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SEDIMENT QUALITY IN THE ST. JOHNS RIVER WATER MANAGEMENT DISTRICT: PHYSICAL AND CHEMICAL CHARACTERISTICS

REVISED

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EXECUTIVE SUMMARY

Background

The St. Johns River Water Management District (SJRWMD) comprises 12,000 square miles in northeastern Florida — almost one quarter of the total area of the state. The SJRWMD includes several major and smaller urban centers and large tracts of agriculture and forestry land, and the region's population is growing rapidly.

The SJRWMD was created in 1972 to protect and preserve the water resources, which are critical to many regional economies. The mission of the SJRWMD is to manage water resources to ensure their continued availability while maximizing both environmental and economic benefits. Most SJRWMD programs to date have focused on surface water monitoring, but it has become increasingly recognized that the sediments that underlie water bodies also need to be studied to fully assess aquatic ecosystem health. Sediment-bound contaminants can pose a direct risk to benthic organisms and aquatic food web due to their acute or chronic toxicity. Unlike rapidly changing water chemistry, sediments integrate pollution over time can thus indicate a history of contamination.

A SJRWMD region-wide baseline monitoring project was therefore performed in the winter of 1996–1997 to assess the current status of the freshwater sediment quality at 86 selected stations in the region. The stations were selected to provide a representative cross-section of the region, with respect to the land use patterns and the types of water bodies investigated. A general "environmental barometer" assessment of the sediment quality of the region, and sub-regions, was to be obtained.

Methods

It is widely recognized that the analytical methods that have been used in most priority pollutant tracking programs nation-wide are not sufficiently sensitive to detect low, but environmentally relevant, levels of contaminants. Additionally, application of "standard" analyte lists are not always effective to address specific, or even broad based, contaminant issues. Therefore, to meet the objectives of this program, analytical methods were used that would provide trace-level data of highly relevant toxic compounds.

The objective was to measure trace organic and trace metal contaminants in sediments from 86 fresh water locations throughout the SJRWMD. The analytes included 95 discrete organic compounds, 15 environmentally relevant metals, and a set of ancillary measurements, and they were chosen based on the following considerations:

- Identification of the most environmentally important and persistent contaminants found in sediments, as documented by major monitoring programs (e.g., National Status and Trends Program, EMAP). Central to this theme was the selection of chemicals that accumulate in sediments, and have demonstrated abilities to bioaccumulate in benthic and higher aquatic organisms.

- Inclusion of the most useful chemical-physical parameters for data interpretation

- Comparability with the target analyte list and methods currently used for the St. Johns River mainstem monitoring project.

Triplicate surface sediments were collected at each site. Rigorous "clean" procedures were adhered to, ensuring that the sample collection and handling did not introduce contamination. Samples were chilled immediately after collection and shipped to the analytical laboratory within 2 days of collection. Laboratory analysis began promptly, adhering to common holding times.

The sample analysis required the use of specialized low detection limit procedures. Two principal considerations drove the selection of analytical methods for this study:

- To assess the true status of anthropogenic chemicals, contaminant measurements at ambient (background) concentrations needed to be obtained. In this way, true representation of the background conditions, areas of impact, and severity of chemical contamination could be achieved.
- To determine linkages between observed bioeffects, ecological perturbations or change, sufficiently sensitive measurements were needed. A large body of literature has been amassed demonstrating that such effects occur at very low contaminant concentrations (e.g., EPA Water Quality Criteria, EPA Proposed Sediment Quality Criteria, NOAA ER-L and ER-M Observed Effect Concentrations) — well below concentrations that can be measured by standard EPA methods.

Optimized versions of the NOAA NS&T analytical methods were employed for the analysis of trace metals and the nonpolar organic compounds. Generally, the very low detection limits provided by the NOAA NS&T analytical methods are achieved by using larger sample sizes, employing several additional sample cleanup steps prior to instrumental analysis, and targeted final instrumental analysis. The techniques that were used provide analytical data down to "clean", background concentrations, allowing for true risk-based analysis of the data and monitoring of subtle changes and elevations over background.

Findings

The physical nature of the sediments analyzed in this study were extremely variable. Many samples had large quantities of partially decomposed plant debris, which made it difficult to apply standard data normalizing techniques (i.e., use of TOC and grain size information) for the data interpretation. Similarly, the differing geological characteristics of the sediment made it inappropriate to broadly use major element normalization for comparing toxic metal concentrations across the entire region. As expected, the sediment from lakes and rivers had the highest TOC (some >25%), and the finest grain size. Creeks and coastal systems were typically sandier.

Site Intercomparison. There were notable distributions and/or concentrations of particularly PAH, selected pesticides, PCBs, and some metals:

Aromatic Hydrocarbons

- The PAH concentrations varied greatly, but were clearly highest in the lower St. Johns River.
- 15 of the 86 sites had total PAH above the NOAA NS&T "high" concentration of 2,180 µg/kg. Only one site had total PAH above 10,000 µg/kg.
- The PAH were mostly pyrogenic, with only a few sites showing evidence of significant contribution from petrogenic sources.
- Generally, the PAH concentrations at urban sites were no higher than most comparable US locations — there were no obvious or dramatic "hot spots".

PCBs

- The highest PCB concentrations were in the lower St. Johns River and some mid-Florida lakes. TOC normalizing the PCB and other organic contaminant data resulted in significant data scatter because of the highly variable sediment organic composition.
- The highest PCB levels were comparable to urban sites in the NS&T Program — they were between 50 and 200 µg/kg at 16 of the 86 sites. There was evidence of scattered minor "hot-spots", and not a general elevation in urban/industrial areas.

Chlorinated Pesticides

- The pesticide (e.g., DDT and chlordane) concentrations followed no broad geographic pattern, and were likely related to localized sources and uses. The mid-Florida lakes region, and a few other scattered lakes, had among the highest DDT and chlordane levels.
- The DDT compounds were typically substantially degraded. The predominant DDT compounds were generally DDE and DDD, with, for the most part, much less parent DDT.

Metals

- The environmentally relevant toxic metals (e.g., mercury, lead, arsenic, silver) concentrations were relatively higher in the lower St. Johns River than most other areas.
- Two water bodies near Gainesville, and some of the mid-Florida lakes, also consistently had elevated levels of several toxic metals.
- Lakes and river sediment generally had the higher toxic metal (and organic analyte) concentrations than creeks and coastal water bodies.

Sediment Quality Reference Value Comparison. The sediment contaminant concentrations determined in this study were compared to effects-based sediment quality guideline values (ER-L/ER-M and TEL/PEL values). These general guidelines were developed for coastal sediments, and there are no widely used equivalent U.S. reference values for fresh water systems. The TEL/PEL values (developed for Florida coastal waters) are generally comparable to or slightly lower than the more widely used ER-L/ER-Ms. Highlights of this comparative exercise were:

- There were few organic compound concentrations that exceeded ER-Ms (between 1 and 5 exceedances for PAH, PCB, and DDT).
- 7, 9, and 14 sites exceeded the total, low- and high-PAH ER-L, respectively
- 40 and 49 sites, respectively, exceeded the PCB and DDT ER-Ls.
- Most organic compound ER-L exceedances were within a factor of two of the ER-L, except for DDT which often exceeded the ERL by a greater amount (but only had 3 ER-M exceedances).
- Lead levels exceeded the ER-L ***and*** the ER-M at two sites near Gainesville.
- Mercury was the parameter that had the most ER-L exceedances (but no ER-M exceedances). The mercury ER-L was exceeded at 28 of the 86 sites. There were only a few isolated ER-L exceedances for other metals.

Conclusions

The general quality of the fresh water sediment in the SJRWMD appears to be quite good. Even the most contaminated locations appear to have contaminant levels that are comparable to typical U.S. urban coastal sediments. A few general locations with elevated concentrations of a number of organic and metal contaminants were identified, and they include:

- The Lower St. Johns River area near Jacksonville. Elevated concentrations of most contaminants were found in this area, most notably PAH, PCB, and toxic metals.
- The Middle St. Johns River area near Rice Creek. Elevated concentrations of PCB and other chlorinated industrial compounds were found in this area, as were moderate levels of relatively undegraded DDT.
- The water bodies sampled on the south side of Gainesville [OR908 (Bivens Arm West) and SWBPP1 (Sweetwater Branch at Paynes Prairie)]. These sites had elevated concentrations of PAH, PCB, metals (most notably lead), chlordane, and DDT, and the total phosphorus levels were very high at SWBPP1.
- The mid-Florida lakes region, and other lakes. Several of the mid-Florida lakes, including Lake Harris, Lake Eustin, and Lake Griffin had high concentrations of PCB and several metals, and the DDT concentrations were high in Lake Dora. Away from this region, Lake Disston had very high concentrations of DDT and elevated chlordane, and Lake George had elevated concentrations of several chlorinated pesticides (e.g., chlordane, BHCs, and DDT).

The potential for biological impact from the measured contaminants generally appears to be low, based on the ER-L and TEL comparison approach, and is consistent with the generally low to moderate organic contaminant and metals concentrations measured in most of these sediments. With the possible exception for the locations indicated above, the potential for biological impact is likely low, based on the ER-L/ER-M assessment method.

The data that were generated in this study provide useful information on the ***general*** status of the quality of the fresh water sediments in the SJRWMD, on general problem areas, and on specific potential hot spots that may warrant further investigation.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Explanation
BHC	Benzene Hexachloride
BS	Blank Spike
CLP	Contract Laboratory Program
CVAAS	Cold Vapor Atomic Absorption Spectroscopy
DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
DEP	Department of Environmental Protection
DQO	Data Quality Objective
DUP	Duplicate
EAS	Environmental Assessment Section
EMAP	Environmental Monitoring and Assessment Program
EPC	Electronic Pressure Control
ER-L	Effects Range-Low
ER-M	Effects Range-Medium
ES	Environmental Sciences
FDEP	Florida Department of Environmental Protection
GFAAS	Graphite Furnace Atomic Absorption Spectroscopy
GPC	Gel Permeation Chromatography
GS/MS	Gas Chromatography/Mass Spectrometry
HCI	Hydrochloric Acid
HPLC	High Performance Liquid Chromatography
ICP/MS	Inductively Coupled Plasma/Mass Spectroscopy
LCS	Laboratory Control Sample
LEL	Lowest Effect Level
LPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbon
LSJRB	Lower St. Johns River Basin
MDL	Method Detection Limit
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ND	Not Detected
N-Evap	Nitrogen Evaporation
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NS&T	National Status and Trends
OP	Ortho-Phosphate (Soluble Reactive Phosphorous)
PAH	Polycyclic Aromatic Hydrocarbon
PB	Procedural Blank
PCB	Polychlorinated Biphenyl
PEL	Probable Effect Level

Abbreviation or Acronym	Explanation
PFTBA	Perfluorotributylamine
QA	Quality Assurance
QAP	Quality Assurance Plan
QAPP	Quality Assurance Project Plan
QC	Quality Control
QMP	Quality Management Plan
RIS	Recovery Internal Standards
SIM	Selected Ion Monitoring
SIS	Surrogate Internal Standards
SJRWMD	St. Johns River Water Management District
SOP	Standard Operating Procedure
SRM	Standard Reference Material
STORET	Storage and Retrieval System for Water and Biological Monitoring Data
SWIM	Surface Water Improvement and Management
SWQMP	Surface Water Quality Monitoring Program
TEL	Threshold Effects Level
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorous
TS	Total Solids
TVS	Total Volatile Solids

1. INTRODUCTION

1.1 Background

The St. Johns River Water Management District (SJRWMD) comprises approximately 12,000 square miles in northeastern Florida, or about 21 percent of the state's total area. The SJRWMD includes all or parts of 19 counties. The region comprises several major urban centers; numerous smaller cities, towns, and residential developments; and large tracts of rural land in agriculture and forestry. Nine percent of the SJRWMD's area is water. The SJRWMD has a population of approximately 3.2 million (1990 census), or 25 percent of the state's total. The SJRWMD's population has grown rapidly in recent decades and is expected to continue growing at a comparable rate in the future. The population is projected to reach over 4.5 million by the year 2010. The most prevalent economic activities within the SJRWMD are tourism, agriculture, forestry, and paper manufacturing. The SJRWMD contains about one-third of the state's citrus acreage and produces 10% percent of Florida's fresh winter vegetables. Half of the state's pulp mills are located in the SJRWMD. Many regional economies depend on the SJRWMD's water resources. A generalized land use distribution is shown in Figure 1-1.

The St. Johns River, approximately 270 miles long, is the longest river located entirely in Florida and is one of the few northward flowing rivers in the United States. The average gradient of the river is less than 0.1 foot per mile. To facilitate the planning and management of surface water, the SJRWMD is divided into ten hydrologic units or surface water basins (Figure 1-2). The boundaries of these basins approximate drainage basins delineated by the U.S. Geological Survey. Approximately 70 percent of the SJRWMD is drained by the St. Johns River and its tributaries. The St. Johns River and its principal tributary, the Ocklawaha River, drain about one-sixth of the total area of Florida. The remainder of the SJRWMD is drained by the Nassau and St. Mary's rivers in the north and by various streams in the coastal area along the Atlantic Ocean. The SJRWMD includes a major portion of Florida's lake region. The chain of interconnected lakes in the Ocklawaha River basin, including Lakes Apopka, Harris, Eustis, Griffin, and Dora, are important recreational assets. Large, shallow lakes along the main stem of the St. Johns River, such as Lakes George, Harney, and Monroe, are also distinctive features of the SJRWMD.

The SJRWMD was created in 1972 by the Florida Legislature in response to the need for protecting and preserving the state's water resources. The mission of the SJRWMD is to manage water resources to ensure their continued availability while maximizing both environmental and economic benefits. The responsibilities of the SJRWMD have expanded greatly since its inception. The SJRWMD's original focus on flood control has broadened to include water supply protection, water quality protection, and environmental enhancement. Various programs and projects have been initiated to address these responsibilities. Since 1987, the SJRWMD has been required by Florida Statute (Chap. 373.451-373.4595 F.S.) to develop and implement Surface Water Improvement and Management (SWIM) Plans. To date, four waterbodies have been identified for priority restoration and protection: the Indian River Lagoon, Lake Apopka, the Upper Ocklawaha River, and the Lower St. Johns River.

Surface water quality monitoring began at SJRWMD in 1979 as a component of the Upper St. Johns River Basin Project. A district-wide monitoring program, known as the Permanent Monitoring Network Project, began in 1983 with the objectives of locating polluted surface waters and creating a long-term water quality database for analyzing temporal trends in water quality. The project was renamed Surface Water Quality Monitoring Program (SWQMP) in 1988 to more specifically reflect project activities and is managed by the Environmental Assessment Section (EAS) within the Environmental Sciences (ES) division.

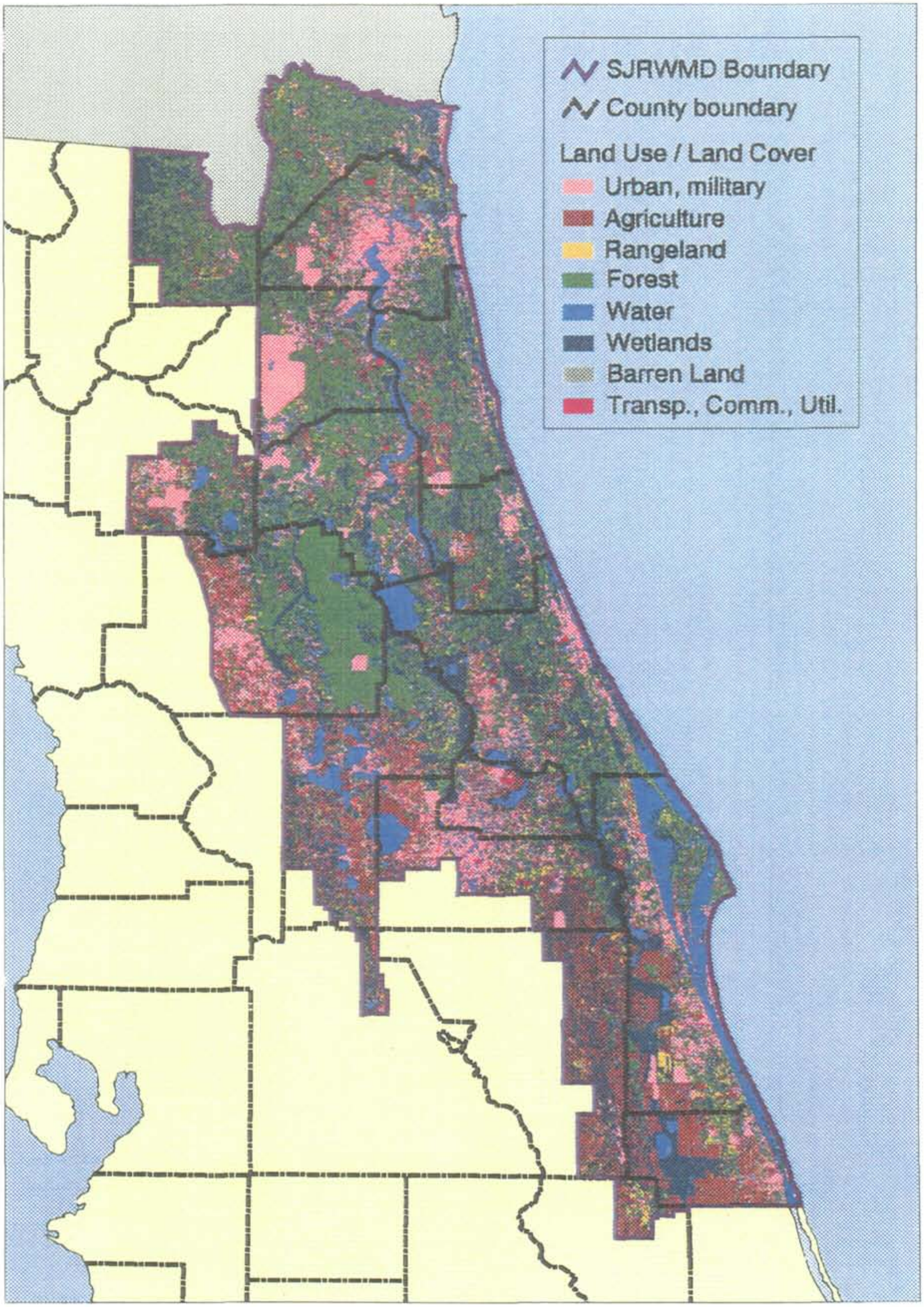

Figure 1-1. Land Uses in the St. Johns River Water Management District

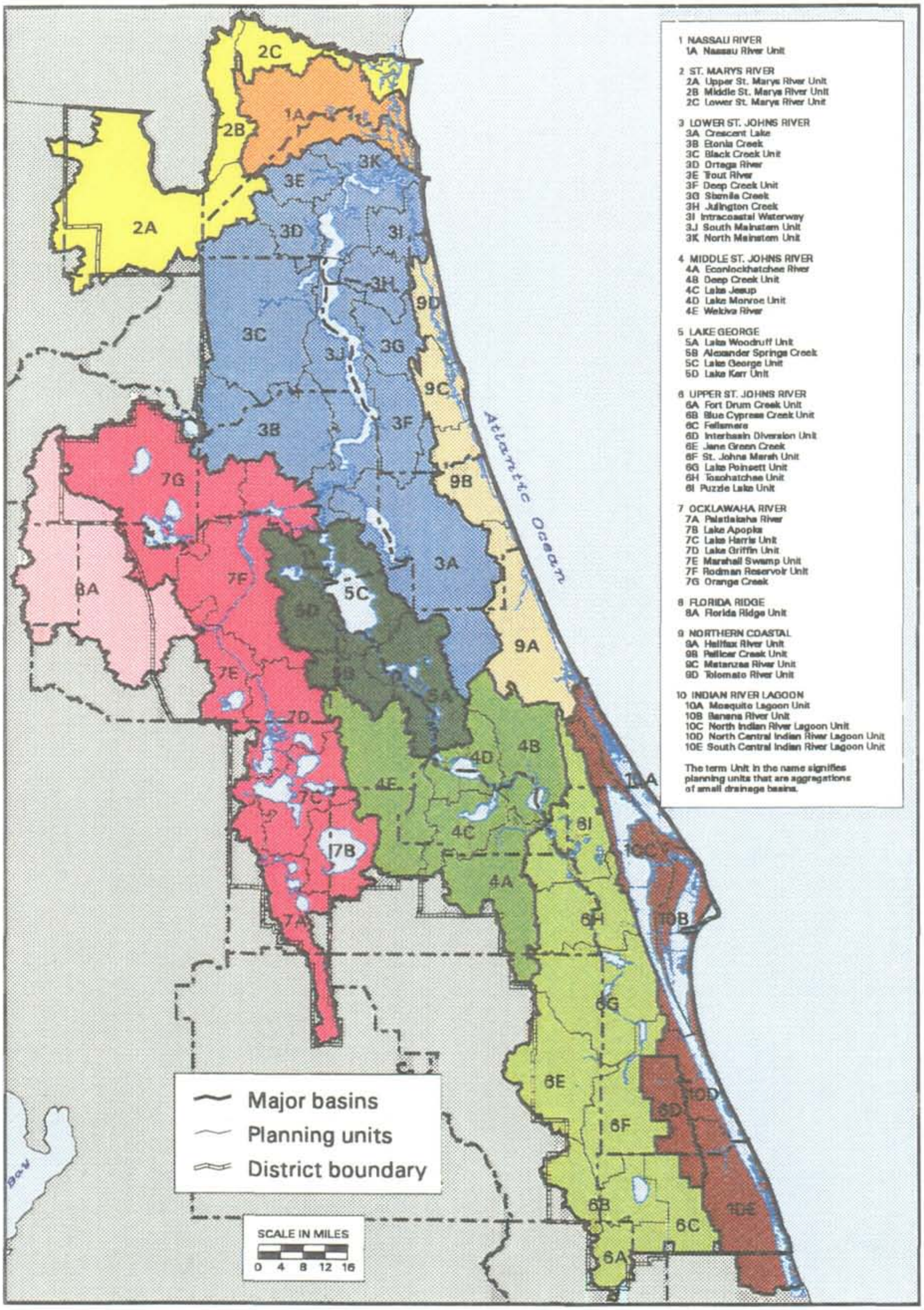

Figure 1-2. Hydrological Units in the St. Johns River Water Management District

Originally the SJRWMD's only surface water quality monitoring project, the SWQMP is now one of five equivalently sized monitoring programs (including Upper St. Johns Basin non-SWIM, Lower St. Johns River Basin SWIM, Apopka/Upper Ocklawaha SWIM, and Indian River Lagoon SWIM Programs) in the ES division. In 1990, the SWQMP started monitoring sediments for priority pollutants. Priority pollutants include metals, hydrocarbons, pesticides and industrial chemicals known to be acutely or chronically toxic. All data collected under this program have been uploaded to the EPA's National Water Quality Data Base (STORET) and are used by the FDEP for the State biennial assessment of water quality — the 305(b) report.

