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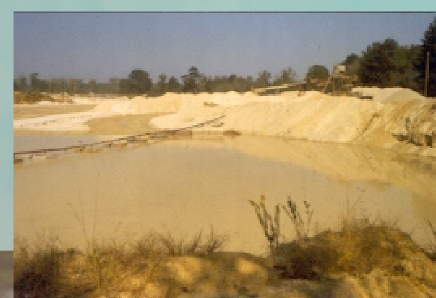
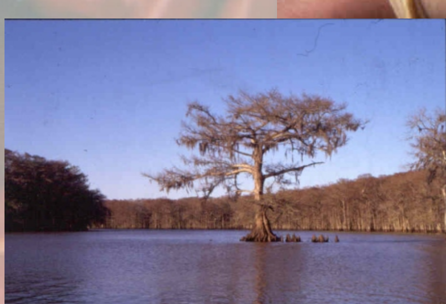
Trace Elements and Organic Compounds in Bed Sediment from Selected Streams in Southern Louisiana, 1998

Water-Resources Investigations Report 02-4089





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

Front cover:

Upper left: Crawfish; Upper right: Amite River, Louisiana;
Lower left: Bayou Lacassine, Louisiana; Lower right: Bayou Boeuf, Louisiana
(Photographs by Dennis K. Demcheck, U.S. Geological Survey)

Center: Bed sediment subsample
(Photograph by Douglas A. Harned, U.S. Geological Survey)

Trace Elements and Organic Compounds in Bed Sediment from Selected Streams in Southern Louisiana, 1998

By Stanley C. Skrobialowski

U.S. GEOLOGICAL SURVEY
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Information regarding the National Water-Quality Assessment (NAWQA) Program is available on the Internet via the World Wide Web. You may connect to the NAWQA Home Page using the Universal Resource Locator (URL) at:

http://water.usgs.gov/nawqa

FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multiscale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings.

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Associate Director for Water

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By Stanley C. Skrobialowski

ABSTRACT

Bed-sediment samples from 21 selected streams in southern Louisiana were collected and analyzed for the presence of trace elements and organic compounds during 1998 as part of the U.S. Geological Survey National Water-Quality Assessment Program. Concentrations of selected trace elements and organic compounds were compared on the basis of sediment-quality criteria, land use, and grain size; concentrations of selected trace elements also were compared with concentrations from previous studies.

Concentrations of seven selected trace elements and 21 organic compounds were evaluated with sediment-quality criteria established by the Canadian Council of Ministers of the Environment. Concentrations of selected trace elements and organic compounds were highest at sites draining urban and agricultural areas and may result from cumulative effects of relatively high percentages of fine-grained material, iron, and organic material. Concentrations exceeding sediment-quality criteria for the protection of aquatic life occurred most frequently at Bayou Grosse Tete at Rosedale and Bayou Lafourche below weir at Thibodaux. Exceedance of Interim Sediment Quality Guidelines occurred most frequently for arsenic and chromium.

Trace-element concentrations in fine-grained samples were compared with concentrations in bulk samples and were determined to be significantly different, and concentrations were generally higher in fine-grained sediment. Shapiro-Wilk, paired t-test, and Wilcoxon rank sum statistical procedures, with an alpha of 0.05, were used to compare concentrations of 21 trace elements, total organic carbon, and total carbon in fine-grained and bulk sediment samples for 19 sites. Significant differences were determined between fine-grained and bulk sediment samples for aluminum, barium, beryllium, chromium, copper, iron, lithium, nickel, phosphorus, selenium, titanium, and zinc concentrations. Of 133 paired concentrations, 69 percent were greater in fine-grained samples, and 23 percent were greater in bulk samples. Comparisons with data from previous studies indicate increases by more than 20 percent in concentrations of antimony at Bayou Lafourche below weir at Thibodaux, arsenic and chromium at Tickfaw River at Liverpool, lead at Bayou Lafourche below weir at Thibodaux, and zinc at Bayou Lafourche below weir at Thibodaux and Vermilion River at Perry. Historic comparisons also indicate decreases by more than 20 percent in concentrations of chromium at Bayou des Cannes near Eunice and mercury at Mermentau River at Mermentau.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) began implementation of the National Water Quality Assessment (NAWQA) Program to describe the status and trends in the quality of the Nation’s surface- and ground-water resources (Gilliom and others, 1995). The NAWQA Program consists of more than 50 study units, including the Acadian-Pontchartrain (ACAD) Study Unit located in southern Louisiana and southwestern Mississippi, that incorporate more than 60 percent of the Nation’s water use and population served by public water supply. The NAWQA Program integrates chemical, physical, and biological data to assess the quality of surface and ground water at local, regional, and national levels (Meador and Gurtz, 1994). The surface-water and biological components of the NAWQA Program include characterizing chemical and biological interactions at the bed sediment-water interface. The analysis of organic compounds and trace elements in water, bed-sediment, and biota are combined to describe the source, transport, and fate of these constituents in the aquatic environment.

Bed sediment are sources and sinks for trace elements and organic compounds in aquatic systems and may be considered a source of these contaminants in the food web (Horowitz, 1991). Understanding bed-sediment chemistry in the Acadian-Pontchartrain Study Unit is important because organisms dwelling or feeding in or near contaminated streambed sediment can introduce these contaminants into the food web (Hem, 1985; Horowitz, 1991). Currently, several fish consumption advisories are in effect in the study unit area, and bed-sediment chemistry may help explain uptake in biota in the Gulf Coast area (Louisiana Department of Environmental Quality, 2001). Concentrations of trace elements and organic compounds in bed sediment and biota can exceed those of overlying waters by several orders of magnitude, and bed sediment may be used to evaluate water-quality trends, because bed sediment are integrators of water quality over time and space (Horowitz, 1991; Horowitz and Elrick, 1988).

Purpose and Scope

This report describes the occurrence and distribution of selected trace elements and organic compounds in bed sediment at selected streams in southern Louisiana in the ACAD Study Unit. Concentrations of selected trace elements were compared with sediment-quality criteria (SQC) established by the Canadian Council of Ministers of the Environment (CCME) (1999), dominant land use, and percent fine-grained sediment. The SQC used for comparison included background concentrations, Interim Sediment Quality Guidelines (ISQG's), and Potential Effects Levels (PEL's) for freshwater sediment. Site information, evaluation criteria, and concentration data for selected trace elements and organic compounds are presented. Bed-sediment samples were collected at 21 stream sites in the ACAD Study Unit between May and August 1998 and split into subsamples. For all sites, subsamples were prepared for analysis of trace elements in fine-grained samples and for analysis of grain size and organic compounds in bulk samples. Samples were analyzed for two groups of organic compounds, organochlorines and polycyclic aromatic hydrocarbons (PAH's). For 19 of the 21 sites, a subsample also was prepared for the analysis of trace elements and total organic carbon in a bulk sample. Trace-element concentrations from fine-grained and bulk samples were compared with land use, percent iron and organic carbon, and manganese concentrations. Parametric and non-parametric statistical procedures also were used to compare concentrations of 21 selected trace elements, total organic carbon, and total carbon in fine-grained samples that were detected in bulk samples. Concentrations of 11 selected trace elements in bulk samples were compared to concentrations from previous studies for sites common to this and previous studies.

Description of Study Unit

The ACAD Study Unit (fig. 1) encompasses approximately 26,000 square miles and includes parts of southern Louisiana and southwestern Mississippi, but excludes the Mississippi River and the Atchafalaya River Swamp. The study unit includes 21 streams discussed in this report, and land use within the study unit includes urban, forest, agriculture, wetlands, open water, and barren land (table 1). Agriculture in the study unit includes timber; crops such as rice, soybeans, sugarcane, and corn; and beef production. Aquacultural activities within the study unit are common, especially for the breeding and production of catfish and crawfish. Petrochemical and gas exploration and production, and marine transport are the major nonagricultural industries within the study unit. Soils within the ACAD Study Unit consist of clay, silt, and sand with varied drainage characteristics. Soils in the northern section of the study unit are mostly well-drained sands and gravels that transition to poorly-drained silts and clays (Boniol, 1988) and contain higher amounts of organic and woody debris in the southern section of the study area.

Acknowledgments

The author thanks colleagues in the USGS for collecting samples and reviewing previous drafts of this report. Roland W. Tollett, Van G. Bergeron, Dennis K. Demcheck, and Robert B. Fendick assisted in the collection, processing, and shipping of samples. Patricia J. D'Arconte prepared Geographic Information System coverages and land-use maps. Critical reviews by Dennis K. Demcheck, Rodney R. Knight, John A. Robinson, Verlin C. Stephens, and Michael D. Woodside greatly improved the quality of the manuscript.

FACTORS INFLUENCING BED-SEDIMENT QUALITY

Physio-chemical and anthropogenic factors influence bed-sediment quality. Physio-chemical factors include weathering, grain size, sediment surface coatings, geochemical substrate, interstitial-water chemistry, and hydrologic conditions. Concentrations of some compounds are controlled by overlying water-quality conditions such as dissolved oxygen, pH, specific conductance, and oxidation-reduction potential. Large trace-element concentrations have been linked with small grain size and presence of organic matter (Horowitz, 1991).

Figure 1. Location of bed-sediment sampling sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998.

Table 1. Drainage area and land-use information for bed-sediment sampling sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[Sites were designated as urban when the percentage of urban land use exceeded 25 percent, regardless of the other land-use percentages. <, less than]

Site number (see fig. 1)	Site name	Drainage area, in square miles	Land-use category	Land-use area, in percent[1]				
				Urban	Forest	Agriculture	Wetlands	Open water or barren land
1	Tchefuncte River near Covington	141	Forest	<1	60	36	2	2
2	Bogue Falaya at Lee Road at Covington	130	Forest	1	62	32	<1	3
3	Tangipahoa River at Robert	647	Forest	2	59	34	3	2
4	Tickfaw River at Liverpool	87.8	Forest	<1	67	29	3	1
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	15.1	Urban	78	18	<1	<1	3
6	Amite River at Port Vincent	1,490	Forest	8	62	25	3	2
7	Bayou Des Allemands at Des Allemands	619	Wetland	2	2	28	62	5
8	Bayou Lafourche below weir at Thibodaux	4.2	Urban	29	13	47	1	10
9	Bayou Grosse Tete at Rosedale	118	Agriculture	2	3	58	36	<1
10	Bayou Boeuf at Railroad Bridge at Amelia	1,220	Wetland	3	4	38	51	5
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	69.9	Agriculture	8	7	73	11	2
12	Vermilion River at Perry	436	Agriculture	13	5	72	9	<1
13	Bayou des Cannes near Eunice	142	Agriculture	4	7	85	3	<1
14	Bayou Nezpique near Basile	505	Forest	2	39	38	19	2
15	Mermentau River at Mermentau	1,380	Agriculture	3	21	64	10	1
16	Bayou Que De Tortue at Riceville	216	Agriculture	1	3	93	3	<1
17	Bayou Lacassine near Lake Arthur	296	Agriculture	2	3	88	7	<1
18	Whisky Chitto Creek near Oberlin	503	Forest	1	66	8	15	9
19	Calcasieu River near Kinder	1,720	Forest	1	65	12	16	6
20	Turtle Bayou north of Bayou Penchant near Amelia	15.6	Wetland	<1	<1	<1	74	26
21	Bayou Segnette 4.6 miles south of Westwego	23.8	Urban	34	6	<1	54	5

[1]Percent totals may not equal 100 due to rounding.

Physio-Chemical Factors

Grain size, sediment surface coatings, and presence or absence of organic matter are probably the most important factors influencing trace-element sediment quality. Horowitz (1991) discussed the interrelation between surface area and surface coatings that concentrate trace elements. As particle sizes decrease, surface areas increase, resulting in higher surface area to grain-size ratios for fine-grained material compared to coarse-grained material. Organic matter, silt, and clay constitute the majority of fine-grained material in the study area. As surface area increases, the potential for trace-element concentrators such as hydrous iron and manganese oxides, and organic carbon to adsorb to particle surfaces increases. Horowitz (1991) discussed the importance of organic carbon, iron, and manganese coatings as concentrators of trace elements in aquatic systems, and described how trace elements can be physically trapped in particulate organic matter or chemically bound to sediment by organic surface coatings. Organic matter as coatings and particulates may account for up to 10 percent dry weight of cobalt, copper, iron, lead, manganese, molybdenum, nickel, silver, vanadium, and zinc (Horowitz, 1991). Geochemical substrate or parent material influences bed-sediment quality because surface coatings formed by hydrous iron and manganese oxides provide surface charges on sediment particles that tend to increase surface area and concentrate trace elements.

Hydrologic conditions influence bed-sediment quality. During periods of high flow, stream velocities suspend and transport bed sediment. As velocities decrease, particles may settle on the streambed or continue to move along the streambed as bedload. Transport exposes sediment particles to different water-quality conditions that may facilitate a change in surface charge or coating. Dissolved oxygen, pH, specific conductance, oxidation-reduction potential, and total organic carbon may affect bed-sediment quality (Horowitz, 1991).

Anthropogenic Factors

Anthropogenic factors are associated with land use and linked directly or indirectly to human activities. Land-use activities such as agriculture, aquaculture, mining, construction, industry, transportation, and recreation activities influence bed-sediment quality. Agricultural practices affect bed-sediment quality through the routine or seasonal application of pesticides and fertilizers on crops and cropland, the maintenance of water control structures used to irrigate or flood cropland, and the management of irrigation tailwater. Aquaculture activities, mainly for the production of catfish and crawfish, may influence bed-sediment chemistry through the diversion and release of water to and from breeding and production ponds. Sand mining activities disturb stream and river bottoms and result in resuspension and exposure of bed sediment to different water-quality conditions. Oil and gas exploration and production activities may influence bed-sediment quality through incidental release or spill of drilling fluids or products, and brine disposal. Construction and land- and lumber-clearing activities may disturb sediment particles, and make them more prone to erosion and subsequent suspension and deposition in streams. Urban activities such as applying fertilizers and pesticides to lawns, gardens, golf courses, and other landscaped areas also may influence bed-sediment quality. Industrial, commercial, and transportation activities influence bed-sediment quality by introducing into the environment trace elements and organic compounds that are subsequently trapped chemically or physically in bed sediment. Concentrations of trace elements may be higher in urban areas because trace elements, especially lead and zinc, have been linked to municipal, industrial, and transportation activities (Callender and Rice, 2000).

METHODS OF STUDY

Sample collection, laboratory methods, statistical methods, and comparison criteria for bed-sediment data are described in this section. Methods used to collect and prepare samples for this study followed standard NAWQA protocols. All samples discussed in this report were collected and processed by USGS personnel and analyzed at USGS laboratories.

