Sediment-Deposition Rates and Organic Compounds in Bottom Sediment at Four Sites in Lake Mead, Nevada, May 1998

By Kenneth J. Covay *and* David A. Beck

U.S. Department of the Interior

U.S. Geological Survey

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS

Multiply	by	To obtain
centimeter (cm)	0.3937	inch
cubic meter per second (m^3/s)	35.31	cubic foot per second
cubic meter per year (m^3/yr)	0.000811	acre-foot per year
gram (g)	0.03527	ounce
gram per cubic centimeter (g/cm^3)	62.4220	pound per cubic foot
gram per square centimeter per year (g/cm^2)/yr)	0.22757	ounce per square inch per year
hectare (ha)	2.471	acre
kilometer (km)	0.6214	mile
meter (m)	3.281	foot
microgram per kilogram (μg/kg)	1	parts per billion
square kilometer (km^2)	0.3861	square mile

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929, formerly called "Sea-Level Datum of 1929"), which is derived from a general adjustment of the first-order leveling networks of the United States and Canada.

Chemical abbreviations:

[137]Cs (cesium-137)
DDD (dichlorodiphenyldichloroethane)
DDE (dichlorodiphenyldichloroethylene)
DDT (dichlorodiphenyltrichloroethane)
OCs (organochlorine compounds)
OCDD (octochlorodibenzo-p-dioxin)

OCDF (octochlorodibenzofuran)
PAHs (polycyclic aromatic hydrocarbons)
PCBs (polychlorinated biphenyls)
SVOCs (semivolatile organic compounds)
TCDD (tetrachlorodibenzo-p-dioxin)
TCDF (tetrachlorodibenzofuran)

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ABSTRACT

In May 1998 the U.S. Geological Survey, in cooperation with the University of Nevada, Las Vegas, investigated rates of sediment deposition and concentrations of selected synthetic organic compounds at four sites in Lake Mead. Sediment cores were extracted from two sites (one shallow and one deep) in Las Vegas Bay, from one site in the Overton Arm, and from one site near the historic confluence of the Colorado and Virgin Rivers. The sediment cores were age-dated using cesium-137 and were analyzed for the presence of organochlorine compounds (pesticides and degradation products, polychlorinated biphenyls, dioxins, and furans) and for semivolatile organic compounds (polycyclic aromatic hydrocarbons and phenols).

Sediment-deposition rates after impoundment of the Colorado River by Hoover Dam were determined by measuring the accumulation of mass during three different periods: (1) from the approximate impoundment date for each site (1935–37) to the initial occurrence of cesium-137 in the atmosphere (1952); (2) from 1952 to the maximum concentration of cesium-137 in the atmosphere (1964); and (3) from 1964 to the collection date of the sample (1998). Sediment-deposition rates for the entire post-impoundment period (1935–98) averaged 1.45 (g/cm^2)/yr (grams per square centimeter per year) at the Las Vegas Bay shallow site, 1.25 (g/cm^2)/yr at the Las Vegas Bay deep site, 0.80 (g/cm^2)/yr at the Overton Arm site, and 0.65 (g/cm^2)/yr at the Colorado and Virgin Rivers confluence site.

Total numbers of synthetic organic compounds detected in sediment samples were 48 at the Las Vegas Bay shallow site, 57 at the Las Vegas Bay deep site, 26 at the Overton Arm site, and 31 at the Colorado and Virgin Rivers confluence site. The most commonly detected organochlorine pesticide and polychlorinated biphenyl compounds were dichlorodiphenyldichloroethane and dichlorodiphenyldichloroethylene. The most commonly detected dioxin compounds were tetrachlorodibenzo-*p*-dioxin and octochlorodibenzo-*p*-dioxin. The most commonly detected furan compounds were tetrachlorodibenzofuran and octochlorodibenzofuran. The most commonly detected polycyclic aromatic hydrocarbons included perylene, benzo[*g,h,i*]perylene, 2,6-dimethylnaphthalene, and indeno[1,2,3-*c,d*]pyrene. The most commonly detected phenol compound was phenol.

INTRODUCTION

Lake Mead, on the Colorado River in Nevada and Arizona (fig. 1), has been impounded by Hoover Dam since 1935. The lake is the largest reservoir by volume in the United States and is an important source of water for more than 22 million residents of southern Nevada, Arizona, and southern California. Sources of inflow to Lake Mead include the Colorado River, Las Vegas Wash, and the combined flow of the Virgin and Muddy Rivers.
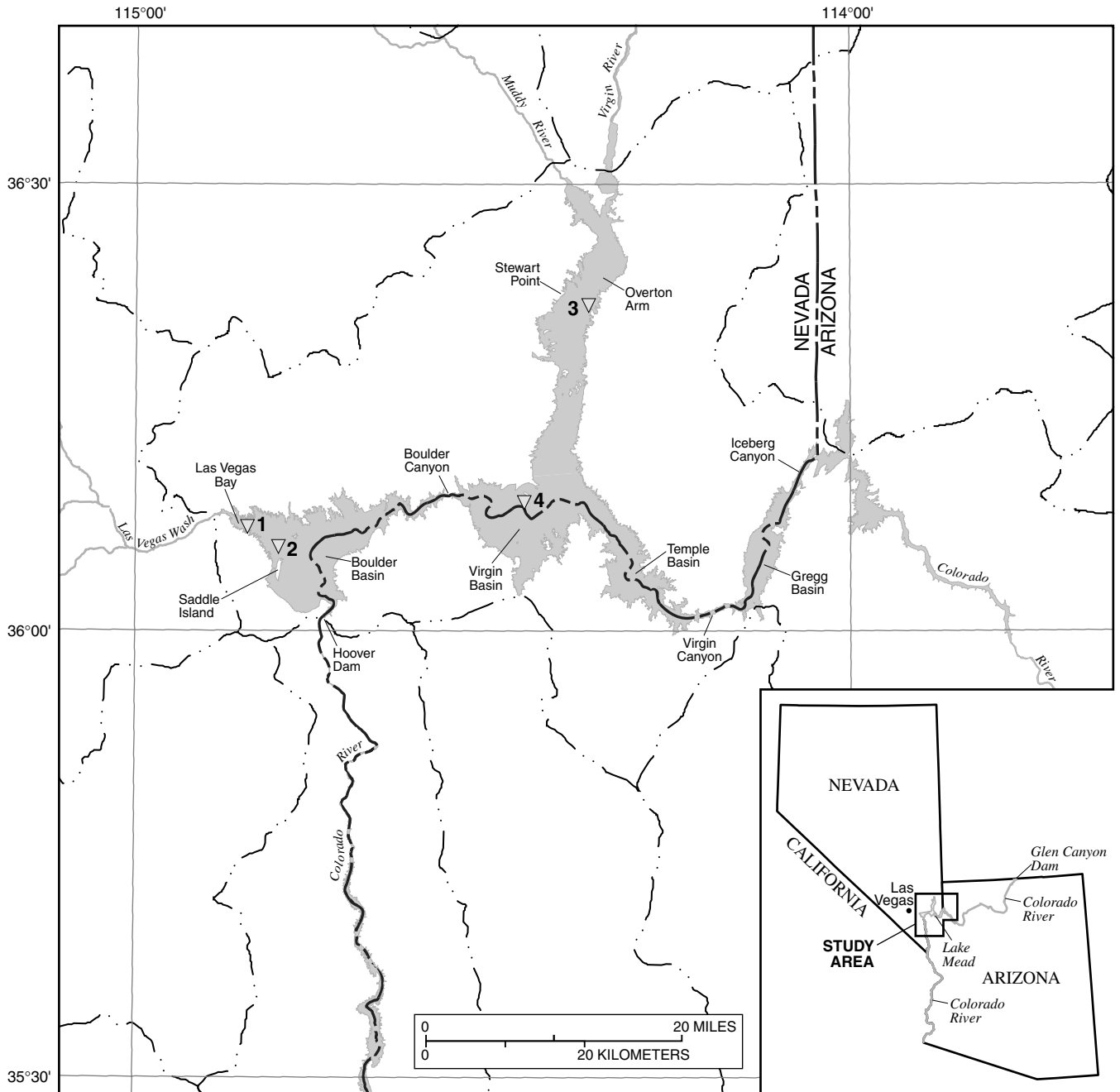
Figure 1. Location of data-collection sites in Lake Mead, Nevada.

EXPLANATION

⎯ ·· ⎯ **Hydrographic-area boundary**

1 ▽   **Data-collection site and number**
        (see table 1 for site names and type
        of data collected)

The Las Vegas area, Nevada, is one of the Nation's fastest-growing urban areas. Urban runoff, industrial drainage, and treated municipal wastewater from the Las Vegas area are transported by Las Vegas Wash to Las Vegas Bay on Lake Mead. Bevans and others (1996) indicated that the discharge from the Las Vegas area probably is a source of organochlorine compounds (OCs) and semivolatile organic compounds (SVOCs) to Las Vegas Wash and Las Vegas Bay on Lake Mead. OCs include organochlorine pesticides and degradation products, polychlorinated biphenyls (PCBs), dioxins, and furans. SVOCs include polycyclic aromatic hydrocarbons (PAHs), phthalates, and phenols. Concentrations of some OCs and SVOCs in the water column, in bottom sediments, or in fish-tissue samples were nearly an order of magnitude larger in Las Vegas Wash and Las Vegas Bay than in an upstream area on Lake Mead (Bevans and others, 1996).

The U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program and the Reconstructed Trends (RT) Study, in cooperation with the Department of Health Physics, University of Nevada, Las Vegas (UNLV), collected bottom-sediment core samples to investigate sediment-deposition rates and historic concentrations of OCs and SVOCs near the major inflows to Lake Mead.

Purpose and Scope

This report presents data on sediment-deposition rates and chemical analyses of samples from bottom-sediment cores collected in May 1998 at four sites in Lake Mead. These sites were selected to provide information on the spatial and temporal characteristics of sedimentation and selected chemical constituents of the lake bottom adjacent to the major contributory inflows. Bottom-sediment cores at site 1 were collected in the delta of Las Vegas Wash where it enters Las Vegas Bay. Cores at site 2 were collected farther out in Las Vegas Bay. Cores at site 3 were collected in the Overton Arm of Lake Mead across from Stewart Point. Cores at site 4 were collected near the pre-impoundment confluence of the Colorado and Virgin Rivers (fig. 1).

Sediment-deposition rates were calculated using the pre-impoundment interface and cesium-137 (^{137}Cs) activities in bottom-sediment core samples at the four sites. The pre-impoundment interface at each

of the four sites occurred between 1935 and 1937. A by-product of nuclear weapons testing, ^{137}Cs first occurred in the atmosphere in about 1952 and peaked in concentration in about 1964 (Van Metre and others, 1996, Van Metre and others, 1997a and 1997b, and Hoffman and Taylor, 1998). Separate sediment-deposition rates are reported for three periods—from the pre-impoundment interface to 1952, from 1952 to 1964, and from 1964 to 1998.

Chemical analyses of bottom-sediment samples collected from Lake Mead during the study included organochlorine pesticides and degradation products, PCBs, dioxins, furans, PAHs, and phenols.

Description of Study Area

Lake Mead is the largest reservoir in the United States by volume and is second largest in terms of surface area (Lara and Sanders, 1970). Its maximum depth is about 180 m and the surface area is about 660 km^2 (Paulson and Baker, 1980). At a maximum lake-surface elevation of 374 m above sea level, the lake extends about 106 km from Hoover Dam up the Colorado River. The maximum width of Lake Mead is about 15 km and its irregular shoreline is about 885 km in length (LaBounty and Horn, 1997). Lake Mead has four major subbasins; Boulder, Virgin, Temple, and Gregg; and three narrow canyons: Boulder, Virgin, and Iceberg (fig. 1).

Depending on release and inflow patterns, the retention time of water in Lake Mead averages 3.9 years (LaBounty and Horn, 1997). The Colorado River contributes about 98 percent of the annual inflow; the remainder is contributed by Las Vegas Wash and by the combined flow of the Virgin and Muddy Rivers (fig. 1). Las Vegas Wash contributes the second highest percentage of inflow to the lake. From 1992 to 1998, the mean daily discharge for Las Vegas Wash was about 5.9 m^3/s (Preissler and others, 1999). Flow in Las Vegas Wash is perennial because of discharge from municipal wastewater treatment plants (Covay and others, 1996) and urban runoff. Discharge of treated wastewater effluent to lower Las Vegas Wash has steadily increased since the 1940s. In 1993, treated wastewater effluent constituted about 96 percent of the annual discharge into Las Vegas Wash (Bevans and others, 1996), which is the likely source of some of the synthetic organic compounds being discharged into

Las Vegas Bay (Covay and Leiker, 1998; Bevans and others, 1996). A complete description of the environmental and hydrologic setting of the Las Vegas area is available in a report by Covay and others (1996).

Lake Mead is classified as mildly mesotrophic (Vollenweider, 1970; Carlson, 1977), based on its moderate nutrient concentrations and biological productivity. The hydrodynamics of Lake Mead are very complex and not well understood. Each basin in Lake Mead responds differently to the inflow-outflow regime and each basin is ecologically unique (La Bounty and Horn, 1997). Annual mean discharge for the Colorado River below Hoover Dam from 1935 to September 1998 was about 394 m^3/s (Preissler and others, 1999). During bottom-sediment core sampling in May 1998, the water-surface elevation of Lake Mead was about 369 m above sea level (U.S. Bureau of Reclamation, 1998).

Acknowledgements

METHODS

Vertical cores of bottom sediments from Lake Mead were collected using a Benthos gravity corer and a Benthos piston corer (each is 4 m long and 6.3 cm in diameter). The corers were deployed from a custom-built pontoon boat (Van Metre and others, 1997a and 1997b). An A-frame and hydraulic winch were used to raise and lower the coring devices. Four cores ranging in length from 48 to 158 cm were taken from site 1. Three cores ranging in length from 111 to 161 cm were taken from site 2. Five cores ranging in length from 70 to 90 cm were taken from site 3. Four cores ranging in length from 65 to 127 cm were taken from site 4. All cores were believed to have penetrated pre-impoundment sediments. The pre-impoundment interface in each core was ascribed to a change in the physical appearance of the sediment, its particle-size composition, or the presence of pre-impoundment soil-surface organic matter. The presence of pre-impoundment sediment ensured that a complete post-impoundment sedimentation record was represented by each core.

The replicate cores collected at each site were used for different physical and chemical analyses. At each site, one core was split lengthwise to reveal its physical characteristics. One extracted core from each site was subsampled to determine wet and dry weights needed to calculate porosity for subsampled intervals. Other cores were extruded vertically and samples were collected for chemical analyses of organochlorine pesticides and PCBs, dioxins, furans, PAHs, phenols, and ^{137}Cs (table 1). Organochlorine pesticides and PCBs were analyzed in organic-solvent extracts using dual capillary-column gas chromatography with dual electron-capture detectors (Wershaw and others, 1987; Foreman and others, 1995). Dioxins and furans were analyzed in organic-solvent extracts using gas chromatography/high-resolution mass spectrometry (U.S. Environmental Protection Agency, 1986). PAHs and phenols were analyzed in organic-solvent extracts using gas chromatography/mass spectrometry (Furlong and others, 1996). ^{137}Cs was analyzed using a high-purity intrinsic germanium detector gamma spectrometer (Dr. Mark J. Rudin, University of Nevada, Las Vegas, Department of Health Physics, oral commun., 1999).