1.2 Objectives

The District-wide survey of toxic compounds in sediments was initiated in FY 89-90 following several studies which documented the prevalence of toxic organic compounds in sediments of the Lower St. Johns River (Dames and Moore, 1983; Shropp and Windom, 1987; Pierce *et al.*, 1988; FDER, 1988). Sediment studies were continued under the SWQMP during FY 90-93. More than half of the stations surveyed to date indicate widespread contamination from polycyclic aromatic hydrocarbons (Delfino *et al.*, 1991 and 1993).

The objective of this program is to determine the presence and concentration of potentially toxic organic compounds and metals in sediments. Areas of high concentration warrant more intensive sampling to characterize the sediment. Sediments are analyzed for multiple constituents such as semi-volatile organic compounds, pesticides, and polychlorinated biphenyls, and screened for heavy metals such as mercury, cadmium, and lead.

Most SJRWMD programs to date have focused on water monitoring. In recent years the sediments that underlie water bodies have also been chosen as a medium for assessing aquatic ecosystem health. Sediment-bound contaminants can pose a direct risk to benthic organisms and the aquatic food web due to their acute or chronic toxicity. Unlike rapidly changing water chemistry, sediments integrate pollution over time and can thus indicate a history of contamination. A sampling program that addresses the distribution and change over time of toxic substances (i.e., metals and synthetic organic compounds) in sediment is therefore an essential component of an integrated and comprehensive environmental quality assessment.

This report describes (1) an assessment of sediment quality at the SWQMP and selected LSJRB stations, (2) background conditions in the study area, (3) the stations with elevated pollution in the sediments, and (4) recommendations for further studies.

1.3 Scope of Work

Battelle and the SJRWMD jointly developed an analytical program in which Battelle could assist the SJRWMD with the measurement and assessment of organic and trace metal contaminants in sediments from water bodies throughout the SJRWMD. The scope of work was as follows:

Sediment sampling locations were selected and sampled by SJRWMD staff following appropriate procedures, and the samples were shipped to the laboratory for chemical and physical-chemical analysis. The target analytical parameters, and the method detection limits, are listed in Table 1-1. Battelle was responsible for determining the sediment concentrations of the target organic and trace metal contaminants and Battelle's subcontracting laboratory (Mote Marine) performed the analysis for the nutrient and physical-chemical parameters identified as Ancillary Measurements.

Table 1-1. Analytical Parameters and Method Detection Limits

TARGET ANALYTE	Sediment MDL (μg/kg, dry weight)	Analysis Method [a]
Organic Compounds - PAH		
1-Methylnaphthalene	0.46	8270M
1-Methylphenanthrene	0.30	8270M
2-Methylnaphthalene	0.71	8270M
1-Chloronaphthalene	0.43	8270M
2-Chloronaphthalene	0.47	8270M
2,6-Dimethylnaphthalene	0.36	8270M
2,3,5-Trimethylnaphthalene	0.32	8270M
Acenaphthene	0.40	8270M
Acenaphthylene	0.31	8270M
Anthracene	0.24	8270M
Benzo(a)anthracene	0.21	8270M
Benzo(a)pyrene	0.30	8270M
Benzo(e)pyrene	0.21	8270M
Benzo(b)fluoranthene	0.19	8270M
Benzo(g,h,i)perylene	0.83	8270M
Benzo(k)fluoranthene	0.24	8270M
Biphenyl	0.38	8270M
Chrysene	0.24	8270M
Dibenz(a,h)anthracene	0.16	8270M
Fluoranthene	0.29	8270M
Fluorene	0.34	8270M
Indeno(1,2,3-cd)pyrene	0.17	8270M
Isophorone	0.36	8270M
Naphthalene	0.60	8270M
Perylene	0.15	8270M
Phenanthrene	0.88	8270M
Pyrene	0.26	8270M
Organic Compounds - Phthalates		
Butylbenzylphthalate	1.97	8270M
Di-N-butylphthalate	6.00	8270M
Diethylphthalate	12.0	8270M
Dimethylphathalate	2.33	8270M
Bis(2-ethylhexyl)phthalate	8.97	8270M
Di-N-octylphthalate	2.03	8270M
Organic Compounds - Pesticide		
Chlordecone (Kepone)	0.10	8270M

Table 1-1 (continued). Analytical Parameters and Method Detection Limits

TARGET ANALYTE	Sediment MDL (μg/kg, dry weight)	Analysis Method [a]
Organic Compounds - PCB Congeners		
Cl_2(8)	0.08	8081M
Cl_3(18)	0.09	8081M
Cl_3(28)	0.15	8081M
Cl_4(52)	0.09	8081M
Cl_4(44)	0.07	8081M
Cl_4(66)	0.07	8081M
Cl_4(77)/Cl_5(110)	0.07	8081M
Cl_5(101)	0.10	8081M
Cl_5(118)	0.07	8081M
Cl_6(153)	0.08	8081M
Cl_5(105)	0.07	8081M
Cl_6(138)	0.07	8081M
Cl_5(126)/Cl_6(129)	0.59	8081M
Cl_7(187)	0.07	8081M
Cl_6(128)	0.07	8081M
Cl_7(180)	0.06	8081M
Cl_6(169)	0.1	8081M
Cl_7(170)	0.10	8081M
Cl_8(195)	0.08	8081M
Cl_9(206)	0.11	8081M
Cl_{10}(209)	0.12	8081M
Organic Compounds - Other Chlorinated		
1,2-Dichlorobenzene	1.31	8081M
1,3-Dichlorobenzene	0.80	8081M
1,4-Dichlorobenzene	1.32	8081M
1,2,4-Trichlorobenzene	0.29	8081M
1,2,4,5-Tetrachlorobenzene	0.11	8081M
Hexachlorobutadiene	0.16	8081M
Hexachloroethane	0.12	8081M
Hexachlorocyclopentadiene	0.20	8081M
Organic Compounds - Pesticides		
4,4'-DDD	0.05	8081M
2,4'-DDD	0.06	8081M
4,4'-DDE	0.06	8081M
2,4'-DDE	0.08	8081M
4,4'-DDT	0.08	8081M
2,4'-DDT	0.08	8081M
Aldrin	0.12	8081M
α-BHC	0.09	8081M
β-BHC	0.08	8081M
δ-BHC	0.06	8081M
γ-BHC (Lindane)	0.09	8081M
Chlorpyriphos (Dursban)	0.10	8081M
α-Chlordane	0.08	8081M
γ-Chlordane	0.07	8081M
Oxychlordane	0.1	8081M

Table 1-1 (continued). Analytical Parameters and Method Detection Limits

TARGET ANALYTE	Sediment MDL (µg/kg, dry weight)	Analysis Method [a]
Organic Compounds - Pesticides (cont.)		
trans-Nonachlor	0.07	8081M
cis-Nonachlor	0.1	8081M
Dieldrin	0.07	8081M
Endosulfan I	0.08	8081M
Endosulfan II	0.06	8081M
Endosulfan sulfate	0.06	8081M
Endrin	0.09	8081M
Endrin aldehyde	0.10	8081M
Endrin ketone	0.07	8081M
Heptachlor	0.12	8081M
Heptachlor epoxide	0.08	8081M
Hexachlorobenzene	0.11	8081M
Methoxychlor	0.10	8081M
Mirex	0.07	8081M
Toxaphene	5	8081M
Metals	(mg/kg, dry weight)	
Aluminum (Al)	14.3	200.8M
Arsenic (As)	1.03	200.9M
Cadmium (Cd)	0.074	200.8M
Chromium (Cr)	1.0	200.8M
Copper (Cu)	0.657	200.8M
Iron (Fe)	400	200.8M
Lead (Pb)	0.746	200.8M
Lithium (Li)	0.928	200.8M
Manganese (Mn)	0.662	200.8M
Mercury (Hg)	0.01	245.5
Nickel (Ni)	1.14	200.8M
Selenium (Se)	0.27	200.9M
Silver (Ag)	0.022	200.9M
Tin (Sn)	0.056	200.8M
Zinc (Zn)	3.26	200.8M
Ancillary Measurements		
Total Kjeldahl nitrogen (TKN)	5	
Total phosphorous (TP)	5	
Orthophosphate (OP)	0.5	
Total Organic Carbon (TOC)	0.01 %	
Total solids (TS)	0.5 % (wet weight)	
Total volatile solids (TVS)	0.5 % (dry weight)	
Grain Size	0.5 %	
% Moisture	0.5 %	

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[a] The instrumental analysis methods listed apply the following analytical instrumentation:
8270M: Gas chromatography/mass spectrometry (GC/MS)
8081M: Gas chromatography/electron capture detection (GC/ECD)
200.8M: Inductively coupled plasma/mass spectrometry (ICP/MS)
200.9M: Graphite furnace atomic absorption spectroscopy (GFAAS)
245.5: Cold vapor atomic absorption spectroscopy (CVAAS)

The target contaminants and ancillary measures list was developed based on the following considerations:

- Identification of the most important and persistent organic and metal contaminants found in sediments, as documented by major monitoring programs conducted in this country over the last 10 years (e.g., EMAP, National Status and Trends Program). Central to this theme was the selection of those organic compounds which are sufficiently non-polar, and thus accumulate in sediments, and have demonstrated abilities to bioaccumulate in benthic and higher aquatic organisms.
- Inclusion of the most useful physical parameters and methods for their measurement.
- Comparability with the target analyte list currently being used by the LSJRB project for the St. Johns River mainstem so as to ensure comparability, continuity in methods, detection limits, and appropriate quality control measures.

Sediment analytical results have been reported to the SJRWMD in both hardcopy and electronic format (for inclusion in the SJRWMD database). Battelle was then responsible for preparing this interpretative report based on the results of the sediment analyses of the 71 stations under this project and 15 selected stations within the LSJRB from a separate analytical task (for a total of 86 stations). The report format and content were finalized through discussions between Battelle and SJRWMD staff. The report includes the following:

- Study objectives
- Listing of sampling locations and the nature of the sediments
- The analytical methods used and the detection limits
- The Quality Control program and summary of results
- Analytical results in tabular and, where applicable, graphical form
- Analysis of relationships among chemical contaminant burdens and physiochemical composition of the sediments
- Intercomparison of contaminant burdens among sampling stations
- A comparison of measured sediment burdens with NOAA ER-L and ER-M values as first-level indicators of possible risks that in-place contaminants might pose to the benthic ecological systems
- Conclusions and recommendations

2. TECHNICAL APPROACH

2.1 Site Selection — Rationale and Objectives

The study sites included in this report are the 71 that comprise the SJRWMD's Surface Water Quality Monitoring Program (SWQMP) and 15 selected sites that represent the Lower St. Johns River Basin (LSJRB). The SWQMP performs a District-wide assessment of water quality using data derived from both its own network as well as data acquired from other agencies. This assessment is directed toward 1) establishing background conditions, 2) determining temporal trends, and 3) identifying areas of poor or impacted water quality. The SWQMP maintains a surface water quality monitoring network which currently collects samples at 71 locations throughout the SJRWMD at a frequency of 6 times per year.

The SWQMP stations were selected based on the following criteria:

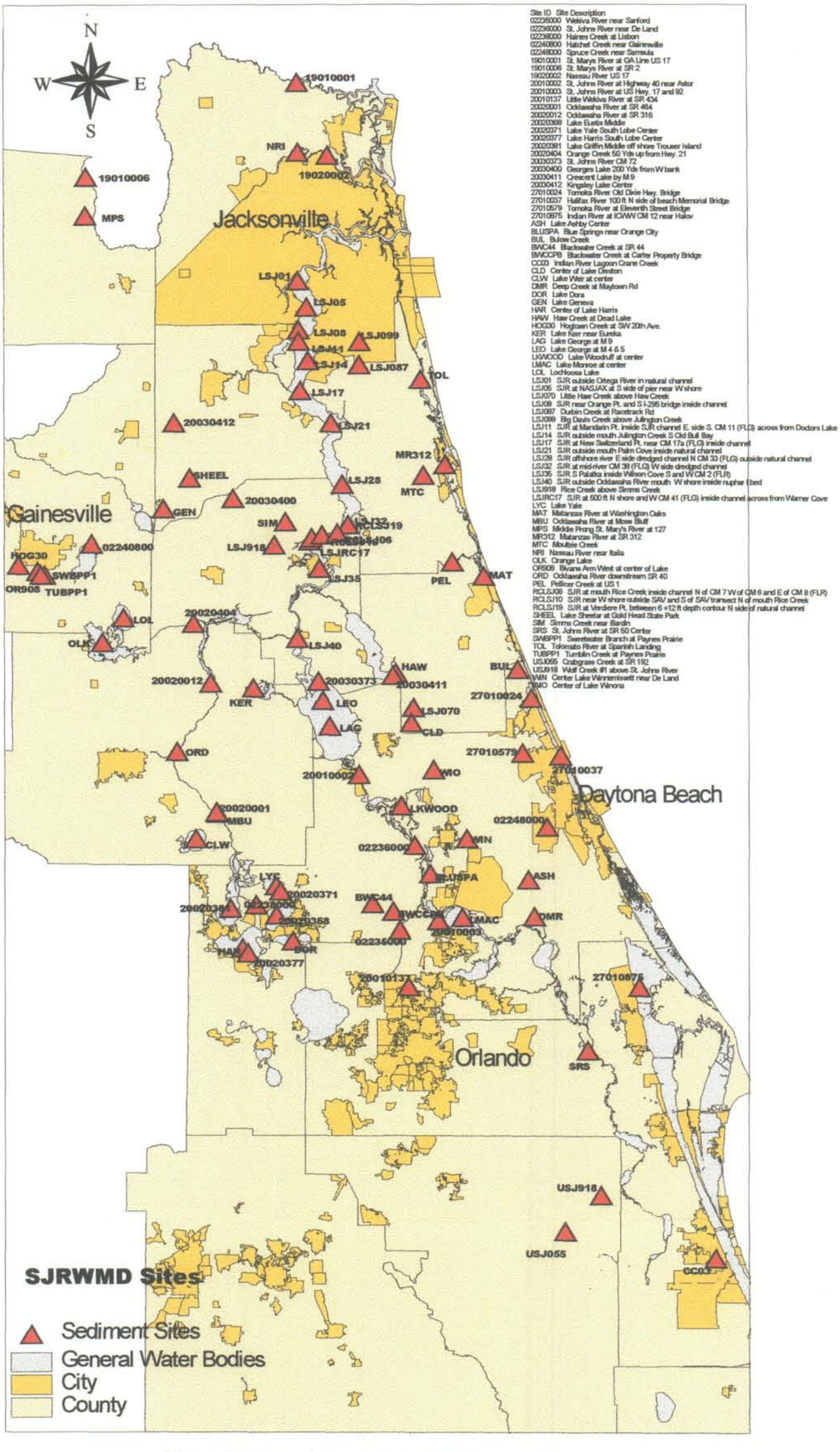
- Presence or absence of elevation/discharge gauging station
- Period of record for water quality data
- Designation as an Outstanding Florida Water
- Designation as a biological monitoring site
- SJRWMD water classification
- Designation as a Surface Water Improvement and Management (SWIM) site
- Site accessibility
- Placement inside or outside SJRWMD pollution loading zone

The water quality stations are geographically comprehensive. Since the primary environmental assessment goals of the sediment program are similar to those for the water program, sediment samples were taken at the same locations. The 15 LSJRB sites included in this report were selected following the EPA's EMAP probability based sampling design protocol.

Through coordination and cooperation with other agencies and programs, the District's SWQMP program is annually refined to complement other networks and reduce sampling redundancy. The locations of all 71 stations sampled under the SWQMP project, together with the 15 stations sampled under the LSJRB SWIM project that were used in this study, are shown in Figure 2-1, and they are briefly described in Table 2-1. The detailed site maps for each station are presented in Appendix A.

2.2 Sediment Sample Collection and Field Procedures

The SJRWMD staff collected the samples for this project. Battelle provided the SJRWMD with clean, empty jars for the sample collection, along with labels, chain-of-custody forms, and coolers for sample storage and shipment. Three sediment grabs were collected at each sampling site, as illustrated in Figure 2-2. These three site replicates were placed in separate glass jars, chilled and shipped to the laboratory for analysis. At the laboratory, the sediment were mixed thoroughly and equal amounts from each of the three site replicates were removed and placed in a new jar, mixed, and used for the subsequent analyses. Individual site grabs were not analyzed separately.



