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## Geochemical Data for Mercury, Methylmercury, and Other Constituents in Sediments from Englebright Lake, California, 2002

Charles N. Alpers  
*U.S. Geological Survey*

Michael P. Hunerlach  
*U.S. Geological Survey*

Mark C. Marvin-DiPasquale  
*U.S. Geological Survey, mmarvin@usgs.gov*

Ronald C. Antweiler  
*U.S. Geological Survey*

Brenda K. Lasorsa  
*Battelle Marine Sciences Laboratory*

*See next page for additional authors*

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**Authors**

Charles N. Alpers, Michael P. Hunerlach, Mark C. Marvin-DiPasquale, Ronald C. Antweiler, Brenda K. Lasorsa, John F. De Wild, and Noah P. Snyder

CALFED Ecosystem Restoration Program, California Bay–Delta Authority, and  
California Resources Agency

# Geochemical Data for Mercury, Methylmercury, and Other Constituents in Sediments from Englebright Lake, California, 2002

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Data Series 151

**U.S. Department of the Interior**  
**U.S. Geological Survey**

Photograph on front cover: Three cores from Englebright Lake, site 8, showing correlation of stratigraphy, November 11, 2002. Photograph by Noah P. Snyder.

# **Geochemical Data for Mercury, Methylmercury, and Other Constituents in Sediments from Englebright Lake, California, 2002**

By Charles N. Alpers<sup>1</sup>, Michael P. Hunerlach<sup>1</sup>, Mark C. Marvin-DiPasquale<sup>2</sup>,  
Ronald C. Antweiler<sup>3</sup>, Brenda K. Lasorsa<sup>4</sup>, John F. De Wild<sup>5</sup>, and Noah P. Snyder<sup>6</sup>

Prepared in cooperation with the

CALFED Ecosystem Restoration Program, the California Bay-Delta Authority, and the  
California Resources Agency

Data Series 151

<sup>1</sup>U.S. Geological Survey, 6000 J Street, Placer Hall, Sacramento, CA 95819-6129.

<sup>2</sup>U.S. Geological Survey, 345 Middlefield Road, Mailstop 480, Menlo Park, CA 94025.

<sup>3</sup>U.S. Geological Survey, 3215 Marine Street, Suite E-127, Boulder, CO 80303.

<sup>4</sup>Battelle Marine Sciences Laboratory, 1529 West Sequim Bay Road, Sequim, WA 98382.

<sup>5</sup>U.S. Geological Survey, 8505 Research Way, Middleton, WI 53562.

<sup>6</sup>Dept. of Geology and Geophysics, Boston College, 140 Commonwealth Avenue, Chestnut Hill, MA 02467.

**U.S. Department of the Interior  
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## Conversion Factors, Datums Used, and Abbreviations

### Conversion Factors—SI to Inch/Pound

Multiply	By	To obtain
<b>Length</b>		
centimeter (cm)	0.3937	inch (in.)
kilometer (km)	0.6214	mile (mi)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
nanometer (nm)	$3.0937 \times 10^{-8}$	inch (in.)
<b>Area</b>		
square kilometer (km <sup>2</sup> )	247.1	acre
square centimeter (cm <sup>2</sup> )	0.001076	square foot (ft <sup>2</sup> )
square meter (m <sup>2</sup> )	10.76	square foot (ft <sup>2</sup> )
hectare (ha)	0.003861	square mile (mi <sup>2</sup> )
square kilometer (km <sup>2</sup> )	0.3861	square mile (mi <sup>2</sup> )
<b>Volume</b>		
cubic meter (m <sup>3</sup> )	264.2	gallon (gal)
cubic centimeter (cm <sup>3</sup> )	0.06102	cubic inch (in <sup>3</sup> )
cubic meter (m <sup>3</sup> )	35.31	cubic foot (ft <sup>3</sup> )
cubic meter (m <sup>3</sup> )	1.308	cubic yard (yd <sup>3</sup> )
cubic meter (m <sup>3</sup> )	0.0008107	acre-foot (acre-ft)
liter (L)	61.02	cubic inch (in <sup>3</sup> )
liter (L)	0.2642	gallon (gal)
milliliter (mL)	0.0610	cubic inch (in <sup>3</sup> )
<b>Mass and Mass Flux</b>		
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound, avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
metric ton per day (tonne/d)	1.102	ton, short, per day (ton/d)
megagram per day (Mg/d)	1.102	ton, short, per day (ton/d)
megagram per day per square kilometer [(Mg/d)/km <sup>2</sup> ]	2.8547	ton, short, per day per square mile [(ton/d)/mi <sup>2</sup> ]
megagram per year (Mg/yr)	1.102	ton, short, per year (ton/yr)
metric ton per year (tonne/yr)	1.102	ton, short, per year (ton/yr)
<b>Radioactivity</b>		
becquerel per liter (Bq/L)	27.027	picocurie per liter (pCi/L)

### Datums Used

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Elevation, as used in this report, refers to distance above the vertical datum.

## Acronyms, Abbreviations, and Chemical Notation

### Acronyms

ASL, above sea level  
ASTM, American Society for Testing and Materials  
BMSL, Battelle Marine Sciences Laboratory (Sequim, Washington)  
CRV, certified reference value  
CVAAS, cold vapor atomic-absorption spectrometry  
CVAFS, cold vapor atomic-fluorescence spectrometry  
DI, deionized (water)  
DOC, dissolved organic carbon  
EDS, energy dispersive spectrometer  
IAEA, International Atomic Energy Agency  
ICP–AES, inductively coupled plasma–atomic emission spectrometry  
ICP–MS, inductively coupled plasma–mass spectrometry  
MD, methylmercury degradation  
MDL, method detection limit  
MEM series, MEthylMercury sample series  
MP, methylmercury production (sample series)  
NIST, National Institute of Standards and Technology  
QA, quality assurance  
QC, quality control  
RPD, relative percentage difference  
RSD, relative standard deviation  
SEM, scanning electron microscope  
SR, sulfate reduction  
SRM, standard reference material  
USEPA, United States Environmental Protection Agency  
USGS, United States Geological Survey  
UYRSP, Upper Yuba River Studies Program  
WDML, Wisconsin District Mercury Laboratory (Middleton, Wisconsin)

### Abbreviations

cm, centimeter  
cm<sup>3</sup>, cubic centimeter  
g, gram  
kg, kilogram  
L, liter  
mCi/mg, millicurie per milligram  
mg, milligram  
mg Au/m<sup>3</sup>, milligram of gold per cubic meter  
MΩ-cm, megaohm-centimeter  
μCi/100 μL, microcurie per 100 microliters  
μg, microgram  
μm, micrometer  
ng, nanogram  
ng/g, nanogram per gram  
ng Hg/g dry sediment/d, nanograms of mercury per gram dry sediment per day  
ppb, parts per billion

ppm, parts per million  
 $R^2$ , coefficient of determination for linear least-squares regression  
rpm, revolutions per minute  
 $t/\text{km}^2/\text{yr}$ , tonnes per square kilometer per year  
wt, weight  
>, greater than  
<, less than  
~, approximately, about

## Chemical Elements

Al, aluminum  
As, arsenic  
Au, gold  
B, boron  
Ba, barium  
Be, beryllium  
Bi, bismuth  
Ca, calcium  
Cd, cadmium  
Ce, cerium  
Cl, chloride  
Co, cobalt  
Cr, chromium  
Cs, cesium  
Cu, copper  
Dy, dysprosium  
Er, erbium  
Eu, europium  
Fe, iron  
Gd, gadolinium  
Ho, holmium  
Hg, mercury  
In, indium  
Ir, iridium  
K, potassium  
La, lanthanum  
Li, lithium  
Lu, lutetium  
Mg, magnesium  
Mn, manganese  
Mo, molybdenum  
N, nitrogen  
Na, sodium  
Nd, neodymium  
Ni, nickel  
P, phosphorus  
Pb, lead  
Pr, praseodymium  
Rb, rubidium  
Re, rhenium

Rh, rhodium  
 S, sulfur  
 Sb, antimony  
 Se, selenium  
 Si, silicon  
 Sm, samarium  
 Sn, tin  
 Sr, strontium  
 Tb, terbium  
 Te, tellurium  
 Th, thorium  
 Ti, titanium  
 Tl, thallium  
 Tm, thulium  
 U, uranium  
 V, vanadium  
 W, tungsten  
 Y, yttrium  
 Yb, ytterbium  
 Zn, zinc  
 Zr, zirconium

### Chemical Compounds, Isotopes, and Other Chemical Notation

$\text{CH}_3^{203}\text{Hg}^+$ , methylmercury ion with radiolabeled mercury  
 $\text{CH}_4$ , methane  
 $\text{CH}_2\text{Cl}_2$ , methylene chloride  
 $\text{CuSO}_4$ , copper sulfate  
 Fe(II), ferrous (divalent) iron  
 Fe(III), ferric (trivalent) iron  
 HCl, hydrochloric acid  
 HF, hydrofluoric acid  
 $\text{HNO}_3$ , nitric acid  
 $\text{Hg}^0$ , elemental mercury  
 $\text{Hg}^+$ , mercurous ion  
 $\text{Hg}^{2+}$ , mercuric ion  
 Hg(II), divalent mercury  
 $\text{HgCl}_2$ , mercuric chloride  
 $\text{Hg}_T$ , total mercury  
 $^{203}\text{Hg}(\text{II})$ , mercury-203 radiotracer divalent inorganic mercury  
 KBr, potassium bromide  
 MeHg, methylmercury (monomethylmercury)  
 $\text{N}_2$ , nitrogen gas  
 $\text{NaBEt}_4$ , sodium tetra-ethyl borate  
 $\text{O}_2$ , oxygen gas  
 $\text{SiO}_2$ , silicon dioxide, or silica  
 $\text{SnCl}_2$ , stannous chloride

# Geochemical Data for Mercury, Methylmercury, and Other Constituents in Sediments from Englebright Lake, California, 2002

By Charles N. Alpers, Michael P. Hunerlach, Mark C. Marvin-DiPasquale, Ronald C. Antweiler, Brenda K. Lasorsa, John F. De Wild, and Noah P. Snyder

## Abstract

This report presents geochemical data from two 2002 sampling campaigns conducted in Englebright Lake on the Yuba River in northern California. A deep coring campaign was done in May–June 2002 and a shallow sampling campaign was completed in October 2002. This work assessed the chemical composition of material deposited in the reservoir between 1940, the year Englebright Dam was completed, and 2002 as part of the Upper Yuba River Studies Program, an effort designed to evaluate the feasibility of introducing anadromous fish, including steelhead and spring-run Chinook salmon, upstream from Englebright Dam. Results of analyses of total mercury ( $Hg_T$ ) in 444 subsamples, methylmercury (MeHg) in 243 subsamples, and other trace and major elements in 202 subsamples are presented. Data quality was evaluated on the basis of analyses of replicate pairs of subsamples, standard reference materials, blanks, and spike additions.

Deep coring penetrated the full thickness of material deposited after 1940 at six locations in the reservoir; the cores reached a maximum depth of 32.8 meters below the reservoir floor. At the three deep coring sites closest to Englebright Dam, concentrations of  $Hg_T$  (dry basis) were consistently in the range of 100 to 500 ng/g (nanogram per gram), in sediment dominantly of silt size (median grain size of 0.004 to 0.063 mm [millimeter]). At the deep coring sites located farther upstream, the upper parts of the profile had lower concentrations of  $Hg_T$ , generally ranging from 2 to 100 ng/g, in sediment dominantly of sand size (median grain size from 0.063 to 2 mm). The lower part of the vertical profiles at three upstream coring sites had higher concentrations of  $Hg_T$  than the upper and middle parts of these profiles, and had finer median grain size.

The highest median concentration of MeHg (1.1 ng/g) was in the top 2 cm (centimeter) of the shallow box cores. This vertical interval also had the highest value of the ratio of MeHg to  $Hg_T$ , 0.41 percent. Median concentrations of MeHg and median values of MeHg/ $Hg_T$  decreased systematically with depth from 0–4 to 4–8 to 8–12 cm in the shallow cores.

However, similar systematic decreases were not observed at the meter scale in the deep cores of the MEM (MEthylMercury) series. The overall median of the ratio MeHg/ $Hg_T$  in the deep cores was 0.25 percent, not much less than the overall median value for the shallow cores (0.33 percent).

Mercury-203 radiotracer divalent inorganic mercury ( $^{203}Hg(II)$ ) was used to determine microbial mercury-methylation potential rates for 11 samples collected from three reservoir locations and various depths in the sediment profile. For the five shallow mercury-methylation subsamples, ancillary geochemical parameters were assayed, including microbial sulfate reduction rates, sulfur speciation (sediment acid volatile sulfide, total reduced sulfur, and pore-water sulfate), iron speciation (sediment acid extractable iron(II), amorphous iron(III), crystalline iron(III) and pore-water iron(II)), pore-water chloride and dissolved organic carbon, and pH, oxidation-reduction potential (Eh) and whole-sediment organic content. The highest potential rates of microbial mercury methylation were measured in shallow (0 to 8 cm depth) sediments (5 to 30 nanograms of mercury per gram dry sediment per day), whereas potential rates for subsamples collected from depths greater than 500 cm were consistently below the detection limit of the radiotracer method (< 0.02 nanogram of mercury per gram dry sediment per day).

Chemical analyses of trace and major elements in bed sediment are presented for 202 samples from deep cores from five locations in Englebright Lake. The mean values and standard deviations for selected trace elements were as follows (in micrograms per gram): antimony,  $2.4 \pm 1.6$ ; arsenic,  $69 \pm 48$ ; chromium,  $134 \pm 23$ ; lead,  $33 \pm 25$ ; and nickel,  $87 \pm 24$ .

Concentrated samples of heavy-mineral grains, prepared using nine large-volume composite samples from deep cores, were examined using optical and scanning-electron microscopy. Estimated gold concentrations in the composite sediment samples ranged from 38 to 840 milligrams per cubic meter. Grains of gold-mercury amalgam and grains of electrum (native gold), with and without mercury staining, were observed in the heavy-mineral concentrates.

Results of this study will be used to evaluate potential effects on fish habitat and trace-element transport in relation to various scenarios regarding efforts to improve fish passage at Englebright Lake. The scenarios include dredging or release of sediments to downstream environments in association with dam modification or removal.

## Introduction

Harry L. Englebright Lake (Englebright Lake; *fig. 1*) is a 14-kilometer-long reservoir located on the Yuba River in the Sierra Nevada foothills of northern California. The reservoir is impounded by Englebright Dam, which is 80 m (meter) tall and was completed in December 1940 by the California Debris Commission. Its primary purpose was to help mitigate flood risk in the Central Valley around Marysville by impounding sediment from anticipated future hydraulic-mining activity in the watershed upstream. At present, the reservoir is a popular destination for recreational boaters and campers and is a site for hydroelectric power generation. The reservoir also serves as an afterbay for peak power generation at the New Colgate Powerhouse, which receives water from New Bullards Bar Reservoir on the North Yuba River (*fig. 1*).

The Upper Yuba River Studies Program (UYRSP), sponsored by the California Bay-Delta Authority (formerly the California-Federal Bay-Delta Program, or CALFED), is evaluating the feasibility of introducing anadromous fish species to the Yuba River system upstream from Englebright Dam (*fig. 1*). The scope of the UYRSP has six elements: sediment (quality and quantity), water quality, habitat, flood risk, water supply and hydropower, and socio-economics; the U.S. Geological Survey (USGS) is responsible for the technical aspects of the sediment and water-quality elements of the program. To achieve the UYRSP objective of fish passage at Englebright Dam, management scenarios under consideration include lowering or removing the dam. Any reduction in size of the dam would result in some change in the sediment regime of the lower Yuba River and could cause the release of sediment stored in Englebright Lake. This increased sediment load could exacerbate existing physical and chemical hazards in the lower Yuba River area. Sediment deposition could raise riverbed elevations and therefore increase flood risk in the valley around Marysville (*fig. 1*). Because much of the stored material is likely derived from historical gold mining areas in the Yuba River watershed (James, 2005), it may contain high concentrations of mercury (Hg) and other heavy metals that were lost during gold mining and recovery operations (Alpers and Hunerlach, 2000; Ashley, 2002; Alpers and others, 2005a, 2005b).

The release of Hg-rich sediment from Englebright Lake could increase the amount of Hg available for bioaccumulation in downstream areas. The ability to predict accurately the fate and transport of the material stored in Englebright Lake is critical to assessing the feasibility of various dam-management

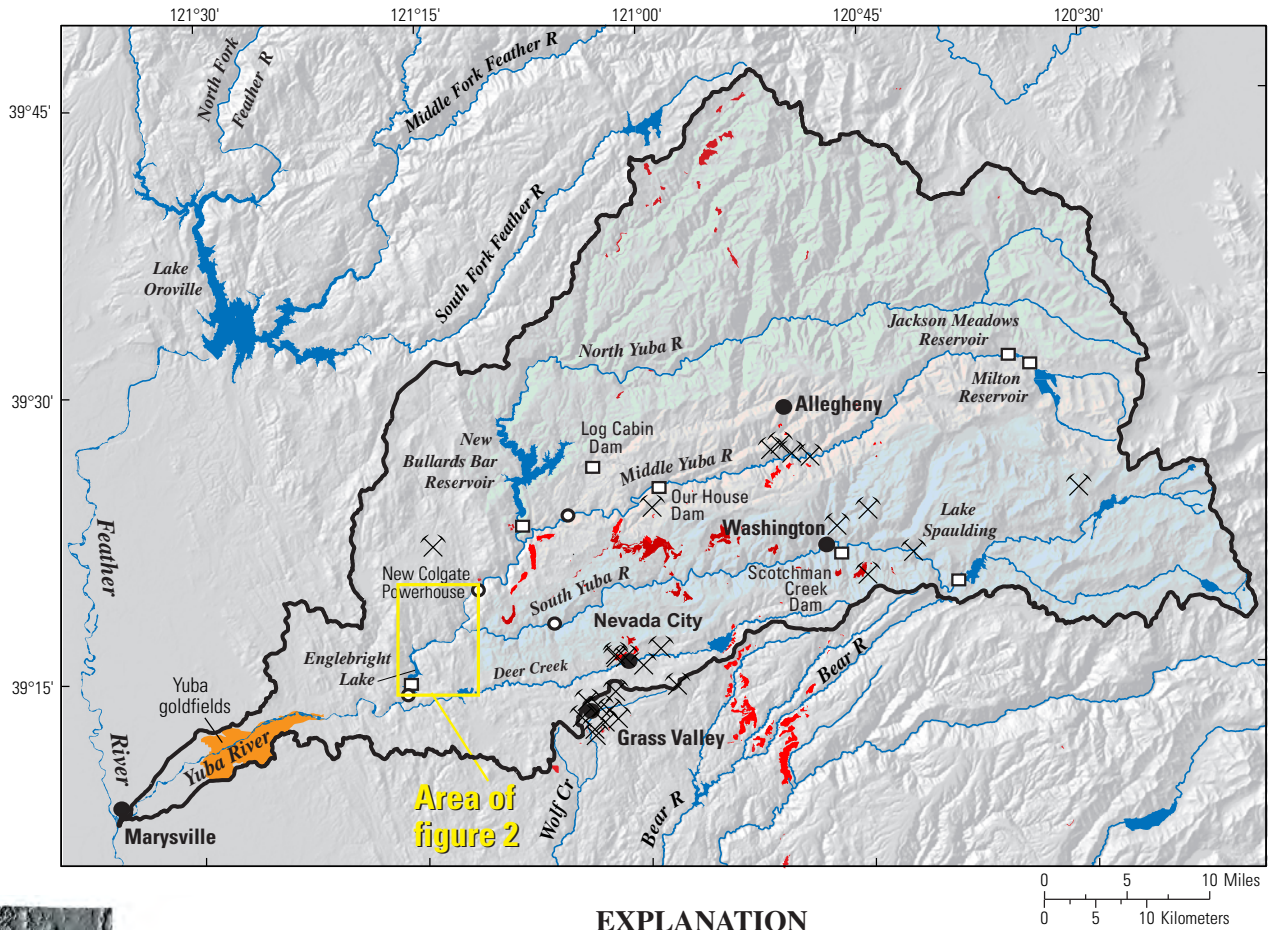
scenarios. This report presents data from two 2002 sediment-sampling campaigns undertaken by the USGS to characterize the three-dimensional distribution of mercury, methylmercury, and other constituents in sediments trapped in Englebright Lake, and the current potential for active methylmercury production in vertical sediment profiles.

## Previous Work and Related Investigations

A previous report as part of the UYRSP describing reservoir bathymetry and pre-dam Yuba River topography (Childs and others, 2003) concluded that, in 2001, Englebright Lake contained 21,890,000 m<sup>3</sup> (cubic meter) of material deposited since the completion of Englebright Dam, reducing the original storage capacity (85,970,000 m<sup>3</sup>) by 25.5 percent. Details of a deep coring campaign conducted in May–June 2002 by the USGS were documented by Snyder and others (2004a), who also presented data on the moisture content and bulk density of reservoir bed sediment. Results of grain-size distribution and loss-on-ignition (a proxy for organic content) analyses for subsamples from the deep coring campaign and a shallow coring campaign conducted in October 2002 were provided by Snyder and others (2004b). Using the data for grain-size distribution, density, and loss on ignition derived from the deep cores and shallow subsamples, Snyder and others (2004c) quantified the mass, organic content, and grain-size distribution of Englebright Lake sediments. Two distinct extrapolation methods yielded nearly identical estimates of the mass of the reservoir deposit:  $26 \times 10^6$  metric tons, of which 64.7–68.5 percent is sand (0.063–2 mm [millimeter]) and gravel (coarser than 2 mm).

The sedimentation rate for Englebright Lake is high compared with that for many other lakes and reservoirs. A prograding delta near the middle of the lake has accumulated sediment up to 32.8 m (meter) thick over the 61-year history of the reservoir, or an average of more than 0.5 m/yr (meter per year). Near Englebright Dam, where the grain-size distribution is dominated by silt, the overall accumulation during 1941–2002 was about 6 m, for an average accumulation rate of about 0.1 m/yr. In comparison, much lower sedimentation rates, ranging from 0.004 to 0.066 m/yr, were reported by Van Metre and others (2001) for 3 lakes and 8 reservoirs located throughout the United States. Sedimentation rates in Englebright Lake are also higher than those in each of 56 U.S. lakes and reservoirs cored by the USGS during 1992–2001 (Van Metre and others 2004). Snyder and others (2004c) computed a maximum basin-wide sediment yield of 340 metric t/km<sup>2</sup>/yr (tonne per square kilometer per year) over the 61-year history of Englebright Lake, assuming no contribution from upstream parts of the watershed impounded by other dams such as Spaulding Dam and Milton Dam (*fig. 1*). A conceptual model for erosion and sedimentation in the upper Yuba River watershed was presented by Curtis and others (2005). Less than 5 percent of Englebright Lake sedimentation can be accounted for by mass wasting on hill slopes in





**EXPLANATION**

- |                               |                |  |
|-------------------------------|----------------|--|
| <b>Subwatersheds</b>          |                | Stream channel                               |
| North Yuba                    | Middle Yuba    | Sediment and stream discharge gaging station |
| South Yuba                    | Hydraulic mine | Major gold mine (hard rock)                  |
| Yuba River watershed boundary | Dam            |  |

**Figure 1.** Location of Englebright Lake in the Yuba River watershed, California.

the Middle Yuba River and South Yuba River, two of the three main tributaries to Englebright Lake. In the third main tributary, the North Yuba River, transport of coarse sediment has been blocked since the construction of New Bullards Bar Dam in 1970. Licensed hydraulic mining during 1893–1950 (James, 2005) can account for an additional 10 percent of Englebright

Lake sedimentation (Curtis and others, 2005). The remainder (more than 85 percent) is thought to be primarily from remobilization of sediment stored in active and semi-active channels; much of this stored sediment is from unregulated hydraulic mining of placer gold deposits in the watershed from the early 1850s through 1884 (Curtis and others, 2005).

The effect on sediments of legacy contamination associated with historical hardrock gold mining is also an issue in the Yuba River watershed. Hardrock mining in the Mother Lode gold belt was concentrated in the vicinity of Grass Valley and Nevada City and also in the Alleghany District (Clark, 1963; Alpers and others, 2005b). Some of the largest hardrock mines in the Grass Valley and Nevada City areas do not drain into tributaries of Englebright Lake; the Grass Valley area drains primarily into Wolf Creek, a tributary of the Bear River (*fig. 1*), and the Nevada City area drains primarily into Deer Creek, a tributary to the Yuba River downstream of Englebright Dam (*fig. 1*). However, some of the hardrock mines near Nevada City, such as the Davis and Hoge mines on Little Rock Creek and the Ancho Erie mine on Poorman Creek, drain into the South Yuba River. The Alleghany mining district is located primarily within the Kanaka Creek subwatershed, which drains into the Middle Yuba River, a tributary to Englebright Lake (*fig. 1*). In general, mill tailings from hardrock gold mines of the Sierra Nevada may contain elevated concentrations of mercury that was added to enhance gold recovery by amalgamation at stamp mills (Churchill, 2000; Ashley, 2002). These tailings may also contain naturally occurring concentrations of trace elements such as arsenic, antimony, and lead (Ashley, 2002). Historical mining practices included depositing mill tailings directly into streams or capturing tailings in impoundments, some of which remain prone to failure during large storm events (Ashley, 2002).

The bioaccumulation of mercury in aquatic organisms, including invertebrates and fish, is most elevated in the portions of the northern Sierra Nevada that are affected by historical gold mining (Slotton and others, 1997, 2004; Alpers and Hunerlach, 2000; Alpers and others, 2004a, 2005b). Data for mercury bioaccumulation in sport fish from a reconnaissance sampling by the USGS of Englebright Lake and other water bodies in the Yuba River and Bear River watersheds were published by May and others (2000). These data led the State of California to issue an advisory that recommends limited consumption of smallmouth bass in Englebright Lake (Klasing and Brodberg, 2003). Results of additional studies of mercury bioaccumulation in fish and zooplankton from Englebright Lake and in fish and invertebrates from stream sites in South Yuba, Middle Yuba, and lower Yuba Rivers (Slotton and others, 2004) are part of the UYRSP Water Quality scope of work and will be published in separate reports. An additional component of the UYRSP Water Quality work involved USGS monitoring of mercury and methylmercury concentrations and other water-quality parameters in the main tributaries to Englebright Lake and the Yuba River below Englebright Dam (Alpers and others, 2004b) during 2001–04. Load calculations and mass balances of mercury and methylmercury with regard to Englebright Lake based on the water-quality monitoring will be published separately.

Downstream of Englebright Dam, the lower Yuba River is considered to be a critical habitat for endangered aquatic species, including steelhead trout (*Oncorhynchus mykiss*) and spring-run Chinook salmon (*O. tshawytscha*) (National Marine

Fisheries Service, 2005). A USGS investigation (Hunerlach and others, 2004) characterized the concentrations of mercury and methylmercury, mercury methylation potential, and the grain-size distribution of sediment trapped behind Daguerre Point Dam in the Yuba Goldfields area (*fig. 1*), which was affected by deposition of hydraulic mining debris and subsequent dredging of placer gold deposits. Resource management issues at Daguerre Point Dam are similar to those at Englebright Dam because removing or modifying either dam to improve anadromous fish passage may disturb the sediments contaminated with mercury from historical gold mining (California Department of Water Resources, 2003). Although concentrations of methylmercury in sediments trapped behind Daguerre Point Dam were low, moderately elevated concentrations of total mercury were found in fine-grained sediment fractions (Hunerlach and others, 2004). The environmental risk associated with release of fine-grained sediment containing an elevated concentration of mercury is related to the potential for the mercury to be converted to the more toxic form of methylmercury if conditions are favorable. Aquatic life is exposed to methylmercury through dietary pathways, leading to biomagnification in the food web and potential harm to higher-trophic-level organisms, including humans and piscivorous wildlife (Wiener and others, 2003).

## **Purpose and Scope**

The purpose of this report is to present data collected by the USGS on the geochemistry of sediments in Englebright Lake and associated information regarding data quality and methods of sampling and analysis. Data for subsamples of deep cores taken during May–June 2002 and of shallow cores taken during October 2002 are presented. Results for total mercury ( $Hg_T$ ) analyses on 444 subsamples, methylmercury (MeHg) analyses on 243 subsamples, and analyses of other trace and major elements on 202 subsamples are presented. Methods used to collect, preserve, and analyze geochemical samples are described. Data quality is evaluated on the basis of analyses of replicate pairs of subsamples, standard reference materials, blanks, and spike additions.

Radiolabeled mercury ( $^{203}Hg(II)$ ) was used to determine microbial mercury-methylation potential rates for 11 samples collected from three reservoir locations and various depths in the sediment profile. Ancillary geochemical parameters associated with sulfur, iron, and carbon biogeochemistry were assayed in these same subsamples. Basic, summary statistics are given regarding the spatial variation (longitudinal and vertical) of  $Hg_T$ , MeHg, and the ratio of MeHg to  $Hg_T$  in Englebright Lake sediments. A quantitative statistical analysis of the relationships between grain-size distribution and concentrations of  $Hg_T$ , MeHg, loss on ignition, and other sediment properties will be published separately.

## Acknowledgments

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## Reservoir Sampling

The sample locations for the deep and shallow coring campaigns of 2002 are shown in *figures 2 and 3*. For additional information on sampling locations, sample numbering conventions, and core handling, see Snyder and others (2004a). Several series of subsamples were taken from the deep cores (*table 1*). Details are provided below regarding subsampling methods and the handling and preserving of subsamples prior to analysis.

### Deep Coring Campaign

The deep coring campaign was conducted on the DOSECC (Drilling, Observation, and Sampling of the Earth’s Continental Crust, <http://www.dosecc.org/>) research drilling company’s GLAD200 rig (Global LAke Drilling, 200-m maximum depth of water plus sediment), mostly using a hydraulic-piston apparatus that was advanced 3 m per run (Snyder and others, 2004a). Cored sediment was recovered in clear, plastic liners approximately 7 cm (centimeter) in diameter. Deep coring penetrated the full thickness of material deposited after 1940 at six locations in the reservoir; the cores reached a maximum depth of 32.8 m below the reservoir floor (Snyder and others, 2004a). Cores were cut into sections 1.5 m or less (depending on recovery) in length and capped at both ends on the drilling platform. Core depths were recorded relative to a fixed reference datum, the elevation of the Englebright

Dam spillway (160.60 m above sea level), as explained by Snyder and others (2004a). Cores were kept chilled until splitting, which was done at the USGS laboratory in Menlo Park, California. Before splitting, multi-sensor logging was done to determine compressional wave (p-wave) velocity, wet bulk density, and magnetic susceptibility (Snyder and others, 2004a). After splitting down the long axis, a dual-blade cutting tool was used to slice the liner, and then a thin wire was drawn through the core section to separate the unconsolidated sediment into two halves. The two halves were then assigned for working and archive purposes. The archive half of each section was photographed in 30-cm lengths using a digital camera.

Immediately after splitting, the working half of the core was subsampled to determine values for parameters that can change with exposure to the air. These parameters included moisture content (Snyder and others, 2004a) and methylmercury concentration (this report). The MEM (MEthylMercury) series of subsamples was taken for the primary purpose of methylmercury analysis. In representative core sections from a range of depths at each sampling location, 1 or 2 subsamples were taken for the MEM series by removing a series of sediment plugs from the cores using an ~1-cm diameter syringe over an ~10-cm interval. Care was taken to subsample material at least ~0.5 cm from the core liner to avoid the effects of post-coring chemical reactions (such as iron oxidation) that could have occurred in the sediment in contact with the liner. Subsamples were divided in half and stored in pre-cleaned, acid-washed, glass jars (Environmental Sampling Supply, Inc., Oakland, Calif., model PC0125). The half of the subsample that was collected for analysis of methylmercury and total mercury was frozen immediately. The other half was chilled and used for analysis of grain-size distribution and loss on ignition (results reported by Snyder and others, 2004b).

At each coring location, 2 to 5 boreholes were cored to retrieve a continuous section of the stratigraphy, despite material lost between core pushes (Snyder and others, 2004a). With the exception of site 2 in the upper reservoir area, drilling at each location penetrated to the pre-reservoir surface digitized from topographic maps provided by the U.S. Army Corps of Engineers (Childs and others, 2003). Direct evidence of reaching the pre-reservoir surface was the recovery of very coarse (cobble-sized) material from the pre-dam river bed (Childs and others, 2003; Snyder and others, 2004a). After the initial logging and description phase was completed for most of the core sections, the core depth estimates were refined, and then resulting stratigraphy for each hole was graphed and plotted. This working stratigraphy provided a structure for a composite subsampling scheme that sought to retrieve a set of material that was as continuous as possible. This material was termed the Y series of subsamples (for example, the series collected at site 1 from boreholes 1A, 1B, 1C, and 1D was 1Y). Each subsample included about 10–100 cm of material. These subsamples were collected using a U-shaped channel sampler having a 1-cm<sup>2</sup> or 4-cm<sup>2</sup> cross-sectional area. The channel sampler was made from white Delrin®, an acetal

**Table 1.** Basic data for sediment sample series from Englebright Lake, California, 2002.

[Sample series, data series presented in this report (short series name in parentheses). Sample ID range, sample identification numbers used in laboratory, often listed downstream to upstream, which can differ from numerical order (figure 2). Table number, mercury (Hg) and methylmercury data in tables 2-4; mercury methylation potential data in table 8; trace element data in table B5; data for heavy mineral concentrates in tables C1-C4. Number of samples does not include replicate analyses; see table numbers shown for replicate analyses. LOI, loss on ignition; b, data published by Snyder and others (2004b); t, data in this report; —, not determined]

Sample series	Deep (D) or shallow (S) cores	Sample ID range (numerical)	Table number	Number of samples analyzed			LOI analysis	Grain-size distribution analysis
				for mercury	for methylmercury	for trace elements		
Continuous composites (Y series)	D	1Y-1 to 9Y-39	2, B5	202	—	202	b	b
Methyl-Hg & total Hg analysis (MEM series)	D	GS 1 to GS 166	3	166	166	—	b	b
October 2002 box cores	S	GS 200 to GS 282	4	76	77	—	b	b
Methylmercury production (MP series)	D, S	1C-mid to 9A-bottom	8	—	—	—	b	b
Large-volume integrated samples (heavy mineral concentrates)	D	2-upper to 9-lower	C1-C4	—	—	—	—	t
Totals				444	243	202		

homopolymer. The length of each individual subsample was determined by the stratigraphic layering. Each subsample was divided into at least two splits, which were placed in pre-cleaned glass jars and chilled. One split was used for analysis of grain-size distribution and loss on ignition (Snyder and others, 2004b). The other split was used for geochemical analysis of total mercury, other trace elements, and major elements (this report). As a quality-control check, we collected additional material from selected intervals to make replicate subsamples (labeled “1 of 2” and “2 of 2”) for each type of analysis.

The first step in the Y-series subsampling from each coring location was generally to identify a “master” borehole that included the most complete recovery. This borehole was used for subsampling as much as possible to minimize the uncertainty created by hole-to-hole correlations. The first subsample collected from each coring location was the uppermost material recovered, as indicated by the properties of the material (usually fine grained, poorly consolidated, and high water content) and the core depths. The subsampling then continued in the same core whenever possible, shifting to adjacent boreholes when needed to fill in gaps in the “master” borehole, to ensure a record as continuous as possible. These shifts were based upon direct, visual correlations of the stratigraphy whenever possible and the estimated core depths in some cases where the visual correlations could not be made with confidence. Rarely, short gaps in the series of subsamples were unavoidable due to incomplete recovery of a stratigraphic unit from all of the parallel holes. At the base of each coring location, an effort was made to include the lowermost material recovered, generally based on the core-depth estimates. After subsampling was completed for each coring location, the depth interval for each subsample was computed on the basis of the “master” hole that contained the majority of the material.

Y-series subsamples from location 4 (labeled 4Y-1 through 4Y-34) were analyzed in their entirety (without sieving) for total mercury, other trace elements, and major elements. To achieve homogeneity, subsamples first were crushed using a tungsten-carbide ball mill and then were split using a stainless-steel sediment-splitting device. Because of the relatively coarse grain size in cores from the upper part of the reservoir (sites 7, 8, and 9; *fig. 2*), Y-series subsamples from these locations were sieved using a nylon screen with an opening size of 0.06 mm, and only the silt- and clay-sized material that passed through the screen was analyzed. Y-series subsamples from the site nearest Englebright Dam (site 1) were also sieved so that the chemistry of the silt-and-clay fraction could be compared with that at the sites in the upper part of the reservoir.

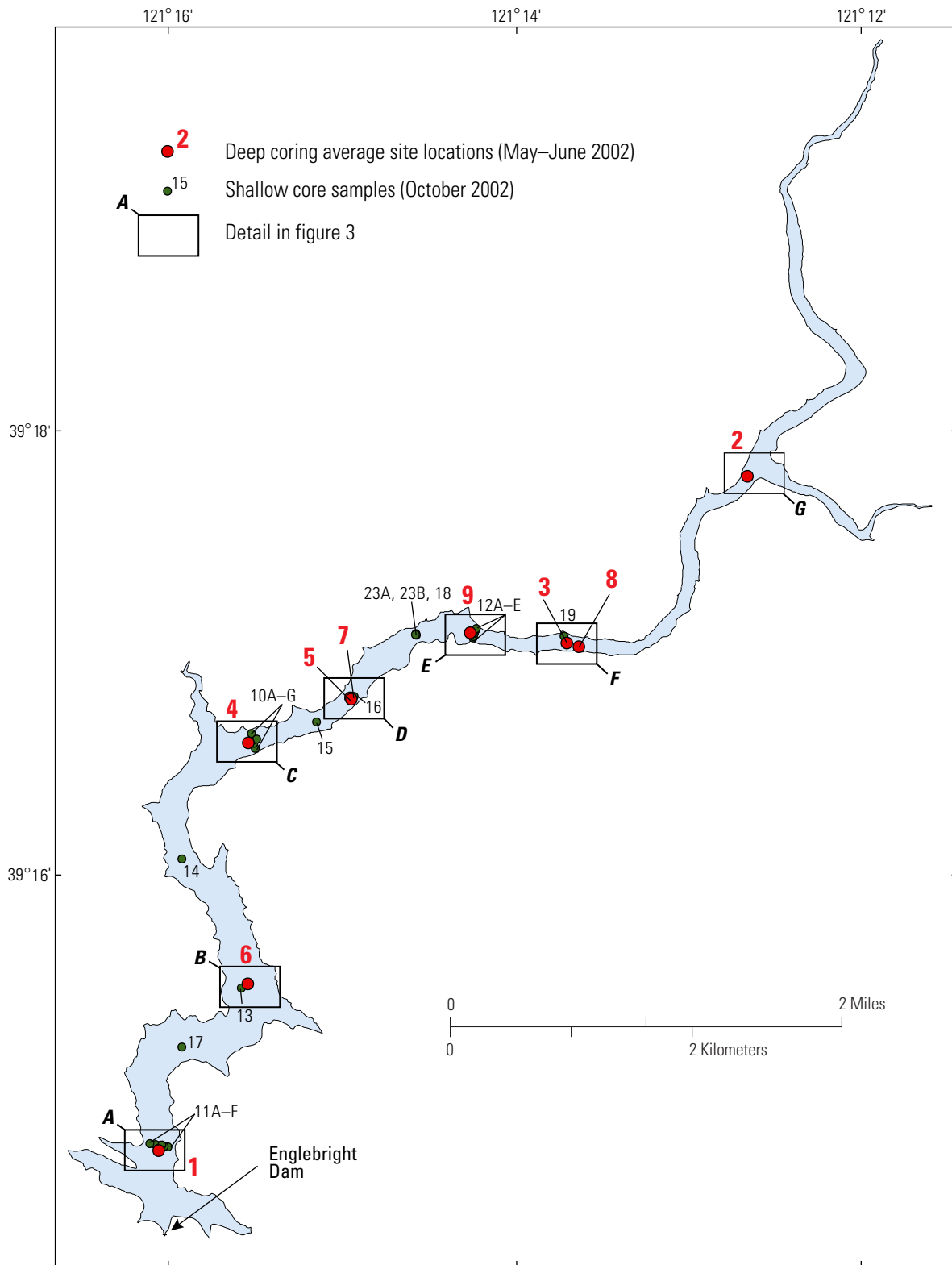
Six subsamples used to determine potential rates of methylmercury production (or Hg Methylation Potential [the MP series]) were taken from deep cores (2–25 m below reservoir floor). Two subsamples each were taken from sites 1, 4, and 9

(*fig. 2*). To our knowledge, these samples represent the deepest sediment depths for which microbial mercury transformations have been examined in any system to date.

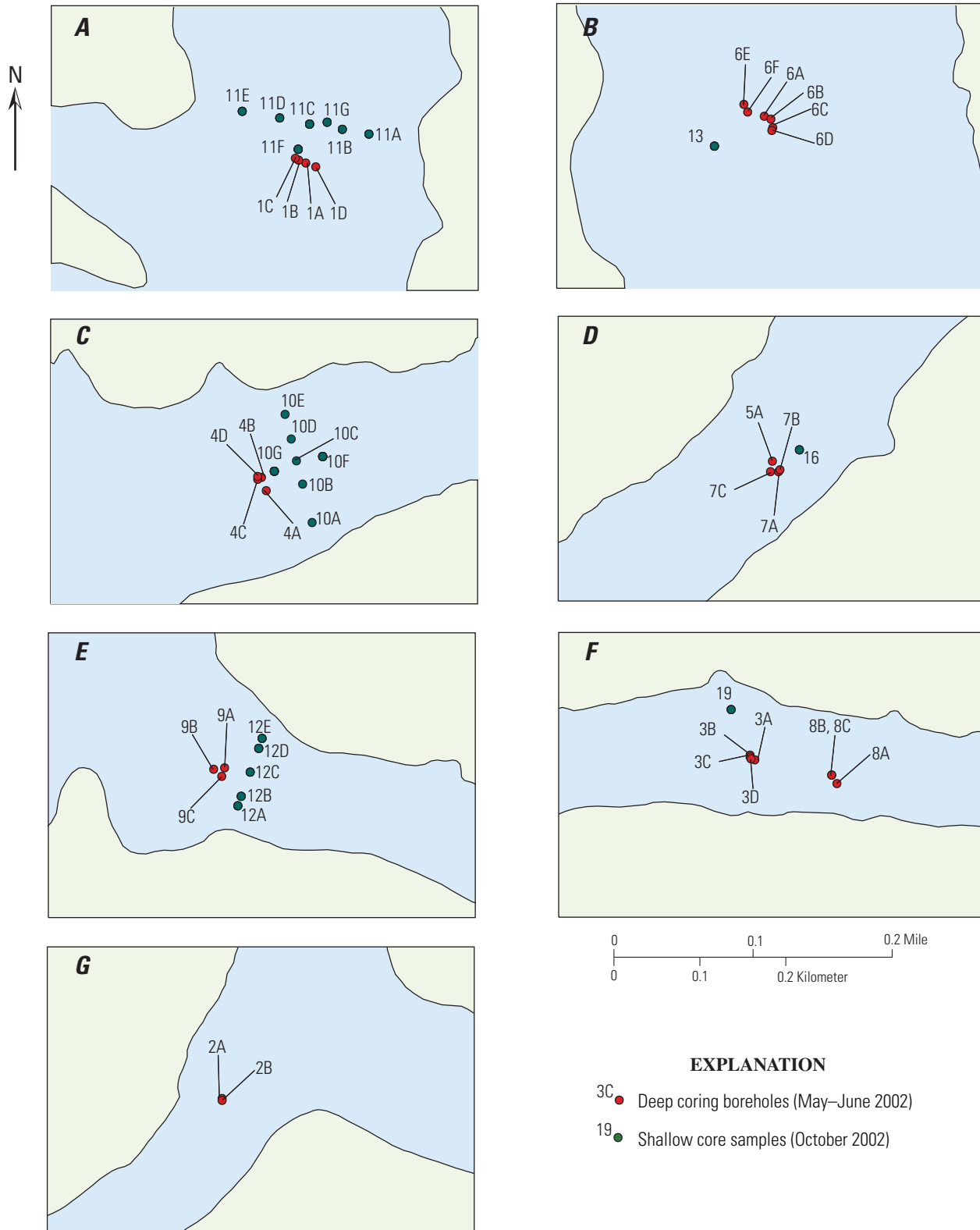
Bulk samples used to prepare heavy mineral concentrates and to estimate gold content consisted of samples from four of the deep coring locations, focusing on the upstream part of the reservoir (sites 5/7, 9, 3/8, and 2; *fig. 2*). Relatively large volumes of sediment were necessary because of expected inhomogeneity (the “nugget effect”). The working halves of several split-core sections were combined to make each composite sample, integrating representative parts of the reservoir stratigraphy. Three composites representing the upper, middle, and lower parts of the reservoir deposit were prepared from samples taken at each of two locations (sites 5/7 and 3/8); two composites representing the upper and lower parts of the deposit were prepared at site 9; and a single composite representing the upper part of the deposit at site 2 brought the total number of composite samples to nine. (For additional details, see Snyder and others, 2004a.)