Post-impoundment sediment-deposition rates at each site were calculated by measuring the accumulation of mass from (1) the approximate impoundment date at each site (ranging from 1935 to 1937) to the first occurrence of ^{137}Cs in the atmosphere in 1952; (2) from 1952 to the maximum activity of ^{137}Cs in the atmosphere in 1964, and (3) from 1964 to the collection date of the sample in 1998. Detailed procedures for calculating mass accumulation rates are presented in Van Metre (U.S. Geological Survey, written commun., 1997) and Van Metre and others (1996, 1997a, and 1997b).

SEDIMENT DEPOSITION

Physical Description of Cores

Physical characteristics, determined in the field from one split core from each of the four sites, included water content, particle size, color, and odor (table 2).

Table 1. Index to sediment coring sites and types of samples collected in Lake Mead, May 1998

<u>Site number</u>: Sites are listed in general west-to-east, then north-to-south order.

<u>U.S. Geological Survey Site Identification</u>: The standard site identification is based on the grid system of latitude and longitude. The number consists of 15 digits. The first six denote the degrees, minutes, and seconds of latitude; the next seven denote the degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify the sites within a 1-second grid. For example, site 360713114504601 is at 36°07′13″N latitude and 114°50′46″W longitude, and is the first site recorded in that 1-second grid. The assigned number is retained as a permanent identifier even if a more precise latitude and longitude are determined.

<u>Lake elevation</u>: Water level of Lake Mead at Hoover Dam, in meters above mean sea level, as reported by the U.S. Bureau of Reclamation (1998).

<u>Water Depth</u>: Depth from the water surface to the bottom of the lake, in meters, at the point of sampling.

[Symbols: X, sample collected; —, no sample collected]

Site number (fig. 1)	USGS site identification	Site name	Latitude	Longitude	Sample date (1998)	Lake elevation (meters)	Water depth (meters)	Number of cores	Pesticides and polychlorinated biphenyls	Polycyclic aromatic hydrocarbons	Dioxins and furans	Phenols	Cesium-137
1	360713114504601	Las Vegas Bay—shallow	36°07′08″	114°50′27″	5/12	369	48.8	4	X	X	X	X	X
2	360576114479401	Las Vegas Bay—deep	36°05′45″	114°50′27″	5/11	369	105.2	3	X	X	X	X	X
3	362193114219001	Overton Arm	36°21′56″	114°21′54″	5/13	369	58.5	5	X	X	—	X	X
4	360875114272601	Colorado and Virgin Rivers confluence (pre-impoundment)	36°08′45″	114°27′15″	5/14	369	125.0	4	X	X	X	X	X

Table 2. Physical characteristics of bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviation: cm, centimeter. Symbol: —, not reported]

Characteristics	Site 1: Las Vegas Bay, shallow — length of core below lake bottom (cm)					
	Top 0-15	15–27	27–36	36–100	100–114	Bottom 114–125
Water content	Saturated	Saturated	Medium saturation	Medium saturation	Minimal saturation	Minimal saturation
Particle size	Medium silt-clay mix with fine-grained sand	Medium silt with fine-grained sand	Medium silt with small amounts of fine-grained sand	Medium silt with small amounts of clay	Medium silt	Fine to coarse sand
Color [1]	Pale yellow-brown, olive gray	Olive gray	Grayish black and olive gray	Olive gray	Light olive-brown	Light brown
Odor	—	—	—	—	—	—
Special comments	No benthos or organic debris	No benthos or organic debris	Fine grain sand	Crumbly texture, very homogenous	Stiff silt texture	Pre-impoundment deposition layer at 116 cm

Characteristics	Site 2: Las Vegas Bay, deep — length of core below lake bottom (cm)							
	Top 0–41	41–75	75–105	105–115	115–120	120–130	130–140	Bottom 140–150
Water content	Saturated	Saturated	Medium saturation	Medium saturation	Medium saturation	Medium saturation	Medium saturation	Medium saturation
Particle size	Medium to fine silt	Medium silt, fine clay	Moderate clay, fine silt	Moderate clay, fine silt	Moderate clay, fine silt	Fine to coarse sand	Coarse sand	Coarse sand to gravel
Color [1]	Olive-gray, light brown	Olive-gray	Olive-gray	Olive-gray	Light olive-brown	Light olive-brown	Light olive-brown	Light olive-brown
Odor	—	—	—	—	—	—	—	—
Special comments	No benthos or organic debris	No benthos or organic debris	75-80 cm disturbed during core dissection	Distinct color change from light olive to olive	Fine sand layer, Pre-impoundment deposition layer at 118 cm	—	—	Gravel sizes up to 2 cm in diameter

Characteristics	Site 3: Overton Arm — length of core below lake bottom (cm)						
	Top 0–12	12–19	19–35	35–60	60–70	70–73	Bottom 73–85
Water content	Saturated	Saturated	Medium saturation	Medium saturation	Medium saturation	Minimal saturation	Minimal saturation
Particle size	Medium silt	Medium silt with minimal fine-grained sand	Medium silt with minimal fine-grained sand	Medium silt with minimal fine-grained sand	Medium silt, minimal clay	Clay	Firm clay to medium-coarse sand
Color[1]	Yellow brown	Gray brown and olive gray	Brown	Olive black with brown stripes	Olive gray with brown stripes	Brown	Brown
Odor	—	—	—	—	—	—	—
Special comments	No benthos or organic debris, homogenous texture	*Corbicula fluminea* alive at 18 cm	*Corbicula fluminea* dead at 25 cm	Smooth, homogenous texture, no organic debris	Smooth, homogenous texture	Stiff texture	Pre-impoundment deposition layer at 75 cm

Characteristics	Site 4: Colorado and Virgin Rivers confluence (pre-impoundment) — length of core below lake bottom (cm)						
	Top 0–5	5–16	16–21	21–45	45–70	70–85	Bottom 85–147
Water content	Saturated	Medium saturation	Medium saturation	Minimal saturation	Minimal saturation	Minimal saturation	Minimal saturation
Particle size	Silt with minimal fine sand	Silt	Silt	Silt	Silt	Medium silt, fine sand, clay	Medium to fine sand
Color[1]	Yellowish brown	Yellowish orange with brown stripes	Brown-black with yellowish stripes and olive-black stripes	Gray-black with olive-black stripes and yellowish brown stripes	Olive-gray with brown-gray stripes and yellowish brown stripes	Olive-gray with brown-gray stripes and yellowish brown stripes	Yellow-brown with olive-gray stripes
Odor	—	Medium hydrogen sulfide odor	Minimal hydrogen sulfide odor	Medium hydrogen sulfide odor	Minimal hydrogen sulfide odor	Minimal hydrogen sulfide odor	—
Special comments	Very fluid texture	Soft texture	Smooth texture	No benthos or debris, smooth texture	Smooth texture	Fine sand layer	Pre-impoundment deposition layer at 85 cm

[1] Rock color chart (Geological Society of America, 1991).

All four cores examined were water saturated near the top; however, water content decreased with depth and compaction. Particle sizes of core sediments varied from site to site. The predominant particle sizes near the top of the cores consisted of clay and silt. The sediment in the cores became more coarse with depth, consisting of fine and coarse sand and some gravel near the pre-impoundment surface. The color of the cores are described as blends of yellow, tan, gray, brown, black, and olive. At site 3, live and dead Asiatic clams (*Corbicula fluminea*) were observed. A moderate odor of marsh gas, possibly hydrogen sulfide, was detected at a depth from 5 to 85 cm in the core from site 4. Distinct sediment layers in the cores were readily observed except in zones where clays were disturbed by the core barrel.

Age Dating

Sediment cores from Lake Mead were age-dated by using core depth and observed ^{137}Cs activities (table 3; Van Metre and others, 1997a and 1997b). ^{137}Cs, an anthropogenic by-product of nuclear weapons testing, has a half-life of about 30.1 years. ^{137}Cs first occurred in the atmosphere in about 1952, with peak activities occurring in 1963–64 (Hoffman and Taylor, 1998). ^{137}Cs strongly sorbs to sediments and is a useful tool for age-dating and assessing sediment input to a reservoir or lake from its watershed. Sediment with sorbed ^{137}Cs that enters a reservoir or lake tends to sink and accumulate on the bottom (Krishnaswami and Lal, 1978, p. 153–177; Hoffman and Taylor, 1998).

The cores from Lake Mead are assumed to represent the entire period of deposition from the time impounded water reached the sampling site to the date of collection in 1998. The top of each core (0 cm) was assigned the sampling date. The pre-impoundment interface (from 1935 to 1937 depending on site location) was determined by a change in either the physical appearance of the sediment, its particle-size composition, or the presence of pre-impoundment soil-surface organic matter. Dates corresponding to the first occurrence of ^{137}Cs in the atmosphere (1952) and the peak activity of ^{137}Cs in the atmosphere (about 1964) were determined by evaluating ^{137}Cs activities in the core samples.

Activities of ^{137}Cs (table 3) are plotted against depth in figure 2. Activities and peaks of ^{137}Cs were variable in sediment samples from each site. The ^{137}Cs peaks at sites 1, 2, 3 and 4 were 0.98, 0.76, 0.69, and 0.95 pCi/g, respectively. Many of the ^{137}Cs activities at sites 1 and 4 could not be determined precisely and were reported as non-detected values less than an assigned reporting limit. Site 1 had two identical peaks, one at a depth of about 88 cm and the second at a depth of about 103 cm. The ^{137}Cs peak at a depth of 88 cm was designated as the 1964 peak (Edward Callender and Peter C. Van Metre, U.S. Geological Survey, written commun., 1998) because it was consistent with the ^{137}Cs peak at site 2, which occurred at a depth of about 63 cm. The ^{137}Cs peak at a depth of 103 cm at site 1 was attributed to nuclear testing in 1958 in Nevada (Peter C. Van Metre, U.S. Geological Survey, written commun., 1998). The ^{137}Cs peak at site 3 for 1964 could not be determined with any certainty and was not used to calculate sediment-deposition rates for the periods 1952–64 and 1964–98. The ^{137}Cs peak at site 4 occurred at a depth of about 20 cm. The shallow depth of the ^{137}Cs peak at site 4 could have resulted from the attenuation of peak flows discharging from the Colorado and Virgin Rivers as a result of impoundment of Lake Mead and regulation of the Colorado River above Lake Mead after 1964.

Sediment-Deposition Rates

Sediment-deposition rates (table 4) at each site were calculated using mass-accumulation rates to normalize for compaction. These calculations assume that sedimentation rates probably are constant in terms of mass, and that the density of solids is 2.5 g/cm^3 (Van Metre and others, 1997a and 1997b). In terms of mass, deposition rates probably became more constant after 1964, when Glen Canyon Dam (fig. 1) began to regulate Colorado River inflow to Lake Mead. Porosity values for subsampled intervals in cores from each site were calculated with the wet and dry weight of sediment samples. These values are listed in table 5.

Sediment-deposition rates calculated for sites 1, 2, 3, and 4 from the pre-impoundment interval to 1998 were 1.45, 1.25, 0.80, and 0.65 (g/cm^2)/yr, respectively. The variation of sediment-deposition rates in Lake Mead could be the result of a combination of factors, such as upstream regulation of the Colorado River, rapid urbanization of Las Vegas Valley, rapid episodic erosion in Las Vegas Wash, the complex hydrology of the lake, and, to a lesser extent, urban development in the Virgin–Muddy River Basin.

Table 3. Depth intervals and cesium-137 concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviations: ^{137}Cs, cesium-137; pCi/g, picocuries per gram. Symbol: <, less than]

Site 1: Las Vegas Bay—shallow		Site 2: Las Vegas Bay—deep		Site 3: Overton Arm		Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	
Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)
0–3	<0.17	0–5	<0.11	0–1.5	0.34	0–1	<1.83
3–6	.08	5–10	<.15	1.5–3	.32	1–2	<.49
6–9	<.06	10–15	<.18	3–4.5	.25	2–3	<.49
9–12	<.10	15–20	.08	4.5–6	.33	3–4	<.44
12–15	<.06	20–25	.12	6–7.5	.30	4–5	<.21
15–18	<.06	25–30	.07	7.05–09	<.22	5–6	.18
18–21	<.08	30–35	.15	9–10.5	.30	6–7	.20
21–24	.11	35–40	.40	10.5–12	.30	7–8	.19
24–27	<.05	40–45	.30	12–13.5	.31	8–9	.26
27–30	<.10	45–50	.23	13.5–15	.34	9–10	.29
30–33	<.08	50–55	.26	15–16	.37	10–11	.50
33–36	<.08	55–60	.72	16–17	.41	11–12	.71
36–39	<.12	60–65	.76	17–18	.51	12–13	.66
39–42	<.08	65–70	.31	18–19	.56	13–14	.50
42–45	<.07	70–75	.44	19–20	.58	14–15	.76
45–50	<.12	75–80	.58	20–21	.53	15–16	.74
50–55	.18	80–85	.40	21–22	.30	16–17	.75
55–60	.33	85–90	.17	22–23	.27	17–18	.84
60–65	.24	90–95	.14	23–24	.41	18–19	.70
65–70	.46	95–100	<.13	24–25	.32	19–20	.71
70–75	.25	100–105	<.12	25–26	.35	20–21	.95
75–80	.73	105–110	<.15	26–27	.29	21–22	.86
80–85	.82	110–115	<.10	27–28	.36	22–23	.88
85–90	.98	115–120	<.08	28–29	.46	23–24	.94
90–95	.44	120–125	<.06	29–30	.60	24–25	.64
95-100	.60	125–130	<.05	30–31	.66	25–26	.68
100-105	.98			31–32	.67	26–27	.76
105-110	.78			32–33	.47	27–28	.85
110-115	.29			33–34	.33	28–29	.63
115-120	<.08			34–36	.33	29–30	.52
120-125	.15			36–37	.30	30–31	.37
125-130	.11			37–38	.37	31–32	.47
130-135	<.11			38–39	.39	32–33	.45
				39–40	.60	33–34	.45
				40–41	.48	34–35	.50
				41–42	.30	35–36	.52
				42–43	.33	36–38	.44
				43–44	.40	38–39.5	<.23
				44–45	.49	39.5–41	.38
				45–46	.69	41–42.5	.23
				46–47	.65	42.5–44	<.23
				47–48	.51	44–45.5	.23
				48–49	.45	45.5–47	.24
				49–49.9	<.16	47–48.5	<.24
				49.9–51	<.12	48.5–50	.19
				51–52	<.15	50–51.5	<.24
				52–53	<.22	51.5–53	.18
				53–54	.37	53–54.5	<.22
				54–55	.53	54.5–56	<.15
				55–56	.59	56–57.5	<.22
				56–57	.62	57.5–59	<.15
				57–58	.32	59–60.5	<.16
				58–59	.35	60.5–62	<.29
				59–60	.37	62–64	<.08

Table 3. Depth intervals and cesium-137 concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998—Continued