Site ID	Site Description
02235000	Wekiva River near Sanford
02236000	St. Johns River near De Land
02238000	Haines Creek at Lisbon
02240800	Hatchet Creek near Gainesville
02248000	Spruce Creek near Samsula
19010001	St. Marys River at GA Line US 17
19010006	St. Marys River at SR 2
19020002	Nassau River US 17
20010002	St. Johns River at Highway 40 near Astor
20010003	St. Johns River at US Hwy. 17 and 92
20010137	Little Wekiva River at SR 434
20020001	Ocklawaha River at SR 464
20020012	Ocklawaha River at SR 316
20020368	Lake Eustis Middle
20020371	Lake Yale South Lobe Center
20020377	Lake Harris South Lobe Center
20020381	Lake Griffin Middle off shore Trouser Island
20020404	Orange Creek 50 Yds up from Hwy. 21
20030373	St. Johns River CM 72
20030400	Georges Lake 200 Yds from W bank
20030411	Crescent Lake by M 9
20030412	Kingsley Lake Center
27010024	Tomoka River Old Dixie Hwy. Bridge
27010037	Halifax River 100 ft N side of beach Memorial Bridge
27010579	Tomoka River at Eleventh Street Bridge
27010875	Indian River at ICWW CM 12 near Halov
ASH	Lake Ashby Center
BLUSPA	Blue Springs near Orange City
BUL	Bulow Creek
BWC44	Blackwater Creek at SR 44
BWCCPB	Blackwater Creek at Carter Property Bridge
CC03	Indian River Lagoon Crane Creek
CLD	Center of Lake Disston
CLW	Lake Weir at center
DMR	Deep Creek at Maytown Rd
DOR	Lake Dora
GEN	Lake Geneva
HAR	Center of Lake Harris
HAW	Haw Creek at Dead Lake
HOG30	Hogtown Creek at SW 20th Ave.
KER	Lake Kerr near Eureka
LAG	Lake George at M 9
LEO	Lake George at M 4 & 5
LKWOOD	Lake Woodruff at center
LMAC	Lake Monroe at center
LOL	Lochloosa Lake
LSJ01	SJR outside Ortega River in natural channel
LSJ05	SJR at NASJAX at S side of pier near W shore
LSJ070	Little Haw Creek above Haw Creek
LSJ08	SJR near Orange Pt. and S I-295 bridge inside channel
LSJ087	Durbin Creek at Racetrack Rd
LSJ099	Big Davis Creek above Julington Creek
LSJ11	SJR at Mandarin Pt. inside SJR channel E. side S. CM 11 (FLG) across from Doctors Lake
LSJ14	SJR outside mouth Julington Creek S Old Bull Bay
LSJ17	SJR at New Switzerland Pt. near CM 17a (FLG) inside channel
LSJ21	SJR outside mouth Palm Cove inside natural channel
LSJ28	SJR offshore river E side dredged channel N CM 33 (FLG) outside natural channel
LSJ32	SJR at mid-river CM 38 (FLG) W side dredged channel
LSJ35	SJR S Palatka inside Wilson Cove S and W CM 2 (FLR)
LSJ40	SJR outside Ocklawaha River mouth W shore inside nuphar bed
LSJ918	Rice Creek above Simms Creek
LSJRC17	SJR at 500 ft N shore and W CM 41 (FLG) inside channel across from Warner Cove
LYC	Lake Yale
MAT	Matanzas River at Washington Oaks
MBU	Ocklawaha River at Moss Bluff
MPS	Middle Prong St. Mary's River at 127
MR312	Matanzas River at SR 312
MTC	Moultrie Creek
NRI	Nassau River near Italia
OLK	Orange Lake
OR908	Bivans Arm West at center of Lake
ORD	Ocklawaha River downstream SR 40
PEL	Pellicer Creek at US 1
RCLSJ06	SJR at mouth Rice Creek inside channel N of CM 7 W of CM 6 and E of CM 8 (FLR)
RCLSJ10	SJR near W shore outside SAV and S of SAV transect N of mouth Rice Creek
RCLSJ19	SJR at Verdiere Pt. between 6 +12 ft depth contour N side of natural channel
SHEEL	Lake Sheelar at Gold Head State Park
SIM	Simms Creek near Bardin
SRS	St. Johns River at SR 50 Center
SWBPP1	Sweetwater Branch at Paynes Prairie
TOL	Tolomato River at Spanish Landing
TUBPP1	Tumblin Creek at Paynes Prairie
USJ055	Crabgrass Creek at SR 192
USJ918	Wolf Creek #1 above St. Johns River
WIN	Center Lake Winnemissett near De Land
WIO	Center of Lake Winona

Figure 2-1. Locations of the 86 Sampling Sites

Table 2-1. Sediment Sampling Site Descriptions

SITE ID	DESCRIPTION	COUNTY
02235000	Wekiva River near Sanford	SEMINOLE
02236000	St. Johns River near De Land	LAKE
02238000	Haines Creek at Lisbon	LAKE
02240800	Hatchet Creek near Gainesville	ALACHUA
02248000	Spruce Creek near Samsula	VOLUSIA
19010001	St. Marys River at GA Line US 17	NASSAU
19010006	St. Marys River at SR 2	BAKER
19020002	Nassau River US 17	DUVAL
20010002	St. Johns River at Highway 40 near Astor	VOLUSIA
20010003	St. Johns River at US Hwy. 17 and 92	VOLUSIA
20010137	Little Wekiva River at SR 434	SEMINOLE
20020001	Ocklawaha River at SR 464	MARION
20020012	Ocklawaha River at SR 316	MARION
20020368	Lake Eustis Middle	LAKE
20020371	Lake Yale South Lobe Center	LAKE
20020377	Lake Harris South Lobe Center	LAKE
20020381	Lake Griffin Middle off shore Trouser Island	LAKE
20020404	Orange Creek 50 Yds up from Hwy. 21	PUTNAM
20030373	St. Johns River CM 72	PUTNAM
20030400	Georges Lake 200 Yds from W bank	PUTNAM
20030411	Crescent Lake by M 9	VOLUSIA
20030412	Kingsley Lake Center	CLAY
27010024	Tomoka River Old Dixie Hwy. Bridge	VOLUSIA
27010037	Halifax River 100 ft N side of beach Memorial Bridge	VOLUSIA
27010579	Tomoka River at Eleventh Street Bridge	VOLUSIA
27010875	Indian River at ICWW CM 12 near Halov	BREVARD
ASH	Lake Ashby Center	VOLUSIA
BLUSPA	Blue Springs near Orange City	VOLUSIA
BUL	Bulow Creek	VOLUSIA
BWC44	Blackwater Creek at SR 44	LAKE
BWCCPB	Blackwater Creek at Carter Property Bridge	LAKE
CC03	Indian River Lagoon Crane Creek	BREVARD
CLD	Center of Lake Disston	FLAGLER
CLW	Lake Weir at center	MARION
DMR	Deep Creek at Maytown Rd	VOLUSIA
DOR	Lake Dora	LAKE
GEN	Lake Geneva	CLAY
HAR	Center of Lake Harris	LAKE
HAW	Haw Creek at Dead Lake	VOLUSIA
HOG30	Hogtown Creek at SW 20th Ave.	ALACHUA
KER	Lake Kerr near Eureka	MARION
LAG	Lake George at M 9	VOLUSIA
LEO	Lake George at M 4 & 5	VOLUSIA
LKWOOD	Lake Woodruff at center	VOLUSIA
LMAC	Lake Monroe at center	VOLUSIA
LOL	Lochloosa Lake	ALACHUA

Table 2-1 (continued). Sediment Sampling Site Descriptions

SITE ID	DESCRIPTION	COUNTY
LSJ01	St. Johns River outside mouth of Ortega River within natural channel	DUVAL
LSJ05	St. Johns River at NASJAX at S side of pier near W shore LSJR	DUVAL
LSJ070	Little Haw Creek above Haw Creek	FLAGLER
LSJ08	St. Johns River near Orange Pt. and S I-295 bridge inside natural SJR channel	DUVAL
LSJ087	Durbin Creek at Racetrack Rd	ST JOHNS
LSJ099	Big Davis Creek above Julington Creek	DUVAL
LSJ11	St. Johns River at Mandarin Pt. inside natural SJR channel E. side S. CM 11 (flash green) across from mouth of Doctors Lake	DUVAL
LSJ14	St. Johns River outside mouth Julington Creek S Old Bull Bay	ST JOHNS
LSJ17	St. Johns River at New Switzerland Pt. near CM 17a (flash green) inside natural SJR channel	ST JOHNS
LSJ21	St. Johns River outside mouth Palm Cove inside natural SJR channel	ST JOHNS
LSJ28	St. Johns River offshore river E side dredged channel N CM 33 (flash green) outside natural SJR channel	ST JOHNS
LSJ32	St. Johns River at mid-river CM 38 (flash red) W side dredged channel	PUTNAM
LSJ35	St. Johns River S Palatka inside Wilson Cove S and W CM 2 (flash red)	PUTNAM
LSJ40	St. Johns River outside Ocklawaha River mouth W shore inside nuphar l bed	PUTNAM
LSJ918	Rice Creek above Simms Creek	PUTNAM
LSJRC17	St. Johns River at 500 ft from N shore N and W CM 41 (flash green) inside natural SJR channel across SJR from Warner Cove	PUTNAM
LYC	Lake Yale	LAKE
MAT	Matanzas River at Washington Oaks	FLAGLER
MBU	Ocklawaha River at Moss Bluff	MARION
MPS	Middle Prong St. Mary's River at 127	BAKER
MR312	Matanzas River at SR 312	ST JOHNS
MTC	Moultrie Creek	ST JOHNS
NRI	Nassau River near Italia	NASSAU
OLK	Orange Lake	ALACHUA
OR908	Bivans Arm West at center of Lake	ALACHUA
ORD	Ocklawaha River downstream SR 40	MARION
PEL	Pellicer Creek at US 1	ST JOHNS
RCLSJ06	St. Johns River at mouth Rice Creek inside channel N of CM 7 W of CM 6 and E of CM 8 (flash red)	PUTNAM
RCLSJ10	St. Johns River near W shore outside SAV and S of transect N of mouth Rice Creek	PUTNAM
RCLSJ19	St. Johns River at Verdiere Pt between 6+12 ft depth contour N of SJR channel	PUTNAM
SHEEL	Lake Sheelar at Gold Head State Park	CLAY
SIM	Simms Creek near Bardin	PUTNAM
SRS	St. Johns River at SR 50 Center	ORANGE
SWBPP1	Sweetwater Branch at Paynes Prairie	ALACHUA
TOL	Tolomato River at Spanish Landing	ST JOHNS
TUBPP1	Tumblin Creek at Paynes Prairie	ALACHUA
USJ055	Crabgrass Creek at SR 192	OSCEOLA
USJ918	Wolf Creek #1 above St. Johns River	OSCEOLA
WIN	Center Lake Winnemissett near De Land	VOLUSIA
WIO	Center of Lake Winona	VOLUSIA

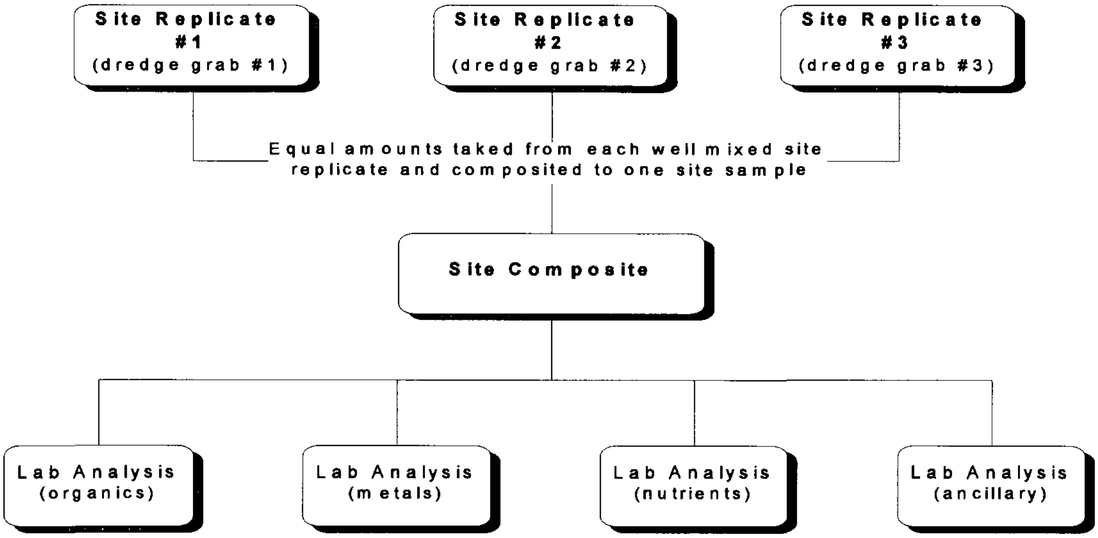


Figure 2-2. Sampling and Compositing Regime for each Site

The SJRWMD Environmental Assessment staff collected the sediment samples in December 1996 and January 1997. The SJRWMD staff followed Quality Assurance/Quality Control procedures in compliance with the SJRWMD's Comprehensive Quality Assurance Plan (CompQAP). The materials (e.g., clean stainless steel, glass, and Teflon materials) and procedures used to collect the samples have been demonstrated to be appropriate for collecting samples for trace chemical analysis (EPA, 1996; EPA, 1994; EPA, 1993; EPA, 1991a,b; Peven and Uhler, 1993a,b).

2.2.1 Sample Collection Containers

The sample containers were 500 mL pre-cleaned glass jars with Teflon lined caps obtained from Battelle for the organic compound and metal analyses, and 120 mL glass and 250 mL plastic jars obtained from Mote Marine for total organic carbon, nutrient and other ancillary analyses. The contract laboratories were responsible for shipping these containers, which had been cleaned in a manner that was consistent with the analysis at hand, to the SJRWMD.

2.2.2 Sample Collection Equipment

SJRWMD staff used pre-cleaned stainless steel petite Ponar dredges and/or Eckman dredges to collect all sediment samples. Pre-cleaned glass dishes and stainless steel spoons were utilized in mixing the individual samples and scooping them into pre-labeled containers. The procedures for the decontamination of the dredges, dishes, and spoons were developed and followed by SJRWMD laboratory staff in accordance with the CompQAP.

2.2.3 Sample Collection Procedures

Sediment collection procedures at the 71 SWQMP and 15 LSJRB SWIM sites involved using boats, bridges, and wading apparel. Most of the lake, river, and estuarine sites were sampled using a boat. SJRWMD field personnel collected samples from smaller streams and rivers by sampling from accessible bridges. One site was sampled by carefully wading into the river, ensuring that the sediment to be collected was not disturbed.

Upon arrival at the site, an Eckman or Ponar dredge was chosen. SJRWMD staff employed the following protocol for dredge usage and sediment collection:

1. Unwrapped aluminum foil from the dredge.
2. Lowered the dredge into the water body until it reached the sediment. A messenger was then sent down the line to trip the spring mechanism and close the jaws of the dredge.
3. Retrieved the sample.
4. Deposited the entire sample into a glass mixing tray
5. Used a stainless steel spoon to thoroughly mix the sample in the mixing tray.
6. Promptly partitioned the mixed sample into the appropriate sample containers in order to prevent oxidation of metal ions or volatilization of organic compounds from the sample.
7. Stored the samples immediately in a cooler with wet ice. No chemical preservative was required. FDEP and EPA sample handling, storage, and holding times were adhered to (Table 2-2).

At each site, SJRWMD staff collected three separate dredge samples (Figure 2-2). The spoon and glass dish were rinsed with de-ionized water between successive samples. The sample containers were filled at each site and immediately placed into a cooler with wet ice.

Sample collection and shipment was coordinated with the analytical laboratories (Battelle and Mote Marine) to ensure that sample holding times were met. The preservation and maximum holding times of sediment samples for laboratory analysis were, as outlined in the FDEP SOPs, as follows:

Table 2-2. Sediment Sample Holding Times

Measurement	Preservation Method	Maximum Holding Time
Extractable Organics	Cool at 4°C	14 days until extraction, 40 days to analysis after extraction
Total Metals (except mercury)	Cool at 4°C	6 months
Mercury	Cool at 4°C	28 days
Total Kjeldahl Nitrogen	Cool at 4°C	28 days
Total Phosphorus	Cool at 4°C	28 days
Total Organic Carbon	Cool at 4°C	28 days
Orthophosphate	Cool at 4°C	48 hours

Field blanks comprised of water were collected at various intervals as required by SJRWMD's CompQAP. Deionized water was poured over the sampling equipment (spoons, dredges, and dishes) and collected into clean containers for analysis. The SJRWMD laboratory analyzed the field blank samples, as per the SJRWMD Field Plan.

2.3 Laboratory Sample Analysis Procedures

Selection of Analytical Parameters

The collected sediment samples were analyzed for a series of organic and trace metal contaminants, nutrient parameters, and various physical and chemical ancillary measures to support the monitoring program objectives of this study. The targeted analytical parameters are listed in Table 1-1. This target analyte list was jointly derived by Battelle and SJRWMD staff and includes most of the applicable contaminants from EPA's priority pollutant list, except for some of the polar organic compounds that do not readily accumulate or do not have significant life-times in sediment. Several compounds were added to the SJRWMD standard monitoring list to complete the suite of contaminants (e.g., addition of certain compounds ensured that all the important 2-, 3-, 4-, and 5- ring polycyclic aromatic hydrocarbons (PAH) were represented) and to improve comparability between the SWQMP monitoring efforts and the LSJRB project. Alkylated PAHs were added to provide more complete data on the type of PAH contamination and assist in the identification of petrogenic contamination (e.g., methylated naphthalenes and phenanthrene). Polychlorinated biphenyls (PCBs — as individual congeners) were added as target parameter because these remain ubiquitous and environmentally important compounds. Several other persistent and environmentally relevant chlorinated pesticides that were not on the base list (e.g., δ-BHC, γ-BHC (Lindane), methoxychlor, trans-nonachlor, chlorpyriphos, a-chlordane, and g-chlordane) were added to improve the representation, data usability, and data comparability.

The contaminants determined in this project include the most environmentally important and persistent organic and metal contaminants found in sediment, as documented by major monitoring programs conducted in the U.S. over the past decade (e.g., NOAA's National Status and Trends, and EPA's EMAP program). The compounds had to be sufficiently non-polar to accumulate in sediments and have demonstrated abilities to bioaccumulate in benthic and higher aquatic organisms to be included in the consideration when selecting the organic target compounds. Additionally, an effort was made to provide comparability to other monitoring projects being conducted by the SJRWMD.

Selection of Analytical Procedures

The analytical work for this study required the use of specialized low detection limit procedures. Two principal considerations drove the selection of analytical methods for this study:

- In order to assess the true status of anthropogenic chemicals, analytical methods capable of measuring contaminants at ambient (background) concentrations were required. Using such methods it would be possible to develop a reliable picture of the background conditions, areas of impact, and severity of chemical contamination.

- Sensitive low-level measurements of contaminants needed to be performed in order to determine linkages between chemical presence and observed bioeffects, ecological perturbations, or change. A large body of literature has been amassed demonstrating that such effects occur at very low contaminant concentrations (e.g., EPA Water Quality Criteria, EPA Proposed Sediment Quality Criteria, NOAA ER-L and ER-M Observed Effect Concentrations), well below concentrations capable of being measured by standard EPA methods of analysis.

It has been clearly documented that standard methods of analysis such as EPA SW-846 or Contract Laboratory Program (CLP) methods cannot obtain the detection limits needed to achieve the goals listed above (e.g., Douglas and Uhler, 1993), simply because those standard methods were designed for high level, hazardous waste site or discharge regulatory compliance monitoring. Hence, another set of analytical procedures were needed to achieve the method performance goals required for environmental quality monitoring.

Achieving meaningful detection limits for organic and trace metal contaminants for environmental quality monitoring has been of special concern to the National Oceanic and Atmospheric Administration (NOAA) and the U.S. EPA. Through the NOAA National Status and Trends (NS&T) Program and the EPA Environmental Monitoring and Assessment Program (EMAP), a set of analytical methods have been developed specifically to meet the low level detection limit requirements necessary for successful environmental quality monitoring. Developed over the last 10 years, these methods are modifications and improvements upon the standard EPA methods of analysis. Generally, the very low detection limits provided by the NOAA NS&T analytical methods are achieved by using larger sample sizes, employing several additional sample cleanup steps prior to instrumental analysis, and by employing instrumental analysis procedures that are highly targeted to the analytes of interest.

These methods are used by NOAA for the National Status and Trends Program, by EPA in the National EMAP Program, and are required by the U.S. Army Corps of Engineers in the guidance manual for *Evaluation of Proposed Discharge of Dredged Material into Ocean Water* ("Green Book"), and the USACE *Inland Testing Manual.* The methods are used in the U.S. Navy CLEAN program, the Navy Installation Restoration Programs, and are approved for use in the Naval Energy and Environmental Support Activity (NEESA) program.