## Shallow Coring Campaign

At each shallow coring location (*fig. 3*), box cores and gravity cores were collected. The box cores were used for geochemical subsampling and the gravity cores were used for mapping of stratigraphic properties. Sampling and processing were done from a pontoon boat. Samples were box cored using an Eckman dredge, a stainless-steel box 30 cm on each side, which penetrated about 6 to 20 cm into the sediment and provided an undisturbed sample of the sediment-water interface. Immediately after collection, subsamples were taken from each box using 7-cm-diameter clear polycarbonate (Lexan®) core tubes. A plunger apparatus was inserted into the bottom of each core tube and the sediment was pushed toward the top, expelling the overlying water. The core tubes were capped temporarily and transferred to a glove bag filled with inert gas (nitrogen, N<sub>2</sub>). Inside the glove bag, material was pushed through the top of the core tube in intervals of 1 cm, 2 cm, or 4 cm. A polycarbonate ring of the appropriate length was placed on the top of the core tube. Once the material filled the ring, an acid-cleaned plastic sheet was used to separate the material in the ring from the rest of the sediment core. The material above the plastic sheet was then transferred to a pre-cleaned glass jar (60 mL), in which the sample was homogenized with a plastic spatula and from which split subsamples were removed. One of these split subsamples was frozen immediately after collection and used for analysis of methylmercury and total mercury. Another split subsample, subsequently analyzed for grain-size distribution and loss on ignition (Snyder and others, 2004b), was stored chilled. Additional subsamples were taken for the purpose of analyzing radioisotopes, including <sup>7</sup>Be, <sup>137</sup>Cs, and <sup>210</sup>Pb, the results of which will be reported separately.



**Figure 2.** Locations of deep and shallow coring, Englebright Lake, California. Modified from Snyder and others (2004b).



**Figure 3.** Detailed maps of sampling locations at Englebright Lake, California. See figure 2 for location of each box. Modified from Snyder and others (2004b).

Shallow sediment subsamples used to determine potential rates of mercury methylation were taken from 0–4 cm below the reservoir floor at three shallow sites (10, 11, and 12) and 4–8 cm at two sites (10 and 11). These shallow sites were located close to sites 1, 4, and 9 (figs. 2 and 3) where subsamples had been taken for similar analysis from deep cores. Methods of sample collection and processing were identical to those described for the other shallow samples with the exception that larger (500 mL) glass jars were used and they were filled to the top to exclude oxygen. For these five shallow mercury-methylation subsamples, ancillary geochemical parameters were assayed: microbial sulfate reduction rates, sulfur speciation (sediment acid volatile sulfide, total reduced sulfur, and pore-water sulfate), iron speciation (sediment acid extractable iron(II), amorphous iron(III), crystalline iron(III), and pore-water iron(II)), pore-water chloride, and dissolved organic carbon.

## Laboratory Methods

Laboratory methods were chosen on the basis of past laboratory performance and data-quality objectives for the present study. Total mercury, methylmercury, trace and major elements, and mercury methylation potential were analyzed, and heavy minerals were identified. Concentrations of mercury, methylmercury, and trace metals in sediment are reported on a dry basis throughout this report.

### Total Mercury

Total mercury ( $Hg_T$ ) in sediment was analyzed by two different laboratories for this study: the USGS laboratory in Boulder, Colorado (USGS-Boulder), and the Battelle Marine Sciences Laboratory (BMSL) in Sequim, Washington. The Y-series subsamples were analyzed by the USGS-Boulder laboratory; the MEM series from the deep cores and the shallow core subsamples were analyzed primarily by the BMSL. As a check on quality control at the BMSL, fifteen split subsamples from the MEM series were also analyzed by the USGS Wisconsin District Mercury Laboratory (USGS-WDML) in Middleton, Wisconsin.

The USGS-Boulder laboratory analyzed  $Hg_T$  in sediment using cold-vapor atomic fluorescence spectrometry (CVAFS) after digestion using a mixture of distilled nitric, hydrochloric, and hydrofluoric acids in a closed Teflon® bomb (Hayes, 1993). Mercury stock and standard solutions were made from Puratronic grade (99.9995 percent) mercuric chloride ( $HgCl_2$ ) salt (Johnson Matthey Public Limited Company) and preserved in a solution of high-purity nitric acid and primary-standard grade potassium dichromate. Deionized (DI) water (American Society for Testing and Materials [ASTM] type 1, 18  $M\Omega$ -cm [megaohm-centimeter]) was used for preparing all

standards and reagent solutions. A solution of 3-percent hydrochloric acid (volume:volume, hydrochloric acid:DI water) was used to prepare a 2-percent stannous chloride ( $SnCl_2$ ) solution (wt:volume, stannous chloride:3-percent hydrochloric acid), which was used to reduce mercury to its elemental form in the cold vapor reactor. The vapor was transported to the detector using a stream of argon gas. Trace concentration levels of mercury were measured using an automated CVAFS analyzer (PS Analytical) using methods described previously (Roth, 1994; David A. Roth, U.S. Geological Survey, written commun., 1999). Instrumental parameters for the CVAFS mercury analysis were the same as those described by Alpers and others (2000). Peak-height intensities of unknown samples were compared to a six-point calibration curve prepared from aqueous standards ranging in concentration from 0 to 50 ng/L (nanogram per liter), preserved with potassium dichromate and nitric acid.

The BMSL analyzed  $Hg_T$  in sediment by cold vapor atomic absorption spectrometry (CVAAS). The procedure (Lasorsa, 2003a) is a modified version of U.S. Environmental Protection Agency (USEPA) method 245.5 (U.S. Environmental Protection Agency, 1991). The USEPA method was modified by eliminating the use of potassium permanganate in the digestions because it was a source of mercury contamination. A digestion using strong acids was carried out in a closed Teflon bomb. Mercury ions in the digestate were reduced by acidic  $SnCl_2$  to  $Hg^+$  and then carried through a flow cell on a stream of inert gas (argon). The luminous intensity of monochromatic light that passes through the sample was compared with the luminous intensity of the same light that passed through a reference beam using a photometric detector at a wavelength of 253.7 nanometers. The attenuation of the light is directly proportional to the concentration of mercury vapor, which was quantified using a standard curve. Mercury stock standards were purchased from High Purity Standards. An intermediate standard with a mercury concentration of 10 mg/L (milligram per liter) was prepared in 1 percent HCl. To develop the standard curves, five mercury working standards (typically ranging from 0.5  $\mu g/L$  [microgram per liter] to 12.5  $\mu g/L$ ) were prepared by diluting the intermediate standard.

### Methylmercury

Monomethylmercury (MeHg) in sediment was analyzed for this study primarily by the BMSL. (For the remainder of this report, “methylmercury” [also abbreviated as MeHg] is used instead of “monomethylmercury”; note that other methylated forms of mercury such as dimethylmercury may have been present but were not included in methylmercury analyses reported in this study.) As a quality assurance check, fifteen replicate subsamples were analyzed by the USGS-WDML. MeHg can be difficult to measure in solids because



of matrix interferences and the possibility of unintentionally producing MeHg during distillation (Bloom and others, 1997; Hintelmann and others, 1997; Hammerschmidt and Fitzgerald, 2001). Therefore, extraction methods using methylene chloride ( $\text{CH}_2\text{Cl}_2$ ) were used by both laboratories to minimize MeHg artifacts.

At the BMSL, MeHg in sediment was analyzed by CVAFS using a procedure (Lasorsa, 2003b) based on Bloom (1989) and equivalent to USEPA method 1630. A minimum of 200 mg (milligrams) of sediment was placed in a 50-mL (milliliter) centrifuge tube along with 5 mL of acidic potassium bromide (KBr) solution, 1 mL of 1 molar copper sulfate ( $\text{CuSO}_4$ ), and 10 mL of  $\text{CH}_2\text{Cl}_2$ . After one hour of vigorous shaking, the samples were centrifuged for 30 minutes at 2,000 rpm (revolutions per minute). Immediately after centrifuging, 2 mL of the  $\text{CH}_2\text{Cl}_2$  layer was transferred by pipette into a distillation vial along with 45 mL of reagent water. The distillation vial was capped and placed in a heating block and connected to  $\text{N}_2$  carrier gas flowing at 60 mL/min (milliliter per minute). The block was heated to 45°C until all of the  $\text{CH}_2\text{Cl}_2$  evaporated. The pH was adjusted to 4.9 (to maximize ethylation potential) using acetate buffer. The sample was then reacted with an ethylating reagent for 17 minutes, after which the sample was purged with argon into a Carbotrap (Supelco, Inc.). Methyl-ethylmercury that resulted from the ethylation of methylmercury in the sample was then quantified using CVAFS.

Methylmercury in sediment was analyzed at the USGS-WDML by inductively coupled plasma mass spectrometry (ICP-MS) using extraction methods very similar to those used at the BMSL. The extraction methods used at the WDML are described by DeWild and others (2004), who adopted the technique of Hintelmann (1999) for extracting MeHg from solids to eliminate formation of MeHg in samples containing high inorganic mercury levels. Solids (0.5 to 1.0 g [gram]) were placed into a centrifuge tube to which 5 mL of acidic KBr solution, 1 mL of 1 molar  $\text{CuSO}_4$ , and 10 mL of  $\text{CH}_2\text{Cl}_2$  were added sequentially. The mixture was allowed to react for an hour and then was shaken for an hour to ensure complete extraction of the MeHg. Following the shaking, the samples were centrifuged to break any emulsion that had formed. An aliquot of 2 mL of the  $\text{CH}_2\text{Cl}_2$  was cleanly transferred to a vial containing reagent water. Each vial was placed in a heating block until all  $\text{CH}_2\text{Cl}_2$  evaporated and the MeHg was extracted back into the reagent water. The pH of the extractant was adjusted to 4.9 (to maximize ethylation potential) using acetate buffer. The extract then was ethylated using sodium tetraethyl borate ( $\text{NaBEt}_4$ ) and allowed to react for 15 minutes. After the reaction, the extractant was purged with  $\text{N}_2$  gas for 20 minutes, and the ethylated forms of Hg were collected on a sample trap containing Carbotrap (Supelco, Inc.). The ethylated Hg species were desorbed thermally from the sample trap, separated using a gas chromatographic (GC) column, reduced using a pyrolytic column, and quantified using inductively coupled plasma-mass spectrometry (ICP-MS). Deionized water blanks

were analyzed as part of each analytical batch; reported results were blank-corrected.

## Trace and Major Elements

Trace and major elements in sediments from the Y-series subsamples were analyzed using inductively coupled plasma (ICP) methods by the USGS-Boulder laboratory. Both atomic emission spectroscopy (ICP-AES) and mass spectrometry (ICP-MS) were used. Sediments in subsamples collected for analysis of trace and major elements were completely dissolved using an  $\text{HCl-HNO}_3\text{-HF}$  acid, microwave, total-digestion procedure (Hayes, 1993). The digested subsamples were diluted at 1:10 (volume:volume, digest:DI water) with 18 M $\Omega$ -cm DI water and were preserved with distilled nitric acid. Major elements, including calcium (Ca), iron (Fe), magnesium (Mg), potassium (K), sodium (Na), and sulfur (S), were determined by ICP-AES techniques using a Perkin-Elmer Optima 3300DV multi-channel emission spectrometer. Using the dual-view (radial and axial) optical configuration provided optimal sensitivity for various elements regardless of concentration. A description of the ICP-AES analysis conditions and procedures is given by Garbarino and Taylor (1979). Details of the operational conditions are described by Mitko and Bebek (1999, 2000). Concentrations of trace elements other than mercury were determined by ICP-MS using a Perkin Elmer Elan Model 6000. Aerosols of acidified aqueous samples were introduced into the spectrometer with a cone-spray pneumatic nebulizer. Multiple internal standards (indium, iridium, and rhodium), which covered the mass range, were used to normalize the system for drift. Details of the specific analysis techniques, procedures, and instrumental settings are described by Garbarino and Taylor (1996) and Taylor (2001).

## Mercury Methylation Potential

Standard radiotracer methods were used to measure potential rates of microbial MeHg production, Hg(II) methylation, at the USGS laboratory in Menlo Park, Calif. (Marvin-DiPasquale and others, 2003). An amendment containing 1.5  $\mu\text{Ci}/100\ \mu\text{L}$  (microcurie per 100 microliters) of radiolabeled divalent mercury  $^{203}\text{Hg}(\text{II})$ , having a half-life of 46.5 days, was used for the MeHg-production rate assay. The  $^{203}\text{Hg}(\text{II})$  specific activity of the injection solution was 1.15 mCi/mg (millicurie per milligram), which resulted in a total Hg(II) amendment of 436 ng/g (nanogram per gram) wet sediment per 3.0-g sediment subsample. Sample sets for each interval assayed for microbial Hg(II)-methylation potential consisted of duplicate, live (incubated) samples and one control sample in which microbes were killed by flash freezing at the beginning of the experiment (time zero). MeHg production sample sets were incubated for 4 hours at 12–16°C for shallow subsamples or for 24 hours at 19°C for deep subsamples. It was assumed that the Hg(II)-methylation process

was first-order for the purposes of calculating potential rates (Marvin-DiPasquale and others, 2003). Potential rates were subsequently calculated as the product of the radiotracer-derived rate constant and the final concentration of radiotracer amendment in the whole sediment, and were thus independent of the amount of Hg(II) that might have been present originally in each subsample.

The five shallow sediment samples that were assayed for Hg(II) methylation potential were also subsampled to determine several ancillary chemical parameters, including microbial sulfate reduction, pH, oxidation-reduction (redox) potential, loss on ignition, acid volatile sulfide, total reduced sulfur, and iron speciation. Sulfate-reduction samples were subsampled and incubated in a manner analogous to that for the mercury methylation rate assays, including replicates consisting of two live (incubated) and one killed control sample per site and depth. Samples were amended with 1.0  $\mu\text{Ci}$ /sample of carrier-free  $^{35}\text{SO}_4^{2-}$  and assayed according to Jørgensen (1978). The pH and redox potential were determined by inserting an electrode directly into sediment. Weight loss on ignition was measured as a proxy for organic content (American Public Health Association, 1981). Two forms of sulfur—acid volatile sulfide and total reduced sulfur—were determined using methods described by Ulrich and others (1997). Iron speciation analyses included acid-extractable Fe(II), acid-extractable amorphous Fe(III), and crystalline Fe(III) (Lovley and Phillips, 1987; Roden and Zachara, 1996). Organic content and both forms of solid-phase sulfur were measured in duplicate samples from each of the five shallow sediment samples. Dissolved organic carbon (DOC) concentrations were assessed by adding DI water (Milli-Q, ASTM type 1, 18 M $\Omega$ -cm; 10 mL) to the sediment (10 g) to obtain enough pore water for analysis. The exact weight of the sediment and the water added per tube was recorded, and subsequent pore-water analyte concentrations were calculated taking this pore-water dilution into account. Samples were shaken until each became a homogenous slurry, which was then centrifuged at 3,000 rpm for 15 minutes in 45-cm<sup>3</sup> polystyrene, screw-cap tubes. The resulting supernatant was filtered (0.45- $\mu\text{m}$  nylon syringe, in-line filter) inside an oxygen-free glove bag. The DOC samples were frozen until analysis, which was done using high-temperature oxidation with infrared detection (Qian and Mopper, 1996). Pore-water sulfate samples were preserved by freezing under anoxic conditions and assayed via ion chromatography (Dionex, 1992). Pore-water iron(II) was preserved by adjusting pH to <2 with 10-percent HCl and assayed via the colorimetric Ferrozine assay (Stookey, 1970).

## Heavy Minerals

Heavy-mineral concentrates were prepared for the composite samples by Cal Sierra Development Company in Marysville, California. First the material was screened using a 9.5-mm sieve. The material passing through the sieve was processed on a shaker table, yielding a concentrated sample

of minerals with greater density, referred to as a heavy-mineral concentrate. The concentrate was then screened using stainless-steel sieves of the following sizes (in mm): 4.75, 2.36, 1.18, 0.60, 0.30, 0.15, 0.075, and 0.063. The mass passing through each sieve was measured, and the material was retained for microscopic examination. Observations were made using a stereo microscope and a scanning electron microscope (SEM) with energy dispersive spectrometer (EDS).

## Quality Assurance and Quality Control

A variety of procedures was used to ensure high data quality and to quantify accuracy and precision when appropriate. Digestion blanks were prepared and analyzed to determine the level of contamination, if any, in the digestion equipment and reagents. Spikes were added to blanks and to a subset of the analyzed samples to ensure that analyses accurately measured concentrations in the range of sample matrixes encountered. Replicates were digested to form a subset of the analyzed samples to assess variability in laboratory procedures and analytical methods. Replicate splits taken at the time of initial subsampling are referred to as core replicates, whereas replicate splits taken at a later time by the analyzing laboratory are referred to as laboratory replicates. Fifteen split subsamples were analyzed for total mercury and methylmercury at two laboratories (BMSL and USGS-WDML) for comparative purposes. At each laboratory, standard reference materials (SRM) were digested along with analyzed samples; results from analysis of SRMs were compared with certified values to determine analytical accuracy.

## Total Mercury

Quality-assurance analyses of SRMs for total mercury ( $\text{Hg}_T$ ) at two of the laboratories used in this study (*table A1*) indicate a high level of accuracy and low variability. The USGS-Boulder laboratory used NIST 2704, Buffalo River Sediment, provided by the National Institute of Standards and Technology. For this SRM, 24 of 27 analyses were within the range of 85 to 115 percent of the certified value, and the average was 101 percent. The BMSL used IAEA-356, provided by the International Atomic Energy Agency. For IAEA-356, all 14 analyses were within the range of 98 to 113 percent of the certified value; the average was 103 percent.

Other quality-assurance procedures used by the USGS-Boulder laboratory and the BMSL in conjunction with their  $\text{Hg}_T$  determinations included analyses of blanks and spike additions. Two types of spikes were prepared, one by adding a known amount of Hg to blanks (referred to as blank spikes) and the other by adding a known amount of Hg to environmental samples that were previously analyzed (referred to as matrix spikes).

At the BMSL, three laboratory blanks were analyzed with each of the 12 batches of samples. Total mercury was detected in only 3 of the 36 blanks. In those 3 blanks, the detected  $Hg_T$  concentrations were less than 10 ng/g, which is twice the method detection limit (MDL) of 5 ng/g. Three of the environmental samples had  $Hg_T$  concentrations less than the MDL, whereas most of the samples had concentrations more than 10 times greater than the MDL. Because of the small number of laboratory blanks with detected concentrations of  $Hg_T$  at the BMSL, the data were not blank-corrected (a procedure in which the amount detected in laboratory blanks is systematically subtracted from the results for environmental samples).

A total of 28 blank spikes were analyzed at the BMSL for  $Hg_T$ . Recoveries ranged from 43 to 103 percent; the average value was 91.8 percent and the median value was 97.5 percent. Three blank spikes that were originally outside the laboratory's data quality objective (75 to 125 percent recovery) were reanalyzed, according to the laboratory's standard operating procedure, and all but one met the laboratory's data-quality objectives.

Twenty-five pairs of  $Hg_T$  matrix spikes and matrix spike replicates were analyzed by the BMSL with the samples. Recoveries for these matrix spikes ranged from 92 percent to 107 percent for  $Hg_T$ , within the laboratory's data-quality objectives. Variability between replicates is described using Relative Percentage Difference (RPD), defined as the 100 times the absolute value of the difference between two concentrations divided by their average. The RPD between the matrix spikes and matrix spike replicates ranged from 0 to 8 percent, well within the laboratory's data-quality objective (RPD values less than 25 percent).

The USGS-Boulder laboratory and the BMSL analyzed a total of 40 pairs of replicate subsamples for  $Hg_T$ ; 31 pairs were laboratory replicates and 9 pairs were core replicates (table A2). Each pair of replicate analyses represented two separate digestions of sediment, so variations in results could have been caused by sample inhomogeneity as well as variability in the analytical determinations. Median values of RPD were 5.8 percent for the 31 laboratory replicates and 13.2 percent for the 9 core replicates. The USGS-Boulder laboratory determined the concentrations of  $Hg_T$  by analyzing each digested Y-series subsample three times and computing the average; the concentrations and standard deviations are given in table 2. The standard deviations were typically less than 2 percent of the average concentrations.

An additional check on data quality is provided by the analyses of  $Hg_T$  in 15 split subsamples that were analyzed by the BMSL and the USGS-WDML. The median of the 15 RPD values for  $Hg_T$  was 11.1 percent, and 12 of the 15 RPD values were less than 15 percent (table A5). RPD values for the other three subsamples were 17, 53, and 109 percent. A correlation plot showing results of the  $Hg_T$  analyses for these 15 split subsamples from the two laboratories (fig. A1) shows that data are distributed on both sides of the 1:1 line, indicating that there is no systematic difference in concentrations.

## Methylmercury

Two SRMs for methylmercury (MeHg), IAEA-356 and IAEA-405, were analyzed by the BMSL along with the samples for this study (table A3). These two SRMs were certified for MeHg by the International Atomic Energy Agency (Horvat and others, 1994; Wyse and others, 2004). Some of the laboratories participating in the certification of these SRMs used the distillation technique, which has since been shown to produce an analytical artifact resulting in inflated values of MeHg (Bloom and others, 1997; Hintelmann and others 1997; Hintelmann, 1999). Therefore, the extraction technique used for MeHg analysis in this study avoids the analytical artifact problem and is now in common use. The extraction method routinely produced MeHg concentrations in the range of 65–95 percent of the certified values for the two SRMs, which was reasonable considering the different analytical methods; the laboratory's data-quality objective is 67 to 133 percent recovery for MeHg in SRMs. For SRM IAEA-356, 17 of the 18 analyses were in the range of 72–95 percent of the certified value, with one outlier; for SRM IAEA-356, 16 of 19 values for recovery were in the range of 65–91 percent of the certified value with three outliers. Because no more than one of the SRM outliers occurred within an individual batch of samples, these results meet the data-quality objective of the BMSL.

A total of 21 environmental samples were analyzed in replicate for MeHg by the BMSL. Nineteen of the samples had a single replicate (two analyses), one had two replicates (three analyses), and one had three replicates (four analyses), bringing the total number of replicate analyses to 24 (table A4). The multiple replicate analyses were compared as follows: for the sample with two replicates (three analyses), three separate RPD values were calculated; for the sample with three replicates (four analyses), six separate RPD values were calculated, representing all possible combinations (table A4). The median value of RPD for MeHg in all replicates was 10.5 percent and the median value of RPD for the 19 laboratory replicates was 8.8 percent. For all but four of the samples, the RPD values were less than or equal to about 20 percent. The other 4 samples showed higher variability; RPD values ranged from about 40 percent to about 60 percent. The BMSL's data-quality objective for replicate analyses of MeHg requires that fewer than 35 percent of the replicate pairs have RPD values greater than 35 percent, so the results are within the objective. Three of the five core replicates were among the samples with higher RPD values, and two of these were from cores 11C-B1 and 11C-B2. These cores were taken in separate, parallel tubes from the same Eckman dredge sample (box core), so they were not split samples in the usual sense. In contrast, the other core replicates were made by homogenizing material from a single core interval in a glass jar and then spooning half of the sample into a second jar. In light of the methods used for taking these samples, the higher values of RPD are more likely to have been caused by sample inhomogeneity than by laboratory error.

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
1Y-1		1A-1H-1, 4–93 cm	60.79	61.68	0.45	468	3	Y
1Y-1A		1D-1H-1, 51–69 cm	61.50	61.68	0.81	491	2	Y
1Y-2		1D-1H-1, 69–80 cm	61.68	61.79	0.95	287	1	Y
1Y-3		1D-1H-1, 80–94 cm	61.79	61.93	1.07	208	5	Y
1Y-4	1 of 2	1D-1H-1, 94–140 cm	61.93	62.39	1.37	208	1	Y
1Y-4	2 of 2	1D-1H-1, 94–140 cm	61.93	62.39	1.37	195	3	Y
1Y-5		1D-1H-2, 0–52 cm	62.39	62.91	1.86	133	3	Y
1Y-6		1D-1H-2, 52–80 cm	62.91	63.19	2.26	139	2	Y
1Y-7		1B-2E-1, 10–33 cm	63.19	63.26	2.44	181	4	Y
1Y-8	1 of 2	1B-2E-2, 0–75 cm	63.26	63.94	2.81	202	1	Y
1Y-8	2 of 2	1B-2E-2, 0–75 cm	63.26	63.94	2.81	196	1	Y
1Y-9		1B-2E-2, 75–150 cm	63.94	64.61	3.49	218	3	Y
1Y-10		1B-2E-3, 0–80 cm	64.61	65.35	4.19	179	1	Y
1Y-11	1 of 2	1B-2E-3, 80–108 cm	65.35	65.61	4.69	366	4	Y
1Y-11	2 of 2	1B-2E-3, 80–108 cm	65.35	65.61	4.69	343	3	Y
1Y-12		1B-2E-3, 108–117 cm	65.61	65.69	4.86	196	2	Y
1Y-13		1B-2E-3, 117–150 cm	65.69	66.00	5.06	299	7	Y
1Y-14		1B-2E-6, 0–5 cm	66.00	66.05	5.24	321	5	Y
1Y-15		1B-2E-7, 0–1 cm	66.05	66.06	5.27	272	4	Y
1Y-16	1 of 2	1B-3E-1, 0–52 cm	66.11	66.63	5.58	258	4	Y
1Y-16	2 of 2	1B-3E-1, 0–52 cm	66.11	66.63	5.58	265	3	Y
1Y-17		1B-3E-1, 52–76 cm	66.63	66.87	5.96	346	3	Y
1Y-18		1B-3E-1, 76–90 cm	66.87	67.01	6.15	175	5	Y
1Y-19	1 of 3	1B-3E-1, 90–101 cm	67.01	67.12	6.28	253	4	Y
1Y-19	2 of 3	1B-3E-1, 90–101 cm	67.01	67.12	6.28	240	4	Y
1Y-19	3 of 3	1B-3E-1, 90–101 cm	67.01	67.12	6.28	251	5	Y
1Y-20		1B-3E-1, 101–110 cm	67.12	67.21	6.37	101	3	Y
1Y-21		1B-3E-6, 0–5 cm	67.21	67.26	6.45	149	2	Y
1Y-22		1B-3E-7, 0–4 cm	67.26	67.30	6.49	258	3	Y
1Y-23		1A-4E-1, 4–72 cm	67.30	67.51	6.62	343	3	Y
4Y-1		4B-1H-1, 4–24 cm	34.37	34.57	0.10	137	0	N
4Y-2		4B-1H-1, 24–70 cm	34.57	35.03	0.43	101	0	N
4Y-3		4A-1H-1, 35–73 cm	35.03	35.41	0.85	133	1	N
4Y-4		4A-1H-1, 73–110 cm	35.41	35.77	1.22	218	4	N
4Y-5		4A-1H-2, 0–27 cm	35.77	36.05	1.54	166	2	N

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
4Y-6		4A-1H-2, 27–62 cm	36.05	36.40	1.86	195	0	N
4Y-7		4A-1H-2, 62–150 cm	36.40	37.27	2.47	355	6	N
4Y-8	1 of 2	4B-2H-1, 14–124 cm	37.27	38.38	3.46	225	5	N
4Y-8	2 of 2	4B-2H-1, 14–124 cm	37.27	38.38	3.46	243	2	N
4Y-9		4B-2H-2, 0–44 cm	38.38	38.86	4.25	231	1	N
4Y-10		4B-2H-2, 44–66 cm	38.86	39.08	4.60	107	1	N
4Y-11		4B-2H-2, 66–78 cm	39.08	39.20	4.77	148	1	N
4Y-12		4A-2H-3, 17–81 cm	39.20	39.84	5.15	134	2	N
4Y-13		4A-2H-3, 81–117 cm	39.84	40.20	5.65	173	1	N
4Y-14		4A-2H-4, 0–25 cm	40.20	40.45	5.96	246	5	N
4Y-15		4B-3H-1, 0–47 cm	40.45	41.06	6.39	279	0	N
4Y-16		4B-3H-1, 47–86 cm	41.06	41.57	6.95	165	1	N
4Y-17		4A-4H-1, 55–108 cm	41.57	42.10	7.47	189	4	N
4Y-18		4A-4H-1, 108–127 cm	42.10	42.38	7.87	266	4	N
4Y-19	1 of 2	4A-4H-2, 9–95 cm	42.38	43.24	8.44	251	0	N
4Y-19	2 of 2	4A-4H-2, 9–95 cm	42.38	43.24	8.44	680	8	N
4Y-20		4A-4H-2, 95–146 cm	43.24	43.75	9.13	299	4	N
4Y-21		4B-4H-1, 26–48 cm	43.75	43.89	9.45	308	6	N
4Y-22		4B-4H-1, 48–73 cm	43.89	44.04	9.60	453	13	N
4Y-23		4B-4H-1, 73–125 cm	44.04	44.36	9.83	326	5	N
4Y-24		4B-4H-1, 125–140 cm	44.36	44.59	10.11	353	5	N
4Y-25		4B-4H-2, 20–89 cm	44.59	45.01	10.43	256	1	N
4Y-26		4B-4H-2, 89–150 cm	45.01	45.39	10.83	471	6	N
4Y-27		4A-5H-2, 51–101 cm	45.39	45.86	11.26	550	4	N
4Y-28		4B-5H-1, 0–56.5 cm	45.86	46.42	11.77	315	3	N
4Y-29		4B-5H-1, 56.5–142 cm	46.42	47.26	12.47	295	2	N
4Y-30		4B-5H-2, 0–71 cm	47.26	47.97	13.25	462	3	N
4Y-31		4B-5H-2, 71–135 cm	47.97	48.61	13.92	296	3	N
4Y-32		4B-5H-2, 135–250 cm	48.61	48.76	14.32	348	0	N
4Y-33		4B-5H-6, 0–5 cm	48.77	48.82	14.43	439	4	N
4Y-34		4B-6H-1, 0–80 cm	48.93	49.70	14.95	269	2	N
7Y-02		7C-1H-1, 80–117 cm	15.13	15.50	0.98	288	1	Y
7Y-03		7C-1H-2, 0–31 cm	15.50	15.81	1.33	246	1	Y
7Y-04	1 of 2	7C-1H-2, 31–97 cm	15.81	16.47	1.81	240	8	Y
7Y-04	2 of 2	7C-1H-2, 31–97 cm	15.81	16.47	1.81	281	4	Y

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
7Y-07		7C-2H-1, 92–150 cm	17.63	18.21	3.59	287	4	Y
7Y-08		7C-2H-2, 0–74 cm	18.21	18.95	4.25	237	1	Y
7Y-09		7A-2H-2, 29.5–66.5 cm	19.28	19.65	5.14	228	3	Y
7Y-10		7A-2H-2, 66.5–112 cm	19.65	20.10	5.55	248	4	Y
7Y-11		7C-3H-1, 46–93.5 cm	20.10	20.58	6.01	263	1	Y
7Y-12		7C-3H-1, 93.5–146 cm	20.58	21.10	6.51	258	2	Y
7Y-13		7C-3H-2, 0–52 cm	21.10	21.60	7.02	178	1	Y
7Y-14		7C-3H-2, 52–101.5 cm	21.60	22.08	7.51	123	3	Y
7Y-15		7C-3H-2, 101.5–150 cm	22.08	22.55	7.99	138	1	Y
7Y-16		7A-3H-2, 40–65 cm	22.55	22.75	8.32	114	0	Y
7Y-17		7C-4H-1, 9–52 cm	22.75	23.18	8.64	144	1	Y
7Y-20		7C-4H-3, 54–124.5 cm	24.47	25.18	10.50	276	3	Y
7Y-21	1 of 2	7A-4H-2, 29.5–73 cm	25.18	25.60	11.06	589	3	Y
7Y-21	2 of 2	7A-4H-2, 29.5–73 cm	25.18	25.60	11.06	585	1	Y
7Y-22		7A-4H-2, 73–109.5 cm	25.60	25.96	11.45	266	3	Y
7Y-23		7C-5H-1, 41.5–98.5 cm	25.96	26.52	11.91	406	3	Y
7Y-24		7C-5H-1, 98.5–140 cm	26.52	26.92	12.39	432	3	Y
7Y-25		7C-5H-2, 0–20 cm	26.92	27.11	12.69	414	4	Y
7Y-26		7C-6H-1, 0–87.5 cm	27.30	28.06	13.35	290	2	Y
7Y-27		7C-6H-1, 87.5–151 cm	28.06	28.61	14.01	448	1	Y
7Y-28		7C-6H-2, 0–78 cm	28.61	29.39	14.67	706	10	Y
7Y-29		7C-6H-2, 78–131 cm	29.39	29.92	15.33	477	4	Y
7Y-30		7C-6H-2, 131–150 cm	29.92	30.11	15.69	425	6	Y
7Y-31		7C-7H-1, 10–71 cm	30.30	30.91	16.28	384	3	Y
7Y-32		7C-7H-1, 71–144 cm	30.91	31.64	16.95	479	3	Y
7Y-34	1 of 2	7C-7H-2, 68–120 cm	32.28	32.77	18.20	477	5	Y
7Y-34	2 of 2	7C-7H-2, 68–120 cm	32.28	32.77	18.20	523	4	Y
7Y-36		7C-8H-1, 23–90 cm	33.33	34.00	19.34	547	6	Y
7Y-37		7C-8H-1, 90–126 cm	34.00	34.36	19.85	495	2	Y
7Y-38		7B-4H-1, 88.5–120 cm	34.36	34.72	20.21	477	3	Y
7Y-39		7C-9H-2, 7–108.5 cm	34.72	35.60	20.83	518	4	Y
7Y-40		7C-9H-2, 108.5–142 cm	35.60	35.89	21.42	816	4	Y
7Y-41	1 of 2	7C-9H-3, 0–93.5 cm	35.92	36.68	21.97	480	5	Y
7Y-41	2 of 2	7C-9H-3, 0–93.5 cm	35.92	36.68	21.97	488	7	Y
7Y-42		7B-6H-1, 50–113 cm	36.68	37.24	22.63	559	4	Y

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
7Y-43		7C-10H-1, 10–98 cm	37.24	38.06	23.32	587	2	Y
7Y-44		7C-10H-1, 98–150 cm	38.06	38.55	23.98	527	8	Y
7Y-45		7C-10H-2, 5–67 cm	38.55	39.17	24.53	569	5	Y
7Y-46		7C-10H-2, 67–137.5 cm	39.17	39.87	25.19	452	2	Y
7Y-47		7B-9H-1, 57–113 cm	39.87	40.41	25.81	473	3	Y
7Y-48	1 of 2	7C-11H-1, 21–70 cm	40.41	40.88	26.32	462	6	Y
7Y-48	2 of 2	7C-11H-1, 21–70 cm	40.41	40.88	26.32	446	6	Y
7Y-49		7C-11H-1, 70–92 cm	40.88	41.10	26.66	388	9	Y
7Y-50		7C-11H-2, 0–44.5 cm	41.10	41.54	26.99	441	7	Y
7Y-51		7C-11H-2, 44.5–104 cm	41.54	42.13	27.51	440	8	Y
7Y-52		7C-11H-2, 104–130 cm	42.13	42.38	27.93	376	4	Y
7Y-53		7B-10H-1, 102–136 cm	42.38	42.74	28.23	501	3	Y
7Y-54		7C-12H-1, 0–47 cm	42.74	43.21	28.65	536	3	Y
7Y-55		7C-12H-1, 47–99.5 cm	43.21	43.74	29.15	667	2	Y
7Y-56		7C-12H-1, 99.5–133 cm	43.74	44.07	29.58	602	3	Y
7Y-57	1 of 2	7C-12H-2, 0–40.5 cm	44.07	44.47	29.94	332	2	Y
7Y-57	2 of 2	7C-12H-2, 0–40.5 cm	44.07	44.47	29.94	336	2	Y
7Y-58		7C-12H-2, 40.5–69 cm	44.47	44.75	30.28	383	4	Y
7Y-59	1 of 2	7C-12H-2, 69–104 cm	44.75	45.10	30.60	259	2	Y
7Y-59	2 of 2	7C-12H-2, 69–104 cm	44.75	45.10	30.60	262	4	Y
7Y-60		7B-11H-2, 4–47 cm	45.10	45.48	30.96	409	6	Y
7Y-60 B		7C-12H-2, 104–123.5 cm	45.10	45.29	30.87	338	2	Y
7Y-60 C		7C-12H-2, 123.5–150 cm	45.29	45.55	31.09	471	4	Y
7Y-61		7B-11H-2, 47–82 cm	45.48	45.78	31.30	424	6	Y
7Y-62		7B-11H-2, 82–113 cm	45.78	46.06	31.59	374	7	Y
7Y-63		7B-11H-2, 113–140.5 cm	46.06	46.30	31.85	297	3	Y
7Y-64		7C-13H-3, 23–55 cm	46.30	46.52	32.08	294	2	Y
7Y-66	1 of 2	7C-13H-3, 61.5–99 cm	46.57	46.83	32.37	188	1	Y
7Y-66	2 of 2	7C-13H-3, 61.5–99 cm	46.57	46.83	32.37	194	2	Y
7Y-67		7C-13H-3, 99–125.5 cm	46.83	47.02	32.60	280	3	Y
7Y-68		7C-13H-3, 125.5–142 cm	47.02	47.13	32.75	1,365	37	Y
9Y-1		9A-1H-1, 1–127 cm	10.56	11.75	0.60	274	1	Y
9Y-2	1 of 2	9A-1H-2, 25.5–119 cm	11.75	12.57	1.60	292	4	Y
9Y-2	2 of 2	9A-1H-2, 25.5–119 cm	11.75	12.57	1.60	284	2	Y
9Y-3		9A-1H-2, 119–134 cm	12.57	12.70	2.08	317	2	Y

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
9Y-4		9A-2H-1, 0–24 cm	13.23	13.43	2.77	218	2	Y
9Y-5		9A-2H-1, 24–89 cm	13.43	13.96	3.14	290	3	Y
9Y-6		9C-2H-1, 74–114 cm	13.96	14.35	3.60	173	0	Y
9Y-7	1 of 2	9C-2H-2, 0–82 cm	14.35	15.15	4.19	211	1	Y
9Y-7	2 of 2	9C-2H-2, 0–82 cm	14.35	15.15	4.19	241	0	Y
9Y-8	1 of 2	9A-2H-3, 56–108.5 cm	15.15	15.70	4.87	283	1	Y
9Y-8	2 of 2	9A-2H-3, 56–108.5 cm	15.15	15.70	4.87	258	3	Y
9Y-9		9A-2H-3, 108.5–150 cm	15.70	16.14	5.36	139	2	Y
9Y-10		9C-3H-1, 18–91 cm	16.14	16.87	5.95	150	0	Y
9Y-11		9A-3H-1, 95–114 cm	16.87	17.07	6.41	140	2	Y
9Y-12		9A-3H-2, 0–44.5 cm	17.07	17.55	6.75	129	0	Y
9Y-13	1 of 2	9A-3H-2, 44.5–82 cm	17.55	17.95	7.19	145	1	Y
9Y-13	2 of 2	9A-3H-2, 44.5–82 cm	17.55	17.95	7.19	106	0	Y
9Y-14		9A-3H-2, 82–150 cm	17.95	18.69	7.76	222	5	Y
9Y-15		9C-4H-1, 0–97 cm	18.69	19.64	8.61	142	1	Y
9Y-16		9C-4H-2, 9–48 cm	19.64	20.03	9.28	227	2	Y
9Y-17	1 of 2	9C-4H-2, 48–131.5 cm	20.03	20.86	9.89	225	7	Y
9Y-17	2 of 2	9C-4H-2, 48–131.5 cm	20.03	20.86	9.89	263	2	Y
9Y-18		9A-5H-1, 24–118 cm	20.86	21.67	10.71	115	2	Y
9Y-19		9A-5H-2, 3–116 cm	21.67	22.80	11.68	309	2	Y
9Y-20		9C-6H-1, 36–98 cm	23.14	23.76	12.89	183	2	Y
9Y-21		9C-6H-2, 0–95 cm	23.76	24.63	13.64	219	5	Y
9Y-22		9C-6H-2, 95–150 cm	24.63	25.14	14.33	386	2	Y
9Y-23		9A-8H-2, 31–129 cm	25.14	25.99	15.01	466	5	Y
9Y-24		9C-7H-1, 21–89 cm	25.99	26.66	15.77	422	3	Y
9Y-25		9C-7H-1, 89–148 cm	26.66	27.25	16.40	430	4	Y
9Y-26		9C-7H-2, 0–60.5 cm	27.25	27.85	16.99	377	2	Y
9Y-27	1 of 2	9C-7H-2, 60.5–140 cm	27.85	28.64	17.69	444	2	Y
9Y-27	2 of 2	9C-7H-2, 60.5–140 cm	27.85	28.64	17.69	348	2	Y
9Y-28	1 of 2	9C-8H-1, 0–84 cm	28.74	29.52	18.57	376	2	Y
9Y-28	2 of 2	9C-8H-1, 0–84 cm	28.74	29.52	18.57	491	7	Y
9Y-29		9C-8H-1, 84–150 cm	29.52	30.14	19.27	227	1	Y
9Y-30		9C-8H-4, 0–38 cm	30.16	30.53	19.79	577	8	Y
9Y-31		9C-8H-4, 38–82.5 cm	30.53	30.97	20.19	342	3	Y
9Y-32		9C-8H-4, 82.5–125.5 cm	30.97	31.40	20.63	501	0	Y



**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
9Y-33		9A-10H-3, 0–35 cm	31.40	31.71	21.00	186	5	Y
9Y-34		9A-10H-3, 35–94.5 cm	31.71	32.26	21.43	232	2	Y
9Y-35	1 of 2	9A-10H-3, 94.5–135.5 cm	32.26	32.63	21.89	192	1	Y
9Y-35	2 of 2	9A-10H-3, 94.5–135.5 cm	32.26	32.63	21.89	184	3	Y
9Y-36		9C-9H-3, 7–41 cm	32.63	32.95	22.23	346	2	Y
9Y-37	1 of 2	9C-9H-3, 41–99 cm	32.95	33.50	22.67	151	3	Y
9Y-37	2 of 2	9C-9H-3, 41–99 cm	32.95	33.50	22.67	153	1	Y
9Y-38		9C-9H-3, 99–130 cm	33.50	33.79	23.09	152	2	Y
9Y-39		9A-11H-2, 55–102 cm	33.79	34.26	23.47	567	9	Y
8Y-1		8A-1H-1, 0–4 cm	10.16	10.20	0.02	211	4	Y
8Y-2		8A-1H-2, 0–17 cm	10.20	10.37	0.13	208	6.3	Y
8Y-3		8A-1H-2, 17–45.5 cm	10.37	10.66	0.36	298	4	Y
8Y-4		8A-1H-2, 45.5–89 cm	10.66	11.09	0.72	127	2	Y
8Y-5		8A-1H-3, 0–127.5 cm	11.09	12.37	1.57	223	5	Y
8Y-6	1 of 2	8A-1H-3, 127.5–150 cm	12.37	12.59	2.32	247	3	Y
8Y-6	2 of 2	8A-1H-3, 127.5–150 cm	12.37	12.59	2.32	263	3	Y
8Y-7		8A-1H-6, 0–5 cm	12.59	12.64	2.46	269	2	Y
8Y-43X		8B-1H-2, 43–101 cm	12.64	13.02	2.67	160	5.8	Y
8Y-8		8A-2H-1, 72–114 cm	13.02	13.44	3.07	165	1	Y
8Y-9		8A-2H-2, 4–22 cm	13.44	13.62	3.37	121	3.0	Y
8Y-10		8A-2H-2, 22–66 cm	13.62	14.06	3.68	235	1.3	Y
8Y-11		8A-2H-2, 66–129 cm	14.06	14.69	4.22	208	4	Y
8Y-12		8B-2H-1, 48–62 cm	14.69	14.83	4.60	16	43	Y
8Y-13		8B-2H-1, 62–127 cm	14.83	15.47	4.99	266	8	Y
8Y-14		8B-2H-2, 5–133 cm	15.47	16.75	5.95	220	4	Y
8Y-15		8A-4H-2, 3–82 cm	16.81	17.60	7.05	152	2	Y
8Y-16		8B-3H-1, 16–83 cm	17.60	18.27	7.78	236	2	Y
8Y-17	1 of 2	8B-3H-2, 0–136 cm	18.27	19.63	8.79	232	0	Y
8Y-17	2 of 2	8B-3H-2, 0–136 cm	18.27	19.63	8.79	221	4	Y
8Y-18		8C-2H-1, 17–81 cm	19.63	20.23	9.77	641	9	Y
8Y-19		8C-2H-1, 81–133 cm	20.23	20.72	10.32	1,020	17	Y
8Y-20		8C-2H-2, 0–31 cm	20.72	20.99	10.70	508	2	Y
8Y-21		8C-2H-2, 31–102 cm	20.99	21.59	11.13	381	9	Y
8Y-22		8A-8H-1, 29–129 cm	21.59	22.59	11.93	284	8	Y
8Y-23		8C-3H-1, 33–66 cm	22.59	22.74	12.51	183	10	Y

**Table 2.** Mercury data from the Y series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by U.S. Geological Survey laboratory in Boulder, Colo. First digit of sample ID and core ID represents coring site, listed in order from downstream to upstream (figure 2). mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; SD, standard deviation; Y, yes; N, no. ng/g, nanogram per gram; mm, millimeter; cm, centimeter; <, less than]

Sample ID	Replicate	Core ID	Relative sample location			Total mercury		Sieved to < 0.060 mm
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)	Concentration (ng/g, dry)	SD (ng/g, dry)	
8Y-24		8C-3H-1, 66–102 cm	22.74	22.91	12.67	243	2	Y
8Y-25		8C-3H-2, 0–73 cm	22.91	23.27	12.93	282	1	Y
8Y-26		8C-3H-2, 73–135 cm	23.27	23.57	13.26	320	2	Y
8Y-27		8A-10H-1, 42.5–76.5 cm	23.57	23.91	13.58	293	11	Y
8Y-28		8A-10H-1, 76.5–110 cm	23.91	24.24	13.92	280	3	Y
8Y-29		8C-4H-1, 22–141 cm	24.24	25.57	14.75	248	0	Y
8Y-30		8C-4H-2, 0–26 cm	25.57	25.84	15.55	180	8	Y
8Y-31	1 of 2	8C-4H-2, 26–151 cm	25.84	27.15	16.34	290	8	Y
8Y-31	2 of 2	8C-4H-2, 26–151 cm	25.84	27.15	16.34	302	2	Y
8Y-32		8A-12H-1, 113.5–142 cm	27.15	27.43	17.13	223	4	Y
8Y-33		8C-5H-1, 34.5–136 cm	27.43	28.18	17.65	262	6	Y
8Y-34	1 of 2	8C-5H-2, 0–59.5 cm	28.18	28.63	18.25	207	8	Y
8Y-34	2 of 2	8C-5H-2, 0–59.5 cm	28.18	28.63	18.25	193	6	Y
8Y-35		8C-5H-2, 0–59.5 cm	28.63	29.07	18.69	213	3	Y
8Y-36		8A-13H-1, 25–144 cm	29.07	30.26	19.51	214	2	Y
8Y-37		8A, 13H-2, 0–50.5 cm	30.26	30.76	20.35	120	5	Y
8Y-38		8A-13H-2, 50.5–126 cm	30.76	31.50	20.97	258	2	Y
8Y-39		8C-6H-3, 65.5–125 cm	31.50	32.02	21.60	115	4	Y
8Y-40		8A-14H-1, 16–81 cm	32.02	32.67	22.19	147	5	Y
8Y-41		8A-14H-2, 0–21.5 cm	32.67	32.89	22.62	1,568	47	Y
8Y-42		8A-14H-2, 21.5–115 cm	32.89	33.82	23.20	1,239	3.9	Y

Other quality-assurance procedures used by the BMSL in conjunction with its MeHg determinations included analyses of blanks and spike additions. Three analytical blanks were analyzed with each analytical batch of samples. MeHg was detected in 13 of the 57 blanks at concentrations less than 0.028 ng/g (four times the MDL of 0.007 ng/g, dry basis); the median blank value was less than the MDL, so the reported data were not blank-corrected. Recalculating the results after blank correction would result in an average change of less than 2 percent. Four of the 166 subsamples in the MEM series had MeHg results less than the MDL, and about 10 percent of all MeHg analyses (including the MEM series and the shallow box cores) had reported values less than five times the MDL. Thirty-four pairs of MeHg matrix spikes and matrix spike replicates were analyzed with the samples. Recoveries ranged from 70 to 130 percent, within the laboratory's data-quality objectives (65 to 135 percent recovery). The RPD between the

matrix spikes and the matrix spike replicates ranged from 1 to 35 percent for MeHg, within the BMSL's data-quality objectives.