Site 1: Las Vegas Bay—shallow		Site 2: Las Vegas Bay—deep		Site 3: Overton Arm		Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	
Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)	Depth interval (centimeters)	^{137}Cs (pCi/g)
				60–61.5	0.35	64–66	<0.10
				61.5–63	.35	66–68	<.11
				63–64.5	.39	68–70	<.12
				64.5–66	.33	70–72	<.08
				66–67.5	.56	72–74	<.12
				67.5–69	.68	74–76	<.08
				69–70.5	.33	76–78	<.08
				70.5–72	<.11	78–80	<.09
				72–73.5	<.07	80–82	<.09
				73.5–75	<.08	82–84	<.06
						84–86	<.12
						86–88	<.07
						88–90	<.12
						90–92	<.08
						92–94	<.13
						94–96	<.08
						96–98	<.12
						98–100	<.07
						100–102	<.13
						102–104	<.08
						104–106	<.12
						106–108	<.07
						108–110	<.12
						110–112	<.08
						112–114	<.12
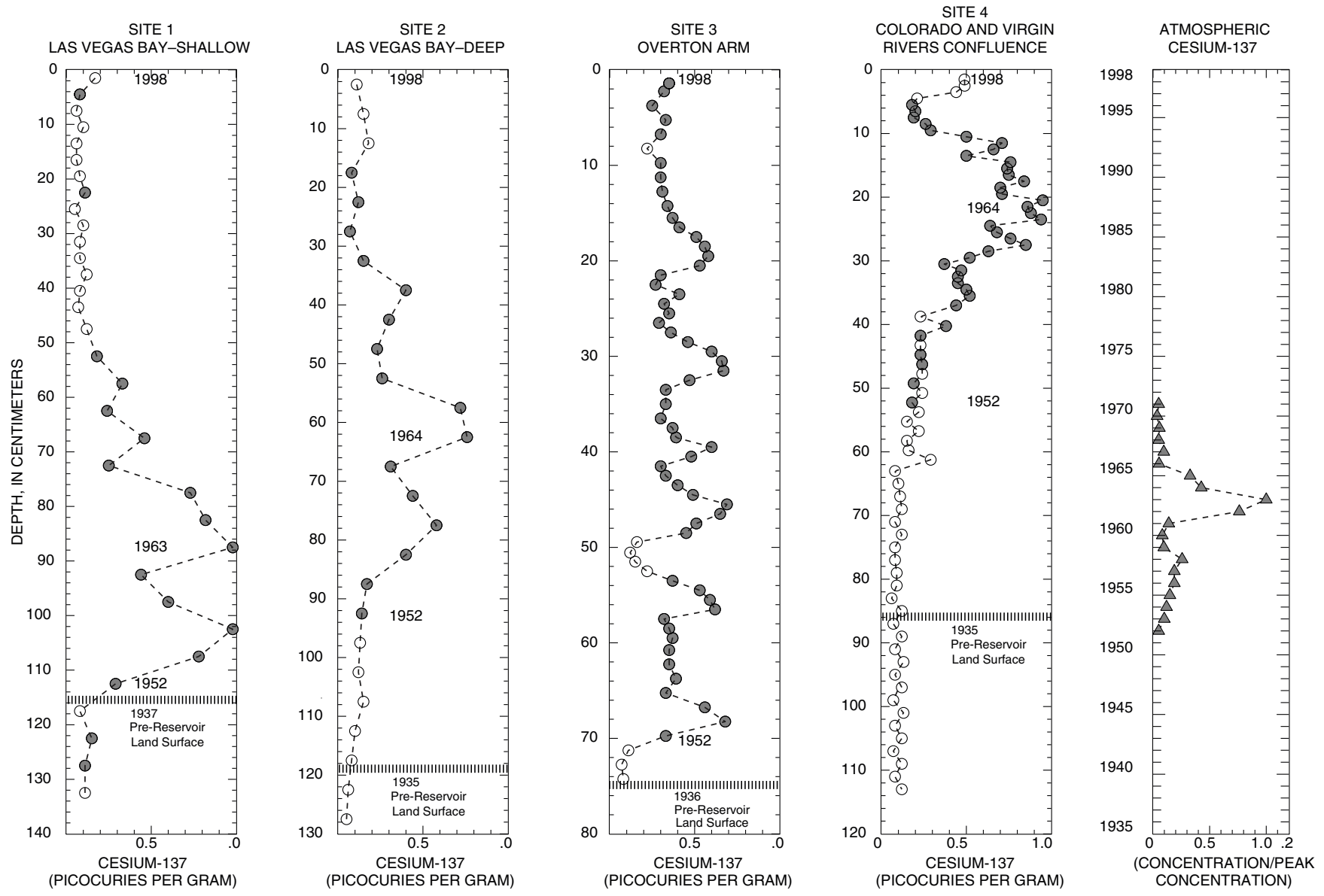
Figure 2. Concentrations of cesium-137 in bottom-sediment cores at four sites in Lake Mead, May 1998, and in the atmosphere, 1952–72. Solid circles represent cesium-137 concentrations. Open circles represent cesium-137 concentrations that are less than the value plotted. Triangles represent atmospheric cesium-137 concentrations divided by the peak concentration.

Table 4. Depth of the pre-impoundment boundary and the 1952 and 1964 cesium-137 peaks, and sediment-deposition rates in bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviations: (g/cm^2)/yr, grams [1] per square centimeter per year; ND, not determined]

Site number	Depth in core (centimeters)			Sediment deposition rates ((g/cm^2)/yr)			
	Pre-impoundment boundary	1952 cesium-137 peak [2]	1964 cesium-137 peak [3]	Pre-impoundment to 1952	1952–64	1964–98	Pre-impoundment to 1998
Site 1: Las Vegas Bay—shallow	[4]116	112.5	87.5	0.41	1.68	1.81	1.45
Site 2: Las Vegas Bay—deep	[5]118	92.5	62.5	1.11	1.44	1.26	1.25
Site 3: Overton Arm	[6]75	69.75	[7]ND	.25	[7]ND	[7]ND	.80
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	[8]85	52.25	20.5	1.03	1.27	.26	.65

[1] Grams in dry weight.
[2] Cesium-137 first appeared in the atmosphere about 1952.
[3] Cesium-137 peaked in the atmosphere about 1963–64.
[4] April 1937.
[5] June 1935.
[6] June 1936.
[7] Not determined because of the many peaks that occur within the core (Jennifer T. Wilson, U.S. Geological Survey, oral commun., 1999).
[8] May 1935.

Table 5. Depth and porosity in bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviation: ND, not determined. Depth is mid-point of an interval]

Site 1: Las Vegas Bay—shallow		Site 2: Las Vegas Bay—deep		Site 3: Overton Arm		Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	
Depth (centimeters)	Porosity	Depth (centimeters)	Porosity	Depth (centimeters)	Porosity	Depth (centimeters)	Porosity
1.5	0.84	2.5	0.79	0.75	0.85	0.5	0.95
4.5	.81	7.5	.79	2.25	.75	1.5	.91
7.5	.78	12.5	.78	3.75	.78	2.5	.92
10.5	.79	17.5	.67	5.25	.77	3.5	.90
13.5	.80	22.5	.69	6.75	.74	4.5	.86
16.5	.74	27.5	.65	8.25	.78	5.5	.83
19.5	.79	32.5	.59	9.75	.75	6.5	.82
22.5	.74	37.5	.64	11.25	.73	7.5	.82
25.5	.71	42.5	.81	12.75	.73	8.5	.82
28.5	.69	47.5	.73	14.25	.73	9.5	.80
31.5	.58	52.5	.73	15.5	.77	10.5	.78
34.5	.63	57.5	.78	16.5	.76	11.5	.76
37.5	.72	62.5	.76	17.5	.71	12.5	.79
40.5	.67	67.5	.78	18.5	.74	13.5	.79
43.5	.71	72.5	.76	19.5	.75	14.5	.80
46.5	.65	77.5	.80	20.5	.76	15.5	.80
52.5	.71	82.5	.79	21.5	.76	16.5	.78
57.5	.71	87.5	.73	22.5	.79	17.5	.78
62.5	.70	92.5	.75	23.5	.75	18.5	.81
67.5	.68	97.5	.75	24.5	.77	19.5	.84
72.5	.72	102.5	.75	25.5	ND	20.5	.82
77.5	.69	107.5	.70	26.5	.72	21.5	.83
82.5	.67	112.5	.70	27.5	.75	22.5	.81
87.5	.69	117.5	.53	28.5	.74	23.5	.79
92.5	.71	122.5	.41	29.5	.75	24.5	.81
97.5	.71	127.5	.38	30.5	.74	25.5	.81
102.5	.68			31.5	.75	26.5	.82
107.5	.66			32.5	.76	27.5	.81
112.5	.55			33.5	.78	28.5	.81
117.5	.49			34.5	.76	29.5	.81
122.5	.50			35.5	.79	30.5	.81
				36.5	.79	31.5	.80
				37.5	.76	32.5	.81
				38.5	.76	33.5	.80
				39.5	.76	34.5	.80
				40.5	.76	35.75	.81
				41.5	.78	37.25	.80
				42.5	.77	38.75	.81
				43.5	.69	40.25	.81
				44.5	.74	41.75	.80
				45.5	.74	43.25	.79
				46.5	.72	44.75	.81

Table 5. Depth and porosity in bottom-sediment cores at four sites in Lake Mead, May 1998—Continued

Site 1: Las Vegas Bay—shallow		Site 2: Las Vegas Bay—deep		Site 3: Overton Arm		Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	
Depth (centimeters)	Porosity	Depth (centimeters)	Porosity	Depth (centimeters)	Porosity	Depth (centimeters)	Porosity
				47.5	0.70	46.25	0.82
				48.5	.72	47.75	.81
				49.5	.71	49.25	.82
				50.5	.63	50.75	.81
				51.5	.62	52.25	.79
				52.5	.66	53.75	.79
				53.5	.71	55.25	.79
				54.5	.74	56.25	.79
						58.25	.79
						59.75	.80
						61.25	.80
						63	.81
						65	.80
						67	.82
						69	.81
						71	.80
						73	.78
						75	.78
						77	.77
						79	.79
						81	.78
						83	.76
						85	.76
						87	.76
						89	.76
						91	.75
						93	.76
						95	.77
						97	.78
						99	.77
						101	.78
						103	.73
						105	.71
						107	.74
						109	.73
						111	.39
						113	.39

Sediment-deposition rates calculated for sites 1, 2, 3, and 4 for the pre-impoundment interval to 1952, when ^{137}Cs first occurred in the atmosphere, were 0.41, 1.11, 0.25, and 1.03 (g/cm^2)/yr, respectively. The variability of these rates could be attributed, in part, to the different date that each site was initially inundated. Inundation dates determined for sites 1, 2, 3, and 4 were April 1937, June 1935, June 1936, and May 1935, respectively.

Sediment-deposition rates for sites 1, 2, and 4 were calculated from 1952 to 1964 and from 1964 to 1998. The ^{137}Cs peak in 1964 coincided with completion of Glen Canyon Dam upstream of Lake Mead (fig. 1). This impoundment of the Colorado River regulated streamflow and reduced the sediment load to Lake Mead. Deposition rates for site 3 from 1952 to 1964 and from 1964 to 1998 were not calculated because the ^{137}Cs peak for 1964 could not be determined with any certainty.

Sediment-deposition rates calculated from 1952 to 1964 at sites 1, 2, and 4 were 1.68, 1.44, and 1.27 (g/cm^2)/yr, respectively. Deposition rates at these three sites from 1964 to 1998 were 1.81, 1.26 and 0.26 (g/cm^2)/yr, respectively. The increased rate of sediment deposition at site 1 likely is the result of increased discharge of treated municipal wastewater effluent and subsequent erosion within lower Las Vegas Wash (P.A. Glancy, U.S. Geological Survey, oral commun., 1998). Sediment-deposition rates at site 2 increased after 1952, but decreased after 1964. This decrease could be the result of higher lake levels and regulation of the Colorado River above Lake Mead after 1964. Sediment-deposition rates at site 4, located near the historic thalweg of the Colorado River, significantly decreased after 1964. This decrease also could be the result of the completion of Glen Canyon Dam, which reduced the sediment load into Lake Mead.

OCCURRENCE OF ORGANIC COMPOUNDS

Sediment-chemistry data indicate that synthetic organic compounds (OCs and SVOCs) were present in Lake Mead sediment samples. OCs include chlorinated pesticides and degradation products, PCBs, dioxins, and furans. PCBs have been used as plasticizers and hydraulic lubricants, in heat-transfer systems, and in electrical capacitors and transformers (Smith and others, 1998). Dioxins and furans were first produced in

the manufacture of herbicides and PCBs. They are formed during municipal waste combustion (Sijm and Opperhuizen, 1996) and commonly are discharged into surface waters by chemical-manufacturing and sewage-treatment plants. SVOCs include PAHs, which originate from anthropogenic and natural sources, and phenols. PAHs mainly are produced by high-temperature reactions such as incineration or fires; however, some are produced commercially for use in pesticides, resins, dyes, cutting fluids, solvents, and lubricants (Smith and others, 1998). Phenols are used to manufacture phenolic resins, herbicides, pharmaceuticals, dyes, plastics, and explosives (Smith and others, 1998).

Concentrations of synthetic organic compounds and their degradation products varied with depth within the sediment cores. Selected synthetic organic compounds, with maximum concentration and depth, for the four sites is listed in table 6.

Dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE) are degradation products of dichlorodiphenyltrichloroethane (DDT), an organochlorine pesticide. DDT was first used as a pesticide in 1939 and usage peaked in the United States in the early 1960's (Van Metre and others, 1997b). It was widely used until about 1970 and was banned in 1972. These compounds are considered toxic, relatively stable in the environment, and very resistant to biodegradation. In addition, these compounds have relatively low solubilities in water and a strong tendency to sorb to particulate matter in water, bed sediment, and soil (Van Metre and Callender, 1997). Concentrations of DDD and DDE in the Lake Mead samples are plotted against depth in figure 3. Concentrations of other pesticides sampled from the four sites either were not detected or were detected at estimated concentrations lower than laboratory reporting limits.

DDD concentrations varied with depth at all four sites. These concentrations were greater at sites 1 and 2 than at sites 3 and 4 (table 7). The maximum DDD concentration at site 1 was 11 µg/kg at a depth range of 30–45 cm; at site 2, 38 µg/kg at a depth range of 20–25 cm; at site 3, <1.5 µg/kg at a depth range of 0–5 cm; and at site 4, 2.0 µg/kg at a depth range of 24–35 cm. The maximum DDD concentrations at sites 1 and 2 occurred in sediment dating between 1964 and 1998, whereas the maximum DDD concentration at site 4 was between 1952 and 1964.