The methods have been published in a NOAA Technical Memorandum in which Battelle scientists were principal authors (Peven and Uhler, 1993a,b; Crecelius *et al.*, 1993), and in EPA/USACE testing and analysis documents (EPA, 1996; EPA, 1994; EPA, 1993; EPA, 1991a,b). Constant refinement to keep the methods state-of-the-art, strict laboratory quality control procedures, and an external quality control program administered by the National Institute of Standards and Technology (NIST) ensure that these methods are robust, accurate, and precise for low-level environmental quality monitoring programs.

Battelle employed the NOAA NS&T analytical methods for the analysis of trace metals and the nonpolar organic compounds (PAH, phthalates, chlorinated benzenes/butadienes, chlorinated pesticides, and PCB). Battelle obtained FDEP approval for the application of these specialized methods, which have been incorporated into Battelle's FDEP CompQAP, and are currently being used to provide analytical support to the SJRWMD for monitoring studies in the St. Johns River. The methods, detection limits, and quality control procedures are described in Battelle's FDEP-approved CompQAP, and are summarized below. The ancillary measurements were also performed in accordance with FDEP CompQAP approved methods.

2.3.1 Sample Analysis for Organic Analytes

The general scheme that was used for the laboratory analyses of organic contaminants and metals is shown in Figure 2-3. The laboratory procedures are further described below.

Sample Preparation

The sediment samples were kept refrigerated at approximately 4 °C until laboratory processing could begin. Sample extraction started within 14 days of collection. Laboratory quality control procedures included the analysis of a procedural blank (PB), a blank spike (BS), a matrix spike (MS), a matrix spike duplicate (MSD), and a sediment Standard Reference Material (SRM) with each set of no more than 20 field samples. Additionally, surrogate compound recoveries were monitored for each sample.

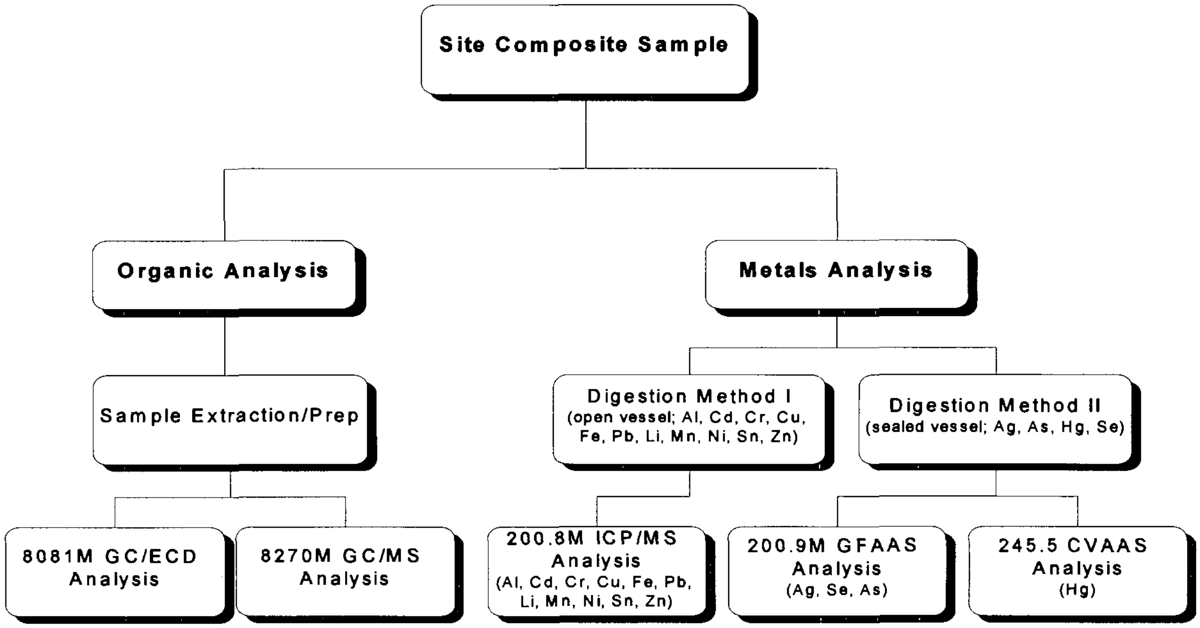


Figure 2-3. Laboratory Scheme for Organic Contaminant and Metals Analysis

The sediment sample was thoroughly homogenized and approximately 30 grams were removed for the extraction. The sample was fortified with surrogate internal standards [(SISs); naphthalene-d_8, phenanthrene-d_{10}, and chrysene-d_{12} for the 8270M analysis; PCB congeners $Cl_3(34)$ and $Cl_5(112)$ for the 8081M analysis)] in order to monitor procedural efficiency and for sample quantification. The sample was then serially extracted three times (24, 4, and 1 hour) in a Teflon jar on a tumbling/agitation table using dichloromethane as the solvent (100, 75, and 75 mL). The combined extract was treated with activated copper for removal of residual sulfur, filtered through a glass fiber filter, and concentrated using a Kuderna-Danish apparatus and gentle nitrogen gas evaporation on an N-Evap.

The extract was next purified using a chromatography column packed with 20 grams of 2% deactivated F-20 alumina to remove biogenic and other bulk undesirable sample matrix material coextracted with the target analytes. Further sample purification was obtained using an automated high performance liquid chromatographic (HPLC) gel permeation chromatography (GPC) cleanup procedure. The GPC column purification procedure employs a 300 mm × 21.2 mm Phenogel (100 Å pore size, 10 µm particle size) semipreparative GPC column (Phenomenex Corp.), with a 50 mm × 7.8 mm Phenogel pre-column. The HPLC system was calibrated specifically for the target analytes of interest prior to the fractionation of each set of samples, and the calibration was monitored with a check standard at least every 10 samples. The sample was loaded onto the column, eluted with 100% dichloromethane, the eluant monitored with a UV detector set at 254 nm, and the target analyte fraction collected using a fraction collector. The entire procedure was automated, and the accuracy and reproducibility of this cleanup process far exceeds what can be obtained with traditional, open, gravity-fed liquid chromatography columns.

The purified sample extract was concentrated using N-Evap and adjusted to a volume of 600–800 µL. The final sample was then solvent exchanged to isooctane, spiked with recovery internal standards [(RIS); acenaphthene-d_{10}, fluorene-d_{10}, and benzo(a)pyrene-d_{12} for the 8270M analysis; PCB congeners Cl_3(29) and Cl_6(166) for the 8081M analysis)], split approximately 50/50, and the two splits submitted for their respective instrumental analyses.

8270M — GC/MS Instrumental Analysis

The concentrations of the Method 8270M target compounds (e.g., PAH, phthalates, kepone) were determined by high-resolution capillary gas chromatography/mass spectrometry (GC/MS). The analytical system was comprised of a Hewlett-Packard (H-P) 5890II GC equipped with an electronic pressure controlled (EPC) inlet and a H-P 5972 MSD operating in the selected ion monitoring (SIM) mode to achieve the needed sensitivity and specificity. Analyte separation was carried out on a 30-m, 0.25-mm i.d., 0.25-µm film thickness, DB-5MS (J&W Scientific, Inc.) fused silica column using helium as the carrier gas. A 2 µL sample was injected and analyzed with the following GC conditions:

Initial column temperature:	40 °C
Initial hold time:	1 minute
Program rate:	6 °C/minutes
Final column temperature:	290 °C
Final hold time:	10 minutes
Injector temperature:	300 °C
Detector temperature:	280 °C
Column flow rate:	1 mL/min (helium; EPC controlled)
Injection mode:	splitless (with EPC control)

The analytical system was tuned with perfluorotributylamine (PFTBA), and calibrated with a five-point calibration curve consisting of each individual target compound with an approximate concentration range of 0.02 to 5 ng/µL. The validity of the initial calibration was monitored with a continuing calibration check analysis at least every 10 samples. Quantification of individual target compounds was performed by the method of internal standards, using the relative response factors versus the RIS.

8081M — GC/ECD Instrumental Analysis

The Method 8081M target analytes (e.g., PCB, pesticides, and other chlorinated organic compounds) were analyzed by high-performance capillary gas chromatography with electron capture detection (GC/ECD) using a Hewlett-Packard 5890II fitted with a ^{63}Ni-electron capture detector. Gas chromatographic separation was carried out on a 60-m, 0.25-mm i.d., 0.25-µm film thickness, DB-5 fused silica capillary column (J&W Scientific, Inc.) using hydrogen as the carrier gas. A 1 µL sample was injected onto the instrument, which was equipped with an EPC inlet for optimum sensitivity and reproducibility. The following gas chromatographic conditions were used:

Initial column temperature:		60 °C
Initial hold time:		1 minute
Program rate.	Ramp 1:	10 °C/minute to 140 °C
	Ramp 2:	1 °C/minute to 220 °C
	Ramp 3:	5 °C/minute to 290 °C
Final column temperature:		290 °C
Final hold time:		15 minutes
Injection temperature:		280 °C
Detector temperature:		300 °C
Column flow rate:		1.2 mL/min (hydrogen; EPC controlled)
Injection mode:		splitless (with EPC control)

The instrumental analysis method used a 5-point calibration curve with an approximate analyte concentration range of 0.005 to 0.12 ng/μL. Each target analyte was fitted to a quadratic equation to best represent the response of the ECD. The validity of the initial calibration was monitored with a continuing calibration check analysis at least every 10 samples. Analytes were quantified by the method of internal standards using the RIS as the quantification internal standard.

8270M and 8081M — Data Quantification and Reporting

The analytical data for the organic compound analyses were originally generated by the method of internal standards using the recovery internal standard (i.e., internal standard added at the end of the sample processing and immediately prior to instrumental analysis) as the quantification internal standard. This is how the data were originally reported to the SJRWMD, in accordance with FDEP guidelines. However, for the purposes of this report those data have been corrected for surrogate compound recoveries. Surrogate corrected data typically provide a much better representation of the actual field sample contaminant concentrations than non-corrected data, and this is the standard analytical approach in most major environmental monitoring programs (e.g., NOAA's National Status and Trends and EPA's EMAP programs). In addition to providing a better representation of the true contaminant levels, surrogate corrected data allow for more reliable comparisons among the study sites.

2.3.2 Sample Analysis for Metal Analytes

The analysis for inorganic parameters involved two digestion procedures to quantitatively recover all elements of interest and three separate instrumental analyses (200.8M, 200.9M, and 245.5). The procedures were designed for quantitative determinations of the following 15 metals (MDLs are listed in Table 1-1): aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), tin (Sn), and zinc (Zn). The general laboratory sample analysis scheme is summarized in Figure 2-3, and further described below.

Laboratory quality control procedures included the analysis of a procedural blank (PB), a blank spike (BS), a matrix spike (MS), a sample duplicate (DUP), and two sediment Standard Reference Materials (SRM) with each set of no more than 20 field samples.

Sample Preparation

To prepare sediment samples for digestion, the samples were dried using a freeze drying technique and blended in a Spex mixer-mill. About 5 g of the mixed sample was then ground in a ceramic ball mill.

For recovery of the majority of the metals (Al, Cd, Cr, Cu, Fe, Pb, Li, Mn, Ni, Sn, and Zn), the samples were digested using a modified version of EPA Method 200.2 *"Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Element"*. This procedure accomplishes a total digestion of the entire sample matrix and allows quantitation of the crustal elements present as part of the matrix itself, as well as those metals bound to the surface of the material. The modifications include precluding the addition of hydrochloric acid and inclusion of hydrofluoric acid instead, in order to achieve a total digestion of the target metals. A 0.2 gram aliquot of dried homogenous sample was digested using a mixture of nitric and hydrofluoric acids in a nitrogen vented system. The acid mixture was brought to dryness and diluted back to 20 mL using dilute nitric acid. This vented digestion bomb method was employed to allow volatilization of SiF_4, thus removing a significant amount of matrix interference from the digestate and allowing quantitative recovery of the crustal elements such as aluminum and Mn.

A second digestion method was used to achieve optimum recovery of Hg, a relatively volatile element that is lost in an evaporative digestion method when the sample is taken to dryness. There would also be significant loss of Hg in a vented digestion system. This second digestion method is similar to EPA

Method 200.2 "*Sample Preparation Procedure for Spectrochemical Determination of Total Recoverable Element*", is known as an Aqua Regia digestion, and was performed to achieve optimum recovery of Ag, As, Se, and Hg. The method modifications include digestion of 0.2 grams of dry sediment (versus 1 gram of wet sediment), and a slight variation in the ratios of the HCl and HNO_3 acids (5 mL HCl and 3.5 mL HNO_3 was used). In addition, the digestion takes place in a sealed Teflon bomb to further reduce the risk of evaporation of Hg.

200.8M — ICP/MS Instrumental Analysis

The Method 200.8M analysis, which is performed by inductively coupled plasma/mass spectroscopy (ICP/MS), is similar to EPA Method 200.8 except that the calibration acceptance criteria have been modified to be of +/- 15%, to reflect the trace detection nature of the method, rather than 10% as specified in Method 200.8. This wider tolerance window is needed to account for the slightly greater variability encountered when analyzing lower concentration standards. The evaporative, open vessel, sediment digests were analyzed by this method for Al, Cd, Cr, Cu, Fe, Pb, Li, Mn, Ni, Sn, and Zn.

200.9M — GFAAS Instrumental Analysis

Method 200.9M is performed by graphite furnace atomic absorption spectroscopy (GFAAS) and is similar to EPA Method 200.9 except that the calibration acceptance criteria of +/- 15% is used rather than 10% as specified in Method 200.9. The modified criteria reflect analytical procedures developed for the analysis of trace levels of the subject metals. The elements Ag, Se, and As were analyzed by this method using the Aqua Regia sediment digestate.

245.5 — CVAAS Instrumental Analysis

The Method 245.5 analysis is a cold vapor atomic absorption spectroscopy (CVAAS) procedure that was performed according to standard protocols, but targeted for ultra-trace concentrations. Mercuric ions in the Aqua Regia digestate were reduced to Hg^o with $SnCl_2$, and then purged onto a gold trap as a means of preconcentration and interference removal. Mercury vapor was thermally desorbed into the absorption pathway. The CVAA technique was based on the atomic absorption of 254 nm radiation by excited Hg^o atoms in an inert gas stream.

2.3.3 Sample Analysis for Nutrients and Ancillary Measurements

Total Organic Carbon

Following Method 9060 (EPA SW-846), organic carbon was converted by high temperature combustion to carbon dioxide and then measured by either infrared absorbance, or by conversion to methane and subsequent flame ionization.

The sediment was dried at 70°C and ground to a powder. The sample was then treated with 10% hydrochloric acid. After effervescing was completed, more HCl was added. This process of incremental addition of acid continued until introduction of an additional aliquot caused no effervescing. After acid treatment, the sample was dried at 70 °C and placed in a desiccator to cool. A 5 to 30 mg aliquot of the ground, dry sediment was weighed to the nearest milligram and placed in a carbon-free crucible. TOC measurements were determined using a high-temperature furnace to combust the material to carbon dioxide in an oxygen atmosphere. From the reaction chamber the sample combustion gases were carried through a Balston water vapor filter to two reaction filters. The first filter contained magnesium perchlorate, which removes any remaining water vapor. The second filter contained acid dichromate on Silocel and manganese dioxide; the manganese dioxide absorbs any sulfur oxides present and the acid dichromate oxidizes and removes NO_x products that would otherwise interfere with the analysis. The gases then passed to a Coulometer that measured the CO_2 by coulometric titration. The output was sent to a PC via interface software that calculated the percent organic carbon present.

Total Solids (Percent Solids) and Percent Moisture

Analysis of samples for total solids (percent solids) and percent moisture followed Method 2540G of Standard Methods, 17th Edition (APHA, 1989). Aliquots of homogenized sample were apportioned into predried, tared crucibles, dried at 103-105 °C to a constant weight in pre-combusted evaporating dishes. The material remaining after a sample was dried is considered to be the total solids. The total solids of the sediment sample were calculated by dividing the weight of the dried residue by the initial weight of the sample. Results were calculated as percent total solids.

Total Volatile Solids (Percent Organics)

Analysis of samples for total volatile solids (percent organics) also followed Method 2540G of Standard Methods, 17th Edition (APHA, 1989). Dried sediments from the total solids determinations were ashed for 1 hour at 550 °C ± 50 °C. The weight of the material lost at the higher temperature was normalized to the initial weight of the sample and reported as percent volatile solids.

Grain Size Distributions, Raw Sample

Grain size distributions of moist field sediment were determined using a laser diffraction instrument (Coulter LS-200), capable of measurement between 0.4 and 2000 µm equivalent spherical diameters. In this instrument, the angle and intensity of laser light scattered by a solution of sediment sample are selectively measured and converted to volume distributions based on a Fraunhofer optical model. Similar to other methods of particle sizing (pipette or hydrometer analyses), the optical model is based on assumptions of partial sphericity.

During operation, filtered tap water was used for background determinations and sample resuspensions. Samples were homogenized and representative portions introduced to the sample chamber. Samples were recirculated for 60 seconds, and then analyzed for 60 seconds. Repetitive analyses of the sample aliquot indicated that a 60 second analysis time was sufficient for reproducible data. The recirculation time was determined to be sufficient for distributions to stabilize (destruction of loose agglomerates), based on experiments with sediments supplied by the SJRWMD. Surfactants provided no additional change in distribution and so were not employed. Sonication, on the other hand, produced extensive changes in sample size distribution, with the numbers of larger particles continuing to decrease and smaller ones continuing to increase as continued sonication disrupted more and more of the fragments within the sediment. Extensively sonicated sediments, however, were not considered to be representative of the collected samples and so after discussions with the SJRWMD, no sonication was used in the protocol.

Duplicate evaluations were conducted on each separate aliquot from a sample jar introduced into the instrument. As sample aliquots were comparatively small (1-2 g wet weight), low or non-representative concentrations of coarser fragments which were not readily homogenized produced variations which were more extensive than from a more uniform sediment. Glass beads of known mean grain size were used to perform continuing calibrations.

Results were determined in 93 logarithmically distributed size channels as the volume percent of the entire sample within that spherical size range. Within rounding error, the sum of volume percents from all size ranges totaled 100%. For purposes of clarity, the 93 channels were combined into 26 intervals (Table 2-3), still totaling 100%, which represents the classical half-phi distribution (Folk, 1974), in which:

$$\phi = -1 \bullet \mathrm{LOG}_2\,(\text{size, mm})$$

Table 2-3. Half-Phi Intervals and Equivalent μm Sizes used for Reporting Grain Size Data

ϕ Size	μm
11.0	0.49
10.5	0.69
10.0	0.98
9.5	1.38
9.0	1.95
8.5	2.76
8.0	3.91
7.5	5.52
7.0	7.81
6.5	11.0
6.0	15.6
5.5	22.1
5.0	31.0
4.5	44.0
4.0	62.5
3.5	88.0
3.0	125
2.5	177
2.0	250
1.5	350
1.0	500
0.5	710
0.0	1,000
-0.5	1,410
-1.0	2,000
-1.5	2,830

As the instrument was sensitive only to 2,000 µm (2.000 mm), sediments were sieved through a 2 mm mesh prior to diffraction analysis. If material was retained by the screen, then a larger sample aliquot was weighed (field moist), wet sieved through a 2 mm mesh, and the coarse retained material dried and ashed as in the determination of percent solids and percent organics discussed above. In these samples, the particles which fail to pass a 2 mm sieve were generally shell fragments or intact shells from small bivalves, and it varied by sample as to whether the larger shell fragments were a representative part of the sample. For calculations, all sediments greater than 2,000 µm were assigned to the range between -1.0ϕ and -1.5ϕ (2,000-2,830 µm), and proportionally incorporated into the results of the diffraction analysis, for presentation of the results on the entire sample.

Total percent sand, silt and clay were calculated as the sum of volume percent between 2,830 and 62.5 µm, 62.5 and 3.91 µm, and 3.91 to 0.04 µm, respectively, using the Wenworth size scales and a 8.0ϕ value as the clay-silt boundary. Only the sand, silt, and clay percentages were reported and used for discussion and interpretive purposes in this report. Data for each of the 26 individual size intervals listed in Table 2-3 are included in the appendices.