Sample Collection

Bed-sediment samples were collected and processed according to methods described by Shelton and Capel (1994). At each site, one bed-sediment sample was collected, subdivided into appropriate volumes, sieved and preserved when necessary, and shipped to the appropriate analytical laboratory. Subsamples at 21 stream sites were analyzed for trace elements in fine-grained sediment, grain size, and organic compounds, and mercury in bulk sediment. For 19 stream sites, a subsample also was analyzed for trace elements in bulk sediment.

For each of the 21 sites (table 1), one trace-element sample was wet-sieved through a nylon sieve to provide a fine-grained sample with particle size smaller than 63 μm (micrometers) in diameter, according to methods described by Shelton and Capel (1994). Bulk samples for the analysis of trace elements, total carbon, and total organic carbon at 19 sites, and for analysis of grain size at 21 sites, were processed according to methods described by McGee and Demcheck (1995). Bulk samples were not sieved but were inspected for large (greater than about 2 millimeters) detritus and debris prior to shipping. Samples were not analyzed for trace elements, total carbon, and total organic carbon in bulk sediment for Whisky Chitto Creek near Oberlin and Tangipahoa River at Robert. Bulk samples for the analysis of mercury at 21 sites were prepared according to methods described by Olson and DeWild (1999). Samples for the analysis of organic compounds were prepared according to methods described by Shelton and Capel (1994).

Laboratory Methods

Analysis for trace elements in fine-grained samples and organic compounds, total carbon, and total organic carbon in bulk samples were performed at the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado. Methods used by the NWQL for the analysis of trace elements include total digestion and are described by Skougstad and others (1979). Methods used by the NWQL for the analysis of organic compounds and total carbon and total organic carbon are described by Foreman and others (1995), Furlong and others (1996), and Arbogast (1990). Particle-size analyses on bulk samples were performed at the USGS Sediment Laboratory in Baton Rouge, Louisiana. Methods used for the determination of particle size are described by Guy (1969). Analyses for trace elements (except mercury), total carbon, and total organic carbon, in bulk samples were performed at the USGS Sediment Partitioning Research Project Laboratory (SPRL) in Atlanta, Georgia. Methods used for the determination of trace-element concentrations in bulk samples include a total digestion and are described by Horowitz and others (1989). Analyses for mercury in bulk samples were performed at the USGS Wisconsin District Mercury Laboratory (WDML) in Madison, Wisconsin. Methods used by the WDML for the analysis of mercury are described by Olson and DeWild (1999).

Statistical Methods

Parametric and nonparametric statistical procedures were used to compare concentrations of 21 trace elements, total organic carbon, and total carbon in fine-grained and bulk samples from 19 sites. Paired differences were initially tested for normality by using the Shapiro-Wilk normality testing procedures with an alpha of 0.05 (SAS Institute, 1990). If the normality assumption was accepted, a parametric paired t-test with an alpha of 0.05 was used to determine significance of difference by comparing the average fine-grained concentration with the average bulk concentration for each element. If the normality assumption was rejected, the non-parametric Wilcoxon-Rank Sums procedure with an alpha of 0.05 was used to test for significant differences (SAS Institute, 1990). Censored values were included in the procedures and assigned the value of the detection limit, because trace-element concentrations determined near the detection limit may vary as much as 100 percent (Kent Elrick, USGS Sediment Partitioning Research Laboratory, written commun., 2001).

Comparison Criteria for the Evaluation of Bed Sediment

Concentrations of trace elements and organic compounds were compared with Canadian sediment-quality guidelines. Because State and Federal standards have not been established for concentrations of trace elements or organic compounds in bed sediment in the United States, Canadian SQC were used to evaluate concentrations of 7 selected trace elements (table 2) and 18 organic compounds (table 3) for which guidelines are available.

Concentrations of seven selected trace elements in fine-grained and bulk bed-sediment samples were compared with background concentrations (Persaud and others, 1993), Interim Sediment Quality Guidelines (ISQG's), and Probable Effects Levels (PEL's) (Canadian Council of Ministers of the Environment, 1999) listed in table 2. Concentrations of 18 organic compounds were compared with ISQG's and PEL's (Canadian Council of Ministers of the Environment, 1999) listed in table 3. Background concentrations for trace elements were based on Great Lakes pre-colonial sediment (Persaud and others, 1993). The ISQG's and PEL's were developed for the protection of aquatic life in bulk (unsieved) bed sediment and are based on associations between chemicals and biological effects and cause and effect relations. Adverse biological effects are not expected for concentrations below the ISQG's. Occasional adverse biological effects may be observed for concentrations between ISQG's and PEL's, and adverse biological effects may be expected for concentrations above PEL's. Although background concen-

Table 2. Background concentrations, Interim Sediment Quality Guideline concentrations, and Probable Effects Levels for selected trace elements in bulk freshwater sediment

[Concentrations are in milligrams per kilogram, dry weight. The ratio of one milligram per kilogram is equal to the ratio of one microgram per gram.]

Trace element	Background concentration[1]	Interim Sediment Quality Guideline concentration[2]	Probable Effects Level[2]
Arsenic	4.2	5.9	17
Cadmium	1.1	.6	3.5
Chromium	31	37.3	90
Copper	25	35.7	197
Lead	23	35.0	91.3
Mercury	.10	.17	.486
Zinc	65	123	315

[1] Source: Persaud and others (1993).
[2] Source: Canadian Council of Ministers of the Environment (1999).

Table 3. Interim Sediment Quality Guideline concentrations and Probable Effects Levels for selected organic compounds in bulk freshwater sediment

[Concentrations are in milligrams per kilogram, dry weight. Source: Canadian Council of Ministers of the Environment (1999).]

Organic compound	Interim Sediment Quality Guideline concentration	Probable Effects Level
	Organochlorines	
Chlordane	4.50	8.87
DDD	3.54	8.51
DDE	1.42	6.75
DDT	1.19	4.77
Dieldrin	2.85	6.67
Total PCB’s	34.1	277
	Polycyclic aromatic hydrocarbons	
Acenaphthene	6.71	88.9
Acenaphthylene	5.87	128
Anthracene	46.9	245
Benz(a)anthracene	31.7	385
Benzo(a)pyrene	31.9	782
Chrysene	57.1	862
Dibenz(a,h)anthracene	6.22	135
Fluoranthene	111	2,355
Fluorene	21.2	144
Naphthalene	34.6	391
Phenanthrene	41.9	515
Pyrene	53	875

trations, ISQG's, and PEL's are based on bulk sediment, these criteria are compared to concentrations in fine-grained and bulk samples in this report.

Trace-element and organic-compound concentrations were used to characterize bed-sediment quality for four land-use categories (urban, forest, agricultural, or wetland) based on National Land Cover Data (U.S. Geological Survey, 1999). Sites were assigned land-use categories based on the dominant land use in the watershed (table 1). Sites were designated as urban when the percentage of urban land use exceeded 25 percent, regardless of the other land-use percentages.

TRACE ELEMENTS AND ORGANIC COMPOUNDS IN BED SEDIMENT

Bed-sediment samples were collected at 21 sites and analyzed for selected trace elements and organic compounds. Concentrations of trace elements in fine-grained sediment were determined for 21 sites and in bulk sediment for 19 sites. Concentrations of trace elements and organic compounds were compared with SQC, including background concentrations, ISQG's, and PEL's developed by the CCME for bulk-bed sediment. Concentrations of trace elements in bulk and fine-grained samples and organic compounds in bulk samples were compared with land use. Trace-element concentrations also were compared for six sites for which historic data were available.

Trace Elements

Concentrations of selected trace elements were compared with SQC, land use, using parametric and nonparametric statistical procedures, and with data from previous studies. Concentrations of selected trace elements were determined and compared for fine and bulk sediment because each size fraction represents exposure to different aquatic biota. Concentrations of trace elements in fine-grained sediment (smaller than 63 µm in diameter) may be useful in the analysis of compounds in the tissue of aquatic organisms because surficial fine-grained bed sediment (1) concentrate in depositional zones, (2) have longer residence times in the water column than coarse grains when resuspended, and therefore, have a higher potential for exposure to biota, (3) usually have higher trace-element concentration than coarse grains, and (4) may better represent sediment accumulating in receiving waterbodies such as a lake, reservoir, and estuary. Fine-grained and bulk samples were compared to SQC because (1) the NAWQA Program protocols require a fine-grained sample for trace-element analysis (Shelton and Capel, 1994); (2) concentrations determined from size-fractions that represent less than 50-70 percent of the sample may not reflect the true chemical concentrations (Horowitz, 1991; D.R. Helsel, USGS, written commun., 2001); (3) SQC were developed for bulk sediment (Canadian Council of Ministers of the Environment, 1999), and (4) concentrations of trace elements in bulk sediment represent levels of exposure for organisms that dwell in or near the benthos.

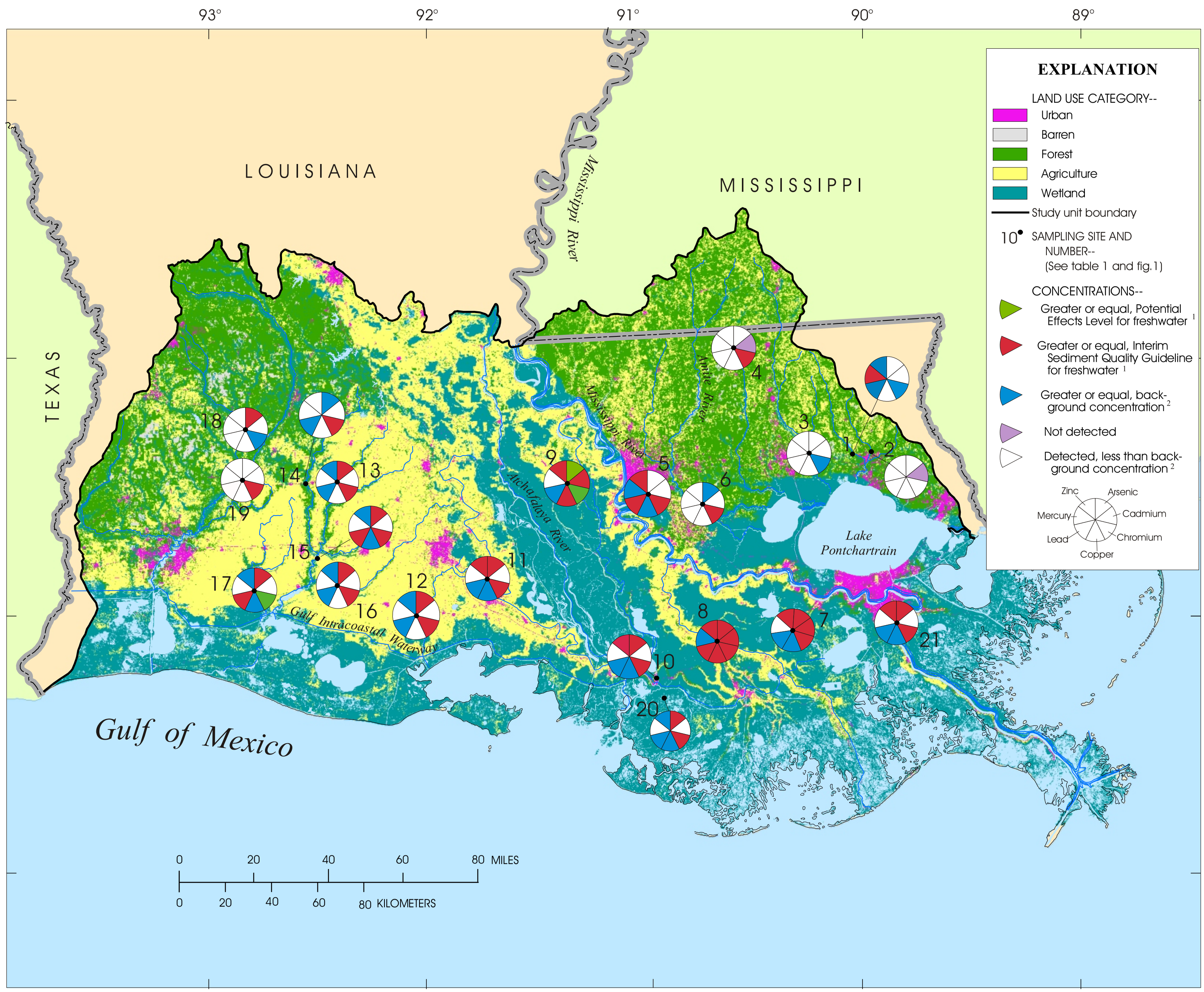
Fine-Grained Samples

Trace-element concentrations for fine-grained samples from 21 sites (fig. 2, appendix A) were compared with SQC (table 2). Seven trace elements for which SQC are available--arsenic, cadmium, chromium, copper, lead, mercury, and zinc--were evaluated with background concentrations established by Persaud and others (1993) and ISQG and PEL concentrations established by CCME (1999).

Arsenic concentrations were detected at all sites (fig. 2) and ranged from 2 µg/g (micrograms per gram) at Tchefuncte River near Covington (site 1) to 17 µg/g at Bayou Grosse Tete at Rosedale (site 9) (table 4). Arsenic concentrations for 15 sites exceeded the background concentration (4.2 µg/g), and concentrations for 13 sites exceeded the ISQG of 5.9 µg/g. The arsenic concentration for Bayou Grosse Tete at Rosedale (site 9) equaled the PEL of 17 µg/g.

Cadmium concentrations were detected at all sites except Bogue Falaya at Lee Road at Covington (site 2) and Tickfaw River at Liverpool (site 4) (fig. 2) and ranged from 0.1 µg/g at Bayou des Cannes near Eunice (site 13) and Bayou Nezpique near Basile (site 14) to 1.0 µg/g at Bayou Lafourche below weir at Thibodaux (site 8) (table 4). Only the ISQG and PEL were used to evaluate cadmium concentrations because the background concentration (1.1 µg/g) is greater than the ISQG (table 2). Concentrations for Bayou Des Allemands at Des Allemands, Bayou Lafourche below weir at Thibodaux, and Bayou Grosse Tete at Rosedale (sites 7, 8, and 9) exceeded the ISQG (0.6 µg/g) with concentrations of 0.7, 1.0, and 0.9 µg/g, respectively. No cadmium concentrations met or exceeded the PEL (3.5 µg/g).

Chromium concentrations (fig. 2) were detected at all sites and ranged from 26 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 96 µg/g at Bayou Lacassine near Lake Arthur (site 17) (table 4). Concentrations for 19 sites exceeded the background concentration (31 µg/g), and concentrations for 17 sites exceeded the ISQG (37.3 µg/g) (table 2). Chromium concentrations exceeded the PEL (90 µg/g) for Bayou Grosse Tete at Rosedale (site 9) and Bayou Lacassine near Lake Arthur (site 17) with concentrations of 95 and 96 µg/g, respectively.