Deep cores were refrigerated at approximately 4°C between collection and splitting; the MEM subsamples used for analysis of MeHg were frozen immediately after splitting. Shallow cores were processed immediately after collection and subsamples for analysis of MeHg were immediately frozen. Elapsed time between coring and analysis of MeHg by the BMSL ranged from 9 to 10 months for shallow cores and 14 to 16 months for deep cores. Despite careful handling, it is possible that MeHg concentration changed during sample storage, particularly when the deep cores were stored at 4°C rather than frozen, because of microbiological activity. However, it is not known whether MeHg may have increased or decreased during chilled or frozen storage, because changes in either direction have been observed in samples from other studies (Eric von

der Geest, Moss Landing Marine Laboratories, California, oral commun., 2005).

As an additional check on the quality of MeHg analyses, 15 subsamples from the MEM series (deep cores) were split evenly and analyzed by both the BMSL and the USGS-WDML (*table A5*). Three of the 15 subsamples had MeHg concentrations below the detection limit of the WDML, which ranged from 0.094 to 0.13 ng/g. The BMSL had a lower detection limit (0.007 ng/g), and it reported MeHg concentrations for these three subsamples that were consistent with the WDML results. No values of RPD were computed for these three subsamples. The median of the RPD values for MeHg analyses in the 12 other split subsamples was 27.7 percent. All 12 of the concentration values reported by the BMSL were higher than the corresponding values reported by the WDML, indicating a consistent bias. The ratio of the MeHg concentrations reported by the two laboratories (WDML:BMSL) ranged from 60 to 92 percent (*table A5*); the mean and the median values for RPD for the 12 subsamples were 76 percent. A linear least-squares regression for these 12 data points indicates a slope of 0.79 and an  $R^2$  value of 0.994. A plot of the split-sample data (*fig. A2*) shows the line of perfect agreement (labeled 100 percent) and a line corresponding to a ratio of 79 percent that represents a reasonable fit to the data.

The WDML analyzed SRMs IAEA-356 and IAEA-405 also for MeHg; overall results were similar to those produced by the BMSL (*table A3*). The average recoveries for the SRMs by the WDML were 92 percent (IAEA-356) and 72 percent (IAEA-405), averaging 82 percent; the average SRM recoveries by the BMSL were 74 percent (IAEA-356) and 84 percent (IAEA-405), averaging 79 percent. These results suggest that laboratory accuracy was not the primary cause of the differences between results for the 15 split subsamples by the two laboratories.

Differences in handling and frozen storage time of the split subsamples analyzed by the two laboratories are possible factors in the differences between the results. The split subsamples were analyzed for MeHg by the BMSL during July–September 2003 and by the WDML during March–April 2005, about 18–21 months later. Another difference in handling samples was that the split subsamples analyzed by the WDML were thawed for a short period (1–2 hours) in August 2004 and then refrozen, whereas the split subsamples analyzed by the BMSL were frozen continuously. Thus it is possible that some MeHg degraded during the extended frozen storage time or the brief additional thawed period, resulting in the lower concentrations measured by the WDML.

Because each laboratory analyzed MeHg in sediment during a relatively narrow time frame, the overall findings of this study relating to the spatial variability of MeHg concentration are not affected by the results of the interlaboratory split-sample comparison or possible sample storage effects. Even if MeHg in the subsamples degraded partially during frozen storage, the extent of degradation would have been similar for all subsamples analyzed by each laboratory. Thus, the

overall findings of this study relating to the spatial variability of MeHg concentration and of the ratio of MeHg to  $Hg_T$  would not be affected.

## Trace and Major Elements

The SRM used for trace and major elements by the USGS laboratory in Boulder, Colorado, was Buffalo River Sediment (NIST 2704; National Institute of Standards and Technology, 1990). Results of 22 analyses of NIST 2704 (*table B1*) using digestion and analysis procedures identical to those used for the environmental samples indicate a wide range of behavior for different groups of elements. For several trace elements, the SRM results are very close to the certified value (recovery values computed by dividing the overall average values by the certified value, in percent): antimony (101), arsenic (91), cadmium (99), chromium (92), copper (98), lead (100), nickel (95), and zinc (95). For several major elements, the SRM results were consistently lower than the certified values: aluminum (59), barium (74), calcium (73), magnesium (46), and potassium (80). This indicates that the acid digestion procedure used for this study did not result in complete recoveries of these major elements, but did result in more complete recoveries of most trace elements, including transition metals and the semi-metals antimony and arsenic.

Digestion blanks were analyzed as part of each batch of environmental samples, a total of 16 (*table B2*). Concentrations measured in these blanks were generally near the detection limit for most trace metals, much lower than the values for environmental samples, so the data did not need to be blank-corrected. Blank spikes were prepared for seven selected elements (arsenic, cadmium, calcium, copper, lead, magnesium, and zinc) on six occasions (*table B3*). Recoveries from blank spikes were within an acceptable range (85 to 115 percent of expected concentration) for all analyses except one of the analyses for arsenic.

Replicate digestions were made of 29 subsamples, which were analyzed for 53 trace and major elements (*table B4*). For several trace elements of interest, median values of RPD were less than or equal to 5 percent, indicating a high degree of reproducibility; median RPD values (in percent) include arsenic (3), antimony (4), copper (5), lead (1.5), nickel (3), and zinc (4). For major elements, median RPD values for replicate subsamples were typically in the range of 9 to 15 percent: aluminum (15), barium (12), calcium (9), magnesium (15), potassium (9), and sodium (6). The digestate from each replicate subsample was analyzed in triplicate. Standard deviations reported in *tables B4* (replicate subsamples) and *B5* (all subsamples) indicate analytical variability (precision). For concentrations greater than 10 times the MDL, standard deviation values for trace metals were generally less than 20 percent of the average amount present. For concentrations closer to the MDL, standard deviation values tend to represent a higher proportion of the amount present (Alpers and others, 2000).

## Results

### Total Mercury and Methylmercury

Concentration data for total mercury ( $Hg_T$ ) and methylmercury (MeHg) in subsamples from shallow and deep cores are presented in this section. Data for grain-size distribution and loss on ignition for these subsamples were reported by Snyder and others (2004b). The Y-series subsamples were analyzed for trace and major elements, as discussed in a later section. Data for  $Hg_T$  are given in *tables 2 and 3* (Y-series and MEM-series) for the deep cores and in *table 4* for the shallow cores. Data for MeHg are given in *table 3* (MEM-series) and *table 4* (shallow cores). The distribution of compositions with depth for  $Hg_T$  and selected trace elements in Y-series subsamples is shown on *figures 4–8*. Data for  $Hg_T$ , MeHg, and the ratio of MeHg to  $Hg_T$  for the MEM-series are plotted with respect to depth in *figure 9*. Some statistics regarding the spatial variation (longitudinal and vertical) of  $Hg_T$ , MeHg, and the ratio of  $Hg_T$  to MeHg are summarized in *tables 5 and 6*. Summary statistics regarding the longitudinal variation of selected trace elements are given in *table 7*. A quantitative statistical analysis of the relations between grain-size distribution and concentrations of  $Hg_T$ , MeHg, loss on ignition, and other sediment properties, and trends of Hg concentration with time in the context of the sedimentation history of the reservoir will be published separately.

The Y-series of subsamples from the deep cores best represent the spatial distribution of  $Hg_T$  in Englebright Lake sediments. The Y-series represents a continuous vertical profile of the sediment deposit at several locations, taking advantage of multiple adjacent drill holes to avoid gaps in the profile between core sections. A total of 202 Y-series subsamples from five deep coring locations were analyzed for total mercury (*table 2*); in upstream order, starting near Englebright Dam, the sites are 1, 4, 7, 9, and 8 (*fig. 2*). Plots of  $Hg_T$  versus depth for the Y-series subsamples are shown in box A of *figures 4–8*. Note that the Y-series subsamples from site 4 were not screened prior to analysis, whereas the subsamples from the other four sites were screened at 0.060 mm and only the fines fraction (silt- and clay-size particles) was analyzed. In general, the fine-grained fraction of sediment tends to have higher concentrations of trace metals, including mercury and methylmercury, because of the association of the trace metals with fine-grained particles containing hydrous ferric oxides, clay minerals, and organic material (Horowitz, 1991; Hunerlach and others, 2004). Lines on the plots in *figures 4–8* represent vertical trends of concentration values; the lines pass through the average of the depth interval values for the replicate subsamples.

The MEM-series of subsamples, also from the deep cores, provided a linkage between analyses of  $Hg_T$  and MeHg. These subsamples are discrete subsamples of a more limited vertical extent (typically about 10–15 cm) compared with the continuous, Y-series subsamples (typically 25 to 100 cm; Snyder and others, 2004a). The MEM-series subsamples were analyzed for  $Hg_T$  and MeHg by the BMSL (*table 3*). The MEM-series subsamples were also analyzed for grain-size distribution (*fig. 9*) and loss on ignition (Snyder and others, 2004b), but were not analyzed for trace or major elements. All seven of the deep coring sites were sampled in the MEM-series; in upstream order, these sites are 1, 6, 4, 7, 9, 8, and 2 (*fig. 2*). Plots of  $Hg_T$  and MeHg versus depth for the MEM-series subsamples are shown in *figures 9A and 9B*. A plot of the ratio MeHg/ $Hg_T$  versus depth is shown in *figure 9C*, and the relation between median grain size and depth is shown in *figure 9D*.

At the deep coring sites closest to Englebright Dam (sites 1, 6, and 4), concentrations of  $Hg_T$  in subsamples from both the Y-series (sites 1 and 4; *figs. 4A, 5A*) and the MEM-series (sites 1, 6, and 4; *fig. 9A*) were generally 100 to 500 ng/g (nanograms per gram). The median grain size at these sites (*figs. 4H, 5H*) was consistently silt-sized (0.004 to 0.063 mm) (*figs. 4H, 5H, 9D*). At the more upstream deep coring sites (7, 9, 8, and 2), unsieved MEM-series subsamples from the upper parts of the profile have lower concentrations of  $Hg_T$ , generally from 2 to 100 ng/g, and typically coarser grain size, with median grain size in the sand range (0.063 to 2.0 mm; *fig. 9D*). In contrast, the MEM-series subsamples from the lower parts of these profiles have median grain size in the fine sand and silt range (about 0.007 to 0.3 mm; *fig. 9D*) and higher concentrations of  $Hg_T$  (*fig. 9A*).

The fines fraction from the upper parts of the upstream coring site profiles (Y-series subsamples, sites 7, 9, and 8) had concentrations of  $Hg_T$  in most subsamples ranging from about 100 to 300 ng/g (*figs. 6A, 7A, and 8A*). In the fines fraction from the sieved Y-series subsamples at sites 7 and 9 (*figs. 6A and 7A*) concentrations of  $Hg_T$  in the lower parts of the profile were generally higher (most subsamples 200 to 600 ng/g) than those in the upper parts of the same profiles. At site 8 (*fig. 8A*), the  $Hg_T$  concentration of the fines fraction ranged from 100 to 300 ng/g for most subsamples; four intervals in the middle of the profile had concentrations from about 300 to 1,000 ng/g.

The highest concentrations of  $Hg_T$  in the fines fraction of sieved subsamples (Y-series) were found in the bottom interval at site 7 (*fig. 6A*) and the bottom two intervals at site 8 (*fig. 8A*). In these three subsamples, concentrations of  $Hg_T$  ranged from about 1,200 to 1,600 ng/g. Other trace elements, including arsenic, lead, and antimony, were also elevated in these subsamples, as discussed below.

**Table 3.** Mercury and methylmercury data from the MEM series of subsamples from deep cores, Englebright Lake, California, May–June 2002.

[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; Hg<sub>T</sub>, total mercury; MeHg, methylmercury; ng/g, nanogram per gram; %, percentage; —, not determined; <, less than]

Sample ID (GS-)	Replicate	Core ID	Relative sample location			Total mercury concentration (ng/g, dry)	Methylmercury concentration (ng/g, dry)	Percent dry weight	Ratio of MeHg to Hg <sub>T</sub> (%)
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)				
1		1C-1E-1 / MEM, 23–34 cm	62.09	62.20	1.36	355	1.5	57.0	0.42
2		1C-1E-2 / MEM, 56–66 cm	62.83	62.93	2.09	176	0.098	62.6	0.056
3		1C-2E-2 / MEM, 15–25 cm	65.27	65.37	4.53	575	0.77	63.8	0.13
4		4C-1H-1 / MEM, 20–30 cm	34.40	34.50	0.08	175	0.64	64.5	0.37
5		2B-1H-1 / MEM, 114–124 cm	4.96	5.06	1.19	12.6	0.051	80.1	0.40
6		2B-1H-1 / MEM, 53–63 cm	4.35	4.45	0.58	21.2	0.065	78.3	0.31
7		4C-1H-2 / MEM, 72–82 cm	35.64	35.74	1.32	26.6	1.4	47.8	5.1
8		4C-2H-1 / MEM, 72–82 cm	37.29	37.39	2.97	364	0.66	59.3	0.18
9		4C-2H-2 / MEM, 64–74 cm	38.65	38.75	4.33	264	0.67	57.4	0.25
10		4C-3H-1 / MEM, 70–80 cm	40.15	40.25	5.83	215	0.50	62.1	0.23
11		4C-3H-2 / MEM, 71–81 cm	41.39	41.48	7.06	223	3.0	60.3	1.3
12	1 of 2	4C-4H-2 / MEM, 63–73 cm	43.25	43.34	8.92	266	1.2	63.6	0.45
12	2 of 2	4C-4H-2 / MEM, 63–73 cm	43.25	43.34	8.92	231	—	63.6	—
13		4C-4H-3 / MEM, 67–77 cm	44.60	44.70	10.28	359	0.36	66.9	0.10
14		4C-5H-2 / MEM, 44–54 cm	46.07	46.16	11.74	363	1.0	63.5	0.28
15		4C-5H-3 / MEM, 52–62 cm	47.08	47.18	12.76	309	0.69	67.7	0.22
16		4C-5H-4 / MEM, 45–55 cm	47.97	48.07	13.65	1,150	3.3	64.1	0.29
17		4C-6E-1 / MEM, 58–68 cm	49.24	49.34	14.92	125	0.060	61.9	0.048
18		4D-1H-1 / MEM, 41–51 cm	34.75	34.85	0.43	115	1.4	59.7	1.2
19		4D-1H-2 / MEM, 60–70 cm	35.82	35.92	1.50	183	1.5	56.2	0.82
20		4D-2E-1 / MEM, 51–61 cm	37.88	37.98	3.56	182	0.58	66.4	0.32
21		4D-3E-1 / MEM, 51–61 cm	40.46	40.54	6.13	241	0.91	58.0	0.38
22		4D-3E-2 / MEM, 49–59 cm	41.28	41.35	6.94	256	0.92	57.2	0.36
23		4D-3E-3 / MEM, 50–60 cm	42.14	42.21	7.81	231	0.79	57.4	0.34
24		4D-4E-1 / MEM, 112–122 cm	43.68	43.76	9.35	232	1.0	63.0	0.44
25		4D-5E-1 / MEM, 32–42 cm	45.70	45.80	11.38	286	1.2	64.8	0.42
26		4D-5E-2 / MEM, 55–65 cm	46.50	46.60	12.18	386	0.89	62.8	0.23
27		4D-6H-1 / MEM, 68–78 cm	49.11	49.21	14.79	251	0.20	67.4	0.081
28	1 of 3	6A-1H-2 / MEM, 70–80 cm	52.69	52.79	1.51	386	1.7	49.4	0.45
28	2 of 3	6A-1H-2 / MEM, 70–80 cm	52.69	52.79	1.51	337	1.9	49.4	0.56
28	3 of 3	6A-1H-2 / MEM, 70–80 cm	52.69	52.79	1.51	—	1.9	49.4	—
29		6A-3E-3 / MEM, 53–63 cm	57.65	57.72	6.45	286	0.85	63.8	0.30
30		6A-4E-1 / MEM, 65–75 cm	59.02	59.12	7.84	539	0.43	60.0	0.080
31		6B-1H-1 / MEM, 48–58 cm	52.00	52.09	0.82	355	1.6	54.6	0.44
32		6B-1H-2 / MEM, 81–91 cm	53.67	53.76	2.48	93.8	0.063	64.3	0.067
33	1 of 2	6B-2H-1 / MEM, 61–71 cm	55.15	55.24	3.96	344	0.87	61.5	0.25
33	2 of 2	6B-2H-1 / MEM, 61–71 cm	55.15	55.24	3.96	—	0.93	61.5	—
34	1 of 2	6B-2H-2 / MEM, 109–119 cm	57.02	57.12	5.84	453	0.88	58.1	0.19

**24 Geochemical Data for Mercury, Methylmercury, and Other Constituents in Sediments, Englebright Lake, California, 2002**

**Table 3.** Mercury and methylmercury data from the MEM series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; Hg<sub>T</sub>, total mercury; MeHg, methylmercury; ng/g, nanogram per gram; %, percentage; —, not determined; <, less than]

Sample ID (GS-)	Replicate	Core ID	Relative sample location			Total mercury concentration (ng/g, dry)	Methylmercury concentration (ng/g, dry)	Percent dry weight	Ratio of MeHg to Hg <sub>T</sub> (%)
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)				
34	2 of 2	6B-2H-2 / MEM, 109–119 cm	57.02	57.12	5.84	471	—	58.1	—
35		6A-3E-1 / MEM, 62–72 cm	56.79	56.86	5.60	259	0.57	64.3	0.22
36		6D-1H-1 / MEM, 110–120 cm	52.26	52.36	1.08	153	0.35	60.6	0.23
37		6D-1H-2 / MEM, 54–64 cm	53.04	53.14	1.86	152	0.093	59.5	0.061
38		6D-2E-1 / MEM, 41–51 cm	54.57	54.67	3.39	391	0.21	59.4	0.053
39		6E-1H-2 / MEM, 51–62 cm	52.92	53.03	1.74	300	0.76	51.9	0.25
40		6E-2H-2 / MEM, 77–83 cm	55.24	55.30	4.04	422	1.3	57.1	0.30
41		6E-3E-1 / MEM, 26–34 cm	57.26	57.34	6.07	301	0.43	59.6	0.14
42		6E-3E-2 / MEM, 26–31 cm	58.28	58.33	7.08	584	3.6	59.8	0.62
43		7A-1H-1 / MEM, 34–40 cm	14.45	14.51	0.15	39.4	0.12	73.8	0.31
44		7A-1H-1 / MEM, 84–92 cm	14.95	15.03	0.66	402	0.86	59.0	0.21
45		7A-1H-2 / MEM, 58–68 cm	15.91	16.01	1.63	219	1.1	53.5	0.52
46		7A-2H-1 / MEM, 107–114 cm	18.13	18.20	3.83	23.6	0.090	74.5	0.38
47		7A-2H-2 / MEM, 32–40 cm	18.76	18.84	4.47	22.6	0.21	73.9	0.91
48		7A-2H-2 / MEM, 124–132 cm	19.68	19.76	5.39	206	0.47	63.6	0.23
49		7A-3H-1 / MEM, 106–114 cm	21.09	21.17	6.80	138	0.27	62.7	0.19
50		7A-3H-2 / MEM, 91–100 cm	22.25	22.34	7.97	224	0.40	62.1	0.18
51		7A-4H-1 / MEM, 40–47 cm	23.44	23.51	9.15	14.7	0.053	80.2	0.36
52		7A-4H-2 / MEM, 92–100 cm	25.14	25.22	10.85	140	1.5	33.6	1.1
53		7B-1H-1 / MEM, 68–79 cm	24.70	24.81	10.43	361	3.0	51.3	0.84
54		7B-1H-2 / MEM, 46–56 cm	25.83	25.93	11.55	51.9	0.026	76.3	0.051
55		7B-2H-1 / MEM, 82–90 cm	28.03	28.11	13.74	58.4	0.023	73.8	0.039
56		7B-2H-2 / MEM, 104–112 cm	29.40	29.48	15.11	37.5	0.13	75.9	0.35
57		7B-3H-1 / MEM, 18–28 cm	30.08	30.18	15.80	132	6.8	43.1	5.2
58		7B-3H-1 / MEM, 74–82 cm	30.64	30.72	16.35	39.8	0.15	75.3	0.37
59		7B-3H-2 / MEM, 24–34 cm	31.38	31.48	17.10	94.5	0.49	74.9	0.52
60		7B-4H-1 / MEM, 54–65 cm	33.00	33.11	18.73	76.3	1.3	69.2	1.7
61		7B-5H-1 / MEM, 57–71 cm	33.86	33.98	19.59	100	1.1	68.5	1.1
62	1 of 2	7B-5H-1 / MEM, 95–107 cm	34.17	34.27	19.89	233	0.77	67.7	0.33
62	2 of 2	7B-5H-1 / MEM, 95–107 cm	34.17	34.27	19.89	247	—	67.7	—
63		7B-6H-1 / MEM, 37–49 cm	34.57	34.68	20.29	298	2.0	64.8	0.65
64		7B-7H-1 / MEM, 95–113 cm	36.30	36.48	22.06	259	0.98	67.1	0.38
65		7B-8H-1 / MEM, 103–114 cm	37.86	37.97	23.59	154	0.20	71.9	0.13
66		7B-9H-1 / MEM, 72–82 cm	39.09	39.19	24.81	635	0.50	65.3	0.079
67		7B-10H-1 / MEM, 61–72 cm	40.48	40.59	26.21	997	0.18	67.7	0.018
68		7B-11H-1 / MEM, 3–15 cm	41.45	41.56	27.18	123	0.53	73.6	0.43
69		7B-11H-2 / MEM, 54–64 cm	43.37	43.47	29.09	239	0.98	67.9	0.41
70		7B-12H-1 / MEM, 7–19 cm	44.48	44.60	30.21	87.7	0.23	65.9	0.26

**Table 3.** Mercury and methylmercury data from the MEM series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

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Sample ID (GS-)	Replicate	Core ID	Relative sample location			Total mercury concentration (ng/g, dry)	Methylmercury concentration (ng/g, dry)	Percent dry weight	Ratio of MeHg to Hg <sub>T</sub> (%)
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)				
71	1 of 2	7B-12H-2 / MEM, 29–39 cm	44.93	44.98	30.63	113	0.044	62.0	0.038
71	2 of 2	7B-12H-2 / MEM, 29–39 cm	44.93	44.98	30.63	—	0.041	62.0	—
72		7B-12H-3 / MEM, 34–44 cm	45.08	45.09	30.76	165	0.058	73.6	0.035
73		7C-1H-1 / MEM, 16–25 cm	14.49	14.58	0.21	46.3	0.27	71.2	0.58
74	1 of 2	7C-1H-2 / MEM, 64–74 cm	16.14	16.24	1.86	133	0.95	62.3	0.72
74	2 of 2	7C-1H-2 / MEM, 64–74 cm	16.14	16.24	1.86	—	1.1	62.3	—
75		7C-2H-1 / MEM, 86–95 cm	17.57	17.66	3.29	33.6	0.22	76.1	0.66
76		7C-2H-2 / MEM, 54–64 cm	18.75	18.85	4.47	33.7	0.069	74.7	0.21
77		7C-3H-1 / MEM, 72–80 cm	20.36	20.44	6.07	236	0.90	63.7	0.38
78		7C-3H-2 / MEM, 70–79 cm	21.78	21.86	7.49	630	1.1	62.5	0.18
79		7C-4H-1 / MEM, 34–44 cm	23.00	23.10	8.72	257	0.78	59.3	0.30
80		7C-4H-2 / MEM, 35–44 cm	23.49	23.58	9.21	27.5	<0.007	78.5	<0.03
81		7C-4H-3 / MEM, 124–131 cm	25.17	25.24	10.88	63.6	0.23	72.3	0.36
82		7C-5H-1 / MEM, 17–29 cm	25.72	25.84	11.45	136	2.2	46.7	1.6
83		7C-6H-1 / MEM, 25–37 cm	27.52	27.62	13.24	191	2.6	34.6	1.4
84		7C-6H-2 / MEM, 73–81 cm	29.34	29.42	15.05	44.0	0.10	76.3	0.23
85		7C-7H-1 / MEM, 90–99 cm	31.10	31.19	16.81	85.1	0.072	74.0	0.085
86		7C-7H-2 / MEM, 92–102 cm	32.50	32.60	18.22	333	1.5	65.5	0.45
87		7C-9H-2 / MEM, 85–93 cm	35.40	35.47	21.10	58.2	0.048	76.6	0.082
88		7C-8H-1 / MEM, 74–81 cm	33.84	33.91	19.55	45.8	0.31	75.6	0.68
89		7C-9H-3 / MEM, 75–84 cm	36.53	36.61	22.24	183	1.5	69.8	0.80
90		7C-10H-1 / MEM, 60–70 cm	37.71	37.80	23.43	110	0.71	69.1	0.65
91		7C-10H-2 / MEM, 73–82 cm	39.23	39.32	24.95	251	0.83	66.7	0.33
92		7C-11H-1 / MEM, 43–52 cm	40.62	40.71	26.33	308	0.34	68.3	0.11
93		7C-11H-2 / MEM, 49–57 cm	41.58	41.66	27.29	460	1.1	69.8	0.25
94		7C-12H-1 / MEM, 58–68 cm	43.32	43.42	29.04	167	1.5	67.9	0.89
95		7C-12H-2 / MEM, 69–79 cm	44.75	44.85	30.47	95.1	0.16	71.2	0.17
96		7C-13H-1 / MEM, 10–20 cm	45.83	45.93	31.55	413	0.20	66.3	0.047
97	1 of 2	7C-13H-3 / MEM, 38–48 cm	46.41	46.48	32.11	237	0.45	68.1	0.19
97	2 of 2	7C-13H-3 / MEM, 38–48 cm	46.41	46.48	32.11	210	—	68.1	—
98		7C-13H-3 / MEM, 126–135 cm	47.02	47.08	32.72	95.7	0.095	78.8	0.10
99		8A-1H-2 / MEM, 64–73 cm	10.64	10.73	0.53	14.2	0.035	80.2	0.24
100		8A-1H-3 / MEM, 89–101 cm	11.78	11.90	1.68	5.7	0.026	77.7	0.46
101		8A-2H-2 / MEM, 47–56 cm	13.87	13.96	3.76	100	0.78	68.6	0.78
102		8A-3H-2 / MEM, 73–84 cm	15.55	15.63	5.43	21.8	0.019	82.4	0.086
103		8A-4H-1 / MEM, 44–51 cm	16.67	16.74	6.55	9.5	0.018	78.9	0.19
104		8A-4H-2 / MEM, 69–77 cm	17.47	17.55	7.35	23.7	0.034	82.3	0.14
105		8A-7H-2 / MEM, 51–63 cm	19.88	20.00	9.78	37.3	0.063	77.7	0.17

**Table 3.** Mercury and methylmercury data from the MEM series of subsamples from deep cores, Englebright Lake, California, May–June 2002—Continued.

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Sample ID (GS-)	Replicate	Core ID	Relative sample location			Total mercury concentration (ng/g, dry)	Methylmercury concentration (ng/g, dry)	Percent dry weight	Ratio of MeHg to Hg <sub>T</sub> (%)
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)				
106		8A-8H-1 / MEM, 110–118 cm	22.40	22.48	12.28	7.6	0.009	84.1	0.12
107		8A-8H-2 / MEM, 0–13 cm	22.71	22.73	12.56	201	0.20	65.4	0.10
108		8A-10H-1 / MEM, 77–85 cm	23.91	23.99	13.79	34.9	0.057	75.1	0.16
109		8A-11H-1 / MEM, 76–83 cm	25.28	25.35	15.16	142	0.86	61.6	0.61
110		8A-12H-1 / MEM, 38–52 cm	26.41	26.55	16.32	174	0.57	63.7	0.33
111		8A-12H-2 / MEM, 38–47 cm	27.77	27.86	17.65	109	0.42	71.7	0.38
112	1 of 2	8A-13H-1 / MEM, 68–78 cm	29.50	29.60	19.39	95.0	0.14	71.7	0.15
112	2 of 2	8A-13H-1 / MEM, 68–78 cm	29.50	29.60	19.39	—	0.15	71.7	—
113		8A-13H-2 / MEM, 44–55 cm	30.69	30.80	20.59	98.6	0.095	66.3	0.10
114		8A-14H-1 / MEM, 27–37 cm	32.13	32.23	22.02	64.3	0.041	62.7	0.063
115		8A-14H-2 / MEM, 25–33 cm	32.92	33.00	22.80	365	0.24	70.9	0.065
116		8B-1H-1 / MEM, 30–38 cm	11.48	11.56	1.36	18.1	0.016	83.2	0.090
117		8B-1H-2 / MEM, 69–78 cm	12.67	12.76	2.56	23.1	<0.007	79.8	<0.03
118		8B-2H-1 / MEM, 104–112 cm	15.24	15.32	5.12	110	0.15	70.0	0.14
119		8B-2H-2 / MEM, 62–71 cm	16.04	16.13	5.93	16.4	0.019	79.2	0.12
120		8B-3H-1 / MEM, 50–58 cm	17.67	17.75	7.55	18.0	0.022	82.9	0.12
121		8B-3H-2 / MEM, 117–127 cm	19.17	19.27	9.06	15.5	0.097	73.5	0.63
122		8C-2H-1 / MEM, 92–101 cm	20.05	20.14	9.94	81.6	0.32	72.9	0.39
123	1 of 2	8C-2H-2 / MEM, 52–61 cm	20.93	21.01	10.81	302	0.94	64.7	0.31
123	2 of 2	8C-2H-2 / MEM, 52–61 cm	20.93	21.01	10.81	—	1.0	64.7	—
124	1 of 2	8C-3H-1 / MEM, 52–61 cm	22.54	22.62	12.42	416	0.51	64.8	0.12
124	2 of 2	8C-3H-1 / MEM, 52–61 cm	22.54	22.62	12.42	237	—	64.8	—
125		8C-3H-2 / MEM, 63–71 cm	23.64	23.72	13.52	<5	<0.007	81.2	—
126		8C-4H-1 / MEM, 75–83 cm	25.18	25.26	15.06	105	0.20	74.5	0.19
127		8C-4H-2 / MEM, 77–87 cm	26.56	26.65	16.45	102	0.71	70.0	0.69
128		8C-5H-1 / MEM, 56–65 cm	27.87	27.96	17.76	100	0.19	69.0	0.19
129		8C-5H-2 / MEM, 26–36 cm	28.93	29.03	18.82	181	0.33	63.7	0.18
130	1 of 2	8C-6H-1 / MEM, 69–79 cm	30.97	31.06	20.86	130	0.074	65.6	0.057
130	2 of 2	8C-6H-1 / MEM, 69–79 cm	30.97	31.06	20.86	—	0.087	65.6	—
131		8C-6H-3 / MEM, 40–50 cm	32.13	32.22	22.01	133	0.62	69.4	0.46
132	1 of 2	8C-7H-1 / MEM, 18–28 cm	33.41	33.50	23.29	128	0.17	60.7	0.13
132	2 of 2	8C-7H-1 / MEM, 18–28 cm	33.41	33.50	23.29	124	—	60.7	—
133		9A-1H-1 / MEM, 90–103 cm	11.31	11.42	0.80	35.6	0.092	74.8	0.26
134		9A-1H-2 / MEM, 83–94 cm	12.43	12.53	1.92	216	1.7	57.9	0.77
135		9A-2H-1 / MEM, 49–56 cm	13.94	14.01	3.41	119	0.55	66.2	0.46
136		9A-2H-3 / MEM, 110–119 cm	15.74	15.83	5.23	20.1	0.027	77.8	0.14
137		9A-3H-1 / MEM, 72–80 cm	16.65	16.73	6.13	21.3	0.020	78.9	0.10
138		9A-3H-2 / MEM, 39–48 cm	17.46	17.55	6.95	70.7	0.43	65.2	0.61



**Table 3.** Mercury and methylmercury data from the MEM series of subsamples from deep cores, Eglebright Lake, California, May–June 2002—Continued.

[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. mbls, meters below lake surface (spillway elevation); mblf, meters below lake floor; Hg<sub>T</sub>, total mercury; MeHg, methylmercury; ng/g, nanogram per gram; %, percentage; —, not determined; <, less than]

Sample ID (GS-)	Replicate	Core ID	Relative sample location			Total mercury concentration (ng/g, dry)	Methylmercury concentration (ng/g, dry)	Percent dry weight	Ratio of MeHg to Hg <sub>T</sub> (%)
			Top (mbls)	Bottom (mbls)	Midpoint (mblf)				
139		9A-4H-2 / MEM, 72–80 cm	19.80	19.87	9.27	5.4	<0.007	86.3	<0.13
140		9A-5H-1 / MEM, 53–61 cm	21.12	21.19	10.59	12.0	0.025	79.7	0.20
141		9A-7H-1 / MEM, 69–78 cm	23.71	23.78	13.18	120	0.012	80.7	0.010
142		9A-8H-2 / MEM, 93–101 cm	25.58	25.66	15.06	44.0	0.37	73.9	0.83
143		9A-9H-1 / MEM, 88–96 cm	26.88	26.96	16.36	245	1.7	68.1	0.68
144		9A-9H-2 / MEM, 74–83 cm	27.94	28.02	17.42	266	0.69	72.2	0.26
145		9A-10H-1 / MEM, 40–49 cm	29.24	29.32	18.72	204	0.87	70.5	0.42
146		9A-10H-3 / MEM, 70–79 cm	30.98	31.07	20.47	206	0.21	69.7	0.10
147		9A-11H-1 / MEM, 107–116 cm	32.28	32.42	21.79	65.5	0.036	63.5	0.054
148		9C-1H-1 / MEM, 62–69 cm	11.29	11.36	0.76	11.6	0.027	77.7	0.23
149		9C-1H-2 / MEM, 105–114 cm	12.56	12.65	2.05	33.2	0.051	74.2	0.15
150	1 of 2	9C-2H-1 / MEM, 16–26 cm	13.40	13.50	2.89	274	2.2	55.4	0.82
150	2 of 2	9C-2H-1 / MEM, 16–26 cm	13.40	13.50	2.89	—	2.3	55.4	—
151		9C-2H-2 / MEM, 17–26 cm	14.51	14.60	4.00	<5	0.016	80.2	—
152		9C-2H-2 / MEM, 98–107 cm	15.31	15.40	4.79	187	0.74	62.8	0.40
153		9C-3H-1 / MEM, 88–98 cm	16.84	16.94	6.33	15.3	0.033	77.8	0.21
154		9C-3H-2 / MEM, 26–36 cm	17.34	17.42	6.82	88.0	0.24	68.4	0.28
155		9C-4H-1 / MEM, 44–54 cm	19.12	19.22	8.61	25.1	0.018	81.0	0.071
156		9C-4H-2 / MEM, 70–79 cm	20.25	20.34	9.73	10.9	0.021	81.4	0.19
157		9C-5H-1 / MEM, 51–61 cm	21.41	21.51	10.90	<5	0.013	85.4	—
158		9C-5H-2 / MEM, 46–57 cm	22.04	22.13	11.52	158	0.99	67.1	0.62
159		9C-6H-1 / MEM, 60–68 cm	23.38	23.46	12.86	34.7	0.014	80.4	0.040
160		9C-6H-2 / MEM, 70–78 cm	24.76	24.83	14.24	12.6	0.22	75.4	1.7
161	1 of 2	9C-7H-1 / MEM, 70–81 cm	26.48	26.59	15.97	172	0.58	69.1	0.33
161	2 of 2	9C-7H-1 / MEM, 70–81 cm	26.48	26.59	15.97	100	—	69.1	—
162		9C-7H-2 / MEM, 65–74 cm	27.89	27.98	17.38	324	0.61	68.2	0.19
163		9C-8H-1 / MEM, 57–67 cm	29.27	29.36	18.76	338	2.3	64.0	0.66
164		9C-8H-4 / MEM, 70–79 cm	30.85	30.94	20.33	337	0.25	65.9	0.074
165	1 of 2	9C-9H-2 / MEM, 33–43 cm	32.09	32.19	21.58	225	0.21	67.0	0.092
165	2 of 2	9C-9H-2 / MEM, 33–43 cm	32.09	32.19	21.58	—	0.21	67.0	—
166		9C-9H-3 / MEM, 10–20 cm	32.66	32.75	22.15	281	0.60	69.7	0.21

**Table 4.** Mercury and methylmercury data for shallow cores taken at Englebright Lake, California, October 2002.[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. MeHg, methylmercury; Hg<sub>T</sub>, total mercury. cm, centimeter; ng/g, nanograms per gram; —, not determined]

Site ID	Depth below lake floor (cm)	Lab ID	Core replicate	Lab replicate	Percent dry weight	Total mercury (ng/g dry)	Methylmercury (ng/g dry)	Ratio of MeHg to Hg <sub>T</sub> (percentage)
10F-B	0-1	GS 200			23.4	307	1.1	0.37
10F-B	1-2	GS 201			29.7	251	1.0	0.40
10F-B	2-3	GS 202			32.8	303	0.90	0.30
10F-B	3-4	GS 203			37.3	283	0.86	0.30
10F-B	4-8	GS 204	1 of 2		43.9	256	0.47	0.18
10F-B	4-8	GS 205	2 of 2		43.2	243	0.80	0.33
10F-B	8-12	GS 206			49.7	265	0.71	0.27
10G-B	0-1	GS 207			26.8	224	0.92	0.41
10G-B	1-2	GS 208			30.6	288	1.5	0.51
10G-B	2-3	GS 209		1 of 2	33.2	258	0.73	0.28
10G-B	2-3	GS 209		2 of 2	33.2	—	0.89	—
10G-B	3-4	GS 210			37.6	288	0.60	0.21
10G-B	4-8	GS 211			43.0	265	0.96	0.36
10G-B	8-12	GS 212	1 of 2		47.0	274	1.1	0.40
10G-B	8-12	GS 213	2 of 2		47.3	237	1.0	0.43
11A-B	0-4	GS 214			36.2	252	1.7	0.66
11A-B	4-8	GS 215		1 of 4	44.4	228	0.57	0.25
11A-B	4-8	GS 215		2 of 4	44.4	—	0.87	—
11A-B	4-8	GS 215		3 of 4	44.4	—	0.90	—
11A-B	4-8	GS 215		4 of 4	44.4	—	0.49	—
11A-B	8-12	GS 216			44.4	233	0.43	0.18
11B-B	0-4	GS 217			27.9	230	0.40	0.17
11B-B	4-8	GS 218		1 of 2	37.5	380	0.37	0.10
11B-B	4-8	GS 218		2 of 2	37.5	295	—	—
11B-B	8-12	GS 219			41.1	298	0.52	0.18
11C-B1	0-4	GS 220	1 of 1		30.5	329	0.85	0.26
11C-B1	4-8	GS 221	1 of 1		48.1	228	0.41	0.18
11C-B1	8-12	GS 222	1 of 1		48.9	227	0.49	0.21
11C-B2	0-4	GS 223	2 of 2		35.1	285	0.49	0.17
11C-B2	4-8	GS 224	2 of 2		48.4	270	0.25	0.091
11C-B2	8-12	GS 225	2 of 2		48.7	268	0.58	0.21
11D-B	0-4	GS 226			40.5	271	0.56	0.21
11D-B	4-8	GS 227			50.4	222	0.33	0.15
11D-B	8-11	GS 228			46.9	222	0.55	0.25
11E-B	0-4	GS 229			40.3	245	4.0	1.6
11E-B	4-7	GS 230			41.7	212	3.8	1.8
11F-B	0-1	GS 231			29.1	308	1.1	0.35
11F-B	1-2	GS 232			39.5	333	0.69	0.21

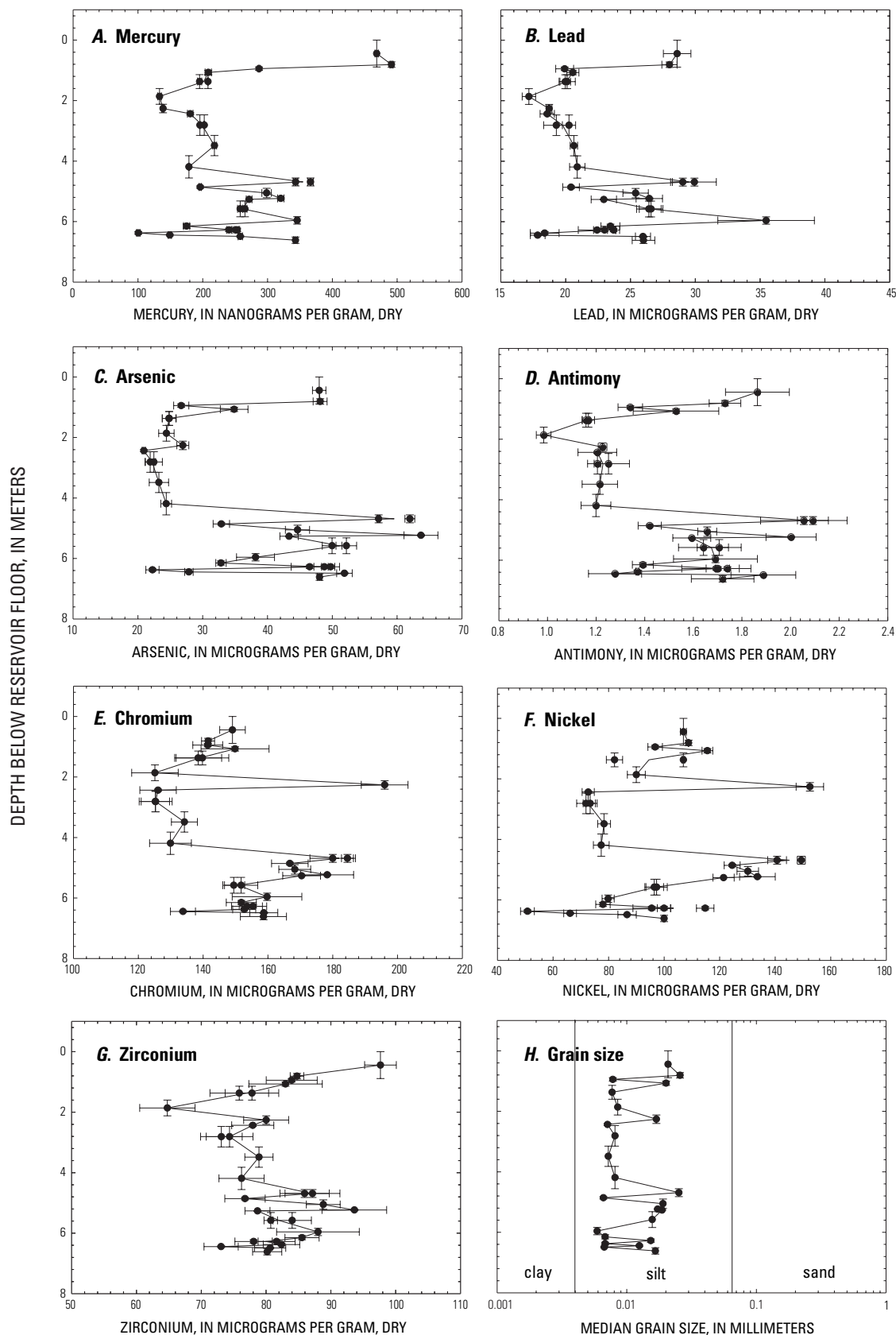
**Table 4.** Mercury and methylmercury data for shallow cores taken at Englebright Lake, California, October 2002—Continued.