That grain size data included in the appendices also include geometric distributional statistics, which were computations based on the logarithmic center of each size grouping as sediment distributions are typically more log-normal than normal. Statistics provided included mean, median, and modal grain sizes and are in units of µm. The standard deviation was also reported in µm and is a measure of the spread of the sediment distribution. Skewness, a unitless coefficient, is a measure of the distortion from a symmetrical distribution, with a skewness of zero (where mean, median, and mode coincide) being perfectly symmetrical. Samples with an excess of material in the finer sizes (left-hand skewed) will have negative skewness coefficients, while samples with an excess of coarser material (right-hand skewed) will have skewness values greater than zero. Kurtosis is also unitless and is a measure of the peakedness of a distribution, with kurtosis values of zero representing a normal distribution (mesokurtic), values greater than zero (leptokurtic) indicating a higher sharper peak, and values less than zero (platykurtic) indicating a comparatively broad distribution.

Soluble Reactive Phosphorus

Soluble reactive phosphorus (EPA/CE-81-1, p.3-223) for sediments was determined by an operationally defined procedure in which a 10 g wet weight aliquot of sediment was passively extracted overnight with a fixed volume of laboratory water. The resultant solution was filtered, digested with dilute acid and heat, and analyzed for reactive phosphate (also commonly referred to as ortho-phosphate).

Total Phosphorus and Total Kjeldahl Nitrogen

Both total phosphorus and total Kjeldahl nitrogen were determined on a single sample digest (EPA/CE-81-1, p.3-227 [e], p.3-201,2), using a digestion block and sulfuric acid-persulfate-mercuric oxide solution. The resulting clear or pale yellow digestate was analyzed with an automated segmented flow analyzer.

2.4 Laboratory Quality Assurance and Quality Control Procedures

2.4.1 Implementation of Battelle's Quality Assurance Program

Battelle's Quality Assurance (QA) program is described in Battelle's Quality Management Plan (QMP). The QA program is implemented by each Project Manager to ensure that data generated by Battelle are of known and acceptable quality. It is designed to support the commitment to quality defined in Battelle's quality policy statement.

> *Battelle is committed to providing the highest quality programs designed to meet the needs of its clients, and to ensuring that all environmental data collection activities be scientifically valid, and that the data so collected be complete, representative, comparable, and of a known and documented quality. It is also Battelle policy that all Battelle-generated field and laboratory data include, where possible, documented quality control (QC) data. This policy is implemented by ensuring that adequate quality assurance (QA) procedures are employed for all data generating activities, from study design and sample analysis to data generation, reduction, and reporting.*

At the *organizational level,* policies defined in the QMP apply to all program activities and address management assessment, personnel qualifications and training, procurement policies, and document control. These policies provide guidance to project management so that consistent technical management and data collection activities are implemented. At the *technical level,* the implementation of QA program activities identified in the QMP are defined in project-specific Quality Assurance Project Plans (QAPPs) to ensure that the data collected are of the appropriate amount, type, and quality. The project scope, organization, schedule, communication plan, quality control requirements, analytical procedures (defined as standard operating procedures), and reporting requirements are defined in the QAPP. The QMP defines roles and responsibilities at the organizational level; the QAPPs define roles and responsibilities for each project.

Battelle is certified to perform analyses for the Florida State DEP, Commonwealth of Massachusetts DEP, New Jersey DEP, US Army Corps of Engineers, and the US Naval Energy and Environmental Support Activity. In addition, Battelle participates in the NIST annual interlaboratory calibration program for the extraction and analysis of sediments and tissues for PCBs, pesticides, and PAHs.

Several components of this Program have particular relevance to the SJRWMD Project. A *QAPP* was prepared for this project prior to the initiation of work. This document was prepared by the Project Manager, distributed to each member of the project team, and discussed during a project kick-off meeting prior to the start of project activities.

Standard Operating Procedures (SOPs) were in place for the operation, maintenance, and calibration of all data-generating equipment and all environmental data collection activities performed for the project. SOPs applicable to the project were cited in the QAPP; these SOPs were readily available in laboratory SOP manuals. It is a Battelle requirement that *training* is complete and documented before a staff member uses equipment or a technical procedure. All project staff are trained in each SOP. Each SOP contains a "training" section that defines appropriate training and proficiency requirements for a specific procedure. Documented training records were in place for all members of the project team.

Quality Assurance audits were performed throughout the study. As part of the Quality Assurance initiation audit, the QAPP was reviewed for completeness, the training records for each team member were reviewed to ensure that documented training had been completed for each team member, and the SOPs applicable to the project were reviewed to ensure that they were current.

All data packages and final report tables were audited by Quality Assurance personnel to verify that the reported data were complete, accurate, and traceable. The results of each audit were reported to the project manager and the laboratory manager. Corrective action for each audit finding was documented and verified prior to release of data to the client. All audit issues were addressed during these audits; no unresolved issues exist.

2.4.2 Compliance with Florida Department of Environmental Protection (FDEP) CompQAP

Battelle has obtained FDEP approval for the application of the specialized low detection limit methods that were used in this program, and these methods have been incorporated into Battelle's FDEP CompQAP. The Project Manager and the project QA Officer reviewed both the original CompQAP and the amendments to verify that the documents were accurate and current. To ensure that all staff members were familiar with the specific requirements of the FDEP SOPs, training packets were assembled for the project and laboratory manager, the sample custodian, the laboratory technicians, the analysts, and QA personnel. These packets included the specific FDEP SOPs that applied to the project activities anticipated for each staff member with a sign-off sheet indicating that each SOP had been read and understood. Battelle's intent to comply with FDEPs SOPs was documented with FDEP on 10/10/95.

2.4.3 Quality Control Program

The accuracy, precision, and reliability of data generated for the SJRWMD was of paramount importance. The quality control procedures that were followed to assure analytical integrity associated with the determination of trace levels of organic and inorganic analytes include the following:

- Documentation of method detection limits
- Documentation of analytical accuracy
- Documentation of analytical precision

The quality control samples incorporated into each batch of no more than 20 field samples included:

- Procedural Blank
- Blank Spike
- Matrix Spike
- Matrix Spike Duplicate
- Field Sample Duplicate
- Standard Reference Material
- Surrogate Internal Standards (2 or 3 per sample for organic compound analysis)

2.4.3.1 Method Detection Limits

The method detection limit (MDL) is the lowest concentration of an analyte that a method can reliably detect in either a sample or blank. The MDLs reported in Battelle's CompQAP were determined following protocols published in the *Federal Register* (40 CFR part 136, Appendix A). Seven aliquots of sediment were spiked with the analytes of interest at concentrations equivalent to approximately 3 to 5 times the detection limits. The MDL for each compound was calculated by multiplying the standard deviation of the seven replicates by the student-*t* value (3.000, as per FDEP guidelines — EPA protocol is to use 3.143). This MDL represents the statistically determined minimum concentration of the compound that can be measured with 99% confidence that the analyte concentration is greater than zero. Target compounds confidently detected below the MDL (typically with a signal:noise criteria of approximately 3:1) were reported and qualified appropriately in the original data delivery.

However, actual detectability varies on a sample-by-sample basis depending on the actual sample matrix and target compound concentration. For this report, *uncensored* data were generated, reported, and used (i.e., if the analysts could confidently detect and identify an analyte in a sample it was reported, regardless of how it compared to a calculated MDL).

2.4.3.2 Analytical Accuracy and Precision

Analytical accuracy and precision is ensured by conducting all analytical work within the framework of a well-defined and appropriate quality control plan. Analytical accuracy was monitored through the use of standard reference materials, surrogate internal standards, and procedural (method) blanks. In addition, blank spikes, matrix spikes, and matrix spike duplicate samples were spiked with target analytes at concentrations near the project MDLs and processed and analyzed with each analytical batch. Analytical precision was monitored as the relative percent difference between matrix spike and matrix spike duplicate samples, and/or field sample duplicate samples.

- *Standard Reference Materials* (SRMs) were processed and analyzed with each analytical batch of no more than 20 field samples (two SRMs with each batch of trace metals samples). The National Institute of Standards and Testing Materials (NIST) provides certified concentration values for analytes present in the SRM sample; these values were used to calculate the SRM percent recovery. The NIST SRMs are appropriate because they have certified concentrations for many of the target analytes at environmentally relevant concentrations, which are often near the project's MDLs.

- *Surrogate Internal Standards* (SIS) were spiked into each field and quality control sample prior to organic compound extraction and analysis. The percentage of spiked SIS compounds recovered in each sample provides a measure of the overall sample extraction and processing efficiency.

- *Procedural (Method) Blanks* (PB) were prepared, processed, and analyzed with each analytical batch of no more than 20 field samples to check the purity of reagents and glassware, as well as to monitor the possibility of laboratory contamination. The PB is a combination of all solvents and/or reagents used during the extraction, and for organic contaminant analysis also the surrogate compounds, and is subjected to the same sample processing as the field samples.

- *Blank Spikes* (BS) or Laboratory Control samples (LCS) were processed with each batch of trace metals, organic contaminant, and TOC analysis. The BS or LCS was prepared identically to the procedural blank and spiked with contaminants of interest at known or certified concentrations. Recovery of the target analytes in the BS/LCS samples provided a measure of the extraction efficiency for the analytes in the absence of matrix interference.

- *Matrix Spikes/Matrix Spike Duplicate* (MS/MSD) samples were processed and analyzed with each batch of organic compound analysis samples. Two aliquots of one field sample were spiked with known amounts of target contaminants prior to extraction. The background-corrected recovery of spiked contaminants in the environmental samples demonstrates the extraction efficiency possible in the presence of a matrix that may impair either complete extraction during sample processing or detection and quantitation. When used in conjunction with the BS/LCS samples, the recovery of target compounds that may be affected by the sample matrix can be identified. The reproducibility in the two recovery determinations provides a measure of the analytical precision.

- *Duplicate (DUP)* field samples were processed with each batch of samples for trace metals and nutrient analysis, and the ancillary measurements. Field duplicates incorporated the precision in the field sampling with the analytical precision.

2.4.3.3 Quality Control Program Results

The quality control data quality objectives (DQOs) are presented in Table 2-4. The DQOs for organic compound analysis reflect the fact that surrogate corrected data are used in this report, and the DQOs have been appropriately modified from those that applied to the non-corrected data that were reported to the SJRWMD earlier. The complete data for all quality control samples have been reported to the SJRWMD along with the field sample data.

Table 2-4. Laboratory Analysis Data Quality Objectives – Organic Compound Analysis

QC Sample	Frequency	Data Quality Objective
Procedural Blank (PB)	1 per analytical batch [a]	< 3 ×MDL
Blank Spike (BS)	1 per analytical batch	50–150% recovery [b]
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	1 pair per analytical batch	50–150% recovery [b] RPD <30% for duplicates Objectives apply to analytes with a spiking level >5× the background.
Standard Reference Material (SRM)	1 per analytical batch	70–130% recovery relative to the certified/consensus value [b] Objectives apply to analytes with certified or consensus concentrations >10× MDL.
SIS Compounds	Every field and QC sample	30–130% recovery
Initial Instrument Calibration (GC/ECD and GC/MS)	At initiation of analytical sequence	GC/ECD: Correlation coef. >0.995. GC/MS: < 25% RSD for individual RRFs and <15% RSD on average.
Continuing Instrument Calibration Check (GC/ECD and GC/MS)	No less frequently than every 12 samples	GC/ECD: determined concentration ±25% of true concentration of individual analytes and ±15% on average. GC/MS: <25% RPD for individual RRFs versus initial calibration and <15% RPD on average.

[a] Analytical Batch: Sample set of no more than 20 field samples.
[b] Relative recoveries (i.e., surrogate corrected recoveries)

Table 2-4 (continued). Laboratory Analysis Data Quality Objectives – Metals Analysis

QC Sample	Frequency	Data Quality Objective
Procedural Blank (PB)	1 per analytical batch [a]	< 5 × MDL or <1/5 sample concentration
Blank Spike (BS)	1 per analytical batch	70–130% recovery
Matrix Spike (MS)	1 per analytical batch	70–130% recovery Objectives apply to analytes with a spiking level > the background.
Standard Reference Material (SRM)	1 per analytical batch	70–130% recovery relative to the certified/consensus value
Sample Duplicate (DUP)	1 per analytical batch	RPD <20% unless sample concentration is < 10 × MDL
ICP-MS Internal Standard	1 per analytical batch	60–125%
ICP-MS tuning solution	Prior to daily calibration	Isotope densities meet manufacturers specifications and replicates must be within 10% of each other
Initial Interference Check	1 per calibration	None. Signal will be automatically subtracted from calibration and results
Initial Instrument Calibration	At initiation of analytical sequence	Correlation coef. >0.99
Initial Calibration Verification	Immediately following calibration	Within 15% of true value
Continuing Calibration Verification	Every 10 samples	Within 15% of true value

[a] Analytical Batch: Sample set of no more than 20 field samples.

Table 2-4 (continued). Laboratory Analysis Data Quality Objectives – Ancillary Measurements

QC Sample	Frequency	Data Quality Objective
Procedural Blank	1 per every 20 samples	TOC and OP: <5 × MDL
Laboratory Control Spike	1 per every 20 samples	TOC: 90–110% recovery OP: 85–108% recovery TP: 76–125% recovery TKN: 75–115% recovery
Duplicate	1 per every 20 samples	TOC (<20% RPD if concentration <2,000 mg/kg; <10% RPD if concentration >2,000 mg/kg) OP: <32 %RPD TP: <21 %RPD TKN: <26 %RPD Grain size: <20% RPD TS: <20% RPD TVS: <20% RPD
Calibration Check	1 per every 10 samples	TOC: ±5% of true value TP, TKN and OP: ±5% of true value Grain size: ±10% of certified/acceptance value

A summary of the results of the quality control program is presented in Table 2-5. The contaminant parameter analyses yielded quality control data of high quality, and with few exceptions met the relatively strict quality control program that had been developed for the project. The few exceedances of procedural blank DQOs were typically minor exceedances (analytes in the 3-5 × MDL range) of compounds that were measured at significantly higher concentrations in the field samples and therefore had no notable impact on the reliability of the field sample results. The field blank analyses (performed by the SJRWMD in accordance with the District's CompQAP and Field Plan, and not reported in this document) yielded non-detects for all target analytes, indicating that the samples were not contaminated during the field activities.

The few target compound recovery (accuracy) exceedances that were observed in fortified samples (BS and MS/MSD) were typically slight exceedances. Similarly, the exceedances that were observed for certified materials analysis (SRMs) were generally for target compounds with concentrations near or below the detection limit, or for trace-level constituents that do not have certified values but only semi-quantitative consensus values — this was particularly the case for the exceedances observed for the Method 8081M analyses. The limited number of DQO exceedances in replicate analyses (precision) were also mostly observed for parameters with concentrations near the MDL (the analytical accuracy and precision, by definition, increases as the concentration approaches the detection limit). In general, these quality control sample results verified that sample processing and analytical procedures were in control.

Table 2-5. Summary of Laboratory Quality Control Sample Results

Method	No. of Data Points		No. of Exceedences	
8270M Procedural Blank (PB)	340		29	
Blank Spike (BS)	268		0	
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	% recovery 672	RPD 336	%recovery 65	RPD 13
Standard Reference Material (SRM)	160		15	
SIS Compounds	414		22	
8081M Procedural Blank (PB)	610		11	
Blank Spike (BS)	480		20	
Matrix Spike/Matrix Spike Duplicate (MS/MSD)	% recovery 1,200	RPD 600	% recovery 158	RPD 24
Standard Reference Material (SRM)	200		62	
SIS Compounds	276		4	
Metals Procedural Blank (PB)	150		2	
Blank Spike (BS)	142		5	
Matrix Spike (MS)	126		2	
Standard Reference Material (SRM)	255		19	
Sample Duplicate (DUP)	142		6	

Table 2-5 (continued). Summary of Laboratory Quality Control Sample Results

Method	No. of Data Points	No. of Exceedences
Ancillary Measurements		
Procedural Blank		
TOC	13	0
OP	8	0
Laboratory Control Spike		
TOC	27	0
OP	29	1
TP	43	0
TKN	53	0
Duplicate		
TOC	14	0
OP	18	0
TP	19	0
TKN	22	0
Grain Size	15	0
TS	20	0
TVS	20	0

3. RESULTS

This section summarizes the results of the organic [polynuclear aromatic hydrocarbons (PAH), phthalate esters, polychlorinated biphenyl (PCB), pesticides, other chlorinated compounds], metals, and nutrient analyses, along with the data from the geophysical (ancillary) analyses [total organic carbon (TOC), grain size, moisture content, total solids (TS), and total volatile solids (TVS)]. Complete field sample sediment chemistry results are reported in Appendices B through E. All data discussed in this section are presented on a dry weight basis. The use of dry weight to report contaminant concentrations reduces data variability caused by varying amounts of water retained by the sediment. The term dry weight refers to sediment that has been dried to remove water and is the standard method of reporting and comparing sediment contaminant concentrations.

3.1 Results for Organic Compound Analysis

Individual concentrations for a total of 95 organic compounds were determined in this study. The analytical data for each individual compound are listed in Appendix B (Method 8270M analytes) and Appendix C (Method 8081M analytes). All individual compound data were reviewed. However, it is most illuminating to focus on classes of analytes for data summary and analysis purposes, and that is the approach used for this report. A few individual organic compounds are also discussed, when the data revealed them to be of particular interest.

3.1.1 PAH and Phthalate Compound Results

Sediment samples were analyzed for 34 aromatic compounds by method 8270M; 24 individual polycyclic aromatic hydrocarbons (PAHs), 6 phthalate esters, 2 chlorinated naphthalenes, isophorone, and kepone. For presentation and discussion purposes this report focuses on the 30 individual PAH and phthalate compounds, which are categorized as (1) low molecular weight PAH (LPAH), (2) high molecular weight PAH (HPAH), (3) total PAH, and (4) total phthalate. Table 3-1 below lists the analytes that comprise each group.

Table 3-1. Aromatic Hydrocarbon and Phthalate Groups

Low Molecular Weight PAH (Σ of)	High Molecular Weight PAH (Σ of)	Total PAH (Σ of)	Total Phthalate (Σ of)
Naphthalene	Fluoranthene	LPAH	Dimethylphthalate
2-Methylnaphthalene	Pyrene	HPAH	Diethylphthalate
1-Methylnaphthalene	Benz(a)anthracene		Di-N-butylphthalate
Biphenyl	Chrysene		Butylbenzylphthalate
2,6-Dimethylnaphthalene	Benzo(b)fluoranthene		Bis(2-ethylhexyl)phthalate
2,3,5-Trimethylnaphthalene	Benzo(k)fluoranthene		Di-N-octylphthalate
Acenaphthylene	Benzo(e)pyrene		
Acenaphthene	Benzo(a)pyrene		
Fluorene	Indeno(1,2,3-c,d)pyrene		
Phenanthrene	Dibenz(a,h)anthracene		
Anthracene	Benzo(g,h,I)perylene		
1-Methyphenanthrene	Perylene		

Low molecular weight PAH are frequently associated with refined and unrefined petroleum products. High molecular weight PAH are primarily derived from the combustion of fossil fuels or as principal components of creosote-type formulations. Phthalates are widely used industrial compounds, primarily associated with the manufacture and handling of plastics, and are, like PAH, ubiquitous throughout our society and environment.

A summary of the ranges of concentrations of selected classes of aromatic organic compounds is listed in Table 3-2 below. A summary of the concentration data for each of the 86 sites is presented in Table 3-3. These data are presented both non-normalized and normalized to percent total organic carbon (TOC).

Table 3-2. Concentration Ranges for PAH and Phthalates

	Not Normalized (raw) (µg/kg dry weight)		Normalized to %TOC (µg/kg dry weight/%TOC)	
	Min	Max	Min	Max
Total PAH	2.70	13,800	5.10	10,100
Low PAH	0.71	5,540	1.31	634
High PAH	0.78	10,600	2.37	9,530
Total Phthalate	6.09	1,840	2.08	3,890

The data indicate that the PAH concentrations in the sediment samples varied greatly. Total PAH concentrations ranged from 2.7 [site MPS (Middle Prong St. Mary's River)] to 13,800 µg/kg [site LSJ01 (Lower St. Johns River at Ortega River)]. The concentration of low molecular weight PAH (Low PAH) ranged from 0.7 [site 20020404 (Orange Creek)] to 5,540 µg/kg [site ORD (Ocklawaha River downstream of SR 40)] and the concentration of high molecular weight PAH (High PAH) ranged from 0.8 [site BLUSPA (Blue Springs)] to 10,600 µg/kg [site LSJ01 (Lower St. Johns River at Ortega River)]. The concentration of high PAH was, on average, approximately 2 times higher than the concentration of low PAH, although there was significant site-to-site variability. Total phthalate concentrations ranged from 6.1 [site TOL (Tolomato River)] to 1,840 µg/kg [site HAR (Lake Harris)].

