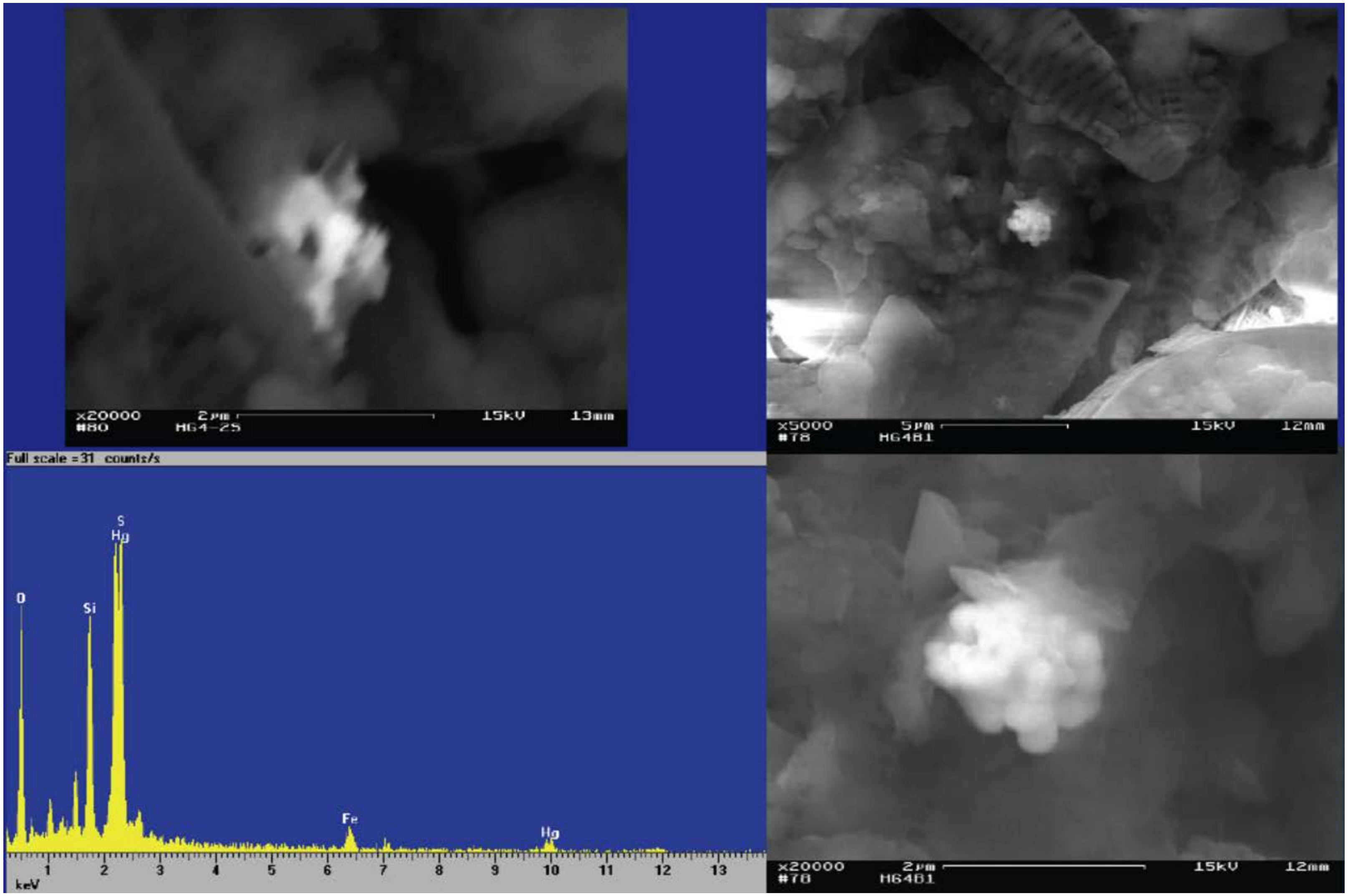

Figure 33. SEM (scanning electron microscopy) image of micron to submicron grains and aggregates of HgS in the biogenic sediment. EDAX spectrum confirms the presence of only Hg and sulfur (S) in the bright particles in the SEM image.

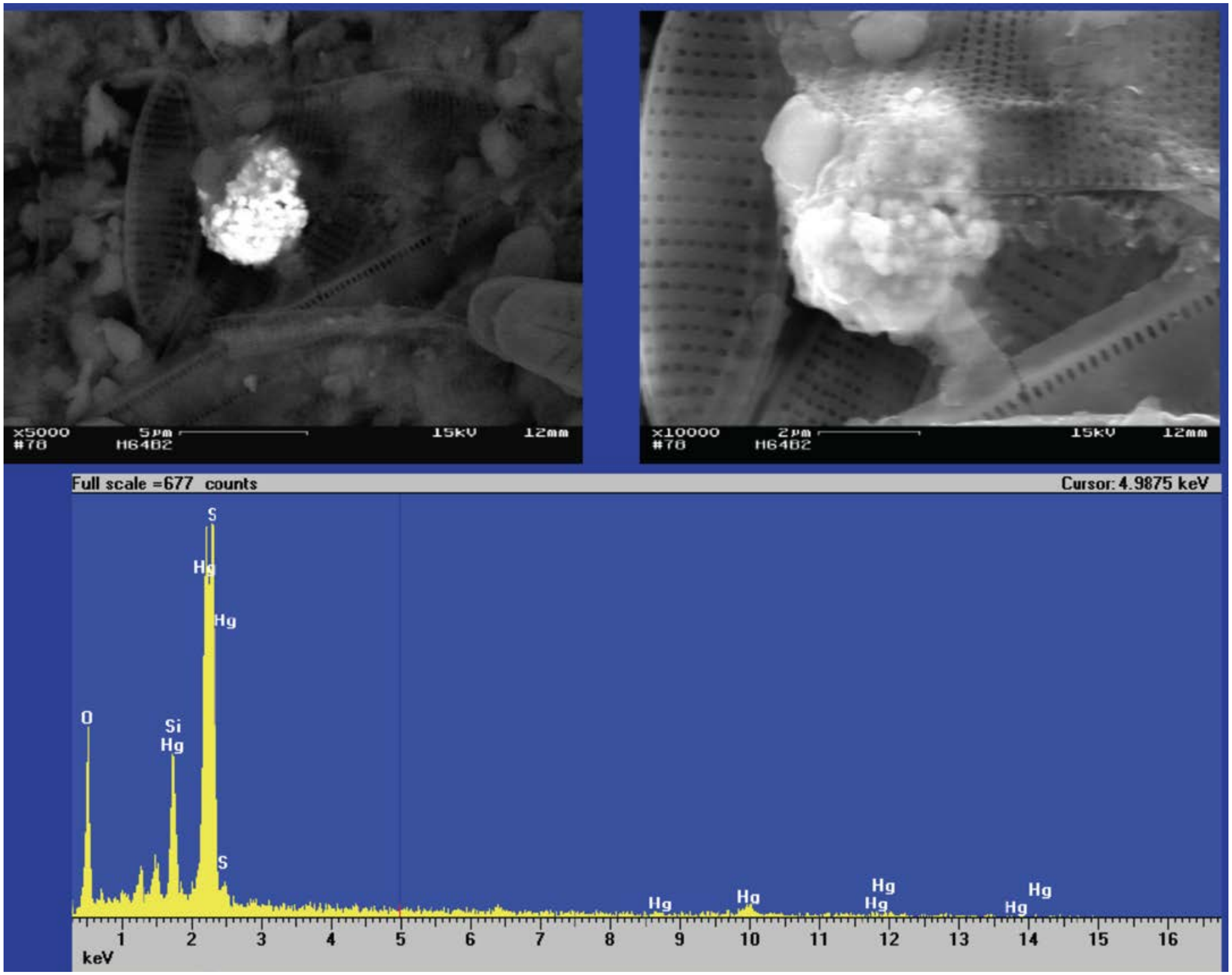

Figure 34. SEM (scanning electron microscopy) image of micron to and aggregate of submicron grains of HgS in association with diatoms in the biogenic sediment. EDAX spectrum confirms the presence of only Hg and S in the high reflectivity aggregate of HgS in the SEM image.

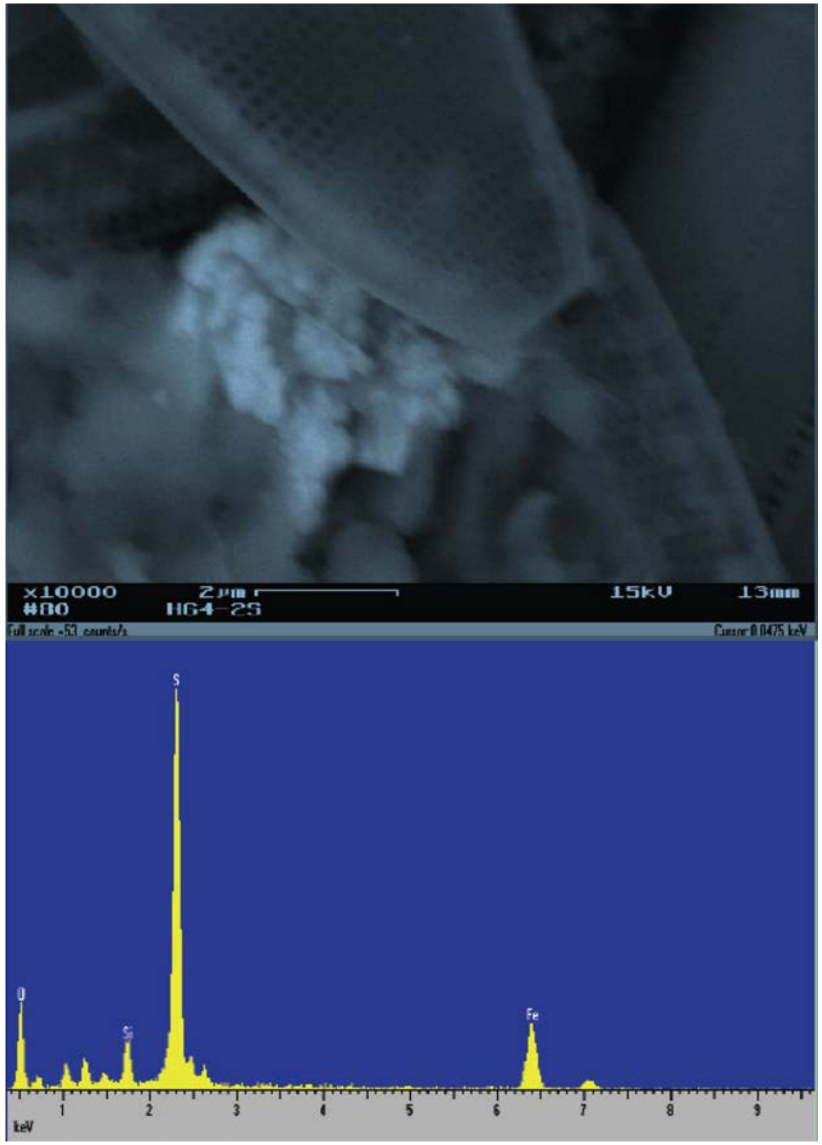

Figure 35. SEM (scanning electron microscopy) image of aggregate of submicron grains of FeS in association with diatoms in the biogenic sediment. EDAX spectrum confirms the presence of only Fe and S in the high reflectivity aggregate of FeS in the SEM image.