[1] (Source: Canadian Council of Ministers of the Environment, 1999)
[2] (Source: Persaud and Others, 1993)

Figure 2. Land use, bed-sediment sampling sites, and concentrations of selected trace elements in fine-grained samples in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998.

Table 4. Selected trace-element concentrations and number of Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) exceedances for fine-grained and bulk bed-sediment samples collected at selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[Concentrations in color are noted as follows: blue, greater than or equal to background concentration; **red**, equals or exceeds the ISQG; purple, is less than the method reporting limit; and **green**, equals or exceeds PEL. Fine, fine-grained sample; Bulk, bulk sample; <, less than; na, not analyzed]

Site number (see fig. 1)	Site name	Number of times equalled or exceeded: ISQG Fine	ISQG Bulk	PEL Fine	PEL Bulk	Arsenic Fine[1]	Arsenic Bulk[2]	Cadmium[4] Fine[1]	Cadmium[4] Bulk[2]	Chromium Fine[1]	Chromium Bulk[2]	Copper Fine[1]	Copper Bulk[2]	Lead Fine[1]	Lead Bulk[2]	Mercury Fine[1]	Mercury Bulk[3]	Zinc Fine[1]	Zinc Bulk[2]
1	Tchefuncte River near Covington	1	0	0	0	2	0.9	0.3	0.2	**36**	11	20	3	**25**	10	**0.27**	0.02	**65**	17
2	Bogue Falaya at Lee Road at Covington	0	0	0	0	2.5	.3	**<.1**	.1	26	2	8	**<1**	22	1	.03	<.01	43	2
3	Tangipahoa River at Robert	0	0	0	0	3.3	na	.2	na	**31**	na	9	na	19	na	.04	.02	50	na
4	Tickfaw River at Liverpool	1	0	0	0	3.4	1.7	**<.1**	.1	**38**	16	14	3	19	10	.04	.02	49	19
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	3	2	0	0	3.9	3.9	.5	.2	**47**	**40**	**26**	20	**57**	**66**	**.10**	**.12**	**130**	**110**
6	Amite River at Port Vincent	1	0	0	0	**5**	3.1	.2	**<.1**	**45**	30	20	6	18	15	.03	.03	57	40
7	Bayou Des Allemands at Des Allemands	3	3	0	0	**11**	**12**	**.7**	.2	**75**	**59**	**30**	24	**34**	**66**	.07	.05	**120**	**110**
8	Bayou Lafourche below weir at Thibodaux	6	6	0	1	**15**	**16**	**1.0**	**.7**	**76**	**63**	**38**	**37**	**67**	**130**	**.15**	**.16**	**160**	**220**
9	Bayou Grosse Tete at Rosedale	5	4	2	0	**17**	**14**	**.9**	**.7**	**95**	**80**	**46**	**32**	**31**	**26**	.07	.08	**190**	**160**
10	Bayou Boeuf at Railroad Bridge at Amelia	3	3	0	0	**9.8**	**10**	.5	.1	**78**	**58**	**32**	24	**29**	**32**	.05	.05	**150**	**170**
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	3	3	0	0	**7.8**	**8.3**	.4	.5	**74**	**68**	**33**	**32**	**29**	**28**	.07	.07	**130**	**130**
12	Vermilion River at Perry	2	3	0	0	**6.6**	**7.6**	.3	**<.1**	**59**	**55**	22	21	**34**	**42**	.07	.09	**110**	**110**
13	Bayou des Cannes near Eunice	2	2	0	0	**7.2**	**8.6**	.1	**<.1**	**56**	**38**	18	10	**33**	**27**	.03	.02	**72**	42
14	Bayou Nezpique near Basile	1	0	0	0	**5.4**	**4.4**	.1	.2	**49**	27	14	5	**24**	20	.03	.02	59	26
15	Mermentau River at Mermentau	3	2	0	0	**8.9**	**8.2**	.2	.3	**83**	**71**	**27**	22	**36**	**34**	.07	**.11**	**120**	**110**
16	Bayou Que De Tortue at Riceville	2	3	0	0	**7.2**	**8.2**	.2	.4	**75**	**74**	23	21	**33**	**35**	.05	.07	**97**	**96**
17	Bayou Lacassine near Lake Arthur	3	3	1	0	**7.8**	**7.9**	.2	.3	**96**	**86**	**30**	22	**41**	**47**	.07	.07	**110**	**100**
18	Whisky Chitto Creek near Oberlin	1	na	0	0	**8.8**	na	.2	na	**34**	na	9	na	18	na	.03	<.01	48	na
19	Calcasieu River near Kinder	1	0	0	0	3.2	.5	.2	.1	**38**	4	16	1	20	7	.03	<.01	54	5
20	Turtle Bayou north of Bayou Penchant near Amelia	2	2	0	0	**6.6**	**6.7**	.3	.4	**67**	**60**	**29**	**26**	**30**	**31**	.09	.09	**110**	**100**
21	Bayou Segnette 4.6 miles south of Westwego	3	2	0	0	**9.5**	**13**	.5	**<.1**	**54**	**48**	**25**	23	**34**	**30**	.09	**.11**	**127**	**94**

Samples were analyzed by one of the following U.S. Geological Survey laboratories: [1]National Water Quality Laboratory, [2]Sediment Research Partitioning Laboratory, or [3]Wisconsin District Mercury Laboratory.

[4]ISQG concentration is less than background concentration.

Copper concentrations were detected at all sites (fig. 2) and ranged from 8 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 46 µg/g at Bayou Grosse Tete at Rosedale (site 9) (table 4). Concentrations for nine sites exceeded the background concentration (25 µg/g), and concentrations exceeded the ISQG (35.7 µg/g) (table 2) at Bayou Lafourche below weir at Thibodaux and Bayou Grosse Tete at Rosedale (sites 8 and 9). No copper concentrations met or exceeded the PEL (197 µg/g).

Lead concentrations (fig. 2) were detected at all sites and ranged from 18 µg/g at Amite River at Port Vincent and Whisky Chitto Creek near Oberlin (sites 6 and 18) to 67 µg/g at Bayou Lafourche below weir at Thibodaux (site 8) (table 4). Concentrations for 15 sites exceeded the background concentration (23 µg/g) (table 2), and concentrations for Dawson Creek at Bluebonnet Boulevard at Baton Rouge (site 5), Bayou Lafourche below weir at Thibodaux (site 8), Mermentau River at Mermentau (site 15), and Bayou Lacassine near Lake Arthur (site 17) exceeded the ISQG (35 µg/g) with concentrations of 57, 67, 36, and 41 µg/g, respectively (table 4). No lead concentrations met or exceeded the PEL (91.3 µg/g).

Mercury concentrations (fig. 2) were detected at all sites and ranged from 0.03 µg/g at Bogue Falaya at Lee Road at Covington, Amite River at Port Vincent, Bayou des Cannes near Eunice, Bayou Nezpique near Basile, Whisky Chitto Creek near Oberlin, and Calcasieu River near Kinder (sites 2, 6, 13, 14, 18, and 19) to 0.27 µg/g at Tchefuncte River near Covington (site 1) (table 4). Concentrations for Dawson Creek at Bluebonnet Boulevard at Baton Rouge (site 5) and Bayou Lafourche below weir at Thibodaux (site 8) met or exceeded the background concentration (0.10 µg/g) (table 2). The concentration for Tchefuncte River near Covington (site 1) (0.27 µg/g), exceeded the background concentration and the ISQG (0.17 µg/g). No mercury concentrations met or exceeded the PEL (0.486 µg/g).

Zinc concentrations (fig. 2) were detected at all sites and ranged from 43 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 190 µg/g at Bayou Grosse Tete at Rosedale (site 9) (table 4). Concentrations for 14 sites met or exceeded the background concentration (65 µg/g) (table 2). Concentrations for Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Lafourche below weir at Thibodaux, Bayou Grosse Tete at Rosedale, Bayou Boeuf at Railroad Bridge at Amelia, Bayou Teche at Keystone Lock and Dam near St. Martinville, and Bayou Segnette 4.6 miles south of Westwego (sites 5, 8, 9, 10, 11, and 21) exceeded the ISQG (123 µg/g) (table 4). No zinc concentrations met or exceeded the PEL (315 µg/g).

The ISQG and PEL exceedances in fine-grained sediment may be linked to land use and grain size. The ISQG was met or exceeded for arsenic at 13 sites, cadmium at 3 sites, chromium at 17 sites, copper at 2 sites, lead at 4 sites, mercury at 1 site, and zinc at 6 sites. Concentrations of seven selected trace elements occurred at or below background concentrations at Bogue Falaya at Lee Road at Covington (site 2) and Tangipahoa River at Robert (site 3). These sites drain forested areas and had the lowest percentages of fine-grained material (table 5).

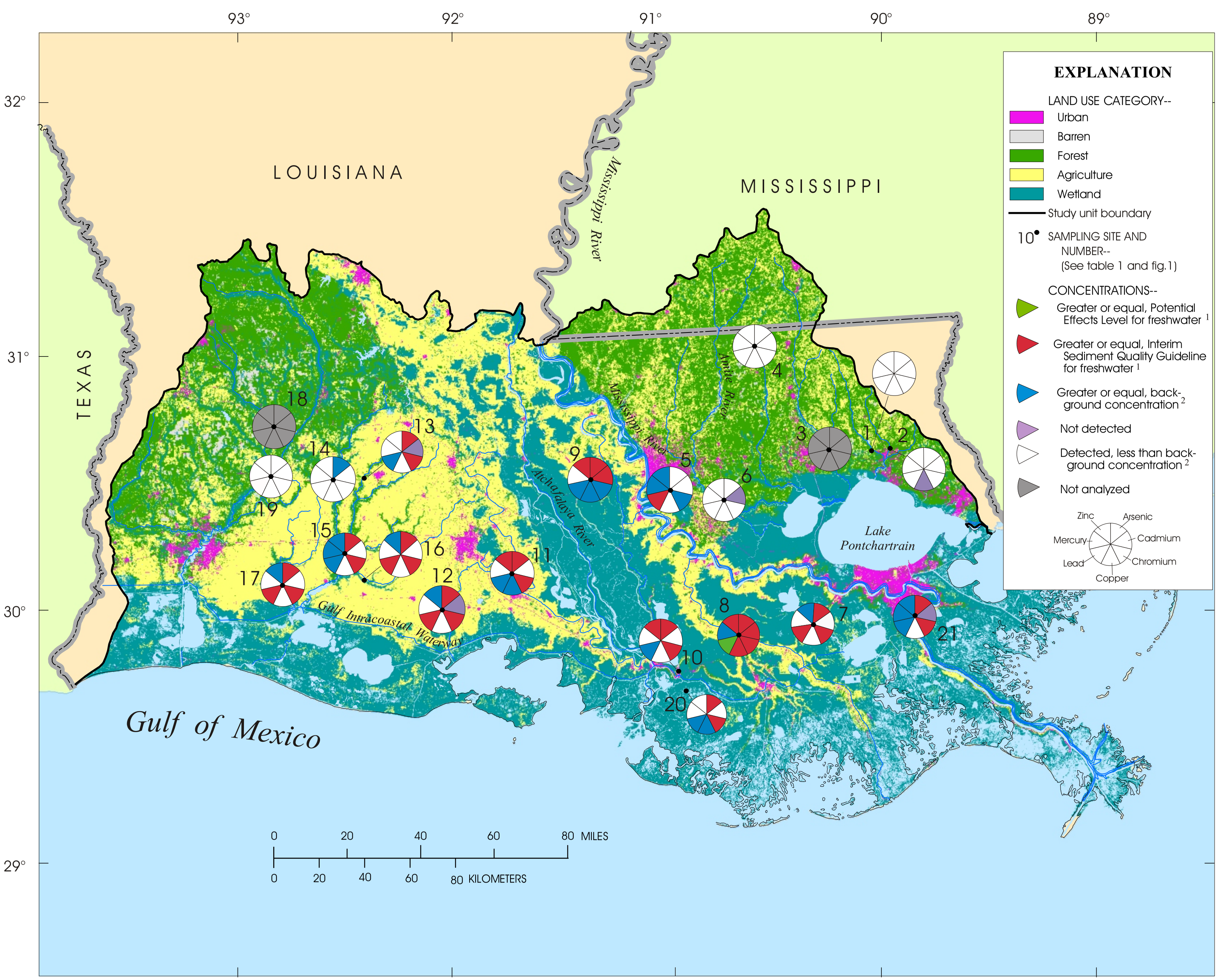
The most ISQG exceedances occurred at Bayou Lafourche below weir at Thibodaux and Bayou Grosse Tete at Rosedale (sites 8 and 9). Arsenic, cadmium, chromium, copper, lead, and zinc concentrations exceeded the ISQG at Bayou Lafourche below weir at Thibodaux (site 8). Arsenic, cadmium, chromium, copper, and zinc concentrations exceeded the ISQG, and arsenic and chromium exceeded the PEL, at Bayou Grosse Tete at Rosedale (site 9). These bayous drain areas adjacent to roads and rural residences consistent with urban settings and have soils that consist of sandy and clayey alluvium.

Bulk Samples

Trace-element concentrations for bulk samples from 19 sites (fig. 3, appendix B) were evaluated with SQC (table 2). Seven trace elements for which SQC are available--arsenic, cadmium, chromium, copper, lead, mercury, and zinc--were compared with background concentrations established by Persaud and others (1993) and ISQG and PEL concentrations established by CCME (1999) (table 2).

Arsenic concentrations (fig. 3) were detected at all sites and ranged from 0.3 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 16 µg/g at Bayou Lafourche below weir at Thibodaux (site 8) (table 4). Concentrations for 13 sites exceeded the background concentration (4.2 µg/g) and for 12 sites exceeded the ISQG (5.9 µg/g) (table 2). No arsenic concentrations met or exceeded the PEL (17 µg/g).

Cadmium concentrations (fig. 3) were detected at 15 sites and ranged from less than 0.1 µg/g at Amite River at Port Vincent, Vermilion River at Perry, Bayou des Cannes near Eunice, and Bayou Segnette 4.6 miles south of Westwego (sites 6, 12, 13, and 21) to 0.7 µg/g at Bayou Lafourche below weir at Thibodaux and Bayou Grosse Tete at Rosedale (sites 8 and 9) (table 4). Concentrations at Bayou Lafourche below weir at Thibodaux and Bayou Grosse Tete at Rosedale exceeded the ISQG (0.6 µg/g, table 2). No cadmium concentrations met or exceeded the PEL (3.5 µg/g).



