Prepared in Cooperation with the
NATIONAL PARK SERVICE,
GLEN CANYON NATIONAL RECREATION AREA

# Sediment Chemistry of the Colorado River Delta of Lake Powell, Utah, 2001

Open-File Report 2005–1178

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

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By R.J. Hart, H.E. Taylor, R.C. Antweiler, D.D. Graham, G.G. Fisk, S.G. Riggins, and M.E. Flynn

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## Compact Disc (in pocket at back of report)

Format: American Standard Code for Information Interchange (ASCII) and Microsoft Excel
Operating system used: Windows XP Professional

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| | 1_README.TXT (4 KB) | Table 9.xls |
| | Table 5.xls | Table 10.xls |
| | Table 6.xls | Table 11.xls |
| | Table 7.xls | Table 12.xls |
| | Table 8.xls | Table 13.xls |

## Conversion Factors and Datum

| Multiply | By | To obtain |
|---|---|---|
| Length | | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| Volume | | |
| cubic meter (m3) | 0.0008107 | acre-foot (acre-ft) |
| milliliter (mL) | 0.0002642 | gallon (gal) |
| liter (L) | 0.2642 | gallon (gal) |
| cubic meter (m3) | 264.2 | gallon (gal) |
| Mass | | |
| gram (g) | 0.03527 | ounce, avoirdupois (oz) |
| kilogram (kg) | 2.205 | pound avoirdupois (lb) |

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

$$°F=(1.8x°C)+32$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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

## Abbreviated Water-Quality Units

Chemical concentration and water temperature are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (mg/L). Milligrams per liter is a unit expressing the solute mass (milligrams) per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (mS/cm at 25°C). Radioactivity is expressed in picocuries per liter (pCi/L) or picocuries per gram (pCi/g), which is the amount of radioactive decay producing 2.2 disintegrations per minute in a unit volume (liter) of water or mass (gram) of sediment. Chemical concentration in bottom sediment is given in grams per kilogram (g/kg), micrograms per gram (mg/g), milligrams per kilogram (mg/kg), or micrograms per kilogram (mg/kg). Grams per kilogram is equal to parts per thousands (ppt). Milligrams per kilogram and micrograms per gram are equal to parts per million (ppm). Micrograms per kilogram are equal to parts per billion (ppb).

## Acronyms

| | |
|---|---|
| BOR | Bureau of Reclamation |
| CVAFS | cold-vapor atomic fluorescence spectrometry |
| GPS | Global Positioning System |
| ICP-AES | inductively coupled plasma-atomic emission spectrometry |
| ICP-MS | inductively coupled plasma-mass spectrometry |
| LRL | laboratory reporting level |
| NIST | National Institute of Standards and Technology |
| NPS | National Park Service |
| NRP | National Research Program |
| NWQL | U.S. Geological Survey National Water Quality Laboratory |
| PAH | polycyclic aromatic hydrocarbon |
| PCB | polychlorinated biphenol |
| QA | quality assurance |
| QC | quality control |
| USEPA | U.S. Environmental Protection Agency |
| USGS | U.S. Geological Survey |
| WQAM | Water Quality Assessment and Monitoring |

## Chemical Symbols

| | | | | | |
|---|---|---|---|---|---|
| Al | aluminum | Ho | holminim | Sb | antimony |
| As | arsenic | K | potassium | Se | selenium |
| Ba | barium | Li | lithium | $SiO_2$ | silica |
| Be | beryllium | Lu | lutetium | $SO_4$ | sulfate |
| Bi | bismuth | Mg | magnesium | Sm | samarium |
| Bo | boron | Mn | manganese | Sr | strontium |
| Ca | calcium | Mo | molybdenum | Ta | tantalium |
| Cd | cadmium | Na | sodium | Tb | terbium |
| Ce | cerium | Nd | neodymium | Th | thorium |
| Cl | chloride | $NH_4$ | ammonium | Ti | titanium |
| Co | cobalt | Ni | nickel | Tl | thallium |
| Cr | chromium | $NO_2$ | nitrite | Tm | thulium |
| Cu | copper | $NO_3$ | nitrate | U | uranium |
| Dy | dysprosium | P | phosphorus | V | vanadium |
| Er | erbium | Pb | lead | W | tungsten |
| Eu | eruopium | $PO_4$ | phosphate | Y | yttrium |
| Fe | iron | Pr | praseodymium | Yb | ytterbium |
| Gd | gadolinium | Rb | rubidium | Zn | zinc |
| Hg | mercury | Re | rhenium | Zr | zirconium |
| Ho | holminim | S | sulfur | | |

# Sediment Chemistry of the Colorado River Delta of Lake Powell, Utah, 2001

By R.J. Hart, H.E. Taylor, R.C. Antweiler, D.D. Graham, G.G. Fisk, S.G. Riggins, and M.E. Flynn

## Abstract

Sediment delta deposits in Lake Powell provide a repository for the potential accumulation of various natural and human-introduced chemicals. The Colorado River delta of Lake Powell near Hite, Utah, extends for many miles into Lake Powell and is thickest near the mouth of the Dirty Devil River. Other significant deltas in Lake Powell occur at the mouths of the San Juan and Escalante Rivers.

Sediment samples collected from the Colorado River delta during July 2001 were analyzed for concentrations of major ions; trace elements; organic compounds, including low-level organochlorine pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons; and radionuclides. Three cores and six sediment samples from the sediment-water interface were collected near Hite marina in southeastern Utah where the delta is thickest. No trends were discernable between major-ion concentrations in different cores. Concentrations of several trace elements were correlative with sediment color and texture. Elements that are considered to be environmental contaminants, such as arsenic, uranium, selenium, and mercury, were detected in core samples. Some elements increased in concentration with core depth. Organochlorine pesticides and polychlorinated biphenyls were not detected in composited sections of the cores above the laboratory detection limit except for p,p'-DDE. A total of 19 parent polycyclic aromatic hydrocarbons and multiple alkyl-polycyclic aromatic hydrocarbons were detected in core samples. All core samples contained concentrations of gross alpha and gross beta radionuclides; concentrations in composited samples ranged from 11 to 17 picocuries per gram.

## Introduction

Lake Powell, on the Colorado River in Arizona and Utah (fig. 1), began to fill in 1963 from the construction of Glen Canyon Dam and was at full pool elevation by 1980. Major sediment deposits in Lake Powell occur in inflow areas of the Colorado, San Juan, and Escalante Rivers, forming deltas. These deltas are potential sites for accumulation and storage of contaminants. The fate of contaminants, especially organic compounds that are hydrophobic, is often dependent on sediment composition and transport.

Lake Powell's physical, chemical, and biological properties continuously change owing to natural reservoir processes (evaporation and runoff), drought, reservoir management (storage and releases), increasing recreational use, and watershed activities that include mining and agriculture in tributary drainages of Lake Powell. Fluctuation of reservoir levels at Lake Powell can mobilize sediments and any associated contaminants. Because of the potential for resuspension of sediments and resolubilization of contaminants into the water column of Lake Powell, chemical analysis was done to determine the presence of contaminants in the sediments and water of Lake Powell's tributary deltas.

During July 2001, the U.S. Geological Survey (USGS) and Glen Canyon National Recreation Area (Glen Canyon NRA) completed a sediment coring program that documented the presence of major and trace elements and selected organic compounds and radionuclides in the Colorado River delta near Hite, Utah. The study was funded by the USGS Office of Water Quality's Water-Quality Assessment and Monitoring (WQAM) program, which is designed to assist national parks with water-quality issues. Supplemental funding was provided by Glen Canyon NRA.

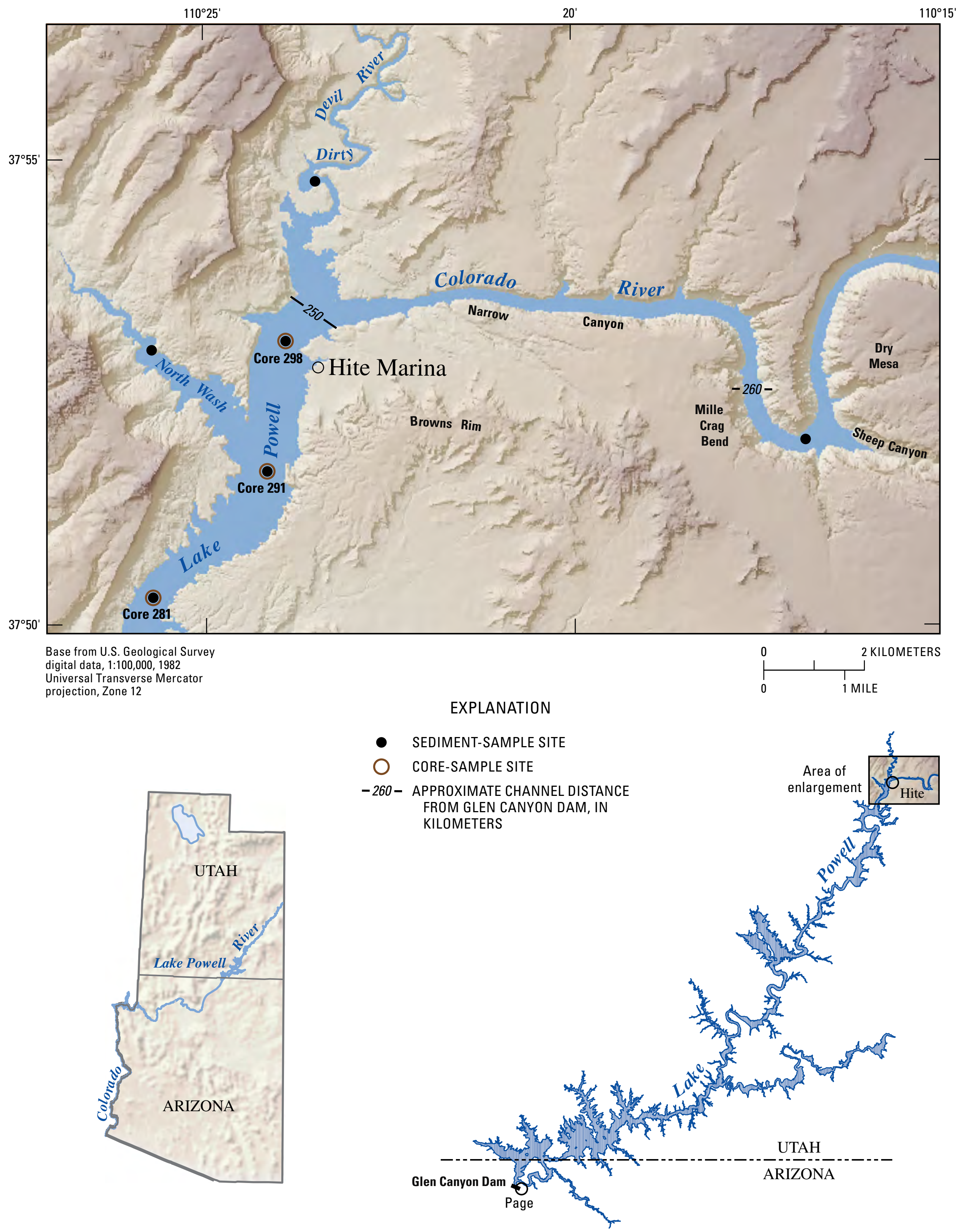


**Figure 1**. Location of study area and sampling sites, Colorado River delta of Lake Powell, Utah.

## Purpose and Scope

This report presents data and information on the concentration and distribution of selected chemical constituents from three sediment cores and six sediment samples collected from the sediment-water interface in the Colorado River delta and selected tributaries near the Hite marina in southeastern Utah, in July 2001. Core sediments or composited cores were analyzed for concentrations of major elemental components, selected trace elements, organochlorine pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and for gross alpha and beta radioactivity. The anoxic zone of water that is in contact with the lakebed material also was sampled coincidently at the six sediment-water interface sites. Grain-size analysis was completed on selected sections of the cores. Clay mineralogy was determined for selected core samples by Northern Arizona University, but the results are not presented in this report. Results of standard reference material analyses and all chemical data are provided in tabular form on the compact disc at the back of this report (tables 5–13).

## Water-Quality Issues of Glen Canyon National Recreation Area

The water quality of Lake Powell is a major management concern for Glen Canyon NRA staff because of potential health implications to both wildlife and human users of the lake. Lake Powell's water quality also has a direct effect on the downstream reaches of the Colorado River. Water-quality information needed by Glen Canyon NRA staff for managing Lake Powell includes characterization of (1) potential contaminants in sedimentary deltas and other areas of sediment deposition, (2) hydrocarbon contamination of water and sediment resulting from the use of two-stroke, two-cycle engines, (3) bacterial concentrations in waters associated with heavily used beaches, and (4) nutrients that could contribute to eutrophication of the lake. Determining the presence of contaminants stored in sediments is a priority for Glen Canyon NRA staff.

Hydrophobic organic contaminants, including organochlorine pesticides, PCBs, and PAHs, may have been released into Lake Powell as a result of human activity in the lake and in the Colorado River Basin. Metals, nutrients, and many dissolved organic compounds tend to sorb to clay particles and organic particulate matter. Resuspension of lakebed sediments can remobilize hydrophobic constituents. Phosphorus, manganese, iron, and sulfide sorbed to sediments can be resolubilized if the sediments are deposited where anaerobic conditions exist, potentially degrading water quality.

Uranium deposits occur in rock formations of the Colorado Plateau (Wenrich and others, 1989). Natural erosion of these rocks and human activities such as mining can potentially transfer high levels of radioactivity associated with uranium to water and surficial sediments, such as the delta deposits in Lake Powell. Radionuclides can pose a health risk to wildlife and humans owing to radiotoxicity and chemical toxicity.

## Description of Study Area

Lake Powell is the youngest of four large reservoirs on the Colorado River and extends more than 290 km from the dam near Page, in northern Arizona, into southeastern Utah within the Colorado Plateau (fig. 1). The lake was created after construction of Glen Canyon Dam on the Colorado River in 1963 and reached full-conservation pool elevation, 1,128 m above NGVD 29, in 1980. Glen Canyon Dam is the only major dam on the main stem of the Colorado River upstream from Lees Ferry, Arizona, and it controls almost all the flow leaving the upper Colorado River Basin. The farthest upstream marina during 2001 was at Hite, Utah, which is about 225 km from Glen Canyon Dam. The lake can reach a depth of 180 m in the forebay area of the dam and have more than 3,060 km of shoreline. At full pool, the reservoir stores about 33 billion cubic meters (27 million acre-feet) of water that is used to satisfy required water delivery to the lower Colorado River Basin as defined in the Colorado River Compact of 1922. This compact, administered by the Bureau of Reclamation (BOR), allocates water delivery from the upper Colorado River Basin States to the lower Colorado River Basin States at a compact point at Lees Ferry, Arizona (National Research Counsil, 1987). Reservoir storage in Lake Powell also accommodates recreation and electrical-power production.