Table 6. Summary of selected synthetic organic compounds, with maximum concentration and depth, in bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviations: cm, centimeters; µg/kg, micrograms per kilogram; pg/g, picograms per gram; NA, not analyzed; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; TCDD, tetrachlorodibenzo-p-dioxin; OCDD, octochlorodibenzo-p-dioxin; TCDF, tetrachlorodibenzofuran; OCDF, octochlorodibenzofuran. Symbols: —, not determined; <, less than; *, estimated (reported when the compound has passed all criteria used to identify its presence and only the concentration is estimated)]

Site	Number of organic compounds detected	Synthetic organic compounds					
		Pesticides and total polychlorinated biphenyls	Maximum concentration (µg/kg)	Depth (cm)	Dioxins	Maximum concentration (pg/g)	Depth (cm)
Site 1: Las Vegas Bay—shallow	48	DDD	11	30–45	TCDD	39	5–10
		DDE	25	30–35	OCDD	93	95–100
Site 2: Las Vegas Bay—deep	57	DDD	38	20–25	TCDD	22	15–20
		DDE	57	20–25	OCDD	44	5–10
Site 3: Overton Arm	26	DDD	<1.5	0–5	TCDD	NA	—
		DDE	1.4	30–35	OCDD	NA	—
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	31	DDD	2.0	24–35	TCDD	<.76	3–6
		DDE	2.3	18–21	OCDD	<11	3–6

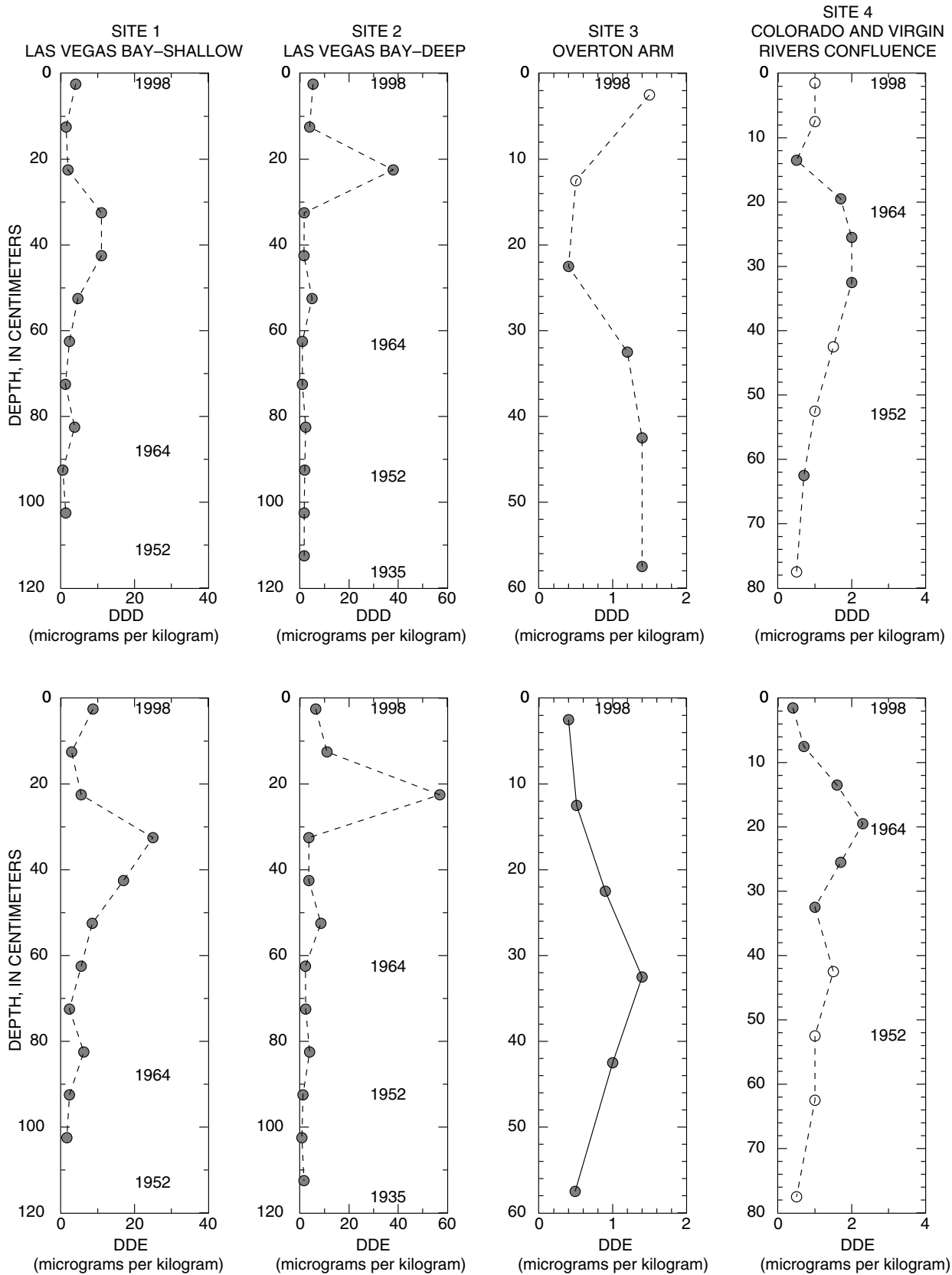| Site	Synthetic organic compounds—Continued								
	Furans	Maximum concentration (pg/g)	Depth (cm)	Polycyclic aromatic hydrocarbons	Maximum concentration (µg/kg))	Depth (cm)	Phenols	Maximum concentration (µg/kg)	Depth (cm)
Site 1: Las Vegas Bay—shallow	TCDF	150	35–40	Benzo[g,h,i]perylene	16.5	30–35	Phenol	*9.8	20–25
	OCDF	110	35–40	2,6-dimethylnaphthalene	81.9	60–65			
				Indeno[1,2,3-c,d]pyrene	15.3	30–35			
				Perylene	*7.6	10–15			
				Pyrene	10.7	10–15			
Site 2: Las Vegas Bay—deep	TCDF	320	15–20	Benzo[g,h,i]perylene	17.4	20–25	Phenol	18.3	80–85
	OCDF	280	25–30	2,6-dimethylnaphthalene	123	60–65			
				Indeno[1,2,3-c,d]pyrene	21.2	80–85			
				Perylene	11.3	80–85			
				Pyrene	8.8	80–85			
Site 3: Overton Arm	TCDF	NA	—	Benzo[g,h,i]perylene	*3.4	0–5	Phenol	*8.2	0–5
	OCDF	NA	—	2,6-dimethylnaphthalene	70.7	30–35			
				Indeno[1,2,3-c,d]pyrene	*3.5	0–5			
				Perylene	197	30–35			
				Pyrene	*3.6	10–15			
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	TCDF	<.89	15–18	Benzo[g,h,i]perylene	*7.6	40–45	Phenol	33	50–55
	OCDF	<4.8	3–6	2,6-dimethylnaphthalene	77.8	18–21			
				Indeno[1,2,3-c,d]pyrene	*5.8	40–45			
				Perylene	259	75–80			
				Pyrene	*5.8	40–45			

Figure 3. Concentrations of DDD and DDE in bottom-sediment cores at four sites in Lake Mead, May 1998. Solid circles represent cesium-137 concentrations. Open circles represent cesium-137 concentrations that are less than the value plotted. Years shown indicate the approximate date of that section of the core.

Table 7. Pesticide and total polychlorinated biphenyl concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998

[Abbreviations: cm, centimeter; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane.

[Symbols: <, less than; *, estimated (reported when the compound has passed all criteria used to identify its presence and only the concentration is estimated). All concentrations are in micrograms per kilogram]

Depth interval (cm)	Aldrin	Chlorodane	DDD	DDE	DDT	Dieldrin	Endosulfan	Endrin
				Site 1: Las Vegas Bay—shallow				
0–5	<0.5	<5.0	4.0	8.7	1.3	<0.5	<0.5	<0.5
10–15	<1.0	<10	1.4	2.9	<1.0	<1.0	<1.0	<1.0
20–25	<1.0	<10	1.9	5.5	*.56	<1.0	<1.0	<1.0
30–35	<.5	<5.0	11	25	.43	<.5	<.5	<.5
40–45	<.5	<5.0	11	17	.40	<.5	<.5	<.5
50–55	<.5	<5.0	4.6	8.5	*.34	<.5	<.5	<.5
60–65	<.5	<5.0	2.3	5.5	*.33	<.5	<.5	<.5
70–75	<.5	<5.0	1.2	2.3	.25	<.5	<.5	<.5
80–85	<.5	<5.0	3.7	6.2	*.40	<.5	<.5	<.5
90–95	<.5	<5.0	.5	2.3	<.50	<.5	<.5	<.5
100–105	<.5	<5.0	1.3	1.6	<.50	<.5	<.5	<.5
				Site 2: Las Vegas Bay—deep				
0–5	<0.5	<5.0	5.3	6.4	<2.6	*0.49	<0.5	<0.5
10–15	<.5	<5.0	3.9	11	2.4	<.6	<.5	<.5
20–25	<.5	5.3	38	57	<2.3	.83	<.5	<.5
30–35	<.5	<5.0	1.7	3.6	<1.3	<.53	<.5	<.5
40–45	<.5	<5.0	1.6	3.6	<.5	<.5	<.5	<.5
50–55	<.5	<5.0	4.9	8.5	<2.8	.61	<.5	<.5
60–65	<.5	<5.0	.94	2.2	<.5	.93	<.5	<.5
70–75	<.5	<5.0	.95	2.3	<.5	<1.1	<.5	<.5
80–85	<.5	<5.0	2.3	3.9	.89	<1.5	<.5	<.5
90–95	<.5	<5.0	1.9	1.2	<.5	<.5	<.5	<.5
100–105	<.5	<5.0	1.7	.74	<.5	<.5	<.5	<.5
110–115	<.5	<5.0	1.7	1.6	<.5	<.5	<.5	<.5
				Site 3: Overton Arm				
0–5	<1.5	<15.0	<1.5	*0.4	<1.5	<1.5	<1.5	<1.5
10–15	<.5	<5.0	<.5	.51	<.5	<.5	<.5	<.5
20–25	<.5	<5.0	*.4	.9	<.5	<.5	<.5	<.5
30–35	<.5	<5.0	1.2	1.4	<.6	<.5	<.5	<.5
40–45	<.5	<5.0	1.4	1.0	<.5	<.5	<.5	<.5
55–60	<.5	<5.0	1.4	*.49	<.5	<.5	<.5	<.5
				Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)				
0–3	<1.0	<10	<1.0	*0.4	<1.0	<1.0	<1.0	<1.0
6–9	<1.0	<10	<1.0	*.7	<1.0	<1.0	<1.0	<1.0
12–15	<.5	<5.0	.5	1.6	<.5	<.5	<.5	<.5
18–21	<1.0	<5.0	1.7	2.3	<1.0	<.8	<1.0	<1.0
24–27	<1.0	<10	2.0	1.7	<1.0	<1.0	<1.0	<1.0
30–35	<1.0	<10	2.0	1.0	<1.0	<1.0	<1.0	<1.0
40–45	<1.5	<15	<1.5	<1.5	<1.5	<1.5	<1.5	<1.5
50–55	<1.0	<10	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
60–65	<1.0	<10	*.7	<1.0	<1.0	<1.0	<1.0	<1.0
75–80	<.5	<5.0	<.5	<.5	<.5	<.5	<.5	<.5

Table 7. Pesticide and total polychlorinated biphenyl concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998—Continued

Depth interval (cm)	Heptachlor	Heptachlorepoxide	Lindane	Methoxychlor	Mirex	Total polychlorinated biphenyls	Toxaphene
			Site 1: Las Vegas Bay—shallow				
0–5	<0.5	<0.5	<0.5	<0.5	<0.5	<11.3	<50
10–15	<1.0	<1.0	<1.0	<1.0	<1.0	<30	<100
20–25	<1.0	<1.0	<1.0	<4.0	<1.0	*9.8	<100
30–35	<.5	<.5	<.5	<.5	<.5	<11.7	<50
40–45	<.5	<.5	<.5	<.5	<.5	<17	<50
50–55	<.5	<.5	<.5	<.5	<.5	*11.8	<50
60–65	<.5	<.5	<.5	<.5	<.5	<13.8	<50
70–75	<.5	<.5	<.5	<.5	<.5	<15	<50
80–85	<.5	<.5	<.5	<.5	<.5	<15	<50
90–95	<.5	<.5	<.5	<.5	<.5	<15	<50
100–105	<.5	<.5	<.5	<.5	<.5	<15	<50
			Site 2: Las Vegas Bay—deep				
0–5	<0.5	<0.5	<0.5	<0.5	<0.5	<15	<50
10–15	<.5	<.5	<.5	<.5	<.5	*8.8	<50
20–25	<.5	<.5	<.5	<.5	<.5	18.2	<50
30–35	<.5	<.5	<.5	<.5	<.5	*10.4	<50
40–45	<.5	<.5	<.5	<.5	<.5	<15	<50
50–55	<.5	<.5	<.5	<.5	<.5	*10.7	<50
60–65	<.5	<.5	<.5	<.5	<.5	<15	<50
70–75	<.5	<.5	<.5	<.5	<.5	<15	<50
80–85	<.5	<.5	<.5	<.5	<.5	<15	<50
90–95	<.5	<.5	<.5	<.5	<.5	<15	<50
100–105	<.5	<.5	<.5	<.5	<.5	<15	<50
110–115	<.5	<.5	<.5	<.5	<.5	<15	<50
			Site 3: Overton Arm				
0–5	<1.5	<1.5	<1.5	<6.0	<1.5	<45	<150
10–15	<.5	<.5	<.5	<.5	<.5	<15	<50
20–25	<.5	<.5	<.5	<2.0	<.5	<15	<50
30–35	<.5	<.5	<.7	<2.5	<.5	<15	<50
40–45	<.5	<.5	<.5	<2.0	<.5	<15	<50
55–60	<.5	<.5	<.5	<.5	<.5	<15	<50
			Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)				
0–3	<1.0	<1.0	<1.0	<1.0	<1.0	<30	<100
6–9	<1.0	<1.0	<1.0	<4.0	<1.0	<30	<100
12–15	<.5	<.5	<.5	<2.0	<.5	<15	<50
18–21	<1.0	<1.0	<1.0	<5.0	<1.0	<15	<100
24–27	<1.0	<1.0	<1.0	<4.0	<1.0	<30	<100
30–35	<1.0	<1.0	<1.0	<4.0	<1.0	<30	<100
40–45	<1.5	<1.5	<1.5	<6.0	<1.5	<45	<150
50–55	<1.0	<1.0	<1.0	<4.0	<1.0	<30	<100
60–65	<1.0	<1.0	<1.0	<4.0	<1.0	<30	<100
75–80	.5	.5	<.5	<2.0	<.5	<15	<50

1

DDE concentrations also varied with depth at all four sites. Concentrations in samples from sites 1 and 2 generally were greater than were concentrations in samples from sites 3 and 4 (table 7). The maximum concentration at site 1 was 25 µg/kg at a depth range of 30–35 cm; at site 2, 57 µg/kg at a depth range of 20–25 cm; at site 3, 1.4 µg/kg at a depth range of 30–35 cm; and at site 4, 2.3 µg/kg at a depth range of 18–21 cm. The maximum concentrations at sites 1 and 2 occurred in sediment dating between 1964 and 1998 and the maximum concentration at site 4 was near the 1964 interface.

Although analyses of total PCBs were available for all four sites, most concentrations either were not detected or were reported as estimated concentrations lower than the laboratory reporting limit. The maximum concentration at site 1 was <30 µg/kg at a depth range of 10–15 cm; at site 2, 18.2 µg/kg at a depth range of 20–25 cm; at site 3, <45 µg/kg at a depth range of 0–5 cm; and at site 4, <45 µg/kg at a depth range of 40–45 cm. Analytical results of chlorinated pesticides and PCBs in cores from the four sites are listed in table 7.

Analyses for dioxins were available only for sites 1, 2, and 4. Concentrations of total tetrachlorodibenzo-p-dioxin (TCDD) varied with depth at all three sites, with greater concentrations occurring near the top of the cores (table 8). Concentrations in samples from sites 1 and 2 were significantly greater than in samples from site 4, in which all concentrations were not-detected values. The maximum concentration at site 1 was 39 pg/g at a depth range of 5–10 cm; at site 2, 22 pg/g at a depth range of 15–20 cm; and at site 4, <0.76 pg/g at a depth range of 3–6 cm. TCDD concentrations were relatively constant at sites 1 and 2 before 1964; however, sometime after 1964, TCDD concentrations began to increase. TCDD concentrations at site 1 continued to increase up to the top of the core. TCDD concentrations at site 2 increased for about half the distance of sediment dating between 1964 and 1998, stabilized, then showed a small decrease at the top of the core. Concentrations of TCDD for the three sites are plotted against depth in figure 4.