[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. MeHg, methylmercury; Hg<sub>T</sub>, total mercury. cm, centimeter; ng/g, nanograms per gram; —, not determined]

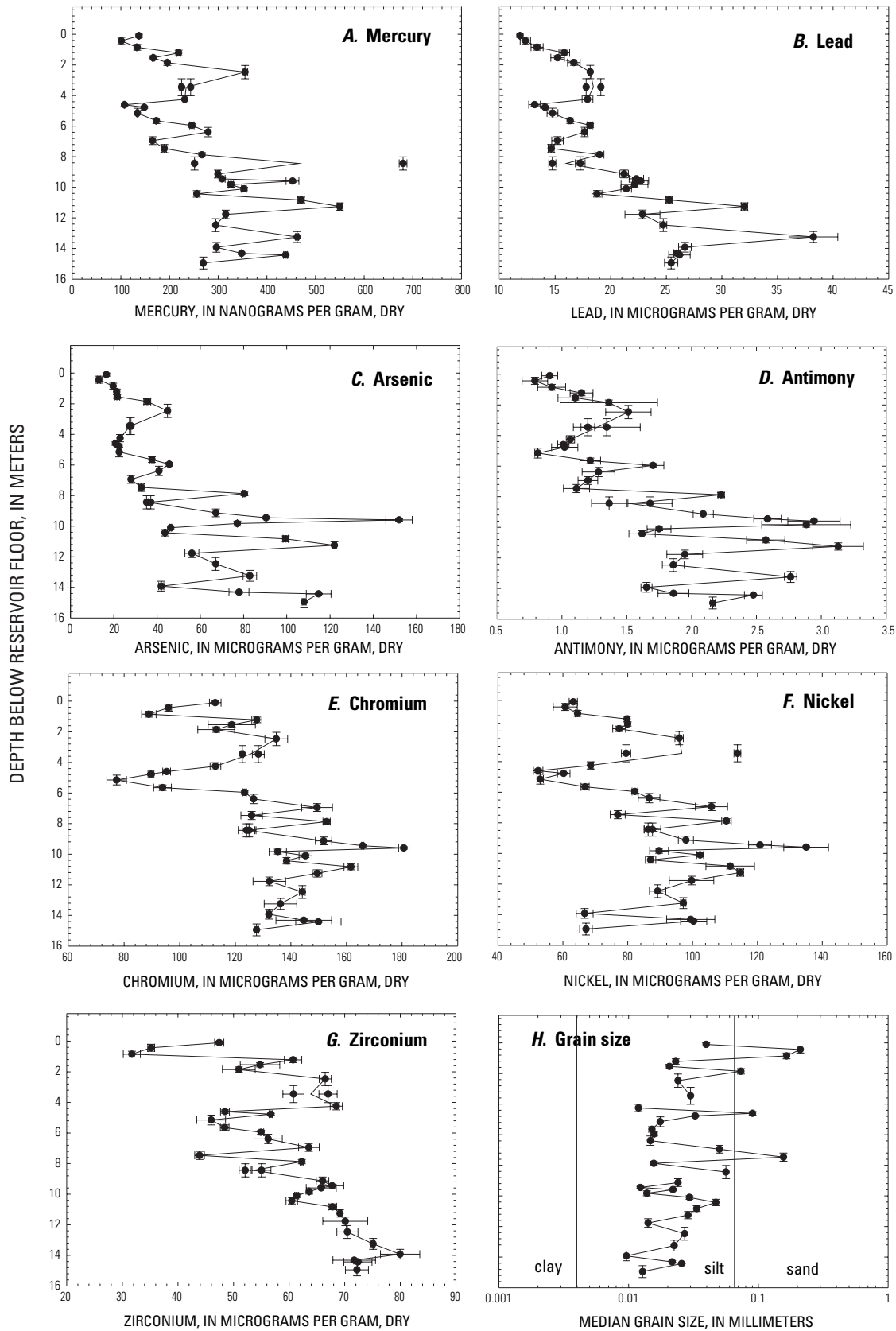
Site ID	Depth below lake floor (cm)	Lab ID	Core replicate	Lab replicate	Percent dry weight	Total mercury (ng/g dry)	Methylmercury (ng/g dry)	Ratio of MeHg to Hg <sub>T</sub> (percentage)
11F-B	2–3	GS 233		1 of 2	48.3	265	0.47	0.18
11F-B	2–3	GS 233		2 of 2	48.3	—	0.48	—
11F-B	3–4	GS 234			51.1	240	0.37	0.16
11F-B	4–8	GS 235		1 of 2	50.2	269	0.46	0.17
11F-B	4–8	GS 235		2 of 2	50.2	264	—	—
11F-B	8–9	GS 236			51.1	218	0.32	0.14
11G-B	0–4	GS 237			42.8	246	0.68	0.28
11G-B	4–8	GS 238			49.9	251	0.32	0.13
11G-B	8–12	GS 239			48.8	244	0.48	0.20
12A-B	0–4	GS 240			36.5	245	1.4	0.58
12A-B	4–8	GS 241			48.1	248	1.4	0.55
12A-B	8–10	GS 242			49.7	251	0.63	0.25
12B-B	0–2	GS 243			39.1	174	0.75	0.43
12B-B	2–4	GS 244			50.4	240	0.87	0.36
12B-B	4–7.5	GS 245			57.1	184	0.45	0.25
12C-B	0–2	GS 246			47.6	243	1.0	0.41
12C-B	2–4	GS 247		1 of 2	61.6	148	0.73	0.49
12C-B	2–4	GS 247		2 of 2	61.6	—	0.75	—
12C-B	4–5.5	GS 248		1 of 2	69.0	91.4	0.52	0.57
12C-B	4–5.5	GS 248		2 of 2	69.0	101	—	—
12D-B	0–2	GS 249			44.8	201	1.2	0.60
12D-B	2–4	GS 250			52.3	228	1.2	0.54
12D-B	4–7	GS 251			59.1	139	0.95	0.68
12E-B	2–4	GS 252			51.9	175	1.3	0.75
12E-B	4–6	GS 253			54.0	204	0.93	0.45
13-B	0–4	GS 254			39.4	230	0.80	0.35
13-B	4–8	GS 255			49.5	240	0.41	0.17
13-B	8–12	GS 256			53.0	226	0.49	0.22
14-B	0–4	GS 257			32.9	225	0.69	0.31
14-B	4–8	GS 258		1 of 2	43.7	241	0.62	0.26
14-B	4–8	GS 258		2 of 2	43.7	—	0.70	—
14-B	8–12	GS 259			47.8	233	0.81	0.35
15-B	0–4	GS 260			31.4	263	1.0	0.39
15-B	4–8	GS 261			43.0	281	1.2	0.44
15-B	8–12	GS 262			47.9	261	1.2	0.48
16-B	0–4	GS 263			31.8	267	0.56	0.21
16-B	4–8	GS 264			46.8	258	1.4	0.54
17-B	0–4	GS 265			38.0	220	0.43	0.20

**Table 4.** Mercury and methylmercury data for shallow cores taken at Englebright Lake, California, October 2002—Continued.[Analyses by Battelle Marine Sciences Laboratory, Sequim, Wash. MeHg, methylmercury; Hg<sub>T</sub>, total mercury. cm, centimeter; ng/g, nanograms per gram; —, not determined]

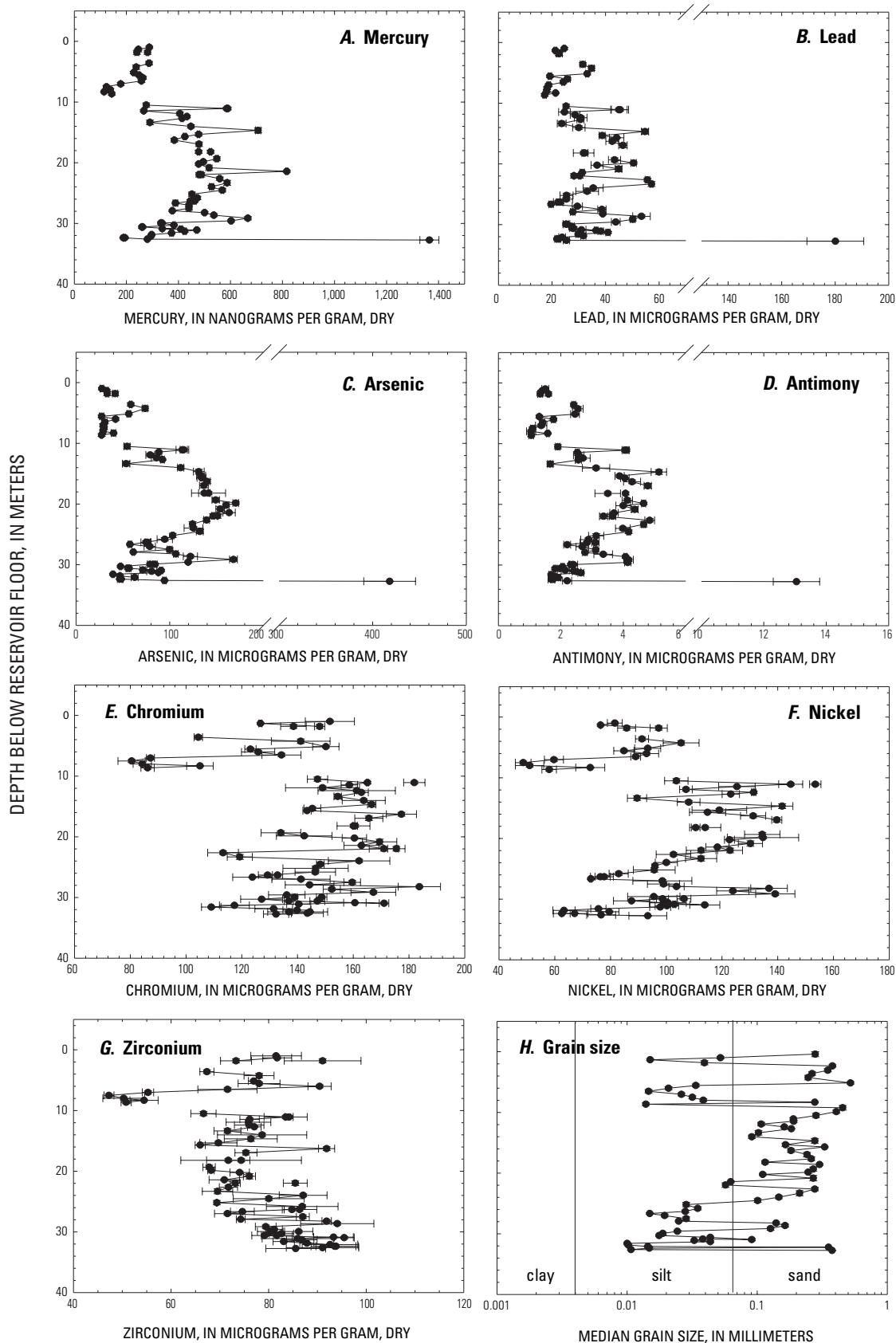
Site ID	Depth below lake floor (cm)	Lab ID	Core replicate	Lab replicate	Percent dry weight	Total mercury (ng/g dry)	Methylmercury (ng/g dry)	Ratio of MeHg to Hg <sub>T</sub> (percentage)
17-B	4–8	GS 266			48.9	220	0.47	0.21
17-B	8–10	GS 267		1 of 2	53.5	200	0.43	0.22
17-B	8–10	GS 267		2 of 2	53.5	197	—	—
18-B	0–4	GS 268			30.6	253	1.6	0.64
18-B	4–8	GS 269			40.6	257	1.2	0.47
18-B	8–12	GS 270			52.8	334	0.87	0.26
19-B	0–4	GS 271			38.5	241	2.3	0.96
19-B	4–8	GS 272		1 of 2	51.0	232	1.8	0.78
19-B	4–8	GS 272		2 of 2	51.0	—	1.7	—
19-B	8–10	GS 273			51.5	219	1.8	0.82
23A-B	0–1	GS 274			32.3	176	1.1	0.62
23A-B	1–2	GS 275			38.3	428	1.1	0.26
23A-B	2–3	GS 276			38.5	261	1.3	0.48
23A-B	3–4	GS 277			41.6	257	1.3	0.50
23A-B	4–8	GS 278			47.1	258	0.89	0.34
23A-B	8–10	GS 279			56.2	3,430	1.4	0.040
23A-B	0–4	GS 280			45.4	—	1.4	—
12E-B	0–2	GS-282		1 of 2	47.5	216	1.2	0.56
12E-B	0–2	GS-282		2 of 2	47.5	—	1.0	—



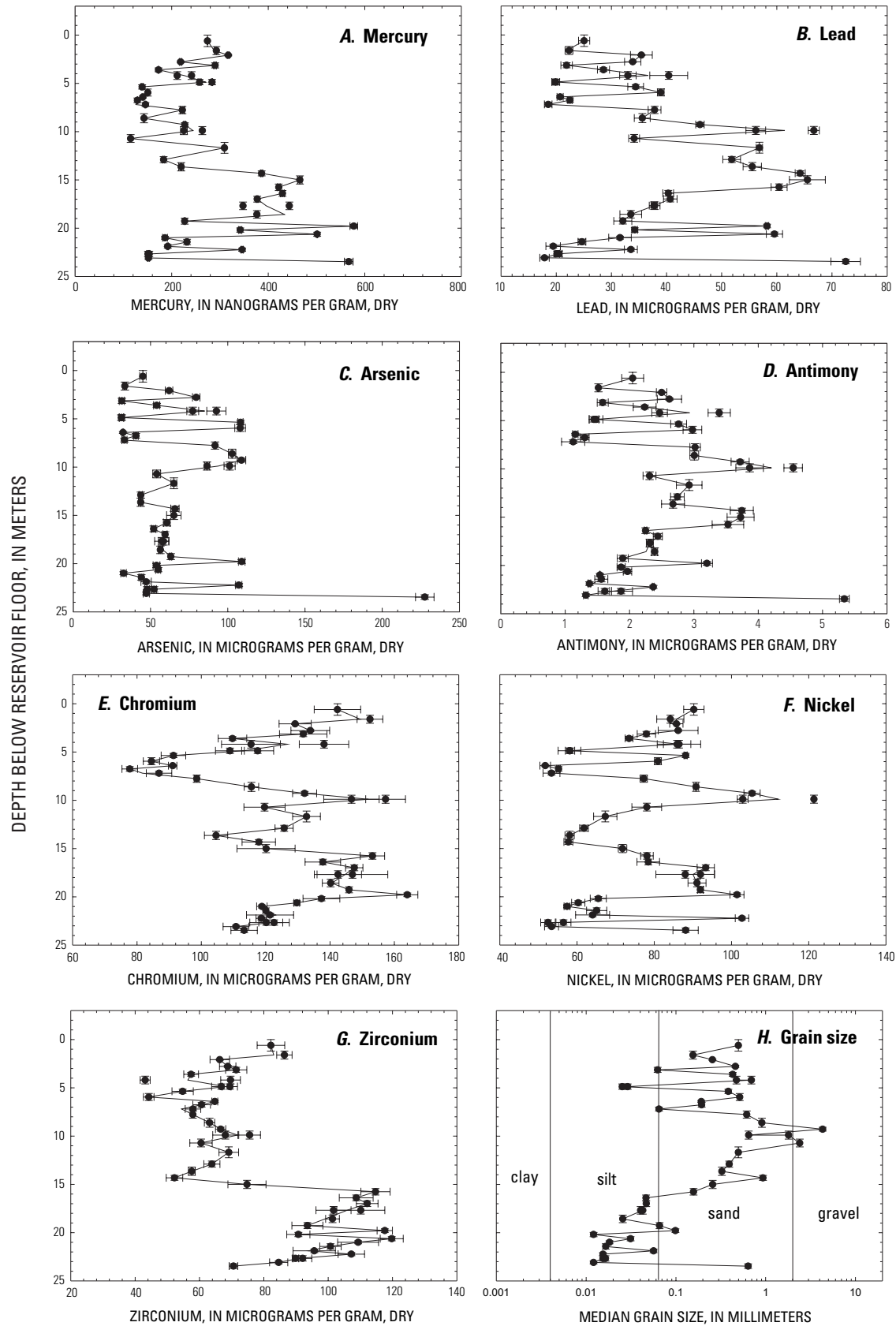
**Figure 4.** Deep coring profiles showing concentrations of trace metals and median grain size in sieved sediment subsamples (Y-series) from site 1 at Englebright Lake, California, May–June, 2002: (A) Mercury, (B) Lead, (C) Arsenic, (D) Antimony, (E) Chromium, (F) Nickel, (G) Zirconium, and (H) Median grain size. Grain-size data from Snyder and others (2004b). Lines represent vertical trends of concentration values. Horizontal error bars represent standard deviation of multiple analyses. Vertical bars show depth intervals. Sieve size 0.06 millimeter.



**Figure 5.** Deep coring profiles showing concentrations of trace metals and median grain size in unsieved sediment subsamples (Y-series) from site 4 at Englebright Lake, California, May–June, 2002: (A) Mercury, (B) Lead, (C) Arsenic, (D) Antimony, (E) Chromium, (F) Nickel, (G) Zirconium, and (H) Median grain size. Grain-size data from Snyder and others (2004b). Lines represent vertical trends of concentration values. Horizontal error bars represent standard deviation of multiple analyses. Vertical bars show depth intervals.

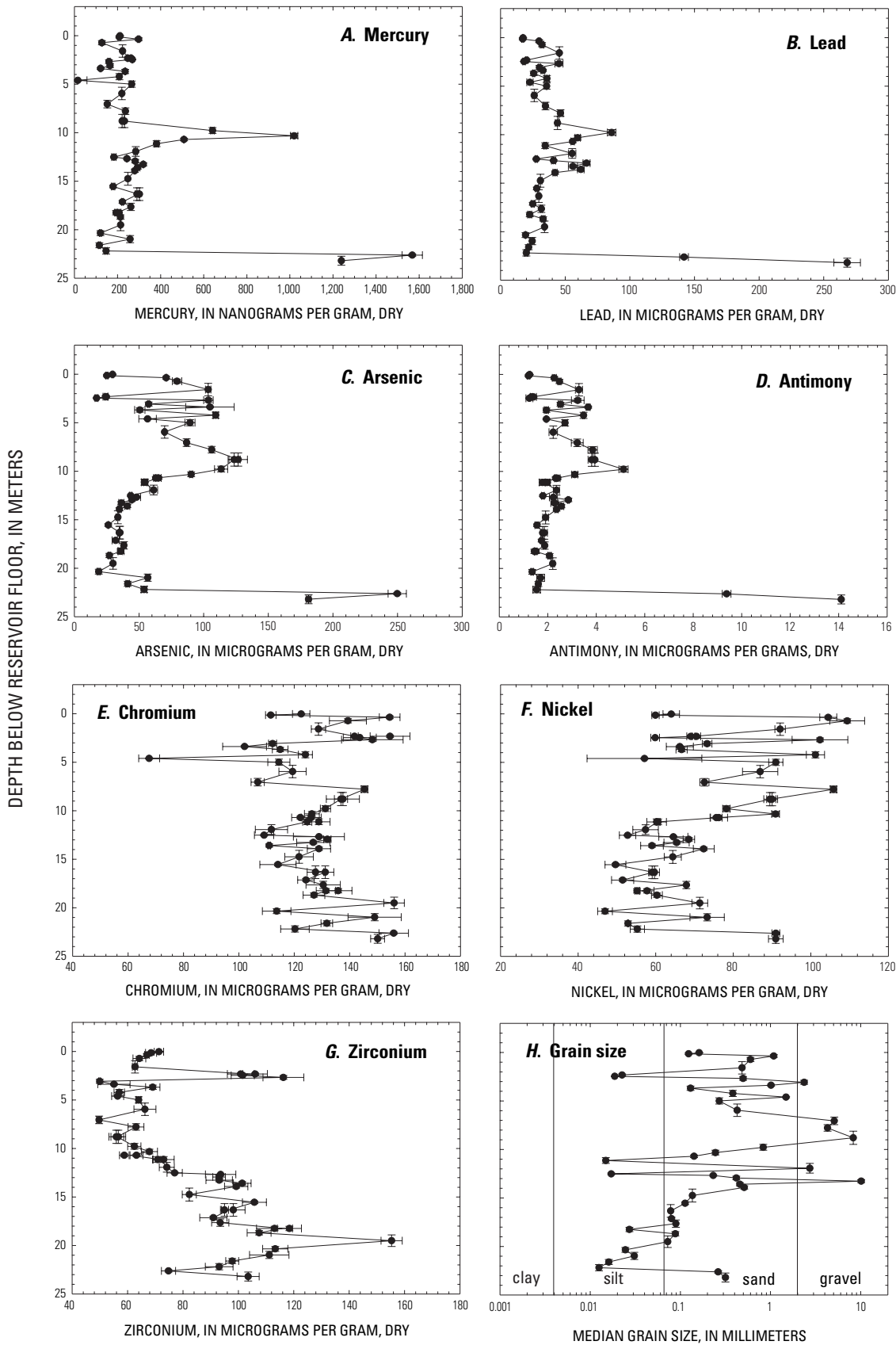


**Figure 6.** Deep coring profiles showing concentrations of trace metals and median grain size in sieved sediment subsamples (Y-series) from site 7 at Englebright Lake, California, May–June, 2002: (A) Mercury, (B) Lead, (C) Arsenic, (D) Antimony, (E) Chromium, (F) Nickel, (G) Zirconium, and (H) Median grain size. Grain-size data from Snyder and others (2004b). Lines represent vertical trends of concentration values. Horizontal error bars represent standard deviation of multiple analyses. Vertical bars show depth intervals. Sieve size 0.06 millimeter.

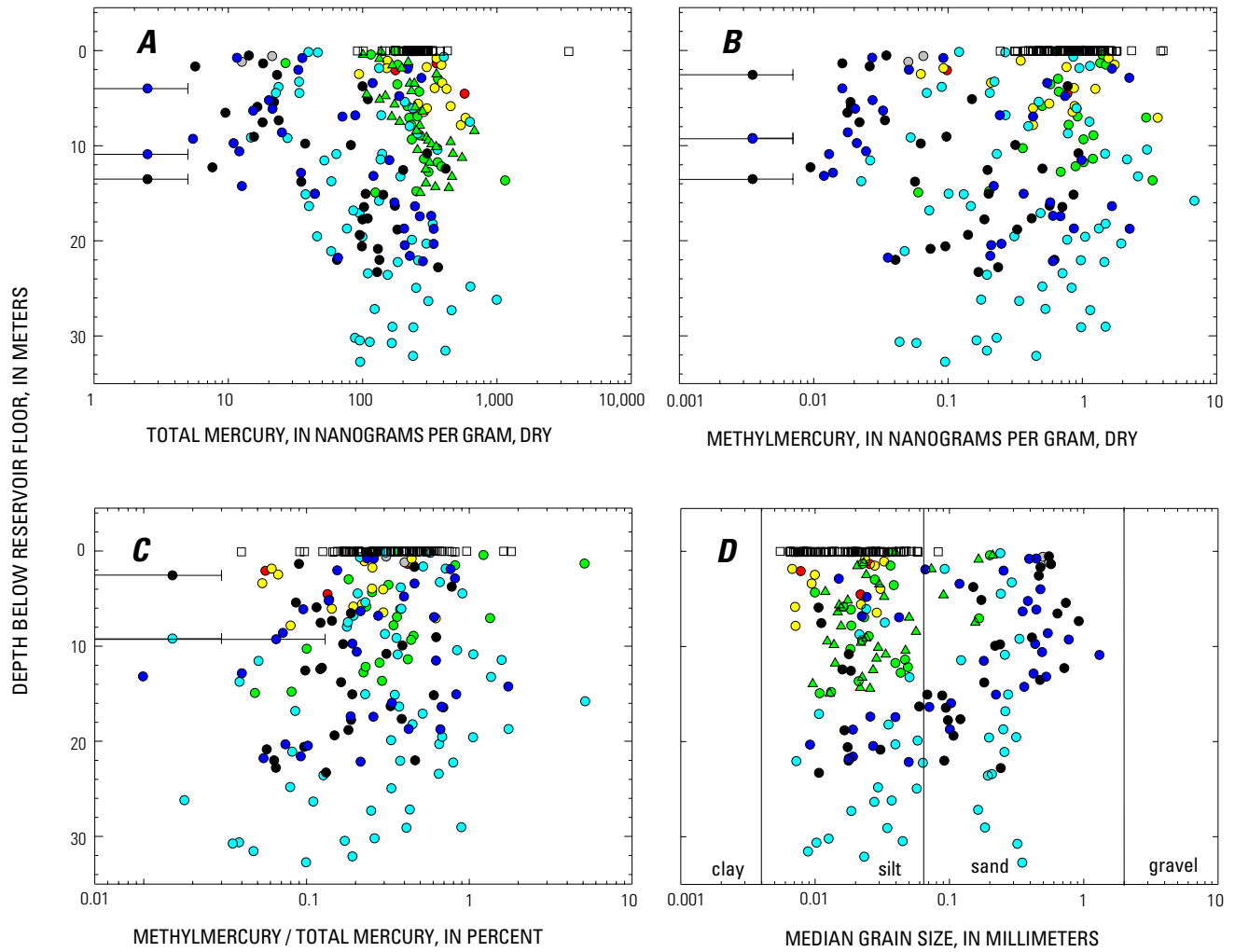


**Figure 7.** Deep coring profiles showing concentrations of trace metals and median grain size in sieved sediment subsamples (Y-series) from site 9 at Englebright Lake, California, May–June, 2002: (A) Mercury, (B) Lead, (C) Arsenic, (D) Antimony, (E) Chromium, (F) Nickel, (G) Zirconium, and (H) Median grain size. Grain-size data from Snyder and others (2004b). Lines represent vertical trends of concentration values. Horizontal error bars represent standard deviation of multiple analyses. Vertical bars show depth intervals. Sieve size 0.06 millimeter.





**Figure 8.** Deep coring profiles showing concentrations of trace metals and median grain size in sieved sediment subsamples (Y-series) from site 8 at Englebright Lake, California, May–June, 2002: (A) Mercury, (B) Lead, (C) Arsenic, (D) Antimony, (E) Chromium, (F) Nickel, (G) Zirconium, and (H) Median grain size. Grain-size data from Snyder and others (2004b). Lines represent vertical trends of concentration values. Horizontal error bars represent standard deviation of multiple analyses. Vertical bars show depth intervals. Sieve size 0.06 millimeter.



**EXPLANATION**

- Shallow cores: □ Sites 10–19, 23
- Deep cores: MEM-series: downstream 1 (red), 6 (yellow), 4 (green), 7 (cyan), 9 (blue), 8 (black), 2 (grey) upstream
- Y-series: ▲ (green triangle)

**Figure 9.** Plots showing relations with depth for unsieved sediment subsamples (shallow cores and selected deep cores) at Englebright Lake, California, May–June, 2002: (A) Total mercury, (B) Methylmercury, (C) Ratio of methylmercury to total mercury, and (D) Median grain size. Results less than detection limit are indicated by a symbol at half the detection limit and an error bar from the axis to the detection limit. Vertical lines separate grain-size data into categories of clay, silt, sand, and gravel. Grain-size data from Snyder and others (2004b).

**Table 5.** Statistical data showing longitudinal variation in mercury and methylmercury concentrations in sediments collected during 2002 from Englebright Lake, California.

[Replicate analyses averaged before statistical computations. SD, standard deviation; n, number of analyses. ng/g, nanogram per gram; <, less than; —, not determined]

<b>A. Total mercury concentration</b> (All values in ng/g, dry)												
	<b>Near dam</b>		→	<b>Mid-reservoir</b>						→	<b>Up-stream</b>	
<b>Shallow cores</b>												
<b>Site number</b>	<b>11</b>	<b>17</b>	<b>13</b>	<b>14</b>	<b>10</b>	<b>15</b>	<b>16</b>	<b>23, 18</b>	<b>12</b>	<b>19</b>	<b>All shallow</b>	
minimum	212	199	226	225	224	261	258	176	96	219	96	
maximum	338	220	240	241	307	281	267	3,430	251	241	3,430	
median	248	220	230	233	265	263	263	258	204	232	245	
mean	258	213	232	233	270	268	263	628	200	231	288	
SD	36	12	7	8	24	11	6	1,050	47	11	368	
n	23	3	3	3	12	3	2	9	15	3	76	
<b>Deep cores</b>												
<b>MEM Series</b>	<b>1</b>	<b>6</b>	<b>4</b>	<b>7</b>	<b>9</b>	<b>8</b>	<b>2</b>	<b>All MEM Series</b>				
<b>Site number</b>	<b>1</b>	<b>6</b>	<b>4</b>	<b>7</b>	<b>9</b>	<b>8</b>	<b>2</b>					
minimum	176	94	27	15	<5	<5	13	<5				
maximum	575	584	1150	997	338	365	21	1,150				
median	355	344	245	135	80	97	17	137				
mean	369	334	281	185	122	97	17	182				
SD	200	138	213	180	113	93	6	172				
n	3	15	22	56	34	34	2	166				
<b>Y Series</b>	<b>1</b>	<b>6</b>	<b>4</b>	<b>7</b>	<b>9</b>	<b>8</b>	<b>All Y Series</b>					
<b>Site number</b>	<b>1</b>	<b>6</b>	<b>4</b>	<b>7</b>	<b>9</b>	<b>8</b>						
<b>(S = sieved, &lt;0.060 mm)</b>	<b>S</b>			<b>S</b>	<b>S</b>	<b>S</b>						
minimum	101	—	101	114	115	16	16					
maximum	491	—	550	1,360	577	1,090	1,360					
median	233	—	261	412	232	235	271					
mean	251	—	270	410	276	295	317					
SD	100	—	113	192	126	236	182					
n	24	—	34	62	39	43	202					
<b>B. Methylmercury concentration</b> (All values in ng/g, dry)												
	<b>Near Dam</b>		→	<b>Mid-reservoir</b>						→	<b>Up-stream</b>	
<b>Shallow cores</b>												
<b>Site number</b>	<b>11</b>	<b>17</b>	<b>13</b>	<b>14</b>	<b>10</b>	<b>15</b>	<b>16</b>	<b>23, 18</b>	<b>12</b>	<b>19</b>	<b>All shallow</b>	
minimum	0.32	0.43	0.41	0.66	0.60	1.0	0.56	0.87	0.45	1.7	0.32	
maximum	4.0	0.47	0.80	0.81	1.5	1.2	1.4	1.6	1.4	2.3	4.0	
median	0.52	0.43	0.49	0.69	0.91	1.2	0.98	1.3	0.95	1.8	0.86	
mean	0.86	0.44	0.57	0.72	0.92	1.1	0.98	1.2	0.96	1.9	0.96	
SD	1.00	0.02	0.21	0.08	0.24	0.12	0.59	0.23	0.31	0.32	0.64	
n	23	3	3	3	12	3	2	10	15	3	77	

**Table 5.** Statistical data showing longitudinal variation in mercury and methylmercury concentrations in sediments collected during 2002 from Englebright Lake, California—Continued.

[Replicate analyses averaged before statistical computations. SD, standard deviation; n, number of analyses. ng/g, nanogram per gram; &lt;, less than; —, not determined]

<b>B. Methylmercury concentration—Continued</b> (All values in ng/g, dry)											
	Near Dam		Mid-reservoir						Up-stream		
	→							→			
<b>Deep cores</b>											
MEM Series Site number	1	6	4	7	9	8	2	All MEM Series			
minimum	0.098	0.063	0.060	<0.007	<0.007	<0.007	0.051	<0.007			
maximum	1.5	3.6	3.3	6.8	2.3	0.97	0.065	6.8			
median	0.77	0.76	0.90	0.43	0.22	0.12	0.058	0.37			
mean	0.79	1.0	1.0	0.77	0.47	0.24	0.058	0.64			
SD	0.70	0.92	0.78	1.1	0.63	0.28	0.010	0.84			
n	3	15	22	56	34	34	2	166			
<b>C. Ratio of methylmercury to total mercury</b> (All values in percent)											
	Near Dam		Mid-reservoir						Up-stream		
	→							→			
<b>Shallow cores</b>											
Site number	11	17	13	14	10	15	16	23, 18	12	19	All shallow
minimum	0.11	0.20	0.17	0.27	0.21	0.39	0.21	0.04	0.25	0.75	0.04
maximum	1.8	0.22	0.35	0.35	0.51	0.48	0.54	0.64	0.75	0.96	1.8
median	0.20	0.21	0.22	0.31	0.34	0.44	0.38	0.47	0.52	0.82	0.33
mean	0.35	0.21	0.24	0.31	0.34	0.44	0.38	0.40	0.49	0.84	0.40
SD	0.44	0.01	0.09	0.04	0.08	0.05	0.23	0.19	0.14	0.11	0.28
n	23	3	3	3	12	3	2	9	15	3	76
<b>Deep cores</b>											
MEM Series Site number	1	6	4	7	9	8	2	All MEM Series			
minimum	0.060	0.050	0.050	<0.03	<0.03	<0.13	0.31	<0.03			
maximum	0.42	0.62	5.1	5.2	1.7	0.78	0.40	5.2			
median	0.13	0.23	0.33	0.34	0.22	0.16	0.36	0.25			
mean	0.20	0.25	0.62	0.51	0.35	0.24	0.36	0.41			
SD	0.19	0.17	1.06	0.74	0.35	0.20	0.064	0.62			
n	3	15	22	56	32	33	2	163			

**Table 6.** Statistical data showing vertical variation in the mercury and methylmercury concentrations of sediments collected during 2002 from Englebright Lake, California.

[Replicate analyses averaged before statistical computations. blf, below lake floor; SD, standard deviation; n, number of analyses. ng/g, nanograms per gram; cm, centimeter; m, meter; mm, millimeter; >, greater than. 0–4 cm (0–4), intervals exactly 0–4 cm blf; 0–4 cm (all), all intervals within 0–4 cm blf including 0–1, 1–2, 0–2, 2–3, 3–4, 2–4, and 0–4 cm blf]

<b>A. Total mercury concentration</b>										
<b>(All values in ng/g, dry)</b>										
<b>Shallow cores (all sites)</b>							<b>All</b>			
<b>Depth (blf)</b>	<b>0–2 cm</b>	<b>2–4 cm</b>	<b>0–4 cm</b>	<b>0–4 cm</b>	<b>4–8 cm</b>	<b>8–12 cm</b>	<b>0–12 cm</b>			
<b>(Intervals, cm blf)</b>	<b>(0–1, 1–2, 0–2)</b>	<b>(2–3, 3–4, 2–4)</b>	<b>(0–4)</b>	<b>(all)</b>	<b>(all)</b>	<b>(all)</b>	<b>(all)</b>			
minimum	174	148	220	148	96	199	96			
maximum	428	303	307	428	338	3,430	3,430			
median	247	258	246	249	245	246	247			
mean	262	246	250	252	233	446	288			
SD	74	45	23	50	49	796	368			
n	12	12	15	39	22	16	77			
<b>Deep cores: MEM-Series (all sites)</b>										
<b>Depth (blf)</b>	<b>0–3 m</b>	<b>3–6 m</b>	<b>6–9 m</b>	<b>9–12 m</b>	<b>12–15 m</b>	<b>15–18 m</b>	<b>18–21 m</b>	<b>21–24 m</b>	<b>&gt;24 m</b>	<b>All MEM Series</b>
minimum	6	<5	10	<5	<5	38	46	58	88	<5
maximum	402	575	630	363	1,150	324	338	365	997	1,150
median	133	151	228	73	125	105	193	144	224	137
mean	149	183	212	133	214	128	192	169	292	182
SD	132	168	183	134	288	83	104	97	250	172
n	29	22	22	20	15	17	14	12	15	166
<b>B. Methylmercury concentration</b>										
<b>(All values in ng/g, dry)</b>										
<b>Shallow cores (all sites)</b>							<b>All</b>			
<b>Depth (blf)</b>	<b>0–2 cm</b>	<b>2–4 cm</b>	<b>0–4 cm</b>	<b>0–4 cm</b>	<b>4–8 cm</b>	<b>8–12 cm</b>	<b>0–12 cm</b>			
<b>(Intervals, cm blf)</b>	<b>(0–1, 1–2, 0–2)</b>	<b>(2–3, 3–4, 2–4)</b>	<b>(0–4)</b>	<b>(all)</b>	<b>(all)</b>	<b>(all)</b>	<b>(all)</b>			
minimum	0.69	0.37	0.40	0.37	0.32	0.32	0.32			
maximum	1.5	1.3	4.0	4.0	3.8	1.8	4.0			
median	1.1	0.87	0.80	1.0	0.69	0.59	0.86			
mean	1.0	0.89	1.2	1.1	0.91	0.76	0.96			
SD	0.21	0.32	0.95	0.63	0.76	0.41	0.64			
n	12	12	15	39	22	16	77			
<b>Deep cores: MEM-Series (all sites)</b>										
<b>Depth (blf)</b>	<b>0–3 m</b>	<b>3–6 m</b>	<b>6–9 m</b>	<b>9–12 m</b>	<b>12–15 m</b>	<b>15–18 m</b>	<b>18–21 m</b>	<b>21–24 m</b>	<b>&gt;24 m</b>	<b>All MEM Series</b>
minimum	<0.007	0.016	0.018	<0.007	<0.007	0.072	0.080	0.036	0.042	<0.007
maximum	2.3	1.3	3.6	3.0	3.3	6.8	2.3	1.5	1.5	6.8
median	0.35	0.49	0.43	0.28	0.20	0.49	0.55	0.23	0.34	0.37
mean	0.68	0.44	0.75	0.65	0.59	0.86	0.80	0.44	0.48	0.64
SD	0.70	0.36	0.92	0.83	1.0	1.58	0.47	0.44	0.44	0.84
n	29	22	22	20	15	17	14	12	15	166

**Table 6.** Statistical data showing vertical variation in the mercury and methylmercury concentrations of sediments collected during 2002 from Englebright Lake, California—Continued.