Subsequent to the impoundment of Lake Powell, thick sequences of delta deposits formed near tributary mouths of the Colorado, San Juan, and Escalante Rivers. This investigation is focused on sediments deposited in the Colorado River delta (fig. 2). In the most recent reservoir-wide sediment survey, done by the BOR in 1986, the average sediment thickness in about a 45-km reach above the Hite marina was 38.7 m (Ferrari, 1988). As of 1986, approximately 24 m of sediment had deposited in the bottom of the reservoir in the vicinity of the Hite marina (fig. 2). By the end of 2001, about another 10 m of sediment had deposited in this area (Mussetter Engineering, Inc., written commun., May 22, 2001). The maximum water depth during 1986 near the Hite marina was about 41 m (Ferrari, 1988). During July 2001, the maximum water depth in the same area was about 30 m (fig. 2). In the present investigation, sediment core samples from the upper part of the Colorado River delta deposits were collected at three locations (fig. 2) for analyses of physical properties and chemical composition.

## Acknowledgments

The authors acknowledge Mark Anderson, aquatic ecologist, Glen Canyon National Recreation Area, and Natasha Kramer, former Northern Arizona University graduate student, for their assistance with this project. In addition, Dale Peart, hydrologist; Terry Plowman, chemist; and David Roth, chemist, U.S. Geological Survey-Water Resources Discipline-National Research Program (NRP), Boulder, Colorado, and James Woods, hydrologic technician, U.S. Geological Survey, Nevada Water Science Center, made significant contributions to the project.

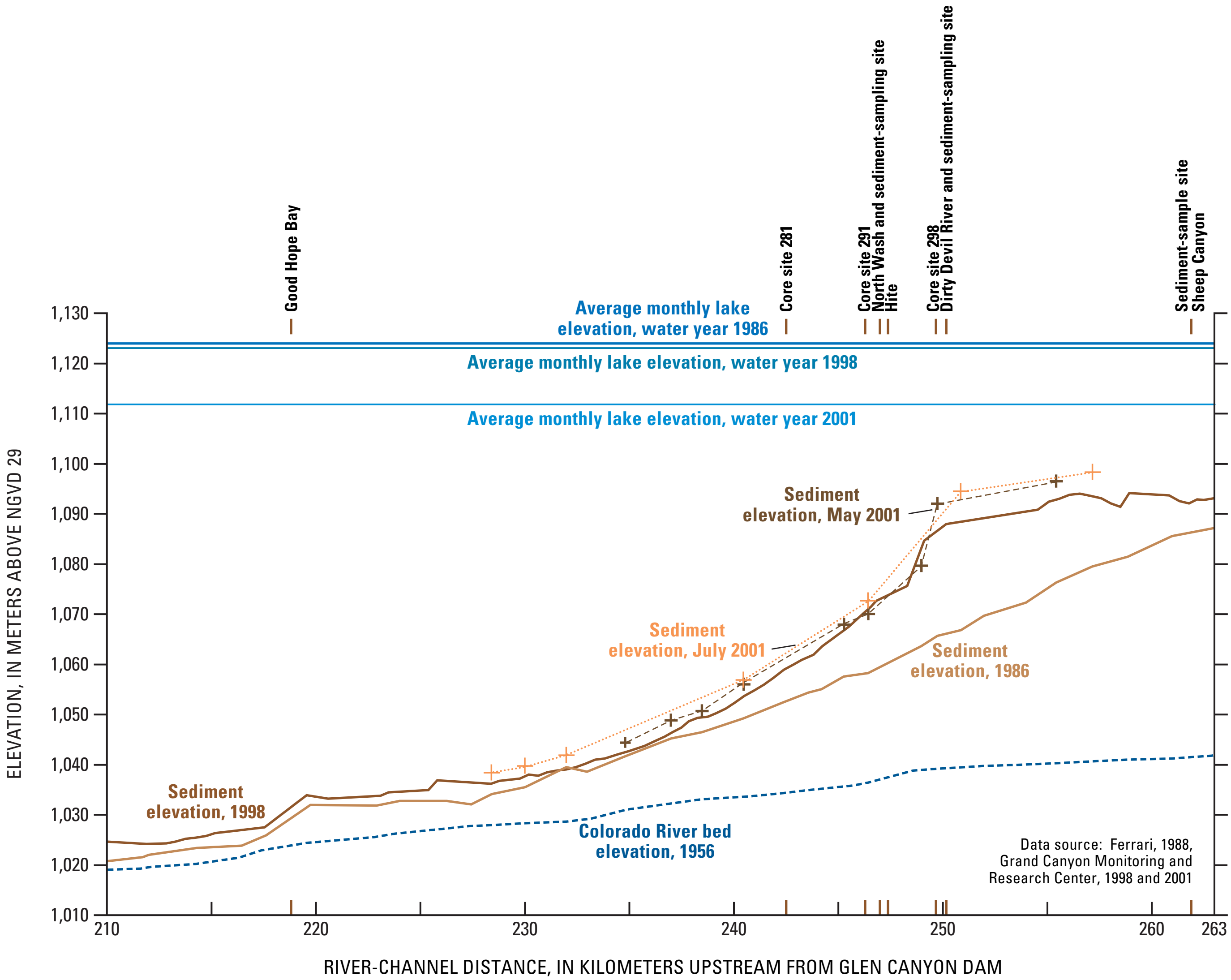


**Figure 2.** Sediment accumulation profiles in the delta of the Colorado River inflow area to Lake Powell, Utah, for 1986 and 1998, and from discrete depth soundings in the delta during 2001.

# Methods

The Colorado River delta sampling sites (fig. 1) were selected from previous bathymetric surveys made by the BOR (Ferrari, 1988) and from more recent sonar measurements made in 1998 and 2001 by the Grand Canyon Monitoring and Research Center, a program of the USGS (fig. 2).

Three sites along the old Colorado River thalweg upstream and downstream from the Hite marina were selected for sediment core collection (fig. 1). Six sediment samples from the sediment-water interface were collected (1) at the same locations as the cores, (2) at a site on the Colorado River near Sheep Canyon, and (3) in the Dirty Devil River and North Wash—tributaries of the Colorado River (fig. 1 and table 1). The Global Positioning System (GPS) was used to determine the location of all core sites.

## Coring Methods

Bottom-sediment cores from the Colorado River delta were collected at sites 298, 291, and 281 (fig. 1) and measured 3,130 mm, 3,280 mm, and 3,745 mm, respectively (table 1). The USGS core boat (fig. 3) used to collect these samples was equipped with a benthos-gravity piston corer (fig. 4). Each core barrel is approximately 3.5 m long and 6.3 cm in diameter. A polycarbonate liner was inserted into the core barrel and used to collect the core sample and to minimize chemical contamination of the samples from the core barrel.

**Table 1.** Summary of sediment core and sediment-water interface sample collection, Colorado River delta, Lake Powell, Utah, 2001

[BOR, Bureau of Reclamation; NA, not applicable]

Core Samples

| Core date | Core site | Latitude | Longitude | Lake elevation (meters) | BOR rangeline | Core length (millimeters) |
|---|---|---|---|---|---|---|
| 07-27-2001 | Core 298 | 375307 | 1102342 | 1,118.86 | 298 | 3,130 |
| 07-27-2001 | Core 291 | 375136 | 1102403 | 1,118.86 | 291 | 3,280 |
| 07-28-2001 | Core 281 | 375018 | 1102544 | 1,118.62 | 281 | 3,745 |

Sediment-Water Interface Samples

| Sample date | Sample name | Latitude | Longitude | Lake elevation (meters) | BOR rangeline | Number of replicates |
|---|---|---|---|---|---|---|
| 7/27/2001 | Lake Powell at core 298 site | 375307 | 1102342 | 1,118.62 | 298 | 3 |
| 7/27/2001 | Lake Powell at core 291 site | 375136 | 1102403 | 1,118.62 | 291 | 2 |
| 7/28/2001 | Lake Powell at core 281 site | 375018 | 1102544 | 1,118.62 | 281 | 1 |
| 7/28/2001 | Colorado River near Sheep Canyon | 375200 | 1101641 | 1,118.62 | 313 | 3 |
| 7/28/2001 | Dirty Devil River | 375446 | 1102333 | 1,118.62 | NA | 3 |
| 7/28/2001 | North Wash | 375257 | 1102546 | 1,118.62 | NA | 4 |

**Figure 3.** U.S. Geological Survey core boat on Lake Powell, Utah.

The corer contains a stainless-steel piston, a leaf-spring core catcher designed to prevent loss of fine-grained sediments as the sampler is retrieved from the lake, and a hardened steel alloy core cutter. As many as six 50-lb head weights were used to drive the corer into the lake sediments, depending on the consistency of the sediment material.

For core sampling, the piston corer was lowered rapidly through the water column until it reached the lakebed. The winch that allowed the corer to drop and penetrate into the sediment was then released. The gravity corer is attached to a wire clamp-release device with a loop of slack wire that allows the corer to fall freely when released into the sediments the moment the trigger weight touches the lakebed (fig. 4).

Sediment samples, approximately 300 mm in length, were collected from the sediment-water interface by using a modified sampler designed by the USGS NRP in Boulder, Colorado (fig. 5). This device is constructed of polycarbonate plastic to prevent contamination of samples (Moody, 1997). Samples were collected at each core sample location and sediment samples were collected at the same locations as the cores, at a site on the Colorado River near Sheep Canyon, and in the Dirty Devil River and North Wash (fig. 1). Replicate sediment-water interface samples were collected at all sampling locations.

## Sediment Core Processing and Preservation

Sediment cores were preserved in the field by chilling the samples in the polycarbonate tubing used as a liner for the coring device. The core liners containing the core samples were cut into approximately 3-m sections in the field to facilitate transport to the laboratory (fig. 6). Aluminum foil with an overwrap of polyethylene plastic sheeting was used to seal the ends of the core samples. Samples were transported to the USGS NRP laboratory where they were kept frozen until subsequent subsampling.

At the NRP laboratory, each sediment core was subsampled using the following procedure:

1. The polycarbonate liner (fig. 6) containing the sediment core section was cut longitudinally using a router and jig designed to permit cutting the tubing without penetrating the sediment core inside (fig. 7). Cuts were made on two sides of the entire length of tubing at an angle of about 180 degrees.

2. The sediment core was allowed to thaw partially before being cut longitudinally into roughly equal halves using a length of stainless-steel wire worked carefully down the length of the core along the slots made when the tubing was cut with the router. Splitting the core in this manner generally maintained the internal structure of the sediment core and allowed for visual inspection and photographing of core layering (fig. 7). Half of the split sediment core was resealed using aluminum foil and an overwrap of polyethylene plastic sheeting, refrozen, and archived at the NRP laboratory. The remaining half of the sediment core split was subsampled for analyses of chemical constituents and description of physical properties.

3. After the cores were cut longitudinally and half of each core was archived, the other half was fully thawed and cut radially into subsections for analysis. The radial cuts were made approximately every 20–30 mm along the core using a Teflon spatula. This subsectioning began at the bottom of the core and proceeded upward. The placement of the cuts was dictated by visual changes in the core (for example, differences in texture, color, and grain size that result in nonuniform core-segment lengths). The entire contents of each segment were frozen until digestion.

4. A detailed physical description of the cores was recorded (table 2).

## Subsampling and Digestion Procedure

In order to prepare the core and sediment samples for digestion, each sample was thawed and subsampled for analysis using techniques described by Reeves and Brooks (1978) to ensure homogeneity. A portion of the subsample sediment was used for digestion; the remainder was archived. The portion of the subsample used for digestion was then freeze-dried and subsequently pulverized with precleaned acrylic-plastic beads in an end-mill shaker.

A custom digestion procedure was used to obtain a complete digestion of each sediment sample. Approximately 100 mg was removed from each pulverized and homogenized sample, carefully weighed, and transferred to a 100-mL Teflon digestion vessel. Then, 0.89 g of doubly distilled, ultrapure nitric acid; 2.36 g of doubly distilled, ultrapure hydrochloric acid; and 0.99 g of trace-metal grade hydrofluoric acid were added to each vessel. In addition, 0.25 mL of deionized water was added to each vessel to facilitate the digestion. The digestion vessels were closed and placed in a Milestone MLS-1200 MEGA microwave digestion system that has a capacity for six simultaneous digestions. The digestion consisted of four steps of varying power and time: (1) microwaved at 250 watts for 5 minutes, (2) microwaved at 400 watts for 5 minutes, (3) microwaved at 650 watts for 10 minutes, and (4) microwaved at 400 watts for 10 minutes. The digestion vessels were then cooled in an ice bath for 1.5 hours.

After cooling, the digestates were transferred to 30-mL Savillex Teflon vessels and diluted to 20 mL with deionized water. A 2-mL aliquot from this solution was removed and set aside for mercury analysis. The remaining 18 mL was evaporated to dryness under an infrared heat lamp; the conditions of evaporation were established so that the temperature of each digestate solution during evaporation was between 40 and 50 degrees Celsius. The dried residue was resolubilized using 20 mL of a solution of 50 percent nitric acid/50 percent deionized water. This 20-mL solution was further diluted to 100 mL with deionized water for use in trace-metals analysis.