The variability in the sediment PAH and phthalate concentrations remains high even after the PAH data are normalized to sediment TOC content (Table 3-3). The TOC-normalized total PAH concentration ranged from 5.1 [site 20020377 (Lake Harris)] to 10,100 µg/kg/%TOC [site 20010137 (Little Wekiva River)]. TOC-normalized Low PAH concentrations ranged of 1.3 [site LEO (Lake George at M 4 & M 5)] to 634 µg/kg/%TOC [site ORD (Ocklawaha River downstream of SR 40)] and TOC-normalized high PAH concentrations ranged from 2.4 [site 20020377 (Lake Harris)] to 9,530 µg/kg/%TOC [site 20010137 (Little Wekiva River)]. TOC-normalized total phthalate concentrations ranged from 2.1 [site LEO (Lake George at M 4 & M 5)] to 3,890 µg/kg/%TOC (site DMR).

3.1.2 PCB, Pesticide, and Other Chlorinated Compound Results

Sediment samples were analyzed for 61 individual chlorinated compounds (23 individual PCB congeners, 30 pesticides, and 8 other chlorinated compounds) using Method 8081M. Table 3-4 below shows the analytes that are summarized as separate groups/classes for presentation and discussion purposes. The analytes are categorized as (1) total DDT compounds, (2) sum of PCB, (3) total other industrial chlorinated compounds, (4) total chlordanes, (5) total benzene hexachlorides [(BHCs), which includes the pesticide lindane (γ-BHC)], and (6) total DDTs, DDEs, and DDDs.

Table 3-3. Organic Contaminant Summary Data — PAH and Phthalates

FIELD ID	Not Normalized (raw) (µg/kg dry weight)				Normalized to %TOC (µg/kg/%TOC)			
	Total PAH	Low PAH	High PAH	Total Phthalate	Total PAH	Low PAH	High PAH	Total Phthalate
02235000	408	50.5	357	256	88.5	11.0	77.5	55.5
02236000	176	24.1	152	46.0	75.1	10.3	64.8	19.6
02238000	16.8	8.96	7.86	21.2	43.3	23.1	20.3	54.6
02240800	3.54	1.93	1.60	7.01	84.2	46.1	38.1	167
02248000	13.1	3.50	9.64	9.24	158	42.2	116	111
19010001	1,460	239	1,220	43.0	601	98.3	503	17.7
19010006	22.2	8.63	13.5	198	50.9	21.5	33.7	454
19020002	2,350	2170	183	292	335	309	26.1	41.7
20010002	40.9	7.21	33.7	429	151	26.6	124	1,580
20010003	686	217	469	26.4	338	107	231	13.0
20010137	1,070	65.4	1,000	64.4	10,100	623	9,530	614
20020001	115	31.9	82.6	28.2	69.0	19.2	49.8	17.0
20020012	40.6	4.29	36.3	13.7	71.8	7.59	64.2	24.3
20020368	652	152	500	1,530	19.7	4.60	15.2	46.2
20020371	297	114	182	1,330	9.60	3.70	5.90	43.0
20020377	116	62.1	54.1	1,400	5.10	2.72	2.37	61.2
20020381	465	114	351	157	12.1	2.95	9.13	4.08
20020404	4.51	0.71	3.80	8.42	83.5	13.1	70.4	156
20030373	56.7	7.85	48.9	72.1	65.7	9.10	56.6	83.5
20030400	35.3	6.08	29.3	13.0	11.6	2.09	10.1	4.27
20030411	879	81.7	797	197	36.8	3.46	33.8	8.25
20030412	1,920	309	1,610	83.8	2,720	437	2,280	118
27010024	331	29.6	301	57.9	64.1	5.73	58.4	11.2
27010037	317	21.9	295	63.8	1,270	87.8	1,180	256
27010579	29.9	3.08	26.9	13.0	40.0	4.11	35.9	17.3
27010875	23.1	6.10	17.0	27.1	27.5	7.28	20.2	32.4
ASH	563	60.7	502	84.0	25.0	2.70	22.3	3.73
BLUSPA	3.61	2.83	0.78	60.7	21.7	17.0	4.68	366
BUL	11.8	1.24	10.5	10.6	17.1	1.81	15.3	15.5
BWC44	638	59.7	578	281	265	20.4	198	117
BWCCPB	535	103	432	233	181	34.9	147	79.1
CC03	277	17.6	259	18.7	1,650	104	1,540	111
CLD	1,920	120	1,800	125	86.5	5.39	81.1	5.62
CLW	4.74	1.9	2.84	17.0	18.5	7.42	11.1	66.3
DMR	62.1	16.3	45.8	405	597	157	440	3,890
DOR	417	111	306	1,120	15.1	4.00	11.1	40.3
GEN	316	34.2	282	135	59.3	6.42	52.9	25.3
HAR	308	115	193	1,840	10.5	3.92	6.55	62.6
HAW	218	12.2	205	35.0	38.6	2.17	36.4	6.20
HOG30	206	20.9	185	53.4	840	85.3	754	218
KER	203	99.4	104	237	8.66	4.23	4.43	10.1
LAG	332	17.4	314	505	28.8	1.51	27.3	43.9
LEO	1,080	45.2	1,030	71.5	31.3	1.31	29.9	2.08

Table 3-3 (continued). Organic Contaminant Summary Data — PAH and Phthalates

FIELD ID	Not Normalized (raw) (µg/kg dry weight)				Normalized to %TOC (µg/kg/%TOC)			
	Total PAH	Low PAH	High PAH	Total Phthalate	Total PAH	Low PAH	High PAH	Total Phthalate
LKWOOD	290	89.5	200	1,330	13.4	4.13	9.24	61.4
LMAC	1,800	248	1,560	101	126	17.3	109	7.08
LOL	805	226	579	524	23.7	6.65	17.1	15.5
LSJ01	13,800	3,190	10,600	830	1,890	437	1,460	114
LSJ05	6,900	1,080	5,820	317	448	70.1	378	20.6
LSJ070	74.9	10.1	64.8	10.6	851	115	737	120
LSJ08	2,900	381	2,520	166	185	24.3	161	10.6
LSJ087	358	41.2	317	249	142	16.3	125	98.2
LSJ099	446	26.7	419	65.3	474	28.3	446	69.4
LSJ11	2,260	314	1,950	110	130	18.1	112	6.32
LSJ14	2,080	226	1,850	276	115	12.5	103	15.3
LSJ17	1,020	103	917	182	95.1	9.60	85.5	16.9
LSJ21	442	55.4	386	168	39.8	4.99	34.8	15.1
LSJ28	1,240	103	1,140	67.1	99.8	8.30	91.5	5.39
LSJ32	2,120	216	1,900	89.3	143	14.6	128	6.02
LSJ35	1,810	222	1,580	719	71.8	8.84	63.0	28.6
LSJ40	2,340	179	2,160	157	108	8.25	100	7.24
LSJ918	460	330	130	36.9	246	176	69.4	19.7
LSJRC17	586	89.7	496	56.0	81.1	12.4	68.7	7.76
LYC	211	91.5	120	406	9.49	4.24	5.53	18.3
MAT	865	29.1	835	10.6	4,040	136	3,900	49.4
MBU	8,360	859	7,500	1,570	2,870	295	2,580	541
MPS	2.70	1.83	0.869	13.7	117	79.7	37.8	596
MR312	63.4	10.3	53.1	84.1	83.8	13.6	70.2	111
MTC	1,360	728	630	108	166	89.0	77.0	13.2
NRI	55.3	10.1	45.2	14.0	136	24.9	111	34.6
OLK	314	76.3	238	661	6.96	1.69	5.27	14.7
OR908	8,060	507	7,550	1,120	401	25.2	376	55.5
ORD	6,210	5,540	669	183	711	634	76.7	21.0
PEL	854	132	722	19.0	405	62.6	342	8.99
RCLSJ06	7,360	2,660	4,700	647	186	67.3	119	16.3
RCLSJ10	3,100	1,020	2,080	505	92.9	30.4	62.4	15.1
RCLSJ19	1,440	185	1250	160	58.9	7.58	51.3	6.54
SHEEL	7.84	3.74	4.10	53.7	74.0	35.3	38.7	507
SIM	2,550	737	1,810	28.9	1,100	319	785	12.5
SRS	56.2	11.3	44.9	304	42.3	8.52	33.8	229
SWBPP1	5,080	439	4,640	304	1,550	133	1,410	92.3
TOL	3.59	1.96	1.63	6.09	31.2	17.1	14.1	52.9
TUBPP1	623	67	556	318	844	90.7	753	431
USJ055	283	22.8	260	651	54.1	4.36	49.7	125
USJ918	619	160	459	37.7	156	40.4	116	9.5
WIN	34.6	7.86	26.7	77.2	20.1	4.57	15.5	44.9
WIO	16.4	3.87	12.6	52.6	157	36.9	120	501

Table 3-4. Chlorinated Organic Compound Groups

Sum of DDTs (Σ of)	Sum of PCB (Σ of)		Other Chlorinated Compounds (Total Chloros) (Σ of)	Total Chlordanes (Σ of)	Total BHCs (Σ of)	Total DDTs, DDEs, and DDDs (Σ of)
2,4'-DDT	Cl_2(8)	Cl_3(18)	1,3-Dichlorobenzene	Oxychlordane	α-BHC	2,4'-isomer
4,4'-DDT	Cl_3(28)	Cl_4(52)	1,4-Dichlorobenzene	γ-Chlordane	β-BHC	4,4'-isomer
2,4'-DDE	Cl_4(44)	Cl_4(66)	1,2-Dichlorobenzene	α-chlordane	γ-BHC	
4,4'-DDE	Cl_4(77)	Cl_5(110)	1,2,4-Trichlorobenzene		δ-BHC	
2,4'-DDD	Cl_5(101)	Cl_5(118)	1,2,4,5-Tetrachlrorobenzene			
2,4'-DDD	Cl_6(153)	Cl_5(105)	Hexachloroethane			
	Cl_6(138)	Cl_5(126)	Hexachlorobutadiene			
	Cl_6(129)	Cl_7(187)	Hexachlororcyclopentadiene			
	Cl_6(128)	Cl_7(180)				
	Cl_6(169)	Cl_7(170)				
	Cl_8(195)	Cl_9(206)				
	Cl_{10}(209)					

Table 3-5 below presents the concentration ranges of chlorinated compounds found at the sampling locations, and the data for the individual sites are presented in Table 3-6. The data indicate that concentrations of PCB, pesticides, and other chlorinated compounds were quite variable in the sediment samples. The sum of the PCB congener concentrations ranged from 0.1 [site 20020404 (Orange Creek)] to 198 μg/kg [site RCLSJ06 (St Johns River at Rice Creek)] and total DDT compound concentrations ranged from not detected (ND) to 118 μg/kg [site DOR (Lake Dora)]. The sum of the PCB congeners determined in this project typically constitute about one-half of the total PCB concentrations in most environmental samples (i.e., the true total PCB concentrations is generally approximately two times the sum of these congeners).

Table 3-5. Concentration Ranges for Chlorinated Organic Compounds

	Not Normalized (raw) (μg/kg dry weight)		Normalized to %TOC (μg/kg dry weight/%TOC)	
	Min	Max	Min	Max
ΣPCB	0.100	198	0.203	39.1
ΣDDT Compounds	ND	118	ND	6.48
DDTs	ND	15.5	ND	2.73
DDDs	ND	52.9	ND	4.45
DDEs	ND	103	ND	3.81
ΣChloros	ND	127	ND	94.1
ΣChlordane	ND	5.83	ND	9.05
ΣBHCs	ND	8.94	ND	0.38

Investigation of concentrations of DDT and its degradation products DDD and DDE, reveal that the greatest concentration of DDT compounds was typically found as DDE. The concentrations of the individual DDT, DDD, and DDE classes ranged from ND to 15.5 μg/kg [site RCLSJ10 (St. Johns River near Rice Creek)], ND to 52.9 μg/kg [site CLD (Lake Disston)], and ND to 103 μg/kg [site DOR (Lake Dora)], respectively. Concentrations of total other chlorinated compounds ranged from ND to 127 μg/kg [site OLK (Orange Lake)]. In comparison, total chlordane and BHC concentrations are

Table 3-6. Organic Contaminant Summary Data — PCB, Pesticides, and Other Chlorinated Compounds

	Not Normalized (raw) (µg/kg dry weight)								Normalized to %TOC (µg/kg/%TOC)							
FIELD ID	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT
02235000	1.61	12.2	1.89	ND	0.52	0.67	0.48	0.45	0.349	2.65	0.410	ND	0.113	0.146	0.105	0.098
02236000	1.19	6.08	4.02	ND	ND	0.37	0.37	0.46	0.508	2.59	1.71	ND	ND	0.155	0.157	0.196
02238000	1.06	3.78	1.61	ND	0.10	ND	ND	1.06	2.73	9.74	4.15	ND	0.259	ND	ND	2.73
02240800	ND	0.11	0.79	ND	ND	ND	ND	ND	ND	2.62	18.9	ND	ND	ND	ND	ND
02248000	0.03	0.20	0.97	ND	0.02	0.03	ND	ND	0.382	2.44	11.7	ND	0.202	0.382	ND	ND
19010001	2.75	11.0	1.80	0.08	0.39	0.61	2.14	ND	1.13	4.53	0.742	0.031	0.159	0.251	0.881	ND
19010006	0.05	2.46	2.73	ND	ND	ND	ND	0.05	0.110	5.65	6.80	ND	ND	ND	ND	0.119
19020002	0.32	17.0	5.90	ND	3.54	ND	ND	0.32	0.046	2.42	0.840	ND	0.504	ND	ND	0.046
20010002	ND	4.00	1.31	ND	ND	ND	ND	ND	ND	14.8	4.82	ND	ND	ND	ND	ND
20010003	3.36	6.31	1.80	ND	0.38	1.21	0.41	1.74	1.66	3.11	0.886	ND	0.186	0.598	0.201	0.856
20010137	0.41	4.11	1.24	ND	0.95	ND	0.41	ND	3.89	39.1	11.8	ND	9.05	ND	3.89	ND
20020001	2.31	2.59	3.20	0.24	0.69	0.63	0.44	1.24	1.39	1.56	1.93	0.146	0.416	0.380	0.266	0.748
20020012	0.16	1.12	3.29	ND	ND	ND	ND	0.16	0.276	1.98	5.81	ND	ND	ND	ND	0.276
20020368	55.5	99.4	36.5	2.85	ND	45.1	10.4	ND	1.67	2.99	1.11	0.086	ND	1.37	0.316	ND
20020371	15.7	58.1	16.7	ND	ND	13.6	2.14	ND	0.508	1.88	0.539	ND	ND	0.439	0.070	ND
20020377	5.27	87.0	32.6	ND	ND	2.93	2.33	ND	0.231	3.81	1.43	ND	ND	0.129	0.102	ND
20020381	13.0	74.6	27.9	ND	ND	10.7	2.24	ND	0.337	1.94	0.724	ND	ND	0.278	0.058	ND
20020404	ND	0.10	0.88	ND	ND	ND	ND	ND	ND	1.85	16.2	ND	ND	ND	ND	ND
20030373	0.10	3.30	1.54	ND	0.31	0.10	ND	ND	0.126	3.83	1.72	ND	0.391	0.126	ND	ND
20030400	1.00	1.06	2.51	ND	0.14	0.45	0.54	ND	0.326	0.348	0.863	ND	0.049	0.154	0.187	ND
20030411	8.89	18.0	14.9	2.74	ND	6.36	2.53	ND	0.372	0.755	0.631	0.116	ND	0.270	0.107	ND
20030412	1.95	2.81	2.28	ND	0.13	0.10	1.63	0.22	2.75	3.96	3.22	ND	0.185	0.144	2.30	0.309
27010024	1.05	7.35	10.6	0.35	0.68	1.05	ND	ND	0.203	1.42	2.05	0.068	0.132	0.203	ND	ND
27010037	1.26	2.24	1.49	ND	0.13	0.95	0.31	ND	5.06	8.99	5.97	ND	0.510	3.81	1.25	ND
27010579	1.10	3.48	1.20	0.29	ND	ND	ND	1.1	1.48	4.66	1.60	0.382	ND	ND	ND	1.48
27010875	0.13	2.58	2.44	0.26	ND	ND	0.13	ND	0.156	3.07	2.91	0.309	ND	ND	0.156	ND
ASH	27.9	16.9	28.4	ND	0.78	17.1	10.8	ND	1.24	0.750	1.26	ND	0.035	0.760	0.482	ND
BLUSPA	ND	2.31	ND	ND	ND	ND	ND	ND	ND	13.9	ND	ND	ND	ND	ND	ND

Table 3-6 (continued). Organic Contaminant Summary Data — PCB, Pesticides, and Other Chlorinated Compounds

	Not Normalized (raw) (µg/kg dry weight)								Normalized to %TOC (µg/kg/%TOC)							
FIELD ID	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT
BUL	ND	0.61	1.05	ND	ND	ND	ND	ND	ND	0.885	1.52	ND	ND	ND	ND	ND
BWC44	5.59	21.2	4.44	0.19	0.74	0.91	0.92	3.76	2.32	8.81	1.52	0.065	0.252	0.313	0.314	1.29
BWCCPB	11.2	17.0	ND	ND	ND	1.70	1.65	7.89	3.81	5.75	ND	ND	ND	0.576	0.559	2.68
CC03	0.60	1.15	0.21	ND	1.39	0.43	0.17	ND	3.54	6.86	1.25	ND	8.25	2.56	0.984	ND
CLD	113	30.9	25.2	ND	3.43	55.6	52.9	4.86	5.11	1.39	1.14	ND	0.155	2.50	2.38	0.219
CLW	ND	0.97	1.54	ND	ND	ND	ND	ND	ND	3.78	6.01	ND	ND	ND	ND	ND
DMR	ND	0.16	0.94	ND	ND	ND	ND	ND	ND	1.51	9.07	ND	ND	ND	ND	ND
DOR	118	69.2	34.9	ND	1.49	103	11.3	3.66	4.26	2.50	1.26	ND	0.054	3.72	0.409	0.132
GEN	2.64	9.49	3.81	ND	0.50	1.62	0.72	0.30	0.496	1.78	0.715	ND	0.094	0.305	0.135	0.056
HAR	39.7	85.6	31.5	ND	0.45	31.6	8.09	ND	1.35	2.91	1.07	ND	0.015	1.07	0.275	ND
HAW	18.4	6.47	5.17	0.54	ND	1.77	2.89	13.7	3.26	1.15	0.917	0.097	ND	0.314	0.512	2.44
HOG30	0.37	3.70	1.28	ND	0.11	0.18	0.20	ND	1.53	15.1	5.24	ND	0.463	0.727	0.799	ND
KER	6.66	25.1	21.9	2.04	ND	0.63	6.03	ND	0.284	1.07	0.932	0.087	ND	0.027	0.257	ND
LAG	2.90	5.32	6.05	ND	0.31	0.77	1.58	0.56	0.252	0.462	0.526	ND	0.027	0.067	0.137	0.049
LEO	13.6	33.8	24.7	8.94	5.83	2.75	8.00	2.86	0.396	0.982	0.719	0.260	0.170	0.080	0.233	0.083
LKWOOD	8.86	44.3	18.3	ND	ND	2.68	6.19	ND	0.409	2.05	0.845	ND	ND	0.124	0.286	ND
LMAC	26.8	43.9	17.5	4.33	1.70	16.8	7.09	2.95	1.87	3.07	1.22	0.303	0.119	1.17	0.496	0.207
LOL	25.8	46.0	105	1.27	ND	7.65	8.97	9.16	0.745	1.35	3.08	0.039	ND	0.225	0.259	0.261
LSJ01	30.3	195	7.82	1.08	3.52	6.61	13.3	10.4	4.15	26.7	1.07	0.149	0.482	0.905	1.82	1.42
LSJ05	12.6	67.3	48.4	1.48	2.47	5.60	4.26	2.76	0.819	4.37	3.14	0.096	0.16	0.364	0.277	0.179
LSJ070	0.10	0.31	ND	ND	ND	ND	0.10	ND	1.11	3.54	ND	ND	ND	ND	1.11	ND
LSJ08	10.2	107	45.9	0.44	0.78	4.55	3.68	1.98	0.653	6.82	2.93	0.028	0.050	0.291	0.235	0.127
LSJ087	1.53	9.06	3.28	ND	0.12	ND	1.00	0.54	0.606	3.58	1.30	ND	0.048	ND	0.394	0.212
LSJ099	0.42	6.90	2.32	ND	0.05	ND	0.26	0.16	0.441	7.33	2.46	ND	0.049	ND	0.275	0.166
LSJ11	10.3	88.5	55.6	0.79	1.03	3.13	5.91	1.26	0.594	5.10	3.21	0.046	0.059	0.180	0.341	0.073
LSJ14	10.0	52.0	34.2	2.44	1.35	3.64	5.14	1.21	0.554	2.88	1.90	0.135	0.075	0.202	0.285	0.067
LSJ17	5.00	18.2	21.8	2.06	0.48	2.04	1.96	1.00	0.466	1.70	2.03	0.192	0.045	0.190	0.183	0.094
LSJ21	2.05	9.84	24.5	1.18	0.60	0.70	0.86	0.48	0.184	0.887	2.20	0.106	0.054	0.063	0.078	0.044
LSJ28	13.9	41.1	7.92	1.14	ND	6.28	6.47	1.10	1.11	3.30	0.636	0.091	ND	0.505	0.520	0.089
LSJ32	11.9	68.6	9.44	1.57	ND	5.89	2.00	3.96	0.798	4.62	0.636	0.106	ND	0.396	0.135	0.267
LSJ35	6.54	28.4	12.4	3.33	2.05	1.70	3.45	1.39	0.260	1.13	0.493	0.133	0.082	0.068	0.137	0.055