[Replicate analyses averaged before statistical computations. blf, below lake floor; SD, standard deviation; n, number of analyses. ng/g, nanograms per gram; cm, centimeter; m, meter; mm, millimeter; >, greater than. 0–4 cm (0–4), intervals exactly 0–4 cm blf; 0–4 cm (all), all intervals within 0–4 cm blf including 0–1, 1–2, 0–2, 2–3, 3–4, 2–4, and 0–4 cm blf]

<b>C. Ratio of Methylmercury to Total Mercury (All values in percent)</b>										
<b>Shallow cores (all sites)</b>										<b>All</b>
<b>Depth (blf)</b>	<b>0–2 cm</b>	<b>2–4 cm</b>	<b>0–4 cm</b>	<b>0–4 cm</b>	<b>4–8 cm</b>	<b>8–12 cm</b>				
<b>(Intervals, cm blf)</b>	<b>(0–1, 1–2, 0–2)</b>	<b>(2–3, 3–4, 2–4)</b>	<b>(0–4)</b>	<b>(all)</b>	<b>(all)</b>	<b>(all)</b>	<b>0–12 cm</b>			
							<b>(all)</b>			
minimum	0.21	0.16	0.17	0.16	0.11	0.04	0.04			
maximum	0.62	0.75	1.6	1.6	1.8	0.82	1.8			
median	0.41	0.34	0.33	0.38	0.33	0.24	0.33			
mean	0.42	0.38	0.48	0.43	0.41	0.28	0.40			
SD	0.12	0.17	0.40	0.27	0.36	0.18	0.28			
n	12	12	15	39	22	16	77			
<b>Deep cores: MEM-Series (all sites)</b>										
<b>Depth (blf)</b>	<b>0–3 m</b>	<b>3–6 m</b>	<b>6–9 m</b>	<b>9–12 m</b>	<b>12–15 m</b>	<b>15–18 m</b>	<b>18–21 m</b>	<b>21–24 m</b>	<b>&gt;24 m</b>	<b>All MEM Series</b>
minimum	<0.03	0.053	0.071	<0.03	0.010	0.085	0.062	0.054	0.018	<0.03
maximum	5.1	0.91	1.3	1.6	1.7	5.2	1.7	0.80	0.89	5.2
median	0.31	0.23	0.25	0.36	0.14	0.37	0.37	0.13	0.17	0.25
mean	0.55	0.31	0.32	0.43	0.33	0.68	0.47	0.26	0.22	0.41
SD	0.92	0.23	0.28	0.39	0.53	1.2	0.47	0.25	0.23	0.62
n	29	21	22	19	14	17	14	12	15	163

**Table 7.** Statistical data showing longitudinal variation in concentrations of select trace metals in sediments collected during 2002 from Englebright Lake, California.

[Replicate analyses averaged before statistical computations. S, sieved (<0.060 millimeter [mm]); SD, standard deviation; n, number of analyses. µg/g, microgram per gram; mm, millimeter; <, less than, —, not determined]

Deep Cores: Y Series	Near Dam	→	Mid-reservoir	→	Upstream		
<b>A. Lead concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	17	—	12	17	18	17	12
maximum	35	—	38	180	72	268	268
median	22	—	18	31	34	33	28
mean	23	—	20	35	38	44	33
SD	5	—	6	21	15	41	25
n	24	—	34	62	39	43	202
<b>B. Arsenic concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	21	—	13	27	31	17	13
maximum	64	—	152	418	228	250	418
median	34	—	43	87	58	54	55
mean	37	—	54	94	67	65	69
SD	13	—	35	60	36	45	48
n	24	—	34	62	39	43	202
<b>C. Antimony concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	1.0	—	0.8	1.0	1.1	1.2	0.8
maximum	2.1	—	3.1	13	5.3	14	14
median	1.5	—	1.6	2.6	2.3	2.2	2.1
mean	1.5	—	1.7	3.0	2.4	2.8	2.4
SD	0.3	—	0.7	1.7	0.9	2.2	1.6
n	24	—	34	62	39	43	202

**Table 7.** Statistical data showing longitudinal variation in concentrations of select trace metals in sediments collected during 2002 from Englebright Lake, California—Continued.

[Replicate analyses averaged before statistical computations. S, sieved (<0.060 millimeter [mm]); SD, standard deviation; n, number of analyses. µg/g, microgram per gram; mm, millimeter; <, less than, —, not determined]

Deep Cores: Y Series	Near Dam	→	Mid-reservoir	→	Upstream		
<b>D. Chromium concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	125	—	77	80	78	68	68
maximum	196	—	181	184	164	156	196
median	150	—	130	144	123	127	134
mean	151	—	129	142	123	127	134
SD	19	—	24	23	21	17	23
n	24	—	34	62	39	43	202
<b>E. Nickel concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	51	—	52	49	52	47	47
maximum	152	—	135	149	112	109	152
median	97	—	87	100	78	68	87
mean	99	—	87	101	77	72	87
SD	26	—	20	24	17	17	24
n	24	—	34	62	39	43	202
<b>F. Zirconium concentration (All values in µg/g, dry)</b>							
Site number	1	6	4	7	9	8	All Y Series
	S			S	S	S	
minimum	65	—	32	47	44	50	32
maximum	98	—	80	96	120	155	155
median	80	—	63	78	71	77	75
mean	81	—	60	78	79	83	77
SD	7	—	11	11	22	23	18
n	24	—	34	62	39	43	202



Subsamples from shallow box cores taken at ten sampling sites in Englebright Lake (figs. 2, 3) were analyzed for  $Hg_T$  and MeHg (table 4). Variations in the spatial distribution of  $Hg_T$ , MeHg, and MeHg/ $Hg_T$  in subsamples from shallow and deep cores are summarized in tables 5 (longitudinal variation, along the long axis of the reservoir) and 6 (vertical variation). The columns in table 5 are arranged in upstream order from left to right. Median values of  $Hg_T$  in shallow box cores from all ten sites ranged from 204 to 265 ng/g, and all but one standard deviation was relatively small, indicating that nearly all concentration values were in the range of 200 to 300 ng/g. Median values of  $Hg_T$  in the MEM-series showed considerable longitudinal variation; highest median values were for sites 1 and 6 near the dam (355 and 344 ng/g, respectively); lowest median values were for the three most upstream sites (80, 97, and 17 ng/g for sites 9, 8, and 2, respectively); intermediate values were for the mid-reservoir sites (245 and 135 ng/g for sites 4 and 7, respectively). The longitudinal trend in median  $Hg_T$  concentration of unsieved subsamples from the deep cores follows the trend in median grain size;  $Hg_T$  concentrations increase as median grain size gets finer toward the dam (Snyder and others, 2004c).

Interpreting total mercury concentration in the Y-series subsamples will be complicated by the fact that only the fines (silt-clay) fraction was analyzed in profiles 1Y, 7Y, 8Y, and 9Y, whereas the whole sediment was analyzed in profile 4Y. The sieved material in profiles 7Y, 8Y, and 9Y had higher median concentrations of  $Hg_T$  (232–412 ng/g) than unsieved subsamples (MEM-series) from the same sites (80–135 ng/g) (table 5). The unsieved subsamples from profile 4Y had a median concentration of  $Hg_T$  (261 ng/g) which is comparable to the median value for MEM-series subsamples from this location (245 ng/g).

Methylmercury concentrations in shallow cores ranged from 0.32 to 4.0 ng/g; the median value was 0.86 ng/g. Median MeHg concentrations were low in box cores from the three sites nearest to Englebright Dam (sites 11, 17 and 13; 0.43 to 0.52 ng/g) compared with those for sites in the mid-reservoir and upstream areas (0.69 to 1.8 ng/g). In contrast, median MeHg concentrations in subsamples from the deep cores (MEM-series) were higher at sites near the dam (sites 1, 6 and 4; 0.76 to 0.90 ng/g) than at the mid-reservoir and upstream locations (sites 7, 9, 8, and 2; 0.058 to 0.43 ng/g).

The ratio MeHg/ $Hg_T$  (expressed as a percentage of  $Hg_T$ ) showed some similarity in the trends of longitudinal variation among shallow and deep subsamples (table 5). Lowest median values of MeHg/ $Hg_T$  were for the site closest to the dam for both the shallow cores (site 11; 0.20 percent) and the deep cores (site 1; 0.13 percent). Highest median values of MeHg/ $Hg_T$  were for shallow cores at the mid-reservoir and upstream sites (0.31 to 0.82 percent), and for deep cores at two mid-reservoir sites (0.33 and 0.34 percent) and the most upstream site (0.36 percent). However, the upstream sites were not uniformly high in values of MeHg/ $Hg_T$  in the deep cores, as sites 9 and 8 had median values of 0.22 and 0.16 percent, respectively.

The spatial variability of  $Hg_T$ , MeHg, and MeHg/ $Hg_T$  as a function of depth in the cores is summarized in table 6. There was little vertical variation in  $Hg_T$  within the top 12 cm sampled by the shallow cores, similar to the lack of longitudinal variation. In the deeper cores, vertical trends in the concentration of  $Hg_T$  were more apparent in the individual profiles (figs. 4A–8A) compared with the summary statistics based on absolute depth (table 6) because of the varying thickness of the bed sediments along the longitudinal axis of the reservoir. An analysis of reservoir stratigraphy using  $^{137}Cs$  dating (Snyder and others, in press) is providing additional insights into temporal variations in the deposition of Hg and other trace metals. The highest median concentration of MeHg was in the top 2 centimeters of the shallow box cores. Median concentrations of MeHg and median values of MeHg/ $Hg_T$  decreased with depth from 0–4 to 4–8 cm, and from 4–8 to 8–12 cm in the shallow cores (table 6). However, similar decreases were not systematic on a larger scale in the deep cores of the MEM series. The overall median of MeHg/ $Hg_T$  in the deep cores was 0.25 percent, not much less than the overall median value for the shallow cores (0.33 percent). The persistence of MeHg at depth in the sediments of Englebright Lake at median concentrations of 0.20 to 0.55 ng/g indicates either preservation of MeHg after burial and (or) an ongoing balance between rates of Hg methylation and MeHg demethylation in the subsurface.

## Trace and Major Elements

Chemical analyses of trace and major elements in Y-series subsamples (table B5) provide information on the sediment geochemistry at five locations in Englebright Lake. Depth profiles of lead, arsenic, antimony, chromium, nickel, and zirconium were plotted in figures 4B–G through 8B–G. An interpretation of these profiles in terms of the depositional history of Englebright Lake sediments will be published separately; therefore only a few features of the spatial distribution of trace elements are described here. Longitudinal variations in the silt and clay fraction of select trace metals from sites 1, 7, 9, and 8 were evaluated using statistical data compiled in table 7 and the plots in figures 4, 6, 7, and 8. (Data from site 4 were not used in this comparison because the subsamples were not sieved prior to analysis.)

Lead concentrations in subsamples from site 1 (near Englebright Dam) had a mean concentration of 23  $\mu g/g$  and a standard deviation of 5  $\mu g/g$ , and ranged from a minimum of 17  $\mu g/g$  to a maximum of 35  $\mu g/g$ . In contrast, lead concentrations at the three upstream sites (7, 9, and 8) had mean values of 35 to 44  $\mu g/g$  and much higher maximum values (72 to 268  $\mu g/g$ ). The maximum lead values at the three upstream sites were from the deepest interval in each of the profiles. Median lead concentrations at the three upstream sites (31 to 34  $\mu g/g$ ) were also higher than the median value at site 1 (22  $\mu g/g$ ).

The longitudinal variation of arsenic and antimony concentrations in the silt-clay fraction was similar to that of lead, in that concentrations were lower in subsamples from the site nearest the dam (site 1) compared with the three upstream locations (sites 7, 9, and 8; *table 7*). The mean value of arsenic concentration at site 1 was 37  $\mu\text{g/g}$  with a standard deviation of 13  $\mu\text{g/g}$  and a maximum value of 64  $\mu\text{g/g}$ . In contrast, the mean arsenic concentrations in subsamples from the three upper locations ranged from 65 to 94  $\mu\text{g/g}$ . Several subsamples from sites 7, 9, and 8 had arsenic concentrations greater than 100  $\mu\text{g/g}$ . The mean antimony concentration at site 1 was 1.5  $\mu\text{g/g}$  with a standard deviation of 0.3  $\mu\text{g/g}$ . At the three upstream sites, the mean antimony values ranged from 2.4 to 3.0  $\mu\text{g/g}$ . Like lead, maximum arsenic and antimony concentrations were in the deepest subsamples from each of the three upstream locations.

Longitudinal trends in concentrations of chromium and nickel are opposite those described for lead, arsenic, and antimony, in that the concentrations at the two sites located farthest upstream (sites 9 and 8) are generally lower than those from the two sites located relatively downstream (sites 1 and 7; *table 7*). Mean values ( $\pm$  standard deviation, SD) of chromium concentration were  $151 \pm 19$   $\mu\text{g/g}$  and  $142 \pm 23$   $\mu\text{g/g}$  at relatively downstream sites 1 and 7, respectively, whereas the mean values ( $\pm$  SD) were  $123 \pm 21$  and  $127 \pm 17$   $\mu\text{g/g}$  at the relatively upstream sites 9 and 8, respectively. Maximum values of chromium were also higher at sites 1 and 7 (196 and 184  $\mu\text{g/g}$  respectively) compared with those for sites 9 and 8 (164 and 156  $\mu\text{g/g}$ , respectively). Nickel concentrations followed a trend similar to that for chromium; mean values ( $\pm$  SD) at the upstream locations (sites 9 and 8) were  $77 \pm 17$   $\mu\text{g/g}$  and  $72 \pm 17$   $\mu\text{g/g}$ , respectively, compared with values from the downstream locations (sites 1 and 7) of  $99 \pm 26$   $\mu\text{g/g}$  and  $101 \pm 24$   $\mu\text{g/g}$ , respectively. Maximum concentrations of nickel were 112 and 109  $\mu\text{g/g}$  at sites 9 and 8, respectively, compared with 152 and 149  $\mu\text{g/g}$  at sites 1 and 7, respectively. The maximum concentrations of chromium and nickel were not located in the deepest intervals of sites 7, 9 and 8, in contrast to lead, arsenic, and antimony (*figs. 6–8*).

Mean concentrations of zirconium were in the relatively narrow range of 78 to 83  $\mu\text{g/g}$  at the four reservoir sites (1, 7, 9, and 8) where the silt-clay fraction was analyzed. Maximum values of zirconium concentration generally were in samples having relatively small median grain size. The maximum concentrations of zirconium at the upstream locations (sites 9 and

8) were 120 and 155  $\mu\text{g/g}$ , respectively, whereas maximum concentrations at the more downstream locations were lower (98 and 96  $\mu\text{g/g}$  at sites 1 and 7, respectively). Zirconium occurs primarily in the mineral zircon ( $\text{ZrSiO}_3$ ), which tends to be silt-sized.

## Mercury Methylation Potential

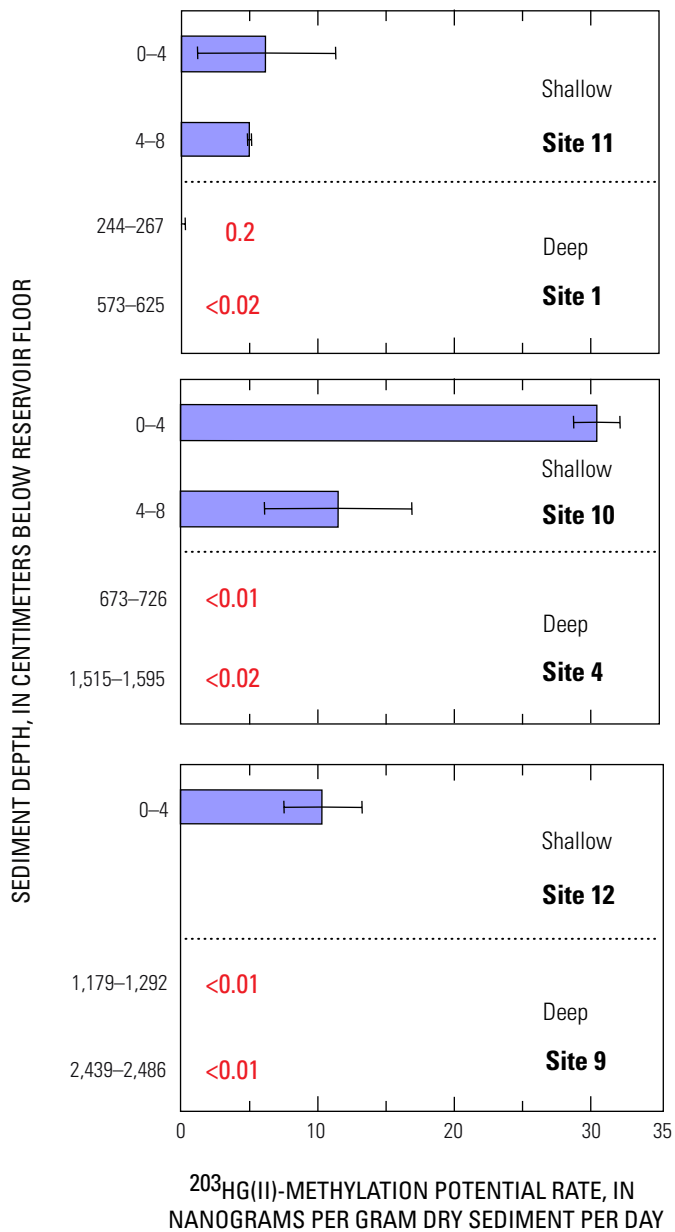
Results from radiotracer measurements of  $^{203}\text{Hg(II)}$ -methylation potential rates for shallow and deep sediments from Englebright Lake are shown in *table 8* and *figure 10*. Potential rates of microbial MeHg production in shallow sediments averaged about one percent per day (percent/d), whereas in deeper sediments, the rate was less than detection (0.01 percent/d) in five of six samples and 0.08 percent/d in the other. Shallow sediments also had higher average values of weight loss on ignition (a proxy for organic content) and porosity, significantly higher concentrations of most solid-phase Fe species, and lower dry weight (equivalent to a higher moisture content) than deeper sediments (*table 9*).

Sulfate reduction (SR) is the microbial process thought to be most responsible for Hg methylation in anoxic sediments (Gilmour and others, 1992), although iron-reducing bacteria may play a role in some environmental settings, such as Clear Lake, California (Fleming and others, 2006). The presence of active microbial SR in the shallow sediments (*table 9*), along with the high Hg-methylation rates in this zone (*table 8*), support this generally held view. Although we did not measure SR rates in deep sediments, very low Hg-methylation rates observed in the deep cores would be consistent with low rates of SR. Below a depth of 10–50 cm in freshwater systems, it is quite common for SR to become limited as pore-water sulfate, the primary electron acceptor for this process, becomes depleted. The low measured concentrations of amorphous Fe(III) (*table 9*), needed to fuel microbial Fe(III)-reduction, indicates that important electron acceptors needed to drive anaerobic microbial processes are limiting in deeper sediments of Englebright Lake. Loss on ignition values were higher in shallow sediments than deeper sediments at two of the three sites (deep sites 4 and 9 corresponding to shallow sites 10 and 12, respectively); data for the third site (deep site 1 corresponding to shallow site 11) are equivocal (*table 9*).

**Table 8.** Whole-sediment  $^{203}\text{Hg}(\text{II})$ -methylation rate constants and calculated potential rates for shallow and deep sediments (MP series) from Englebright Lake, California, 2002.

[Each value for rate constant and potential rate (in bold) represents the mean of two incubated samples (kill corrected); absolute deviation for each measurement given in parentheses.  $^{203}\text{Hg}(\text{II})$ , mercury-203 radiotracer divalent inorganic mercury; SD, standard deviation. cm, centimeter; %/d, percent per day; ng/g dry sed/d, nanogram per gram dry sediment per day; <, less than detection limit.  $^{203}\text{Hg}$ -kmeth or kmeth, whole-sediment  $^{203}\text{Hg}(\text{II})$ -methylation rate constant expressed as percentage of  $^{203}\text{Hg}(\text{II})$  converted to  $\text{CH}_3^{203}\text{Hg}$  per day, calculated as  $[\text{kmeth} = \ln(1-\text{fm})/t \cdot 100]$ ; fm, fraction of added  $^{203}\text{Hg}(\text{II})$  converted to  $\text{CH}_3^{203}\text{Hg}$ ; t, incubation time. Whole-sediment  $^{203}\text{Hg}(\text{II})$ -methylation potential (MP) rate calculated as  $\text{MP} = \text{Hgd}_s - \text{Hgd}_s \cdot e^{-(\text{kmeth} \cdot t)}$ ;  $\text{Hgd}_s$ , concentration of radiotracer  $^{203}\text{Hg}(\text{II})$  per gram dry sediment]

Site	Depth interval (cm)	Whole-sediment $^{203}\text{Hg}(\text{II})$ -methylation rate constant, $^{203}\text{Hg}$ -kmeth (%/d)		Whole-sediment $^{203}\text{Hg}(\text{II})$ -methylation potential rate (ng/g dry sed/d)	
		Kill-corrected average	Absolute deviation	Kill-corrected average	Absolute deviation
Shallow core samples					
11	0–4	<b>0.55</b>	(0.45)	<b>6.2</b>	(5.1)
11	4–8	<b>0.48</b>	(0.01)	<b>5.0</b>	(0.1)
10	0–4	<b>2.16</b>	(0.12)	<b>30.4</b>	(1.6)
10	4–8	<b>1.04</b>	(0.48)	<b>11.5</b>	(5.3)
12	0–4	<b>1.17</b>	(0.32)	<b>10.3</b>	(2.8)
	mean	1.08		12.66	
	SD	0.67		10.27	
Deep core samples					
1	244–267	<b>0.08</b>	(0.05)	<b>0.19</b>	(0.12)
1	573–625	< <b>0.01</b>		< <b>0.02</b>	
4	673–726	< <b>0.01</b>		< <b>0.01</b>	
4	1,515–1,595	< <b>0.01</b>		< <b>0.02</b>	
9	1,179–1,292	< <b>0.01</b>		< <b>0.01</b>	
9	2,439–2,486	< <b>0.01</b>		< <b>0.01</b>	
	mean	< 0.02		< 0.04	
	SD	—		—	



**Figure 10.** Plots showing  $^{203}\text{Hg(II)}$ -methylation potential rate as a function of depth for sediments from Englebright Lake, California, 2002: (A) Sites 1 and 11, (B) Sites 4 and 10, (C) Sites 9 and 12. Bar represents average of two observations. Error bars indicate absolute deviation.

**Table 9.** Chemical data for the MP series of sediment samples from Englebright Lake, California, 2002.

[<sup>35</sup>S-sulfate, sulfate with S-35 radiotracer; Fe(II), ferrous iron; Fe(III), ferric iron; nmol/g dry sed/d, nanomole per gram dry sediment per day; mg/g dry sed, milligram per gram dry sediment; μmol/g dry sed, micromole per gram dry sediment; g/cc, gram per cubic centimeter; mL PW/cc wet sed, milliliter pore water per cubic centimeter wet sediment; μg/g dry sed, microgram per gram dry sediment; ng/g dry sed, nanogram per gram dry sediment; <, less than; —, not determined]

Site	Depth below lake floor, in centimeters	<sup>35</sup> S-Sulfate reduction rate, in nmol/g dry sed/d	Fe(II), in mg/g dry sed	Amorphous Fe(III), in mg/g dry sed	Crystal-line Fe(III), in mg/g dry sed	Acid volatile sulfide, in μmol/g dry sed	Total reduced sulfur, in μmol/g dry sed	Loss on ignition, in percent	Percent-age dry weight	Bulk density, in g/cc wet sed	Porosity, in mL PW/cc wet sed	Total mercury (Hg <sub>T</sub> ), in μg/g dry sed	Methyl-mercury (MeHg), in ng/g dry sed	MeHg, in percent
Shallow core samples														
11	0-4	19.7	11.4	0.40	7.5	5.8	7.8	7.4	44.5	1.32	0.73	0.27	0.87	0.32
11	4-8	31.3	9.5	<0.02	11.1	2.4	2.8	5.9	48.5	1.40	0.72	0.27	0.50	0.19
10	0-4	27.8	9.8	0.27	4.9	2.5	1.7	8.8	35.2	1.22	0.79	0.28	0.95	0.35
10	4-8	28.6	11.2	<0.02	4.4	4.8	10.1	8.3	45.0	1.33	0.73	0.25	0.74	0.29
12	0-4	32.0	5.7	0.18	0.1	1.9	4.4	5.2	56.5	1.46	0.63	0.22	1.08	0.50
mean		27.9	9.5	<0.15	5.6	3.5	5.4	7.1	46.0	1.35	0.72	0.26	0.83	0.32
standard deviation		4.9	2.3	—	4.1	1.7	3.5	1.5	7.7	0.09	0.06	0.02	0.22	0.13
Deep core samples														
1	244-267	—	3.2	0.03	1.8	—	—	9.2	58.8	1.48	0.61	—	—	—
1	573-625	—	2.4	0.04	2.0	—	—	5.7	58.7	1.46	0.60	—	—	—
4	673-726	—	4.1	0.06	<0.01	—	—	6.7	62.9	1.55	0.58	—	—	—
4	1,515-1,595	—	3.1	0.05	0.5	—	—	6.2	61.7	1.54	0.59	—	—	—
9	1,179-1,292	—	0.4	0.05	0.4	—	—	0.2	83.8	1.36	0.22	—	—	—
9	2,439-2,486	—	0.6	0.17	—	—	—	3.8	63.6	1.60	0.58	—	—	—
mean		—	2.3	0.07	—	—	—	5.3	64.9	1.50	0.53	—	—	—
standard deviation		—	1.5	0.05	—	—	—	3.0	9.5	0.09	0.15	—	—	—

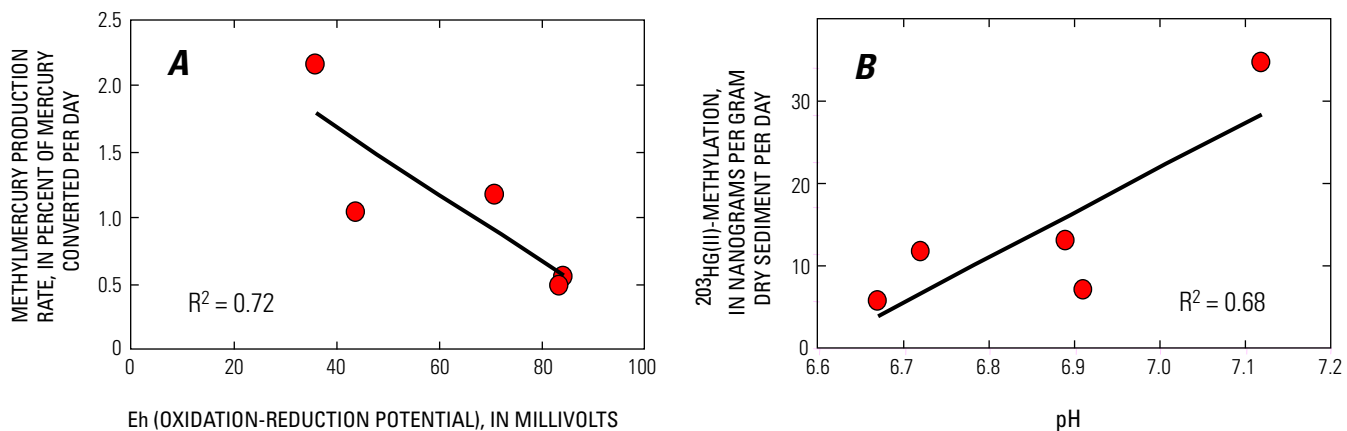
Comparing shallow (0–4 cm depth) sediment Hg-transformation dynamics among sites 10–12 (table 8 and fig. 10), the mid-reservoir site (10) had the highest rate of MeHg production, whereas the site closest to the dam (site 11) had the lowest, lower than the highest site by a factor of about five. For the two shallow sites (10 and 11) where two depth intervals (0–4 cm and 4–8 cm) were sampled, the highest rates of MeHg production occurred in the 0–4 cm layer, by factors of 1.2 and 2.6 relative to the 4–8 cm interval at the two sites, respectively. Comparing these Hg-transformation rates with the other measured parameters suggests that MeHg production was negatively correlated with redox potential and positively correlated with sediment pH (fig. 11). Further, the ratio of methylmercury to total mercury (MeHg/Hg<sub>T</sub>), which has been used as a proxy for the relative activity of MeHg production, appeared to be negatively correlated with concentrations of crystalline Fe(III) in sediment, ferrous iron (Fe(II)) in pore water, and DOC in pore water (fig. 12). However, the small number of samples (n = 5) caused the trends associated with MeHg production (fig. 11) and MeHg/Hg<sub>T</sub> (fig. 12) to be somewhat tenuous. Also, because of covariation among these and other ancillary sediment parameters (for example, concentrations of crystalline iron(III) in sediment, iron(II) in pore water, and dissolved organic carbon in pore water; tables 9, 10; fig. 12), it is difficult to separate out which factors ultimately control Hg methylation in this system based on the current limited number of shallow sediment observations (n = 5).

The trend towards low rates of Hg methylation in deep sediments observed in the current study parallels earlier results from Daguerre Point Dam, located on the lower Yuba River (12 km downstream of Englebright Dam), where similarly low MeHg production rates were measured in cores ranging from 0.6 to 9.1 m below the river bed (Hunerlach and others, 2004). No shallow sediments were taken from Daguerre Point Dam

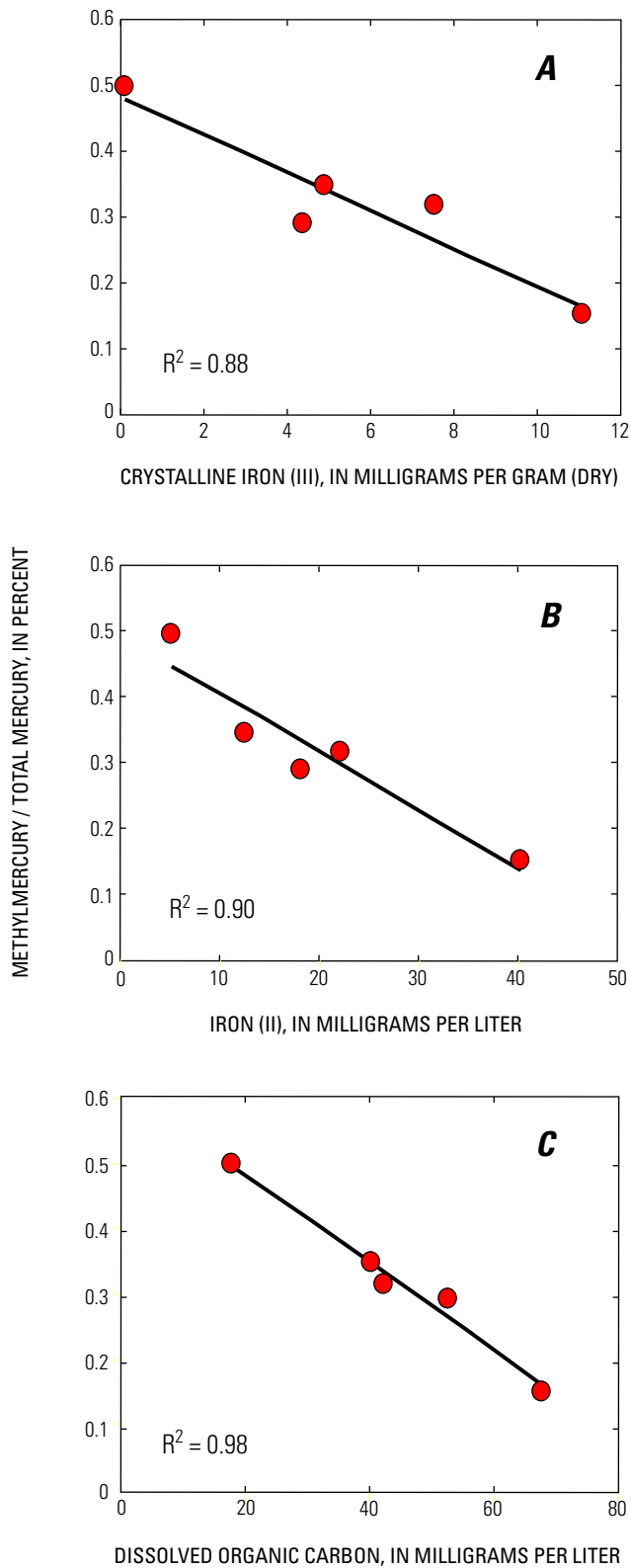
for comparison with those analyzed in the current study. However, MeHg production rates for shallow sediment (0–4 cm) samples collected from the Yuba River upstream (n = 3) and downstream (n = 3) of Daguerre Point Dam were, on average, about 1/50th of the rates for samples collected from shallow sediments in Englebright Lake. The primary differences between shallow sediments collected within Englebright Lake and shallow sediments collected in the lower Yuba River were that the former (a) had more organic material, (b) had higher rates of SR, and (c) were more reduced than the latter.

## Heavy Minerals

Particle-size distribution was determined for nine composite samples that were used to evaluate gold concentration and to observe heavy minerals microscopically (table C1). Heavy mineral concentrates prepared from these composite samples provided an opportunity to observe grains of gold, amalgam, and other heavy minerals such as iron sulfides. A photograph of heavy minerals from sample 5A is shown in figure 13. A series of SEM photomicrographs showing gold and amalgam textures from the heavy mineral concentrates is given in Appendix D (figs. D1–D16). The particle-size distribution and gold tenor (a mining term for concentration) were determined for the heavy mineral concentrates prepared from these composite samples (table C2). The spatial distribution of the gold tenor results was plotted on a longitudinal section of the reservoir (fig. 14). The highest values of gold tenor were for the four samples from sites 2 and 5/7; these values ranged from 270 to 840 milligrams of gold per cubic meter (mg Au/m<sup>3</sup>). The median value of gold tenor for the nine composite samples was 92 mg Au/m<sup>3</sup>. For comparison, the average gold tenor for major hydraulic placer mines in the Sierra Nevada was 189 mg Au/m<sup>3</sup> (Yeend, 1974).



**Figure 11.** Plots showing correlation of the <sup>203</sup>Hg(II)-methylation potential rate for shallow sediments from Englebright Lake, California, 2002: (A) Redox potential, (B) pH. Redox, reduction-oxidation; R<sup>2</sup>, coefficient of determination for linear least-squares regression.



**Figure 12.** Plots showing correlation of the ratio of methylmercury to total mercury with forms of iron and carbon in shallow sediments from Englebright Lake, California, 2002. (A) Concentration of crystalline iron (III) in sediment, (B) Concentration of iron (II) in pore water, (C) Concentration of dissolved organic carbon in pore water.  $R^2$ , coefficient of determination for linear least-squares regression.

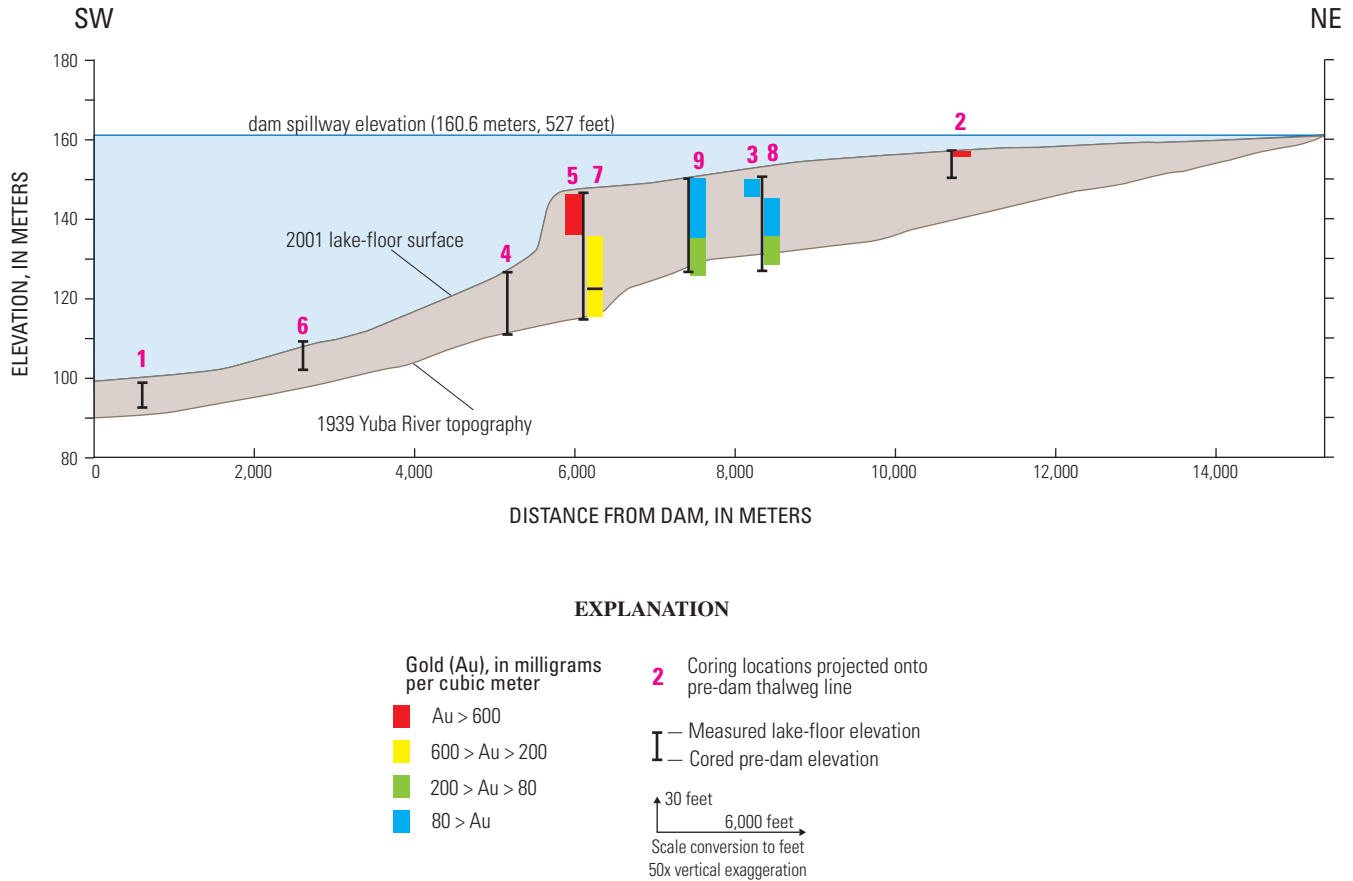
**Table 10.** Chemical data for pore water from the MP series of sediment samples from Englebright Lake, California, 2002.

[Fe(II), ferrous iron. Deep core samples were not analyzed]

Site	Depth below lake floor, in centimeters	Sulfate, in micromoles per liter	Chloride, in micromoles per liter	Fe(II), in milligrams per liter	Dissolved organic carbon, in milligrams per liter	pH	Oxidation-reduction potential, Eh, in millivolts
Shallow core samples							
11	0-4	18.4	0.3	22.0	42.3	6.91	84
11	4-8	21.7	0.3	40.1	67.7	6.67	83
10	0-4	31.3	0.3	12.5	40.2	7.12	36
10	4-8	9.9	0.1	18.1	52.6	6.89	44
12	0-4	33.4	0.4	5.1	18.2	6.72	71
mean		22.9	0.3	19.6	44.2	6.86	64
standard deviation		9.6	0.1	13.1	18.2	0.18	23

**Figure 13.** Gold and amalgam grains from heavy-mineral concentrate 5A from Englebright Lake, California.





**Figure 14.** Longitudinal section showing gold tenor in composite core intervals from Englebright Lake, California, 2002. Vertical exaggeration 50X. 2001 lake-floor surface from Childs and others (2003); 1939 Yuba River topography from U.S. Army Corps of Engineers maps, digitized by Childs and others (2003). Measured lake-floor elevation and cored pre-dam elevation from deep drilling, May–June 2002 (Childs and others, 2003; Snyder and others, 2004a).

## Summary and Conclusions

Methods and results are presented for geochemical analyses of sediment samples from two coring campaigns at Englebright Lake, California, conducted by the U.S. Geological Survey: a deep coring campaign completed during May–June 2002 and a shallow sampling campaign completed during October 2002. Total mercury was analyzed in 444 subsamples, methylmercury in 243 subsamples, and other trace and major elements in 202 subsamples. Quality-assurance and quality-control procedures including analyses of replicate pairs of split subsamples (in some cases analyzed by two different laboratories), standard reference materials, blanks, and spike additions were used to demonstrate a high level of confidence in data quality for mercury, methylmercury, other trace elements, and major elements.

The spatial variation of total mercury ( $Hg_T$ ) and methylmercury (MeHg), and the ratio of MeHg to  $Hg_T$  were evaluated using data derived from the deep and shallow cores. At the three deep coring sites closest to Englebright Dam, concentrations of  $Hg_T$  were generally in the range of 100 to 500 ng/g, dry (nanogram per gram), and the median grain size

for most samples was in the silt range (0.004 to 0.063 mm [millimeter]). At the deep coring sites located farther upstream, the upper parts of the profile had coarser grain size; median values were in the sand range (0.063 to 2.0 mm), and concentrations of  $Hg_T$  in unsieved samples were lower, generally 2.0 to 100 ng/g. The lower part of the vertical profiles at three upstream coring sites had finer median grain size and higher concentrations of  $Hg_T$  in unsieved samples than the upper and middle parts of these profiles.

Longitudinal variation in  $Hg_T$  concentration was more pronounced in deep cores than in shallow cores. Median values of  $Hg_T$  in shallow cores from all ten sampling sites were consistently in the range of 204 to 265 ng/g, and standard deviations generally were small, indicating that nearly all concentration values were in the range of 200 to 300 ng/g. Median values of  $Hg_T$  in unsieved deep cores showed considerable longitudinal variation; highest median values for  $Hg_T$  were found at sites near the dam (344 and 355 ng/g); lowest median values for  $Hg_T$  were at the three most upstream sites (17 to 97 ng/g), and intermediate values for  $Hg_T$  were at the mid-reservoir sites (135 and 245 ng/g).

The ratio MeHg/Hg<sub>T</sub> showed less variation among adjacent locations than the MeHg concentration when shallow and deep samples were compared. Lowest median values of MeHg/Hg<sub>T</sub> were for the site closest to the dam both for shallow cores (0.20 percent) and deep cores (0.13 percent). The highest median values of MeHg/Hg<sub>T</sub> were for shallow cores from the mid-reservoir and upstream sites (0.31 to 0.82 percent), and for deep cores from two mid-reservoir sites (0.33 and 0.34 percent) and the most upstream site (0.36 percent).

As expected based on observations in other freshwater systems, the shallowest samples (0–4 cm [centimeter] below the reservoir floor) had a higher median concentration of MeHg (1.0 ng/g) than deeper samples from the shallow cores (4–8 cm, 0.69 ng/g; 8–12 cm, 0.59 ng/g). The shallowest vertical interval had the highest value of the ratio MeHg to Hg<sub>T</sub> (0.38 percent) also. Median concentrations of MeHg and median values of MeHg/Hg<sub>T</sub> decreased systematically with depth from 0–4 to 4–8 to 8–12 cm in the shallow cores. However, similar systematic decreases were not observed at the meter scale in the deep cores of the MEM series. The overall median of the ratio MeHg/Hg<sub>T</sub> in the deep cores was 0.25 percent, not much lower than the overall median value for the shallow cores (0.33 percent).

The highest potential rates of microbial mercury methylation, determined with radiotracer methods, were measured in shallow (0 to 8 centimeter depth) sediments (5 to 30 nanograms of mercury per gram dry sediment per day), whereas potential rates for samples collected from depths greater than 500 centimeters were consistently near or below the detection limit of the radiotracer method. Shallow sediments also had higher average values of loss on ignition (a proxy for organic content) and porosity, significantly higher concentrations of most solid-phase Fe species, and lower dry weight (equivalent to a higher moisture content) than deeper sediments. These results are consistent with the direction of the observed trend toward lower concentrations of MeHg and lower values of MeHg/Hg<sub>T</sub> in deep sediments compared with shallow sediments.

Chemical analyses of trace and major elements in bed sediment are presented for 202 samples of deep cores from five sites in Englebright Lake. The overall average values and standard deviations for selected trace elements were as follows (in micrograms per gram): antimony  $2.4 \pm 1.6$ , arsenic  $69 \pm 48$ , chromium  $134 \pm 23$ , lead  $33 \pm 25$ , and nickel  $87 \pm 24$ .

Heavy-mineral concentrates were prepared using nine large-volume composite samples from deep cores taken at four locations in the upper- and mid-reservoir. Estimated gold concentrations in sediment from ranged from 38 to 840 milligrams per cubic meter. Grains of gold-mercury amalgam and grains of electrum (native gold), with and without mercury staining, were observed in the heavy-mineral concentrates.