[1] (Source: Canadian Council of Ministers of the Environment, 1999)
[2] (Source: Persaud and Others, 1993)

Figure 3. Land use, bed-sediment sampling sites, and concentrations of selected trace elements in bulk samples in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998.

Table 5. Percent fine-grained material, iron, and total organic carbon and manganese concentrations for bed-sediment sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[fine, fine-grained; µg/g, micrograms per gram; na, not available]

Site number (see fig. 1)	Site name	Land-use category	Percent fine-grained material	Percent iron		Percent total organic carbon		Manganese (µg/g)	
				Fine	Bulk	Fine	Bulk	Fine	Bulk
1	Tchefuncte River near Covington	Forest	28.7	1.0	0.4	1.9	0.7	250	120
2	Bogue Falaya at Lee Road at Covington	Forest	1.8	.92	.1	1.3	.1	190	19
3	Tangipahoa River at Robert	Forest	3.2	1.4	na	1.4	na	770	na
4	Tickfaw River at Liverpool	Forest	8.7	1.3	.6	1.5	1.3	1,200	620
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	Urban	86.6	2.0	1.7	.8	1.6	300	330
6	Amite River at Port Vincent	Forest	67.8	1.6	1.3	.8	.7	930	570
7	Bayou Des Allemands at Des Allemands	Wetland	93.6	4.1	3.8	5.7	5.9	1,000	1,100
8	Bayou Lafourche below weir at Thibodaux	Urban	78.8	3.4	2.9	1.7	2.7	640	610
9	Bayou Grosse Tete at Rosedale	Agriculture	93.6	4.9	4.3	2.1	2.7	570	660
10	Bayou Boeuf at Railroad Bridge at Amelia	Wetland	86.4	3.8	3.2	1.9	1.7	890	860
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	Agriculture	98.6	3.5	3.4	1.8	2.0	530	610
12	Vermilion River at Perry	Agriculture	93.2	2.4	2.6	1.4	1.8	440	580
13	Bayou des Cannes near Eunice	Agriculture	25.8	2.7	2.2	.7	.6	830	840
14	Bayou Nezpique near Basile	Forest	57.0	2.2	1.3	1.1	.6	780	440
15	Mermentau River at Mermentau	Agriculture	96.8	4.0	3.5	2.3	2.6	820	830
16	Bayou Que De Tortue at Riceville	Agriculture	99.4	3.3	3.3	1.9	2.3	480	580
17	Bayou Lacassine near Lake Arthur	Agriculture	99.2	4.0	3.6	2.9	3.1	490	490
18	Whisky Chitto Creek near Oberlin	Forest	16.1	2.9	na	2.3	na	730	na
19	Calcasieu River near Kinder	Forest	3.7	1.6	.1	1.3	.1	830	160
20	Turtle Bayou north of Bayou Penchant near Amelia	Wetland	99.4	3.3	3.1	14.0	16.2	560	580
21	Bayou Segnette 4.6 miles south of Westwego	Urban	94.6	3.0	3.0	8.1	11.2	700	850

Chromium concentrations (fig. 3) were detected at all sites and ranged from 2 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 86 µg/g at Bayou Lacassine near Lake Arthur (site 17). Chromium concentrations for 13 sites (table 4) exceeded the background concentration (31 µg/g) and the ISQG (37.3 µg/g) (table 2). No chromium concentrations met or exceeded the PEL (90 µg/g).

Copper concentrations (fig. 3) were detected at 18 sites and ranged from less than 1 µg/g at Bogue Falaya at Lee Road at Covington (site 2) (table 4) to 37 µg/g at Bayou Lafourche below weir at Thibodaux (site 8). Copper concentrations exceeded the background concentration (25 µg/g) at Bayou Lafourche below weir at Thibodaux, Bayou Grosse Tete at Rosedale, Bayou Teche at Keystone Lock and Dam near St. Martinville, and Turtle Bayou north of Bayou Penchant near Amelia (sites 8, 9, 11, and 20). The copper concentration at Bayou Lafourche below weir at Thibodaux (site 8) exceeded the ISQG (35.7 µg/g) (table 2), and no copper concentrations met or exceeded the PEL (197 µg/g).

Lead concentrations (fig. 3) were detected at all sites and ranged from 1 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 130 µg/g at Bayou Lafourche below weir at Thibodaux (site 8) (table 4). Lead concentrations for 13 sites exceeded the background concentration (23 µg/g), and concentrations for Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Des Allemands at Des Allemands, Bayou Lafourche below weir at Thibodaux, Vermilion River at Perry, Bayou Que de Tortue at Riceville, and Bayou Lacassine near Lake Arthur (sites 5, 7, 8, 12, 16, and 17) met or exceeded the ISQG (35 µg/g) (table 2). The lead concentration for Bayou Lafourche below weir at Thibodaux (site 8) exceeded the PEL (91.3 µg/g).

Mercury concentrations (fig. 3) were detected at all sites (table 4) and ranged from less than 0.1 µg/g at Bogue Falaya at Lee Road at Covington, Whisky Chitto Creek near Oberlin, and Calcasieu River near Kinder (sites 2, 18, and 19), to 0.16 µg/g at Bayou Lafourche below weir at Thibodaux (site 8). Concentrations for Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Lafourche below weir at Thibodaux, Mermentau River at Mermentau, and Bayou Segnette 4.6 miles south of Westwego (sites 5, 8, 15, and 21) exceeded the background concentration (0.10 µg/g). No concentrations met or exceeded the ISQG (0.17 µg/g) or PEL (0.486 µg/g) for mercury.

Zinc concentrations (fig. 3) were detected at all sites and ranged from 2 µg/g at Bogue Falaya at Lee Road at Covington (site 2) to 220 µg/g at Bayou Lafourche below weir at Thibodaux (site 8) (table 4). Concentrations for 12 sites exceeded the background concentration (65 µg/g), and concentrations for Bayou Lafourche below weir at Thibodaux, Bayou Grosse Tete at Rosedale, Bayou Boeuf at Railroad Bridge at Amelia, and Bayou Teche at Keystone Lock and Dam near St. Martinville (sites 8, 9, 10, and 11) exceeded the ISQG (123 µg/g) (table 2). No zinc concentrations met or exceeded the PEL (315 µg/g).

ISQG and PEL exceedances in bulk samples may be linked to land use and grain size. The ISQG for arsenic was met or exceeded at 12 sites, cadmium at 2 sites, chromium at 13 sites, copper at 1 site, lead at 5 sites, and zinc at 4 sites. Concentrations of seven selected trace elements occurred below background concentrations at the Tchefuncte River near Covington, Bogue Falaya at Lee Road at Covington, Tickfaw River at Liverpool, Amite River at Port Vincent, and Calcasieu River near Kinder (sites 1, 2, 4, 6, and 19). The forested drainage areas for these sites contain sandy and thick loess soils in forested areas (fig. 3), and, except for Amite River at Port Vincent, bed sediment had less than 30 percent fine-grained material (table 5). Concentrations of arsenic, cadmium, chromium, copper, lead, and zinc exceeded the ISQG or PEL at Bayou Lafourche below weir at Thibodaux. Concentrations of arsenic, cadmium, chromium, and zinc exceeded the ISQG or PEL at Bayou Grosse Tete at Rosedale (site 9).

Relation of Physio-Chemical Factors to Sediment-Quality Criteria

Concentrations of selected trace elements in fine-grained and bulk samples were compared with concentrations of total carbon, total organic carbon, and SQC, and tested for significant differences. Concentrations also were compared with each other and land use. Percentages of fine-grained material, iron, and total organic carbon, and manganese concentrations in fine-grained samples were compared to those in bulk samples. Horowitz (1991) discussed iron and manganese oxide coating and their importance as trace-element concentrators and described the dual role of organic matter in sediment trace-element chemistry. Organic coatings on fine-grained material may concentrate trace elements at the molecular level; for example, organic compounds may coat a silt particle and attract trace elements. Organic matter functions as a trace-element diluent at the particulate level; for example, partially-decomposed vegetation may trap trace elements.

Total Organic Carbon

Sites with percentages of fine-grained material less than 70 percent had higher total organic carbon (TOC) percentages in fine-grained samples than bulk samples (table 5). With the exception of wetlands, TOC percentages generally increased with respect to land use intensity. Percent TOC minima and maxima in each land-use category for bulk samples, and maxima for fine samples, increased in the following order of land use: forest, agriculture, urban, and wetland. High TOC percentages in wetlands (table 5) probably result from deposition of detritus common to wetlands and from sediment in receiving waters.

Sediment-Quality Criteria

More ISQG exceedances occurred in fine-grained samples than bulk samples. Of 133 paired samples for which ISQG criteria are available, 69 percent of the concentrations were greater in fine-grained samples; 23 percent of the concentrations were greater in bulk samples; and 8 percent of the concentrations were similar. Concentrations exceeding ISQG's were most common for arsenic and chromium. The ISQG for arsenic, cadmium, chromium, copper, lead, and zinc was exceeded in both fine-grained and bulk samples at least once. Although trace-element concentrations were usually higher in fine-grained samples than in bulk samples, lead concentrations in the bulk samples for Bayou Lafourche below weir at Thibodaux (site 8) and Bayou Des Allemands at Des Allemands (site 7) were almost twice the concentration in the fine-grained sample. Arsenic, chromium, lead, mercury, and zinc concentrations were detected in all bulk and fine-grained samples; copper was detected in all fine-grained samples.

Trace-element concentrations and exceedances of ISQG's may be linked to land use, grain size, and trace elements concentrators such as iron and manganese (as grain coating of hydrous iron and manganese oxides) and organic matter (table 5). Fewer ISQG exceedances occurred in forested areas than in other land-use types. Forested sites have relatively low iron (less than three percent) and fine-grained percentages (less than 70 percent) (table 5). Low manganese concentrations and low percentages of iron, total organic carbon, and fine-grained material may limit the concentration of other trace elements (Horowitz, 1991). Bogue Falaya at Lee Road at Covington, Tangipahoa River at Robert, and Calcasieu River near Kinder (sites 2, 3, and 19) had no ISQG exceedances in fine-grained or bulk samples and had less than 3.5 percent fine-grained material. Sites with three or more ISQG exceedances in fine-grained or bulk samples have more than 78 percent fine-grained material, drain wetlands, agricultural and urban areas, and may result from the cumulative effects of relatively high percentages of fine-grained material, grain coatings such as hydrous iron and manganese oxide, and organic material (Horowitz and others, 1989). Manganese coatings probably are not a substantial concentrator of trace elements in forested areas of the ACAD Study Unit. The highest and lowest manganese concentrations, for both fine-grained and bulk bed-sediment samples in all land-use categories, occurred in forested areas. Detected manganese concentrations ranged between 190 and 1,200 μg/g (micrograms per gram) in fine-grained samples and between 120 and 19 μg/g in bulk samples.

More PEL exceedances occurred for fine-grained samples than for bulk samples, but the concentrations in fine-grained samples did not always exceed that of bulk samples. PEL's were met or exceeded in fine-grained samples at Bayou Grosse Tete at Rosedale (site 9) for arsenic and chromium, and at Bayou Lacassine near Lake Arthur (site 17) for chromium. Although the lead concentration in the bulk sample at Bayou Lafourche below weir at Thibodaux (site 8) exceeded the PEL, the concentration in the fine-grained sample was less than the PEL but exceeded the ISQG. Bayou Lafourche below weir at Thibodaux and Bayou Grosse Tete at Rosedale (site 9) drain areas with rural residences immediately adjacent to the receiving water body; Bayou Lafourche below weir at Thibodaux also receives water and suspended sediment from the Mississippi River (fig. 2).

Differences Between Fine-grained and Bulk Samples

Results from statistical procedures indicate concentrations of some trace elements are significantly different in fine-grained and bulk samples (table 6). Parametric and nonparametric statistical procedures were used to compare concentrations of 21 trace elements, total organic carbon, and total carbon in fine-grained and bulk bed-sediment samples. The Shapiro-Wilk procedure (with alpha at 0.05) was used to test sample data for normality. If the normality assumption was accepted, a parametric two-tailed paired t-test (with alpha at 0.05) was used to compare sample groups for significance of difference. If the normality assumption was rejected, the Wilcoxon rank sum procedure (with alpha at 0.05) was used to compare sample groups for significance of difference. Concentrations of 21 trace elements, total organic carbon, and total carbon for 19 sites and mercury for 21 sites were compared for fine-grained and bulk samples. Results from the statistical procedures indicate no significant differences between sample groups for antimony, arsenic, cadmium, cobalt, lead, manganese, mercury, strontium, vanadium, total organic carbon, and total carbon. Statistical results indicate significant differences between sample groups for aluminum, barium, beryllium, chromium, copper, iron, lithium, nickel, phosphorus, selenium, titanium, and zinc.

Table 6. P-values for statistical procedures used to compare concentrations of selected trace-elements and total organic carbon in fine-grained and bulk bed-sediment samples

[Shapiro-Wilk values in bold indicate the Wilcoxon rank sum procedure was used to determine significance of difference. Paired t-test and Wilcoxon rank sum values in bold indicate significance of difference. alpha=0.05; Y, yes; N, no]

Constituent	Accepted normal	P-value (0.05)			Fine and bulk samples significantly different
		Shapiro-Wilk	Paired t-test	Wilcoxon rank sum	
Aluminum	Y	0.0529	**0.0004**	**0.0020**	Y
Antimony	N	**.0001**	.3255	.3303	N
Arsenic	Y	.5688	.5531	.6168	N
Barium	N	**.0001**	.1174	**.0001**	Y
Beryllium	Y	.5885	**.0006**	**.0044**	Y
Cadmium	Y	.1654	.0805	.1150	N
Chromium	Y	.7527	**.0001**	**.0001**	Y
Cobalt	N	**.0014**	.0984	.1265	N
Copper	Y	.1463	**.0001**	**.0001**	Y
Iron	Y	.3838	**.0001**	**.0001**	Y
Lead	N	**.0002**	.6162	.6577	N
Lithium	Y	.2628	**.0001**	**.0001**	Y
Manganese	N	**.0013**	.1459	.5154	N
Mercury	N	**.0001**	.5154	.8420	N
Nickel	Y	.2044	**.0040**	**.0040**	Y
Phosphorus	Y	.2812	**.0001**	**.0001**	Y
Selenium	Y	.3308	**.0001**	**.0010**	Y
Strontium	Y	.3031	.3752	.3978	N
Titanium	Y	.1706	**.0095**	**.0086**	Y
Vanadium	Y	.7126	.5331	.5572	N
Zinc	N	**.0376**	**.0172**	**.0115**	Y
Total organic carbon	N	**.0001**	.5939	.5301	N
Total carbon	N	**.0001**	.8403	.8495	N

Results from the statistical procedures indicate that the purpose for which bed-sediment data are to be used may influence the type of sample, fine or bulk, to be collected for trace-element analysis in future studies. Trace-element concentrations determined from fine-grained or bulk samples may be acceptable, if no significant differences exist between sample types. For example, aluminum concentrations were determined to be significantly different, and concentrations may be different depending upon the sample type collected, but sample type may not be relevant for antimony concentrations.