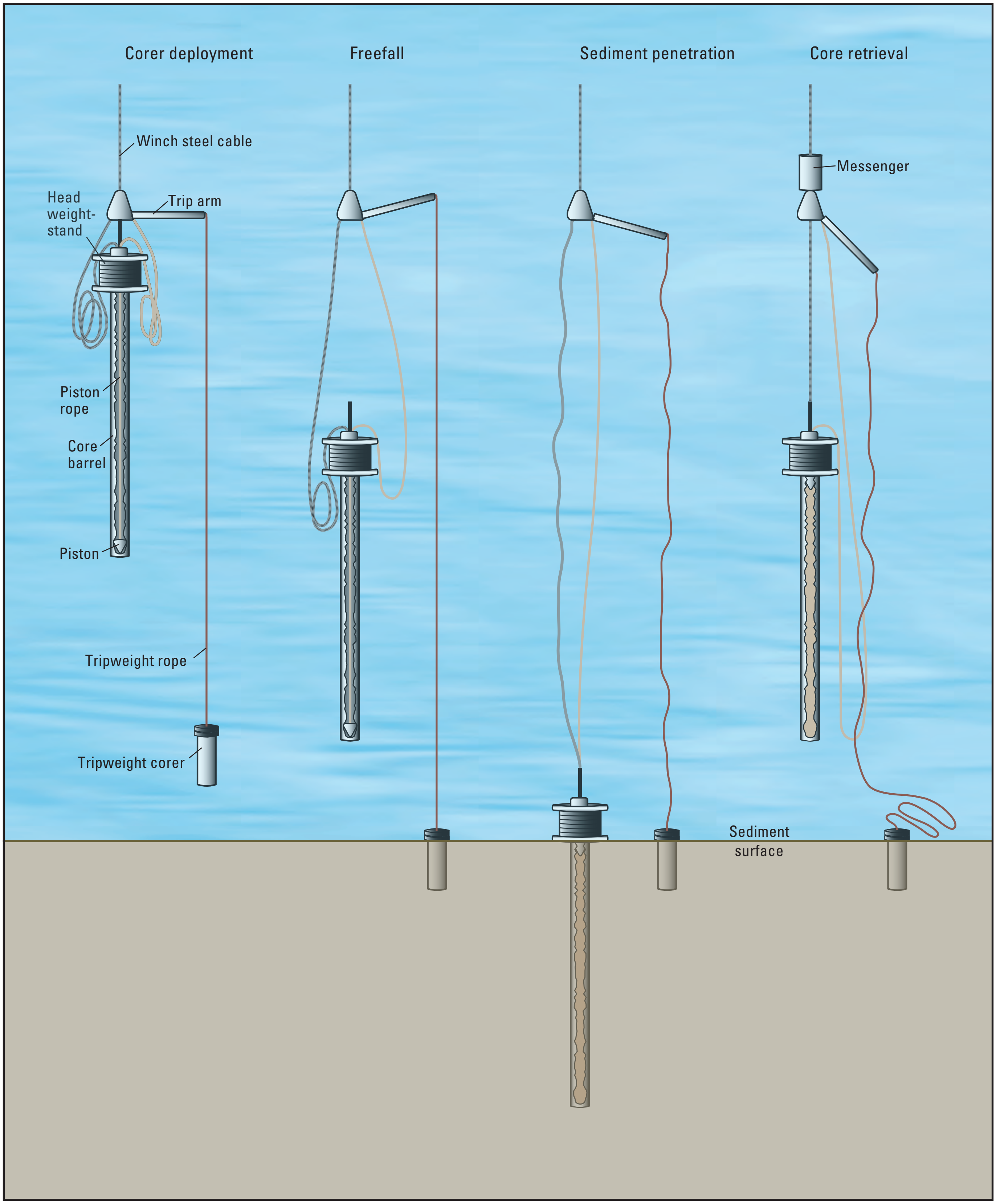


**Figure 4.** Benthos-gravity piston corer.

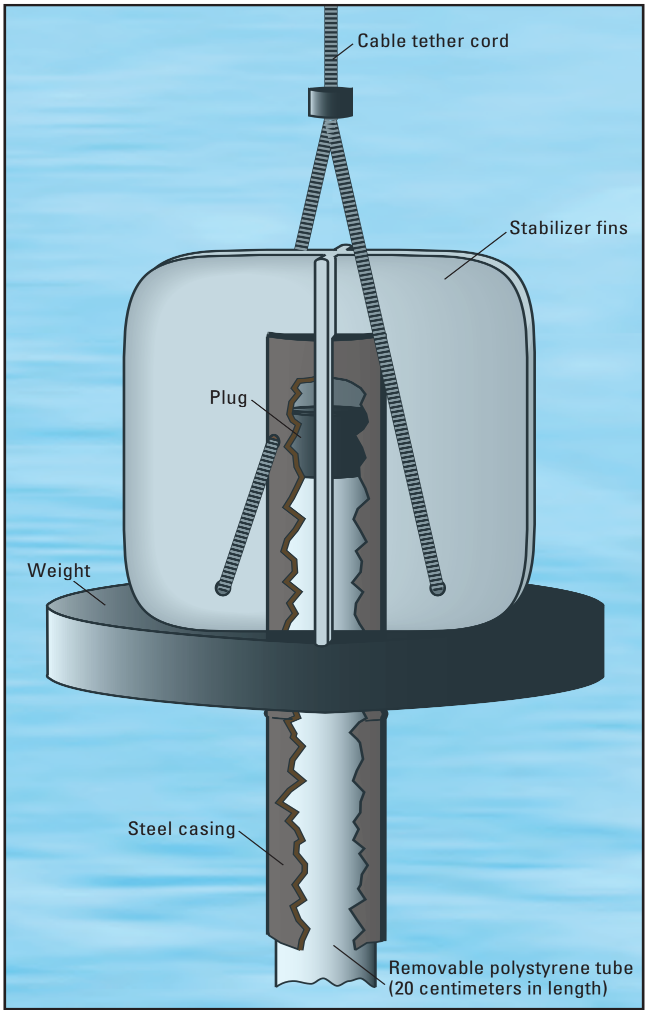


**Figure 5**. Modified sediment sampler.

**Figure 6**. Preparation of polycarbonate core tube liner for transport to laboratory.


**Figure 7**. Section of core 298, showing sediment stratification, after polycarbonate liner was cut longitudinally in the laboratory.

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001

| Core 298 | | |
|---|---|---|
| Section number | Length of section (millimeters) | Description (total core length 3,130 millimeters) |
| 4 | 0-340 | Grayish brown, unconsolidated |
| 3 | 910-930 Top | Grayish brown, slightly darker than above, homogeneous, consolidated, pebble (~4 millimeters)? Or lake trash? |
| 3 | 880-910 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 850-880 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 820-850 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 790-820 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 790-820 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 760-790 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 760-790 | Grayish brown slightly darker than above, homogeneous, consolidated |
| 3 | 740-760 | Grayish brown, homogeneous, consolidated |
| 3 | 710-740 | Grayish brown, homogeneous, consolidated |
| 3 | 680-710 | Grayish brown, homogeneous, consolidated |
| 3 | 650-680 | Grayish brown, homogeneous, consolidated |
| 3 | 620-650 | Grayish brown, homogeneous, consolidated |
| 3 | 585-620 | Grayish brown, homogeneous, consolidated |
| 3 | 560-585 | Dark gray and reddish brown (some), homogeneous, consolidated |
| 3 | 530-560 | Reddish brown/dark gray (some), homogeneous, consolidated |
| 3 | 510-530 | Reddish brown, homogeneous, consolidated |
| 3 | 480-510 | Reddish brown, homogeneous, consolidated |
| 3 | 450-480 | Reddish brown, homogeneous, consolidated |
| 3 | 430-450 | Brownish gray, homogeneous, consolidated |
| 3 | 400-430 | Brownish gray, homogeneous, consolidated |
| 3 | 370-400 | Brownish gray, homogeneous, consolidated |
| 3 | 330-370 | Light reddish brown, homogeneous, consolidated |
| 3 | 310-330 | Light brownish gray homogeneous, consolidated |
| 3 | 280-310 | Light brownish gray homogeneous, consolidated |
| 3 | 250-280 | Light brownish gray homogeneous, consolidated |
| 3 | 230-250 | Light reddish-brown band, homogeneous, consolidated |
| 3 | 195-230 | Light brownish gray, homogeneous, consolidated |
| 3 | 170-195 | Dark brown and reddish brown and dark gray, distorted and convoluted, consolidated |
| 3 | 150-170 | Dark brown and reddish brown and dark gray, distorted and convoluted, consolidated |
| 3 | 120-150 | Light brownish-gray band, homogeneous, consolidated |
| 3 | 100-120 | Dark blackish-gray band, homogeneous, consolidated |
| 3 | 70-100 | Dark grayish brown with very fine (<1 millimeters) dark blackish-gray laminate |
| 3 | 60-70 | Reddish-brown band, homogeneous, consolidated |
| 3 | 30-60 | Grayish brown, homogeneous, consolidated |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 298—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,130 millimeters)** |
| 3 | 0-30 Bottom | Grayish brown, homogeneous, consolidated |
| 2 | 910-930 Top | Very light brown, homogeneous, consolidated |
| 2 | 880-910 | Very light brown, homogeneous, consolidated |
| 2 | 865-880 | Light brown with few dark gray bands (0.25 millimeters), consolidated |
| 2 | 835-865 | Very light brown, homogeneous, consolidated |
| 2 | 825-835 | Very dark gray band, homogeneous, consolidated |
| 2 | 810-825 | Brownish-red band, homogeneous, consolidated |
| 2 | 770-800 | Light brown, homogeneous, consolidated |
| 2 | 740-770 | Light brown, homogeneous, consolidated |
| 2 | 710-740 | Light brown, homogeneous, consolidated |
| 2 | 680-710 | Light brown, homogeneous, consolidated |
| 2 | 650-680 | Light brown, homogeneous, consolidated |
| 2 | 585-650 | Dark brownish red, homogeneous, consolidated |
| 2 | 560-585 | Light gray band, homogeneous, consolidated |
| 2 | 530-560 | Brownish red, homogeneous, consolidated |
| 2 | 500-530 | Brownish red, homogeneous, consolidated |
| 2 | 490-500 | Dark gray band, homogeneous, consolidated |
| 2 | 460-490 | Light brown band, homogeneous, consolidated |
| 2 | 435-460 | Reddish-brown band, homogeneous, consolidated |
| 2 | 415-435 | Finely laminated brownish-red, light gray, dark gray bands (0.5–1 centimeter thick) |
| 2 | 390-415 | Finely laminated brownish-red, light gray, dark gray bands (0.5–1 centimeter thick) |
| 2 | 360-390 | Very finely laminated brownish-red, light gray, and dark gray bands (>1 millimeter thick bands) |
| 2 | 345-360 | Stark brownish-red band grades into a darker brownish red, consolidated |
| 2 | 335-345 | Dark-gray band, homogeneous, consolidated |
| 2 | 320-335 | Reddish-brown band, homogeneous, consolidated |
| 2 | 310-320 | Brownish-gray band, homogeneous, consolidated |
| 2 | 280-310 | Grayish brown with indistinct darker brown banding, consolidated |
| 2 | 255-280 | Grayish brown, homogeneous, consolidated |
| 2 | 225-255 | Grayish brown, homogeneous, consolidated |
| 2 | 190-225 | Dark gray/black band, homogeneous, consolidated |
| 2 | 170-190 | Light brown, homogeneous, consolidated |
| 2 | 140-170 | Light brown, homogeneous, consolidated |
| 2 | 115-140 | Reddish brown, homogeneous, consolidated |
| 2 | 85-115 | Reddish brown, homogeneous, consolidated |
| 2 | 60-85 | Light gray, homogeneous, consolidated |
| 2 | 30-60 | Light grayish brown, homogeneous, consolidated |
| 2 | 0-30 Bottom | Light grayish brown, homogeneous, consolidated |
| 1 | 905-930 Top | Brown-gray, homogeneous, consolidated |
| 1 | 880-905 | Brown-gray, homogeneous, consolidated |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 298—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,130 millimeters)** |
| 1 | 850-880 | Brown-gray, homogeneous, consolidated |
| 1 | 825-850 | Brown-gray, homogeneous, consolidated |
| 1 | 795-825 | Brown-gray, homogeneous, consolidated |
| 1 | 765-795 | Gray, homogeneous, band |
| 1 | 755-765 | Reddish, homogeneous, band |
| 1 | 720-755 | Brown-gray, homogeneous |
| 1 | 685-720 | Reddish, homogeneous, band |
| 1 | 670-685 | Dark gray, homogeneous |
| 1 | 650-670 | Gray, with wide diffuse reddish bands (~1 centimeter) |
| 1 | 615-650 | Gray, with wide diffuse reddish bands (~1 centimeter) |
| 1 | 590-615 | Gray, with wide diffuse reddish bands (~1 centimeter) |
| 1 | 565-590 | Light gray, homogeneous, consolidated |
| 1 | 540-565 | Light gray, homogeneous, consolidated |
| 1 | 530-540 | Reddish, homogenous, consolidated, band |
| 1 | 510-530 | Dark gray, homogeneous, consolidated, band |
| 1 | 485-510 | Light gray, homogeneous, consolidated |
| 1 | 460-485 | Light gray, homogeneous, consolidated |
| 1 | 440-460 | Finely banded (~1 millimeter) gray/reddish/dark gray |
| 1 | 420-440 | Finely banded (~1 millimeter) gray/reddish/dark gray |
| 1 | 390-420 | Finely banded (~1 millimeter) gray/reddish/dark gray |
| 1 | 370-390 | Light gray band, homogeneous, grading to dark gray, up core |
| 1 | 360-370 | Dark gray, homogeneous, band |
| 1 | 350-360 | Light gray, homogeneous, band |
| 1 | 335-350 | Finely banded (~1 millimeter) gray/reddish/dark gray, consolidated |
| 1 | 305-335 | Finely banded (~1 millimeter) gray/reddish/dark gray, consolidated |
| 1 | 290-305 | Light gray, homogeneous band, consolidated |
| 1 | 270-290 | Slightly darker (gray), homogeneous, consolidated material |
| 1 | 250-270 | Gray, homogeneous, consolidated material |
| 1 | 220-250 | Gray, homogeneous, consolidated material |
| 1 | 190-220 | Finely banded (~1 millimeter) gray/reddish/dark gray |
| 1 | 165-190 | Gray, homogeneous, consolidated material |
| 1 | 140-165 | Gray, homogeneous, consolidated material |
| 1 | 115-140 | Gray, homogeneous, consolidated material |
| 1 | 105-115 | Lighter reddish band |
| 1 | 85-105 | Homogeneous, consolidated material |
| 1 | 60-85 | Homogeneous, consolidated material |
| 1 | 0-60 Bottom | Unconsolidated material at bottom |