Table 3-6 (continued). Organic Contaminant Summary Data — PCB, Pesticides, and Other Chlorinated Compounds

	Not Normalized (raw) (µg/kg dry weight)								Normalized to %TOC (µg/kg/%TOC)							
FIELD ID	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT	ΣDDTs	ΣPCB	ΣChloros	ΣBHCs	ΣChlordane	DDE	DDD	DDT
LSJ40	4.60	4.40	7.32	1.90	ND	2.57	ND	2.03	0.213	0.203	0.338	0.088	ND	0.119	ND	0.094
LSJ918	1.51	7.58	4.39	ND	ND	0.34	1.17	ND	0.805	4.05	2.35	ND	ND	0.181	0.624	ND
LSJRC17	4.79	26.2	35.9	0.11	0.85	0.52	1.48	2.79	0.664	3.62	4.97	0.015	0.118	0.072	0.205	0.386
LYC	10.6	26.1	40.9	ND	ND	4.75	5.81	ND	0.474	1.17	1.89	ND	ND	0.220	0.269	ND
MAT	1.39	1.67	1.42	ND	1.17	0.26	0.95	0.17	6.48	7.80	6.63	ND	5.46	1.23	4.45	0.805
MBU	8.61	23.1	4.37	0.49	0.19	1.44	2.42	4.76	2.96	7.93	1.50	0.167	0.065	0.493	0.831	1.64
MPS	ND	0.61	2.16	ND	ND	ND	ND	ND	ND	26.6	94.1	ND	ND	ND	ND	ND
MR312	0.03	4.48	1.53	ND	ND	ND	0.03	ND	0.044	5.92	2.02	ND	ND	ND	0.044	ND
MTC	5.19	11.9	3.83	0.26	ND	1.96	0.82	2.41	0.634	1.45	0.468	0.032	ND	0.240	0.100	0.294
NRI	ND	0.92	2.23	ND	ND	ND	ND	ND	ND	2.27	5.49	ND	ND	ND	ND	ND
OLK	7.35	54.5	127	ND	ND	7.35	ND	ND	0.163	1.21	2.82	ND	ND	0.163	ND	ND
OR908	29.5	95.1	17.9	ND	3.44	21.7	6.09	1.71	1.47	4.73	0.893	ND	0.171	1.08	0.303	0.086
ORD	4.80	23.9	6.31	1.49	ND	ND	0.94	3.86	0.550	2.74	0.722	0.171	ND	ND	0.107	0.442
PEL	2.37	20.1	1.85	0.16	0.21	ND	0.48	1.89	1.13	9.55	0.875	0.073	0.102	ND	0.228	0.898
RCLSJ06	18.3	198	81.2	6.25	2.22	0.32	9.34	8.65	0.462	4.99	2.05	0.158	0.056	0.008	0.236	0.218
RCLSJ10	18.8	84.8	47.6	3.68	2.89	0.62	2.73	15.5	0.566	2.54	1.43	0.110	0.087	0.018	0.082	0.466
RCLSJ19	4.56	37.9	104	0.52	1.54	1.33	1.44	1.79	0.186	1.55	4.25	0.021	0.063	0.054	0.059	0.073
SHEEL	ND	2.97	1.34	ND	ND	ND	ND	ND	ND	28.0	12.7	ND	ND	ND	ND	ND
SIM	0.72	2.03	2.77	ND	ND	ND	0.72	ND	0.313	0.880	1.20	ND	ND	ND	0.313	ND
SRS	0.11	4.47	2.48	ND	ND	ND	0.11	ND	0.083	3.36	1.87	ND	ND	ND	0.083	ND
SWBPP1	8.68	35.3	6.12	1.08	5.53	3.28	4.12	1.28	2.64	10.7	1.86	0.330	1.68	0.998	1.25	0.390
TOL	0.16	0.15	1.19	ND	ND	0.16	ND	ND	1.38	1.34	10.3	ND	ND	1.38	ND	ND
TUBPP1	0.87	8.45	2.53	0.09	0.23	0.74	0.14	ND	1.18	11.5	3.43	0.125	0.311	0.997	0.186	ND
USJ055	6.89	46.9	22.5	0.75	1.50	3.23	ND	3.66	1.32	8.96	4.30	0.144	0.287	0.618	ND	0.699
USJ918	4.21	7.42	2.85	0.27	0.25	1.53	0.65	2.03	1.06	1.87	0.717	0.069	0.062	0.385	0.163	0.512
WIN	0.96	4.43	2.30	ND	0.44	0.56	0.40	ND	0.556	2.58	1.34	ND	0.257	0.323	0.233	ND
WIO	0.34	2.58	ND	ND	ND	0.10	0.19	0.06	3.23	24.5	ND	ND	ND	0.928	1.76	0.545

significantly lower and their concentration ranges are much smaller. Total chlordane concentrations ranged from ND to 5.8 μg/kg [site LEO (Lake George at M 4 & M 5)] and total BHC concentrations from ND to 8.9 μg/kg (also site LEO).

The variability of the sediment concentrations of chlorinated compounds was reduced when the data were normalized to sediment TOC content (Table 3-6). TOC-normalized PCB concentrations ranged from 0.20 [site LSJ40 (St. Johns River at Ocklawaha River)] to 39.1 μg/kg/%TOC [site 20010137 (Little Wekiva River)]. The TOC-normalized total DDT concentrations ranged from ND to 6.48 μg/kg/%TOC [site MAT (Matanzas River at Washington Oaks)]. The concentrations of TOC-normalized DDT, DDD, and DDE class compounds ranged from ND to 2.73 μg/kg/%TOC [site 02238000 (Hatchet Creek)], ND to 4.45 μg/kg/%TOC [site MAT (Matanzas River at Washington Oaks)], and ND to 3.81 μg/kg/%TOC [site 27010037 (Halifax River)], respectively. Concentrations of TOC-normalized total other chlorinated compounds ranged from ND to 94.1 μg/kg/%TOC [site MPS (Middle Prong St. Mary's River)]. Total chlordane and total BHC concentrations ranged from ND to 9.05 μg/kg/%TOC [site 20010137 (Little Wekiva River)] and ND to 0.382 μg/kg/%TOC [site 27010579 (Tomoka River at 11:th St.)], respectively.

3.2 Results for Metals Analysis

Sediment metals concentrations were determined for 15 elements. Three of the metals (aluminum, iron, and manganese) are considered major metals and are naturally abundant in most geological formations. The 12 other metals that were analyzed are potentially environmental contaminants of concern. The three major metals are commonly used as data normalizers to distinguish between metals concentrations that can be attributed to the natural geology of the location, and those that can potentially be attributed to anthropogenic sources of contamination.

The ranges of major and trace metal concentrations varied widely within the study area (see summary Table 3-7 below). The data from the metals analyses of sediment samples are summarized for each of the 86 sites in Tables 3-8a through 3-8d.

Table 3-7. Concentration Ranges for Major and Trace Metals

	Not Normalized (raw) (mg/kg dry weight)		Normalized to %Mud (mg/kg/%Mud)		Normalized to Al		Normalized to %TOC (mg/kg/%TOC)	
	Min	Max	Min	Max	Min	Max	Min	Max
Major Metals								
Al	239	48,400	58	1,110	1	1	277	42,000
Fe	111	29,400	29	767	0.130	4.19	228	22,300
Mn	2.72	425	0.582	30.3	0.002	0.213	1.62	673
Trace Metals								
As	ND	15.2	ND	1.03	ND	2.22E-3	ND	3.57
Cd	ND	1.33	ND	0.135	ND	1.52E-4	ND	2.11
Cr	0.507	139	0.136	7.46	6.35E-4	1.58E-2	0.543	59.3
Cu	0.256	59.7	0.063	3.73	1.46E-4	2.88E-2	0.157	23.6
Pb	0.661	343	0.080	13.3	5.20E-4	3.60E-2	0.349	145
Li	1.31	50.0	0.044	2.05	4.09E-4	7.66E-3	0.115	89.1
Hg	ND	0.440	ND	0.022	ND	7.63E-5	ND	0.483
Ni	0.123	29.8	0.042	0.688	1.02E-4	1.33E-3	0.168	9.82
Se	ND	5.51	ND	0.179	ND	6.66E-2	ND	1.66
Ag	ND	0.959	ND	0.018	ND	9.10E-5	ND	0.257
Sn	0.067	8.35	0.008	0.755	3.13E-5	2.53E-3	0.016	10.2
Zn	0.901	361	0.130	19.5	6.57E-4	7.89E-2	0.439	149

Table 3-8a. Metals Data — Non-Normalized

	Non-Normalized Metals Concentrations (mg/kg, dry weight)													
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
02235000	5,000	2.52	0.369	13.8	5.33	6,020	14.2	4.18	46.6	0.0914	4.00	3.33	0.015	0.63	21.4
02236000	8,040	0.99	0.100	13.3	3.63	4,300	7.99	5.36	101	0.0360	2.13	0.63	0.023	0.71	19.5
02238000	568	0.13	0.087	8.53	2.84	2,380	3.14	1.83	121	0.0156	0.45	ND	0.006	0.57	7.86
02240800	464	1.03	ND	0.90	0.40	111	0.66	1.67	2.72	0.0143	0.18	ND	0.009	0.08	0.90
02248000	1,020	0.09	ND	1.38	0.48	433	1.11	1.95	6.11	0.0130	0.39	ND	0.012	0.07	3.69
19010001	12,700	1.94	0.125	17.2	4.44	8,250	61.5	8.23	131	0.0386	3.26	0.28	0.033	1.85	361
19010006	3,120	0.42	ND	7.26	1.04	1,070	5.74	1.31	41.0	0.0080	0.32	ND	0.010	0.83	3.53
19020002	38,700	8.00	0.179	49.3	6.33	21,500	21.6	37.7	343	0.0666	11.1	0.56	0.037	1.21	63.7
20010002	764	ND	ND	2.62	0.96	718	1.31	1.91	20.6	0.0057	0.50	ND	0.016	0.22	2.52
20010003	10,300	0.87	0.136	16.1	4.55	6,570	8.62	10.2	77.7	0.0412	5.03	0.55	0.051	0.64	12.6
20010137	985	0.11	0.082	1.61	0.76	283	1.47	1.78	8.30	0.0323	0.43	ND	ND	0.10	3.85
20020001	4,890	0.44	ND	7.10	2.02	1,710	4.83	2.12	40.0	0.0254	1.88	ND	0.018	0.53	6.57
20020012	3,330	0.42	ND	15.3	2.30	2,380	4.59	2.41	90.3	0.0230	1.31	0.94	0.028	0.54	7.69
20020368	18,000	14.7	0.395	20.8	15.6	11,000	44.4	9.76	53.5	0.3340	8.24	2.84	0.270	1.81	50.2
20020371	16,700	5.41	0.371	22.3	20.5	12,500	43.6	11.1	58.2	0.2550	7.09	2.91	0.054	1.48	36.2
20020377	10,900	6.37	0.120	12.6	3.59	6,460	7.96	4.89	46.2	0.1440	4.26	2.53	ND	0.37	10.0
20020381	14,400	8.10	0.278	20.9	12.2	8,770	25.9	7.17	79.4	0.2150	6.86	2.74	0.170	1.19	31.1
20020404	279	ND	ND	0.51	0.26	117	0.75	1.61	3.25	0.0069	0.26	ND	0.006	0.17	1.18
20030373	1,030	0.27	ND	3.90	1.53	1,110	2.70	1.86	46.2	0.0152	0.65	0.19	0.098	0.40	5.01
20030400	3,250	0.89	0.113	6.10	2.9	1,440	8.01	1.36	40.7	0.0884	1.75	0.71	0.015	0.32	8.36
20030411	37,000	2.55	0.750	54.6	12.3	24,600	29.2	40.5	134	0.2420	14.7	1.74	0.078	1.86	74.2
20030412	926	1.37	0.103	3.57	3.68	776	8.96	1.42	24.6	0.0227	0.98	ND	0.011	0.81	21.5
27010024	41,500	5.00	0.190	67.3	10.7	29,400	24.1	50.0	197	0.1030	13.4	0.84	0.080	1.72	68.6
27010037	7,370	0.63	0.095	9.83	3.13	4,290	8.81	6.2	107	0.0304	2.02	ND	0.064	0.49	16.5
27010579	1,960	0.09	ND	4.25	1.48	1,580	3.51	3.44	49.4	0.0171	0.66	ND	0.030	0.26	6.80
27010875	10,600	0.66	0.105	11.1	2.71	4,100	7.77	7.86	96.4	0.0210	2.54	0.19	0.034	0.44	9.66
ASH	41,600	3.38	0.525	48.2	15.0	15,100	33.8	39.2	143	0.2720	21.1	4.70	0.100	1.58	50.0
BLUSPA	2,420	0.43	0.351	7.99	1.34	1,950	2.74	1.72	77.0	0.0275	1.63	0.2	ND	0.29	5.92
BUL	3,430	0.18	ND	5.28	1.62	2,210	3.71	3.51	64.6	0.0168	1.20	ND	0.019	0.39	6.64
BWC44	2,150	0.33	0.224	5.64	3.90	2,360	28.9	2.40	27.0	0.0342	1.74	0.34	ND	0.86	84.5

Table 3-8a (continued). Metals Data — Non-Normalized

	Non-Normalized Metals Concentrations (mg/kg, dry weight)													
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
BWCCPB	4,460	0.51	0.230	10.2	2.74	4,010	6.20	4.71	43.4	0.0830	2.52	2.96	0.012	0.33	9.61
CC03	475	0.11	ND	0.84	0.48	310	1.02	2.13	5.50	0.0132	0.40	ND	0.013	0.13	3.03
CLD	31,400	2.55	0.484	43.5	9.27	17,200	43.1	26.5	61.5	0.2920	14.3	1.99	0.180	1.82	39.1
CLW	239	0.22	ND	1.72	0.49	587	1.31	1.83	8.52	0.0114	0.32	ND	ND	0.09	1.74
DMR	1,030	ND	0.085	2.62	0.66	1,240	1.37	2.71	18.9	ND	0.39	ND	0.013	0.20	2.26
DOR	21,200	15.2	0.371	21.5	18.2	13,200	43.8	11.2	77.3	0.2480	7.79	2.42	0.180	1.61	50.0
GEN	21,100	2.72	0.246	13.4	5.85	2,750	31.8	8.63	35.9	0.1010	6.00	3.10	0.033	1.03	28.4
HAR	19,900	7.07	0.245	20.4	13.0	9,500	37.6	8.13	53.1	0.2040	7.13	2.79	0.020	1.05	30.6
HAW	18,700	1.06	0.185	24.1	3.52	7,720	20.3	15.3	60.0	0.0923	4.08	0.47	0.037	0.79	19.6
HOG30	985	0.12	0.075	3.09	1.16	338	35.5	1.87	11.0	0.0350	0.70	ND	ND	2.49	3.34
KER	21,500	4.32	0.458	28.1	12.1	8,450	13.5	12.9	81.0	0.0929	11.0	5.51	0.070	0.93	23.8
LAG	4,680	1.32	0.142	12.5	3.47	5,860	4.37	4.08	60.8	0.0781	6.24	2.05	0.067	0.46	7.16
LEO	10,500	3.71	0.297	19.7	7.85	9,360	12.3	7.07	162	0.1490	9.56	3.30	0.250	0.80	18.5
LKWOOD	28,400	3.04	0.260	39.4	10.1	17,200	25.9	20.3	104	0.1700	12.6	2.74	0.150	1.22	28.9
LMAC	34,700	2.19	0.714	56.9	23.6	24,400	33.0	33.2	116	0.3200	17.4	1.52	0.690	2.54	67.2
LOL	24,700	4.47	0.542	47.3	13.5	12,200	35.2	14.6	76.5	0.2890	11.8	3.44	0.078	1.21	69.5
LSJ01	48,400	6.27	0.587	66.4	37.3	24,400	63.0	34.9	364	0.3180	16.3	1.21	0.552	2.72	169
LSJ05	42,500	7.52	0.766	62.6	20.3	24,200	35.4	29.7	347	0.2650	16.0	2.44	0.547	3.42	109
LSJ070	330	0.06	ND	5.22	1.39	909	3.75	1.33	36.4	0.0051	0.31	ND	0.022	0.39	4.15
LSJ08	40,000	7.08	0.707	55.7	17.4	18,800	39.2	26.0	312	0.3360	14.6	2.48	0.687	3.14	95.9
LSJ087	2,070	0.30	0.090	2.99	59.7	1,210	46.7	2.10	35.1	0.1580	0.85	0.14	ND	0.71	18.3
LSJ099	3,370	0.24	0.111	5.13	2.54	1,320	35.3	3.43	34.5	0.0146	1.06	ND	ND	0.36	29.2
LSJ11	41,200	7.62	0.843	68.7	22.8	23,200	50.6	30.8	425	0.4230	17.3	2.77	0.959	4.10	109
LSJ14	41,200	7.90	0.650	63.2	20.8	22,900	43.3	34.8	306	0.3090	16.0	2.80	0.507	3.53	110
LSJ17	21,100	10.4	0.196	32.2	8.51	14,300	13.4	17.2	139	0.1410	7.05	1.47	0.147	1.31	37.9
LSJ21	20,600	10.5	0.279	25.3	9.79	11,400	15.0	12.8	175	0.1660	7.39	1.78	0.152	1.35	47.3
LSJ28	12,700	5.14	0.270	23.3	6.63	14,400	15.8	9.11	91.4	0.2320	5.85	2.61	0.090	0.46	34.3
LSJ32	18,600	3.68	0.355	33.9	11.0	14,300	20.7	11.4	96.5	0.2450	9.56	2.89	0.141	1.44	42.9
LSJ35	25,300	3.32	0.440	42.0	15.9	17,600	29.1	15.5	87.2	0.1710	13.1	3.18	0.207	2.08	52.4
LSJ40	20,700	3.27	0.397	56.9	9.34	17,200	24.7	14.1	131	0.1610	8.78	4.74	0.109	1.73	41.8