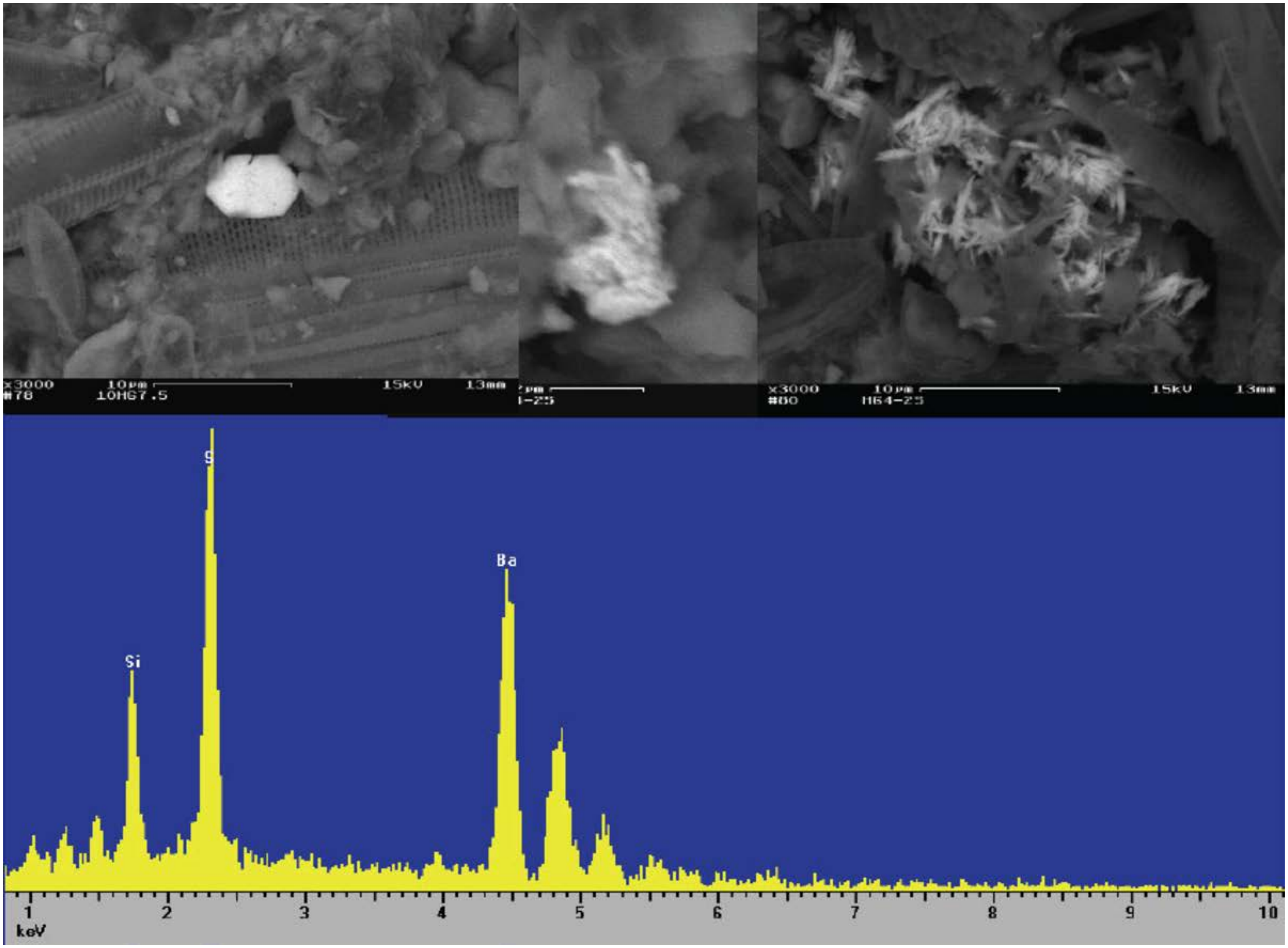

Figure 36. SEM (scanning electron microscopy) image of micron crystals and acicular grains of barite in association with diatoms in the biogenic sediment. EDAX spectrum confirms the presence of only Ba and S in the high reflectivity grains of barite.

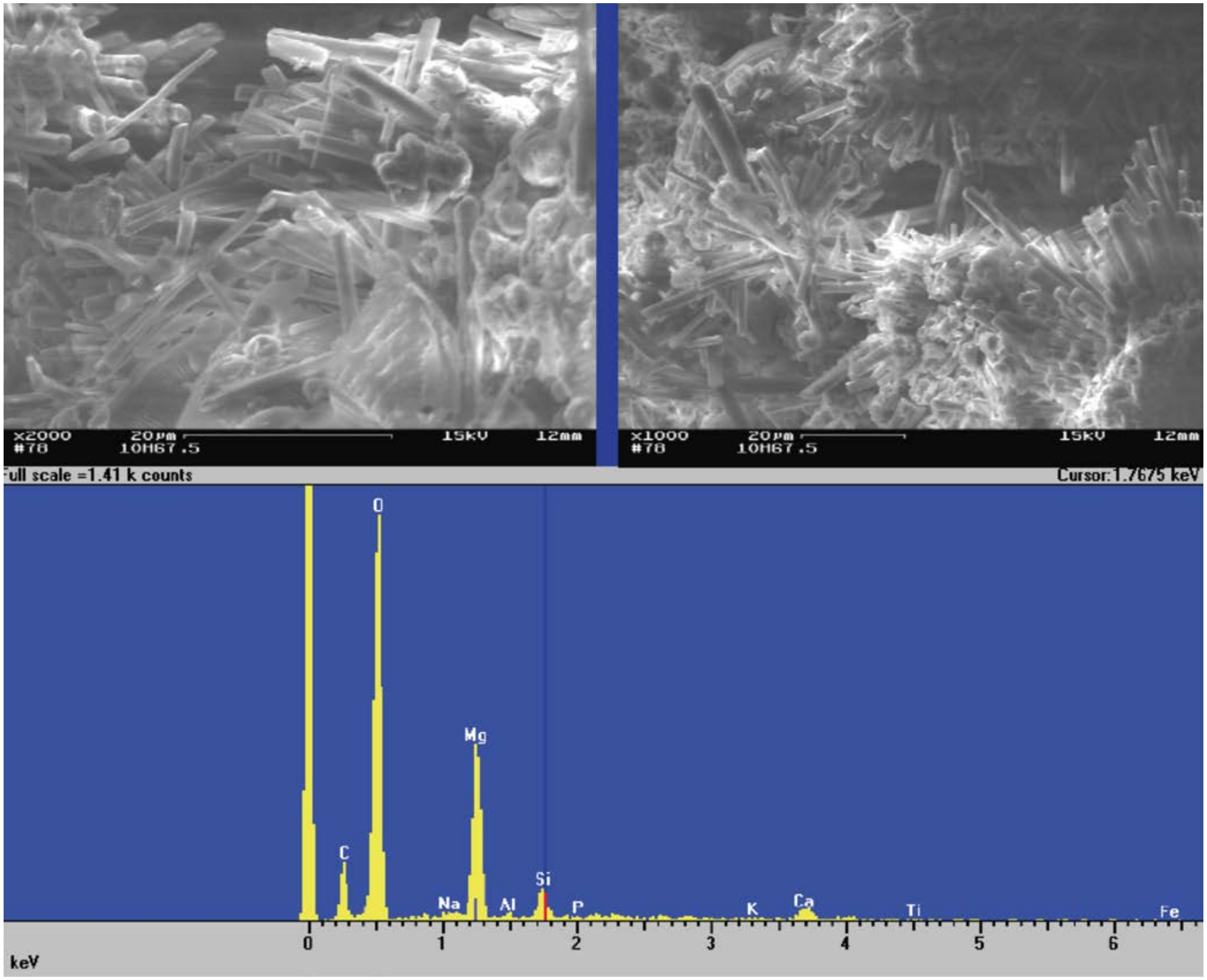

Figure 37. SEM (scanning electron microscopy) image of epsomite crystals in biogenic sediment. EDAX spectrum confirms the presence of Mg and S in the crystals.