Concentrations of octochlorodibenzo-p-dioxin (OCDD) varied with depth at all three sites (table 8). OCDD concentrations in samples from sites 1 and 2 generally were greater than in samples from site 4, in which all concentrations were not-detected values. The maximum concentration at site 1 was 93 pg/g at a depth range of 95–100 cm; at site 2, 44 pg/g at a depth range

of 5–10 cm; and at site 4, <11 pg/g at a depth range of 3–6 cm. The maximum concentration at site 1 occurred in sediment dating between 1952 and 1964, whereas the maximum concentrations at site 2 were at the top of the core. Concentrations of OCDD for sites 1, 2, and 4 are plotted against depth in figure 4.

Analyses for furan compounds were available only for sites 1, 2, and 4. Concentrations of total tetrachlorodibenzofuran (TCDF) generally were constant at sites 1 and 4, but significantly varied with depth at site 2 (table 9). TCDF concentrations generally were greater in samples from sites 1 and 2 than in samples from site 4, in which all concentrations were not-detected values. The maximum TCDF concentration at site 1 was 150 pg/g at a depth range of 35–40 cm; at site 2, 320 pg/g at a depth range of 15–20 cm; and at site 4, <0.89 pg/g at a depth range of 15–18 cm. The maximum TCDF concentrations at sites 1 and 2 occurred in sediment dating between 1964 and 1998. TCDF concentrations for the three sites are plotted against depth in figure 5.

Octochlorodibenzofuran (OCDF) concentrations were fairly constant at sites 1 and 4, but varied near the upper end of the core at site 2 (table 9). OCDF concentrations generally were greater in samples from sites 1 and 2 than in samples from site 4, in which all concentrations were not-detected values. The maximum OCDF concentration at site 1 was 110 pg/g at a depth range of 35–40 cm; at site 2, 280 pg/g at a depth range of 25–30 cm; and at site 4, <4.8 pg/g at a depth range of 3–6 cm. Maximum OCDF concentrations at sites 1 and 2 occurred in sediment dating between 1964 and 1998. OCDF concentrations for the three sites are plotted against depth in figure 5.

Analyses for PAHs were available for all four sites. Concentrations of benzo[g,h,i]perylene were fairly constant at sites 1, 2, and 3, but varied with depth in samples from site 4 (table 10). Benzo[g,h,i]perylene concentrations in samples from sites 1 and 2 generally were greater than in samples from sites 3 and 4, in which all concentrations were non-detected values or were estimated values lower than laboratory reporting limits. The maximum concentration at site 1 was 16.5 µg/kg at a depth range of 30–35 cm; at site 2, 17.4 µg/kg at a depth range of 20–25 cm; at site 3, estimated as 3.4 µg/kg at a depth range of 0–5 cm; and at site 4, estimated as 7.6 µg/kg at a depth range of 40–45 cm. Maximum concentrations at sites 1, 2, and 3 occurred in sediment dating between 1964 and 1998, while the

Table 8. Dioxin concentrations in bottom-sediment cores at three sites in Lake Mead, May 1998

[Abbreviations: TCDD, tetrachlorodibenzo-*p*-dioxin; PeCDD, pentachlorodibenzo-*p*-dioxin; HxCDD, hexachlorodibenzo-*p*-dioxin; HpCDD, heptachlorodibenzo-*p*-dioxin; OCDD, octachlorodibenzo-*p*-dioxin. Symbols: <, less than; *, estimated (reported when the compound has passed all criteria used to identify its presence and only the concentration is estimated). All concentrations are in picograms per gram]

| Depth interval (centimeters)	Total TCDDs	2,3,7,8 TCDD	Total PeCDD	1,2,3,7,8 PeCDD	Total HxCDD	1,2,3,4,7,8 HxCDD	1,2,3,6,7,8 HxCDD	1,2,3,7,8,9 HxCDD	Total HpCDD	1,2,3,4,6,7,8 HpCDD	OCDD
Site 1: Las Vegas Bay—shallow											
5–10	39	<0.88	<5.8	<0.61	<3.4	<0.66	<1.5	<1.1	19	*10	72
15–20	17	<.80	<5.9	<2.4	<1.8	<.50	<.98	<1.2	<4.9	<4.3	34
25–30	13	<.59	<6.1	<2.7	<1.8	<.97	<1.1	<.97	<4.5	<4.5	28
35–40	12	<.38	<3.9	<.86	<2.6	<.56	<1.4	<1.3	5.7	*5.7	20
55–60	5.3	<.66	<2.7	<2.3	<2.0	<1.9	<2.0	<1.8	<2.3	<2.3	*10
75–80	.86	<.62	<1.3	<1.3	<1.8	<1.7	<1.8	<1.6	<1.7	<1.7	*8.6
95–100	1.5	<.55	<2.4	<1.9	<3.4	<1.7	<1.7	<1.6	23	10	93
Site 2: Las Vegas Bay—deep											
5–10	20	<.72	<6.4	<2.5	<3.6	<.98	<1.5	<1.6	7.5	*7.5	44
15–20	22	*.98	5.2	<1.7	9.6	<1.5	<2.7	<3.0	16	9.7	35
25–30	21	*.97	9.6	<1.9	10	<1.4	<3.1	<2.7	17	10	40
35–40	7.5	<.57	<3.8	<1.4	<1.7	<.39	<.96	<1.1	<3.4	<3.4	15
55–60	1.3	<.69	<4.6	<.86	<1.0	<.96	<1.0	<.92	<2.3	<2.3	*12
75–80	2.4	<.51	<5.5	<.86	<1.1	<.86	<.86	<.82	<4.4	<2.8	26
95–100	<.82	<.44	<5.5	<.55	<.89	<.86	<.89	<.82	<.99	<.61	<2.5
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)											
3–6	<.76	<.76	<2.0	<1.6	<1.6	<1.5	<1.6	<1.5	<1.8	<1.5	<11
9–12	<.69	<.69	<1.8	<1.7	<1.5	<1.5	<1.5	<1.4	<1.0	<1.0	<3.6
15–18	<.58	<.58	<1.7	<1.7	<1.3	<1.3	<1.3	<1.2	<1.2	<1.2	<5.8
21–24	<.52	<.52	<2.4	<2.4	<1.8	<1.8	<1.8	<1.6	<1.4	<1.4	<9.8
45–50	<.66	<.66	<2.2	<1.8	<1.7	<1.5	<1.7	<1.5	<1.0	<1.0	<3.2
65–70	<.64	<.61	<2.5	<1.7	<1.6	<1.5	<1.6	<1.5	<1.4	<1.4	<5.8
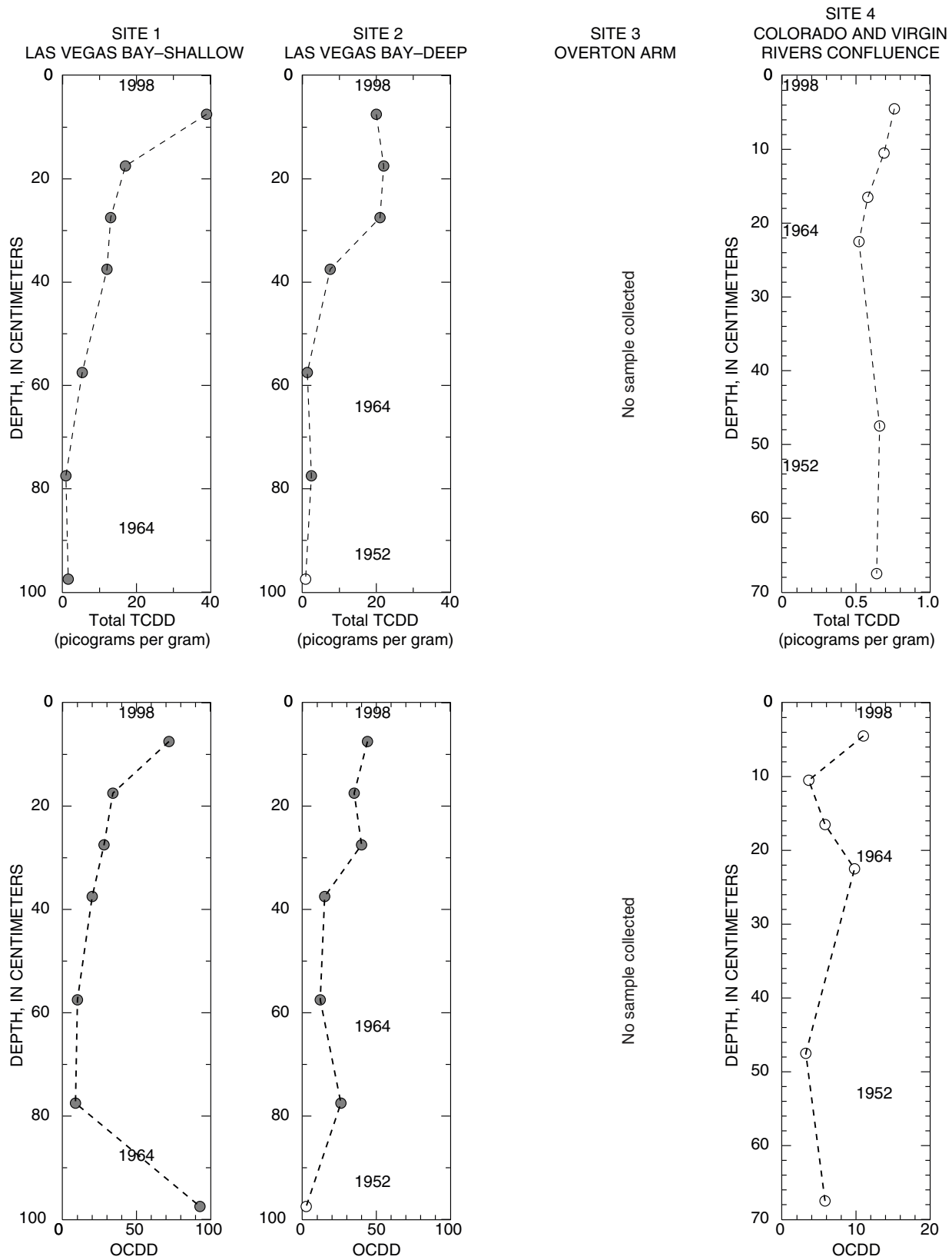
Figure 4. Concentrations of total TCDD and OCDD in bottom-sediment cores at three sites in Lake Mead, May 1998. Solid circles represent cesium-137 concentrations. Open circles represent cesium-137 concentrations that are less than the value plotted. Years shown indicate the approximate date of that section of the core.

Table 9. Furan concentrations in bottom-sediment cores at three sites in Lake Mead, May 1998

[Abbreviations: TCDF, tetrachlorodibenzofuran; PeCDF, pentachlorodibenzofuran; HxCDF, hexachlorodibenzofuran; HpCDF, heptachloro-dibenzofuran; OCDF, octachlorodibenzofuran. Symbols: <, less than; *, estimated (reported when the compound has passed all criteria used to identify its presence and only the concentration is estimated). All concentrations are in picograms per gram]

Depth interval (centimeters)	Total TCDF	2,3,7,8 TCDF	Total PeCDF	1,2,3,7,8 PeCDF	2,3,4,7,8 PeCDF	Total HxCDF	1,2,3,4,7,8 HxCDF
Site 1: Las Vegas Bay—shallow							
5–10	85	4.5	54	*10	<4.7	46	15
15–20	86	5.3	36	*8.2	<4.1	19	*10
25–30	110	6.1	44	*9.5	<4.5	33	*11
35–40	150	9.0	100	15	*7.5	72	20
55–60	92	5.4	28	*7.9	<3.6	20	*8.4
75–80	32	2.1	7.4	<3.3	<1.2	8.2	*4.1
95–100	48	2.8	49	*8.0	<3.4	48	13
Site 2: Las Vegas Bay—deep							
5–10	97	6.8	64	*12	<5.8	50	17
15–20	320	20	220	27	13	180	41
25–30	260	16	220	25	13	190	42
35–40	85	5.4	62	9.5	*4.5	28	12
55–60	41	3.0	9.7	<3.7	<2.2	<4.3	<4.5
75–80	36	*2.1	17	<3.4	<1.7	<4.4	<4.4
95–100	19	*1.3	<5.2	<1.8	<1.2	<1.8	<1.8
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)							
3–6	<.76	<.76	<1.6	<1.6	<1.6	<.66	<.59
9–12	<.72	<.72	<1.1	<1.1	<1.1	<.65	<.56
15–18	<.89	<.33	<1.5	<1.5	<1.5	<.73	<.58
21–24	<.74	<.74	<2.1	<2.1	<2.1	<.96	<.85
45–50	<.55	<.55	<.60	<.60	<.60	<.69	<.60
65–70	<.64	<.64	<1.5	<1.4	<1.5	<.67	<.58