**Table 2**. Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 291 | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,280 millimeters)** |
| 4 | 470-490 Top | Reddish brown, homogeneous |
| 4 | 440-470 | Reddish brown, homogeneous |
| 4 | 410-440 | Reddish brown, homogeneous |
| 4 | 380-410 | Reddish brown, homogeneous |
| 4 | 350-380 | Reddish brown, homogeneous |
| 4 | 335-350 | Reddish brown, homogeneous |
| 4 | 305-335 | Reddish brown, homogeneous |
| 4 | 275-305 | Reddish brown, homogeneous |
| 4 | 245-275 | Reddish brown, homogeneous |
| 4 | 215-245 | Reddish brown, homogeneous |
| 4 | 185-215 | Reddish brown, homogeneous |
| 4 | 165-185 | Reddish brown with black mottles |
| 4 | 150-165 | Reddish brown, homogeneous |
| 4 | 120-150 | Reddish brown, homogeneous |
| 4 | 90-120 | Reddish brown, homogeneous |
| 4 | 75-90 | Blackish brown with reddish-brown mottles |
| 4 | 60-75 | Dark brown and reddish brown |
| 4 | 30-60 | Dark brown and reddish brown |
| 4 | 0-30 Bottom | Dark brown and reddish brown |
| 3 | 910-930 Top | Reddish brown and grayish brown |
| 3 | 880-910 | Reddish brown and grayish brown |
| 3 | 850-880 | Grayish reddish brown, homogeneous |
| 3 | 840-850 | Blackish brown, homogeneous |
| 3 | 815-840 | Grayish brown with reddish-brown streaks |
| 3 | 790-815 | Light brown band, homogeneous |
| 3 | 780-790 | Stark reddish-brown band, homogeneous |
| 3 | 750-780 | Reddish-brown band, homogeneous |
| 3 | 730-750 | Grayish brown with reddish-brown mottles |
| 3 | 700-730 | Grayish brown with reddish-brown mottles |
| 3 | 680-700 | Reddish brown and brown |
| 3 | 665-680 | Grayish brown, homogeneous |
| 3 | 645-665 | Reddish-brown band, homogeneous |
| 3 | 620-645 | Grayish brown with reddish-brown streaks |
| 3 | 590-620 | Grayish brown with reddish-brown streaks |
| 3 | 560-590 | Grayish brown with reddish-brown streaks |
| 3 | 545-560 | Dark blackish brown |
| 3 | 520-545 | Light grayish brown with black and yellow streaks |
| 3 | 500-520 | Light grayish brown with black and yellow streaks |
| 3 | 500-520 | Light grayish brown with black and yellow streaks |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 291—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,280 millimeters)** |
| 3 | 485-500 | Dark grayish brown band |
| 3 | 470-485 | Stark reddish-brown band, homogeneous |
| 3 | 460-470 | Dark brown band, homogeneous |
| 3 | 460-470 | Dark brown band, homogeneous |
| 3 | 435-460 | Brown, homogeneous |
| 3 | 425-435 | Brown, homogeneous |
| 3 | 400-425 | Dark brown with light brown streaks |
| 3 | 390-400 | Light grayish tan, homogeneous |
| 3 | 380-390 | Reddish brown, homogeneous |
| 3 | 350-380 | Dark grayish brown with reddish brown streaks |
| 3 | 330-350 | Grayish reddish brown, homogeneous |
| 3 | 300-330 | Grayish reddish brown, homogeneous |
| 3 | 270-300 | Grayish brown with black streaks |
| 3 | 240-270 | Grayish brown with black streaks |
| 3 | 210-240 | (Reddish-brown mottles) grayish-brown |
| 3 | 180-210 | (Reddish-brown mottles) grayish-brown |
| 3 | 170-180 | Grayish brown with reddish brown and black streaks |
| 3 | 140-170 | Grayish brown with reddish brown and black streaks |
| 3 | 110-140 | Grayish brown with reddish brown and black streaks |
| 3 | 100-110 | Reddish-brown band, homogeneous |
| 3 | 80-100 | Dark grayish brown |
| 3 | 60-80 | Reddish brown, homogeneous |
| 3 | 30-60 | Dark brown with reddish-brown streaks |
| 3 | 0-30 Bottom | Dark brown with reddish-brown streaks |
| 2 | 895-930 Top | Dark brown with reddish-brown and black streaks |
| 2 | 870-895 | Dark brown, homogeneous |
| 2 | 850-870 | Dark brown with reddish-brown and black streaks |
| 2 | 830-850 | Dark brown with reddish-brown and black streaks |
| 2 | 810-830 | Dark brown with gray and reddish-brown streaks |
| 2 | 780-810 | Dark brown with gray and reddish-brown streaks |
| 2 | 750-780 | Dark brown, homogeneous |
| 2 | 730-750 | Dark reddish brown, homogeneous |
| 2 | 700-730 | Reddish brown, homogeneous |
| 2 | 670-700 | Reddish brown, homogeneous |
| 2 | 650-670 | Dark brown, homogeneous |
| 2 | 620-650 | Dark brown, homogeneous |
| 2 | 590-620 | Dark brown, homogeneous |
| 2 | 560-590 | Reddish brown, homogeneous |
| 2 | 530-560 | Reddish brown, homogeneous |

**Table 2**. Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 291—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,280 millimeters)** |
| 2 | 510-530 | Dark brown with reddish-brown streaks |
| 2 | 490-510 | Reddish brown, homogeneous |
| 2 | 460-490 | Reddish brown, homogeneous |
| 2 | 430-460 | Grayish brown with reddish-brown streaks |
| 2 | 430-460 | Grayish brown with reddish-brown streaks |
| 2 | 400-430 | Grayish brown with reddish-brown streaks |
| 2 | 390-400 | Dark brown band, homogeneous |
| 2 | 380-390 | Reddish-brown band, homogeneous |
| 2 | 360-380 | Grayish brown, homogeneous |
| 2 | 340-360 | Dark reddish brown, homogeneous |
| 2 | 320-340 | Grayish brown, homogeneous |
| 2 | 310-320 | Brown with reddish-brown mottles |
| 2 | 280-310 | Grayish brown, homogeneous |
| 2 | 250-280 | Grayish brown with reddish-brown mottles |
| 2 | 230-250 | Reddish-brown band, homogeneous |
| 2 | 215-230 | Dark brown band, homogeneous |
| 2 | 185-215 | Brown with reddish-brown streaks |
| 2 | 175-185 | Blackish-brown band |
| 2 | 160-175 | Light reddish brown |
| 2 | 150-160 | Same with black streaks |
| 2 | 120-150 | Dark brown with reddish-tan streaks |
| 2 | 90-120 | Dark brown with reddish-tan streaks |
| 2 | 90-120 | Dark brown with reddish-tan streaks |
| 2 | 60-90 | Dark brown with reddish-tan streaks |
| 2 | 30-60 | Dark blackish brown, homogeneous |
| 2 | 0-30 Bottom | Dark brown with reddish-tan streaks mottles |
| 1 | 895-930 Top | Dark brown with black streaks |
| 1 | 885-895 | Reddish-brown band, homogeneous |
| 1 | 860-885 | Dark brown, with tan streaks and reddish-tan streaks |
| 1 | 840-860 | Dark brown, with tan streaks |
| 1 | 830-840 | Reddish-tan band, homogeneous |
| 1 | 800-830 | Dark brown, homogeneous |
| 1 | 790-800 | Reddish-tan band, homogeneous |
| 1 | 760-790 | Dark brown with yellow mottle |
| 1 | 730-760 | Dark brown with yellow mottle |
| 1 | 710-730 | Dark brown with yellow mottle |
| 1 | 680-710 | Dark brown, homogeneous |
| 1 | 660-680 | Dark brown with yellow streak mottle |
| 1 | 640-660 | Dark brown, homogeneous |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Section number | Length of section (millimeters) | Description (total core length 3,280 millimeters) |
|---|---|---|
| Core 291—Continued | | |
| 1 | 620-640 | Dark brown with yellow, red and black mottles |
| 1 | 600-620 | Dark brown with yellow, red and black mottles |
| 1 | 590-600 | Dark brown, homogeneous |
| 1 | 575-590 | Dark brown, homogeneous |
| 1 | 545-575 | Dark gray brown with light gray streaks |
| 1 | 515-545 | Dark gray brown with light gray streaks |
| 1 | 500-515 | Dark brown, homogeneous |
| 1 | 470-500 | Dark brown, homogeneous |
| 1 | 440-470 | Dark brown, homogeneous |
| 1 | 410-440 | Dark brown, homogeneous |
| 1 | 380-410 | Dark brown, homogeneous |
| 1 | 360-380 | Reddish-brown band, homogeneous |
| 1 | 340-360 | Dark grayish brown, homogeneous |
| 1 | 310-340 | Dark grayish brown, homogeneous |
| 1 | 310-340 | Dark grayish brown, homogeneous |
| 1 | 290-310 | Reddish gray brown, homogeneous |
| 1 | 270-290 | Dark grayish-brown |
| 1 | 230-270 | Dark grayish brown, homogeneous |
| 1 | 210-230 | Dark grayish brown |
| 1 | 180-210 | Slightly lighter grayish brown, homogeneous |
| 1 | 150-180 | Slightly lighter grayish brown, homogeneous |
| 1 | 120-150 | Slightly lighter grayish brown, homogeneous |
| 1 | 90-120 | Grayish brown, homogeneous |
| 1 | 60-90 | Grayish brown, homogeneous |
| 1 | 30-60 | Grayish brown, homogeneous |
| 1 | 0-30 Bottom | Grayish brown, homogeneous |

| Section number | Length of section (millimeters) | Description (total core length 3,745 millimeters) |
|---|---|---|
| Core 281 | | |
| 4 | 900-940 | Black, homogeneous |
| 4 | 880-900 | Brown, homogeneous |
| 4 | 850-880 | Brown, homogeneous |
| 4 | 820-850 | Brown with black mottles |
| 4 | 800-820 | Brown with black mottles |
| 4 | 770-800 | Brown with black mottles |
| 4 | 740-770 | Brown, homogeneous |
| 4 | 740-770 | Brown, homogeneous |
| 4 | 710-740 | Reddish-brown and dark-brown mottles |
| 4 | 700-710 | Dark-brown to black band, homogeneous |
| 4 | 670-700 | Reddish brown, homogeneous |
| 4 | 660-670 | Dark brown to black with reddish-brown mottles |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 281—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,745 millimeters)** |
| 4 | 630-660 | Dark brown to black with reddish-brown mottles |
| 4 | 600-630 | Reddish brown with black mottles |
| 4 | 570-600 | Reddish brown with black mottles |
| 4 | 540-570 | Reddish brown with black mottles |
| 4 | 520-540 | Gray reddish brown, homogeneous |
| 4 | 495-520 | Gray reddish brown, homogeneous |
| 4 | 480-495 | Light grayish brown, homogeneous |
| 4 | 460-480 | Grayish brown, homogeneous |
| 4 | 440-460 | Black band, homogeneous |
| 4 | 410-440 | Reddish brown, homogeneous |
| 4 | 380-410 | Reddish brown, homogeneous |
| 4 | 360-380 | Dark brown with red and black mottles |
| 4 | 340-360 | Light brown with red and black mottles |
| 4 | 310-340 | Brown with red and black mottles |
| 4 | 280-310 | Brown with red and black mottles |
| 4 | 250-280 | Reddish brown, homogeneous |
| 4 | 220-250 | Dark brown with tan, red mottles |
| 4 | 220-250 | Dark brown with tan, red mottles |
| 4 | 190-220 | Dark brown with tan, red mottles |
| 4 | 165-190 | Brown with tan and red mottles |
| 4 | 150-165 | Light tan, homogeneous |
| 4 | 130-150 | Light brown, homogeneous |
| 4 | 120-130 | Tan brown with black mottles |
| 4 | 90-120 | Tan brown with black mottles |
| 4 | 60-90 | Tan brown with black mottles |
| 4 | 30-60 | Tan brown with black mottles |
| 4 | 0-30 Bottom | Tan brown with black mottles |
| 3 | 910-930 Top | Light reddish brown, homogeneous |
| 3 | 880-910 | Light reddish brown, homogeneous |
| 3 | 880-910 | Light reddish brown, homogeneous |
| 3 | 855-880 | Dark grayish brown, homogeneous |
| 3 | 825-855 | Dark grayish brown, homogeneous |
| 3 | 795-825 | Dark grayish brown, homogeneous |
| 3 | 780-795 | Light reddish brown |
| 3 | 765-780 | Dark grayish brown, homogeneous |
| 3 | 745-765 | Light reddish brown |
| 3 | 720-745 | Dark grayish brown, homogeneous |
| 3 | 690-720 | Light reddish brown |
| 3 | 660-690 | Light reddish brown |
| 3 | 640-660 | Reddish brown, homogeneous |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