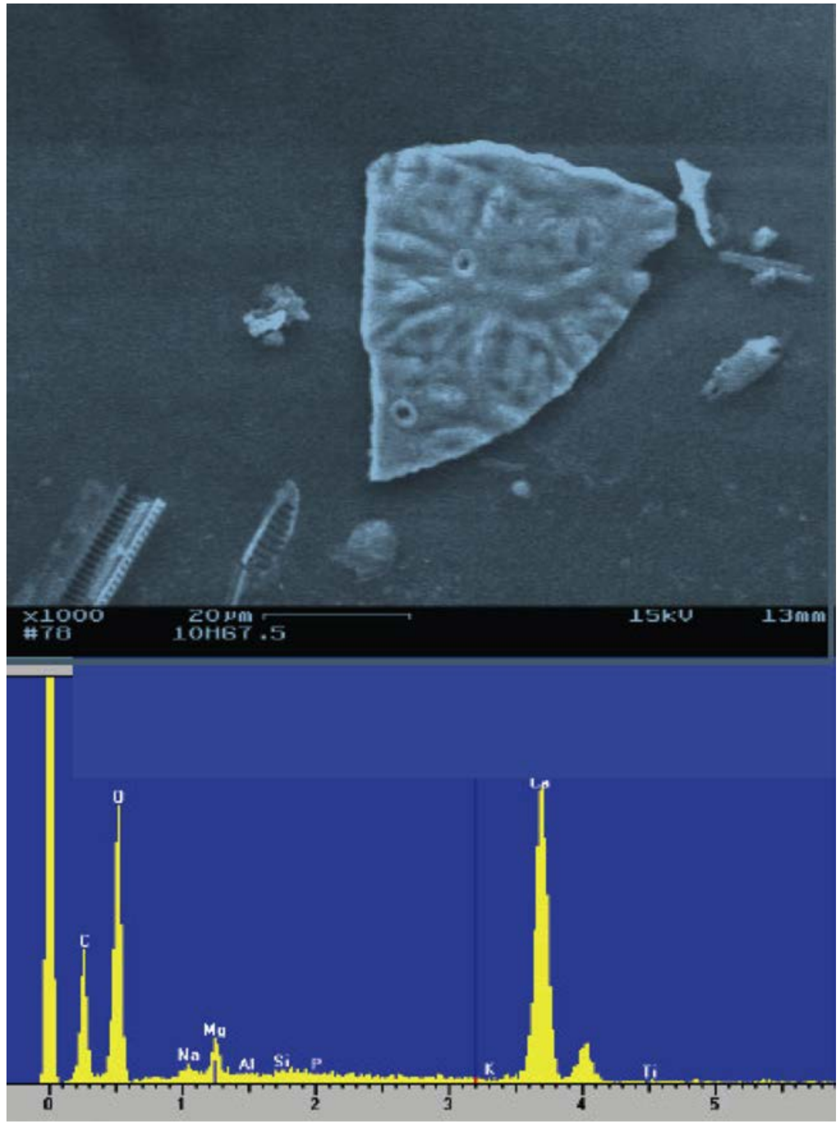

Figure 38. SEM (scanning electron microscopy) image of biogenic calcite fragment in biogenic sediment. EDAX spectrum confirms the presence of Ca and C in the crystals.

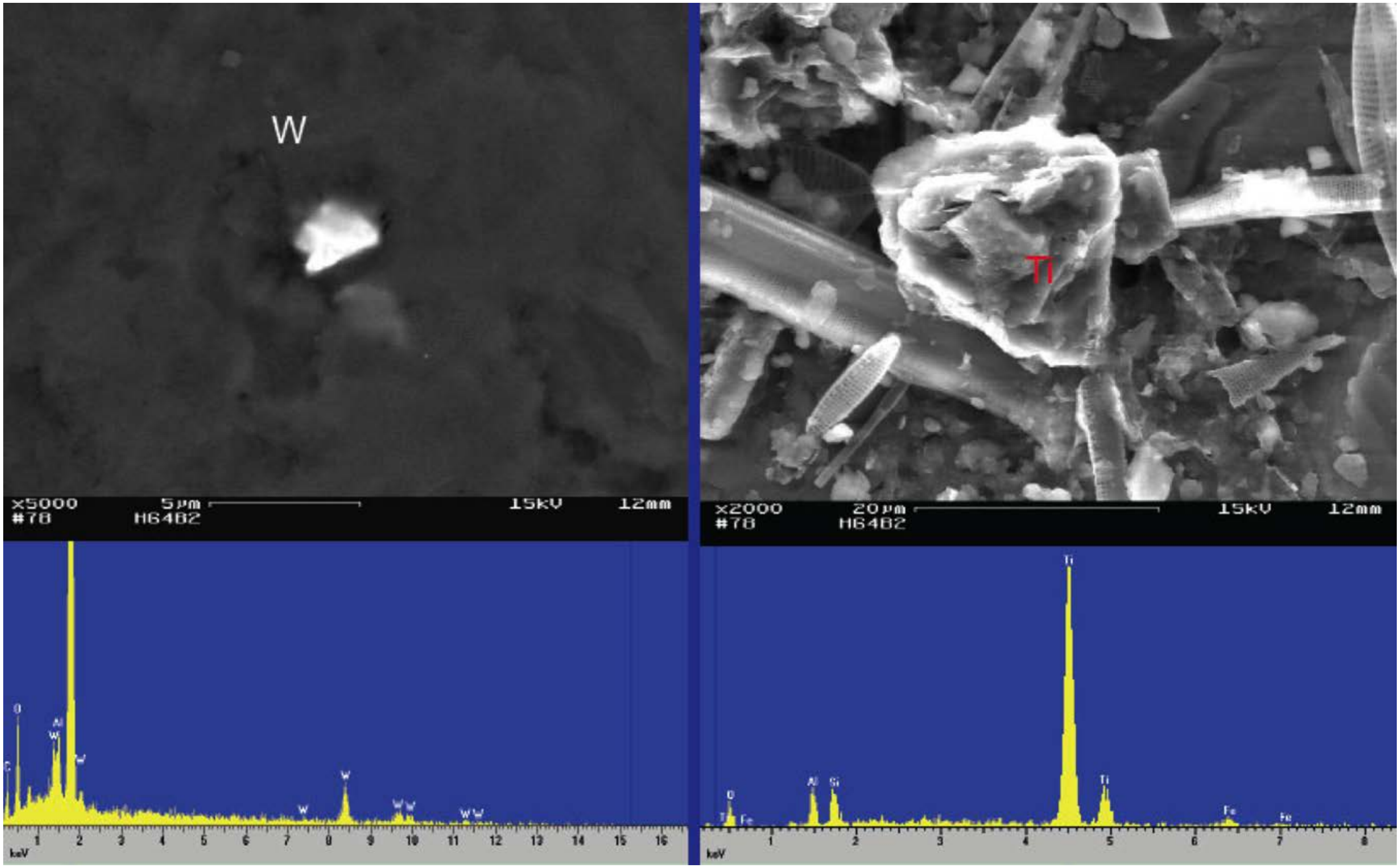

Figure 39. SEM (scanning electron microscopy) image of tungsten- (W) and titanium- (Ti) oxide phases in biogenic sediment. EDAX spectrum confirms the composition of the phases.

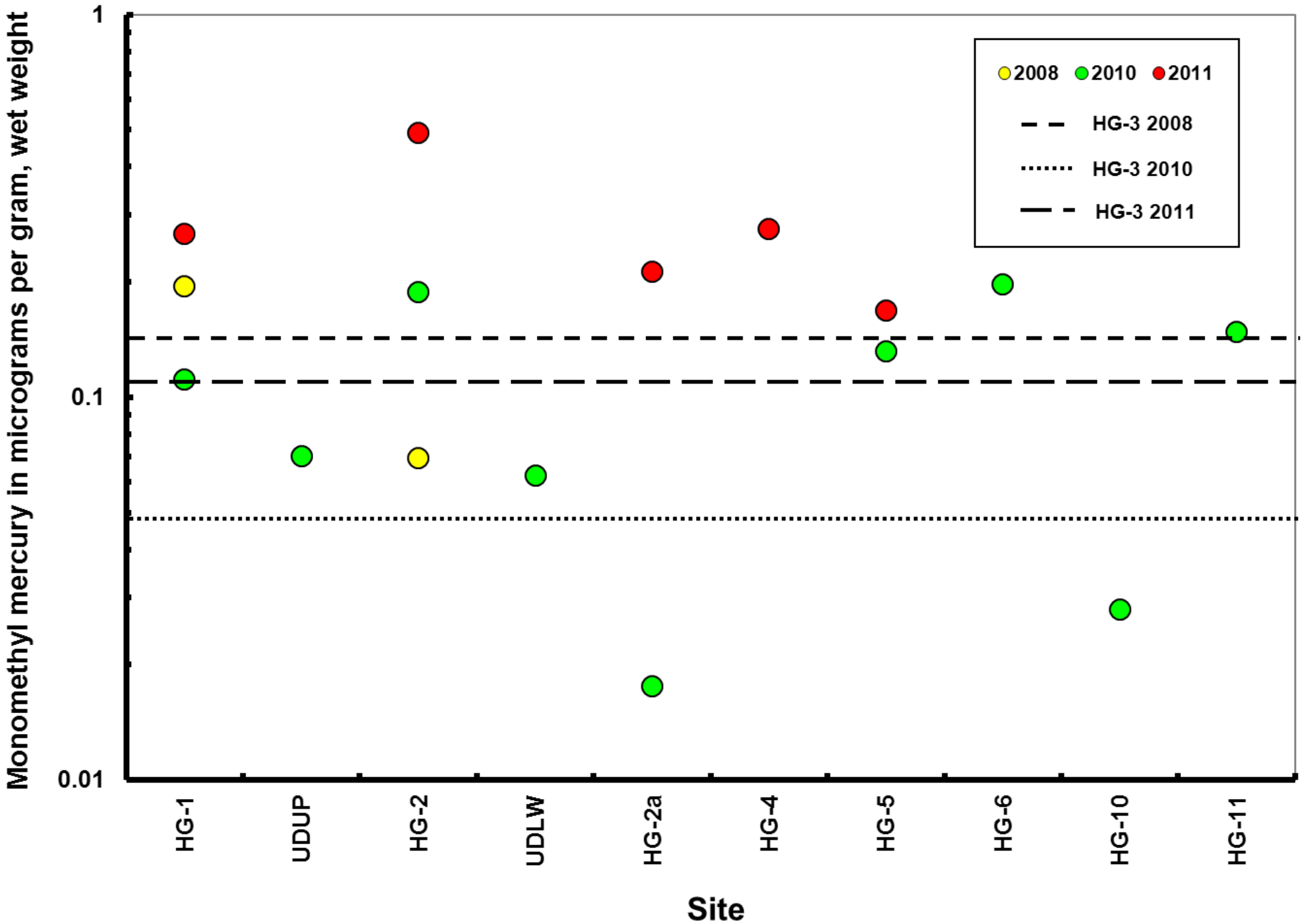

Figure 40. Monomethylmercury (MMeHg, µg/g, wet wt) in individual composite samples of predaceous diving beetles (Order Coleoptera, Family Dytiscidae) collected from Harley Gulch, Lake County, California, in2008, 2010, and 2011.