Historic Comparisons

Temporal and spatial trends in bed-sediment trace-element concentrations were difficult to discern, because data are limited and errors are associated with sampling and analytical accuracy. Only six sites with historic data and concentrations for 11 trace elements are common to this study and available for comparison (table 7). McGee and Demcheck (1995) studied trace element concentrations and estimated background concentrations, using stepwise regression, in bed sediment for Tickfaw River at Liverpool, Bayou Lafourche below weir at Thibodaux, and Vermilion River at Perry (sites 4, 8, and 12). Demcheck (1994) studied trace-element concentrations in bed sediment for Bayou des Cannes near Eunice, Mermentau River at Mermentau, and Bayou Lacassine near Lake Arthur (sites 13, 15, and 17). Concentrations for both studies were determined at SPRL with similar methods. Concentrations of antimony, arsenic, cadmium, chromium, cobalt, copper, lead, mercury, nickel, selenium, and zinc were compared for these sites (table 7). Analytical accuracy for trace elements in bulk samples is plus or minus 10 percent, and sampling error may be greater than analytical accuracy (Horowitz, 1991; A.J. Horowitz, U.S. Geological Survey, oral commun., 2001). Because trace-element concentrations may vary within a sample, concentrations were considered different if the concentration for this study differed by more than 20 percent with the concentration for the previous study (A.J. Horowitz, U.S. Geological Survey, oral commun., 2001).

No trace element had a significant increase or decrease throughout the study unit, although increases or decreases greater than 20 percent were observed for specific sites. Antimony concentrations more than quadrupled at Bayou Lafourche below weir at Thibodaux (site 8). Arsenic concentrations increased by more than 20 percent at Tickfaw River at Liverpool, Mermentau River at Mermentau, and Bayou Lacassine near Lake Arthur (sites 4, 15, and 17). Chromium concentrations increased by more than 20 percent at Tickfaw River at Liverpool. Lead concentrations increased at Tickfaw River at Liverpool and Vermilion River at Perry (site 12), and more than doubled at Bayou Lafourche below weir at Thibodaux. Zinc concentrations more than tripled at Tickfaw River at Liverpool and increased at Bayou Lafourche below weir at Thibodaux. Chromium concentrations decreased by more than 20 percent at Bayou des Cannes near Eunice. Mercury concentrations decreased at Mermentau River at Mermentau, and zinc concentrations decreased at Bayou des Cannes near Eunice (site 13).

Trends in trace-element concentrations probably are caused by changes in land and water use. Changes in antimony, arsenic, and lead concentrations may result from ammunition used in waterfowl hunting activities (Weast, 1983). Increases in arsenic at Mermentau River at Mermentau (site 15) and Bayou Lacassine near Lake Arthur (site 17) may be from industrial and petrochemical support activities. The drainage area for Bayou Lafourche near Thibodaux (site 8) is 4.2 square miles (table 1). Flow for this site is maintained by diverting 200 to 300 cubic feet per second from the Mississippi River (Goree and others, 2000, p. 296). Thus, Bayou Lafourche receives water from both a small basin as well as 1.25 million square miles of the Mississippi River Basin. Differences in trace-element concentrations may be attributed to dilution or concentration effects caused by the source water diversion or activities in the basin associated with land use.

Organic Compounds

Bed-sediment samples collected from 21 sites were analyzed for 111 organic compounds. Concentrations of 6 organochlorines and 12 polycyclic aromatic hydrocarbons (PAH's) (table 8) were compared with SQC (ISQG's and PEL's) (table 3). Endrin, heptachlor epoxide, lindane, and toxaphene were not detected in any of the samples. Tangipahoa River near Robert, Tickfaw River at Liverpool, and Whisky Chitto Creek near Oberlin (sites 3, 4, and 18) drain forested areas and had no detectable concentrations of organic compounds for which SQC are available. No ISQG exceedances occurred at Tchefuncte River at Covington, Bogue Falaya at Lee Road at Covington, Amite River at Port Vincent, Bayou Nezpique near Basile, and Calcasieu River near Kinder (sites 1, 2, 6, 14, and 19), which drain forested areas, and Bayou Que De Tortue at Riceville and Bayou Lacassine near Lake Arthur (sites 16 and 17), which drain agricultural areas.

Of the 130 detected concentrations, 72 exceeded ISQG's at 11 sites, and 12 concentrations exceeded PEL's at 5 sites. All PEL exceedances occurred at sites with seven or more ISQG exceedances: Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Lafourche below weir at Thibodaux, Bayou Boeuf at Railroad Bridge at Amelia, Bayou Teche at Keystone Lock and Dam near St. Martinville, and Vermilion River at Perry (sites 5, 8, 10, 11, and 12). The most

Table 7. Comparison of historic and 1998 data for selected trace-element concentrations in bed sediment from selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana

[Concentrations are in micrograms per gram. Value in bold differs by more than 20 percent of the 1998 concentration. na, not analyzed; <, less than]

Site number (see fig. 1)	Site name	Antimony		Arsenic		Cadmium		Chromium		Cobalt	
		Historic	1998	Historic	1998	Historic	1998	Historic	1998	Historic	1998
4	Tickfaw River at Liverpool[1]	**0.1**	**0.3**	**0.7**	**1.7**	na	0.1	**3**	**16**	**3**	**5**
8	Bayou Lafourche below weir at Thibodaux[1]	**.8**	**4.0**	16	16	na	.7	70	63	13	11
12	Vermilion River at Perry[1]	**.5**	**.9**	7.2	7.6	na	<.1	49	55	9	10
13	Bayou des Cannes near Eunice[2]	.8	.8	9.5	8.6	<0.5	<.1	**50**	**38**	12	11
15	Mermentau River at Mermentau[2]	.9	1.0	**5**	**8.2**	**<.5**	**.3**	77	71	13	13
17	Bayou Lacassine near Lake Arthur[2]	1.1	1.1	**5.3**	**7.9**	**<.5**	**.3**	93	86	14	17

Site number (see fig. 1)	Site name	Copper		Lead		Mercury		Nickel		Selenium		Zinc	
		Historic	1998	Historic	1998	Historic	1998	Historic	1998	Historic	1998	Historic	1998
4	Tickfaw River at Liverpool[1]	3	3	**5**	**10**	0.02	0.02	**3**	**7**	0.2	0.2	**6**	**19**
8	Bayou Lafourche below weir at Thibodaux[1]	31	37	**50**	**130**	.09	.10	**35**	**28**	**.9**	**.6**	**153**	**220**
12	Vermilion River at Perry[1]	23	21	**25**	**42**	**.06**	**.04**	23	23	**.4**	**.3**	117	110
13	Bayou des Cannes near Eunice[2]	**15**	**10**	31	27	.03	.03	15	16	**.3**	**.1**	**52**	**42**
15	Mermentau River at Mermentau[2]	23	22	34	34	**.17**	**.11**	24	28	.6	.5	105	110
17	Bayou Lacassine near Lake Arthur[2]	22	22	46	47	.10	.09	27	31	.7	.6	105	100

[1]Historic data from McGee and Demcheck (1995).

[2]Historic data from Demcheck (1994).

ISQG exceedances occurred at sites on streams draining urban areas, Dawson Creek at Bluebonnet Boulevard at Baton Rouge and Bayou Lafourche below weir at Thibodaux. The most PEL exceedances occurred at a site draining an urban area, Bayou Lafourche below weir at Thibodaux, and a site draining wetlands where support for petrochemical and marine activities occur, Bayou Boeuf at Railroad Bridge at Amelia.

Organochlorines

Organochlorine compounds, especially DDT and polychlorinated biphenyls (PCB's), have gained public awareness because they are persistent, hydrophobic, and concentrate in biota. In this report, the terms DDT, DDD, and DDE refer to the sum of $o'p'$ and $p'p'$ isomers; the term total DDT refers to DDT and all metabolites; and the term total chlordane refers to the sum of all chlordane metabolites (CIS- and trans-chlordane, and CIS- and trans-nonachlor). Nowell and others (1999) found detectable concentrations of organochlorine compounds in bed sediment may not be indicative of recent application, but may be the result of recent erosion or disturbance of contaminated soils associated with agricultural practices and urban activities. According to Nowell and others (1999), ratios of DDT to total DDT greater than 10 percent indicate DDT-contaminated soils have recently entered the hydrologic system.

Organochlorine compounds were detected at 10 sites and compared with ISQG's and PEL's. Detections occurred most frequently at Bayou Lafourche below weir at Thibodaux (site 8). Dieldrin concentrations were detected at Dawson Creek at Bluebonnet Boulevard at Baton Rouge (site 5) and Bayou Lafourche below weir at Thibodaux, but did not exceed the ISQG. Concentrations of DDD were detected at five sites and exceeded the ISQG only at Bayou Lafourche below weir at Thibodaux. Concentrations of DDE were detected at 9 sites and exceeded the ISQG at 7 sites. The PEL for DDE was exceeded at Bayou Teche at Keystone Lock and Dam near St. Martinville (site 6) and Vermilion River at Perry (site 12). DDT only was detected at Bayou Lafourche below weir at Thibodaux and the concentration exceeded the ISQG. The ratio of DDT to total DDT was 25 percent and indicates possible disturbance or recent erosion of DDT-contaminated soil. Total chlordane concentrations were detected at four sites; concentrations at Dawson Creek at Bluebonnet Boulevard at Baton Rouge and Bayou Lafourche below weir at Thibodaux exceeded the PEL. PCB's were detected at Bayou Lafourche below weir at Thibodaux and exceeded the ISQG.

Polycyclic Aromatic Hydrocarbons

Concentrations of 12 PAH's were detected at 18 sites and compared with ISQG's and PEL's. Exceedances occurred most frequently at Bayou Lafourche below weir at Thibodaux (site 8). Anthracene concentrations were detected at more than one-half the sites, and benz(*a*)anthracene, chrysene, fluoranthene, and pyrene concentrations exceeded the ISQG's in samples collected from at least one-third of the sites. More than eight ISQG's were exceeded at sites on Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Lafourche below weir at Thibodaux, Bayou Boeuf at Railroad Bridge at Amelia, Bayou Teche at Keystone Lock and Dam near St. Martinville, and Vermilion River at Perry (sites 5, 8, 10, 11, and 12). Benz(*a*)anthracene, acenaphthene, anthracene, phenanthrene, and pyrene account for all PEL exceedances in PAH's. The PEL's for benz(*a*)anthracene and phenanthrene were exceeded at Bayou Lafourche below weir at Thibodaux (site 8) and Bayou Boeuf at Railroad Bridge at Amelia (site 10), for acenaphthene and anthracene at Bayou Boeuf at Railroad Bridge at Amelia, and for pyrene at Bayou Lafourche below weir at Thibodaux.

Anthropogenic organic compounds in the environment are the direct result of human activity and dominant land use. Organic compounds were not detected at three forested sites--Tangipahoa River at Robert (site 3), Tickfaw River at Liverpool (site 4), and Whisky Chitto Creek near Oberlin (site 18). The highest concentrations of organic compounds occurred at sites on streams that drain areas of land use characterized by intense human activity. Bayou Lafourche below weir at Thibodaux (site 8) drains mostly urban land, and Bayou Boeuf at Railroad Bridge at Amelia (site 10) is in a tidally-affected area that supports petrochemical and marine transport activities. Bayou Teche at Keystone Lock and Dam near St. Martinville (site 11) and Vermilion River at Perry (site 12) drain mostly agricultural land. Dawson Creek at Bluebonnet Boulevard at Baton Rouge (site 5) drains urban land, had 10 ISQG exceedances of organic compounds, and is entirely within the drainage area of the Amite River at Port Vincent (site 6), which drains mostly forested land and had no ISQG exceedances. Organic compounds detected at Dawson Creek at Bluebonnet Boulevard at Baton Rouge may be assimilated by fish or algae, metabolized by bacteria, diluted, or chemically bound to trapped sediment or sediment that have not yet been transported and, therefore, not yet detected at Amite River at Port Vincent.