| Depth interval (centimeters)	1,2,3,6,7,8 HxCDF	2,3,4,6,7,8 HxCDF	1,2,3,7,8,9 HxCDF	Total HpCDF	1,2,3,4,6,7,8 HpCDF	1,2,3,4,7,8,9 HpCDF	OCDF
Site 1: Las Vegas Bay—shallow—Continued							
5–10	*9.2	<2.2	<2.2	60	29	*11	100
15–20	<5.9	<1.7	<1.6	30	16	*6.7	58
25–30	*6.9	<1.5	<1.6	35	19	*8.2	66
35–40	12	<3.3	<2.3	66	31	15	110
55–60	<4.4	<1.5	<1.2	20	13	*6.9	44
75–80	<2.5	<.87	<1.6	8.0	*8.0	<2.8	23
95–100	*8.8	<2.2	<2.1	65	32	11	90
Site 2: Las Vegas Bay—deep—Continued							
5–10	*9.6	<2.0	<2.1	60	28	*13	100
15–20	24	*5.9	*4.5	150	72	31	260
25–30	24	*6.4	*4.4	150	69	32	280
35–40	*6.4	<1.4	<1.4	39	19	7.8	67
55–60	<2.9	<.73	<.63	7.6	*7.6	<2.5	23
75–80	<2.7	<1.1	<.80	13	*7.8	<2.8	26
95–100	<1.3	<.38	<.30	<3.8	<3.8	<1.6	*11
Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)—Continued							
3–6	<.64	<.57	<.66	<1.8	<1.6	<1.8	<4.8
9–12	<.63	<.58	<.65	<.85	<.85	<.43	<.74
15–18	<.63	<.61	<.73	<.65	<.47	<.65	<.89
21–24	<.90	<.79	<.96	<.68	<.68	<.68	<2.4
45–50	<.66	<.58	<.69	<.52	<.38	<.52	<1.5
65–70	<.64	<.55	<.67	<.70	<.46	<.70	<1.3
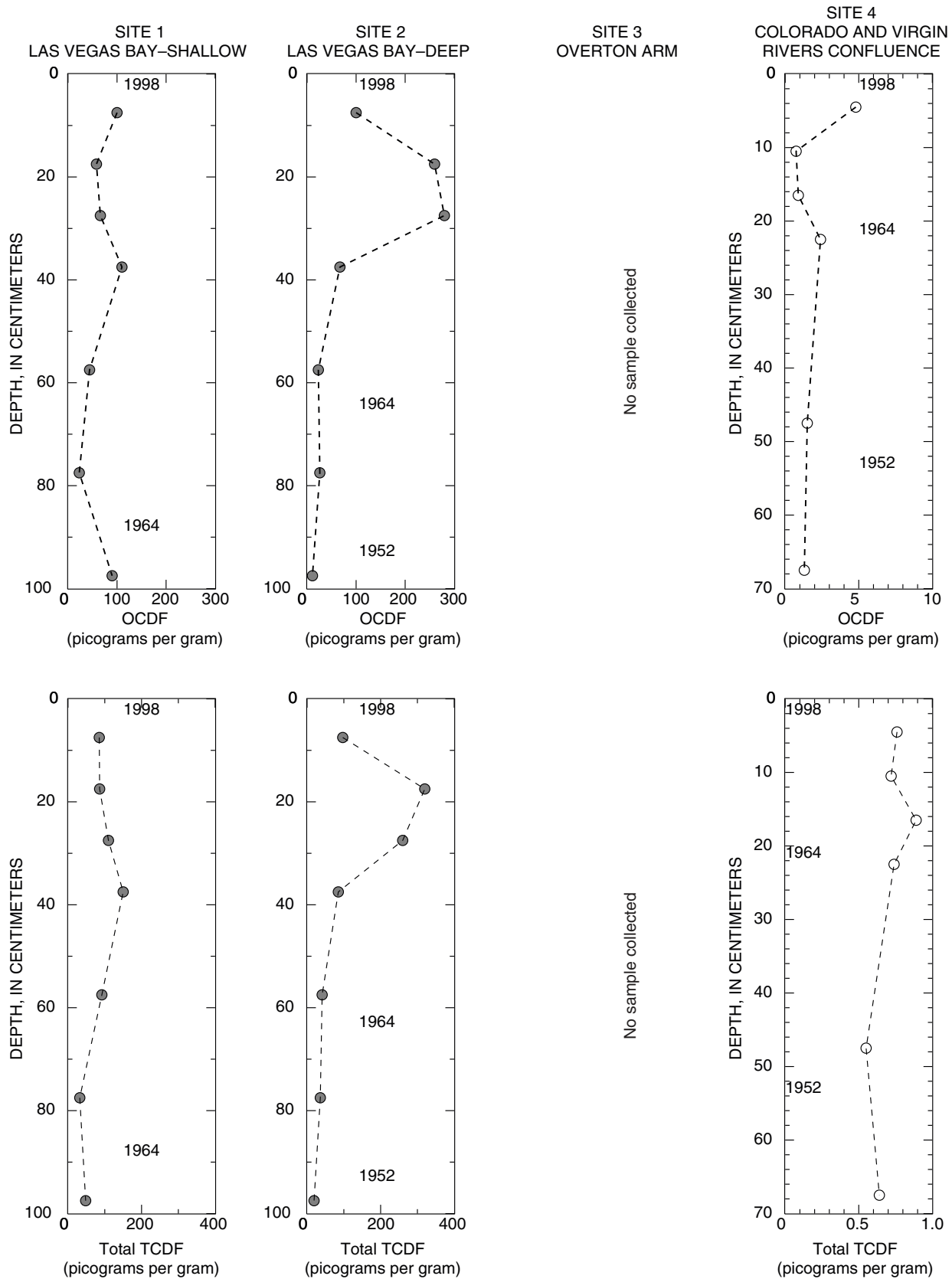
Figure 5. Concentrations of OCDF and total TCDF in bottom-sediment cores at three sites in Lake Mead, May 1998. Solid circles represent cesium-137 concentrations. Open circles represent cesium-137 concentrations that are less than the value plotted. Years shown indicate the approximate date of that section of the core.

Table 10. Polycyclic aromatic hydrocarbon and phenol concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998

[Symbols: <, less than; *, estimated (reported when the compound has passed all criteria used to identify its presence and only the concentration is estimated). All concentrations are in micrograms per kilogram]

Site 1: Las Vegas Bay—shallow	Depth interval (centimeters)										
	0–5	10–15	20–25	30–35	40–45	50–55	60–65	70–75	80–85	90–95	100–105
Acenapthalene	*3.0	*5.0	*3.4	*2.6	*2.3	*2.4	*3.7	*1.7	*3.0	*2.5	*2.6
Anthracene	*3.6	*5.2	*4.4	*3.5	*3.8	*3.0	*3.9	*2.4	*3.9	*3.3	*2.0
Benzo[a]anthracene	*3.5	*5.1	*4.2	*3.2	*3.9	*2.9	*3.7	*2.7	*3.7	*3.4	*2.9
Benzo[b]fluoranthene	*7.7	*6.6	*6.8	7.4	7.7	*4.9	*8.1	*4.2	7.0	8.9	5.2
Benzo[k]fluoranthene	*6.7	*7.6	*6.3	6.4	6.0	*4.2	*6.2	*3.4	5.9	7.5	*3.9
Benzo[a]pyrene	*5.4	*7.1	*5.5	5.2	5.7	*4.1	*5.3	*3.4	6.6	7.0	7.0
Benzo[e]pyrene	*8.9	*9.3	*8.0	9.9	9.7	6.1	*8.3	*4.3	9.0	10.6	6.6
Benzo[g,h,i]perylene	12.7	11.4	12.8	16.5	13.8	9.2	13	7.3	13.8	12	6.2
Chrysene	*5.9	*5.8	*5.2	6	7.3	*4.2	*5.2	*3.8	5.3	5.1	*4.2
Coronene	*4.1	*4.4	*4.7	6.4	*5.0	*3.9	*4.5	*3.1	*5.0	*3.3	*2.2
p-Cresol[1]	*4.3	*7.0	*6.1	*2.5	*3.0	*3.3	*5.0	*2.4	*3.8	*3.5	*2.5
Dibenzo[a,h]anthracene	*2.7	*3.6	*3.0	*2.6	*2.4	*2.1	*2.8	*1.7	*2.8	*2.9	*1.8
1,6-dimethylnaphthalene	*4.5	*6.0	*5.7	*2.1	*3.0	*3.0	11.6	*4.3	6.8	5.2	*2.1
2,6-dimethylnaphthalene	42.2	38.5	52.6	11.1	10.4	21.2	81.9	25.6	57.1	39.6	6.4
2-ethylnaphthalene	*2.3	*3.7	*2.9	*1.9	*1.6	*1.8	*2.4	*1.5	*2.1	*1.7	*1.2
Fluoranthene	*6.9	10.2	*7.4	6.2	6.7	5.1	*6.1	*3.8	5.3	*4.2	*4.8
9-H-fluorene	*.61	*1.1	*.91	*.71	*.73	*.45	*.57	*.31	*.48	<5	*.41
Indeno[1,2,3-c,d]pyrene	13.2	12.2	13	15.3	14.4	9.9	12.3	6.5	14.6	12.8	6.6
1-methyl-9H-fluorene	*2.4	<10	*3.6	<5	*1.7	*1.5	<10	<5	<5	<5	<5
2-methylanthracene	<10	<10	<10	*1.7	*1.9	<5	<10	<5	*2.1	<5	<5
1-methylphenanthrene	<10	11	<10	*1.9	*1.9	*1.7	<10	*1.6	*2.3	<5	<5
4,5-methylenephenanthrene	*2.5	*4.1	<10	*2.0	*2.0	*1.8	*2.4	*1.6	*2.1	*2.0	*2.0
Methylpyrene	*2.3	*4.0	*3.0	*1.8	*1.6	*1.9	<10	*1.5	*2.1	*1.9	*1.5
Perylene	*6.7	*7.6	*6.3	6.4	6	*4.2	*6.2	*3.4	5.9	7.5	*3.9
Phenanthrene	*3.9	*5.0	*5.1	*3.9	*4.2	*3.1	*3.6	*2.3	*3.4	*2.8	*2.1
Phenol[1]	*7.0	*8.2	*9.8	*4.3	5.3	*4.6	*5.8	*4.2	5.6	*4.0	5.1
Pyrene	*7.7	10.7	*8.3	7.4	8	5.4	*7.2	*4.4	6.5	6.4	7.2
2,3,6-trimethylnaphthalene	<10	<10	<10	<5	*1.6	*1.9	<10	<5	*2.0	*2.1	<5

Table 10. Polycyclic aromatic hydrocarbon and phenol concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998—Continued

Site 2: Las Vegas Bay—deep	Depth interval (centimeters)											
	0–5	10–15	20–25	30–35	40–45	50–55	60–65	70–75	80–85	90–95	100–105	110–115
Acenaphthene	<5	<5	<5	*1.0	<5	<5	<5	<5	<5	<5	<5	<5
Acenaphthylene	*2.0	*3.1	*3.4	*4.7	*2.3	*2.2	<5	*2.6	*4.0	*1.5	*1.6	*2.5
Anthracene	*2.9	*3.1	*4.3	*4.4	*2.6	*3.3	*3.5	*4.1	*5.0	*1.8	*1.9	*2.9
Benzo[a]anthracene	*2.8	*2.9	*4.4	*3.9	*2.5	*3.3	*2.9	*3.6	*4.9	*2.3	*1.7	*2.2
Benzo[b]fluoranthene	*4.8	*5.0	8.8	9.1	*4.3	5.7	5.8	7.7	14.4	*3.5	*2.3	*2.8
Benzo[k]fluoranthene	*4.3	5.2	7.2	6.8	*4.0	5.2	*4.8	6.4	11.3	*3.0	*2.1	*2.6
Benzo[a]pyrene	*3.9	*4.6	5.8	5.5	*3.8	5.1	*4.4	6	11.7	*2.9	*2.1	*2.7
Benzo[e]pyrene	5.8	6.6	11.9	11.2	*4.6	7	6.6	7.8	15.6	*3.7	*2.3	*3.1
Benzo[g,h,i]perylene	8.1	9.8	17.4	14.8	6.6	9.8	8.8	8.6	15.6	*3.9	*2.1	*3.7
Chrysene	*3.9	*4.1	8.5	6.8	*3.2	*4.6	*4.0	*4.9	7.4	*2.6	*2.2	*2.6
Coronene	*2.8	*2.5	5.4	*3.9	*1.8	*3.3	*3.5	*3.6	*4.0	*1.6	<5	*2.5
p-Cresol[1]	*3.5	*4.5	*2.9	*3.2	*3.5	5.9	5.8	6.4	6.4	*2.3	*3.0	*4.1
Dibenzo[a,h]anthracene	*2.1	*1.9	*2.8	*2.6	*2.0	*2.3	<5	<5	*4.5	*1.6	<5	<5
1,6-dimethylnaphthalene	*3.0	7.6	*2.4	*2.6	*4.0	8.3	13.2	8.9	7.4	*3.0	*4.2	*3.3
2,6-dimethylnaphthalene	18.4	62.9	5.5	9.5	38.2	74.4	123	87	67.4	22.1	38.4	27.5
2-ethylnaphthalene	10.6	<5	<5	*1.2	21.2	<5	<5	<5	<5	<5	<5	<5
Fluoranthene	*4.5	*4.9	7.6	6.4	*3.8	*5.0	*3.9	*4.5	6.2	*3.2	*2.7	*3.0
9H-fluorene	*.38	*.53	*.84	*.72	*.45	<5	<5	*.56	<5	<5	<5	<5
Indeno[1,2,3-c,d]pyrene	7.8	9.6	16	16.1	7	10	8.4	10	21.2	*4.3	*2.2	*3.4
1-methyl-9H-fluorene	*2.1	<5	*1.7	*1.6	<5	<5	<5	*2.7	<5	<5	<5	<5
2-methylanthracene	<5	<5	*1.9	<5	<5	<5	<5	<5	<5	<5	<5	<5
4,5-methylenephenanthrene	*1.8	*1.6	*2.1	*2.0	<5	*1.9	<5	<5	*3.7	*1.4	<5	<5
1-methylphenanthrene	<5	<5	*2.0	<5	<5	<5	<5	<5	<5	<5	<5	<5
1-methylpyrene	*2.1	*1.7	*1.9	*1.6	*1.5	<5	<5	<5	*3.2	*1.4	<5	*2.2
Naphthalene	*1.9	*2.2	*1.9	*2.0	*1.7	*2.1	<5	*2.8	*2.9	<5	*1.5	*2.0
Perylene	*4.3	5.2	7.2	6.8	*4.0	5.2	*4.8	6.4	11.3	*3.0	*2.1	*2.6
Phenanthrene	*3.4	*3.4	*5.0	*4.9	*2.7	*3.7	*2.9	*3.3	*3.8	*1.6	*1.8	*2.0
Phenol[1]	13.5	14	16.9	16.7	11.7	13.8	14.9	12.9	18.3	7.3	10.5	10.1
Pyrene	5.2	5.7	8.7	7.1	*4.0	5.9	*4.7	5.3	8.8	*3.5	*2.8	*3.1
2,3,6-trimethylnaphthalene	<5	<5	<5	<5	*1.6	*1.5	<5	<5	*2.8	<5	<5	<5

Site 3: Overton Arm	Depth interval (centimeters)					
	0–5	10–15	20–25	30–35	40–45	55–60
Acenaphthene	<10	*2.6	*1.9	*1.9	<10	*1.5
Acenaphthylene	*4.1	<10	*2.3	*2.5	<10	*1.4
Anthracene	<10	*3.4	*2.6	*2.7	*2.5	*2.0
Benzo[a]anthracene	<10	<10	*2.2	*2.3	<10	*1.4
Benzo[b]fluoranthene	*3.3	*2.7	*2.3	*2.8	*2.3	*1.9
Benzo[k]fluoranthene	*3.4	*2.6	*2.1	*2.3	*2.2	*1.9
Benzo[a]pyrene	<10	<10	<10	<10	<10	*1.6
Benzo[e]pyrene	*3.8	<10	*2.5	*2.6	*2.5	*1.8
Benzo[g,h,i]perylene	*3.4	*2.4	*2.2	*2.6	*2.4	*1.8
Chrysene	<10	*2.6	*2.1	*2.3	*2.1	*1.9
Coronene	<10	*2.4	*1.9	*2.3	*2.0	*1.5
p-Cresol [1]	*5.1	*3.0	*3.6	*4.4	*3.7	*2.1
1,6-dimethylnaphthalene	*7.0	*3.0	*4.3	*8.5	*6.3	*3.2
2,6-dimethylnaphthalene	43.8	*9.6	30.4	70.7	69.7	31
Fluoranthene	*3.9	*2.7	*2.5	<10	<10	*1.7
9H-fluorene	<10	<10	*.25	*.38	*.28	<5
Indeno[1,2,3-c,d]pyrene	*3.5	*2.6	*2.3	*2.4	*2.4	*1.7
1-methyl-9H-fluorene	<10	<10	*2.2	*2.6	*2.3	<5
Naphthalene	*3.5	*2.4	*2.0	*2.4	*2.2	<5
Perylene	24.4	33.6	174	197	164	130
Phenanthrene	*3.4	*2.3	*2.0	*2.3	*2.2	*1.5
Phenol[1]	*8.2	*4.2	*6.3	*6.8	*7.5	*4.8
Pyrene	*3.5	*3.6	*2.3	*2.6	*2.4	*2.3
2,3,6-trimethylnaphthalene	<10	<10	<10	*2.5	*2.4	*1.7