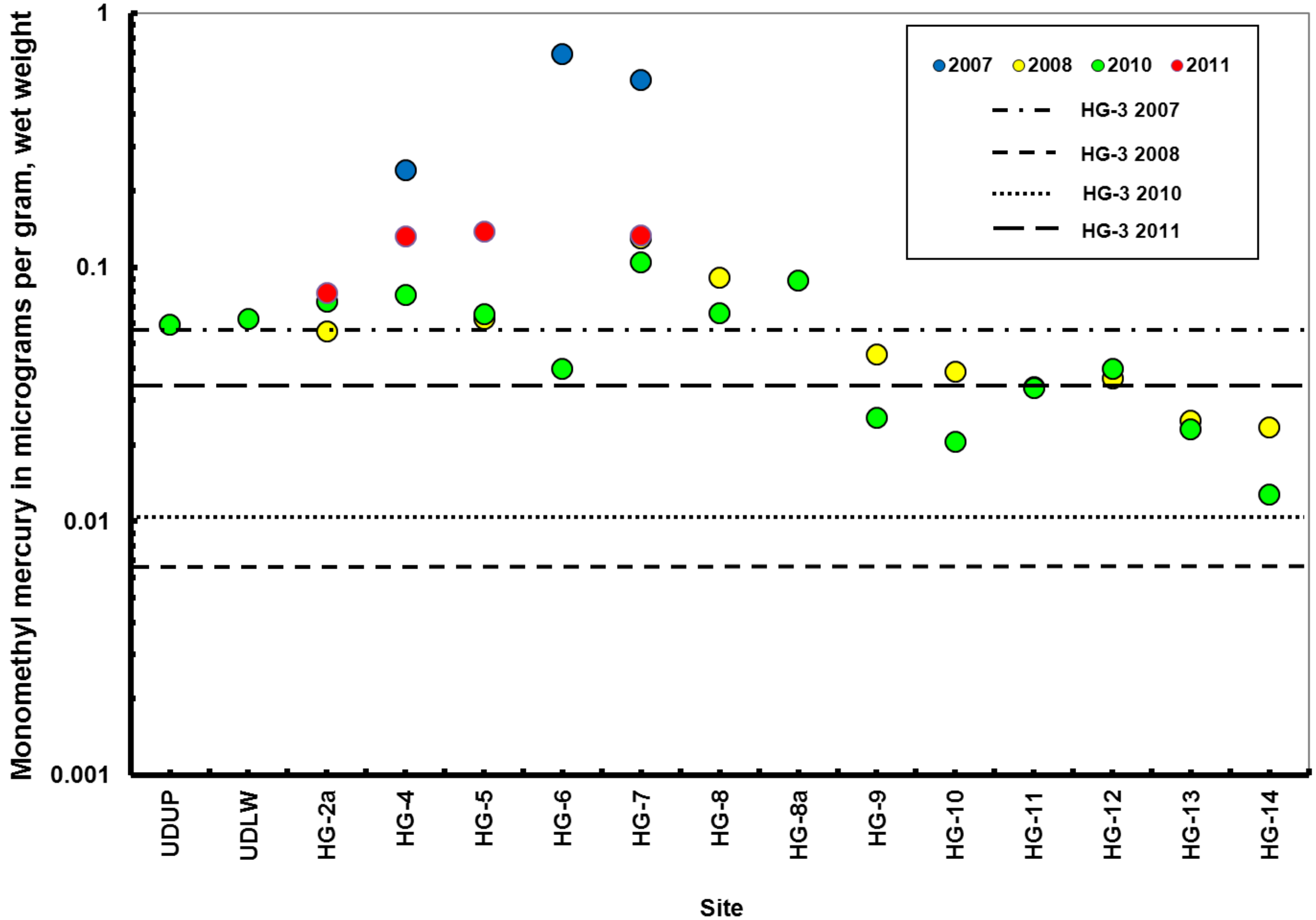

Figure 41. Monomethyl mercury (MMeHg, µg/g, wet wt) in composite samples of water striders (Order Hemiptera, Family Gerridae) collected from Harley Gulch, Lake County, California in 2007, 2008, 2010, and 2011.

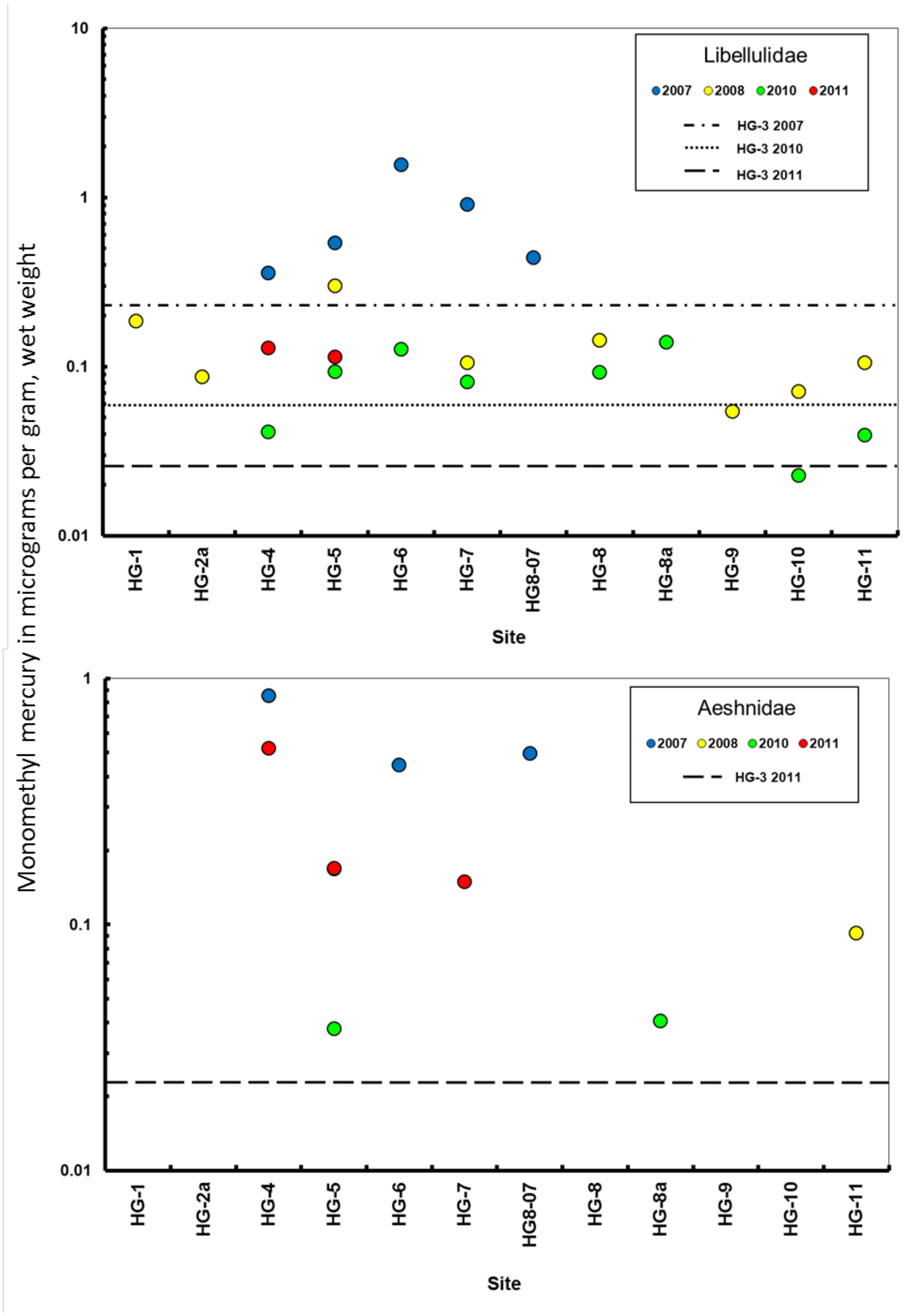

Figure 42. Monomethyl mercury (MMeHg, µg/g, wet wt) in individual composite samples of dragonflies (Order Odonata, Families Libellulidae and Aeshnidae) collected from Harley Gulch, Lake County, California, in 2007, 2008, 2010, and 2011.