Table 8. Selected organic compounds and number of Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) exceedances for bed-sediment samples collected at selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[Concentrations in color are noted as follows: purple, is less than the method reporting limit; **green,** meets or exceeds PEL; and **red,** meets or exceeds the ISQG. E, estimated; M, presence of material verified but not quantified; <, less than; na, not analyzed]

Site number (see fig. 1)	Site name	Number of times equaled or exceeded		Concentration, in micrograms per gram							
		ISQG	PEL	Total chlordane	DDD	DDE	DDT	Dieldrin	Total PCB's	Pyrene	Benzo(*a*) pyrene
1	Tchefuncte River near Covington	0	0	2.6	<1	<1	<1	<1	<50	E20	E30
2	Bogue Falaya at Lee Road at Covington	0	0	<1	<1	<1	<1	<1	<50	<50	<50
3	Tangipahoa River at Robert	0	0	<1	<1	<1	<1	<1	<50	<50	<50
4	Tickfaw River at Liverpool	0	0	<1	<1	<1	<1	<1	<50	<50	<50
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	12	1	28.2	3	2.6	<1	1.3	<50	240	110
6	Amite River at Port Vincent	0	0	<1	<1	<1	<1	<1	<50	E20	E10
7	Bayou Des Allemands at Des Allemands	5	0	<1	<1	0.4	<1	<1	<50	110	E50
8	Bayou Lafourche below weir at Thibodaux	17	5	27.5	6.5	4.3	3.6	1.8	70	1,200	640
9	Bayou Grosse Tete at Rosedale	1	0	<1	1.3	3.4	<1	<1	<50	E10	<50
10	Bayou Boeuf at Railroad Bridge at Amelia	11	4	<1	<1	<1	<1	<1	<50	780	320
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	9	1	<1	<1	20	<1	<1	<50	570	60
12	Vermilion River at Perry	9	1	1.3	2.9	17	<1	<1	<50	240	50
13	Bayou des Cannes near Eunice	1	0	<1	1.8	4.6	<1	<1	<50	50	E20
14	Bayou Nezpique near Basile	0	0	<1	<1	<1	<1	<1	<50	E10	<50
15	Mermentau River at Mermentau	2	0	<1	<1	2	<1	<2	<100	60	<50
16	Bayou Que De Tortue at Riceville	0	0	<1	<1	<1	<1	<1	<50	E10	<50
17	Bayou Lacassine near Lake Arthur	0	0	<1	<1	1.2	<1	<1	<50	E40	<50
18	Whisky Chitto Creek near Oberlin	0	0	<1	<1	<1	<1	<1	<50	<50	<50
19	Calcasieu River near Kinder	0	0	<1	<1	<1	<1	<1	<50	M	<50
20	Turtle Bayou north of Bayou Penchant near Amelia	3	0	<1	<1	<1	<1	<6	<300	90	E50
21	Bayou Segnette 4.6 miles south of Westwego	3	0	<1	<1	<1	<1	<2	<100	140	<50

Table 8. Selected organic compounds and number of Interim Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) exceedances for bed-sediment samples collected at selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Concentration, in micrograms per gram									
	Fluorene	Naph-thalene	Phenanthrene	Acenaphthylene	Acenaphthene	Anthracene	Benz(*a*)anthracene	Chrysene	Dibenz(*a*,*h*)anthracene	Fluoran-thene
1	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	E20	E10	**<50**	na
2	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	E20
3	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**
4	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**
5	**<50**	**<50**	**130**	**E20**	**E20**	**60**	**120**	**150**	**E30**	**280**
6	**<50**	**<50**	M	**<50**	**<50**	M	E10	E10	**<50**	na
7	**<50**	E10	E40	**<50**	**<50**	M	**E50**	**E60**	**<50**	**130**
8	**90**	**90**	**880**	**70**	**90**	**200**	**540**	**640**	**100**	**1,200**
9	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	E40
10	**140**	<100	**770**	**50**	**120**	**320**	**470**	**480**	**60**	**960**
11	**60**	E20	**170**	**<50**	**E20**	E40	**150**	**170**	**<50**	**820**
12	**E50**	E10	**260**	**<50**	**50**	E20	**70**	**80**	**<50**	**280**
13	**<50**	**<50**	E20	**<50**	**<50**	E10	E20	E20	**<50**	70
14	**<50**	**<50**	E1.5	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	E30
15	**<50**	**<50**	M	**<50**	**<50**	E10	E30	E30	**<50**	90
16	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	E20
17	**<50**	**<50**	**<50**	**<50**	**<50**	E20	E20	E20	**<50**	E30
18	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**
19	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**
20	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**<50**	**170**
21	E10	**<50**	**<50**	**<50**	**<50**	<E40	E30	**E60**	**<100**	**150**

SUMMARY AND CONCLUSIONS

Concentrations of selected trace elements and organic compounds were determined for bed-sediment samples collected during 1998 at 21 sites in the Acadian-Pontchartrain Study Unit in southern Louisiana. Concentrations of selected trace elements and organic compounds were compared with background concentrations, Interim Sediment Quality Guidelines (ISQG's), Probable Effects Levels (PEL's), land use, and grain size. Parametric and nonparametric statistical procedures were used to compare trace-element concentrations in fine-grained and bulk samples. Fine-grained and bulk samples were compared to sediment-quality criteria (SQC) because (1) the National Water-Quality Assessment Program protocols require a fine-grained sample for trace elements analysis; (2) concentrations determined from size-fractions that represent less than 50-70 percent of the sample may not reflect the true chemical concentrations; (3) SQC were developed for bulk sediment, and (4) concentrations of trace elements in bulk sediment represent levels of exposure for organisms that dwell in or near the benthos. Concentrations of selected trace elements and organic compounds were compared with land use, and concentrations of selected trace elements were compared with historic values for selected sites.

Grain size, geochemical characteristics, and land use influence bed-sediment quality. More ISQG exceedances for trace elements occurred in fine-grained samples than in bulk samples, and fewer ISQG exceedances occurred at sites with low percentages of iron and organic carbon and at sites on streams draining forested areas. The most ISQG exceedances for trace elements occurred at Bayou Lafourche below weir at Thibodaux. Exceedance of ISQG's occurred most frequently for arsenic and chromium. No ISQG exceedances were reported for organic compounds at eight sites on streams draining forested areas and two sites on streams draining agricultural areas. Total PEL exceedances for trace elements and organic compounds occurred most at one agricultural site, Bayou Grosse Tete at Rosedale, and one urban site, Bayou Lafourche below weir at Thibodaux, and may result from several mechanisms, including land use and relatively high percentages of fine-grained material, iron, and organic material.

Shapiro-Wilk, paired t-test, and Wilcoxon rank sum statistical procedures, with an alpha of 0.05, were used to compare concentrations of 21 trace elements, total organic carbon, and total carbon in fine-grained and bulk sediment samples for 19 sites. Although results from statistical comparisons of fine-grained and bulk samples indicate significant differences for 12 trace elements, concentrations were generally greater in fine-grained samples. Results from statistical procedures indicate significant differences between fine-grained and bulk samples for aluminum, barium, beryllium, chromium, copper, iron, lithium, nickel, phosphorus, selenium, titanium, and zinc concentrations. Of 133 paired concentrations, 69 percent were greater in fine-grained samples, and 23 percent were greater in bulk samples. Comparisons with data from previous studies for six sites indicate increases by more than 20 percent in concentrations of antimony, arsenic, chromium, lead, and zinc for at least one site.

Trends in bed-sediment are probably caused by changes in land and water use. Comparisons with data from previous studies indicate no trace element had a significant increase or decrease throughout the study unit, although increases or decreases greater than 20 percent were observed for specific sites. Comparisons with data from previous studies indicate increases by more than 20 percent in concentrations of antimony at Bayou Lafourche below weir at Thibodaux, arsenic and chromium at Tickfaw River at Liverpool, lead at Bayou Lafourche below weir at Thibodaux, and zinc at Bayou Lafourche below weir at Thibodaux and Vermilion River at Perry. Historic comparisons also indicate decreases by more than 20 percent in concentrations of chromium at Bayou des Cannes near Eunice and mercury at Mermentau River at Mermentau.

Of the 130 detected concentrations of organic compounds, 72 exceeded ISQG's at 11 sites, and 12 concentrations exceeded PEL's at 5 sites. All PEL exceedances occurred at sites with seven or more ISQG exceedances: Dawson Creek at Bluebonnet Boulevard at Baton Rouge, Bayou Lafourche below weir at Thibodaux, Bayou Boeuf at Railroad Bridge at Amelia, Bayou Teche at Keystone Lock and Dam near St. Martinville, and Vermilion River at Perry. The most ISQG exceedances occurred at sites draining urban areas, Bayou Lafourche below weir at Thibodaux and Dawson Creek at Bluebonnet Boulevard at Baton Rouge. The most PEL exceedances occurred at a site draining an urban area, Bayou Lafourche below weir at Thibodaux, and a site draining wetlands where support for petrochemical and marine activities occur, Bayou Boeuf at Railroad Bridge at Amelia.

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APPENDIXES

Appendix A. Selected trace-element concentrations in bulk bed-sediment samples for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

Appendix A. Selected trace-element concentrations in bulk bed-sediment samples for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[Analyses were performed by the USGS Sediment Partitioning Laboratory in Atlanta. Concentrations are in micrograms per gram, except as noted.USGS, U.S. Geological Survey; percent, percent dry weight; <, less than]

Site number (see fig. 1)	Site name	USGS station number	Aluminum (percent)	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Iron (percent))	Lead
1	Tchefuncte River near Covington	07375050	0.9	0.3	0.9	130	0.2	0.2	11	2	3	0.4	10
2	Bogue Falaya at Lee Road at Covington	07375170	.1	.1	.3	18	<.1	.1	2	<1	<1	.1	1
4	Tickfaw River at Liverpool	07375800	1.5	.3	1.7	200	.5	.1	16	5	3	.6	10
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	07379960	4.0	.9	3.9	520	.9	.2	40	7	20	1.7	66
6	Amite River at Port Vincent	07380120	3.1	.6	3.1	350	.8	<.1	30	6	6	1.3	15
7	Bayou Des Allemands at Des Allemands	07380300	6.6	.7	12	680	1.7	.2	59	14	24	3.8	66
8	Bayou Lafourche below weir at Thibodaux	07381002	5.4	4	16	1,700	1.4	.7	63	11	37	2.9	130
9	Bayou Grosse Tete at Rosedale	07381440	8.7	.9	14	740	2.2	.7	80	12	32	4.3	26
10	Bayou Boeuf at Railroad Bridge at Amelia	073814675	6.2	1.1	10	720	1.6	.1	58	12	24	3.2	32
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	07385700	7.7	1.1	8.3	660	2	.5	68	13	32	3.4	28
12	Vermilion River at Perry	07386980	5.7	.9	7.6	830	1.4	<.1	55	10	21	2.6	42
13	Bayou des Cannes near Eunice	08010000	3.7	.8	8.6	430	1.1	<.1	38	11	10	2.2	27
14	Bayou Nezpique near Basile	08012000	2.9	.5	4.4	360	.8	.2	27	6	5	1.3	20
15	Mermentau River at Mermentau	08012150	8.5	1	8.2	770	1.9	.3	71	13	22	3.5	34
16	Bayou Que De Tortue at Riceville	08012300	8.1	1.1	8.2	860	1.8	.4	74	11	21	3.3	35
17	Bayou Lacassine near Lake Arthur	08012470	1.3	1.1	7.9	710	2.3	.3	86	17	22	3.6	47
19	Calcasieu River near Kinder	08015500	.4	.2	.5	170	.1	.1	4	2	1	.1	7
20	Turtle Bayou north of Bayou Penchant near Amelia	293524091041300	5.8	.8	6.7	140	1.5	.4	60	10	26	3.1	31
21	Bayou Segnette 4.6 miles south of Westwego	294957090095300	5.4	1.1	13	330	1.4	<.1	48	11	23	3.0	30

Appendix A. Selected trace-element concentrations in bulk bed-sediment samples for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Lithium	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Selenium	Silver	Strontium (percent)	Sulfur (percent)	Thallium	Titanium (percent)	Uranium	Vanadium	Zinc	Total organic carbon (percent)	Total carbon (percent)
1	6	120	0.05	<5	3	200	0.1	1.0	16	<0.1	<50	0.16	<50	15	17	0.7	0.6
2	2	19	.01	<5	1	19	<.1	<.5	3	<.1	<50	.04	<50	3	2	.1	<.1
4	8	620	.02	<5	7	150	.2	<.5	23	<.1	<50	.24	<50	24	19	1.3	1.2
5	18	330	.17	<5	18	620	.2	1.0	100	<.1	<50	.34	<50	57	110	1.6	1.4
6	14	570	<.01	<5	12	320	.1	<.5	56	<.1	<50	.35	<50	47	40	.7	.6
7	36	1,100	.06	<5	34	2,200	.7	<.5	140	.3	<50	.32	<50	120	110	5.9	6.1
8	29	610	.1	<5	28	1,300	.6	<.5	200	.1	<50	.30	<50	90	220	2.7	3.9
9	48	660	.07	<5	38	1,800	.6	<.5	120	.1	<50	.4	<50	160	160	2.7	2.3
10	32	860	.06	<5	31	1,100	.3	<.5	220	.2	<50	.34	<50	100	170	1.7	1.9
11	50	610	.07	<5	34	1,000	<.1	<.5	100	<.1	<50	.47	<50	120	130	2	1.9
12	27	580	.04	<5	23	1,200	.3	<.5	100	.1	<50	.42	<50	87	110	1.8	2.1
13	20	840	.03	<5	16	450	.1	<.5	61	<.1	<50	.29	<50	68	42	.6	.6
14	16	440	.03	<5	9	280	.2	<.5	53	<.1	<50	.32	<50	43	26	.6	.7
15	49	830	.11	<5	28	1,200	.5	<.5	92	.1	<50	.55	<50	130	110	2.6	2.6
16	43	580	.09	<5	26	830	.5	<.5	95	<.1	<50	.59	<50	130	96	2.3	2.2
17	59	490	.09	<5	31	810	.6	<.5	92	.1	<50	.69	<50	150	100	3.1	3.1
19	3	160	.01	<5	1	42	<.1	<.5	14	<.1	<50	.07	<50	6	5	.1	<.1
20	35	580	.13	<5	30	1,100	.6	<.5	140	1.5	<50	.28	<50	110	100	16.2	1.65
21	29	850	.09	<5	29	1,500	1	<.5	150	1.1	<50	.26	<50	95	94	11.2	11.8

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998

[USGS, U.S. Geological Survey; <63 µm, wet-sieved in field with 0.63-micrometer sieve; percent, percent dry weight; <, less than, <2 mm, wet-sieved in field with 2-millimeter sieve; mg/kg, milligrams per kilogram; g/kg, grams per kilogram; µg/kg, micrograms per kilogram; µg/g, micrograms per gram; E, estimated; M, presence of material verified but not quantified; --, not analyzed]

Site number (see fig. 1)	Site name	USGS station number	Calcium <63 µm (percent)	Magnesium <63 µm (percent)	Potassium <63 µm (percent)	Sodium <63 µm (percent)	Sulfur <63 µm (percent)	Nitrogen, NH_4, total (mg/kg as N)	Nitrogen, NH_4 plus organic, total (mg/kg as N)	Nitrogen, NO_2+NO_3, total (mg/kg as N)	Phosphorus <63 µm (percent)
1	Tchefuncte River near Covington	07375050	0.2	0.12	0.52	0.22	<0.05	200	36	<2	0.06
2	Bogue Falaya at Covington	07375170	.09	.11	.4	.11	<.05	<20	3.4	5	.03
3	Tangipahoa River at Robert	07375500	.14	.2	.84	.25	<.05	300	27	8	.06
4	Tickfaw River at Liverpool	07375800	.13	.19	1.1	.36	<.05	500	16	5	.04
5	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	07379960	.69	.41	1.4	.72	<.05	1,200	65	2	.05
6	Amite River at Port Vincent	07380120	.2	.18	1	.42	<.05	600	92	<2	.05
7	Bayou Des Allemands at Des Allemands	07380300	1	1.1	1.7	.47	.35	5,400	380	3	.17
8	Bayou Lafourche below weir at Thibodaux	07381002	3.5	1	1.8	.53	.1	1,500	72	<2	.13
9	Bayou Grosse Tete at Rosedale	07381440	.91	1.4	2.3	.38	.06	2,200	280	8	.18
10	Bayou Boeuf at Railroad Bridge at Amelia	073814675	1.2	1.1	1.9	.54	.29	1,700	150	4	.08
11	Bayou Teche at Keystone Lock and Dam near St. Martinville	07385700	.53	1.3	2.2	.55	.05	500	65	7	.10
12	Vermilion River at Perry	07386980	.47	.58	1.7	.61	<.05	1,200	100	9	.09
13	Bayou des Cannes near Eunice	08010000	.42	.51	1.3	.5	<.05	670	13	<2	.05
14	Bayou Nezpique near Basile	08012000	.29	.39	1	.41	<.05	610	12	3	.05
15	Mermentau River at Mermentau	08012150	.44	.65	1.2	.28	.05	2,100	160	5	.10
16	Bayou Que De Tortue at Riceville	08012300	.47	.59	1.2	.31	<.05	2,300	1,500	4	.07
17	Bayou Lacassine near Lake Arthur	08012470	.49	.67	1.1	.17	.08	2,900	95	<2	.08
18	Calcasieu River near Kinder	08014500	.12	.18	.71	.16	<.05	20	.6	<2	.11
19	Turtle Bayou north of Bayou Penchant near Amelia	08015500	.13	.17	.57	.16	<.05‘	80	<.2	<2	.04
20	Bayou Segnette 4.6 miles south of Westwego	293524091041300	1.1	.88	1.3	.26	1.4	14,000	5,200	12	.10
21	Dawson Creek at Bluebonnet Boulevard at Baton Rouge	294957090095300	.82	.91	1.6	.64	.88	8,500	300	10	.14