Table 10. Polycyclic aromatic hydrocarbon and phenol concentrations in bottom-sediment cores at four sites in Lake Mead, May 1998—Continued

| Site 4: Colorado and Virgin Rivers confluence (pre-impoundment)	Depth interval (centimeters)									
	0–3	6–9	12–15	18–21	24–27	30–35	40–45	50–55	60–65	75–80
Acenaphthene	*2.5	*2.7	<10	<5	<10	*2.1	<20	<10	<10	<10
Acenaphthylene	*2.9	<10	<10	*3.3	<10	<10	<20	*2.4	<10	*3.0
Anthracene	<10	<10	*2.6	*3.6	*3.4	*3.1	*5.2	*3.2	*3.0	*2.4
Benzo[a]anthracene	<10	<10	*2.0	*2.8	*2.8	*2.7	*4.4	*2.8	*2.8	*1.9
Benzo[b]fluoranthene	*3.0	*3.0	*2.6	*4.0	*3.5	*4.2	*6.8	*5.3	*4.5	*2.4
Benzo[k]fluoranthene	*2.6	*2.8	*2.3	*3.3	*3.1	*3.0	*5.1	*3.4	*2.9	*2.1
Benzo[g,h,i]perylene	*2.9	*3.2	*3.1	*4.2	*3.9	*5.5	*7.6	*6.8	*6.0	*2.1
Benzo[a]pyrene	<10	<10	<10	*3.0	<10	<10	<20	<10	102	*2.1
Benzo[e]pyrene	*3.1	*3.3	*3.0	*4.3	*4.6	*4.6	*6.6	*5.4	*5.2	*2.5
Chrysene	*2.6	*2.9	*2.4	*3.6	*3.4	*3.4	*5.2	*4.0	*4.0	*2.1
Coronene	*2.8	*3.1	*2.6	*2.9	<10	*4.6	*6.4	*4.9	*4.9	*1.7
p-Cresol[1]	*3.7	*4.7	*4.6	10.3	*3.9	*3.7	*5.5	*3.3	*3.8	5.3
Dibenzo[a,h]anthracene	<10	<10	<10	<5	*2.5	<10	<20	*2.4	*2.3	<5
1,2,-dimethylnaphthalene	<10	<10	<10	*2.8	<10	*2.5	*4.2	*2.4	*2.6	*1.9
1,6-dimethylnaphthalene	*3.1	*4.2	*4.5	10.4	*4.1	*5.4	*5.6	*3.9	*5.1	*3.4
2,6-dimethylnaphthalene	*4.7	17.6	30.5	77.8	*9.9	30.8	*5.9	*3.9	15.7	10
2-ethylnaphthalene	<10	<10	<10	<5	<10	<10	<20	*2.5	<10	<5
Fluoranthene	*3.2	*3.3	*2.8	*3.4	*3.4	*3.0	*5.2	*3.9	*3.7	*3.7
9H-fluorene	<10	<10	<10	<5	*.32	<10	<20	*.47	*.54	*.34
Indeno[1,2,3-c,d]pyrene	*2.7	*3.2	*2.6	*3.4	*3.4	*3.6	*5.8	*4.0	*4.0	<5
1-methyl-9H-fluorene	<10	<10	<10	*3.8	*3.2	*2.9	*4.6	*3.0	*3.1	*2.4
2-methylanthracene	<10	<10	<10	<5	*3.8	<10	*5.8	<10	<10	<5
4,5-methylenephenanthrene	<10	<10	<10	<5	<10	<10	*4.6	*2.9	*3.0	<5
1-methylphenanthrene	<10	<10	<10	<5	*3.3	<10	*4.8	<10	<10	<5
1-methylpyrene	<10	<10	<10	*2.9	*2.9	<10	*4.3	*4.3	*2.8	*2.6
Naphthalene	*2.8	*2.8	*2.3	*4.8	*3.1	*3.3	*4.8	*3.5	*3.9	*2.5
Perylene	10.7	14.8	95.4	80.8	47.9	105	113	98	118	259
Phenanthrene	*2.8	*2.8	*2.4	*3.8	*3.6	*3.7	*5.7	*4.7	*5.1	*2.4
Phenol [1]	*6.6	*7.5	*8.4	22	*7.7	*8.2	*11.4	33	22.7	24.8
Pyrene	*3.1	*3.2	*2.7	*3.4	*3.7	*3.5	*5.8	*4.3	*4.0	*2.4
2,3,6-trimethylnaphthalene	<10	<10	<10	*4.1	<10	*3.0	*4.4	*2.9	*2.9	<5

[1] Phenols.
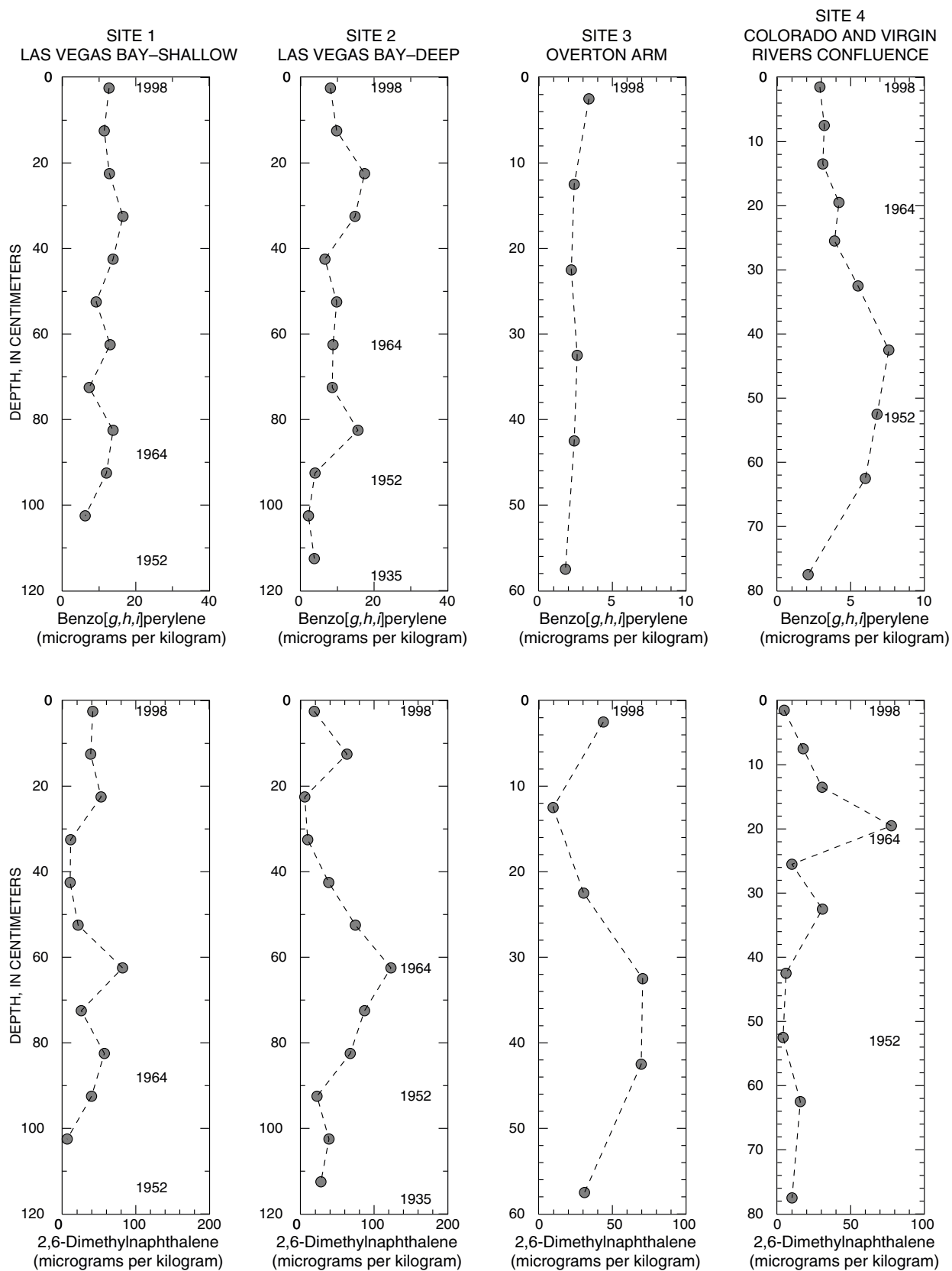
Figure 6. Concentrations of benzo[*g,h,i*]perylene and 2,6-dimethylnaphthalene in bottom-sediment cores at four sites in Lake Mead, May 1998. Years shown indicate the approximate date of that section of the core.

maximum concentration at site 4 was between 1952 and 1964. Concentrations of benzo[*g,h,i*]perylene for the four sites are plotted against depth in figure 6.

Concentrations of 2,6-dimethylnaphthalene varied with depth at all four sites (table 10). The maximum concentration at site 1 was 81.9 µg/kg at a depth range of 60–65 cm; at site 2, 123 µg/kg at a depth range of 60–65 cm; at site 3, 70.7 µg/kg at a depth range of 30–35 cm; and at site 4, 77.8 µg/kg at a depth range of 18–21 cm. The maximum concentration at site 1 occurred in sediment dating between 1964 and 1998, and at sites 2 and 4 near the 1964 interface. Concentrations of 2,6-dimethylnaphthalene for the four sites are plotted against depth in figure 6.

Concentrations of indeno[1,2,3-*c,d*]pyrene at all four sites were fairly constant with depth (table 10). Concentrations at sites 1 and 2 were greater than those at sites 3 and 4, at which all concentrations were either non-detected values or were estimated values lower than laboratory reporting limits. The maximum concentration at site 1 was 15.3 µg/kg at a depth range of 30–35 cm; at site 2, 21.2 µg/kg at a depth range of 80–85 cm; at site 3, estimated as 3.5 µg/kg at a depth range of 0–5 cm; and at site 4, estimated as 5.8 µg/kg at a depth range of 40–45 cm. Maximum concentrations at sites 2 and 4 occurred in sediment dating between 1952 and 1964, whereas the maximum concentration at site 1 was between 1964 and 1998. Concentrations of indeno[1,2,3-*c,d*]pyrene for the four sites are plotted against depth in figure 7.

Perylene concentrations in samples from sites 2, 3, and 4 varied with depth, whereas perylene concentrations in samples from site 1 were fairly constant with depth (table 10). Perylene concentrations in samples from sites 3 and 4 were significantly greater than in samples from sites 1 and 2, in which most concentrations were estimated values lower than laboratory reporting limits. The maximum concentration at site 1 was estimated as 7.6 µg/kg at a depth range of 10–15 cm; at site 2, 11.3 µg/kg at a depth range of 80–85 cm; at site 3, 197 µg/kg at a depth range of 30–35 cm; and at site 4, 259 µg/kg at a depth range of 75–80 cm. The maximum concentration at site 1 occurred in sediment dating between 1964 and 1998; at site 2, between 1952 and 1964; and at site 4, between the pre-impoundment interface and 1952.

Pyrene concentrations were fairly constant with depth in samples from all four sites. Pyrene concentrations in samples from sites 1 and 2 generally were greater than in samples from sites 3 and 4 (table 10).

All concentrations in samples from sites 3 and 4 were estimated values lower than laboratory reporting limits. The maximum concentration at site 1 was 10.7 µg/kg at a depth range of 10–15 cm; at site 2, 8.8 µg/kg at a depth range of 80–85 cm; at site 3, estimated as 3.6 µg/kg at a depth range of 10–15 cm; and at site 4, estimated as 5.8 µg/kg at a depth range of 40–45 cm. Maximum concentrations at sites 2 and 4 occurred in sediment dating between 1952 and 1964, whereas the maximum concentration at site 1 was between 1964 and 1998. Pyrene concentrations in samples from the four sites are plotted against depth in figure 8.

Analyses for phenols were available for all four sites. Phenol concentrations were fairly constant with depth in samples from sites 1, 2, and 3, but varied with depth in samples from site 4 (table 10). All phenol concentrations in samples from site 3 and most concentrations in samples from sites 1 and 4 were estimated values lower than laboratory reporting limits. The maximum concentration at site 1 was estimated as 9.8 µg/kg at a depth range of 20–25 cm; at site 2, 18.3 µg/kg at a depth range of 80–85 cm; at site 3, estimated as 8.2 µg/kg at a depth range of 0–5 cm; and at site 4, 33 µg/kg at a depth range of 50–55 cm. The maximum concentration at site 1 occurred in sediment dating between 1964 and 1998, at site 2 between 1952 and 1964, and at site 4 near the 1952 interface. Phenol concentrations in samples from the four sites are plotted against depth in figure 8. Analytical results for PAHs and phenols in cores from the four sites are listed in table 10.

SUMMARY

In May 1998, the USGS, in cooperation with UNLV, investigated sediment-deposition rates and sediment chemistry at four sites in Lake Mead. Two of the sites (one shallow and one deep) were in Las Vegas Bay, one was in the Overton Arm, and one was near the historic confluence of the Colorado and Virgin Rivers. All sediment cores collected were determined to have penetrated pre-impoundment sediments, thus providing a complete record of sediment deposition after impoundment. Total thicknesses of the post-impoundment sediments accumulated at sites 1, 2, 3, and 4 measured about 116, 118, 75, and 85 cm, respectively.