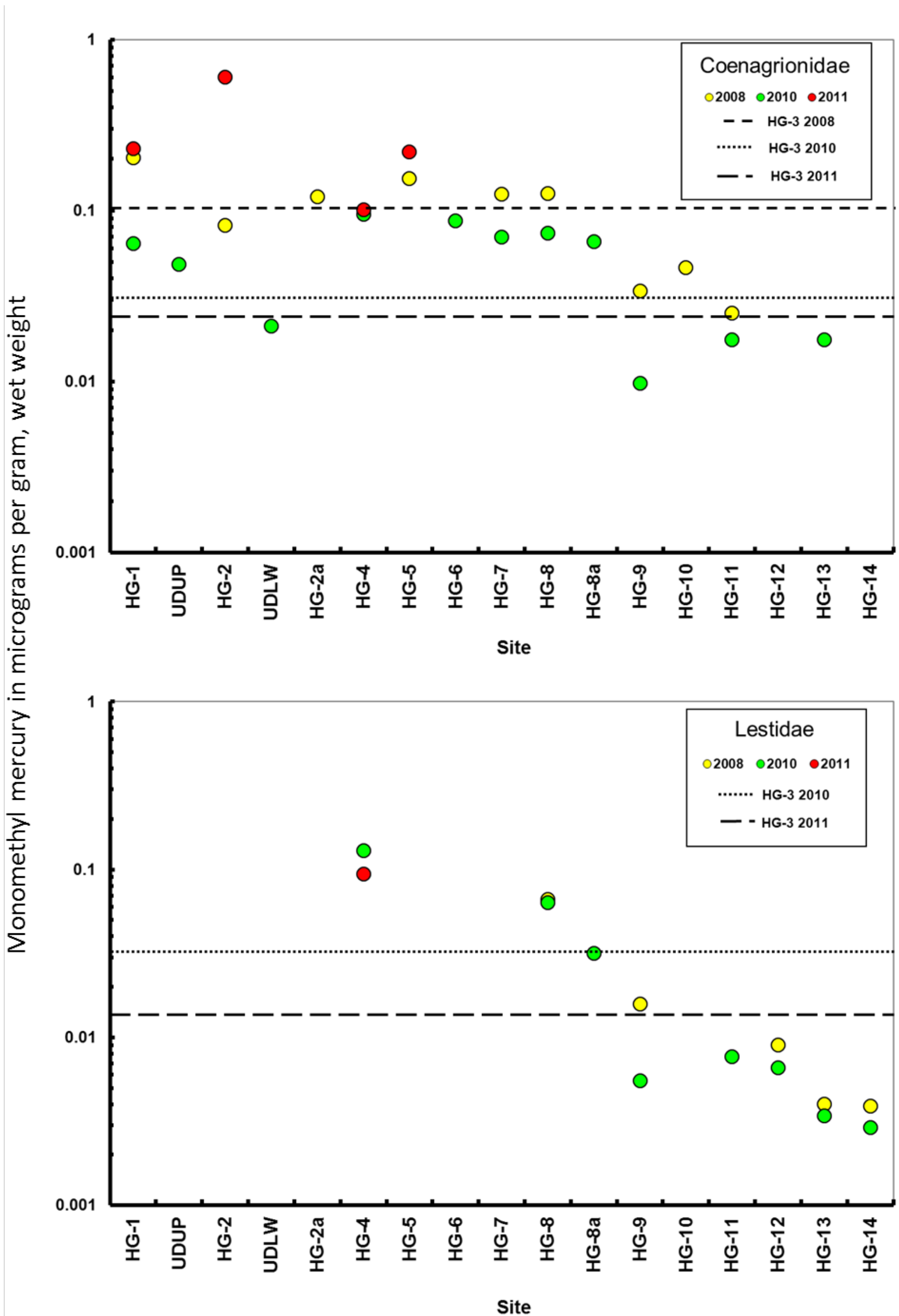

Figure 43. Monomethyl mercury (MMeHg, µg/g, wet wt) in individual composite samples of damselflies (Order Odonata, Families Coenagrionidae and Lestidae) collected from Harley Gulch, Lake County, California, in 2008, 2010, and 2011.

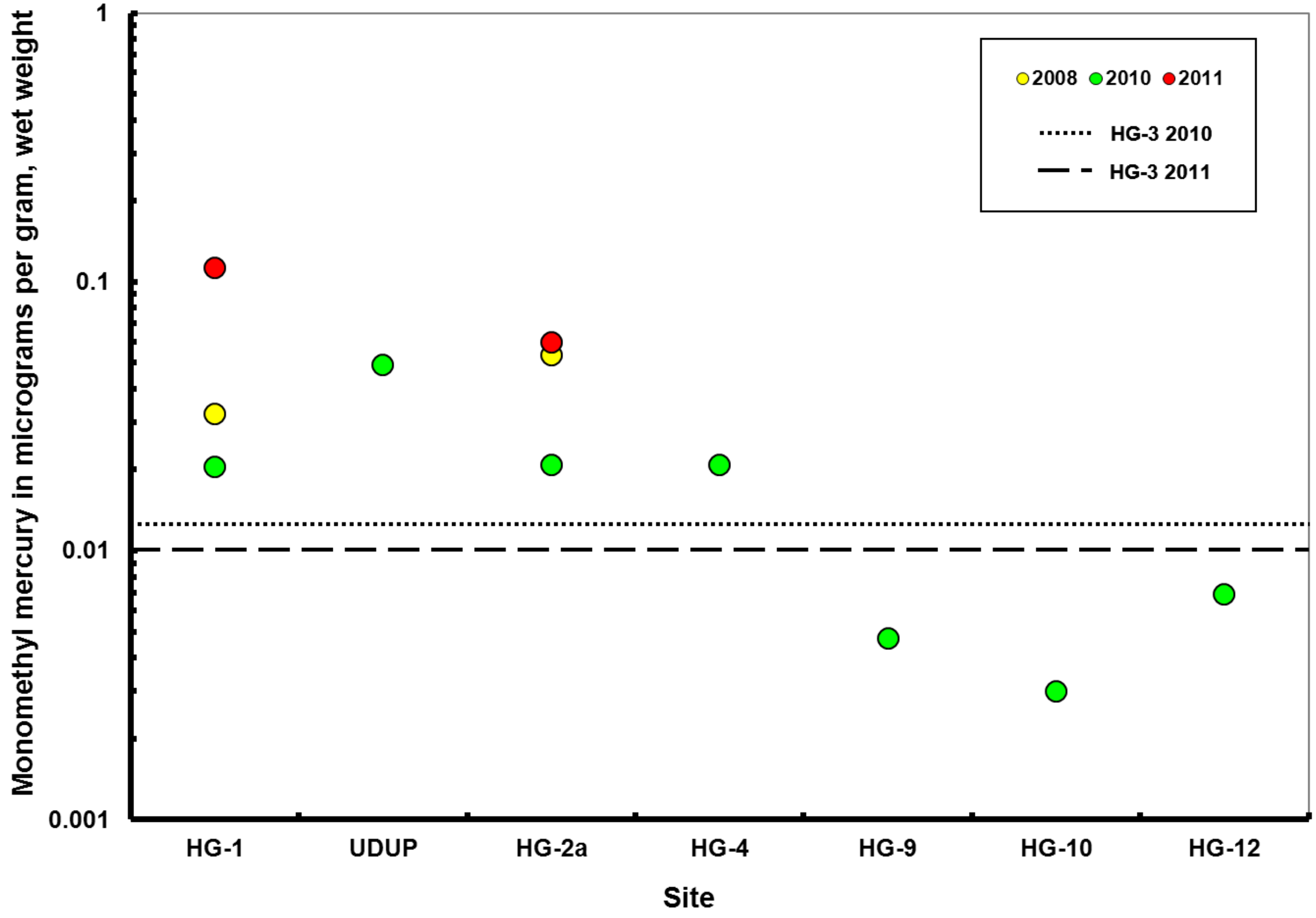

Figure 44. Monomethylmercury (MMeHg, µg/g, wet wt) in individual composite samples of larval water scavenger beetles (Order Coleoptera, Family Hydrophilidae) collected from Harley Gulch, Lake County, California, in 2008, 2010, and 2011.