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Phosphorus, total (mg/kg as P)	Carbon, inorg <63 µm (percent)	Carbon, inorg <2 mm (g/kg)	Carbon, org + inorg <2 mm (g/kg)	Carbon, org + inorg <63 µm (percent)	Carbon, organic <2 mm (g/kg)	Carbon, organic <63 µm (percent)	Aluminum <63 µm (percent)	Antimony <63 µm (µg/g)	Arsenic <63 µm (µg/g)	Barium <63 µm (µg/g)	Beryllium <63 µm (µg/g)	Bismuth <180 (µg/g)	Cadmium <63 µm (µg/g)	Cerium <63 µm (µg/g)
1	200	0.01	<0.1	10	1.9	10	1.9	2.9	0.5	2	330	0.9	1	0.3	83
2	40	.01	<.1	.6	1.3	.6	1.3	3.5	.5	2.5	210	.6	<1	<.1	73
3	200	.01	<.1	5.3	1.4	5.3	1.4	4.4	.5	3.3	400	1.2	<1	.2	72
4	100	.01	<.1	7.2	1.5	7.2	1.5	4.9	.5	3.4	520	1.4	<1	<.1	81
5	470	.08	.7	13	.93	12	.85	4.9	.7	3.9	560	.8	<1	.5	62
6	290	.01	.7	5.8	.82	5.1	.81	4.1	.6	5	460	1.2	<1	.2	70
7	1,700	.13	<.1	58	5.8	58	5.7	7.2	.8	11	740	2.1	<1	.7	64
8	1,100	.88	11	34	2.6	23	1.7	6.7	1.2	15	2,400	2.4	1	1	76
9	1,500	.02	<.1	24	2.1	24	2.1	9.5	.9	17	820	2.8	<1	.9	70
10	940	.19	1.7	19	2.1	17	1.9	7.5	.9	9.8	6,800	2.4	<1	.5	70
11	740	.01	<.1	18	1.8	18	1.8	7.5	.9	7.8	680	2.5	<1	.4	69
12	960	.01	<.1	20	1.4	20	1.4	6.2	.7	6.6	820	1.4	<1	.3	73
13	330	.03	.6	6.7	.75	6.1	.72	5.9	.7	7.2	560	1.4	<1	.1	91
14	190	.01	<.1	6.3	1.1	6.3	1.1	5.5	.6	5.4	460	1.4	<1	.1	79
15	800	.01	<.1	24	2.3	24	2.3	8.9	.9	8.9	770	2.2	<1	.2	90
16	610	.01	<.1	21	1.9	21	1.9	7.8	.9	7.2	830	1.9	<1	.2	80
17	570	.01	<.1	29	2.9	29	2.9	10	1	7.8	720	1.8	<1	.2	110
18	50	.01	<.1	.2	2.3	.2	2.3	3.7	.5	8.8	410	1.6	<1	.2	64
19	40	.01	<.1	1.1	1.3	1.1	1.3	3.8	.8	3.2	370	1.1	<1	.2	65
20	590	.03	<.1	160	14	160	14	5.7	.6	6.6	1,400	1.7	<1	.3	41
21	1,300	.03	.9	110	8.1	110	8.1	6.3	.8	9.5	760	1.6	<1	.5	52

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Chromium <63 µm (µg/g)	Cobalt <63 µm (µg/g)	Copper <63 µm (µg/g)	Europium <63 µm (µg/g)	Gallium <63 µm (µg/g)	Gold <63mm (µg/g)	Holmium <63 µm (µg/g)	Iron <63 µm (percent)	Lanthanum <63 µm (µg/g)	Lead <63mm (µg/g)	Lithium <63 µm (µg/g)	Manganese <63 µm (µg/g)	Mercury <63 µm (µg/g)	Molybdenum <63 µm (µg/g)	Neodymium <63 µm (µg/g)
1	36	5	20	<1	6	<.050	<1	1	34	25	16	250	0.27	0.6	25
2	26	4	8	<1	8	<1	<1	.92	36	22	15	190	.03	<.5	26
3	31	7	9	1	9	<1	1	1.4	40	19	19	770	.04	<.5	33
4	38	9	14	1	10	<1	1	1.3	44	19	22	1,200	.04	.6	35
5	47	6	26	1	10	<1	1	2	33	57	22	300	.1	.9	29
6	45	8	20	1	9	<.050	<1	1.6	38	18	19	930	.03	.6	32
7	75	14	30	1	15	<.050	<1	4.1	36	34	40	1,000	.07	1	30
8	76	12	38	1	14	<.050	1	3.4	42	67	37	640	.15	1	33
9	95	12	46	1	24	<1	1	4.9	42	31	54	570	.07	.8	35
10	78	11	32	2	17	<1	1	3.8	40	29	42	890	.05	.7	34
11	74	12	33	1	19	<1	1	3.5	40	29	50	530	.07	.6	35
12	59	8	22	1	14	<1	1	2.4	42	34	28	440	.07	<.5	36
13	56	13	18	1	14	<1	1	2.7	47	33	32	830	.03	.6	40
14	49	10	14	1	13	<1	1	2.2	41	24	32	780	.03	.6	35
15	83	13	27	2	22	<1	2	4	51	36	51	820	.07	.9	43
16	75	10	23	2	20	<1	1	3.3	44	33	42	480	.05	.9	38
17	96	16	30	2	24	<1	2	4	55	41	63	490	.07	1.2	51
18	34	18	9	<1	8	<1	<1	2.9	34	18	19	730	.03	.6	27
19	38	12	16	1	8	<1	1	1.6	34	20	22	830	.03	.5	28
20	67	10	29	1	16	<1	<1	3.3	24	30	36	560	.09	1	20
21	54	10	25	1	14	<1	<1	3	30	34	32	700	.09	.7	25

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Nickel <63 µm (µg/g)	Niobium <63 µm (µg/g)	Scandium <63 µm (µg/g)	Selenium <63 µm (µg/g)	Silver <63 µm (µg/g)	Strontium <63 µm (µg/g)	Tantalum <63 µm (µg/g)	Thallium, total <63 µm (µg/g)	Tin <63 µm (µg/g)	Titanium <63 µm (percent)	Vanadium <63 µm (µg/g)	Ytterbium <63 µm (µg/g)	Yttrium <63 µm (µg/g)	Zinc <63 µm (µg/g)	P, P′-DDE <2 mm (µg/kg)
1	10	<4	5	0.4	4.3	41	<1	<1	2	0.4	37	2	17	65	M
2	8	6	5	.3	.3	31	<1	<1	2	.48	34	2	12	43	<1
3	12	6	6	.4	.4	48	<1	<1	1	.44	44	2	17	50	<1
4	16	8	7	.4	.5	56	<1	<1	1	.54	50	2	20	49	<1
5	18	7	7	.4	.6	110	<1	<1	3	.34	52	2	18	130	3
6	16	11	6	.3	.2	64	<1	<1	1	.4	52	2	24	57	<1
7	41	13	12	.8	.4	110	<1	<1	7	.3	110	3	27	120	M
8	37	15	12	.7	.3	200	1	<1	6	.4	100	3	30	160	4
9	41	12	17	.8	.6	120	1	<1	4	.54	160	3	24	190	3
10	33	12	12	.7	.7	190	1	<1	3	.39	110	3	23	150	<1
11	33	10	12	.5	.6	100	<1	<1	3	.49	100	2	21	130	20
12	22	10	10	.4	.6	100	1	<1	3	.5	73	2	20	110	17
13	21	10	9	.5	.6	84	1	<1	2	.52	79	2	22	72	5
14	16	10	8	.5	.6	69	<1	<1	2	.53	67	2	18	59	<1
15	30	16	14	.8	.9	90	2	<1	3	.7	120	3	26	120	2
16	24	12	12	.8	.7	90	1	<1	2	.57	110	2	22	97	<1
17	34	18	15	.9	.9	90	2	1	3	.62	120	3	28	110	1
18	13	6	5	.7	.6	40	<1	<1	2	.45	46	2	14	48	<1
19	11	10	6	.5	.6	45	1	<1	1	.47	47	2	16	54	<1
20	32	7	9	1.7	.3	120	<1	<1	2	.25	100	2	14	110	<6
21	28	8	9	1	1.3	140	<1	<1	3	.35	88	2	16	130	<2

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	2,2′-bi quinoline <2 mm (µg/kg)	3,5-xylenol <2 mm (µg/kg)	4-bromo phenyl phenyl ether <2 mm (µg/kg)	4-chloro phenyl phenyl ether <2 mm (µg/kg)	4H-cyclo-penta(def)-phen anthrene <2 mm (µg/kg)	9,10-anthra-quinone <2 mm (µg/kg)	Fluorene, 1-methyl <2 mm (µg/kg)	Fluorene <2 mm (µg/kg)	Acenaph-thene <2 mm (µg/kg)	Acenaph-thylene <2 mm (µg/kg)	Acridine <2 mm (µg/kg)	Aldrin <2 mm (µg/kg)	Alpha-BHC, D6 surrogate <2 mm (percent)	Alpha-BH <2 mm (µg/kg)
1	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	71	<1
2	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	67	<1
3	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	74	<1
4	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	102	<1
5	<50	<50	<50	<50	E20	50	<50	<50	E20	E20	E10	<1	91	<1
6	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	95	<1
7	<50	<50	<50	<50	E40	<50	<50	<50	<50	<50	<50	<1	71	<1
8	<50	E30	<50	<50	120	170	E50	90	90	70	<50	<1	91	<1
9	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	75	<1
10	<100	<100	<100	<100	150	50	E30	140	120	50	E50	<1	91	<1
11	<50	<50	<50	<50	90	<50	<50	60	E20	<50	<50	<1	81	<1
12	<50	<50	<50	<50	E40	60	<50	E50	50	<50	<50	<1	113	<1
13	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	77	<1
14	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	74	<1
15	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<2	74	<2
16	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	69	<1
17	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	78	<1
18	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	69	<1
19	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<1	70	<1
20	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<6	74	<6
21	<100	<100	<100	<100	E40	<100	<100	E10	<100	<100	<100	<2	73	<2

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Anthracene, 2-methyl- <2 mm (µg/kg)	Anthracene <2 mm (µg/kg)	Azobenzene <2 mm (µg/kg)	Benz(A) anthracene <2 mm (µg/kg)	Benzene, 1,2,4-trichloro- <2 mm (µg/kg)	Benzene, hexachloro- <2 mm (µg/kg)	Benzene, M-dichloro- <2 mm (µg/kg)	Benzene, nitro- <2 mm (µg/kg)	Benzene nitro-, D5 surrogate <2 mm (percent)	Benzene, O-dichloro- <2 mm (µg/kg)	Benzene, P-dichloro- <2 mm (µg/kg)	Benzene, pentachor, nitro- <2 mm (µg/kg)	Benzo(A)-pyrene <2 mm (µg/kg)
1	<50	<50	<50	E20	<50	<1	<50	<50	86	<50	<50	<50	E30
2	<50	<50	<50	<50	<50	<1	<50	<50	67	<50	<50	<50	<50
3	<50	<50	<50	<50	<50	<1	<50	<50	96	<50	<50	<50	<50
4	<50	<50	<50	<50	<50	<1	<50	<50	41	<50	<50	<50	<50
5	E20	60	<50	120	<50	<1	<50	<50	51	<50	<50	<50	110
6	<50	M	<50	E10	<50	1	<50	<50	66	<50	<50	<50	E10
7	<50	M	<50	E50	<50	<1	<50	<50	66	<50	<50	<50	E50
8	50	200	<50	540	<50	<1	<50	<50	56	<50	E10	<50	640
9	<50	<50	<50	<50	<50	<1	<50	<50	92	<50	<50	<50	<50
10	130	320	<100	470	<100	<1	<100	<100	48	<100	<100	<100	320
11	E30	E40	<50	150	<50	<1	<50	<50	42	<50	E10	<50	60
12	<50	E20	<50	70	<50	<1	<50	<50	79	<50	<50	<50	50
13	<50	E10	<50	E20	<50	<1	<50	<50	39	<50	<50	<50	E20
14	<50	<50	<50	<50	<50	<1	<50	<50	77	<50	<50	<50	<50
15	<50	E10	<50	E30	<50	<2	<50	<50	52	<50	<50	<50	<50
16	<50	<50	<50	<50	<50	<1	<50	<50	53	<50	<50	<50	<50
17	<50	E20	<50	E20	<50	<1	<50	<50	57	<50	<50	<50	<50
18	<50	<50	<50	<50	<50	<1	<50	<50	42	<50	<50	<50	<50
19	<50	<50	<50	<50	<50	<1	<50	<50	50	<50	<50	<50	<50
20	<50	<50	<50	<50	<50	<6	<50	<50	52	<50	<50	<50	<50
21	<100	E40	<100	E30	<100	<2	<100	<100	54	<100	620	<100	<100