Core 281—Continued

| Section number | Length of section (millimeters) | Description (total core length 3,745 millimeters) |
|---|---|---|
| 3 | 610-640 | Reddish brown, homogeneous |
| 3 | 580-610 | Dark grayish brown with reddish streaks, with >% reddish streaks |
| 3 | 550-580 | Dark grayish brown with reddish streaks |
| 3 | 520-550 | Dark grayish brown with reddish streaks |
| 3 | 500-520 | Grayish brown with dark-gray streaks and reddish streaks |
| 3 | 470-500 | Grayish brown with dark-gray streaks and reddish streaks |
| 3 | 440-470 | Grayish brown with dark-gray streaks and reddish streaks |
| 3 | 410-440 | Grayish brown with dark-gray streaks and reddish streaks |
| 3 | 380-410 | Grayish brown with dark-gray streaks and reddish streaks |
| 3 | 360-380 | Grayish brown, homogeneous |
| 3 | 330-360 | Light reddish brown, homogeneous |
| 3 | 310-330 | Black band with light reddish streaks |
| 3 | 280-310 | Brown, homogeneous |
| 3 | 255-280 | Dark brown with black mottles |
| 3 | 240-255 | Brown, homogeneous |
| 3 | 220-240 | Brown, homogeneous |
| 3 | 220-240 | Brown, homogeneous |
| 3 | 210-220 | Reddish brown |
| 3 | 180-210 | Dark brown, homogeneous |
| 3 | 150-180 | Dark brown, homogeneous |
| 3 | 130-150 | Dark brown, homogeneous with dark-red bands |
| 3 | 100-130 | Dark brown, homogeneous |
| 3 | 70-100 | Dark brown, homogeneous |
| 3 | 30-70 | Dark brown with red and black streaks, mottles? |
| 3 | 0-30 Bottom | Dark brown with red and black streaks, mottles? |
| 2 | 905-935 Top | Grayish brown with light reddish-brown bands/streaks |
| 2 | 875-905 | Grayish brown with light reddish-brown bands/streaks |
| 2 | 865-875 | Light reddish-brown band |
| 2 | 845-865 | Grayish brown with light reddish-brown bands/streaks |
| 2 | 845-865 | Grayish brown with light reddish-brown bands/streaks |
| 2 | 815-845 | Grayish brown with light reddish-brown bands/streaks |
| 2 | 805-815 | Light reddish brown, homogeneous |
| 2 | 790-805 | Dark brown, homogeneous |
| 2 | 765-790 | Light grayish brown, streaked |
| 2 | 765-790 | Light grayish brown, streaked |
| 2 | 735-765 | Dark brown, homogeneous |
| 2 | 705-735 | Dark brown, homogeneous |
| 2 | 695-705 | Light reddish-brown band, homogeneous |
| 2 | 665-695 | Banded light reddish brown dark brown |
| 2 | 635-665 | Banded light reddish brown dark brown |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 281—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,745 millimeters)** |
| 2 | 635-665 | Banded light reddish brown dark brown |
| 2 | 605-635 | Light reddish brown, homogeneous |
| 2 | 570-605 | Dark brownish black, homogeneous |
| 2 | 560-570 | Light reddish-brown band |
| 2 | 525-560 | Dark brownish black, homogeneous |
| 2 | 500-525 | Grayish brown to reddish brown |
| 2 | 485-500 | Reddish brown, homogeneous |
| 2 | 470-485 | Reddish brown |
| 2 | 450-470 | Dark grayish brown |
| 2 | 430-450 | Grayish brown, homogeneous |
| 2 | 420-430 | Light reddish brown, homogeneous |
| 2 | 400-420 | Grayish brown with black streaks |
| 2 | 390-400 | Reddish-brown band |
| 2 | 365-390 | Brown, homogeneous |
| 2 | 355-365 | Light reddish-tan band with black band |
| 2 | 340-355 | Light reddish-tan band |
| 2 | 320-340 | Brown, homogeneous |
| 2 | 300-320 | Brown, homogeneous |
| 2 | 270-300 | Brown, homogeneous |
| 2 | 240-270 | Brown, homogeneous |
| 2 | 225-240 | Light reddish tan |
| 2 | 210-225 | Brown, homogeneous |
| 2 | 185-210 | Brown, homogeneous |
| 2 | 160-185 | Light reddish-tan band, homogeneous |
| 2 | 130-160 | Brown, homogeneous |
| 2 | 100-130 | Brown, homogeneous |
| 2 | 90-100 | Gray-black band, homogeneous |
| 2 | 70-90 | Light reddish-tan bands with black band |
| 2 | 40-70 | Dark brownish black, homogeneous |
| 2 | 20-40 | Light tan, homogeneous |
| 2 | 10-20 | Dark brownish black |
| 2 | 0-10 Bottom | Light tan with light-cream streak |
| 1 | 920-940 Top | Dark reddish brown, homogeneous, consolidated |
| 1 | 900-920 | Reddish brown, homogeneous, consolidated |
| 1 | 880-900 | Reddish brown, homogeneous, consolidated |
| 1 | 860-880 | Gray, homogeneous, consolidated |
| 1 | 840-860 | Gray, homogeneous, consolidated |
| 1 | 810-840 | Dark brownish gray, homogeneous, consolidated |
| 1 | 785-810 | Light reddish brown and dark gray, consolidated |
| 1 | 765-785 | Reddish brown, homogeneous, consolidated |

**Table 2.** Physical description of sediment core samples collected at sites 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001—Continued

| Core 281—Continued | | |
|---|---|---|
| **Section number** | **Length of section (millimeters)** | **Description (total core length 3,745 millimeters)** |
| 1 | 745-765 | Reddish brown, homogeneous, consolidated |
| 1 | 735-745 | Very distinct black band, homogeneous, consolidated |
| 1 | 715-735 | Dark brownish gray, homogeneous, consolidated |
| 1 | 690-715 | Dark brownish gray, homogeneous, consolidated |
| 1 | 660-690 | Dark brownish gray, homogeneous, consolidated |
| 1 | 650-660 | Dark brownish gray, homogeneous, consolidated, with a few streaks of light tan, slightly darker brownish gray |
| 1 | 620-650 | Dark brownish gray, homogeneous, consolidated, with a few streaks of light tan |
| 1 | 590-620 | Dark brownish gray, homogeneous, consolidated, with a few streaks of light tan |
| 1 | 560-590 | Dark brownish gray, homogeneous, consolidated, with a few streaks of light tan |
| 1 | 530-560 | Dark brownish gray, homogeneous, consolidated |
| 1 | 500-530 | Dark brownish gray, homogeneous, consolidated |
| 1 | 470-500 | Dark brownish gray, homogeneous, consolidated, with few streaks of light tan |
| 1 | 440-470 | Dark brownish gray, homogeneous, consolidated, with few streaks of light tan |
| 1 | 430-440 | Light tan band, homogeneous, consolidated |
| 1 | 420-430 | Dark brownish-gray band, homogeneous, consolidated |
| 1 | 390-420 | Brownish gray, homogeneous, consolidated |
| 1 | 360-390 | Brownish gray, homogeneous, consolidated |
| 1 | 330-360 | Brownish gray, homogeneous, consolidated |
| 1 | 300-330 | Brownish gray, homogeneous, consolidated |
| 1 | 270-300 | Brownish gray, homogeneous, consolidated |
| 1 | 240-270 | Brownish gray, homogeneous, consolidated |
| 1 | 220-240 | Lighter reddish brownish gray, homogeneous, consolidated |
| 1 | 180-220 | Brownish gray, homogeneous, consolidated |
| 1 | 150-180 | Brownish gray, homogeneous, consolidated |
| 1 | 120-150 | Brownish gray, homogeneous, consolidated |
| 1 | 90-120 | Brownish gray, homogeneous, consolidated |
| 1 | 60-90 | Brownish gray, homogeneous, consolidated |
| 1 | 30-60 | Brownish gray, homogeneous, consolidated |
| 1 | 0-30 Bottom | Brownish gray, homogeneous, consolidated |

The 2-mL aliquot removed for a mercury determination was treated as follows: a saturated solution of boric acid was prepared by adding at least 6.35 g of ultrapure boric acid to 100 mL of cold, deionized water. Eight milliliters of this saturated solution was then diluted to 1 L with deionized water, and 100 mL of this diluent was added to a tared, 125-mL, precleaned, glass mercury bottle. Then, the 2-mL aliquot was added, followed by a 5-percent (v/v) solution of potassium dichromate/nitric acid. The boric acid was added to complex excess fluoride ions and make them unreactive.

Within each set of 6 digestions (1 microwave session), 4 positions were sediment samples, 1 was a reagent digestion blank, and 1 was a standard-reference sediment sample. The digestion blank was treated precisely as if it were a sediment sample and carried through the entire digestion procedure. The standard-reference sample consisted of 1 of 13 different standards that were digested throughout the study. In addition, at a frequency of about 10 percent of the samples digested, a random, replicate sediment digestion was made.

## Pore Water and Overlying Sediment-Water Interface Water Processing and Preservation

Upon collection, the sediment-water interface samples had between 100 and 300 mm of water immediately overlying the sediment. As soon as these samples were collected, they were frozen for transport to the laboratory. The frozen samples, therefore, preserved not only the sediment, but also the water overlying the sediment-water interface.

These samples were thawed in the laboratory just enough to enable extrusion of the frozen sample from the plastic collection tube. A ceramic knife was used to cut each extruded sample to within a centimeter or two of the sediment-water interface. The upper portion, or "overlying water," which consisted of a column of approximately 20 cm of water, was thawed and filtered through a 0.45-µm Acrodisk cartridge filter into a precleaned, tared polyethylene bottle. The samples were then weighed and acidified with ultrapure nitric acid to a 1-percent concentration. Typically, about 20 mL of each sample was obtained for analysis.

The lower portion of each extruded sample below the ceramic knife cut consisted almost entirely of sediment. These portions were placed into precleaned 250-mL polypropylene centrifuge tubes and allowed to thaw entirely. The tubes were then centrifuged for 10 minutes at 5,000 revolutions per minute, resulting in the pore water separating on top of the sediment. This pore water was decanted and filtered through 0.45-µm Acrodisk cartridge filters and into precleaned tared polyethylene bottles. As with the overlying-water samples, these pore-water samples were weighed and acidified to a 1-percent concentration with ultrapure nitric acid. The amount of pore water obtained by this procedure was small, usually between 0.2 and 0.5 mL. It was therefore necessary to dilute the samples by a considerable amount—usually 100 times—in order to analyze them.

## Chemical Analyses of Sediment Cores and Pore and Overlying Sediment-Water Interface Samples, and Particle-Size Analyses

All sediment samples, including all core samples and sediment-water interface samples (table 1), were analyzed for the following constituents at the USGS NRP laboratory:

1. Major elemental constituents—aluminum, sodium, potassium, calcium, sulfur, phosphorus, titanium, and iron.

2. Trace elements—antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, cerium, cobalt, chromium, cesium, copper, dysprosium, erbium, europium, gadolinium, holmium, lanthanum, lithium, lutetium, mercury, manganese, molybdenum, neodymium, nickel, lead, praseodymium, rhenium, rubidium, samarium, selenium, strontium, terbium, thallium, thorium, thulium, tantalum, tungsten, uranium, vanadium, yttrium, ytterbium, zinc, and zirconium.

Eight composite sections (table 3) from the cores were also analyzed for organic compounds, including low-level organochlorine pesticides, PCBs, and PAHs, and for radionuclides. These analyses were done at the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colorado.

Total concentrations of the major- and trace-inorganic constituents were determined using inductively coupled plasma atomic-emission spectrometry (ICP-AES), inductively coupled plasma-mass spectrometry (ICP-MS; Taylor, 2001), and cold-vapor atomic fluorescence spectrometry (CVAFS; Roth, 1994). Major elemental constituents (with the exception of potassium) were determined with an ICP-AES technique by using a Perkin-Elmer Optima 3300, dual-view emission spectrometer operating in the axial-view mode (Garbarino and Taylor, 1979; Mitko and Bebek, 1999, 2000). Potassium was also determined with an ICP-AES technique by using the same instrumentation operating in the radial-view mode. All samples were determined in triplicate to provide a measure of the variability of the analysis. Trace elements (with the exception of mercury) were determined in triplicate with an ICP-MS technique by using a Perkin Elmer Elan 6000 instrument and methods developed by the USGS NRP as described by Taylor and Garbarino (1991), Garbarino and Taylor (1994), and Roth and others (1997). Mercury was determined in triplicate with CVAFS by using a technique reported by Roth (1994).

Separated pore waters and overlying waters from sediment-water interface samples were analyzed for inorganic constituents by techniques and methods similar to those described for the digested sediment samples. For water samples, aluminum was determined by an ICP-MS technique as reported in Garbarino and Taylor (1994).

Organochlorine pesticide and PCB concentrations were analyzed in organic solvent extracts using a dual-column, capillary-gas chromatograph with dual electron-capture detectors (Wershaw and others, 1987; Foreman and others, 1995). PAHs and phenols were analyzed in organic-solvent extracts using gas chromatography-electron impact mass spectrometry (Furlong and others, 1996). Measurements of gross radioactivity were made using standard methods described by the U.S. Environmental Protection Agency (1980), Thatcher and others (1977), and American Society for Testing and Materials (1992).

Eight composited sections of the cores (table 3) were analyzed for grain size by the USGS sediment laboratory in Vancouver, Washington, using methods described by Guy (1969). Mineralogy of selected sections of the cores was determined by the Department of Geology, Northern Arizona University in Flagstaff, Arizona, using X-ray diffraction methods. The mineralogic descriptions are available from the department.

**Table 3.** Composited sections of cores 298, 291, and 281 used for organic, radiochemistry, and particle-size analyses, Colorado River delta, Lake Powell, Utah, 2001

| Core site | Section numbers | Section length (millimeters) | Section of core composited for organic, radiochemistry, and particle-size analyses, (millimeters) |
|---|---|---|---|
| 298 | 4 | 0 - 340 | 0 - 340 |
| 298 | 3 | 340 - 1,270 | Not sampled |
| 298 | 2 | 1,270 - 2,200 | 650 - 800 |
| 298 | 1 | 2,200 - 3,130 | 0 - 105 |
| 291 | 4 | 0 - 490 | 185 - 490 |
| 291 | 3 | 490 - 1,420 | 560 - 645 |
| 291 | 2 | 1,420 -2,350 | Not sampled |
| 291 | 1 | 2,350 -3,280 | 0 -120 |
| 281 | 4 | 0 - 940 | 770 - 940 |
| 281 | 3 | 940 - 1,870 | Not sampled |
| 281 | 2 | 1,870 - 2,805 | Not sampled |
| 281 | 1 | 2,805 - 3,745 | 0 - 220 |

# Quality of Data

## Quality Control and Assurance

Calibration curves for instrumental determinations performed at the NRP laboratory were established using a minimum of five separate calibration standards. The calibration standards were prepared gravimetrically in deionized water from pure metals or metal salts. Laboratory reagent blanks and field-process blanks were measured frequently to evaluate the integrity of all sample analyses. Periodic analyses of standard reference materials with each set of laboratory samples were performed to ensure the accuracy of the determinations. Natural-water matrix reference samples constituted at least 20 percent of each batch of samples analyzed. Different standard-reference materials (National Institute of Standards and Technology, 1999) and River Sediment Standard Reference Materials (National Institute of Standards and Technology, 1990) were used for each analytical method. Quality-assurance samples, such as field blanks, equipment blanks, and replicate samples, constituted about 10 percent of the total samples collected. Results of quality-control and quality-assurance analyses are tabulated in the data tables (5 and 6) located in the section entitled "Basic Data" on the compact disc at the back of the report. Conventional quality-control procedures were used to evaluate analyses done at the NWQL.