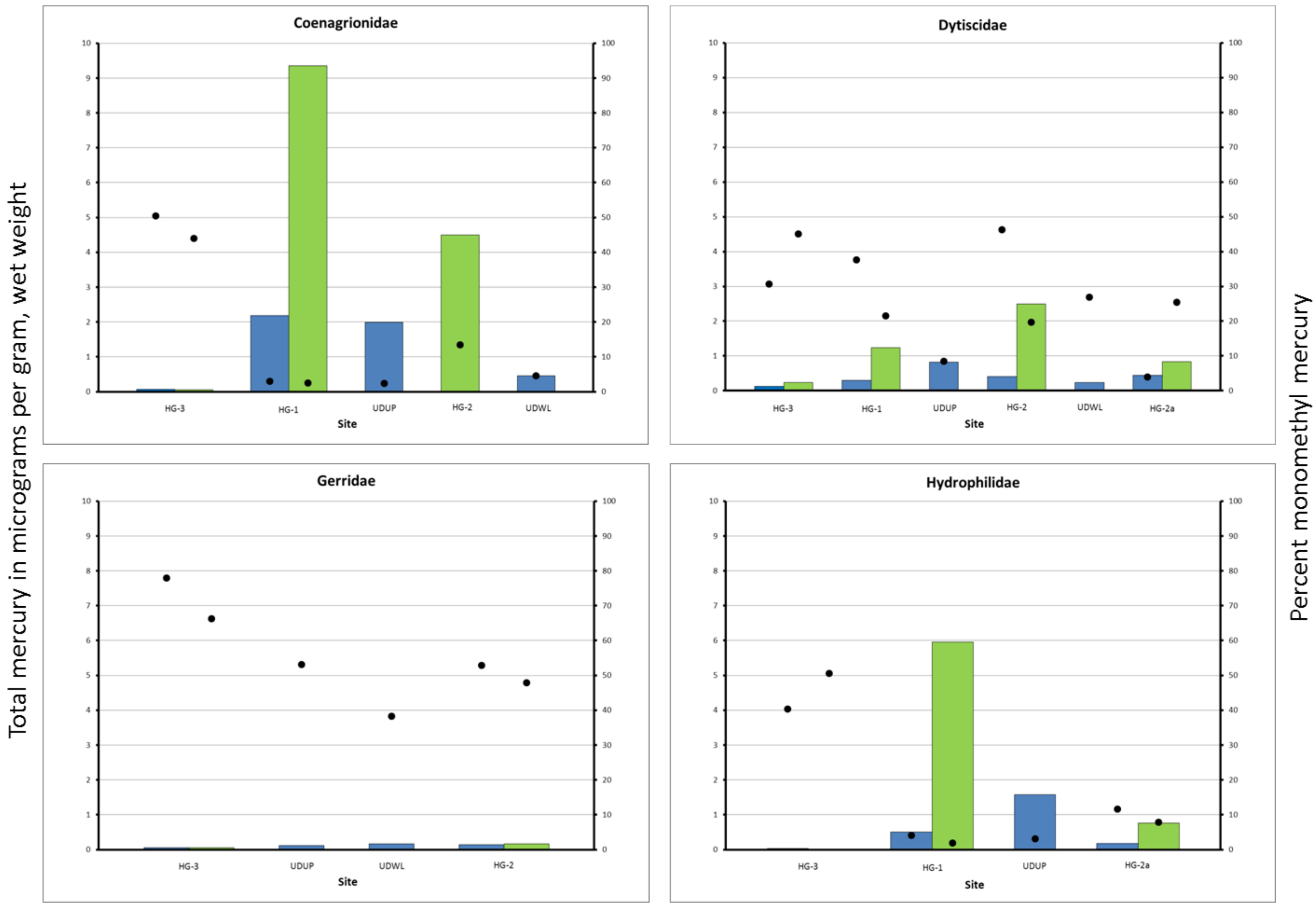

Figure 45. Total mercury (Hg_T, µg/g, wet wt) concentrations and percent monomethyl mercury (MMeHg) (black dots) in individual composite samples of invertebrates (larval Coenagrionidae, adult Dytiscidae, larval Hydrophilidae, and adult Gerridae) collected from a reference site (HG3) and sites in the Harley Gulch wetlands, Lake County, California, in 2010 (blue) and 2011 (green).

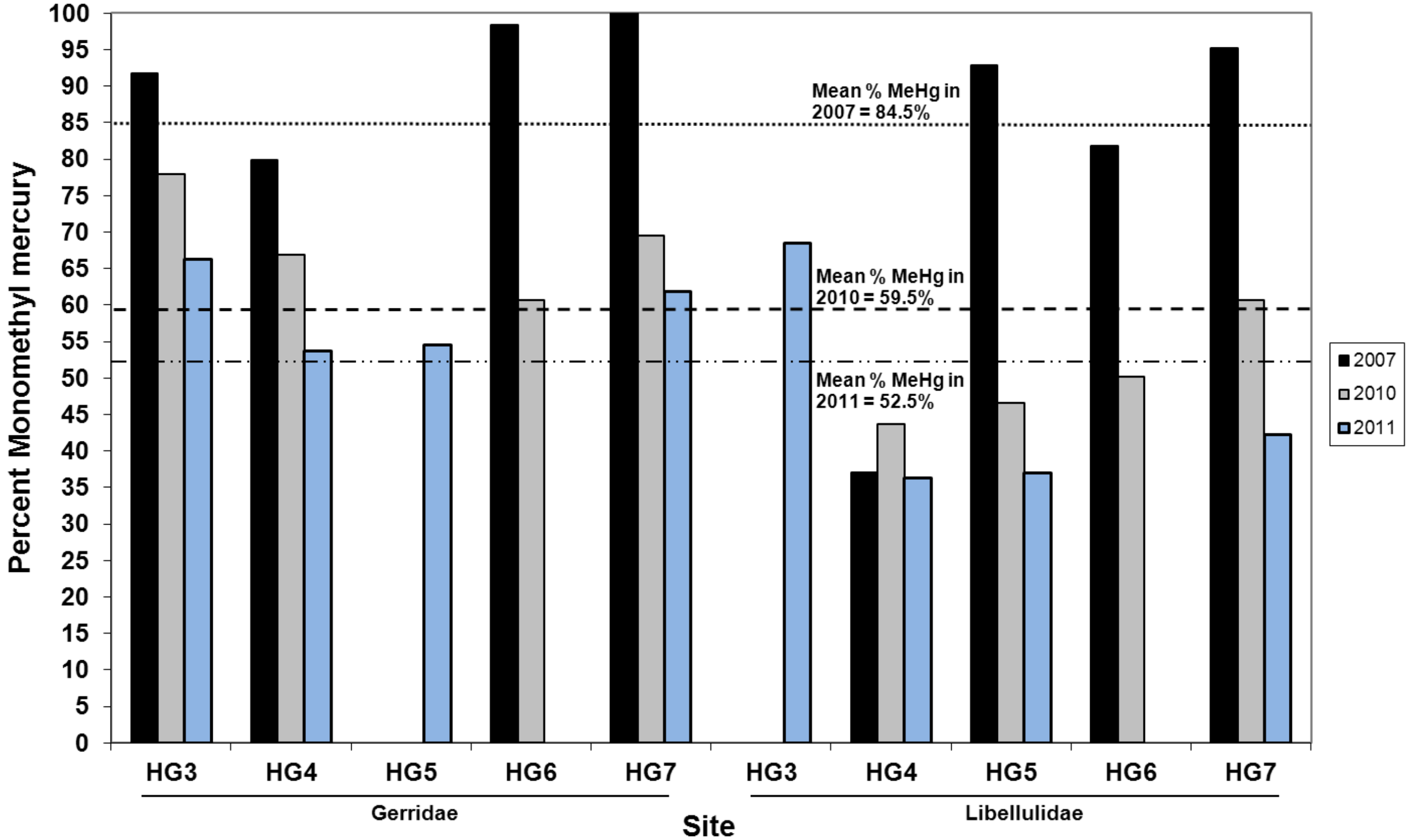

Figure 46. Comparison of percent monomethyl mercury in individual composite samples of water striders (Gerridae) and dragonflies (Libellulidae) collected from four sites in the Harley Gulch, Lake County, California, during 2007 (black), 2010 (gray), and 2011 (blue).

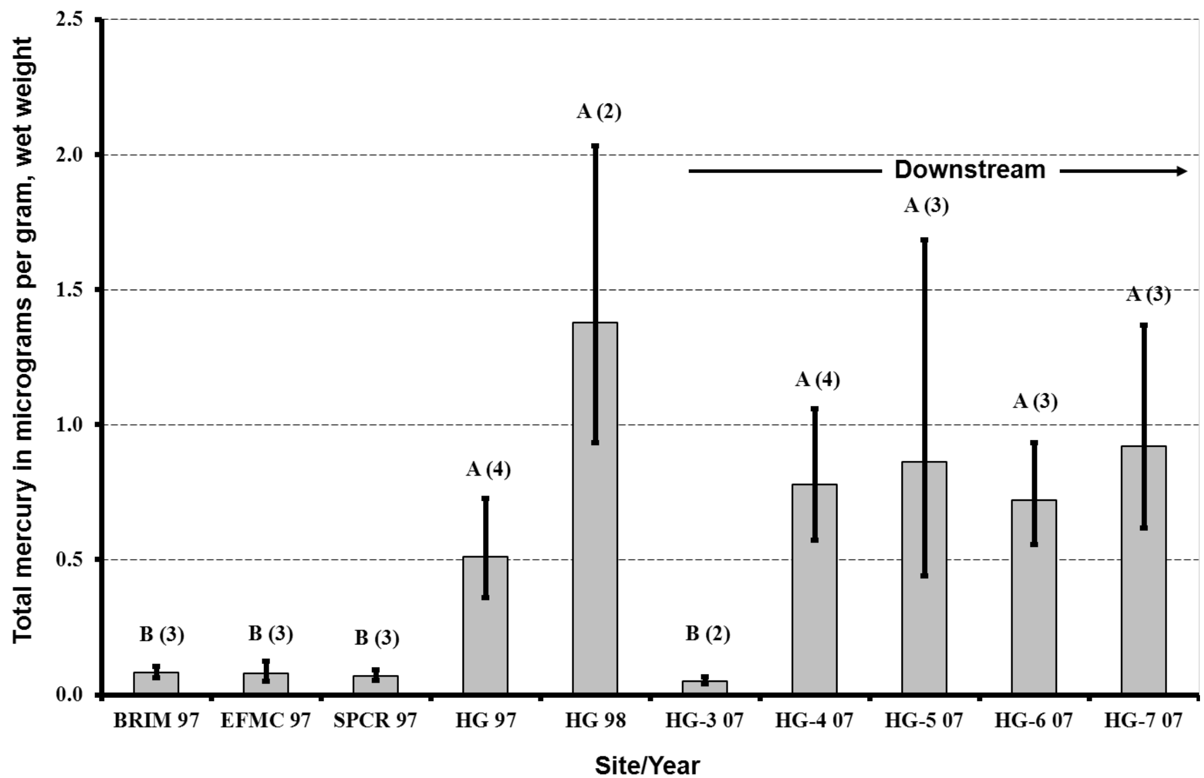

Figure 47. Geometric mean total Hg (Hg_T, µg/g, wet wt), with 95 percent confidence limits and sample sizes (n), in whole bodies of foothill yellow-legged frogs (FYLF) collected from East Fork Harley Gulch (H3) and four sites (H 4–7) downstream of the confluence of East and West Forks Harley Gulch in May 2007 (table 3), from three reference sites during April-May 1997 (SPCR, Spanish Creek; EFMC, East Fork Middle Creek; BRIM, Bear Creek at Brim Road) (fig. 19), and from Harley Gulch in 1997–1998 (table 11). Harley Gulch included one FYLF from Turkey Run upstream of the West Fork of Harley Gulch in 1997 and one FYLF from the Abbott Mine Drain in 1998 (fig. 1). Means not sharing a common letter were different ($P < 0.05$) by Tukey pairwise multiple-comparison procedure.