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Benzo(B)-fluoranthene <2 mm (µg/kg)	Benzo(G,H,I)-perylene <2 mm (µg/kg)	Benzo(K)-fluoranthene <2 mm (µg/kg)	Benzo(C) cinnoline <2 mm (µg/kg)	Beta-BHC <2 mm (µg/kg)	Biphenl, 2-fluoro, surrogate <2 mm (percent)	Biphenl, 3,5-dichlor, surrogate <2 mm (percent)	Bis(2-chloroethyl) ether <2 mm (µg/kg)	Carbazole <2 mm (µg/kg)	Chloroneb <2 mm (µg/kg)	Chrysene <2 mm (µg/kg)	Cis-chlordane <2 mm (µg/kg)	Cis-nonachlor <2 mm (µg/kg)
1	E30	<50	E20	--	<1	75	89	--	<50	<5	E10	1	<1
2	<50	<50	<50	<50	<1	65	71	--	<50	<5	<50	<1	<1
3	<50	<50	<50	<50	<1	74	75	--	<50	<5	<50	<1	<1
4	<50	<50	<50	<50	<1	41	93	--	<50	<5	<50	<1	<1
5	150	80	110	<50	<1	53	46	<50	E30	<5	150	6	4
6	E20	E10	E20	--	<1	55	101	--	<50	<5	E10	<1	<1
7	60	E20	E50	--	<1	72	79	--	<50	<5	60	<1	<1
8	460	E260	1,000	--	<2	61	63	--	130	<5	640	7	2
9	E40	<50	E40	<50	<1	68	91	--	<50	<5	<50	<1	<1
10	280	140	300	<100	<1	40	42	<100	100	<5	480	<1	<1
11	90	E20	90	<50	<1	43	89	--	<50	<5	170	<1	<1
12	70	E30	80	<50	<1	55	81	<50	<50	<5	80	<1	<1
13	E30	<50	E30	<50	<1	55	73	--	<50	<5	E20	<1	<1
14	<50	<50	<50	<50	<1	61	72	--	<50	<5	<50	<1	<1
15	E50	<50	50	<50	<2	47	60	--	<50	<10	E30	<2	<2
16	<50	<50	<50	<50	<1	53	64	--	<50	<5	<50	<1	<1
17	E50	<50	E30	<50	<1	41	74	<50	<50	<5	E20	<1	<1
18	<50	<50	<50	<50	<1	39	66	--	<50	<5	<50	<1	<1
19	<50	E10	<50	<50	<1	42	76	<50	<50	<5	<50	<1	<1
20	<50	<50	<50	<50	<6	48	63	--	<50	<30	<50	<6	<6
21	E80	<100	E50	<100	<2	47	80	--	<100	<10	E60	<2	<2

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Cis-permethrin <2 mm (µg/kg)	DCPA <2 mm (µg/kg)	Dibenz(A,H), anthracene <2 mm (µg/kg)	Dieldrin <2 mm (µg/kg)	Diphenyl-amine, N-nitroso- <2 mm (µg/kg)	Dipropyl-amine, N-nitroso <2 mm (µg/kg)	Endosulfan I <2 mm (µg/kg)	Endrin <2 mm (µg/kg)	Fluor-anthene <2 mm (µg/kg)	Hepta-chlor epoxide <2 mm (µg/kg)	Hepta-chlor <2 mm (µg/kg)	Indeno-(1,2,3-cd) pyrene 1-methyl <2 mm (µg/kg)	Isodrin <2 mm (µg/kg)
1	<5	<5	<50	<1	<50	<50	<1	<2	--	<1	<1	E20	<1
2	<5	<5	<50	<1	<50	<50	<1	<2	E20	<1	<1	<50	<1
3	<5	<5	<50	<1	<50	<50	<1	<2	<50	<1	<1	<50	<1
4	<5	<5	<50	<1	<50	<50	<1	<2	<50	<1	<1	<50	<1
5	<5	<5	E30	1	<50	<50	<1	<2	280	<1	<1	90	<1
6	<5	<5	<50	<1	<50	<50	<1	<2	--	<1	<1	E10	<1
7	<5	<5	<50	<1	<50	<50	<1	<2	130	<1	<1	E30	<1
8	<5	<5	100	2	<50	<50	<1	<2	1,200	<1	E4	E320	<1
9	<5	<5	<50	<1	<50	<50	<1	<2	E40	<1	<1	<50	<1
10	<5	<5	60	<1	<100	<100	<1	<2	960	<1	<1	160	<1
11	<5	<5	<50	<1	<50	<50	<1	<2	820	<1	<1	E30	<1
12	<5	<5	<50	<1	<50	<50	<1	<2	280	<1	<1	<50	<1
13	<5	<5	<50	<1	<50	<50	<1	<2	70	<1	<1	<50	<1
14	<5	<5	<50	<1	<50	<50	<1	<2	E30	<1	<1	<50	<1
15	<10	<10	<50	<2	<50	<50	<2	<4	90	<2	<2	<50	<2
16	<5	<5	<50	<1	<50	<50	<1	<2	E20	<1	<1	<50	<1
17	<5	<5	<50	<1	<50	<50	<1	<2	E30	<1	<1	<50	<1
18	<5	<5	<50	<1	<50	<50	<1	<2	<50	<1	<1	<50	<1
19	<5	<5	<50	<1	<50	<50	<1	<2	<50	<1	<1	<50	<1
20	<30	<30	<50	<6	<50	<50	<6	<12	170	<6	<6	<50	<6
21	<10	<10	<100	<2	<100	<100	<2	<4	150	<2	<2	<100	<2

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Isophorone <2 mm (µg/kg)	Isoquinoline, <2 mm (µg/kg)	Lindane <2 mm (µg/kg)	M-cresol, 4-chloro- <2 mm (µg/kg)	Methane bis(2-chloro ethoxy) <2 mm (µg/kg)	Methoxy-chlor, O,P′-, <2 mm (µg/kg)	Methoxy-chlor, P,P′-, <2 mm (µg/kg)	Mirex, <2 mm (µg/kg)	Napthalene, 1,2-dimethyl <2 mm (µg/kg)	Napthalene, 1,6-dimethyl <2 mm (µg/kg)	Napthalene, 2,3,6-trimethyl <2 mm (µg/kg)	Napthalene, 2,6-dimethyl <2 mm (µg/kg)
1	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
2	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
3	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
4	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
5	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	E50
6	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
7	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	70
8	<50	<50	<1	<50	<50	<5	<5	<1	E20	50	70	120
9	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	E20
10	<100	<100	<1	<100	<100	<5	<5	<1	<100	E20	E10	90
11	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	E10
12	<50	<50	<1	<50	<50	<5	<5	<1	<50	E20	E20	E20
13	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
14	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
15	<50	E40	<2	70	<50	<10	<10	<2	<50	E20	<50	E40
16	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
17	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	E40
18	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
19	<50	<50	<1	<50	<50	<5	<5	<1	<50	<50	<50	<50
20	<50	<50	<6	<50	<50	<30	<30	<6	<50	<50	<50	440
21	<100	<100	<2	<100	<100	<10	<10	<2	<100	<100	<100	120

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Napthalene, 2-chloro- <2 mm (µg/kg)	Napthalene, 2-ethyl- <2 mm (µg/kg)	Naphthalene, <2 mm (µg/kg)	O, P′-DDD, <2 mm (µg/kg)	O, P′-DDE, <2 mm (µg/kg)	O, P′-DDT, <2 mm (µg/kg)	Octachloro-biphenyl, surrogate <2 mm (percent)	Oxychlordane, <2 mm (µg/kg)	P, P′-DDD, <2 mm (µg/kg)	P, P′-DDT, <2 mm (µg/kg)	PCB <2 mm (µg/kg)	P-cresol <2 mm (µg/kg)	Pentachloro-anisole <2 mm (µg/kg)
1	<50	<50	<50	<1	<1	<2	91	<1	<1	<2	<50	<50	<1
2	<50	<50	<50	<1	<1	<2	79	<1	<1	<2	<50	<50	<1
3	<50	<50	<50	<1	<1	<2	83	<1	<1	<2	<50	270	<1
4	<50	<50	<50	<1	<1	<2	92	<1	<1	<2	<50	60	<1
5	<50	<50	<50	<1	<1	<2	64	<1	3	<2	<50	230	<1
6	<50	<50	<50	<1	<1	<2	98	<1	<1	<2	<50	140	<1
7	<50	<50	E10	<1	<1	<2	91	<1	<1	<2	<50	E40	<1
8	<50	E40	90	<1	<1	<2	95	<1	E6	4	70	160	<1
9	<50	<50	<50	<1	<1	<2	76	<1	1	<2	<50	520	<1
10	<100	<100	<100	<1	<1	<2	60	<1	<1	<2	<50	810	<1
11	<50	M	E20	<1	<1	<2	92	<1	<1	<2	<50	50	<1
12	<50	E10	E10	<1	<1	<2	79	<1	3	<2	<50	610	<1
13	<50	<50	<50	<1	<1	<2	85	<1	2	<2	<50	<50	<1
14	<50	<50	<50	<1	<1	<2	88	<1	<1	<2	<50	<50	<1
15	<50	<50	<50	<2	<2	<4	88	<2	<2	<4	<100	<50	<2
16	<50	<50	<50	<1	<1	<2	86	<1	<1	<2	<50	<50	<1
17	<50	<50	<50	<1	<1	<2	94	<1	<1	<2	<50	<50	<1
18	<50	<50	<50	<1	<1	<2	84	<1	<1	<2	<50	<50	<1
19	<50	<50	<50	<1	<1	<2	86	<1	<1	<2	<50	<50	<1
20	<50	<50	<50	<6	<6	<12	84	<6	<6	<12	<300	6,100	<6
21	<100	<100	<100	<2	<2	<4	66	<2	<2	<4	<100	6,100	<2

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Phenanthrene, 1-methyl <2 mm (µg/kg)	Phenanthrene <2 mm (µg/kg)	Phenanthridine <2 mm (µg/kg)	Phenol <2 mm (µg/kg)	Phenol, C8-alkyl- <2 mm (µg/kg)	Phenol, 2-chloro <2 mm (µg/kg)	Phthalate, bis(2-ethyl hexyl)- <2 mm (µg/kg)	Phthalate, butyl benzyl <2 mm (µg/kg)	Phthalate, dibutyl <2 mm (µg/kg)	Phthalate, diethyl <2 mm (µg/kg)	Phthalate, dimethyl <2 mm (µg/kg)	Phthalate, dioctyl <2 mm (µg/kg)	Pyrene, 1-methyl <2 mm (µg/kg)
1	<50	<50	--	<50	<50	--	340	<50	E50	E40	<50	<50	<50
2	<50	<50	<50	<50	<50	<50	E40	<50	60	E40	<50	<50	<50
3	<50	<50	<50	<50	<50	<50	60	<50	E50	50	<50	<50	<50
4	<50	<50	<50	<50	<50	<50	<50	<50	E30	E10	<50	<50	<50
5	E10	130	E10	E10	<50	<50	530	E40	E40	<50	<50	<50	E10
6	E10	M	--	E10	<50	--	110	<50	E20	E20	E10	<50	<50
7	<50	E40	--	M	<50	--	80	<50	60	80	<50	<50	<50
8	70	880	--	50	<50	--	140	<50	E20	<50	<50	<50	80
9	<50	<50	<50	<50	<50	<50	90	<50	70	<50	<50	<50	<50
10	90	770	E40	<100	<100	<100	160	120	60	<100	<100	E40	E50
11	E10	170	<50	<50	<50	<50	80	<50	50	E30	<50	<50	E20
12	E20	260	<50	E10	<50	<50	100	<50	E40	E20	<50	<50	E20
13	<50	E20	<50	<50	<50	<50	E40	E20	E40	<50	<50	<50	<50
14	<50	M	<50	<50	<50	<50	E20	<50	E40	<50	<50	<50	<50
15	<50	E10	<50	<50	<50	<50	90	<50	60	<50	<50	<50	<50
16	<50	<50	<50	<50	<50	<50	<50	<50	E50	<50	<50	<50	<50
17	<50	<50	<50	<50	<50	<50	E40	<50	60	E20	E20	<50	<50
18	<50	<50	<50	<50	<50	<50	E10	E10	E20	<50	<50	<50	<50
19	<50	<50	<50	<50	<50	<50	E10	<50	E20	E10	<50	<50	<50
20	<50	60	<50	<50	<50	<50	330	<50	240	<50	<50	<50	<50
21	<100	E30	<100	220	<100	<100	130	<100	E90	E50	<100	<100	<100

Appendix B. Concentrations of selected trace elements, nutrients, and organic compounds in bed-sediment for selected sites in the Acadian-Pontchartrain Study Unit, southern Louisiana, 1998—Continued

Site number (see fig. 1)	Pyrene <2 mm (µg/kg)	Quinoline <2 mm (µg/kg)	Terphenyl, D14-surrogate <2 mm (percent)	Thiophene, dibenzo- <2 mm (µg/kg)	Toluene, 2,4-dinitro- <2 mm (µg/kg)	Toluene, 2,6-dinitro- <2 mm (µg/kg)	Toxaphene <2 mm (µg/kg)	Trans-chlordane <2 mm (µg/kg)	Trans-nonachlor <2 mm (µg/kg)	Trans-permethrin <2 mm (µg/kg)	Thorium <63 µm (µg/g)	Uranium <63 µm (µg/g)
1	E20	<50	88	<50	<50	<50	<200	E1	E1	<5	8	2.2
2	<50	<50	72	<50	<50	<50	<200	<1	<1	<5	9	2.7
3	<50	<50	83	<50	<50	<50	<200	<1	<1	<5	9	3
4	<50	<50	64	<50	<50	<50	<200	<1	<1	<5	10	3.4
5	240	<50	68	<50	<50	<50	<200	7	10	<5	9	2.7
6	E20	<50	96	<50	<50	<50	<200	<1	<1	<5	9	2.5
7	110	<50	82	<50	<50	<50	<200	<1	<1	<5	11	2.6
8	1,200	<50	69	60	<50	<50	<200	14	5	<5	11	2.9
9	E10	<50	81	<50	<50	<50	<200	<1	<1	<5	13	4
10	780	<100	54	50	<100	<100	<200	<1	<1	<5	12	3
11	570	<50	62	<50	<50	<50	<200	<1	<1	<5	11	3.6
12	240	<50	57	E10	<50	<50	<200	1	<1	<5	11	3.1
13	50	<50	78	<50	<50	<50	<200	<1	<1	<5	12	3.9
14	E10	<50	87	<50	<50	<50	<200	<1	<1	<5	11	3.6
15	60	<50	68	<50	<50	<50	<400	<2	<2	<10	14	4.9
16	E10	<50	89	<50	<50	<50	<200	<1	<1	<5	13	4.8
17	E40	<50	65	<50	<50	<50	<200	<1	<1	<5	17	5
18	<50	<50	66	<50	<50	<50	<200	<1	<1	<5	9	2.8
19	M	<50	66	<50	<50	<50	<200	<1	<1	<5	11	3.3
20	90	<50	64	<50	<50	<50	<1,200	<6	<6	<30	7	3.8
21	140	<100	61	<100	<100	<100	<400	<2	<2	<10	9	3.5