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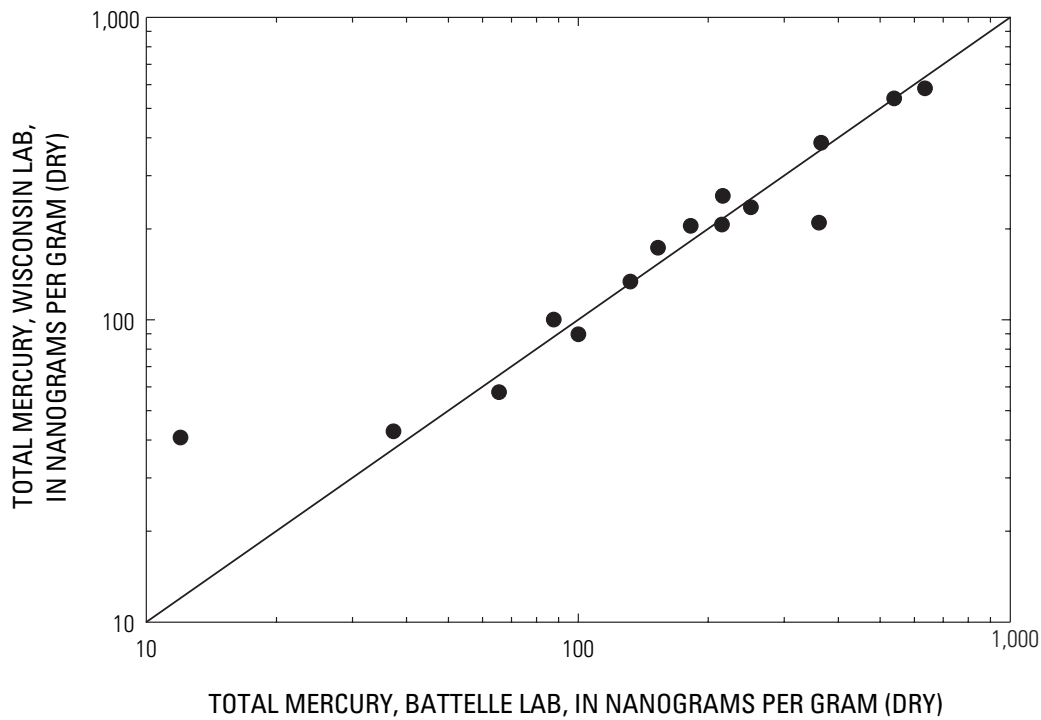
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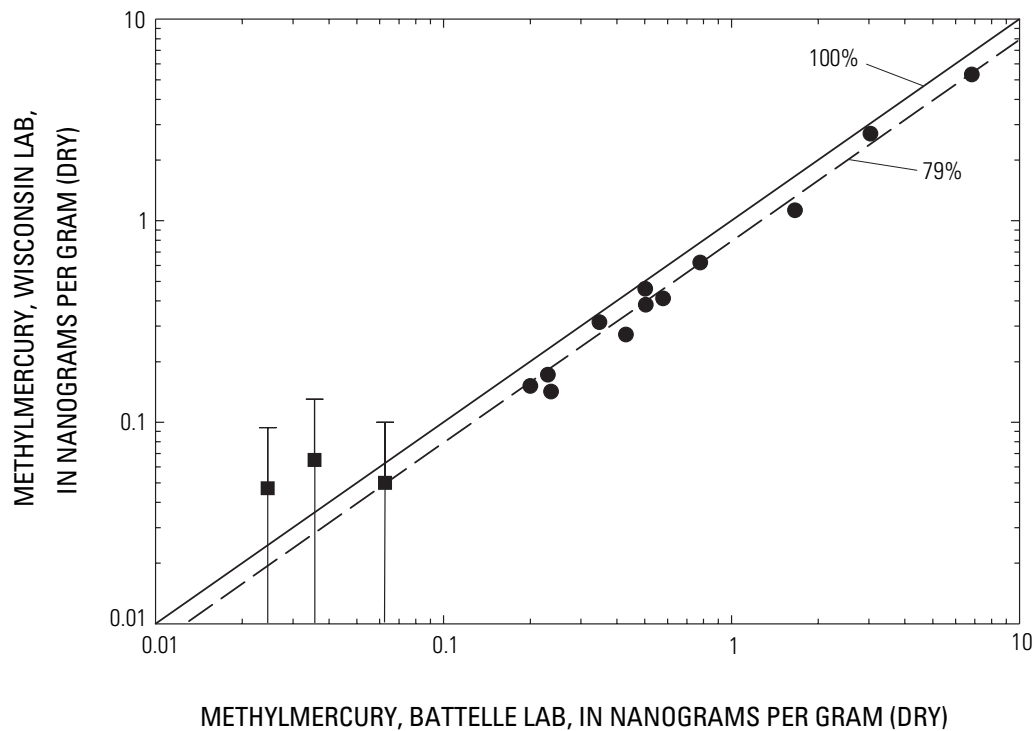
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## **Appendixes**

**Appendix A. Quality Assurance and Quality Control Data for Mercury and Methylmercury Analyses**



**Figure A1.** Results of analysis by two laboratories of total mercury in split subsamples from Englebright Lake, California, 2002.



**Figure A2.** Results of analysis by two laboratories of methylmercury in split subsamples from Englebright Lake, California, 2002. Results less than detection limit are indicated by a symbol at half the detection limit and an error bar from the axis to the detection limit.

**Table A1.** Total mercury concentrations in standard reference materials.

[Recovery is equal to observed value divided by certified value. %, percent; n, number of analyses. ng/g, nanogram per gram; —, not determined]

	Total mercury			Recovery (%)	Laboratory batch
	Certified value ng/g (dry)	Observed value ng/g dry)	Standard deviation ng/g (dry)		
Laboratory: U.S. Geological Survey, Boulder, Colo.					
Buffalo River Sediment 2704	1,470	1,357	15	92	1Y
Buffalo River Sediment 2704	1,470	1,342	5	91	1Y
Buffalo River Sediment 2704	1,470	1,478	5	101	1Y
Buffalo River Sediment 2704	1,470	1,464	16	100	7Y
Buffalo River Sediment 2704	1,470	1,433	11	98	7Y
Buffalo River Sediment 2704	1,470	1,427	10	97	7Y
Buffalo River Sediment 2704	1,470	1,463	11	100	7Y
Buffalo River Sediment 2704	1,470	1,427	9	97	7Y
Buffalo River Sediment 2704	1,470	1,621	40	110	7Y
Buffalo River Sediment 2704	1,470	1,425	20	97	7Y
Buffalo River Sediment 2704	1,470	1,795	6	122	7Y
Buffalo River Sediment 2704	1,470	1,588	18	108	7Y
Buffalo River Sediment 2704	1,470	1,635	8	111	7Y
Buffalo River Sediment 2704	1,470	1,735	20	118	7Y
Buffalo River Sediment 2704	1,470	1,485	16	101	9Y
Buffalo River Sediment 2704	1,470	1,564	7	106	9Y
Buffalo River Sediment 2704	1,470	1,458	21	99	9Y
Buffalo River Sediment 2704	1,470	1,603	10	109	9Y
Buffalo River Sediment 2704	1,470	1,227	10	83	9Y
Buffalo River Sediment 2704	1,470	1,483	1	101	9Y
Buffalo River Sediment 2704	1,470	1,458	16	99	9Y
Buffalo River Sediment 2704	1,470	1,447	4	98	8Y
Buffalo River Sediment 2704	1,470	1,329	26	90	8Y
Buffalo River Sediment 2704	1,470	1,604	23	109	8Y
Buffalo River Sediment 2704	1,470	1,513	29	103	8Y
Buffalo River Sediment 2704	1,470	1,347	28	92	8Y
Buffalo River Sediment 2704	1,470	1,403	42	95	8Y
mean	1,470	1,486		101	
uncertainty (95% prediction interval)	70	—			
standard deviation	—	126		9	
n		27		27	



**Table A1.** Total mercury concentrations in standard reference materials—Continued.

[Recovery is equal to observed value divided by certified value. %, percent; n, number of analyses. ng/g, nanogram per gram; —, not determined]

	Total mercury			Recovery (%)	Laboratory batch
	Certified value ng/g (dry)	Observed value ng/g (dry)	Standard deviation ng/g (dry)		
Laboratory: Battelle Marine Sciences Laboratory, Sequim, Wash.					
IAEA 405	810	803	—	99	072503HGB
IAEA 405	810	813	—	100	072503HGB
IAEA 405	810	828	—	102	072903HGB
IAEA 405	810	820	—	101	072903HGB
IAEA 405	810	824	—	102	080803HGB
IAEA 405	810	833	—	103	080803HGB
IAEA 405	810	839	—	104	082003HGB
IAEA 405	810	825	—	102	092203HGB
IAEA 405	810	800	—	99	092203HGB
IAEA 405	810	793	—	98	092203HGB
IAEA 405	810	912	—	113	092203HGB
IAEA 405	810	870	—	107	100103HGB
IAEA 405	810	844	—	104	100103HGB
IAEA 405	810	844	—	104	100103HGB
mean	810	832		103	
standard deviation	40	31		4	
n		14		14	

**Table A2.** Total mercury data for replicate sediment subsamples from Englebright Lake, California, 2002.

[R1, replicate 1; R2, replicate 2; R3, replicate 3; RPD, relative percentage difference; n, number of analyses; cm, centimeter; ng/g, nanogram per gram]

Site ID	Depth within core sample (cm)	Lab ID	Type of replicate (C=core, L=Lab)	Total mercury concentration			RPD		
				R1 (ng/g, dry)	R2 (ng/g, dry)	R3 (ng/g, dry)	R1, R2	R1, R3	R2, R3
Laboratory: U.S. Geological Survey, Boulder, Colo.									
Y-series: Deep cores									
1D-1H-1	94–140	1Y-4	L	208	195		6.4		
1B-2E-2	0–75	1Y-8	L	202	196		3.4		
1B-2E-3	80–108	1Y-11	L	366	343		6.5		
1B-3E-1	0–52	1Y-16	L	258	265		2.8		
1B-3E-1	90–101	1Y-19	L	253	240	251	5.1	0.8	4.5
4B-2H-1	14–124	4Y-8	C	225	243		7.9		
4A-4H-2	9–95	4Y-19	C	251	680		92.1		
7C-1H-2	31–97	7Y-4	L	240	281		15.8		
7A-4H-2	29.5–73	7Y-21	L	589	585		0.7		
7C-7H-2	68–120	7Y-34	L	477	523		9.2		
7C-9H-3	0–93.5	7Y-41	L	480	488		1.7		
7C-11H-1	21–70	7Y-48	L	462	446		3.6		
7C-12H-2	0–40.5	7Y-57	L	332	336		1.2		
7C-12H-2	69–104	7Y-59	L	259	262		0.9		
7C-13H-3	61.5–99	7Y-66	L	188	194		3.3		
9A-1H-2	25.5–119	9Y-2	L	292	284		3.0		
9C-2H-2	0–82	9Y-7	C	211	241		13.2		
9A-2H-3	56–108.5	9Y-8	L	283	258		9.5		
9A-3H-2	44.5–82	9Y-13	L	145	106		31.5		
9C-4H-2	48–131.5	9Y-17	C	225	263		15.6		
9C-7H-2	60.5–140	9Y-27	C	444	348		24.3		
9C-8H-1	0–84	9Y-28	L	376	491		26.4		
9A-10H-3	94.5–135.5	9Y-35	L	192	184		3.9		
9C-9H-3	41–99	9Y-37	C	151	153		1.7		
8A-1H-3	127.5–150	8Y-6	L	247	263		6.2		
8B-3H-2	0–136	8Y-17	C	232	221		4.7		

**Table A2.** Total mercury data for replicate sediment subsamples from Englebright Lake, California, 2002—Continued.

[R1, replicate 1; R2, replicate 2; R3, replicate 3; RPD, relative percentage difference; n, number of analyses; cm, centimeter; ng/g, nanogram per gram]

Site ID	Depth within core sample (cm)	Lab ID	Type of replicate (C=core, L=Lab)	Total mercury concentration			RPD		
				R1 (ng/g, dry)	R2 (ng/g, dry)	R3 (ng/g, dry)	R1, R2	R1, R3	R2, R3
Laboratory: Battelle Marine Sciences Laboratory, Sequim, Wash.									
MEM-series: Deep cores									
4C-4H-2	63–73	GS 12	L	266	231		14.1		
6A-1H-2	70–80	GS 28	L	386	337		13.6		
6B-2H-2	109–119	GS 34	L	453	471		3.9		
7B-5H-1	95–107	GS 62	L	233	247		5.8		
7C-13H-3	38–48	GS 97	L	237	210		12.3		
8C-3H-1	52–61	GS 124	L	416	237		54.8		
8C-7H-1	18–28	GS 132	L	128	124		3.4		
9C-7H-1	70–81	GS 161	L	172	100		53.1		
Shallow cores									
10F-B	4–8	GS 204, 205	C	256	243		5.2		
10G-B	8–12	GS 212	C	274	237		14.5		
11B-B	4–8	GS 218	L	380	295		25.2		
11F-B	4–8	GS 235	L	269	264		2.1		
12C-B	4–5.5	GS 248	L	91.4	101		10.1		
17-B	8–10	GS 267	L	200	197		1.2		
							<b>n</b>	<b>Mean RPD</b>	<b>Median RPD</b>
				All replicates			40	13.0	6.3
				Laboratory replicates			31	11.0	5.8
				Core replicates			9	19.9	13.2

**Table A3.** Methylmercury concentrations in standard reference materials.

[Recovery is equal to observed value divided by certified value. n, number of analyses; %, percentage; ng/g, nanogram per gram; na, not applicable]

Standard reference material	Methylmercury		Recovery (%)	Date of analysis
	Certified value ng/g (dry)	Observed value ng/g (dry)		
Laboratory: Battelle Marine Sciences Laboratory, Sequim, Wash.				
IAEA-356	5.46	4.79	88	7/14/2003
IAEA-356	5.46	4.60	84	7/15/2003
IAEA-356	5.46	4.26	78	7/16/2003
IAEA-356	5.46	4.51	83	7/18/2003
IAEA-356	5.46	4.61	84	7/22/2003
IAEA-356	5.46	3.75	69	7/23/2003
IAEA-356	5.46	4.78	88	7/31/2003
IAEA-356	5.46	4.96	91	8/6/2003
IAEA-356	5.46	4.74	87	8/8/2003
IAEA-356	5.46	3.36	62	9/3/2003
IAEA-356	5.46	4.12	75	9/4/2003
IAEA-356	5.46	4.06	74	9/5/2003
IAEA-356	5.46	2.29	42	9/12/2003
IAEA-356	5.46	3.58	66	9/16/2003
IAEA-356	5.46	2.96	54	9/18/2003
IAEA-356	5.46	3.55	65	9/23/2003
IAEA-356	5.46	4.02	74	9/24/2003
IAEA-356	5.46	3.93	72	9/25/2003
IAEA-356	5.46	3.92	72	9/26/2003
mean	5.46	4.06	74	
standard deviation	0.39	0.69	13	
n	na	19	19	
Laboratory: Battelle Marine Sciences Laboratory, Sequim, Wash.				
IAEA-405	5.49	4.95	90	7/14/2003
IAEA-405	5.49	4.56	83	7/15/2003
IAEA-405	5.49	5.19	95	7/16/2003
IAEA-405	5.49	4.13	75	7/18/2003
IAEA-405	5.49	5.22	95	7/22/2003
IAEA-405	5.49	5.07	92	7/23/2003
IAEA-405	5.49	4.42	81	7/31/2003
IAEA-405	5.49	4.55	83	8/6/2003
IAEA-405	5.49	4.54	83	8/8/2003
IAEA-405	5.49	3.93	72	9/3/2003
IAEA-405	5.49	4.31	79	9/4/2003
IAEA-405	5.49	4.41	80	9/12/2003
IAEA-405	5.49	4.48	82	9/16/2003
IAEA-405	5.49	3.45	63	9/18/2003

**Table A3.** Methylmercury concentrations in standard reference materials—Continued.

[Recovery is equal to observed value divided by certified value. n, number of analyses;  
%, percentage; ng/g, nanogram per gram; na, not applicable]

Standard reference material	Methylmercury		Recovery (%)	Date of analysis
	Certified value ng/g (dry)	Observed value ng/g (dry)		
Laboratory: Battelle Marine Sciences Laboratory, Sequim, Wash. —Continued				
IAEA-405	5.49	5.15	94	9/23/2003
IAEA-405	5.49	4.97	91	9/24/2003
IAEA-405	5.49	4.66	85	9/25/2003
IAEA-405	5.49	4.66	85	9/26/2003
mean	5.49	4.59	84	
standard deviation	0.53	0.47	8	
n	na	18	18	
Laboratory: U.S. Geological Survey Laboratory, Middleton, Wisc.				
IAEA-356	5.46	5.08	93	2/8/2005
IAEA-356	5.46	4.23	77	2/10/2005
IAEA-356	5.46	5.10	93	2/10/2005
IAEA-356	5.46	6.37	117	2/10/2005
IAEA-356	5.46	6.64	122	3/1/2005
IAEA-356	5.46	5.11	94	3/2/2005
IAEA-356	5.46	5.60	103	3/4/2005
IAEA-356	5.46	4.90	90	3/9/2005
IAEA-356	5.46	5.57	102	3/15/2005
IAEA-356	5.46	4.47	82	3/16/2005
IAEA-356	5.46	5.59	102	3/16/2005
IAEA-356	5.46	4.03	74	3/23/2005
IAEA-356	5.46	5.05	92	3/23/2005
IAEA-356	5.46	4.02	74	3/24/2005
IAEA-356	5.46	4.66	85	3/24/2005
IAEA-356	5.46	4.44	81	3/30/2005
IAEA-356	5.46	4.42	81	3/31/2005
IAEA-356	5.46	4.79	88	3/31/2005
mean	5.46	5.00	92	
standard deviation	0.39	0.74	14	
n	na	18	18	

**Table A3.** Methylmercury concentrations in standard reference materials—Continued.

[Recovery is equal to observed value divided by certified value. n, number of analyses;  
%, percentage; ng/g, nanogram per gram; na, not applicable]

Standard reference material	Methylmercury		Recovery (%)	Date of analysis
	Certified value ng/g (dry)	Observed value ng/g (dry)		
Laboratory: U.S. Geological Survey Laboratory, Middleton, Wisc.—Continued				
IAEA-405	5.49	3.32	61	6/10/2004
IAEA-405	5.49	3.33	61	12/2/2004
IAEA-405	5.49	4.91	89	12/2/2004
IAEA-405	5.49	3.04	55	3/1/2005
IAEA-405	5.49	3.86	70	3/2/2005
IAEA-405	5.49	3.46	63	3/4/2005
IAEA-405	5.49	5.12	93	3/9/2005
IAEA-405	5.49	4.55	83	4/19/2005
IAEA-405	5.49	5.47	100	4/19/2005
IAEA-405	5.49	4.41	80	4/21/2005
IAEA-405	5.49	5.82	106	4/21/2005
IAEA-405	5.49	2.91	53	4/30/2005
IAEA-405	5.49	3.93	72	4/30/2005
IAEA-405	5.49	3.24	59	5/4/2005
IAEA-405	5.49	4.18	76	5/4/2005
IAEA-405	5.49	4.62	84	5/5/2005
IAEA-405	5.49	2.78	51	6/28/2005
IAEA-405	5.49	3.96	72	6/28/2005
IAEA-405	5.49	3.68	67	6/29/2005
IAEA-405	5.49	3.92	71	6/29/2005
IAEA-405	5.49	3.33	61	6/30/2005
IAEA-405	5.49	5.01	91	6/30/2005
IAEA-405	5.49	2.91	53	7/7/2005
IAEA-405	5.49	3.06	56	7/7/2005
mean	5.49	3.95	72	
standard deviation	0.53	0.87	16	
n	na	24	24	

**Table A4.** Methylmercury data for replicate sediment subsamples from Englebright Lake, California, 2002.

[Laboratory: Battelle Marine Sciences, Sequim, Wash.; R1, replicate 1; R2, replicate 2; R3, replicate 3, R4, replicate 4. RPD, relative percentage difference; n, number of analyses. ng/g, nanogram per gram]

Site ID	Depth within core sample (cm)	Lab ID	Type of replicate (C = core, L = lab)	Methylmercury concentration				RPD				
				R1 (ng/g, dry)	R2 (ng/g, dry)	R3 (ng/g, dry)	R4 (ng/g, dry)	R1, R2	R1, R3	R2, R3	R1, R4	R2, R4
MEM series: Deep cores												
6A-1H-2	70-80	GS 28	L	1.74	1.90	1.85		8.8	6.1	2.7		
6B-2H-1	61-71	GS 33	L	0.869	0.933			7.1				
7B-12H-2	29-39	GS 71	L	0.0435	0.0405			7.1				
7C-1H-2	64-74	GS 74	L	0.951	1.08			12.7				
8A-13H-1	68-78	GS 112	L	0.141	0.147			4.2				
8C-2H-2	52-61	GS 123	L	0.936	1.01			7.6				
8C-6H-1	69-79	GS 130	L	0.0740	0.0869			16.0				
9C-2H-1	16-26	GS 150	L	2.24	2.32			3.5				
9C-9H-2	33-43	GS 165	L	0.207	0.208			0.5				
Shallow cores												
10F-B	4-8	GS 204, 205	C	0.472	0.802			51.8				
10G-B	2-3	GS 209	L	0.734	0.891			19.3				
10G-B	8-12	GS 212, 213	C	1.10	1.02			7.5				
11A-B	4-8	GS 215	L	0.574	0.867	0.896	0.490	40.7	43.8	3.3	15.8	55.6
11C-B1, -B2	0-4	GS 220, 223	C	0.846	0.487			53.9				
11C-B1, -B2	4-8	GS 221, 224	C	0.411	0.245			50.6				
11C-B1, -B2	8-12	GS 222, 225	C	0.485	0.575			17.0				
11F-B	2-3	GS 233	L	0.466	0.479			2.8				
12C-B	2-4	GS 247	L	0.728	0.751			3.1				
14-B	4-8	GS 258	L	0.621	0.699			11.8				
19-B	4-8	GS 272	L	1.81	1.66			9.1				
12E-B	0-2	GS 282	L	1.21	1.02			17.0				
				<b>n</b>	<b>Mean RPD</b>	<b>Median RPD</b>						
				24	19.2	10.5						
				19	15.5	8.8						
				5	36.2	50.6						

**Table A5.** Comparison of results from two laboratories for total mercury and methylmercury in split sediment subsamples from Englebright Lake, California, 2002.

[Lab B: Battelle Marine Sciences Laboratory, Sequim, Wash.; Lab C: U.S. Geological Survey Laboratory, Madison, Wisc. ng/g, nanogram per gram; RPD, relative percentage difference; %, percent; —, not determined]

Lab ID	Core section	Type of replicate (C = core, L = lab)	Total mercury concentration		Total mercury RPD	Total mercury, ratio of concentration	Methylmercury concentration		Methylmercury RPD	Methylmercury, ratio of concentration
			Lab B (ng/g, dry)	Lab C (ng/g, dry)		Lab C: Lab B (%)	Lab B (ng/g, dry)	Lab C (ng/g, dry)		Lab C: Lab B (%)
GS 10	4C-3H-1	C	215	206	4.1	96.0	0.502	0.460	8.7	91.6
GS 20	4D-2E-1	C	182	204	11.6	112.4	0.579	0.412	33.8	71.1
GS 27	4D-6H-1	C	251	235	6.5	93.7	0.200	0.151	28.0	75.5
GS 30	6A-4E-1	C	539	539	0.1	100.1	0.430	0.273	44.8	63.4
GS 36	6D-H1-1	C	153	173	12.3	113.1	0.348	0.313	10.5	90.1
GS 53	7B-1H-1	C	361	209	53.1	58.0	3.04	2.70	11.7	88.9
GS 57	7B-3H-1	C	132	134	1.2	101.2	6.83	5.31	25.0	77.7
GS 66	7B-9H-1	C	635	583	8.6	91.7	0.504	0.382	27.5	75.9
GS 70	7B-12H-1	C	87.7	100	13.1	114.0	0.230	0.172	29.0	74.7
GS 101	8A-2H-2	C	100	89.4	11.1	89.4	0.779	0.619	22.9	79.5
GS 105	8A-7H-2	C	37.3	42.7	13.5	114.5	0.0626	< 0.10	—	—
GS 115	8A-14H-2	C	365	385	5.3	105.4	0.236	0.142	49.9	60.0
GS 134	9A-1H-2	C	216	257	17.3	118.9	1.66	1.13	38.3	67.9
GS 140	9A-5H-1	C	12.0	40.7	109.0	339.5	0.0245	< 0.0941	—	—
GS 147	9A-11H-1	C	65.5	57.5	13.0	87.8	0.0356	< 0.13	—	—
			mean		12.1	100.7	mean		27.5	76.4
			median		11.1	101.2	median		27.7	75.7



## Appendix B. Quality Assurance, Quality Control, and Data Tables for Trace and Major Elements

**Table B1.** Concentrations of trace metals and major elements in standard reference materials.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation. µg/g, microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Aluminum Al Wt%		Arsenic As µg/g		Barium Ba µg/g		Beryllium Be µg/g		Bismuth Bi µg/g		Calcium Ca Wt%	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
	23515	5.3	0.1	22	1	378	33	1.8	0.0	0.56	0.02	2.3
23529	6.1	0.2	22	1	396	13	1.7	0.0	0.58	0.03	2.5	0.0
23608	3.1	0.1	22	1	313	19	1.8	0.1	0.58	0.00	1.8	0.1
23619	2.7	0.1	21	1	306	23	1.8	0.1	0.55	0.01	1.7	0.1
23627	3.0	0.2	22	0	343	7	2.0	0.0	0.64	0.00	2.2	0.0
23760	2.7	0.1	21	1	304	11	1.9	0.0	0.52	0.07	1.6	0.0
23771	2.5	0.2	21	1	301	9	1.9	0.0	0.56	0.02	1.8	0.0
24027	3.3	0.1	22	1	300	21	1.8	0.2	0.86	0.03	1.5	0.0
24047	2.7	0.2	22	1	322	19	1.8	0.0	0.61	0.06	1.9	0.1
24059	2.7	0.1	22	1	286	19	1.9	0.0	0.63	0.05	1.5	0.0
24072	2.5	0.1	21	1	271	14	1.8	0.1	0.58	0.04	1.3	0.0
24082	5.6	0.1	22	1	398	16	1.7	0.2	0.62	0.00	2.4	0.0
24088	4.5	0.1	21	1	339	39	1.7	0.1	0.59	0.03	2.4	0.2
24094	3.4	0.2	21	1	281	21	1.7	0.0	0.71	0.00	2.1	0.1
24122	3.4	0.3	21	1	256	15	1.8	0.1	0.58	0.03	1.5	0.0
24128	3.4	0.2	21	2	265	18	1.8	0.0	0.59	0.04	1.6	0.1
24134	4.2	0.2	24	3	287	13	1.8	0.1	0.63	0.02	2.0	0.1
24167	3.7	0.1	22	1	282	1	1.7	0.0	0.64	0.03	2.3	0.0
24173	5.0	0.2	21	2	348	12	2.0	0.0	0.73	0.00	2.2	0.1
24179	5.5	0.1	21	2	391	3	2.0	0.0	0.61	0.03	2.4	0.1
24185	3.2	0.1	20	0	246	18	2.0	0.1	0.64	0.02	2.2	0.1
24191	1.1	0.1	20	1	143	6	1.6	0.3	0.54	0.01	0.8	0.0
Overall average	3.6	1.2	21	1	307	58	1.8	0.1	0.62	0.07	1.9	0.4
Certified value <sup>1</sup>	<b>6.11</b>	<b>0.16</b>	<sup>2</sup> <b>23.4</b>	<b>0.8</b>	<b>414</b>	<b>12</b>	na	na	na	na	<b>2.60</b>	<b>0.03</b>
Recovery (%)	59.4	na	<sup>2</sup> 91.4	na	74.2	na	na	na	na	na	73.4	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

<sup>2</sup>The National Institute of Standards and Technology (2000) indicated that the originally certified concentration for arsenic (23.4 µg/g) was too high by about 6% in analyses made since 1996. Therefore, the concentration at the time of this study was about 22 µg/g and the corresponding recovery was 95.5%.

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Cadmium Cd $\mu\text{g/g}$		Cerium Ce $\mu\text{g/g}$		Cobalt Co $\mu\text{g/g}$		Chromium Cr $\mu\text{g/g}$		Cesium Cs $\mu\text{g/g}$		Copper Cu $\mu\text{g/g}$	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	3.7	0.0	52	3	13	1	130	6	5.4	0.1	99	3
23529	3.3	0.1	55	4	13	0	121	8	6.0	0.1	98	1
23608	3.4	0.0	23	1	13	0	126	5	2.9	0.0	96	1
23619	3.6	0.1	20	2	12	1	121	9	2.6	0.0	93	5
23627	3.4	0.1	27	2	13	0	126	3	4.0	0.0	99	1
23760	3.5	0.2	16	3	13	0	121	3	1.8	0.0	96	4
23771	3.5	0.2	16	0	13	0	126	3	1.4	0.0	100	0
24027	3.5	0.0	15	0	12	0	128	5	4.3	0.0	101	3
24047	3.5	0.2	17	0	13	1	132	6	3.4	0.0	100	5
24059	3.5	0.1	16	0	13	1	130	7	3.4	0.0	100	2
24072	3.4	0.1	19	0	12	1	130	6	2.7	0.0	95	4
24082	3.3	0.1	58	1	12	0	121	4	5.3	0.2	98	0
24088	3.5	0.2	45	2	12	0	120	0	4.0	0.1	94	1
24094	3.4	0.2	27	1	12	1	119	0	3.1	0.0	90	0
24122	3.3	0.2	31	2	12	1	115	2	2.9	0.2	87	1
24128	3.3	0.0	29	2	11	0	115	1	2.6	0.1	90	2
24134	3.3	0.1	41	0	12	1	125	3	5.4	0.0	99	2
24167	3.3	0.1	30	1	12	0	130	3	3.6	0.0	98	1
24173	3.3	0.0	38	1	12	1	126	7	4.0	0.1	100	4
24179	3.2	0.2	51	1	12	0	122	2	5.1	0.1	97	3
24185	3.4	0.1	30	1	12	0	129	3	3.9	0.0	104	3
24191	3.5	0.1	8.6	0.2	12	1	128	6	0.91	0.03	95	3
Overall average	3.4	0.1	30	15	12	0	125	5	3.6	1.3	97	4
Certified value <sup>1</sup>	<b>3.45</b>	<b>0.22</b>	72	na	<b>14.0</b>	<b>0.6</b>	<b>135</b>	<b>5</b>	6	na	<b>98.6</b>	<b>5.0</b>
Recovery (%)	98.8	na	41.7	na	88.2	na	92.3	na	59.7	na	98.1	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Dysprosium Dy $\mu\text{g/g}$		Erbium Er $\mu\text{g/g}$		Europium Eu $\mu\text{g/g}$		Iron Fe Wt%		Gallium Ga $\mu\text{g/g}$		Gadolinium Gd $\mu\text{g/g}$	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	4.1	0.2	2.4	0.1	1.1	0.0	3.8	0.1	13	0	4.4	0.1
23529	3.9	0.2	2.2	0.1	1.1	0.1	3.9	0.1	13	1	4.3	0.4
23608	2.6	0.1	1.5	0.0	0.70	0.03	3.8	0.1	13	0	2.8	0.1
23619	2.5	0.2	1.5	0.1	0.68	0.07	2.8	0.1	12	1	2.8	0.3
23627	3.2	0.0	1.9	0.1	0.81	0.01	3.6	0.1	13	0	3.4	0.0
23760	2.1	0.3	1.4	0.0	0.65	0.03	3.7	0.1	13	0	2.5	0.1
23771	2.4	0.1	1.5	0.0	0.67	0.02	3.7	0.1	13	0	2.7	0.0
24027	1.6	0.0	0.89	0.04	0.41	0.01	3.9	0.2	15	0	1.7	0.0
24047	2.5	0.0	1.5	0.0	0.69	0.01	3.9	0.3	15	1	2.8	0.0
24059	2.0	0.1	1.2	0.0	0.53	0.00	3.8	0.2	15	1	2.1	0.0
24072	2.1	0.1	1.2	0.0	0.57	0.05	3.8	0.1	15	0	2.4	0.1
24082	3.7	0.1	2.1	0.0	1.1	0.0	3.9	0.2	15	0	4.4	0.1
24088	3.8	0.2	2.3	0.1	1.0	0.0	3.8	0.2	15	0	4.1	0.2
24094	2.9	0.0	1.7	0.1	0.72	0.03	3.6	0.0	15	1	3.0	0.2
24122	2.1	0.1	1.3	0.1	0.62	0.02	3.8	0.2	15	1	2.4	0.1
24128	2.2	0.0	1.3	0.1	0.63	0.03	3.7	0.2	14	1	2.5	0.1
24134	3.4	0.1	1.9	0.0	0.89	0.02	4.1	0.3	15	1	3.7	0.2
24167	3.3	0.1	2.0	0.0	0.83	0.01	4.2	0.2	15	0	3.6	0.2
24173	3.6	0.2	2.1	0.1	0.98	0.06	4.2	0.1	15	1	3.9	0.1
24179	3.9	0.3	2.1	0.0	1.1	0.0	4.2	0.0	15	0	4.2	0.1
24185	3.5	0.1	2.1	0.0	0.83	0.02	4.2	0.1	15	0	3.5	0.0
24191	0.63	0.02	0.34	0.03	0.16	0.02	4.2	0.2	15	1	0.66	0.01
Overall average	2.8	0.9	1.6	0.5	0.76	0.24	3.8	0.3	14	1	3.1	1.0
Certified value <sup>1</sup>	6	na	na	na	1.3	na	<b>4.11</b>	<b>0.10</b>	15	na	na	na
Recovery (%)	47.0	na	na	na	58.6	na	93.6	na	95.4	na	na	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Holmium Ho $\mu\text{g/g}$		Potassium K Wt%		Lanthanum La $\mu\text{g/g}$		Lithium Lu $\mu\text{g/g}$		Lutetium Lu $\mu\text{g/g}$		Magnesium Mg Wt%	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	0.79	0.01	1.8	0.0	26	2	46	0	0.34	0.00	0.81	0.01
23529	0.79	0.00	1.9	0.1	27	2	47	1	0.34	0.02	1.13	0.05
23608	0.51	0.02	1.8	0.0	12	1	44	1	0.24	0.00	0.32	0.01
23619	0.49	0.04	1.8	0.1	11	1	43	2	0.23	0.01	0.29	0.02
23627	0.61	0.01	1.7	0.0	15	1	45	1	0.28	0.01	0.34	0.01
23760	0.44	0.01	1.6	0.0	11	1	42	0	0.19	0.01	0.12	0.00
23771	0.48	0.00	1.7	0.1	9.5	0.1	42	2	0.21	0.01	0.14	0.00
24027	0.31	0.02	1.6	0.0	7.8	0.1	41	1	0.13	0.01	0.53	0.02
24047	0.52	0.03	1.8	0.0	11	0	46	1	0.20	0.02	0.23	0.02
24059	0.39	0.01	1.7	0.0	9.1	0.0	42	2	0.17	0.00	0.22	0.01
24072	0.40	0.02	1.8	0.1	8.9	0.2	39	1	0.15	0.01	0.26	0.01
24082	0.70	0.01	1.8	0.1	28	0	45	3	0.28	0.01	1.10	0.03
24088	0.73	0.01	1.5	0.0	21	1	45	0	0.28	0.01	0.89	0.10
24094	0.55	0.02	1.4	0.0	12	0	40	0	0.21	0.01	0.64	0.04
24122	0.42	0.01	1.5	0.0	12	1	36	2	0.16	0.01	0.47	0.02
24128	0.44	0.01	1.4	0.0	12	0	35	1	0.17	0.00	0.50	0.03
24134	0.71	0.01	1.5	0.0	19	0	39	3	0.27	0.00	0.90	0.07
24167	0.65	0.02	1.4	0.0	13	1	43	0	0.26	0.01	0.59	0.01
24173	0.72	0.05	1.8	0.1	18	1	47	0	0.28	0.02	0.83	0.05
24179	0.70	0.01	1.4	0.0	24	0	46	0	0.27	0.00	1.08	0.03
24185	0.68	0.02	1.2	0.0	13	0	45	1	0.27	0.02	0.51	0.03
	0.12	0.00	1.0	0.0	2.4	0.1	29	2	0.047	0.006	0.13	0.01
Overall average	0.55	0.17	1.6	0.2	15	7	42	4	0.23	0.07	0.55	0.33
Certified value <sup>1</sup>	na	na	<b>2.00</b>	<b>0.04</b>	29	na	<b>47.5</b>	<b>4.1</b>	0.6	na	<b>1.20</b>	<b>0.02</b>
Recovery (%)	na	na	79.9	na	50.5	na	88.6	na	37.7	na	45.6	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Manganese Mn $\mu\text{g/g}$		Molybdenum Mo $\mu\text{g/g}$		Sodium Na Wt%		Neodymium Nd $\mu\text{g/g}$		Nickel Ni $\mu\text{g/g}$		Phosphorus P $\mu\text{g/g}$	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
	23515	567	23	3.8	0.0	0.51	0.02	25	0	41	1	949
23529	566	11	4.0	0.3	0.52	0.03	27	2	41	2	975	109
23608	570	4	3.9	0.2	0.48	0.01	14	0	42	1	1030	26
23619	564	22	4.3	0.2	0.49	0.03	14	0	40	3	900	48
23627	609	13	5.3	1.3	0.59	0.01	18	1	41	1	997	28
23760	608	19	4.4	0.4	0.52	0.00	13	2	42	1	1040	28
23771	621	17	3.9	0.3	0.52	0.01	13	0	43	1	1040	42
24027	565	9	4.3	0.1	0.52	0.01	9.7	0.1	43	1	939	11
24047	573	27	4.2	0.3	0.56	0.02	14	0	45	2	969	68
24059	570	24	4.3	0.1	0.52	0.03	11	0	42	2	982	68
24072	561	23	3.9	0.3	0.45	0.02	12	0	41	2	972	48
24082	547	19	5.0	1.1	0.53	0.01	28	0	40	1	947	2
24088	526	2	3.9	0.2	0.52	0.02	24	0	39	1	1050	4
24094	512	6	4.6	0.3	0.46	0.00	15	1	44	0	1000	59
24122	533	30	3.9	0.3	0.34	0.01	15	1	38	0	926	34
24128	507	9	3.9	0.2	0.33	0.03	14	0	39	1	1000	115
24134	536	25	4.3	0.0	0.58	0.00	20	0	42	1	982	38
24167	567	16	4.3	0.3	0.57	0.01	17	0	46	1	955	4
24173	572	25	3.9	0.1	0.58	0.00	21	2	41	2	953	89
24179	569	4	4.1	0.5	0.59	0.00	24	0	41	1	977	24
24185	567	13	3.9	0.2	0.63	0.01	16	1	48	1	934	110
24191	546	33	3.7	0.3	0.55	0.01	3.4	0.1	41	2	947	69
Overall average	562	28	4.2	0.4	0.52	0.07	17	6	42	2	976	40
Certified value <sup>1</sup>	<b>555</b>	<b>19</b>	na	na	<b>0.547</b>	<b>0.014</b>	na	na	<b>44.1</b>	<b>3.0</b>	<b>998</b>	<b>28</b>
Recovery (%)	101.2	na	na	na	94.3	na	na	na	95.2	na	97.8	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Lead Pb $\mu\text{g/g}$		Praseodymium Pr $\mu\text{g/g}$		Rubidium Rb $\mu\text{g/g}$		Rhenium Re $\mu\text{g/g}$		Sulfur S Wt%		Antimony Sb $\mu\text{g/g}$	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	160	1	6.6	0.4	71	1	< 0.002	0.001	0.42	0.01	3.7	0.1
23529	168	1	6.8	0.5	103	7	< 0.002	0.000	0.44	0.01	3.8	0.3
23608	160	0	3.6	0.2	36	1	< 0.002	0.002	0.45	0.02	3.7	0.2
23619	153	8	3.4	0.3	34	2	< 0.002	0.001	0.45	0.02	3.7	0.1
23627	162	2	4.3	0.0	35	1	0.003	0.0008	0.42	0.01	5.2	0.1
23760	153	5	3.3	0.1	37	3	< 0.002	0.000	0.46	0.01	3.6	0.1
23771	151	5	3.2	0.0	27	1	0.0027	0.0001	0.45	0.00	3.8	0.1
24027	184	4	2.3	0.1	56	1	0.003	0.001	0.44	0.01	3.6	0.1
24047	155	9	3.4	0.2	38	1	< 0.002	0.000	0.44	0.01	3.8	0.1
24059	174	6	2.8	0.0	47	0	0.004	0.001	0.46	0.01	4.9	0.2
24072	216	5	2.9	0.1	42	2	0.003	0.000	0.43	0.02	3.9	0.2
24082	154	2	7.0	0.2	106	1	0.003	0.002	0.42	0.02	3.8	0.1
24088	154	1	5.7	0.3	24	1	< 0.002	0.002	0.43	0.05	3.7	0.2
24094	156	0	3.7	0.0	15	1	0.004	0.001	0.43	0.03	3.9	0.1
24122	150	10	3.6	0.3	45	4	0.003	0.002	0.40	0.03	3.4	0.1
24128	156	2	3.5	0.2	31	1	0.003	0.001	0.40	0.02	3.7	0.0
24134	153	8	5.0	0.1	67	2	0.003	0.002	0.43	0.02	3.6	0.1
24167	155	8	3.9	0.1	16	0	0.005	0.000	0.44	0.02	3.6	0.0
24173	152	9	4.9	0.3	50	3	< 0.002	0.002	0.41	0.03	3.6	0.2
24179	150	3	6.1	0.2	97	1	0.003	0.001	0.42	0.01	3.7	0.4
24185	161	0	3.8	0.1	13	0	< 0.002	0.002	0.44	0.03	3.6	0.2
24191	160	9	0.82	0.03	5.5	0.5	< 0.003	0.002	0.43	0.00	3.7	0.2
Overall average	161	15	4.1	1.6	45	28	na	na	0.43	0.02	3.8	0.4
Certified value <sup>1</sup>	<b>161</b>	<b>17</b>	na	na	100	na	na	na	<b>0.397</b>	<b>0.004</b>	<b>3.79</b>	<b>0.15</b>
Recovery (%)	99.8	na	na	na	45.2	na	na	na	109.0	na	100.9	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation.  $\mu\text{g/g}$ , microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on "Overall average" row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Selenium Se $\mu\text{g/g}$		Samarium Sm $\mu\text{g/g}$		Strontium Sr $\mu\text{g/g}$		Terbium Tb $\mu\text{g/g}$		Tellurium Te $\mu\text{g/g}$		Thorium Th $\mu\text{g/g}$	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	2.2	0.7	5.0	0.0	123	2	0.68	0.01	0.18	0.01	16	1
23529	1.8	0.5	5.2	0.2	130	5	0.67	0.05	0.14	0.02	17	0
23608	< 1	0	3.0	0.0	106	5	0.45	0.02	0.17	0.06	9.2	0.1
23619	1.5	0.8	2.9	0.1	102	7	0.42	0.04	0.17	0.02	8.5	0.4
23627	1.9	0.8	4.1	0.1	114	2	0.55	0.05	0.25	0.00	13	0
23760	1.6	0.4	3.0	0.1	107	4	0.37	0.05	0.19	0.01	9.2	0.3
23771	1.5	0.8	3.1	0.1	100	2	0.42	0.00	0.18	0.04	9.7	0.1
24027	< 1	0	1.9	0.0	113	6	0.25	0.01	0.20	0.04	7.4	0.2
24047	< 1	1	3.1	0.2	107	1	0.44	0.01	0.22	0.04	12	1
24059	< 1	0	2.4	0.0	114	1	0.33	0.02	0.19	0.05	8.9	0.3
24072	< 1	1	2.6	0.0	96	2	0.34	0.01	0.12	0.03	9.2	0.2
24082	1.9	1.4	5.5	0.1	127	4	0.66	0.01	0.21	0.05	21	0
24088	1.6	1.2	4.7	0.0	114	4	0.62	0.01	0.14	0.03	18	1
24094	< 1	0	3.4	0.1	97	7	0.49	0.00	0.14	0.06	12	1
24122	< 1	0	3.0	0.2	80	3	0.39	0.00	0.17	0.03	8.8	0.6
24128	< 1	0	3.0	0.2	75	5	0.38	0.00	0.16	0.01	10	0
24134	8.9	13.1	4.2	0.1	90	6	0.57	0.03	0.17	0.06	16	1
24167	4.2	6.6	3.8	0.0	91	0	0.56	0.02	0.16	0.05	13	0
24173	< 1	4	4.4	0.4	109	6	0.62	0.02	0.14	0.02	18	0
24179	< 1	6	4.7	0.0	128	3	0.61	0.01	0.19	0.01	20	0
24185	< 1	2	3.7	0.1	92	7	0.55	0.01	0.17	0.04	14	0
24191	< 1	1	0.76	0.02	62	2	0.11	0.01	0.15	0.04	2.7	0.1
Overall average	< 1	na	3.5	1.1	103	17	0.48	0.15	0.17	0.03	12	5
Certified value <sup>1</sup>	<b>1.12</b>	<b>0.05</b>	6.7	na	130	na	na	na	na	na	9.2	na
Recovery (%)	na	na	52.6	na	79.6	na	na	na	na	na	na	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation. µg/g, microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on “Overall average” row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Titanium Ti Wt%		Thallium Tl µg/g		Thulium Tm µg/g		Uranium U µg/g		Vanadium V µg/g		Tungsten W µg/g	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	0.43	0.03	0.97	0.16	0.34	0.00	3.0	0.1	91	3	1.6	0.0
23529	0.42	0.01	0.87	0.03	0.33	0.00	2.9	0.1	90	4	1.5	0.1
23608	0.45	0.02	0.80	0.01	0.22	0.01	3.0	0.0	94	4	1.6	0.1
23619	0.44	0.03	0.78	0.03	0.22	0.01	3.1	0.1	93	6	1.8	0.1
23627	0.44	0.02	0.88	0.08	0.27	0.01	3.0	0.1	92	2	1.6	0.1
23760	0.44	0.01	0.85	0.02	0.19	0.00	3.0	0.0	90	5	2.0	0.1
23771	0.44	0.01	0.79	0.01	0.21	0.00	3.0	0.2	91	3	1.6	0.1
24027	0.43	0.01	0.85	0.07	0.12	0.00	3.0	0.1	92	3	1.7	0.1
24047	0.45	0.01	0.89	0.02	0.21	0.01	3.1	0.1	95	3	1.6	0.0
24059	0.45	0.02	0.89	0.03	0.16	0.00	3.0	0.1	96	5	1.5	0.1
24072	0.43	0.02	0.84	0.02	0.17	0.00	2.9	0.1	92	3	1.9	0.0
24082	0.34	0.01	0.84	0.07	0.29	0.01	2.8	0.2	90	1	1.4	0.0
24088	0.44	0.05	0.85	0.11	0.32	0.00	3.0	0.1	95	11	1.6	0.1
24094	0.45	0.01	0.85	0.05	0.23	0.00	3.1	0.1	100	1	1.6	0.1
24122	0.39	0.02	0.80	0.08	0.17	0.02	2.9	0.1	91	5	1.5	0.0
24128	0.40	0.03	0.83	0.04	0.18	0.01	2.8	0.0	90	7	1.5	0.0
24134	0.40	0.02	1.0	0.3	0.28	0.00	2.7	0.1	91	7	1.7	0.0
24167	0.41	0.00	0.83	0.03	0.28	0.01	2.8	0.0	91	0	1.6	0.0
24173	0.39	0.02	0.86	0.10	0.29	0.01	3.0	0.0	89	5	1.5	0.1
24179	0.36	0.01	0.85	0.02	0.30	0.01	2.9	0.1	93	5	1.3	0.0
24185	0.42	0.03	0.81	0.07	0.28	0.01	3.1	0.1	94	7	1.5	0.1
24191	0.42	0.02	0.74	0.05	0.052	0.002	2.9	0.2	92	3	1.5	0.1
Overall average	0.42	0.03	0.85	0.06	0.23	0.07	3.0	0.1	92	3	1.6	0.1
Certified value	<b>0.457</b>	<b>0.018</b>	<b>1.06</b>	<b>0.07</b>	na	na	<b>3.13</b>	<b>0.13</b>	<b>95</b>	<b>4</b>	na	na
Recovery (%)	92.0	na	80.1	na	na	na	94.3	na	97.1	na	na	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).