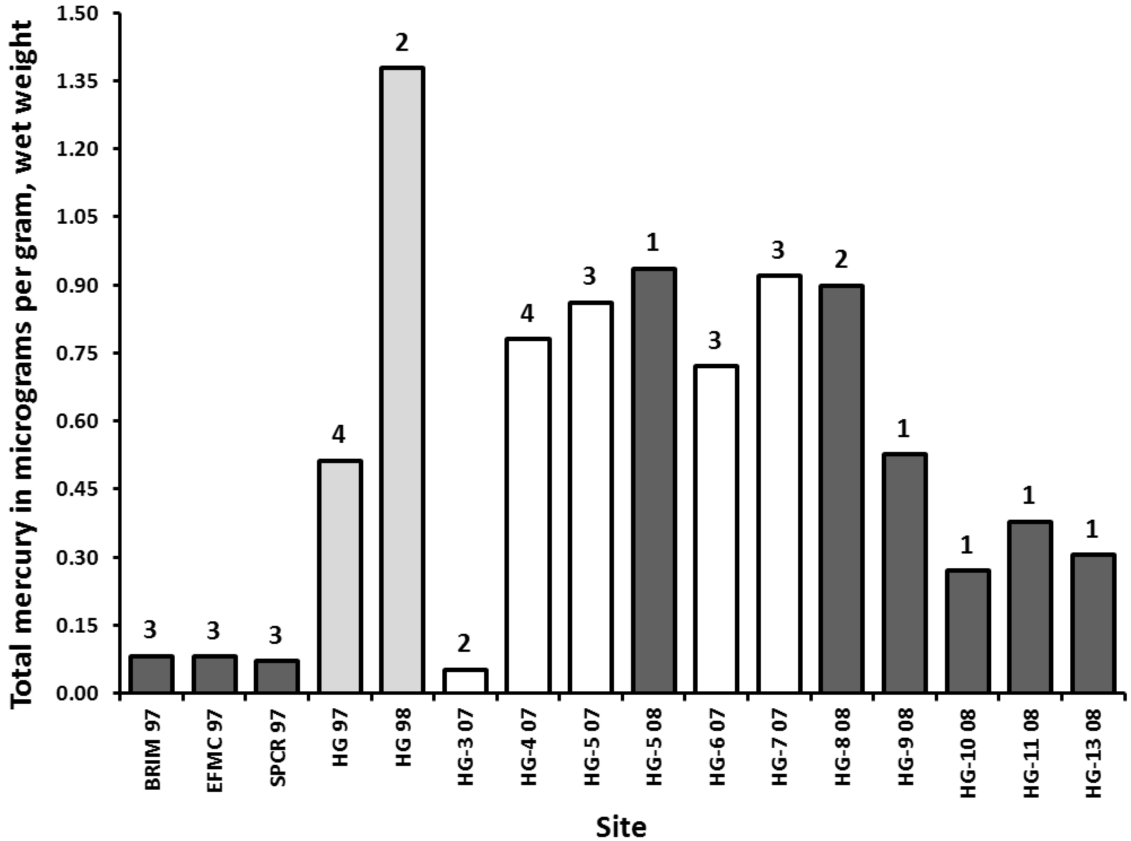

Figure 48. Total mercury (Hg_T) concentrations (µg/g, wet wt) in samples of foothill yellow-legged frogs collected from Harley Gulch, Lake County, California, in March-April 1997, March 1998, May 2007, and June 2008. Geometric means are presented for sites where n >1. Reference sites (SPCR, Spanish Creek; EFMC, East Fork Middle Creek; BRIM, Bear Creek at Brim Road) were sampled in April-May 1997 (fig. 19). Because only monomethyl mercury (MMeHg) was measured in frogs in 2008, Hg_T was estimated for these frogs based on 50 percent MMeHg found in frogs analyzed for both MMeHg and HG_T in 2007.

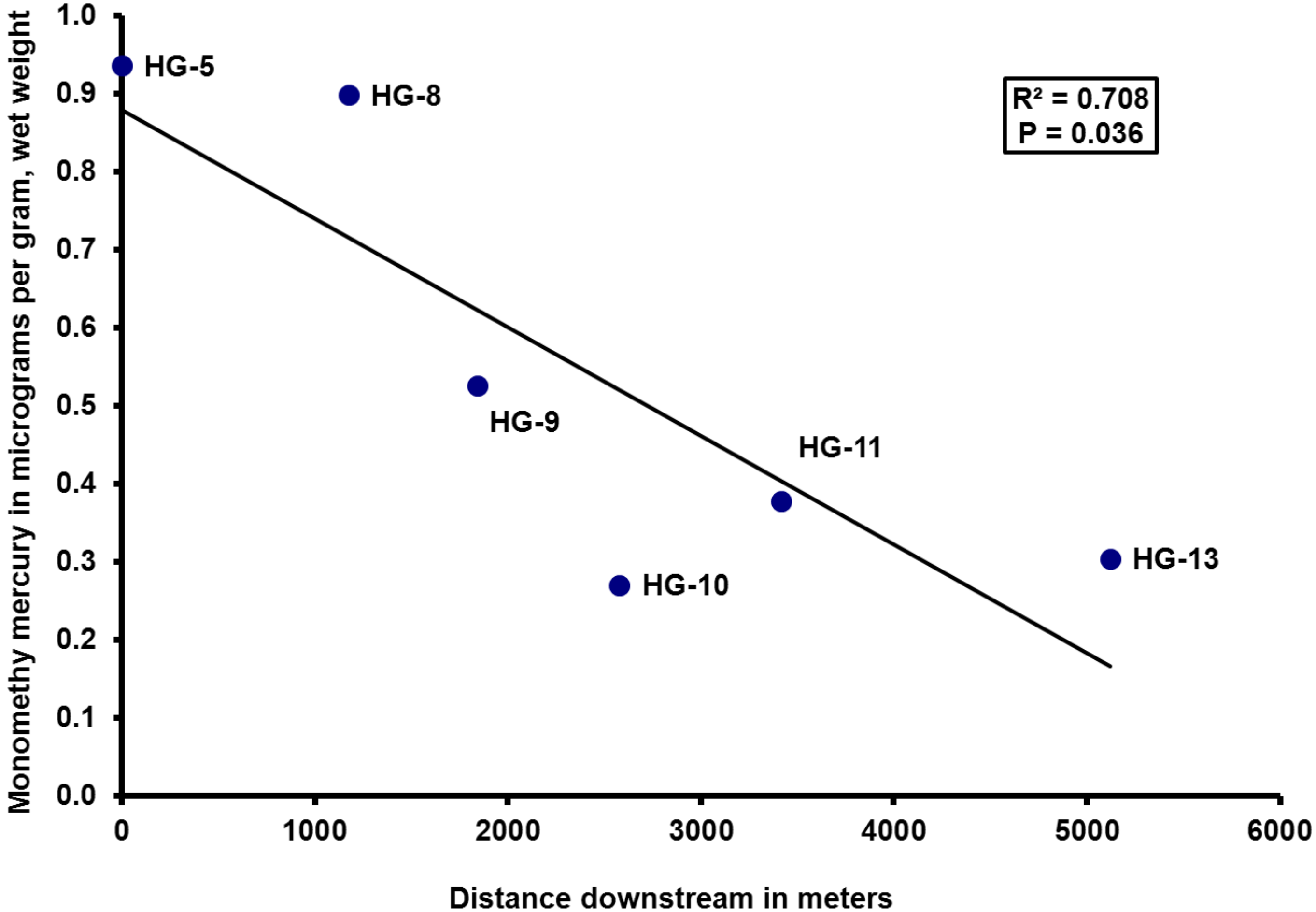

Figure 49. Monomethyl mercury (MMeHg) concentrations (µg/g, wet wt) in foothill yellow-legged frogs collected from Harley Gulch, Lake County, California, in June 2008. N=2 for HG8; for all other sites, N=1.