## Quality Control of Data

In general, the overall quality of a data set can be evaluated by two interconnected parameters: accuracy (bias) and precision (variability). The accuracy of data is usually determined by how well the analyses of known standard-reference materials of similar compositions (analyzed as unknowns) match their certified or published values. If the observed values from the analyses of standard-reference materials—whose composition matches that of unknown samples as closely as possible—closely match their published values, then one can generally be assured that the observed values of the unknown samples are accurate and close to their true values. The precision or reproducibility of data is usually measured by how closely the analyses of replicate samples agree with each other. In general, the best overall estimate of precision is gained by the analysis of true field replicates, that is, samples collected in the field from the same location and at approximately the same time. Analytic replicates, whereby the same processed sample is analyzed in the laboratory by the same method multiple times, are a measure of analysis precision. It is frequently the case with sediment samples that it is not feasible to collect true field replicates; a good alternative for measuring reproducibility is to subsample the sediment multiple times and perform separate digestions and analyses in the laboratory.

## Accuracy of Data

As part of the chemical analyses of 455 sediment core samples, 13 different standard-reference materials were analyzed a total of 139 times to assess the accuracy of the analyses. These 13 different reference materials consisted of 6 river-, lake-, or marine-sediment standards and 7 pulverized-rock standards (table 4). Each of the individual elemental analyses and analytical errors of all standard reference materials measured are shown in table 5. In table 6, results of analyses are summarized, and a comparison of certified and "most probable values" is shown. The results for the Buffalo River and New York-New Jersey Waterway standards show good agreement between the median observed values and the certified values. Median observed values were generally within 7 percent of their certified values (fig. 8).

**Table 4**. Standard reference materials used to determine the accuracy of analyses of sediment samples, Colorado River delta, Lake Powell, Utah, 2001

[Certified, number of elements with certified values; Non, number of elements without certified values; n, number of times analyzed]

| Name | Source | Identifier | Description | Certified | Non | n |
|---|---|---|---|---|---|---|
| | | | Sediment standards | | | |
| BCSS-1 | National Research Council of Canada | BCSS-1 | Estuarine sediment from the Gulf of St. Lawrence (National Research Council of Canada, 1990) | 22 | 5 | 8 |
| Buffalo River | National Institute of Standards and Technology | SRM 2704 | River sediment from the Buffalo River, Buffalo, New York (National Institute of Standards and Technology, 1990) | 26 | 15 | 52 |
| Mess-1 | National Research Council of Canada | MESS-1 | Estuarine sediment from the Gulf of St. Lawrence (National Research Council of Canada, 1990) | 22 | 5 | 12 |
| Mess-2 | National Research Council of Canada | MESS-2 | Estuarine sediment from the Beaufort Sea (National Research Council of Canada, 1999) | 22 | 1 | 11 |
| NY-NJ | National Institute of Standards and Technology | SRM 1944 | A mixture of marine sediment collected near urban areas in New York and New Jersey (National Institute of Standards and Technology, 1999) | 9 | 22 | 22 |
| PACS-1 | National Research Council of Canada | PACS-1 | Sediment from Esquimalt Harbor, British Columbia (National Institute of Standards and Technology, 1990) | 24 | 0 | 20 |
| | | | Rock standards | | | |
| AGV-1 | U.S. Geological Survey | AGV-1 | Andesite from Guano Valley, Lake County, Oregon (Govindavaju, 1994) | 0 | 51 | 2 |
| MAG-1 | U.S. Geological Survey | MAG-1 | Fine-grained clayey-mud from the Wilkinson Basin of the Gulf of Maine (Govindavaju, 1994) | 0 | 51 | 1 |
| RGM-1 | U.S. Geological Survey | RGM-1 | Rhyolite from Glass Mountain, Siskiyou County, California (Govindavaju, 1994) | 0 | 41 | 3 |
| SCo-1 | U.S. Geological Survey | SCo-1 | Silty marine shale from the Cody Shale Formation, Natrona County, Wyoming (Govindavaju, 1994) | 0 | 39 | 1 |
| SDC-1 | U.S. Geological Survey | SDC-1 | Mica schist from the Precambrian near Washington D.C. (Govindavaju, 1994) | 0 | 45 | 2 |
| SDO-1 | U.S. Geological Survey | SDO-1 | Oil shale from the Huron Member of the Ohio Shale near Morehead, KY (Kane, and others, 1990) | 0 | 52 | 2 |
| SGR-1 | U.S. Geological Survey | SGR-1 | Shale from the Mahogany zone of the Green River Formation; it is petroleum and carbonate-rich. (Govindavaju, 1994) | 0 | 48 | 3 |

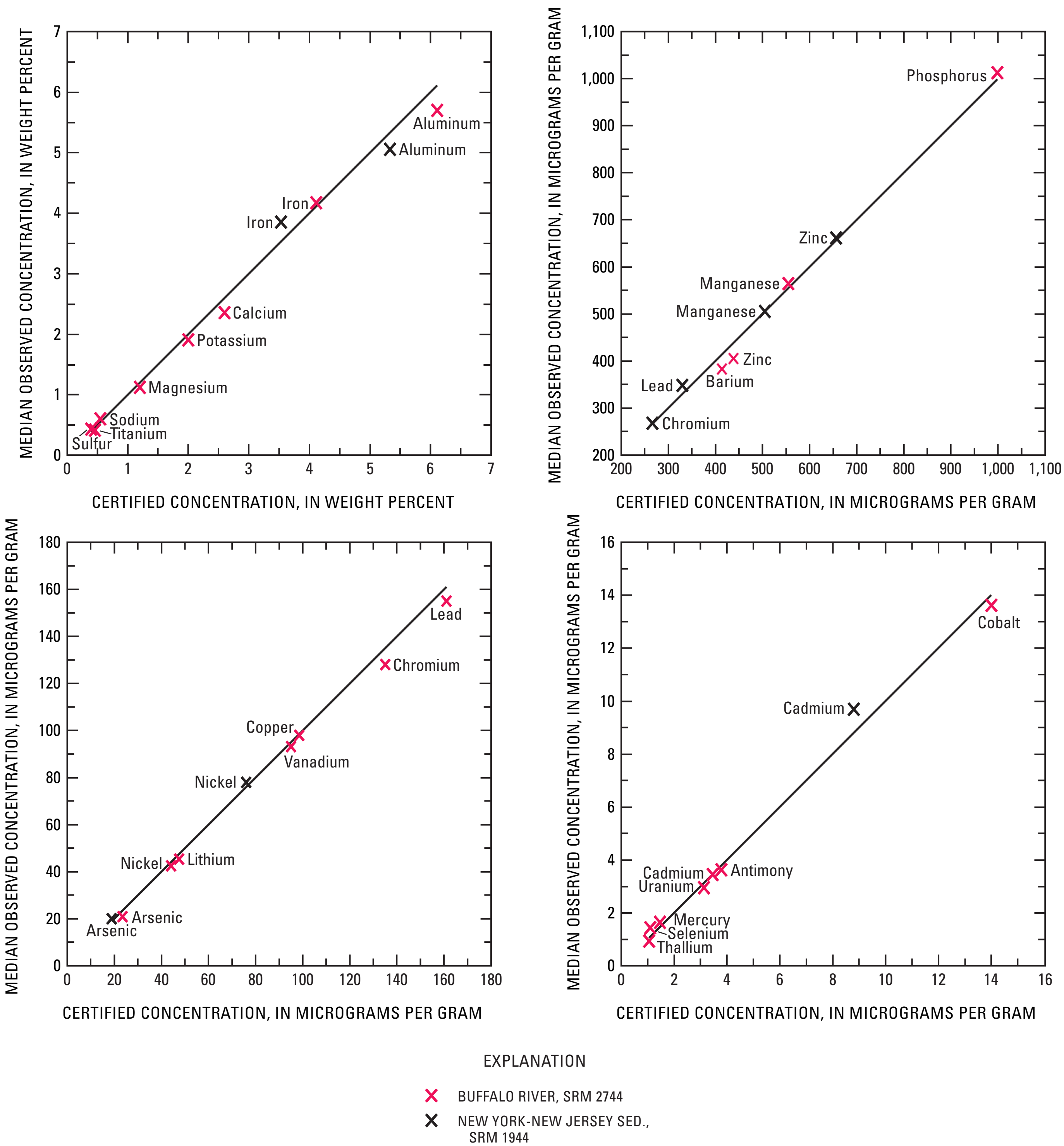


**Figure 8.** Comparison of observed median concentrations and published certified concentrations for Buffalo River and New York-New Jersey Waterway standards.

## Precision of Data

Precision was evaluated in two ways. First, 36 of the individual sediment core samples were randomly selected, redigested, and analyzed to determine the reproducibility of the analyses. Graphs showing correlation plots (fig. 9) demonstrate a good agreement between replicates; $r^2$ values range from 0.541 for lithium to 0.968 for lead. Second, because the standard reference materials were, in general, digested and analyzed many times, examination of these data indicates how reproducible the results were. Among all elemental determinations in the sediment standards, results for each sample pair varied by no more than 7 percent.

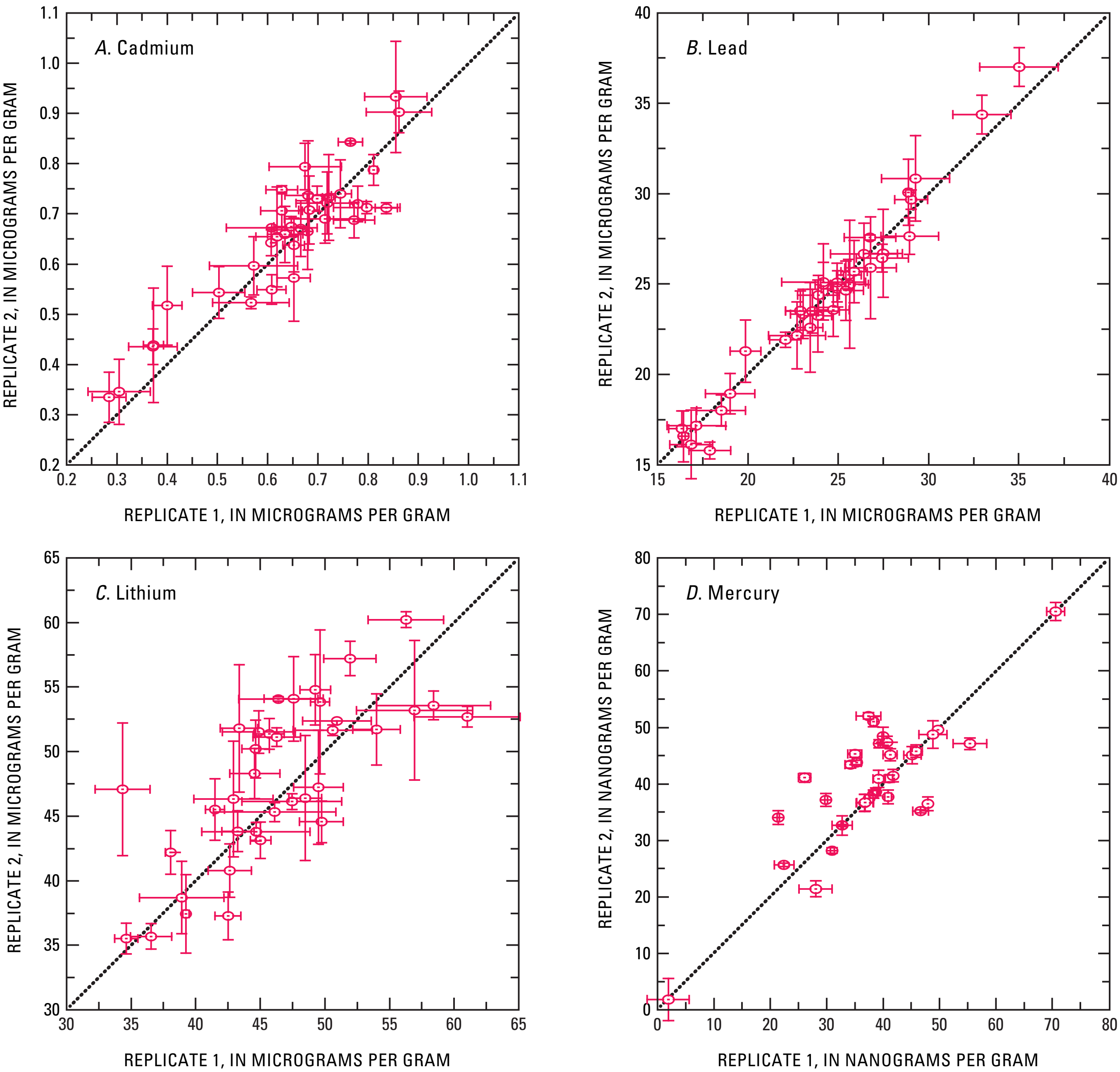


**Figure 9.** Correlation of replicate samples for ***A***, Cadmium; ***B***, Lead; ***C***, Lithium; and ***D***, Mercury.

# Sediment Chemistry, Water Chemistry, and Particle-Size Distribution

Sediment chemistry varied in the cores. Variations in sediment color and texture from visual observations generally correlated with variations in chemical composition (fig. 10).

## Major and Trace Elements

Concentrations of major elements in all the cores and sediment samples were similar to those reported by Mason (1964) for typical sediments (tables 7 and 8 on compact disc). Aluminum ranged from 4.0 weight percent in core 291 to 8.0 weight percent in core 298, iron ranged from 2.1 weight percent in core 298 to 4.0 weight percent in core 281, and calcium ranged from 2.6 weight percent in core 298 to 5.8 weight percent in core 298 (table 7 and fig. 11). For the major elements, there were no discernible trends among the cores.

Trace-element concentrations were strongly dependent on each particular element, ranging from less than 0.001 μg/g for rhenium in all cores to more than 700 μg/g for manganese in core 298 (table 7). Mercury concentrations ranged from less than 2 ng/g to 1,670 ng/g in core 298; uranium concentrations ranged from 3.2 μg/g in core 291 to 4.8 μg/g in core 281; nickel concentrations ranged from 20 μg/g in core 298 to 63 μg/g in core 281; and selenium concentrations ranged from less than 0.8 μg/g in core 281 to 4.3 μg/g in core 298 (table 7).

Concentrations of arsenic, copper, and lead increase from upstream to downstream (core 298 to 281) in the Colorado River channel of the lake (fig. 12). This pattern of increase in a downlake direction was also seen for antimony, bismuth, cadmium, rhenium, and zinc. Most of these elements generally are regarded as contaminants.