**Table B1.** Concentrations of trace metals and major elements in standard reference materials—Continued.

[Standard reference material is Buffalo River Sediment (NIST 2704). NIST, National Institute of Standards and Technology. Wt%, weight percent; Avg, average concentration from three or more replicate measurements of single digestate; SD, standard deviation. µg/g, microgram per gram; na, not applicable; <, less than.

Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. Standard deviation on “Overall average” row represents standard deviation of individual analyses. Recovery computed as Average value divided by Certified value]

Laboratory ID	Yttrium Y µg/g		Ytterbium Yb µg/g		Zinc Zn µg/g		Zirconium Zr µg/g	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23515	23	1	2.4	0.0	410	10	152	5
23529	20	0	2.2	0.1	407	17	136	9
23608	14	0	1.5	0.0	414	2	151	6
23619	13	1	1.5	0.1	409	18	151	11
23627	16	0	1.9	0.0	413	1	179	4
23760	11	0	1.2	0.0	443	1	172	6
23771	11	0	1.4	0.0	428	0	166	2
24027	7.5	0.1	0.88	0.04	412	2	164	7
24047	13	1	1.5	0.1	444	6	158	11
24059	11	0	1.1	0.0	470	6	161	8
24072	9.3	0.4	1.1	0.0	416	14	147	7
24082	20	0	2.1	0.1	407	0	121	1
24088	20	0	2.2	0.1	399	4	146	1
24094	13	1	1.6	0.1	395	2	142	1
24122	8.7	0.5	1.2	0.1	393	0	123	7
24128	10	1	1.3	0.0	397	3	133	2
24134	17	1	1.9	0.0	413	8	138	4
24167	16	1	2.1	0.0	411	3	173	5
24173	17	1	2.1	0.0	422	21	146	8
24179	19	0	2.0	0.0	415	11	132	3
24185	17	0	2.0	0.0	410	7	185	1
24191	2.6	0.2	0.37	0.02	417	4	164	7
Overall average	14	5	1.6	0.5	416	18	152	18
Certified value	na	na	2.8	na	<b>438</b>	<b>12</b>	300	na
Recovery (%)	na	na	58.0	na	94.9	na	50.6	na

<sup>1</sup>Non-bold numbers are not certified and are provided for information only (National Institute of Standards and Technology, 1990).

**Table B2.** Data for trace metals and major elements in digestion blanks.

[Averages (Avg) and standard deviations (SD) are for three or more replicate analyses of single digested subsample. Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Laboratory ID	Aluminum Al µg/L		Arsenic As µg/L		Barium Ba µg/L		Beryllium Be µg/L		Bismuth Bi µg/L		Calcium Ca mg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	15	1	< 0.1	0.1	< 0.7	0.2	< 0.04	0.01	0.014	0.019	< 0.07	0.03
23530	105	5	< 0.1	0.2	< 0.7	0.2	< 0.04	0.02	0.043	0.025	< 0.07	0.04
23611	176	6	< 0.1	0.1	< 0.7	0.2	< 0.04	0.02	0.038	0.010	< 0.07	0.02
23621	23	1	< 0.1	0.1	0.7	1.2	< 0.04	0.01	0.040	0.020	< 0.07	0.04
23631	92	4	< 0.1	0.1	1.1	1.2	< 0.04	0.02	0.063	0.060	0.09	0.00
23767	118	7	0.2	0.5	0.9	0.4	< 0.04	0.02	0.024	0.001	< 0.07	0.02
23777	49	1	< 0.1	0.2	< 0.7	1.0	< 0.04	0.01	< 0.008	0.002	< 0.07	0.00
24031	72	3	< 0.1	0.1	< 0.7	0.1	< 0.04	0.02	0.042	0.016	< 0.07	0.02
24053	121	3	< 0.1	0.1	1.3	0.4	< 0.04	0.01	0.032	0.005	0.09	0.02
24063	66	2	< 0.1	0.1	< 0.7	0.1	< 0.04	0.00	0.038	0.034	< 0.07	0.01
24083	302	8	1.1	1.4	1.3	0.2	< 0.04	0.03	0.085	0.056	0.10	0.02
24089	54	2	0.2	0.3	< 0.7	0.1	< 0.04	0.02	0.030	0.016	< 0.07	0.02
24095	153	10	0.4	0.8	2.1	0.4	< 0.04	0.01	0.032	0.003	< 0.07	0.02
24174	336	15	2.4	3.2	0.7	0.1	< 0.04	0.04	0.092	0.016	< 0.07	0.04
24186	609	11	< 0.1	0.3	0.9	0.2	< 0.04	0.03	0.15	0.02	< 0.07	0.01
24192	181	6	0.3	0.6	2.0	0.1	< 0.04	0.01	0.024	0.008	< 0.07	0.03

Laboratory ID	Cadmium Cd µg/L		Cerium Ce µg/L		Cobalt Co µg/L		Chromium Cr µg/L		Cesium Cs µg/L		Copper Cu µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	0.05	0.01	0.026	0.002	< 0.03	0.01	< 0.9	0.1	< 0.03	0.04	0.3	0.1
23530	0.03	0.01	0.084	0.007	< 0.03	0.00	< 0.9	1.1	< 0.03	0.01	< 0.3	0.1
23611	0.12	0.01	0.059	0.006	< 0.03	0.00	< 0.9	0.6	< 0.03	0.02	0.7	0.0
23621	0.02	0.00	0.019	0.003	< 0.03	0.00	< 0.9	0.9	0.05	0.03	0.5	0.2
23631	< 0.02	0.01	0.042	0.004	< 0.03	0.01	< 0.9	0.3	< 0.03	0.01	< 0.3	0.3
23767	0.05	0.02	0.033	0.001	< 0.03	0.00	< 0.9	0.8	< 0.03	0.02	1.1	0.6
23777	0.02	0.01	0.013	0.001	< 0.03	0.01	< 0.9	1.3	< 0.03	0.04	< 0.3	0.1
24031	0.02	0.01	0.051	0.001	0.08	0.01	2.9	0.6	0.57	0.02	1.5	0.2
24053	0.04	0.01	0.055	0.006	< 0.03	0.01	< 0.9	0.2	< 0.03	0.03	0.4	0.3
24063	< 0.02	0.00	0.034	0.005	0.03	0.01	1.6	0.5	< 0.03	0.03	0.4	0.4
24083	< 0.02	0.01	0.23	0.01	< 0.03	0.01	< 0.9	1.8	0.04	0.01	< 0.3	0.1
24089	< 0.02	0.01	0.047	0.008	< 0.03	0.01	1.1	1.3	< 0.03	0.02	< 0.3	0.1
24095	0.02	0.00	0.11	0.09	< 0.03	0.00	< 0.9	1.5	1.3	0.0	< 0.3	0.0
24174	< 0.02	0.02	0.058	0.007	< 0.03	0.03	< 0.9	1.2	0.13	0.03	< 0.3	0.3
24186	0.02	0.00	0.094	0.017	< 0.03	0.01	< 0.9	1.7	0.06	0.01	< 0.3	0.1
24192	0.05	0.01	0.071	0.028	< 0.03	0.01	0.9	1.6	0.28	0.01	< 0.3	0.0

**Table B2.** Data for trace metals and major elements in digestion blanks—Continued.

[Averages (Avg) and standard deviations (SD) are for three or more replicate analyses of single digested subsample. Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Laboratory ID	Dysprosium Dy µg/L		Erbium Er µg/L		Europium Eu µg/L		Iron Fe µg/L		Gallium Ga µg/L		Gadolinium Gd µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.003	0.002	< 0.004	0.001	< 0.002	0.000	< 50	4	< 0.007	0.002	< 0.004	0.001
23530	0.008	0.003	0.005	0.001	0.004	0.002	66	76	< 0.007	0.004	0.006	0.003
23611	0.004	0.002	0.009	0.001	< 0.002	0.000	< 50	14	< 0.007	0.012	0.004	0.001
23621	< 0.003	0.002	< 0.004	0.000	< 0.002	0.001	< 50	100	0.010	0.008	0.005	0.004
23631	0.004	0.004	< 0.004	0.002	< 0.002	0.001	< 50	41	0.009	0.003	< 0.004	0.001
23767	0.004	0.000	< 0.004	0.003	< 0.002	0.002	60	31	< 0.007	0.004	< 0.004	0.002
23777	< 0.003	0.002	< 0.004	0.002	< 0.002	0.000	52	52	0.010	0.004	< 0.004	0.001
24031	0.003	0.004	< 0.004	0.001	0.002	0.001	97	22	< 0.007	0.005	< 0.004	0.001
24053	0.004	0.004	< 0.004	0.002	0.002	0.001	< 50	28	0.012	0.006	< 0.004	0.005
24063	< 0.003	0.004	< 0.004	0.003	< 0.002	0.000	< 50	8	< 0.007	0.005	< 0.004	0.006
24083	0.014	0.006	0.011	0.008	0.005	0.003	< 50	44	< 0.007	0.004	0.018	0.009
24089	< 0.003	0.002	< 0.004	0.001	< 0.002	0.000	54	39	< 0.007	0.004	< 0.004	0.001
24095	0.003	0.001	< 0.004	0.003	< 0.002	0.002	< 50	48	< 0.007	0.005	< 0.004	0.004
24174	0.006	0.004	< 0.004	0.005	0.003	0.002	162	33	< 0.007	0.017	0.008	0.003
24186	0.009	0.003	0.010	0.007	0.003	0.001	149	22	< 0.007	0.015	0.010	0.005
24192	0.004	0.007	0.006	0.004	< 0.002	0.001	< 50	56	< 0.007	0.011	0.006	0.004

Laboratory ID	Holmium Ho µg/L		Potassium K mg/L		Lanthanum La µg/L		Lithium Li µg/L		Lutetium Lu µg/L		Magnesium Mg mg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.0010	0.001	< 0.09	0.03	0.014	0.002	< 0.1	0.1	< 0.0010	0.000	0.005	0.004
23530	0.002	0.000	< 0.09	0.06	0.039	0.006	< 0.1	0.1	< 0.0010	0.000	0.006	0.010
23611	0.001	0.001	< 0.09	0.03	0.029	0.002	< 0.1	0.0	< 0.0010	0.000	0.030	0.045
23621	< 0.0010	0.001	< 0.09	0.06	0.009	0.003	< 0.1	0.2	< 0.0010	0.001	< 0.004	0.000
23631	< 0.0010	0.001	< 0.09	0.04	0.020	0.001	< 0.1	0.1	< 0.0010	0.001	0.009	0.007
23767	0.001	0.000	0.15	0.21	0.015	0.000	0.2	0.2	0.001	0.001	0.004	0.003
23777	< 0.0010	0.000	< 0.09	0.05	0.006	0.002	0.1	0.2	< 0.0010	0.000	< 0.004	0.002
24031	< 0.0010	0.000	0.12	0.10	0.027	0.001	0.2	0.1	< 0.0010	0.000	0.035	0.011
24053	< 0.0010	0.001	< 0.09	0.09	0.031	0.001	< 0.1	0.1	< 0.0010	0.000	0.025	0.004
24063	< 0.0010	0.001	< 0.09	0.08	0.021	0.002	< 0.1	0.2	< 0.0010	0.000	0.023	0.020
24083	0.003	0.001	0.10	0.07	0.12	0.01	< 0.1	0.0	0.001	0.000	0.053	0.034
24089	0.001	0.000	< 0.09	0.04	0.020	0.006	< 0.1	0.1	< 0.0010	0.001	0.004	0.005
24095	< 0.0010	0.001	< 0.09	0.08	0.060	0.064	0.2	0.0	< 0.0010	0.001	0.020	0.030
24174	0.001	0.001	< 0.09	0.01	0.031	0.003	0.3	0.1	< 0.0010	0.001	< 0.004	0.000
24186	0.003	0.002	< 0.09	0.01	0.043	0.011	0.5	0.1	0.002	0.001	0.013	0.015
24192	< 0.0010	0.000	< 0.09	0.09	0.028	0.012	< 0.1	0.04	< 0.0010	0.001	0.010	0.002

**Table B2.** Data for trace metals and major elements in digestion blanks—Continued.

[Averages (Avg) and standard deviations (SD) are for three or more replicate analyses of single digested subsample. Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Laboratory ID	Manganese Mn µg/L		Molybdenum Mo µg/L		Sodium Na mg/L		Neodymium Nd µg/L		Nickel Ni µg/L		Phosphorus P µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.6	0.7	< 0.3	0.1	< 0.02	0.02	0.018	0.008	< 0.1	0.1	< 50	18
23530	< 0.6	0.5	< 0.3	0.2	0.20	0.03	0.053	0.003	0.1	0.0	< 50	28
23611	1.1	0.5	< 0.3	0.0	0.29	0.02	0.023	0.010	0.1	0.1	< 50	11
23621	< 0.6	0.2	< 0.3	0.2	0.08	0.01	0.011	0.002	0.3	0.0	< 50	23
23631	< 0.6	0.3	< 0.3	0.2	0.17	0.01	0.013	0.003	< 0.1	0.0	< 50	40
23767	0.8	0.1	0.8	0.1	0.33	0.09	< 0.009	0.002	0.5	0.2	< 50	37
23777	< 0.6	0.1	< 0.3	0.2	0.08	0.03	< 0.009	0.001	0.3	0.1	< 50	44
24031	0.8	0.3	0.7	0.3	0.20	0.08	0.021	0.005	1.2	0.1	< 50	60
24053	< 0.6	0.1	< 0.3	0.1	0.28	0.02	0.022	0.007	7.3	0.3	< 50	27
24063	< 0.6	0.1	< 0.3	0.1	0.19	0.06	0.016	0.005	0.9	0.2	< 50	29
24083	0.7	0.2	0.8	1.2	0.25	0.07	0.12	0.02	0.9	0.1	< 50	21
24089	< 0.6	0.2	1.4	0.1	0.04	0.01	0.027	0.014	0.2	0.0	< 50	16
24095	< 0.6	0.1	< 0.3	0.3	0.31	0.02	0.060	0.070	0.6	0.0	< 50	34
24174	< 0.6	0.8	0.3	0.3	0.85	0.06	0.025	0.009	1.0	0.1	< 50	7
24186	< 0.6	0.5	< 0.3	0.4	1.5	0.1	0.030	0.014	0.7	0.2	< 50	33
24192	0.8	0.1	< 0.3	0.2	0.09	0.03	0.025	0.008	0.3	0.1	< 50	26

Laboratory ID	Lead Pb µg/L		Praseodymium Pr µg/L		Rubidium Rb µg/L		Rhenium Re µg/L		Sulfur S mg/L		Antimony Sb µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.1	0.1	0.004	0.001	< 0.06	0.04	< 0.002	0.000	< 0.2	0.1	0.04	0.02
23530	0.2	0.1	0.011	0.001	< 0.06	0.02	< 0.002	0.001	< 0.2	0.1	0.05	0.07
23611	0.2	0.1	0.008	0.001	< 0.06	0.02	< 0.002	0.001	< 0.2	0.1	0.06	0.01
23621	< 0.1	0.0	0.004	0.001	< 0.06	0.02	< 0.002	0.001	< 0.2	0.1	0.03	0.03
23631	< 0.1	0.1	0.005	0.002	< 0.06	0.03	< 0.002	0.001	< 0.2	0.1	0.05	0.05
23767	0.1	0.1	0.004	0.001	0.14	0.15	< 0.002	0.001	< 0.2	0.0	0.29	0.01
23777	< 0.1	0.0	< 0.002	0.000	< 0.06	0.04	< 0.002	0.001	< 0.2	0.1	0.03	0.07
24031	0.4	0.1	0.008	0.002	0.11	0.04	< 0.002	0.001	< 0.2	0.1	0.05	0.02
24053	0.1	0.0	0.006	0.000	0.08	0.04	< 0.002	0.001	< 0.2	0.1	0.02	0.01
24063	0.2	0.0	0.004	0.000	0.14	0.04	< 0.002	0.002	< 0.2	0.1	0.07	0.00
24083	0.3	0.2	0.030	0.003	0.22	0.04	< 0.002	0.001	< 0.2	0.0	0.14	0.10
24089	0.1	0.1	0.005	0.001	< 0.06	0.01	< 0.002	0.000	< 0.2	0.2	0.04	0.02
24095	0.4	0.0	0.016	0.019	0.07	0.04	< 0.002	0.001	< 0.2	0.1	0.38	0.03
24174	0.1	0.1	0.007	0.001	0.13	0.06	< 0.002	0.000	< 0.2	0.1	0.09	0.01
24186	0.2	0.1	0.013	0.003	0.15	0.03	< 0.002	0.002	< 0.2	0.0	0.15	0.05
24192	< 0.1	0.1	0.006	0.002	< 0.06	0.0	< 0.002	0.001	< 0.2	0.1	0.02	0.01

**Table B2.** Data for trace metals and major elements in digestion blanks—Continued.

[Averages (Avg) and standard deviations (SD) are for three or more replicate analyses of single digested subsample. Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Laboratory ID	Selenium Se µg/L		Samarium Sm µg/L		Strontium Sr µg/L		Terbium Tb µg/L		Tellurium Te µg/L		Thorium Th µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.8	0.4	< 0.008	0.004	< 0.1	0.0	< 0.0008	0.001	< 0.04	0.03	0.007	0.003
23530	< 0.8	0.8	0.014	0.003	< 0.1	0.0	0.001	0.001	< 0.04	0.04	0.11	0.10
23611	< 0.8	0.8	< 0.008	0.001	0.2	0.1	0.001	0.001	< 0.04	0.02	0.046	0.006
23621	< 0.8	0.4	< 0.008	0.005	0.6	0.7	< 0.0008	0.000	< 0.04	0.04	0.069	0.110
23631	< 0.8	1.2	< 0.008	0.003	0.4	0.7	< 0.0008	0.000	< 0.04	0.00	0.11	0.13
23767	< 0.8	1.8	< 0.008	0.003	0.2	0.1	< 0.0008	0.000	< 0.04	0.02	0.11	0.13
23777	< 0.8	0.1	< 0.008	0.004	0.2	0.0	< 0.0008	0.001	< 0.04	0.00	0.10	0.17
24031	< 0.8	1.5	< 0.008	0.002	< 0.1	0.1	0.001	0.001	< 0.04	0.02	0.033	0.007
24053	< 0.8	0.3	< 0.008	0.002	0.4	0.4	0.001	0.001	< 0.04	0.02	0.041	0.013
24063	< 0.8	0.4	< 0.008	0.005	< 0.1	0.1	< 0.0008	0.000	< 0.04	0.01	0.030	0.016
24083	5.7	1.5	0.024	0.007	1.0	0.7	0.002	0.001	0.04	0.02	0.37	0.20
24089	< 0.8	0.9	< 0.008	0.006	< 0.1	0.1	0.001	0.001	< 0.04	0.02	0.038	0.011
24095	< 0.8	0.4	0.011	0.005	0.2	0.2	< 0.0008	0.001	< 0.04	0.02	0.072	0.031
24174	8.2	11.8	< 0.008	0.001	0.3	0.2	< 0.0008	0.000	< 0.04	0.04	0.060	0.014
24186	< 0.8	2.1	< 0.008	0.001	0.4	0.0	0.001	0.001	0.05	0.01	0.092	0.014
24192	1.0	2.5	< 0.008	0.001	0.3	0.1	< 0.0008	0.001	< 0.04	0.03	0.030	0.006

Laboratory ID	Titanium Ti µg/L		Thallium Tl µg/L		Thulium Tm µg/L		Uranium U µg/L		Vanadium V µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 6	3	< 0.06	0.05	< 0.001	0.000	< 0.007	0.002	< 2	1
23530	< 6	7	< 0.06	0.09	< 0.001	0.000	0.023	0.019	< 2	0
23611	< 6	6	< 0.06	0.04	< 0.001	0.000	0.019	0.002	< 2	1
23621	< 6	6	< 0.06	0.05	< 0.001	0.001	< 0.007	0.001	< 2	1
23631	15	10	< 0.06	0.03	< 0.001	0.000	< 0.007	0.000	< 2	1
23767	8	2	< 0.06	0.02	< 0.001	0.000	0.035	0.055	< 2	1
23777	< 6	5	< 0.06	0.05	< 0.001	0.001	< 0.007	0.001	< 2	1
24031	7	7	< 0.06	0.03	< 0.001	0.001	< 0.007	0.002	< 2	2
24053	10	6	< 0.06	0.01	< 0.001	0.000	< 0.007	0.003	< 2	2
24063	< 6	8	< 0.06	0.03	< 0.001	0.001	0.014	0.002	< 2	2
24083	< 6	8	< 0.06	0.07	0.001	0.001	0.060	0.075	2	0
24089	7	7	0.07	0.08	< 0.001	0.000	< 0.007	0.01	< 2	1
24095	8	8	< 0.06	0.04	< 0.001	0.001	< 0.007	0.00	< 2	1
24174	< 6	2	< 0.06	0.00	< 0.001	0.001	0.009	0.001	< 2	1
24186	15	4	< 0.06	0.03	0.002	0.001	0.015	0.002	< 2	0
24192	6	7	< 0.06	0.05	< 0.001	0.001	< 0.007	0.004	< 2	0

**Table B2.** Data for trace metals and major elements in digestion blanks—Continued.

[Averages (Avg) and standard deviations (SD) are for three or more replicate analyses of single digested subsample. Standard deviation for each analysis represents standard deviation of three or more ICP (inductively coupled plasma) analyses of single digestate. µg/L, microgram per liter; mg/L, milligram per liter; <, less than]

Laboratory ID	Tungsten W µg/L		Yttrium Y µg/L		Ytterbium Yb µg/L		Zinc Zn µg/L		Zirconium Zr µg/L	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
23520	< 0.02	0.01	0.011	0.002	< 0.002	0.001	4	3	0.11	0.02
23530	< 0.02	0.01	0.044	0.007	0.004	0.001	< 2	1	2.4	0.2
23611	< 0.02	0.00	0.037	0.001	0.005	0.001	3	1	4.0	0.2
23621	< 0.02	0.01	0.009	0.002	< 0.002	0.004	2	1	0.40	0.20
23631	< 0.02	0.00	0.013	0.003	0.003	0.001	7	2	2.2	0.2
23767	< 0.02	0.01	0.018	0.003	0.004	0.002	15	4	2.4	0.1
23777	< 0.02	0.00	0.007	0.003	< 0.002	0.001	5	1	0.73	0.29
24031	4.9	0.1	0.017	0.004	0.004	0.002	13	4	2.1	0.1
24053	0.16	0.01	0.020	0.000	0.003	0.002	8	3	1.7	0.0
24063	1.6	0.0	0.015	0.005	< 0.002	0.003	8	1	1.8	0.1
24083	0.03	0.02	0.090	0.000	0.011	0.001	13	3	2.7	0.3
24089	< 0.02	0.01	0.021	0.006	< 0.002	0.001	5	0	1.0	0.0
24095	< 0.02	0.01	0.026	0.008	0.005	0.002	13	6	2.8	0.1
24174	0.03	0.01	0.039	0.009	0.007	0.005	4	1	8.8	0.4
24186	< 0.02	0.00	0.079	0.009	0.018	0.001	6	1	16	1
24192	< 0.02	0.01	0.020	0.013	< 0.002	0.002	4	1	1.7	0.4

**Table B3.** Recovery data for trace-metal spikes in sediment samples from Englebright Lake, California, 2002.

[Numbers are percent recovery, computed as measured value divided by expected value; —, not determined]

Date	Arsenic As	Cadmium Cd	Calcium Ca	Copper Cu	Lead Pb	Magnesium Mg	Zinc Zn
7/13/2004	107	103	—	100	99	—	106
7/16/2004	97	94	109	93	89	107	97
7/16/2004	121	106	—	102	99	—	106
7/30/2004	101	100	110	98	97	111	102
8/5/2004	100	97	108	89	94	104	97
8/6/2004	105	98	113	89	93	113	97

**Table B4.** Data for trace metals and major elements in replicate sediment subsamples from Englebright Lake, California, 2002.See Excel table B4 at *App\_B\_TableB4.xls***Table B5.** Data for trace metals and major elements from the Y series of subsamples from the May–June 2002 deep cores from Englebright Lake, California.See Excel table B5 at *App\_B\_TableB5.xls*

## Appendix C. Mineralogical and Grain-Size Distribution Data for Heavy Mineral Concentrates

**Table C1.** Particle-size distribution of bulk composite core samples prior to preparation of heavy mineral concentrates, Englebright Lake, California, 2002.

[mm, millimeter; g, gram; m, meter; &gt;, greater than; &lt;, less than]

Site	Location within borehole	Percentage of sample in each range of particle size (mm)									
		>9.5	4.75 to 9.5	2.36 to 4.75	1.18 to 2.36	0.6 to 1.18	0.3 to 0.6	0.15 to 0.3	0.075 to 0.15	0.063 to 0.075	<0.063
5/7	Upper	1.1	2.5	1.5	1.6	8.2	27.7	32.9	11.2	1.7	11.5
5/7	Middle	0.4	0.8	0.9	2.0	7.8	26.7	28.8	22.0	5.3	5.3
5/7	Lower	4.2	11.3	7.5	4.6	3.0	2.6	8.3	26.2	13.0	19.2
9	Upper	3.0	3.1	4.1	6.4	21.6	31.9	17.6	6.5	1.1	4.8
9	Lower	6.5	11.6	5.4	3.1	1.9	1.5	6.0	47.5	0.7	15.7
3/8	Upper	0.2	0.2	0.5	3.4	28.6	49.2	12.6	2.8	0.4	2.0
3/8	Middle	9.0	5.6	7.6	10.8	24.6	22.1	12.8	3.8	0.6	3.2
3/8	Lower	0.9	5.4	3.7	2.7	2.2	2.1	12.3	55.1	0.6	15.0
2	Upper	0.4	2.2	3.5	5.9	19.5	56.8	10.7	0.7	0.1	0.2

Site	Total weight of composite (g)	Amount processed (fraction of total)	Total length of cores composited (m)	Depth range below top of sediment (m)	Core sections
5/7	21,932	1/4	8.83	0 to 10.05	5A-1H-1 through 5A-5H-1
5/7	22,152	1/4	10.59	11.14 to 23.91	7B-1H-2 through 7B-8H-1
5/7	9,876	1/4	6.2	24.15 to 30.82	7B-9H-1 through 7B-12H-1
9	23,708	1/4	11.5	0 to 16.08	9B-1H-1 through 9B-7H-2
9	12,280	1/4	6.51	16.78 to 23.51	9B-8H-1 through 9B-10H-1
3/8	9,680	1/4	3.93	0 to 4.92	3D-1H-1 through 3D-4E-1
3/8	16,992	1/4	6.56	6.16 to 14.08	8A-4H-1 through 8A-10H-1
3/8	10,140	1/4	7.2	14.53 to 22.51	8A-11H-1 through 8A-14H-1
2	2,576	1/2	1.46	0 to 1.46	2B-1H-1



**Table C2.** Particle-size distribution and gold tenor of heavy mineral concentrates, Englebright Lake, California, 2002.[g, gram; mm, millimeter; mg, milligram; mg/m<sup>3</sup>, milligram per cubic meter; <, less than]

Site	Location within borehole	Heavy mineral concentrate, total weight (g)	Percentage of sample in each range of particle size (mm)					Number of gold grains observed	Estimated gold weight (mg)	Gold tenor (mg/m <sup>3</sup> )
			1.0 to 2.0	0.5 to 1.0	0.25 to 0.50	0.063 to 0.25	< 0.063			
5/7	Upper	55.2	0.0	0.2	0.9	96.2	2.4	25	22.2	680
5/7	Middle	73.8	0.0	0.1	0.3	97.3	1.9	15	8.3	270
5/7	Lower	3.8	0.0	2.6	2.6	92.1	2.6	5	6.9	310
9	Upper	107.3	0.1	0.1	6.8	91.9	0.9	8	2.2	92
9	Lower	2.3	0.0	0.0	4.3	91.3	4.3	15	2.1	58
3/8	Upper	49.8	0.4	0.4	14.3	84.7	0.2	8	0.5	38
3/8	Middle	73.9	0.1	1.5	13.8	84.0	0.1	6	1.1	44
3/8	Lower	2.3	0.0	0.0	4.3	91.3	4.3	10	1.7	84
2	Upper	49.3	1.0	0.6	54.8	43.6	0	15	4.3	840
									median	92

**Table C3.** Mineralogical data from magnetic separation and optical microscopy for heavy mineral concentrates, Englebright Lake, California, 2002.

[Observations: —, not observed; x, trace; xx, abundant; xxx, very abundant; C, coarse; F, fine; VF, very fine; rst, rust stained; UF, ultra fine. mg, milligram; mm, millimeter; g, gram. In last column, light minerals include zircon and feldspar; dark include ilmenite, chromite, hornblende, and diopside]

Site	Location within borehole	Gold description	Amalgam (gold-mercury)	Iron ferricrete nodules	Pyrite	Magnetite	Miscellaneous	Total heavy minerals (g)	Strongly magnetic (magnetite) (g)
5/7	Upper	C-F-VF	xxx	xxx	xx	xx	—	55.2	31.4
5/7	Middle	C-F-VF, rst	x	—	—	xx	—	73.8	45.4
5/7	Lower	C-F-VF, rst	—	—	—	xx	—	3.8	1.6
9	Upper	F-VF	—	—	—	xx	—	107.3	39.8
9	Lower	C-VF	—	—	—	xx	—	2.3	0.8
3/8	Upper	F-VF, rst	x	x	—	xx	—	49.8	24.7
3/8	Middle	F-VF	—	—	—	xx	1965 25 ¢ piece	73.9	20.9
3/8	Lower	C-F-UF	—	—	—	xx	—	2.3	1.3
2	Upper	C-VF, rst	—	x	—	xx	—	49.3	4

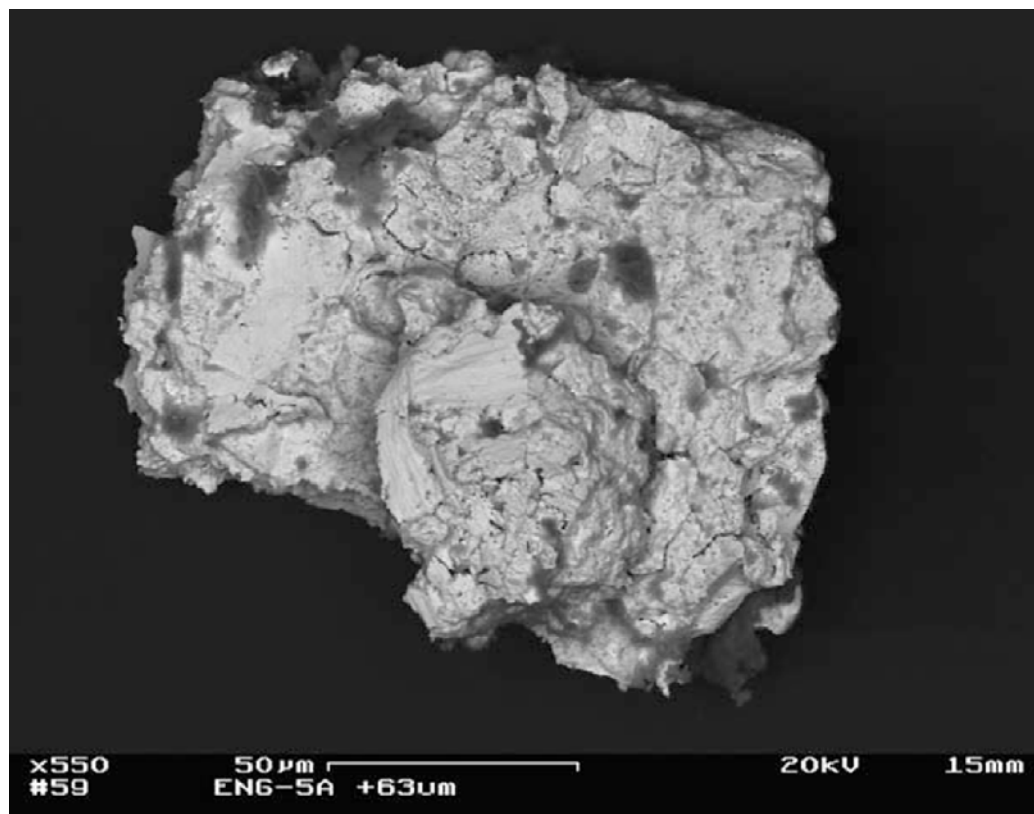
Site	Weakly magnetic (ferromagnesian minerals) (g)	Non-magnetic (light/dark minerals) (g)	Total magnetic fraction (weight percent)	Total non-magnetic fraction (weight percent)	Nonmagnetic fraction: Relative percent of light/dark minerals	
					Light	Dark
5/7	4.2	19.6	65	35	20	80
5/7	8.5	20	73	27	15	85
5/7	0.6	1.6	58	42	60	40
9	3.8	63.7	41	59	60	40
9	0	1.5	35	65	50	50
3/8	2.8	22.3	55	45	80	20
3/8	6.1	46.9	37	63	90	10
3/8	0	1	57	43	60	40
2	1.1	44.2	10	90	95	5

**Table C4.** Summary of textural observations by scanning electron microscope on gold and amalgam in heavy mineral concentrates, Englebright Lake, California, 2002.

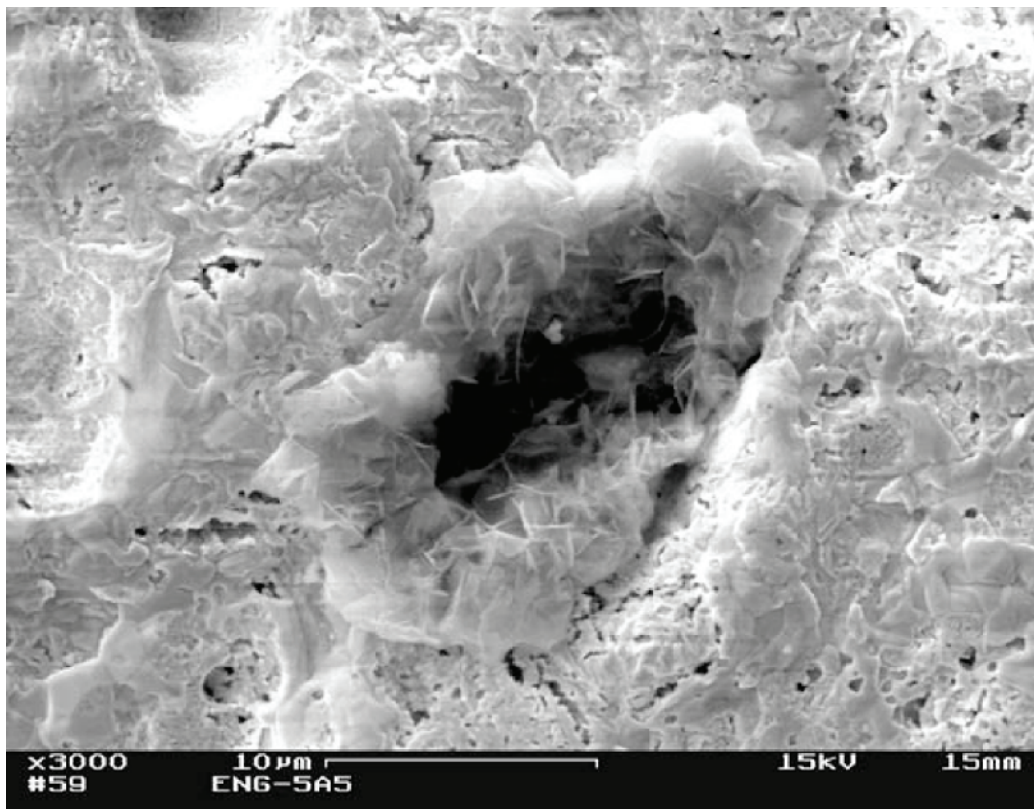
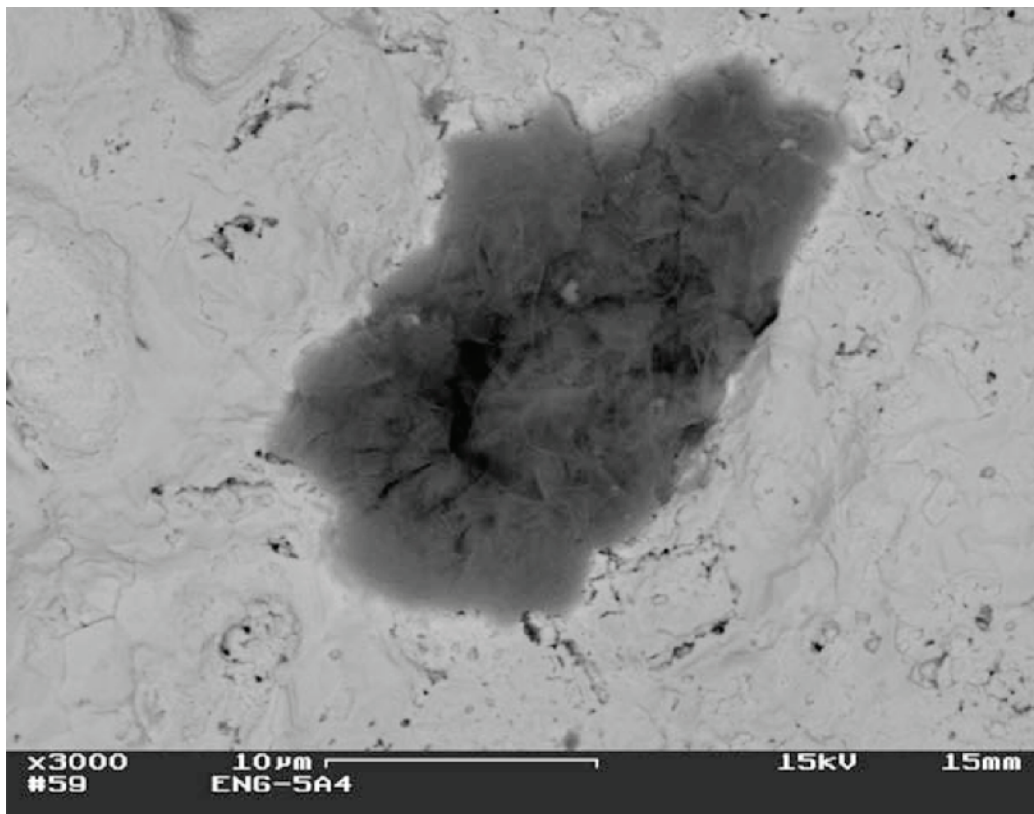
[Textures: 1, primary/hydrothermal; 2, secondary/placer; 3, tertiary/amalgamation; 4, quaternary/post-amalgamation or sample-processing artifact. Observations: x, trace; xx, abundant; xxx, very abundant; —, not observed. Fe, iron; Zr, zirconium; O, oxygen; H, hydrogen; S, sulfur. BSE, backscatter electron; SE, secondary electron; SEM, scanning electron microscope]

Site	Location within borehole	SEM sample ID (ENG-)	Gold (Au)		Mercury (Hg)	Amalgam (AuHg)		Zircon (ZrSiO <sub>4</sub> )	Iron oxides [Fe <sub>2</sub> O <sub>3</sub> , FeO(OH), Fe(OH) <sub>3</sub> ]		Iron sulfide (FeS <sub>2</sub> )	Other minerals	Figure number for photograph	Image type
			Texture	Texture		Texture or morphology	Texture or morphology							
5/7	Upper	5A	3,4	pitted nugget	xxx	abraded aggregate mass	—	x	x	—	—	—	D1	BSE
5/7	Upper	5A4	2,3	Fe-stained nugget	xx	adsorbed Hg near hydrous Fe-oxide	—	xx (hematite)	x	—	—	—	D2A	BSE
5/7	Upper	5A5	2,3	Fe-stained nugget	xx	adsorbed Hg near hydrous Fe-oxide	—	xx (hematite)	x	—	—	—	D2B	SE
5/7	Upper	5A7	2,3	pitted nugget	xx	cracking where Hg abundant	—	x	x	—	—	—	D3	BSE
5/7	Upper	5AC1	2	pyrite-coated nugget	—	—	—	x	xxx	—	—	—	D4	BSE
5/7	Upper	5AC2	2	Fe stained and unstained nuggets	—	—	—	xxx	x	—	—	—	D5	BSE
5/7	Middle	7B1	3	pitted nugget	xxx	extensive pitting	—	—	—	—	—	—	D6	BSE
5/7	Middle	7B1a	3	Hg-saturated nugget	xxx	extensive cracking	—	—	—	—	—	—	D7	BSE
9	Upper	9B	1,2,3,4	crystalline nugget	xxx	abraded platelets	—	—	—	—	quartz	—	D8	BSE
9	Lower	9Bmacro	3,4	pitted nugget	xxx	crystalline aggregate	—	x	—	—	—	—	D9A	BSE
9	Lower	9Bmicro	4	pitted nugget	xxx	single crystal	—	x	—	—	—	—	D9B	BSE
9	Lower	9B8macro	2	nugget	—	—	—	x	—	—	—	—	D10A	BSE
9	Lower	9B8micro	2	nugget	—	—	—	x	—	—	—	—	D10B	BSE
3/8	Upper	3B1	1,2	pitted nugget	xx	—	xx	x	—	—	—	—	D11	BSE
3/8	Upper	3B3	2,3	nugget	xx	Hg beads	—	—	—	—	—	—	D12	BSE
3/8	Upper	3B4	3,4	pitted nugget	xxx	abraded aggregate mass	—	x	—	—	—	—	D13	BSE
3/8	Upper	3B5	3,4	pitted nugget	xxx	cracked amalgam platelet	—	x	—	—	—	—	D14	BSE
3/8	Middle	8A1	1,2	crystalline nugget	—	—	—	—	—	—	—	—	D15	BSE
2	Upper	2B1	2	Fe-stained nugget	—	—	—	xxx	—	—	—	—	D16	BSE

**Appendix D. Scanning Electron Microscope Photomicrographs Showing Gold and Amalgam Textures from the Heavy Mineral Concentrates from Englebright Lake, California 2002**



**Figure D1.** Amalgam grain showing abrasion from processing (sample 5A).



**Figure D2.** Two scanned electron microscope images of pseudo-hexagonal hematite platelets surrounded by mercury-rich halo, (A) Backscatter, (B) Secondary electron.