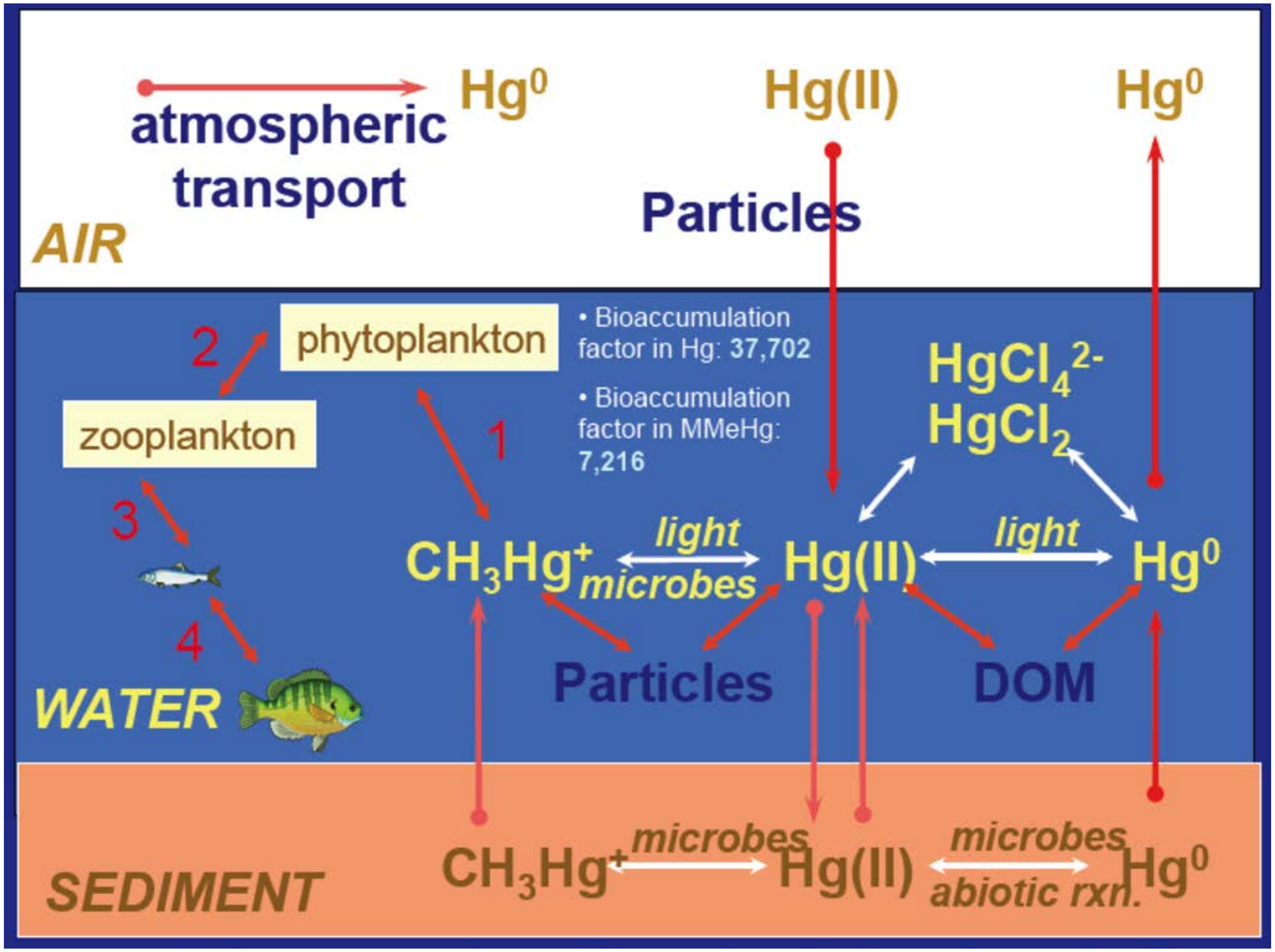

Figure 50. Transfer of Hg and MMeHg from the water column into the food web first occurs in phytoplankton. The bioaccumulation factor for both Hg and MMeHg is the highest during this transfer, but is still significant in the Hg trophic transfer between phytoplankton and zooplankton (step 2) and upward in the food web, such that fish can have very high Hg and MMeHg concentrations.

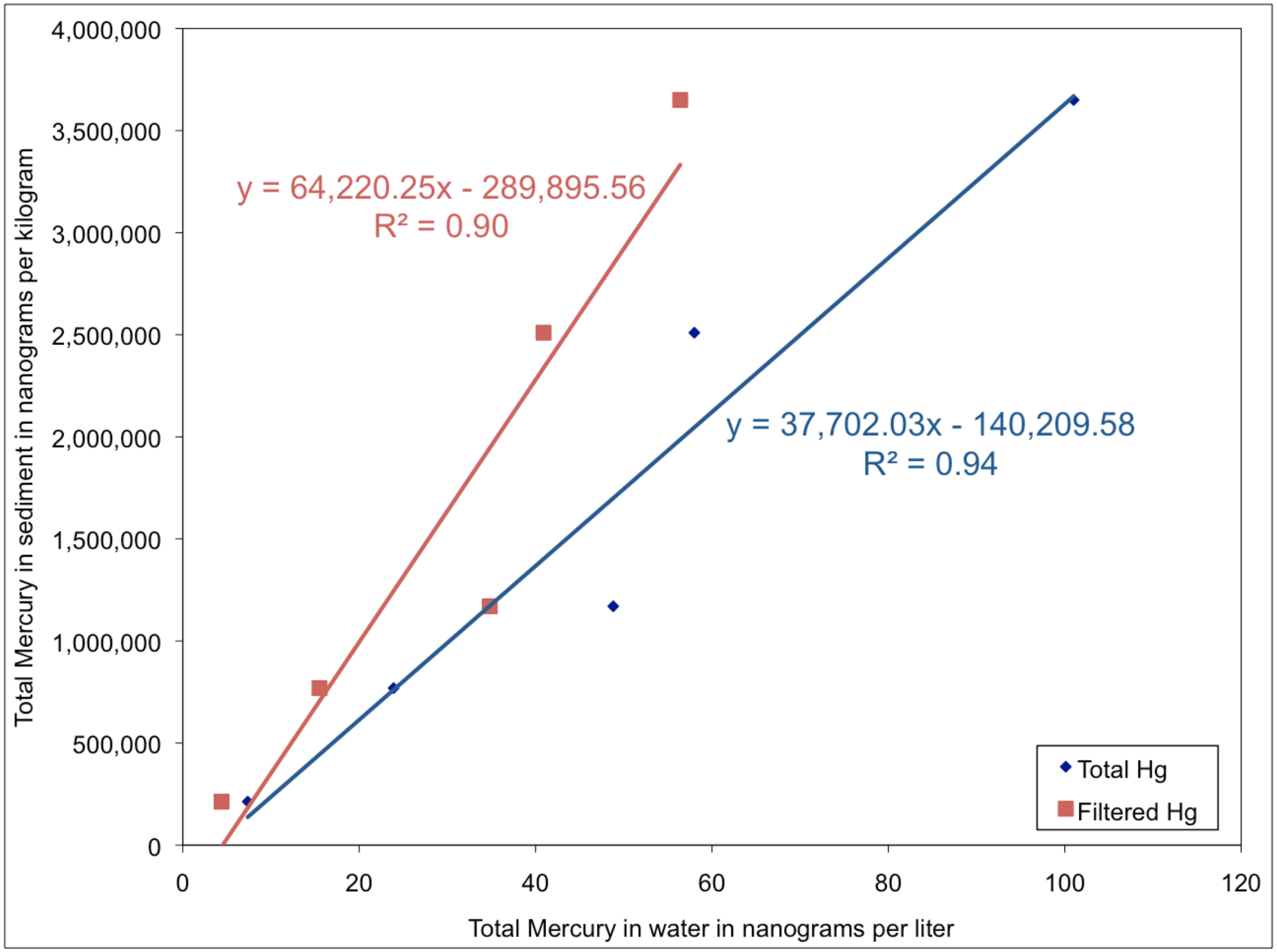

Figure 51. The bioaccumulation factor between phytoplankton in the biogenic sediment in Harley Gulch, Lake County, California, in total Hg (Hg_T) (blue) and filtered Hg (Hg_F) (red) in water is very high; 37,700 in Hg_T and 64,200 in Hg_F. The linear relationship demonstrates the Hg concentration in the biogenic sediment is a function of the Hg concentration in water.

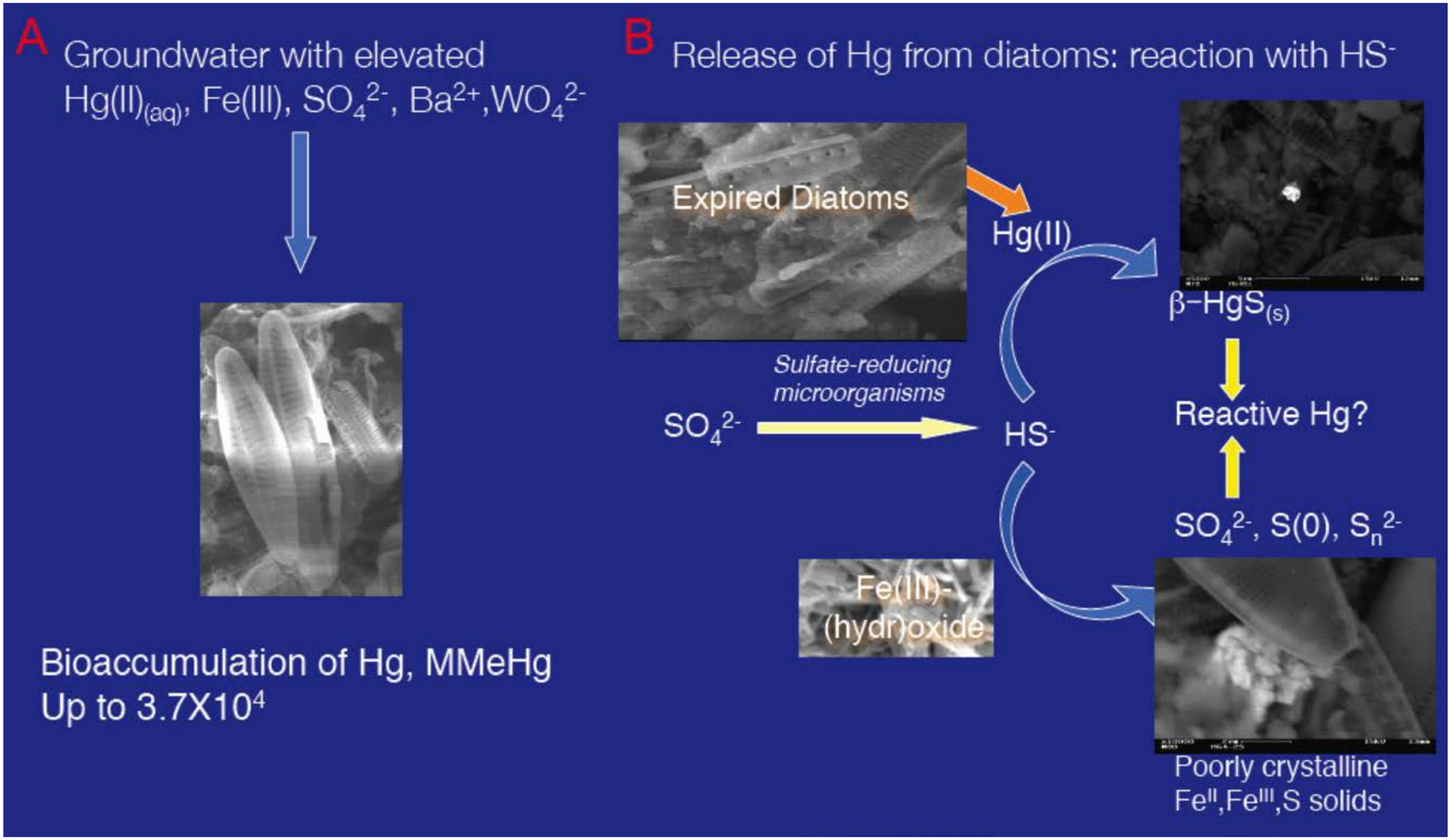

Figure 52. Model for bioaccumulation of Hg and MMeHg in diatoms from the water column and subsequent release of Hg and MMeHg from the expired diatom that reacts with sulfide to form HgS and precipitation FeS from reaction of Fe in the pore fluids with sulfide.