Within each core section that was analyzed, there is a large degree of variation in trace-element concentrations (fig. 13), which masks increasing or decreasing trends related to depth. By using a moving average, much of the "noise" is removed, revealing that cadmium concentrations increase with depth in core 291 until about 1,700 mm.

Trace elements that increased in concentration with depth in the cores were antimony, barium, cadmium, lead, manganese, and mercury (table 7). Trace elements that decreased in concentration with depth were beryllium, cesium, chromium, cobalt, lithium, molybdenum, nickel, rubidium, and vanadium.

Trace elements in cores from atomic number 57 (lanthanum) through atomic number 71 (lutetium) had concentrations that ranged from 0.25 μg/g for lutetium to 72 μg/g for cerium (atomic number 58; table 7). Most of these elements showed slight overall increases in concentration between cores in a downstream direction. For example, praseodymium (atomic number 59) had a median concentration of 7.2 μg/g in the upstream core (core 298) and increased in concentration downstream to 7.4 μg/g in core 291 and 7.8 μg/g in core 281.

## Organic Compounds and Radionuclides

Concentrations of all low-level organochlorine pesticides were less than laboratory detection limits (LDL) for all eight composited core sections analyzed, except for p,p'-DDE, which ranged from 0.06 μg/kg to 1.1 μg/kg in the farthest upstream core (core 298; table 9 on compact disc). The higher concentration of p,p'-DDE was detected in the more recently deposited sediments of core 298 (upper section of the core; table 9).

Nineteen parent PAHs and multiple alkyl-PAH isomers were detected at the core sites (table 10 on compact disc). Parent PAHs include:

1. Naphthalene
2. Acenaphthalene
3. Acenaphthene
4. 9H-Fluorene
5. Phenanthrene
6. Anthracene
7. Fluoranthene
8. Pyrene
9. Benz (a) anthracene
10. Chrysene
11. Benzo (b) fluoranthene
12. Benzo (k) fluoranthene
13. Benzo (a) pyrene
14. Benzo (e) pyrene
15. Perylene
16. Indeno (C,D) pyrene
17. Dibenz (A,H) anthracene
18. Benzo (GHI) perylene
19. Coroene

*A*. Core 298

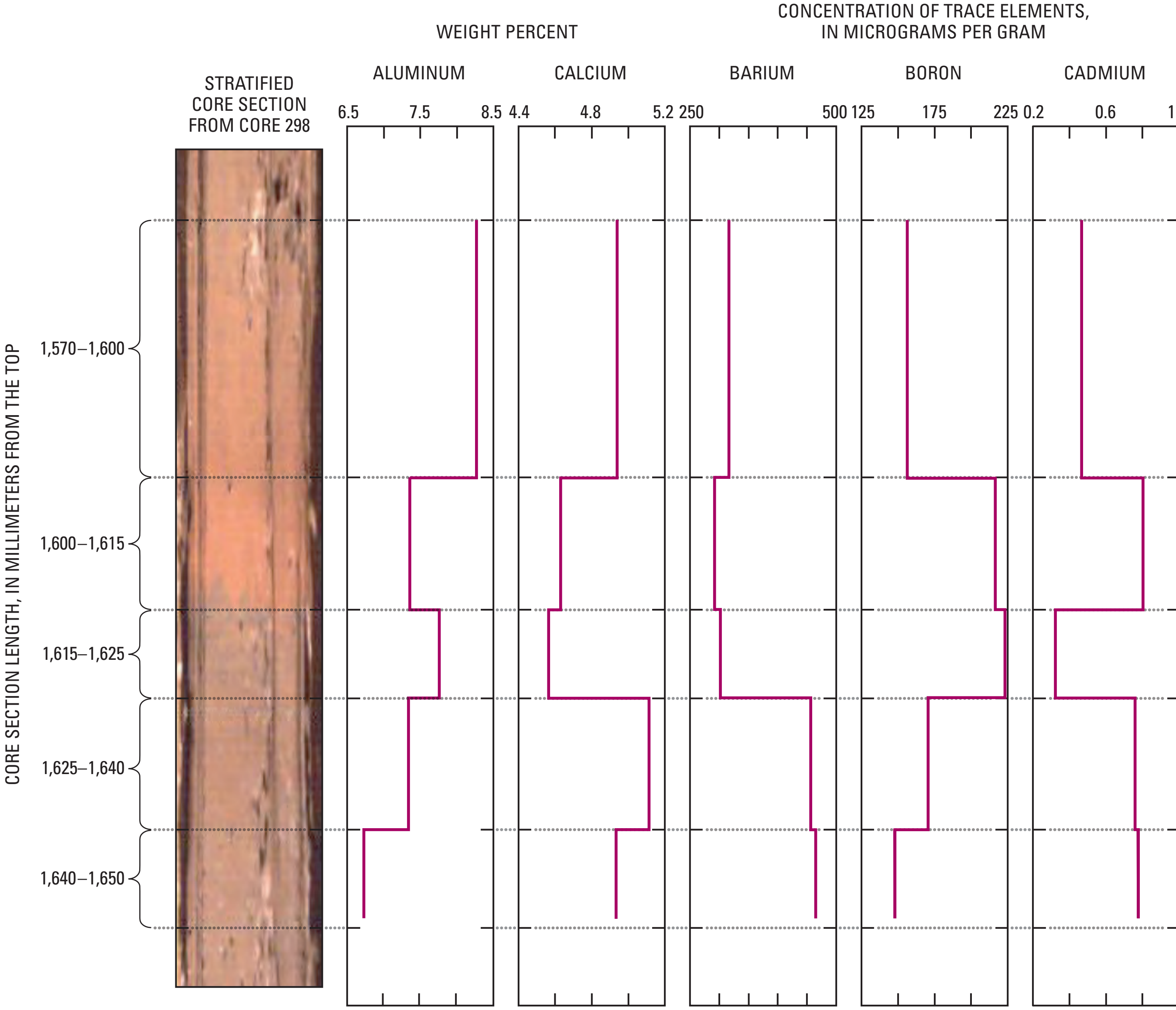


**Figure 10**. Concentrations of selected trace elements, Colorado River delta, Lake Powell, Utah, 2001. ***A***, A section of core 298; ***B***, A section of core 281.

*B*. Core 281

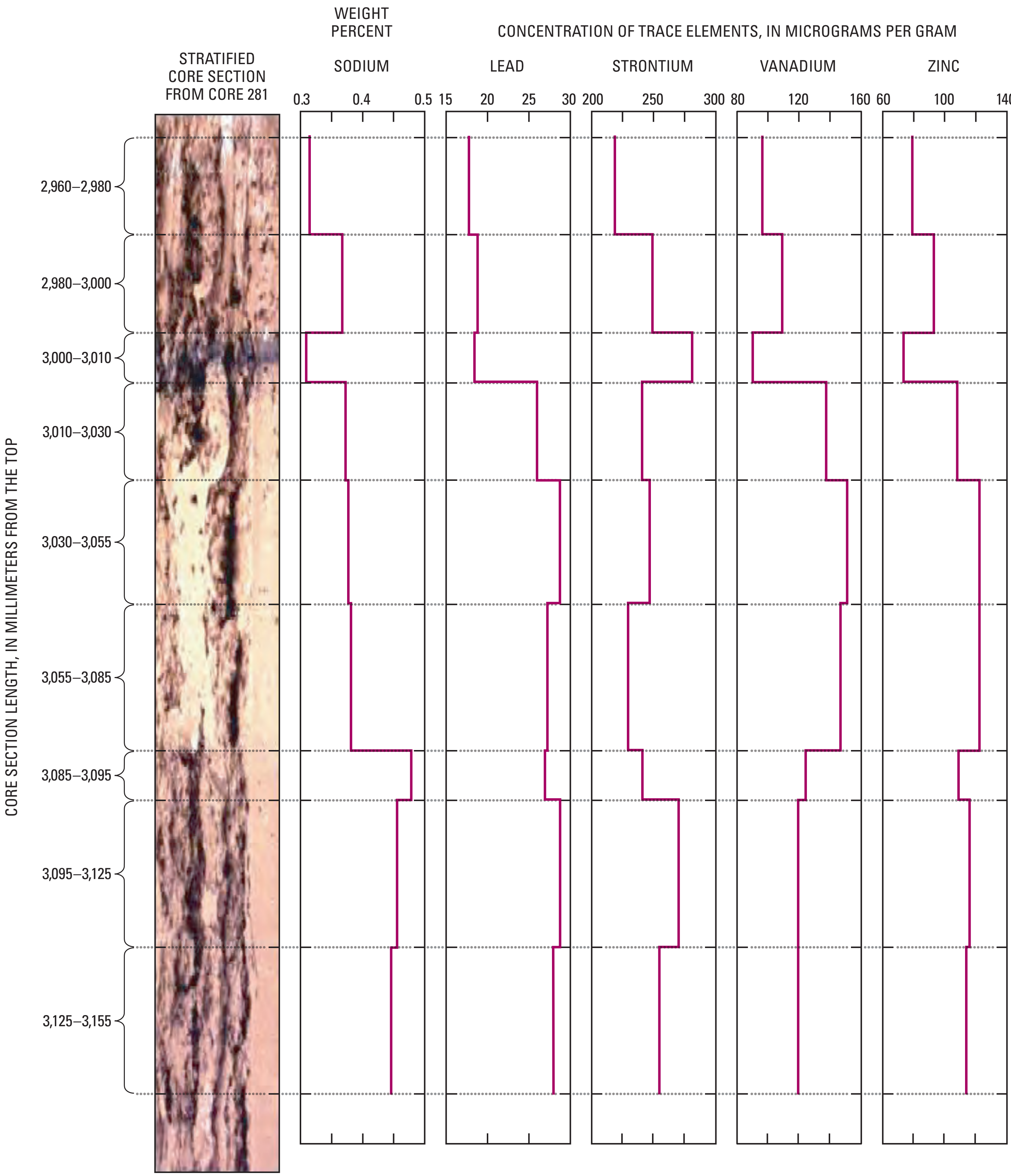


**Figure 10.** Continued.

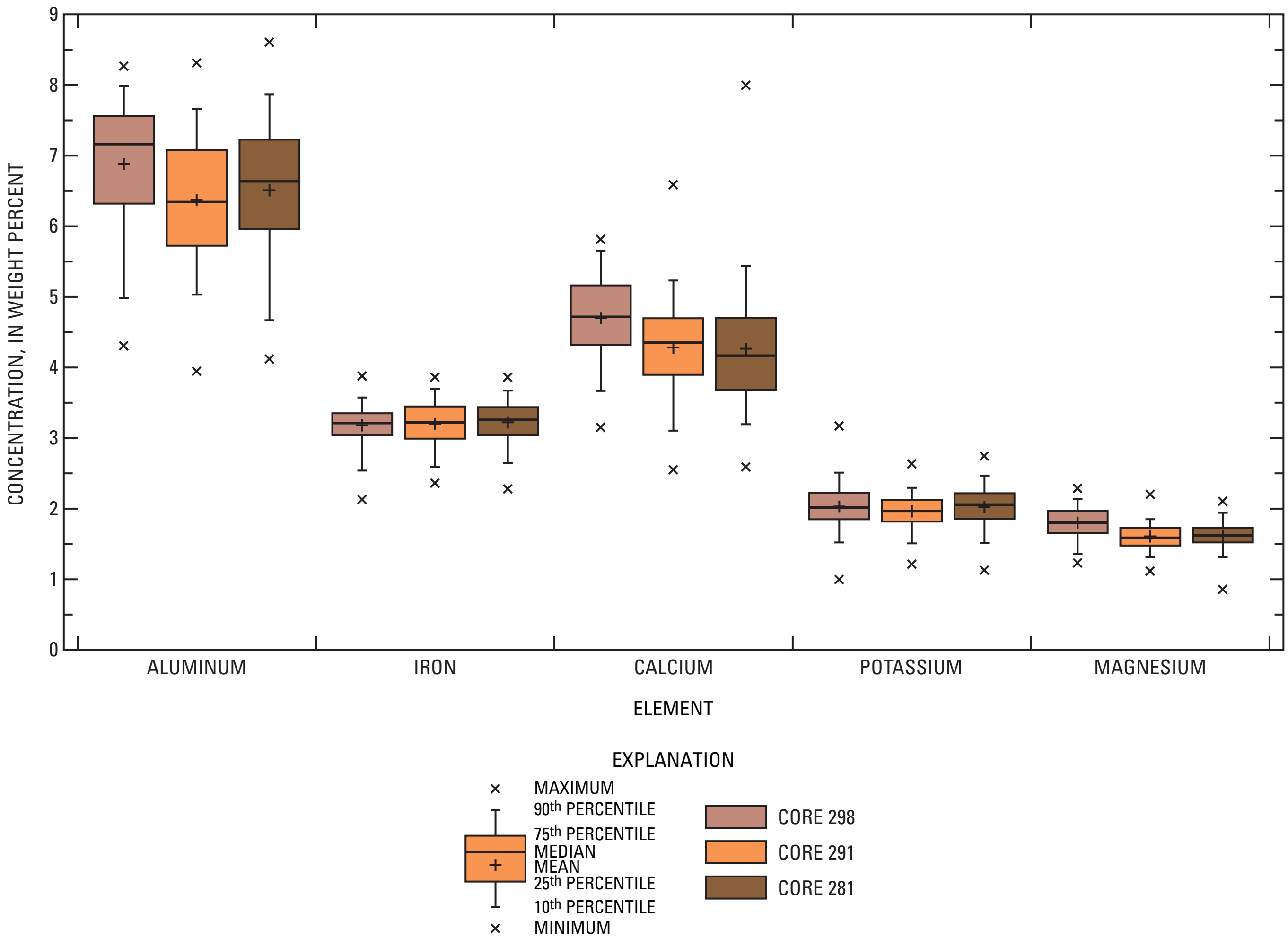


**Figure 11.** Box plots of concentrations of aluminum, iron, calcium, potassium, and magnesium in sections of cores 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001.