Sediment-deposition rates after impoundment of the Colorado River by Hoover Dam were calculated by measuring the accumulation of mass during three different periods: (1) from the approximate impoundment
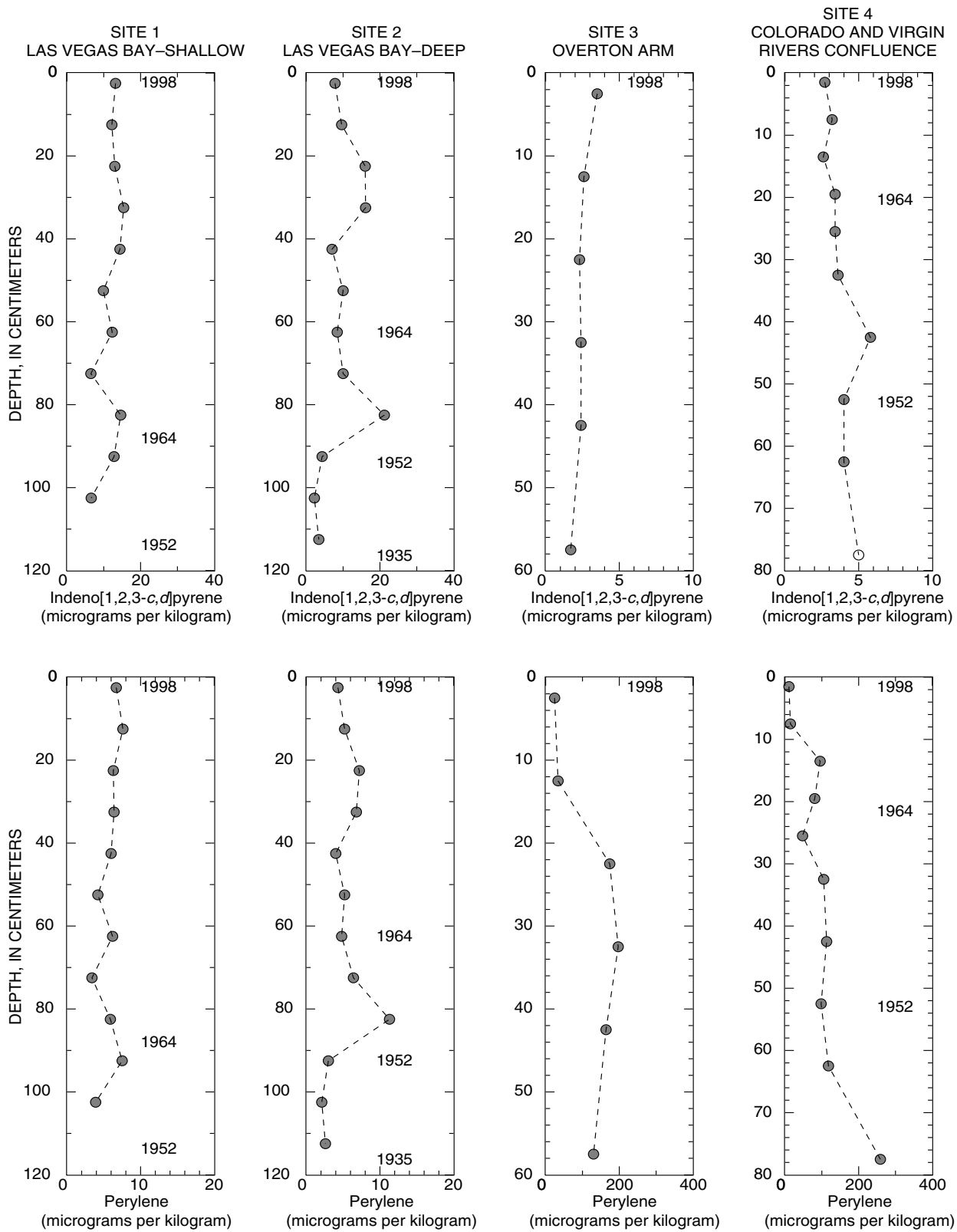
Figure 7. Concentrations of indeno[1,2,3-*c,d*]pyrene and perylene in bottom-sediment cores at four sites in Lake Mead, May 1998. Solid circles represent cesium-137 concentrations. Open circles represent cesium-137 concentrations that are less than the value plotted. Years shown indicate the approximate date of that section of the core.
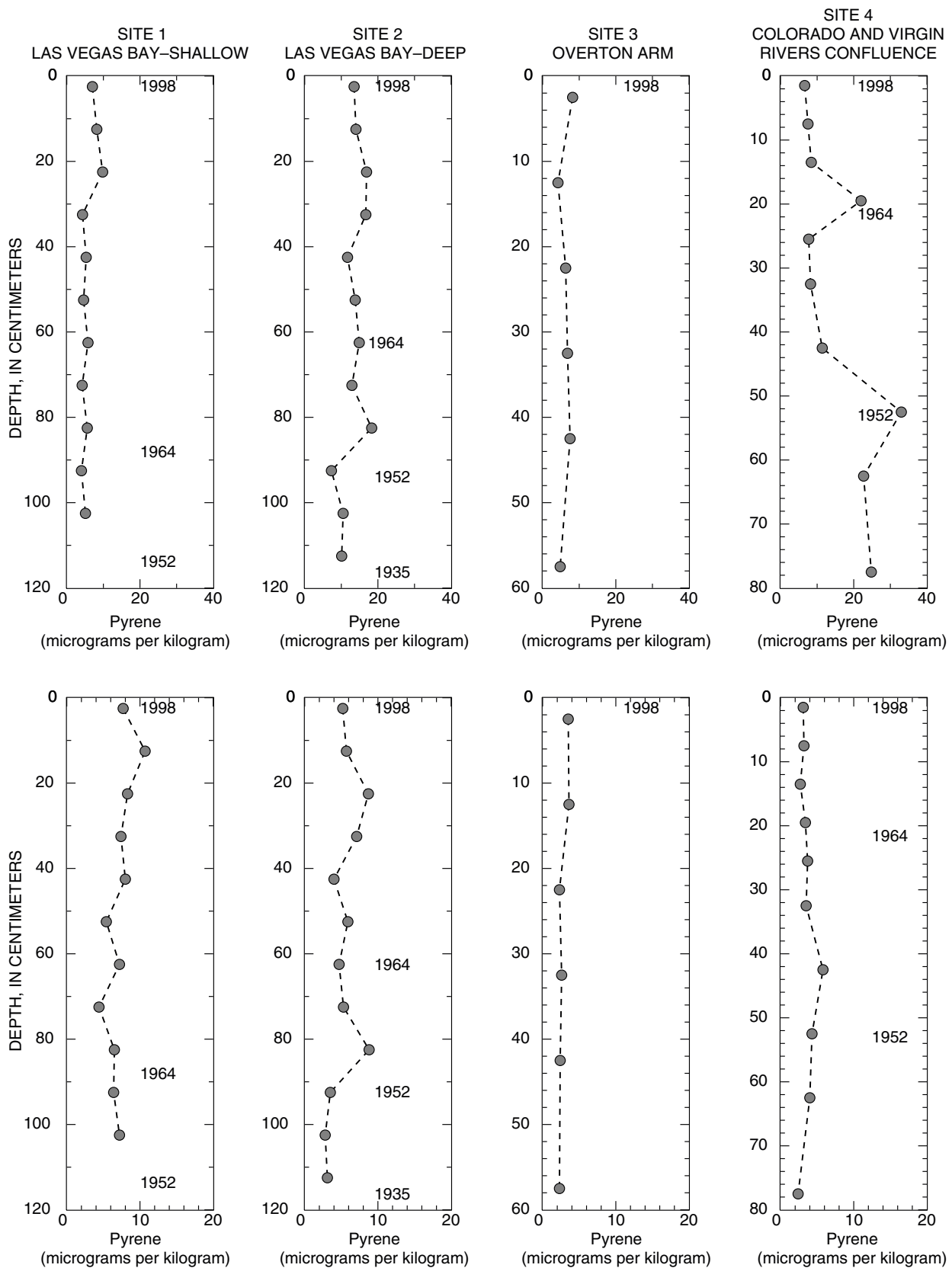
Figure 8. Concentrations of phenol and pyrene in bottom-sediment cores at four sites in Lake Mead, May 1998. Years shown indicate the approximate date of that section of the core.

date for each site (1935–37) to the initial occurrence of ^{137}Cs in the atmosphere (1952); (2) from 1952 to the maximum concentration of ^{137}Cs in the atmosphere (about 1964); and (3) from 1964 to the collection date of the sample (1998). Sediment-deposition rates for the entire post-impoundment period (1935–98) averaged 1.45 (g/cm^2)/yr at the Las Vegas Bay shallow site, 1.25 (g/cm^2)/yr at the Las Vegas Bay deep site, 0.80 (g/cm^2)/yr at the Overton Arm site, and 0.65 (g/cm^2)/yr at the Colorado and Virgin Rivers confluence site. Sediment-deposition rates from the pre-impoundment interface to 1952 ranged from 0.25 (g/cm^2)/yr at the Overton Arm site to 1.11 (g/cm^2)/yr at the Las Vegas Bay deep site. From 1952 to 1964, deposition rates ranged from 1.27 (g/cm^2)/yr at the Colorado and Virgin Rivers confluence site to 1.68 (g/cm^2)/yr at the Las Vegas Bay shallow site. From 1964 to 1998, deposition rates ranged from 0.26 (g/cm^2)/yr at the Colorado and Virgin Rivers confluence site to 1.81 (g/cm^2)/yr at the Las Vegas Bay shallow site. Sediment-deposition rates from 1952 to 1964 and from 1964 to 1998 were not calculated for samples collected at the Overton Arm because the 1964 ^{137}Cs peak could not be determined with any certainty.

Estimated values were not used in reporting minimum constituent values. OCs and SVOCs were detected in the Lake Mead bottom-sediment core samples. The numbers of organic compounds detected were 48 at the Las Vegas Bay shallow site, 57 at the Las Vegas Bay–deep site, 26 at the Overton Arm site, and 31 at the Colorado and Virgin Rivers confluence site. The most commonly detected organochlorine pesticides/polychlorinated biphenyl compounds were DDD, which ranged from 0.5 µg/kg at the Las Vegas–shallow site to 38 µg/kg at the Las Vegas Bay–deep site, and DDE, which ranged from 0.51 µg/kg at the Overton Arm site to 57 µg/kg at the Las Vegas Bay–deep site.

The most frequently detected dioxin compounds were TCDD, which ranged from <0.52 pg/g at the Colorado and Virgin Rivers confluence site to 39 pg/g at the Las Vegas Bay–shallow site, and OCDD, which ranged from <2.5 pg/g at the Las Vegas–deep site to 93 pg/g at the Las Vegas Bay–shallow site.

The most frequently detected furan compounds included TCDF, which ranged from <0.55 pg/g at the Colorado and Virgin Rivers confluence site to 320 pg/g at the Las Vegas Bay–deep site, and OCDF, which ranged from <0.74 pg/g at the Colorado and Virgin Riv-

ers confluence site to 280 pg/g at the Las Vegas Bay deep site. Dioxin and furan analyses were not available for samples collected from the Overton Arm site.

The most frequently detected polycyclic aromatic hydrocarbons included: perylene, which ranged from 5.2 µg/kg at the Las Vegas Bay–deep site to 259 µg/kg at the Colorado and Virgin Rivers confluence site; benzo[g,h,i]perylene, which ranged from 6.2 µg/kg at the Las Vegas–shallow site to 17.4 µg/kg at the Las Vegas Bay deep site; 2,6-dimethylnaphthalene, which ranged from 5.5 µg/kg at the Las Vegas–deep site to 123 µg/kg at the Las Vegas Bay–deep site; and indeno[1,2,3-c,d]pyrene, which ranged from 6.5 µg/kg at the Las Vegas–shallow site to 21.2 µg/kg at the Las Vegas Bay–deep site.

The most frequently detected phenol compound was phenol, which ranged from 5.1 µg/kg at the Las Vegas–shallow site to 33 µg/kg at the Colorado and Virgin Rivers confluence site.

SELECTED REFERENCES

Bevans, H.E., Goodbred, S.L., Miesner, J.F., Watkins, S.A., Gross, T.S., Denslow, N.D., and Schoeb, Trenton, 1996, Synthetic organic compounds and carp endocrinology and histology in Las Vegas Wash and Las Vegas and Callville Bays of Lake Mead, Nevada, 1992 and 1995: U.S. Geological Survey Water-Resources Investigations Report 96-4266, 12 p.

Bevans, H.E., Lico, M.S., and Lawrence, S.J., 1998, Water quality in the Las Vegas area and the Carson and Truckee River Basins, Nevada and Califorinia, 1992–96: U.S. Geological Survey Circular 1170, 47 p.

Callender, Edward, and Van Metre, P.C., 1997, Reservoir sediment cores show U.S. lead declines: Environmental Science & Technology, v. 31, no. 9, p. 424–428.

Carlson, R.E., 1977, A trophic state index for lakes: Limnology and Oceanography, v. 22, p. 361–369.

Covay, K.J., Banks, J. M., Bevans, H.E., and Watkins, S.A., 1996, Environmental and hydrologic settings of the Las Vegas Valley area and the Carson and Truckee River Basins, Nevada and California: U.S. Geological Survery Water-Resources Investigations Report 96-4087, 72 p.

Covay, K.J., and Leiker, T.J., 1998, Synthetic organic compounds in water and bottom sediment from streams, detention basins, and sewage-treatment plant outfalls in Las Vegas Valley, Nevada, 1997: U.S. Geological Survey Open-File Report 98-633, 15 p.

Foreman, W.T., Conner, B.F., Furlong, E.T., Vaught, D.G., Merten, L.M., 1995, Methods on analysis by the U.S. Geological Survey National Water-Quality Labora-

tory—Determination of organochlorine pesticides and polychlorinated biphenyls in bottom sediment by duel capillary-column gas chromatography with electron-capture detection: U.S. Geological Survey Open-File Report 95-140, 78 p.

Furlong, E.T., Vaught, D.G., Merten, L.M., Foreman, W.T., and Gates, P.M., 1996, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory; determination of semivolatile organic compounds in bottom sediment by solvent extraction, gel permeation chromatographic fractionation, and capillary-column gas chromatography/mass spectrometry: U.S. Geological Survey Open-File Report 95-719, 67 p.

Geological Society of America, 1991, Rock color chart, 1991: Geological Society of America.

Hoffman, R.J., and Taylor, R.L., 1998, Mercury and suspended sediment Carson River Basin, Nevada—Loads to and from Lahontan Reservoir in flood year 1997 and deposition in reservoir prior to 1983: U.S. Geological Survey Fact Sheet 001-98, 6 p.

Krishnaswami, S., and Lal, D., 1978, Radionuclide limno-chronology, in Lerman, Abraham, ed., Lakes: Chemistry, geology, physics: New York, Springer-Verlag, p. 153–177.

LaBounty, J.F., and Horn, M.J., 1997, The influence of drainage from the Las Vegas Valley on the limnology of Boulder basin, Lake Mead, Arizona–Nevada: Journal of Lake and Reservoir Management, v. 13, no. 2, p. 95–108 .

Lara, J.M., and Sanders, J.I., 1970, The 1963–64 Lake Mead survey: U.S. Bureau of Reclamation, 172 p.

Paulson, L.J., and Baker, J.R., 1980, Nutrient interactions among reservoirs on the Colorado River, in Proceedings of the symposium on surface water impoundments, American Society of Civil Engineers, June 2–5, 1980, Minneapolis, Minnesota, paper no. 8–9, p. 1647–1656.

Preissler, A.M., Roach, G.A., Thomas, K.A., and Wilson, J.W., 1999, Water resources data—Nevada, water year 1998: U.S. Geological Survey Water-Data Report NV-98-1, 598 p.

Sijm, D.T.H.M., and Opperhuizen, Antoon, 1996, Dioxins—An environmental risk for fish in Beyer, W.N., Heinz G.H., and Redmon-Norwood, A.W., eds., Environmental contaminants in wildlife interpreting tissue concentrations: New York, Lewis Publishers, p. 209–288.

Smith, J.A., Witkowski, P.J., and Fusillo, T.V., 1998, Man-made organic compounds in the surface water of the United States—A review of current understanding: U.S. Geological Survey Fact Sheet 152-95, 6 p.

U.S. Bureau of Reclamation, 1998, <http://www.lc.usbr.gov/~g4000/mead-elv.html>: U.S. Bureau of Reclamation.

U.S. Environmental Protection Agency, 1986 (revised December 1996), Test methods for evaluation of solid waste, physical/chemical methods: U.S. Environmental Protection Agency, EPA-SW-846, 3d ed., variable pagination.

Van Metre, P.C., Land, L.F., and Braun, C.L., 1996, Water-quality trends using sediment cores from White Rock Lake, Dallas, Texas: U.S. Geological Survey Fact Sheet 217-96, 4 p.

Van Metre, P.C., and Callender, Edward, 1997, Water-quality trends in White Rock Creek Basin from 1912–1994 identified using sediment cores from White Rock Lake reservoir, Dallas, Texas: Kluwer Academic Publishers, Belgium, Journal of Paleolimnology, 17, p. 239–249.

Van Metre, P.C., Callender, Edward, and Fuller, C.C., 1997a, Historical trends in organochlorine compounds in river basins identified using sediment cores from reservoirs: Environmental Science & Technology, v. 31, no. 8, p. 2339–2344.

Van Metre, P.C., Mahler, B.J., and Callender, Edward, 1997b, Water-quality trends in the Rio Grande/Rio Bravo Basin using sediment cores from reservoirs: U.S. Geological Survey Fact Sheet 221-96, 8 p.

Vollenweider, R.A., 1970, Scientific fundamentals of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication: Rep. DAS/CSL/6872, Org. Econ. Coop. and Dev., Paris, 192 p.

Wershaw, R.L., Fishman, M.I., Grabbe, R.R., and Lowe, L.E., eds., 1987, Methods for determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 80 p.