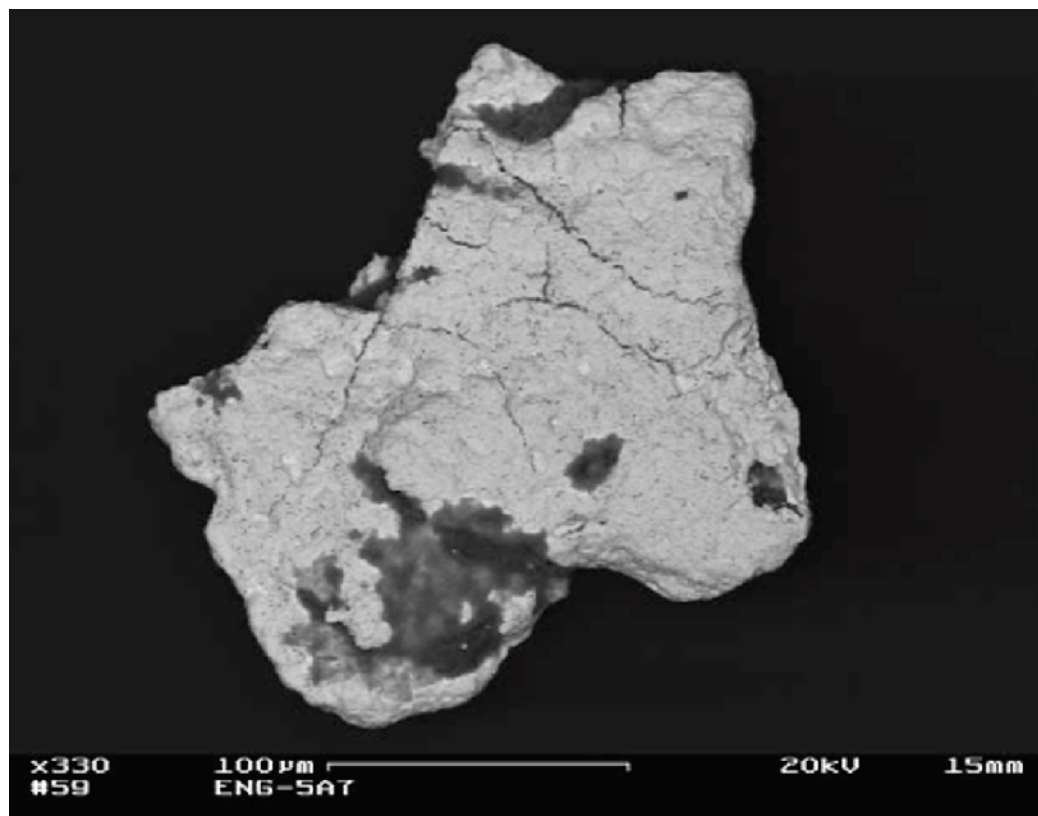


Figure D3. Gold grain with iron oxide (sample 5A7).

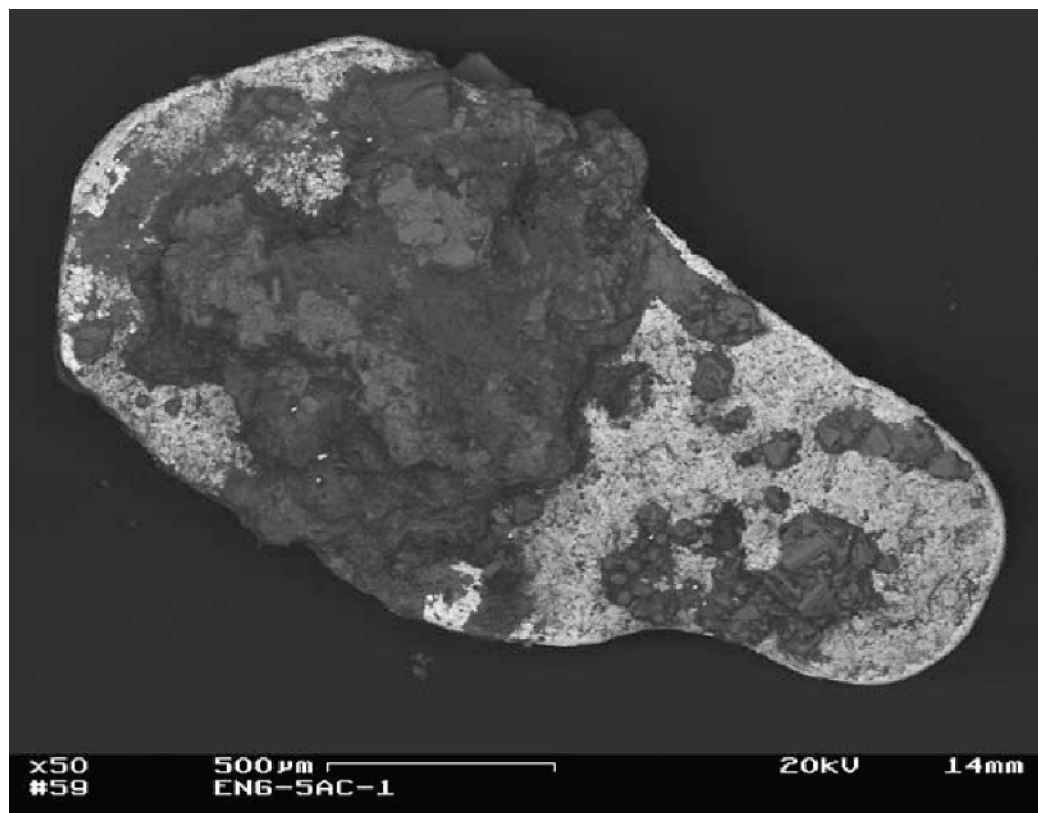


Figure D4. Gold grain with abundant diagenetic pyrite crystals (sample 5AC1).

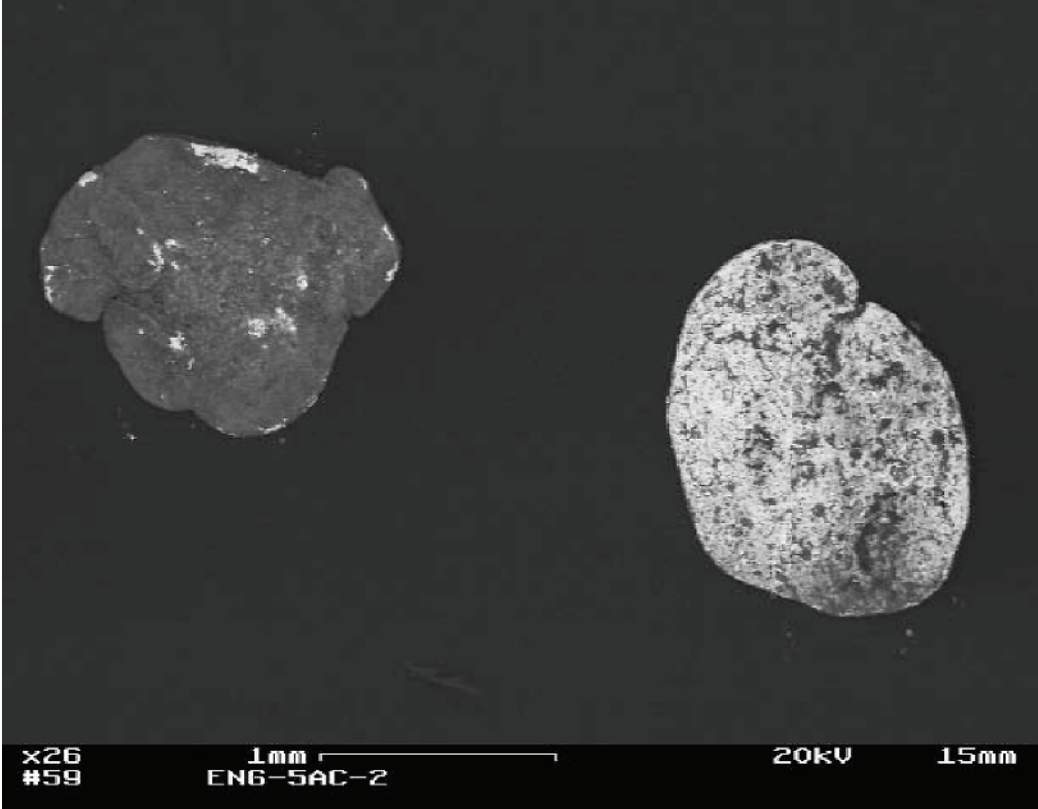


Figure D5. Iron-oxide coated gold nugget (on left) and clean gold nugget (on right) (sample 5AC2).

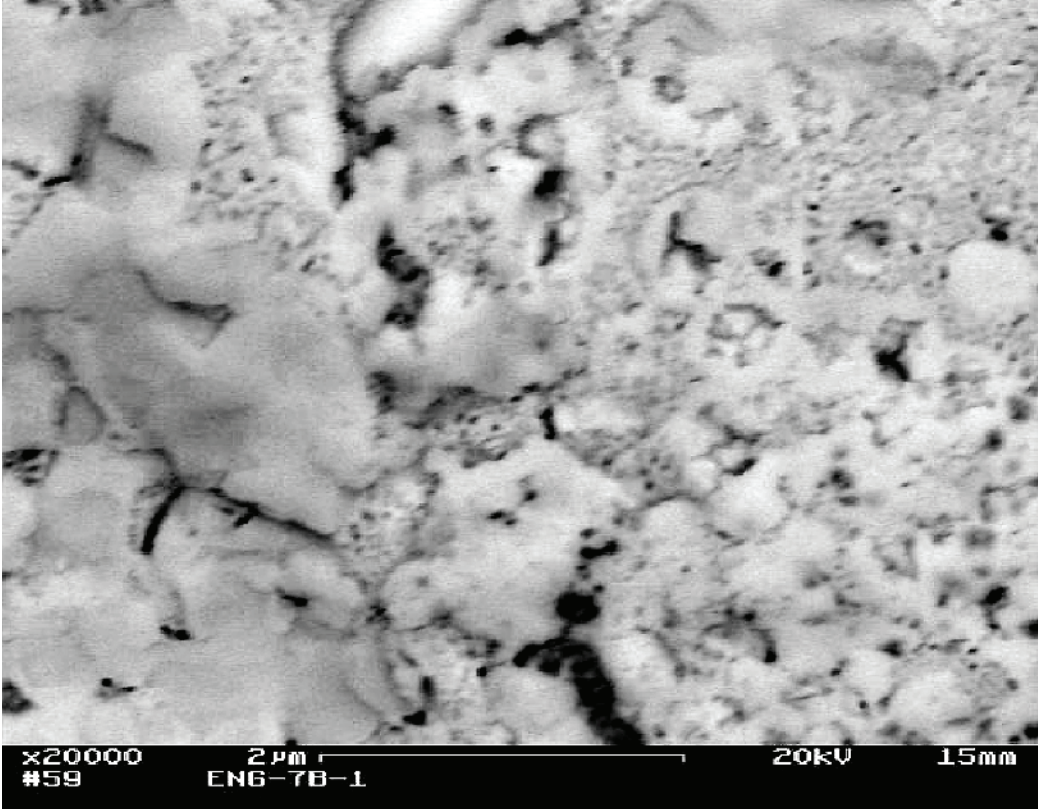


Figure D6. High magnification of pitted surface of gold nugget (sample 7B1).

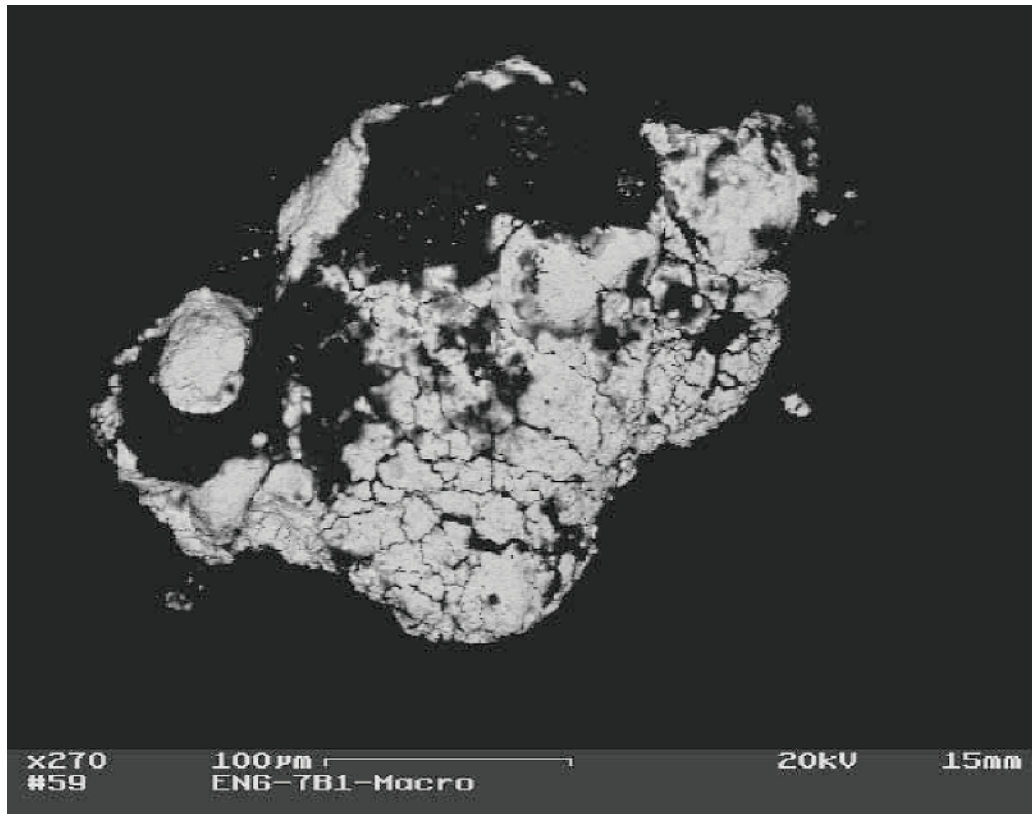


Figure D7. Extensive cracking of amalgam in mercury-saturated gold nugget (sample 7B1).

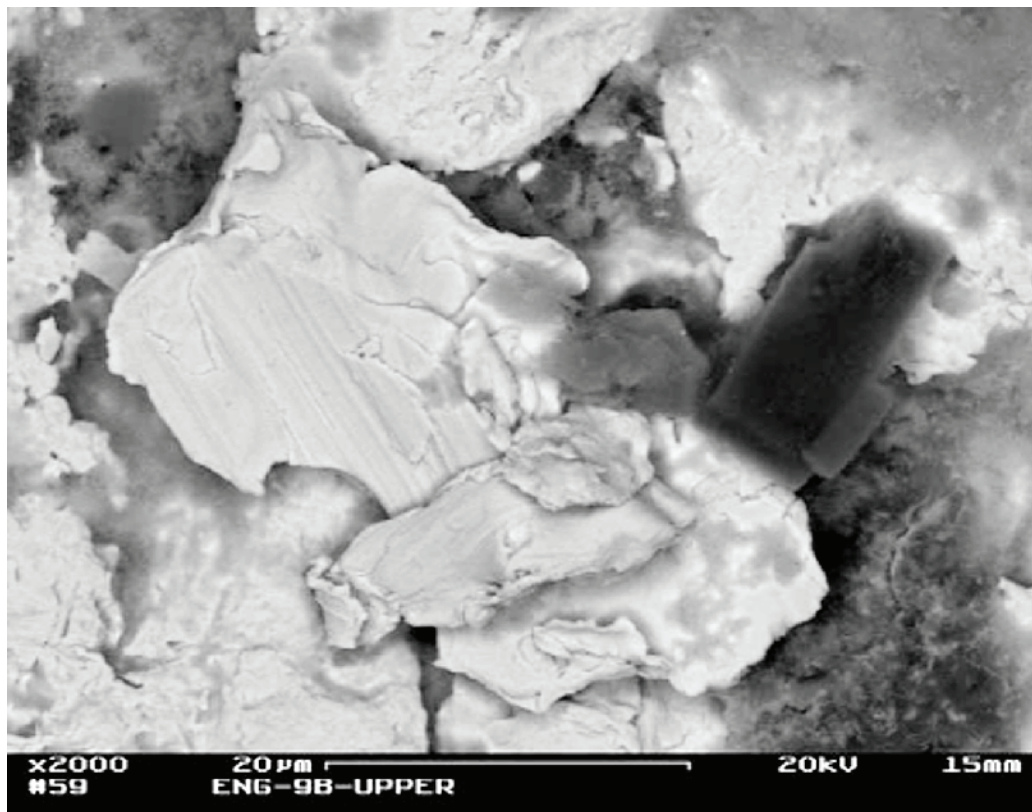
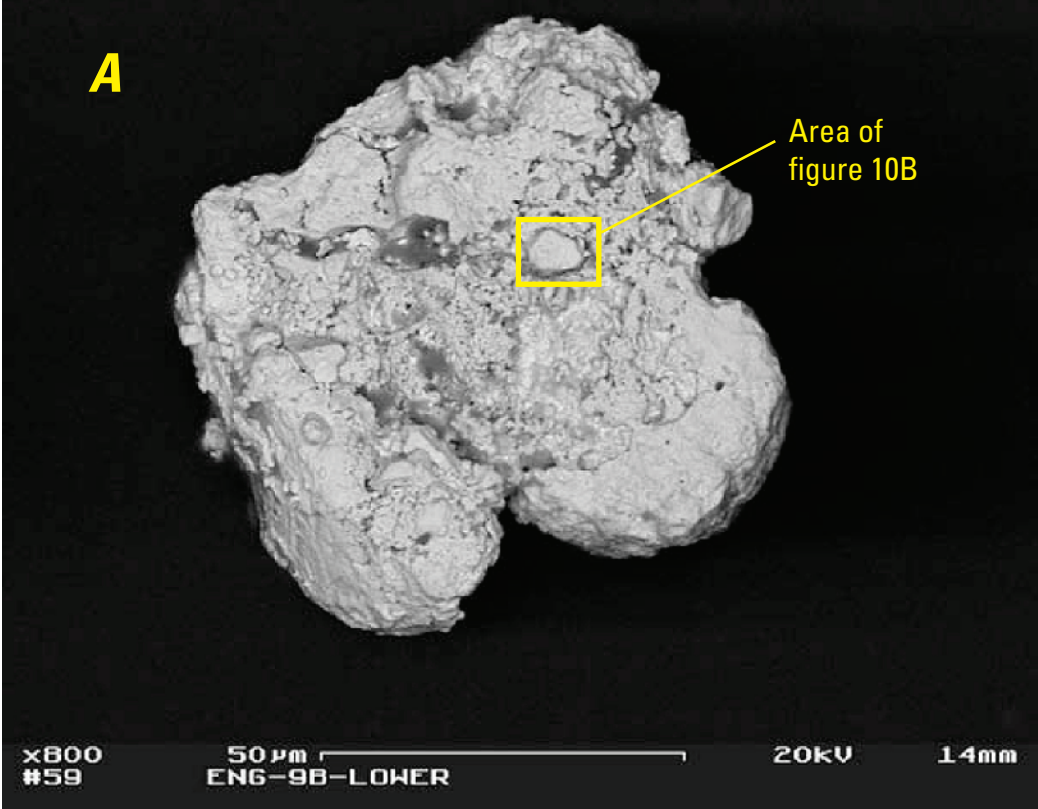
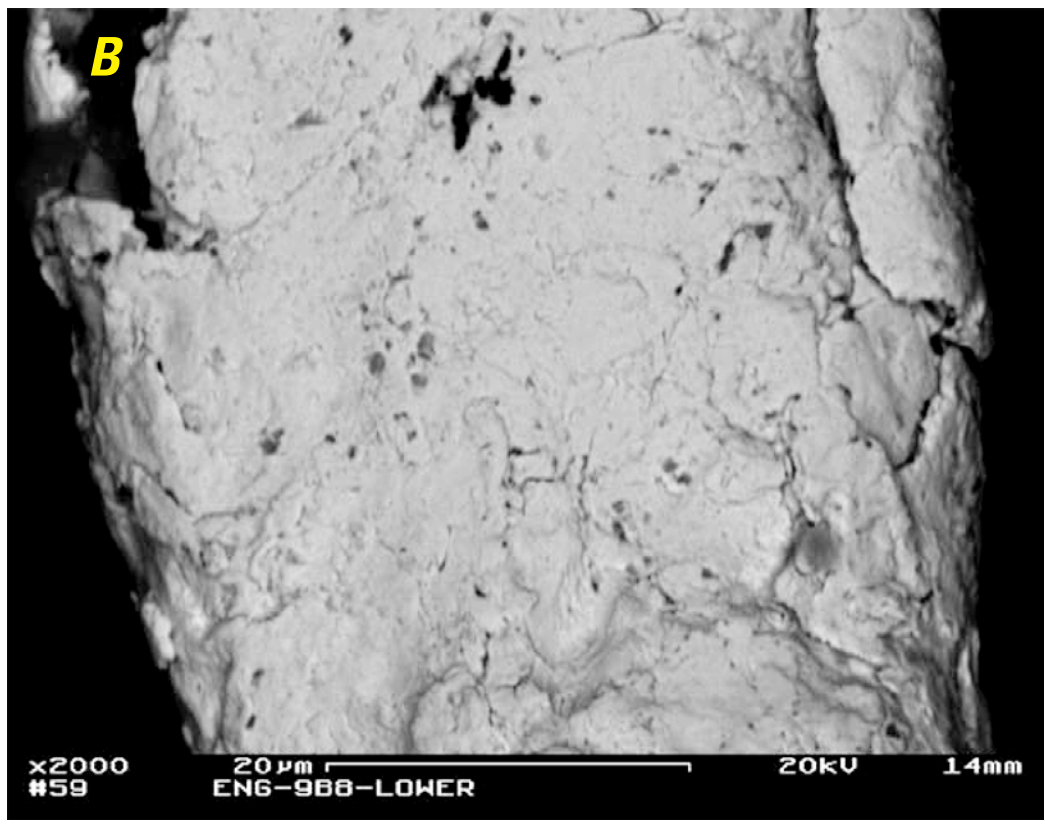
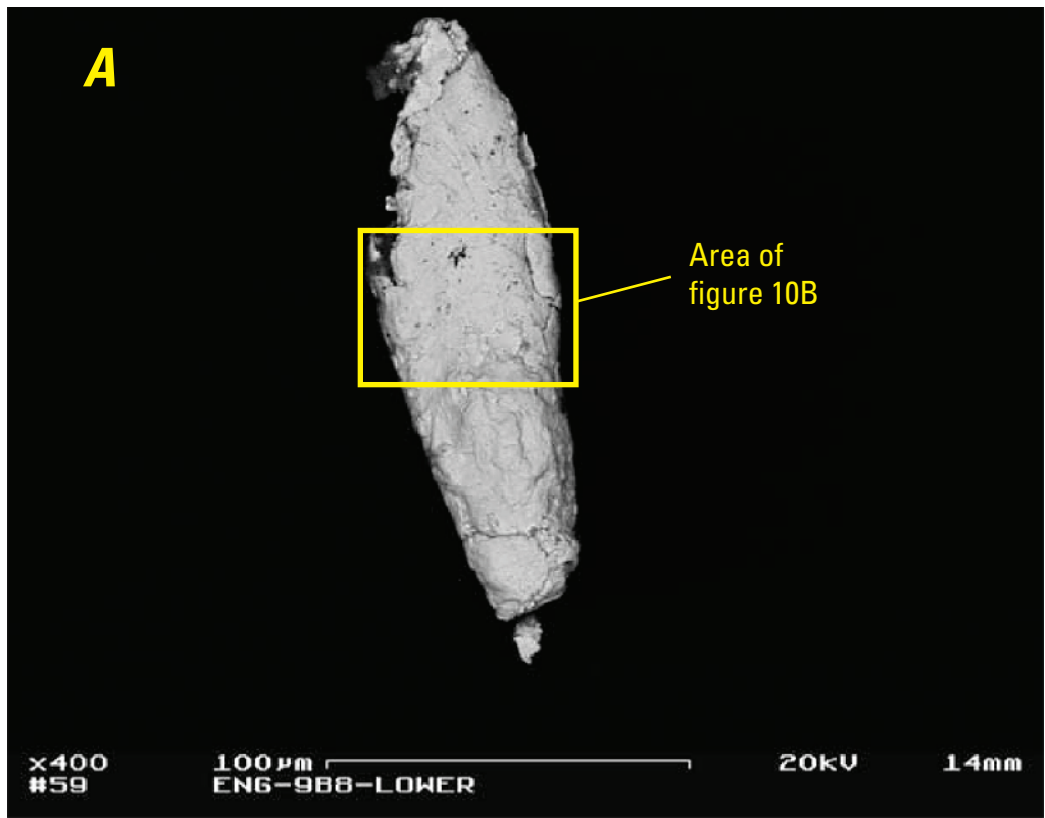


Figure D8. Close-up view of nugget showing abrasion of amalgam in cavity with euhedral quartz crystal (sample 9B).

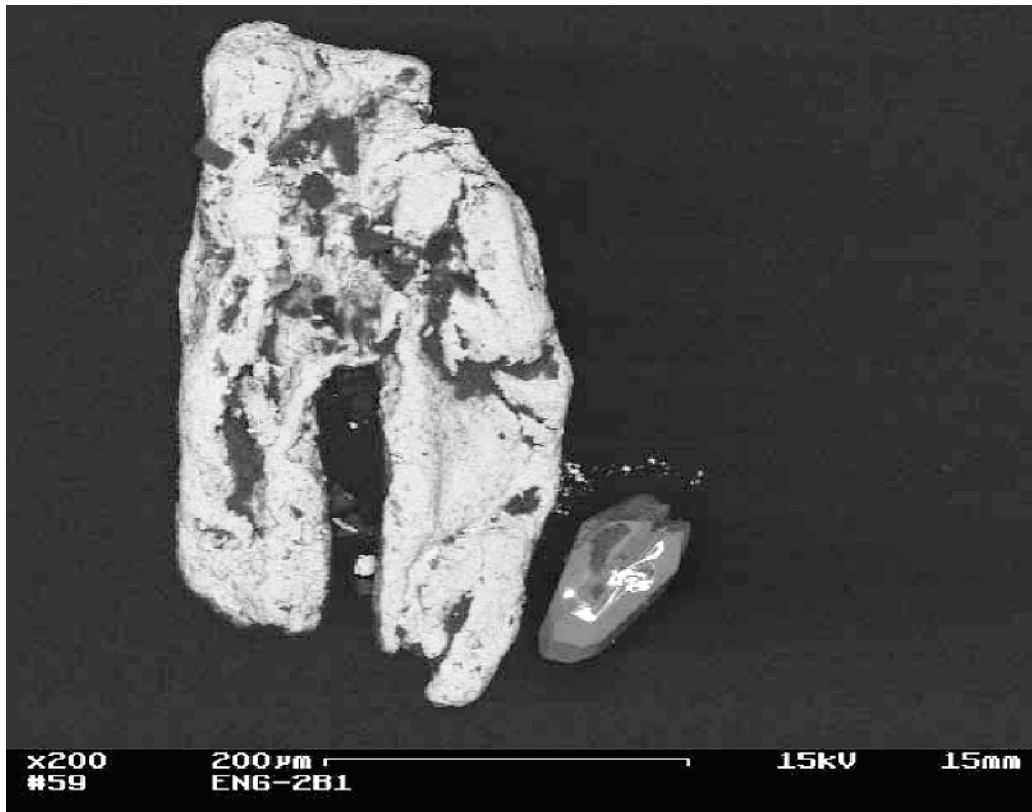




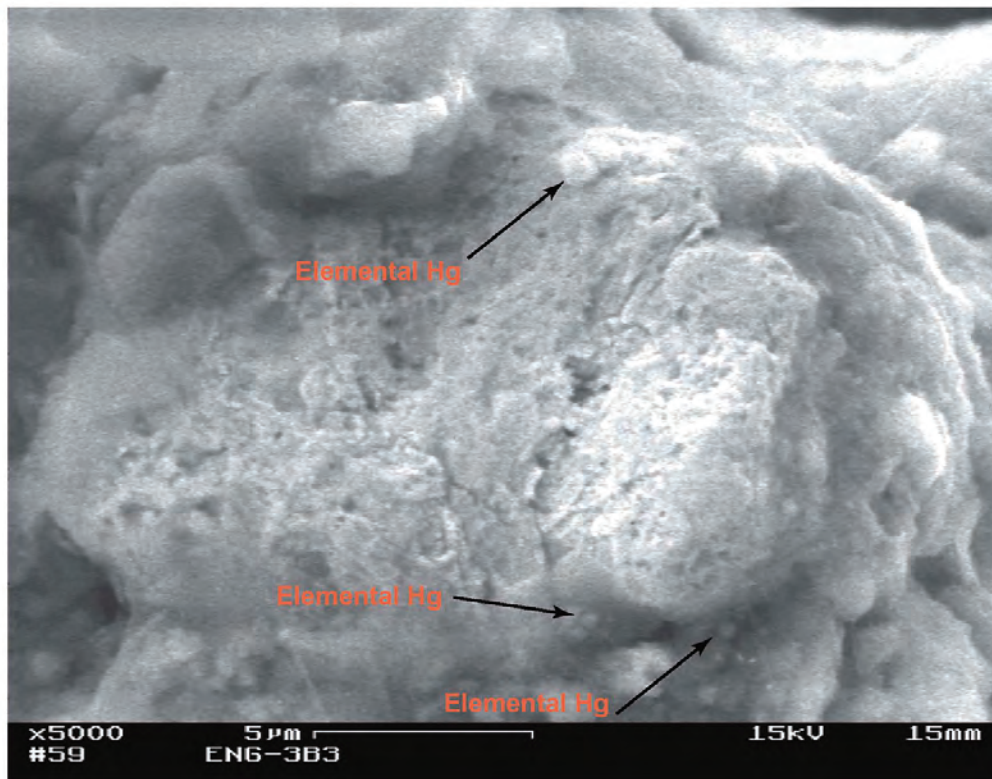
**Figure D9.** Amalgam grains (sample 9B) (A) Aggregate containing amalgam crystal in upper right, and (B) Close-up view of the amalgam crystal, dimensions 6 x 8 micrometers.



**Figure D10.** Placer gold grain of high purity, no visible mercury (sample 9B8) (A) View of entire grain, (B) Close-up view showing smooth texture of gold.



**Figure D11.** Large, pitted gold grain with 100-micrometer, euhedral zircon crystal (sample 3B1).



**Figure D12.** Grain of gold containing small beads of elemental mercury (sample 3B3).

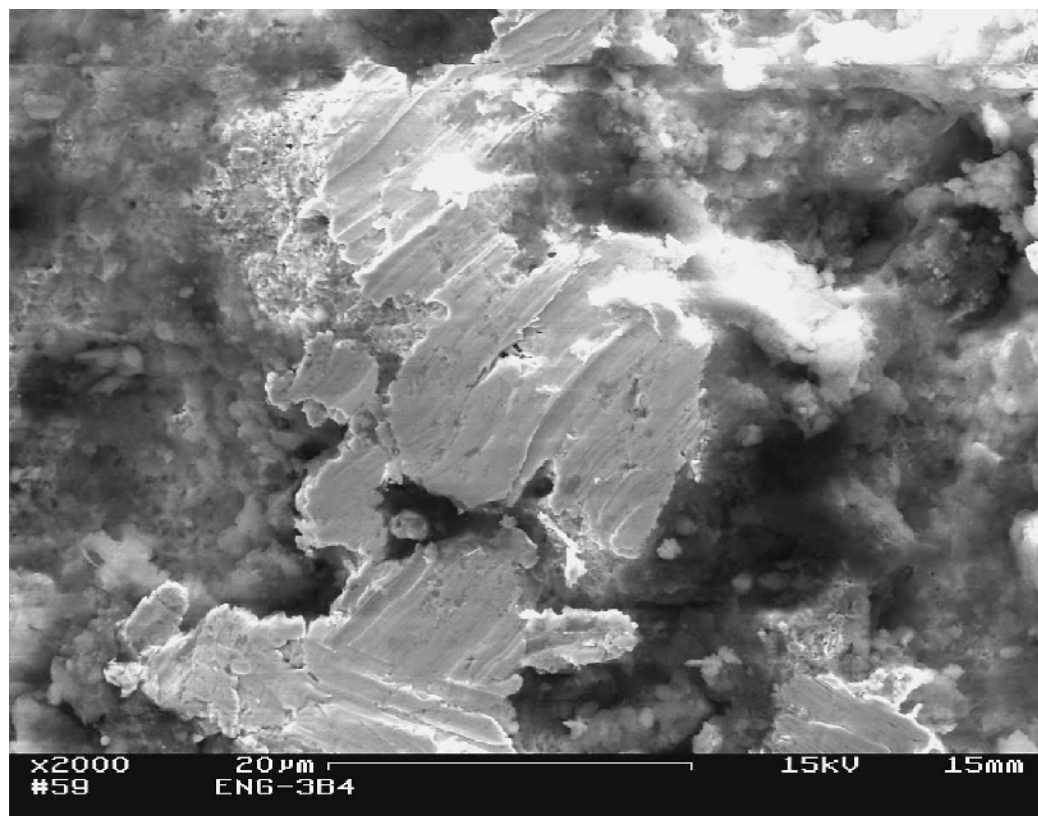


Figure D13. Grain of amalgam showing smearing from processing (sample 3B4).

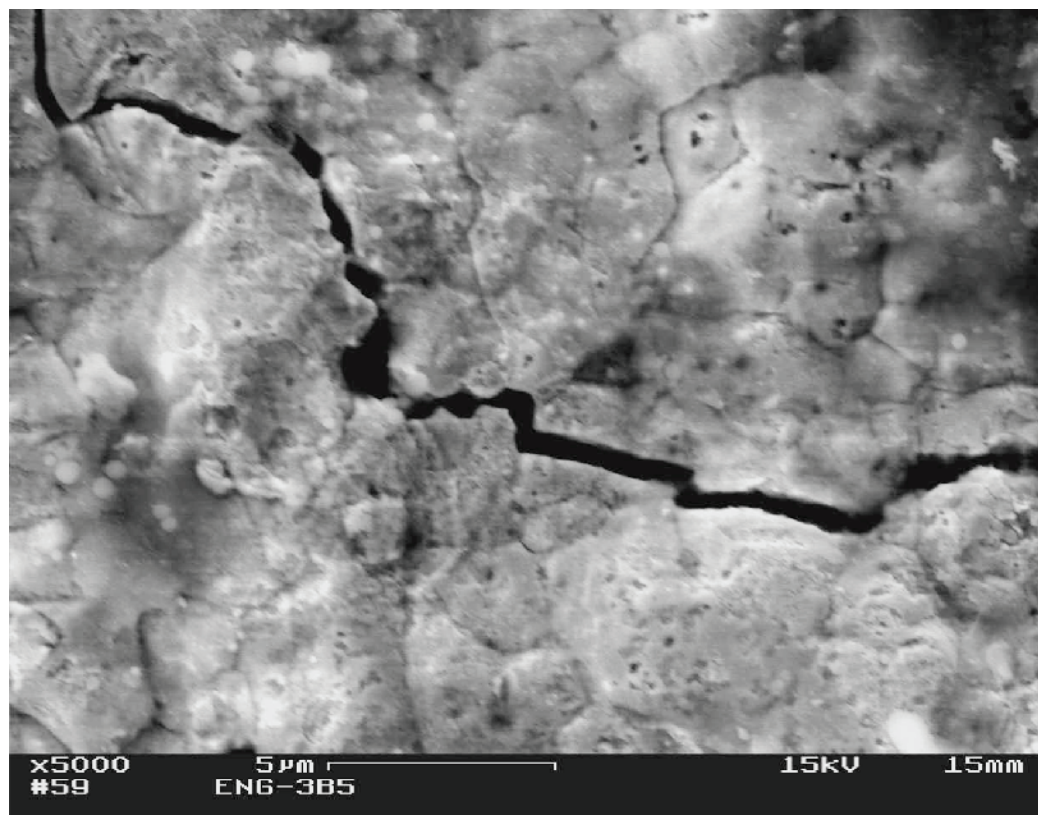


Figure D14. Grain of amalgam showing fracture (sample 3B5).

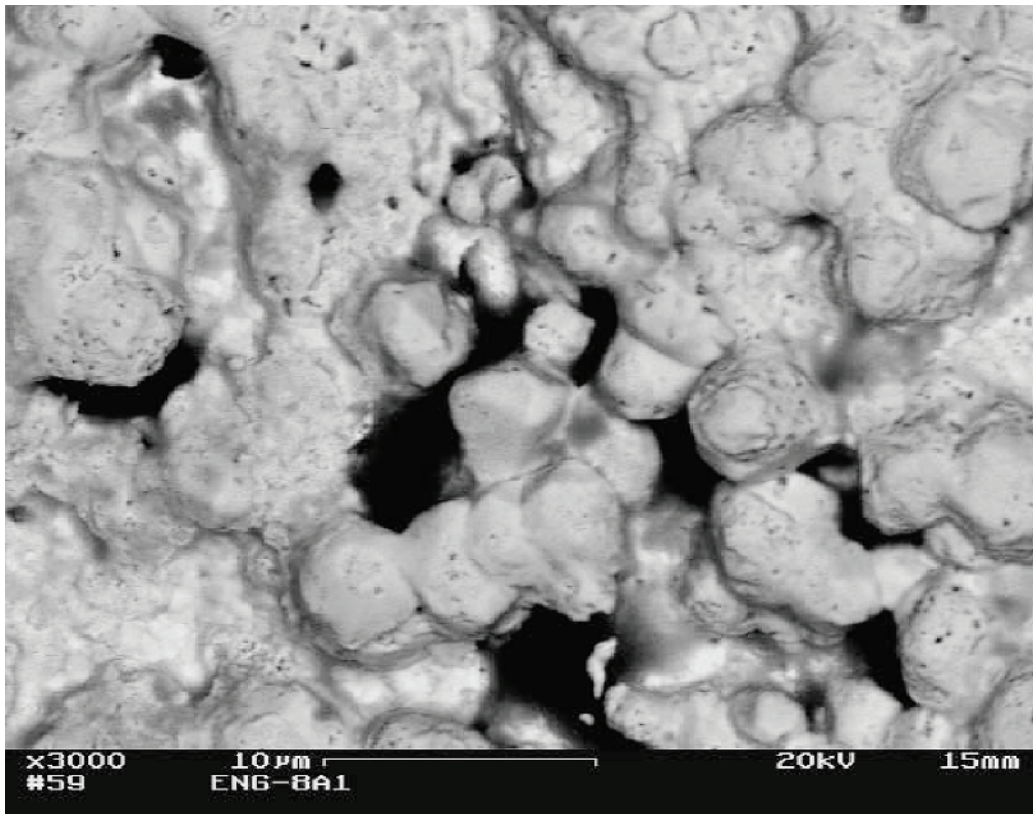


Figure D15. Octahedral crystal forms of gold in vug of nugget (sample 8A1).

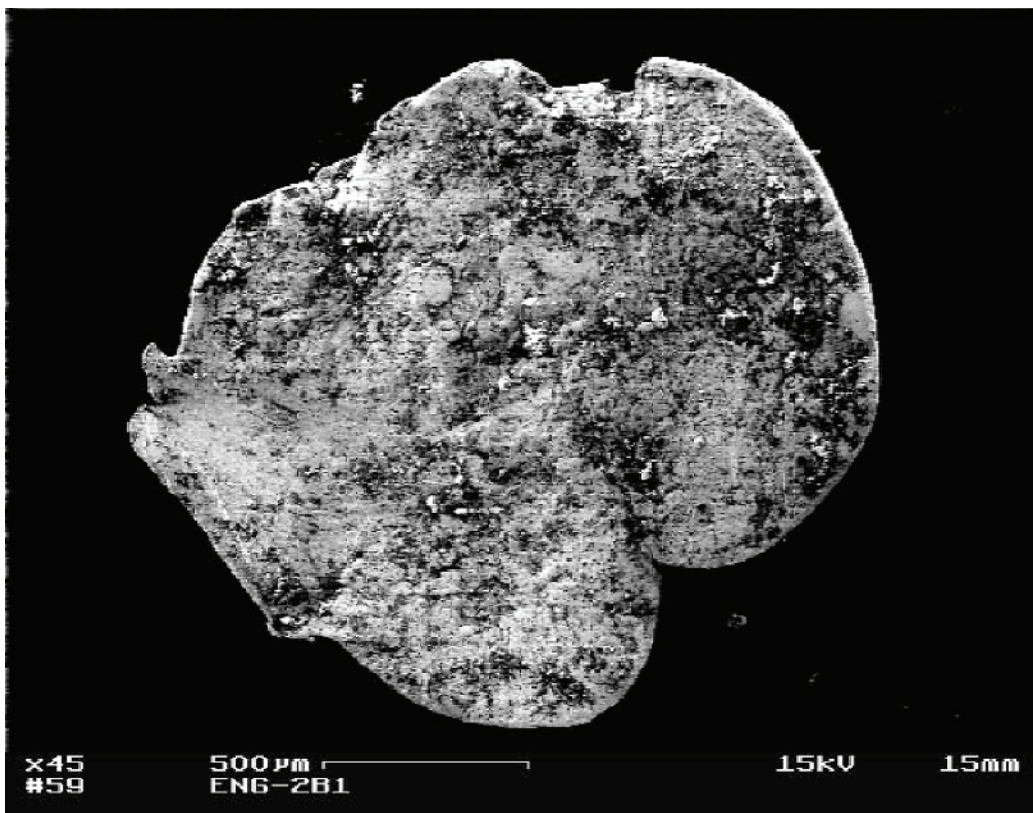


Figure D16. Iron-stained gold nugget with no trace of mercury (sample 2B1).

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