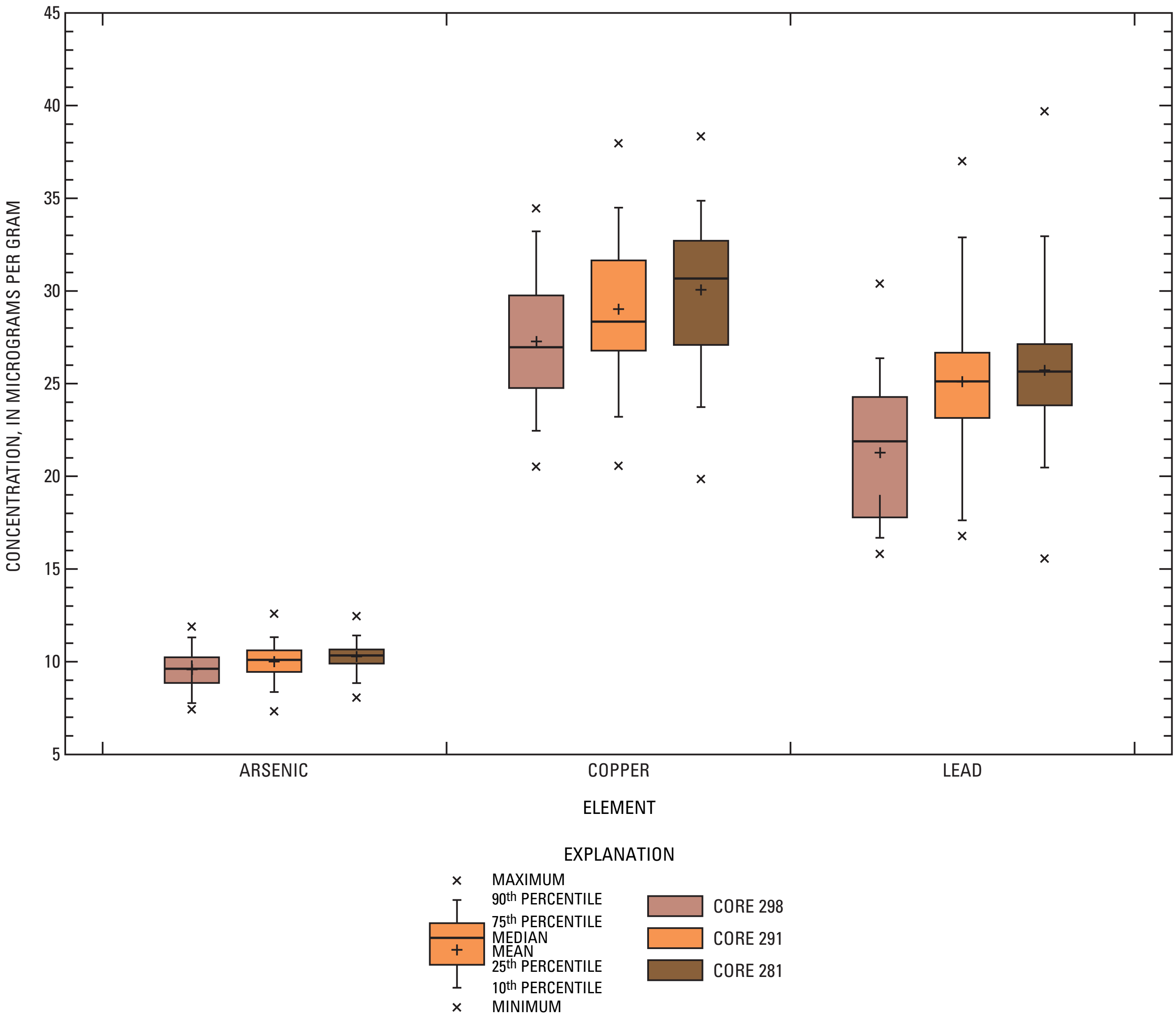


**Figure 12.** Box plots of concentrations of arsenic, copper, and lead in sections of cores 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001.

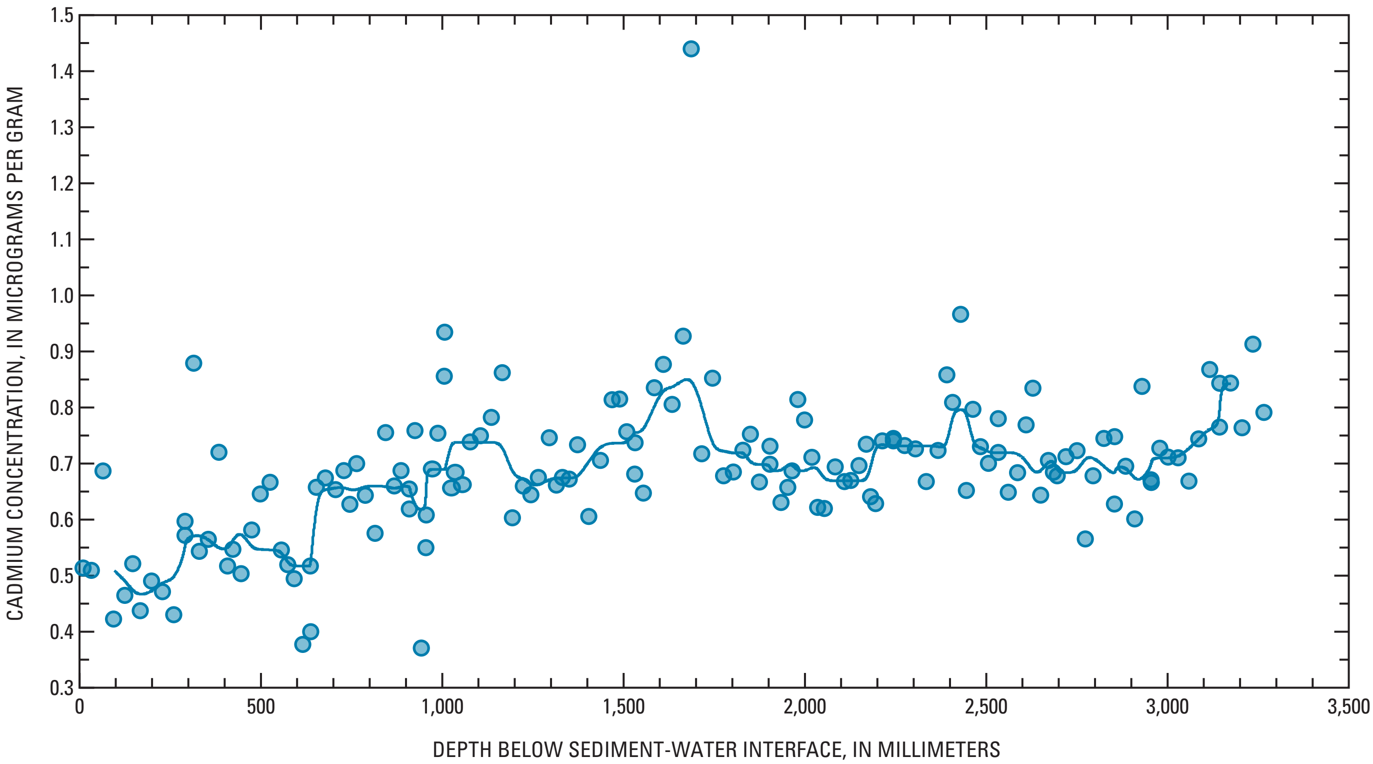


**Figure 13.** Cadmium concentrations in sediment from a section of core 291 and the seven-point moving average (median) curve of the data, Colorado River delta, Lake Powell, Utah, 2001.

Concentrations of naphthalene, for example, ranged from less than 5 µg/kg at core 298 to 28.2 µg/kg at core 291. Concentrations of perylene ranged from 9.5 µg/kg at core 298 to 51.8 µg/kg at core 291; concentrations of benzo(a)pyrene ranged from less than 5 µg/kg at core 298 to 12.3 µg/kg at core 291. Concentrations of many of the PAHs were higher in the deeper layers of the sediment cores than the shallower layers (table 10 on the compact disc).

Gross alpha and gross beta radionuclides were detected in all eight of the composited sections of the sediment cores that were analyzed. Average gross alpha activities ranged from 11pCi/g in core 298 to 17 pCi/g in core 291. Beta particles ranged from 11 pCi/g in core 291 to 18 pCi/g in core 298 (table 11 on compact disc).

## Particle-Size Analyses of Sediment Cores

Surface area of sediment particles has a direct bearing on the physical-chemical behavior of the material (Hem, 1985); therefore, surface area is an important physical property for characterizing delta deposits. Silt and clay fractions have large particle surface areas, which provide a high potential for chemical sorption and exchange. Surface area of sediment also plays an important role in chemical reactions, such as oxidation/reduction, that can release previously insoluble or sequestered constituents into the water column of the reservoir (Forstner, 1981, p. 207). For example, trace elements that may be absorbed to sediment under certain environmental conditions may be solubilized and released into the water column as the sediments are exposed to changing environmental conditions, thus impacting the water quality of the system. Horowitz (1985) reported that there is a strong positive correlation between decreasing grain size and increasing dissolved trace-metal concentrations at other study areas.

The distribution of particle types in sections of the cores varied slightly from site to site (table 12 on compact disc and fig. 14). The predominant particle sizes in each of the core samples were silt and clay; 99 percent of each sample had particle sizes of 0.0625 mm or smaller (fig. 14). Clay made up the bulk of sediment in the cores. Each of the eight composited samples consisted of 43 percent or more particles less than 0.004 mm in diameter (table 12).

## Pore Water and Overlying Sediment-Water Interface Water Analyses

Major and trace elements were analyzed in interstitial pore water and the overlying sediment-water interface water (overlying water; table 13 on compact disc). Organic and radioactive analyses of these samples could not be done owing to budgetary limitations.

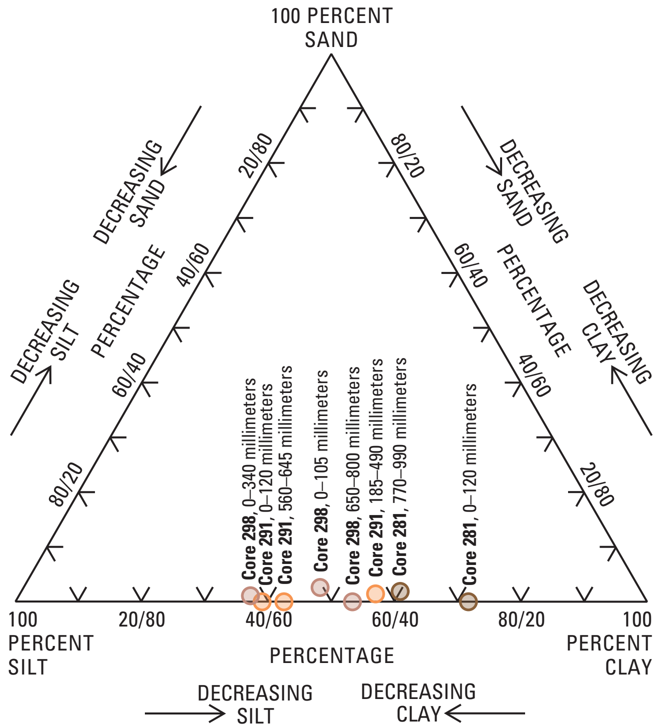


**Figure 14.** Particle-size distribution for eight composited sections of sediment cores 298, 291, and 281, Colorado River delta, Lake Powell, Utah, 2001

The overlying-water samples had higher concentrations of Al, Cd, Ce, Cs, Dy, Er, Eu, Gd, Ho, La, Pb, Lu, Nd, Pr, Sa, Tb, Tm, V, Yb, Y, Zn, and Zr than the pore-water samples. For example, aluminum ranged from 150 to 1,100 µg/L in the overlying-water samples and less than 3 µg/L to 130 µg/L in the pore-water samples (table 13). Several elements, however, had the opposite pattern, in which the pore-water samples contained higher concentrations than the overlying-water samples. These elements included As, Ba, Bi, Ca, Co, Mn, Ni, Ru, Sb, and $SiO_2$ (table 13). Selenium and uranium concentrations tended to be higher in the pore-water samples than in the overlying-water samples (table 13).

# Considerations for Future Studies

Three major rivers, the Colorado, the San Juan, and the Escalante, flow into Lake Powell. These rivers are natural sources of contaminants (trace elements and organic and radioactive compounds) to the lake during surface-water runoff events. Human activities in the watersheds of these rivers and within the lake, including mining, agricultural practices, and recreational boating, also include sources of contaminants to the lake. The lake consists of more than 90 side-canyon tributaries, which contribute suspended sediment to the reservoir. Additional analyses of core sections that were archived from this study could be used to determine the presence of contaminants in these samples.

# Summary

Since 1963, sediment deltas have formed in Lake Powell at the inflow areas of the Colorado, San Juan, and Escalante Rivers. The deltas are temporary repositories for potential contaminants associated with the sediments. Fluctuation of reservoir levels caused by reservoir operations, drought, and runoff, expose delta sediments, which could be resuspended. The potential exists for resolubilization of contaminants into the water column.

During the summer of 2001, the USGS collected three sediment cores from the Colorado River delta and six sediment-water interface samples from selected sites near the Hite marina in southeastern Utah. All sediment samples from the cores were analyzed for inorganic constituents. Composited sediment samples from the cores were analyzed for organic and radioactive compounds, and for particle size. Sediment, pore water, and the overlying water from the six sediment-water interface samples were also analyzed for inorganic chemical constituents. Inorganic constituents included major and trace elements. Organic and radioactive compounds included low-level organochlorine pesticides, PCBs, PAHs, and radionuclides.

Chemical analyses of cores for major elements did not show unusual concentrations for typical delta sediments. Some trace elements, including arsenic, copper, and lead, increased in concentration from upstream to downstream core sites, whereas other elements, including antimony, barium, cadmium, lead, manganese, and mercury, increased in concentration with depth within the cores. Concentrations of mercury ranged from less than 0.2 ng/g to 1,660 ng/g. Some trace elements, including beryllium, cesium, chromium, cobalt, lithium, molybdenum, nickel, rubidium, and vanadium, decreased in concentration with depth within the cores. Many of the low-level organochlorine pesticides were less than the LDL, but 19 parent PAHs were detected in concentrations above the LDL in the deep sediment cores. Many of the PAH concentrations tended to be higher in the deeper layers of the sediment sections than in the shallower layers. Gross alpha and gross beta radionuclide activities ranged between 11 and 18 pCi/g in composited sections of the cores that were analyzed.

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