Table 3-8a (continued). Metals Data — Non-Normalized

	Non-Normalized Metals Concentrations (mg/kg, dry weight)													
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
LSJ918	8,690	0.35	0.080	10.4	1.47	3,600	12.6	6.71	65.3	0.0326	1.61	0.14	0.010	0.55	9.84
LSJRC17	8,590	1.45	0.144	14.5	6.66	5,230	9.24	4.49	71.2	0.1550	4.27	1.36	0.073	0.84	18.8
LYC	15,700	4.29	0.166	20.4	6.72	10,700	13.4	11.4	57.0	0.1300	6.33	3.01	0.030	0.66	14.6
MAT	8,980	0.53	0.098	12.2	3.36	4,770	7.06	5.10	144	0.0177	1.90	ND	0.015	0.47	12.1
MBU	5,560	1.96	0.434	18.9	12.5	3,330	33.7	4.07	68.7	0.0558	3.95	0.84	0.130	0.74	48.7
MPS	331	ND	ND	0.92	0.26	201	0.67	2.05	4.86	0.0022	0.12	ND	ND	0.10	0.93
MR312	19,600	2.37	0.136	21.9	4.78	9,110	12.4	10.7	233	0.0224	4.06	0.31	0.031	0.78	22.1
MTC	6,660	0.04	0.168	9.78	5.55	3,120	26.8	6.65	93.0	0.0856	2.43	0.41	0.086	0.80	35.6
NRI	5,810	0.30	ND	7.97	1.61	3,230	5.48	2.77	131	0.0049	0.86	ND	ND	0.34	7.64
OLK	12,500	4.67	0.400	27.5	9.37	11,400	31.4	5.17	150	0.2220	7.58	3.11	0.046	0.75	41.7
OR908	27,300	3.26	1.33	139	35.0	9,200	260	16.8	82.9	0.3890	17.3	1.09	0.120	6.05	202
ORD	7,160	2.00	0.486	52.7	3.16	4,500	7.86	3.18	41.2	0.0701	6.13	2.29	0.062	0.60	12.1
PEL	3,720	0.41	0.116	6.05	2.94	3,050	15.3	4.66	77.7	0.0326	1.52	ND	0.055	0.47	13.6
RCLSJ06	22,500	2.56	0.907	35.7	27.1	10,500	24.8	11.7	313	0.4400	29.8	2.07	0.223	2.25	162
RCLSJ10	16,700	4.05	0.692	30.7	20.0	10,000	19.9	10.6	161	0.3380	19.3	2.27	0.177	1.87	101
RCLSJ19	25,400	3.46	0.561	43.2	23.4	16,800	23.0	13.2	87.9	0.3120	17.1	3.36	0.205	1.98	64.6
SHEEL	439	ND	ND	4.59	1.58	1,340	6.89	1.43	62.2	0.0235	0.32	0.11	ND	0.60	8.79
SIM	3,420	0.63	0.211	7.34	2.22	1,690	7.74	3.65	29.3	0.0572	1.18	0.65	ND	0.63	270
SRS	17,200	0.37	0.101	21.1	2.51	5,310	8.95	12.8	41.6	0.0368	3.52	0.37	0.056	1.10	11.3
SWBPP1	11,800	0.48	0.957	31.2	14.2	4,560	343	7.44	74.3	0.1140	6.89	0.8	0.270	8.35	86.4
TOL	2,470	0.41	ND	3.70	0.94	1,370	2.19	2.35	41.7	0.0152	0.57	ND	0.013	0.24	4.04
TUBPP1	1,290	2.39	0.125	3.88	1.98	443	11.7	1.85	25.6	0.0349	1.02	0.13	ND	0.25	10.7
USJ055	7,960	0.43	0.160	8.97	3.22	3,300	16.5	10.5	38.7	0.0945	2.34	0.62	0.037	0.57	22.7
USJ918	19,500	0.45	0.097	21.0	4.03	7,000	17.8	14.7	72.1	0.1390	5.04	1.29	0.021	1.10	15.0
WIN	4,460	0.96	0.112	4.31	2.60	923	10.9	2.46	24.3	0.0778	1.66	1.12	0.012	0.38	16.9
WIO	766	0.06	ND	2.90	0.80	596	2.07	1.43	27.8	0.0507	0.38	ND	ND	0.22	6.16

Table 3-8b. Metals Data — Normalized to Aluminum

	Aluminum Normalized Metals Concentrations													
FIELD ID	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Li**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Sn**	**Zn**
02235000	5.04E-04	7.38E-05	2.76E-03	1.07E-03	1.200	2.84E-03	8.36E-04	0.0093	1.83E-05	8.00E-04	6.66E-04	3.00E-06	1.26E-04	4.28E-03
02236000	1.23E-04	1.24E-05	1.65E-03	4.51E-04	0.535	9.94E-04	6.67E-04	0.0126	4.48E-06	2.65E-04	7.84E-05	2.86E-06	8.78E-05	2.43E-03
02238000	2.29E-04	1.52E-04	1.50E-02	5.00E-03	4.190	5.53E-03	3.22E-03	0.2130	2.75E-05	7.83E-04	ND	1.06E-05	1.01E-03	1.38E-02
02240800	2.22E-03	ND	1.94E-03	8.53E-04	0.239	1.42E-03	3.60E-03	0.0059	3.08E-05	3.88E-04	ND	1.94E-05	1.78E-04	1.94E-03
02248000	8.82E-05	ND	1.35E-03	4.71E-04	0.425	1.09E-03	1.91E-03	0.0060	1.27E-05	3.82E-04	ND	1.18E-05	6.56E-05	3.62E-03
19010001	1.53E-04	9.84E-06	1.35E-03	3.50E-04	0.650	4.84E-03	6.48E-04	0.0103	3.04E-06	2.57E-04	2.20E-05	2.60E-06	1.46E-04	2.84E-02
19010006	1.35E-04	ND	2.33E-03	3.33E-04	0.343	1.84E-03	4.20E-04	0.0131	2.56E-06	1.02E-04	ND	3.21E-06	2.67E-04	1.13E-03
19020002	2.07E-04	4.63E-06	1.27E-03	1.64E-04	0.556	5.58E-04	9.74E-04	0.0089	1.72E-06	2.87E-04	1.45E-05	9.56E-07	3.13E-05	1.65E-03
20010002	ND	ND	3.43E-03	1.26E-03	0.940	1.71E-03	2.50E-03	0.0270	7.46E-06	6.52E-04	ND	2.09E-05	2.93E-04	3.30E-03
20010003	8.45E-05	1.32E-05	1.56E-03	4.42E-04	0.638	8.37E-04	9.90E-04	0.0075	4.00E-06	4.88E-04	5.34E-05	4.95E-06	6.17E-05	1.22E-03
20010137	1.12E-04	8.30E-05	1.63E-03	7.68E-04	0.287	1.49E-03	1.81E-03	0.0084	3.28E-05	4.41E-04	ND	ND	9.64E-05	3.91E-03
20020001	9.00E-05	ND	1.45E-03	4.13E-04	0.350	9.88E-04	4.34E-04	0.0082	5.19E-06	3.84E-04	ND	3.68E-06	1.09E-04	1.34E-03
20020012	1.26E-04	ND	4.59E-03	6.91E-04	0.715	1.38E-03	7.24E-04	0.0271	6.91E-06	3.93E-04	2.82E-04	8.41E-06	1.62E-04	2.31E-03
20020368	8.17E-04	2.19E-05	1.16E-03	8.67E-04	0.611	2.47E-03	5.42E-04	0.0030	1.86E-05	4.58E-04	1.58E-04	1.50E-05	1.01E-04	2.79E-03
20020371	3.24E-04	2.22E-05	1.34E-03	1.23E-03	0.749	2.61E-03	6.65E-04	0.0035	1.53E-05	4.25E-04	1.74E-04	3.23E-06	8.86E-05	2.17E-03
20020377	5.84E-04	1.10E-05	1.16E-03	3.29E-04	0.593	7.30E-04	4.49E-04	0.0042	1.32E-05	3.91E-04	2.32E-04	ND	3.39E-05	9.17E-04
20020381	5.63E-04	1.93E-05	1.45E-03	8.47E-04	0.609	1.80E-03	4.98E-04	0.0055	1.49E-05	4.76E-04	1.90E-04	1.18E-05	8.26E-05	2.16E-03
20020404	ND	ND	1.82E-03	9.46E-04	0.419	2.67E-03	5.77E-03	0.0116	2.47E-05	9.18E-04	ND	2.15E-05	6.06E-04	4.23E-03
20030373	2.56E-04	ND	3.79E-03	1.49E-03	1.090	2.64E-03	1.83E-03	0.0450	1.46E-05	6.33E-04	1.74E-04	9.10E-05	3.88E-04	4.85E-03
20030400	2.74E-04	3.48E-05	1.88E-03	8.92E-04	0.443	2.46E-03	4.18E-04	0.0125	2.72E-05	5.38E-04	2.18E-04	4.62E-06	9.82E-05	2.57E-03
20030411	6.89E-05	2.03E-05	1.48E-03	3.32E-04	0.665	7.89E-04	1.09E-03	0.0036	6.54E-06	3.97E-04	4.70E-05	2.11E-06	5.03E-05	2.01E-03
20030412	1.47E-03	1.11E-04	3.85E-03	3.97E-03	0.837	9.68E-03	1.53E-03	0.0266	2.45E-05	1.05E-03	ND	1.13E-05	8.77E-04	2.32E-02
27010024	1.20E-04	4.58E-06	1.62E-03	2.58E-04	0.708	5.81E-04	1.20E-03	0.0048	2.48E-06	3.23E-04	2.02E-05	1.93E-06	4.14E-05	1.65E-03
27010037	8.55E-05	1.28E-05	1.33E-03	4.25E-04	0.582	1.20E-03	8.41E-04	0.0145	4.12E-06	2.74E-04	ND	8.68E-06	6.68E-05	2.24E-03
27010579	4.54E-05	ND	2.17E-03	7.55E-04	0.806	1.79E-03	1.76E-03	0.0252	8.72E-06	3.35E-04	ND	1.53E-05	1.32E-04	3.47E-03
27010875	6.23E-05	9.91E-06	1.05E-03	2.56E-04	0.387	7.33E-04	7.42E-04	0.0091	1.98E-06	2.40E-04	1.79E-05	3.21E-06	4.14E-05	9.11E-04
ASH	8.13E-05	1.26E-05	1.16E-03	3.61E-04	0.363	8.13E-04	9.42E-04	0.0034	6.54E-06	5.07E-04	1.13E-04	2.40E-06	3.80E-05	1.20E-03
BLUSPA	1.78E-04	1.45E-04	3.30E-03	5.54E-04	0.806	1.13E-03	7.11E-04	0.0318	1.14E-05	6.74E-04	8.26E-05	ND	1.18E-04	2.45E-03
BUL	5.25E-05	ND	1.54E-03	4.72E-04	0.644	1.08E-03	1.02E-03	0.0188	4.90E-06	3.50E-04	ND	5.54E-06	1.13E-04	1.94E-03

Table 3-8b (continued). Metals Data — Normalized to Aluminum

	Aluminum Normalized Metals Concentrations												
FIELD ID	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Li**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Sn**	**Zn**
BWC44	1.53E-04	1.04E-04	2.62E-03	1.81E-03	1.100	1.34E-02	1.12E-03	0.0126	1.59E-05	8.09E-04	1.58E-04	ND	4.01E-04	3.93E-02
BWCCPB	1.14E-04	5.16E-05	2.29E-03	6.14E-04	0.899	1.39E-03	1.06E-03	0.0097	1.86E-05	5.65E-04	6.64E-04	2.69E-06	7.31E-05	2.15E-03
CC03	2.32E-04	ND	1.76E-03	1.01E-03	0.653	2.15E-03	4.48E-03	0.0116	2.78E-05	8.40E-04	ND	2.74E-05	2.63E-04	6.38E-03
CLD	8.12E-05	1.54E-05	1.39E-03	2.95E-04	0.548	1.37E-03	8.44E-04	0.0020	9.30E-06	4.55E-04	6.34E-05	5.73E-06	5.80E-05	1.25E-03
CLW	9.21E-04	ND	7.20E-03	2.05E-03	2.460	5.48E-03	7.66E-03	0.0356	4.77E-05	1.33E-03	ND	ND	3.61E-04	7.28E-03
DMR	ND	8.23E-05	2.54E-03	6.44E-04	1.200	1.33E-03	2.63E-03	0.0183	ND	3.80E-04	ND	1.26E-05	1.97E-04	2.19E-03
DOR	7.17E-04	1.75E-05	1.01E-03	8.58E-04	0.623	2.07E-03	5.28E-04	0.0037	1.17E-05	3.67E-04	1.14E-04	8.49E-06	7.59E-05	2.36E-03
GEN	1.29E-04	1.17E-05	6.35E-04	2.77E-04	0.130	1.51E-03	4.09E-04	0.0017	4.79E-06	2.84E-04	1.47E-04	1.56E-06	4.88E-05	1.35E-03
HAR	3.55E-04	1.23E-05	1.03E-03	6.53E-04	0.477	1.89E-03	4.09E-04	0.0027	1.03E-05	3.58E-04	1.40E-04	1.01E-06	5.28E-05	1.54E-03
HAW	5.67E-05	9.89E-06	1.29E-03	1.88E-04	0.413	1.09E-03	8.18E-04	0.0032	4.94E-06	2.18E-04	2.51E-05	1.98E-06	4.21E-05	1.05E-03
HOG30	1.22E-04	7.57E-05	3.14E-03	1.18E-03	0.343	3.60E-02	1.90E-03	0.0112	3.55E-05	7.11E-04	ND	ND	2.53E-03	3.39E-03
KER	2.01E-04	2.13E-05	1.31E-03	5.63E-04	0.393	6.28E-04	6.00E-04	0.0038	4.32E-06	5.12E-04	2.56E-04	3.26E-06	4.34E-05	1.11E-03
LAG	2.82E-04	3.03E-05	2.67E-03	7.41E-04	1.250	9.34E-04	8.72E-04	0.0130	1.67E-05	1.33E-03	4.38E-04	1.43E-05	9.72E-05	1.53E-03
LEO	3.53E-04	2.83E-05	1.88E-03	7.48E-04	0.891	1.17E-03	6.73E-04	0.0154	1.42E-05	9.10E-04	3.14E-04	2.38E-05	7.59E-05	1.76E-03
LKWOOD	1.08E-04	9.15E-06	1.39E-03	3.57E-04	0.607	9.12E-04	7.17E-04	0.0037	6.01E-06	4.45E-04	9.69E-05	5.26E-06	4.29E-05	1.02E-03
LMAC	6.31E-05	2.06E-05	1.64E-03	6.80E-04	0.703	9.51E-04	9.57E-04	0.0033	9.22E-06	5.01E-04	4.38E-05	1.99E-05	7.32E-05	1.94E-03
LOL	1.80E-04	2.19E-05	1.91E-03	5.52E-04	0.493	1.43E-03	5.91E-04	0.0031	1.17E-05	4.77E-04	1.39E-04	3.16E-06	4.87E-05	2.81E-03
LSJ01	1.29E-04	1.21E-05	1.37E-03	7.70E-04	0.504	1.30E-03	7.20E-04	0.0075	6.56E-06	3.37E-04	2.49E-05	1.14E-05	5.63E-05	3.49E-03
LSJ05	1.77E-04	1.80E-05	1.47E-03	4.78E-04	0.569	8.34E-04	7.00E-04	0.0082	6.23E-06	3.76E-04	5.75E-05	1.29E-05	8.06E-05	2.56E-03
LSJ070	1.88E-04	ND	1.58E-02	4.21E-03	2.750	1.14E-02	4.03E-03	0.1100	1.55E-05	9.52E-04	ND	6.67E-05	1.18E-03	1.26E-02
LSJ08	1.77E-04	1.77E-05	1.39E-03	4.34E-04	0.469	9.80E-04	6.50E-04	0.0078	8.40E-06	3.65E-04	6.21E-05	1.72E-05	7.86E-05	2.40E-03
LSJ087	1.45E-04	4.33E-05	1.44E-03	2.88E-02	0.585	2.26E-02	1.01E-03	0.0170	7.63E-05	4.11E-04	6.76E-05	ND	3.42E-04	8.84E-03
LSJ099	7.12E-05	3.29E-05	1.52E-03	7.54E-04	0.392	1.05E-02	1.02E-03	0.0102	4.33E-06	3.15E-04	ND	ND	1.08E-04	8.66E-03
LSJ11	1.85E-04	2.05E-05	1.67E-03	5.53E-04	0.563	1.23E-03	7.47E-04	0.0103	1.03E-05	4.20E-04	6.72E-05	2.33E-05	9.95E-05	2.64E-03
LSJ14	1.92E-04	1.58E-05	1.53E-03	5.05E-04	0.556	1.05E-03	8.45E-04	0.0074	7.49E-06	3.87E-04	6.78E-05	1.23E-05	8.56E-05	2.67E-03
LSJ17	4.95E-04	9.29E-06	1.53E-03	4.04E-04	0.677	6.37E-04	8.17E-04	0.0066	6.67E-06	3.35E-04	6.98E-05	6.96E-06	6.22E-05	1.80E-03
LSJ21	5.08E-04	1.35E-05	1.23E-03	4.75E-04	0.553	7.26E-04	6.19E-04	0.0085	8.06E-06	3.58E-04	8.62E-05	7.35E-06	6.53E-05	2.29E-03
LSJ28	4.04E-04	2.12E-05	1.83E-03	5.21E-04	1.130	1.24E-03	7.16E-04	0.0072	1.82E-05	4.60E-04	2.05E-04	7.09E-06	3.62E-05	2.69E-03
LSJ32	1.98E-04	1.91E-05	1.82E-03	5.89E-04	0.766	1.11E-03	6.13E-04	0.0052	1.31E-05	5.14E-04	1.55E-04	7.55E-06	7.72E-05	2.31E-03
LSJ35	1.31E-04	1.74E-05	1.66E-03	6.30E-04	0.695	1.15E-03	6.14E-04	0.0035	6.75E-06	5.17E-04	1.26E-04	8.20E-06	8.24E-05	2.07E-03

Table 3-8b (continued). Metals Data — Normalized to Aluminum

	Aluminum Normalized Metals Concentrations													
FIELD ID	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
LSJ40	1.58E-04	1.92E-05	2.75E-03	4.51E-04	0.831	1.19E-03	6.79E-04	0.0063	7.78E-06	4.24E-04	2.29E-04	5.24E-06	8.36E-05	2.02E-03
LSJ918	4.03E-05	9.24E-06	1.20E-03	1.69E-04	0.414	1.45E-03	7.72E-04	0.0075	3.75E-06	1.85E-04	1.61E-05	1.15E-06	6.27E-05	1.13E-03
LSJRC17	1.68E-04	1.68E-05	1.69E-03	7.76E-04	0.609	1.08E-03	5.23E-04	0.0083	1.80E-05	4.97E-04	1.58E-04	8.44E-06	9.78E-05	2.19E-03
LYC	2.73E-04	1.06E-05	1.30E-03	4.28E-04	0.682	8.54E-04	7.26E-04	0.0036	8.28E-06	4.03E-04	1.92E-04	1.91E-06	4.18E-05	9.30E-04
MAT	5.90E-05	1.09E-05	1.36E-03	3.74E-04	0.531	7.86E-04	5.68E-04	0.0160	1.97E-06	2.12E-04	ND	1.67E-06	5.28E-05	1.35E-03
MBU	3.53E-04	7.81E-05	3.40E-03	2.25E-03	0.599	6.06E-03	7.32E-04	0.0124	1.00E-05	7.10E-04	1.51E-04	2.34E-05	1.33E-04	8.76E-03
MPS	ND	ND	2.78E-03	7.73E-04	0.607	2.03E-03	6.19E-03	0.0147	6.65E-06	3.72E-04	ND	ND	3.02E-04	2.82E-03
MR312	1.21E-04	6.94E-06	1.12E-03	2.44E-04	0.465	6.33E-04	5.46E-04	0.0119	1.14E-06	2.07E-04	1.58E-05	1.58E-06	3.97E-05	1.13E-03
MTC	5.41E-06	2.52E-05	1.47E-03	8.33E-04	0.468	4.02E-03	9.98E-04	0.0140	1.29E-05	3.65E-04	6.16E-05	1.29E-05	1.20E-04	5.35E-03
NRI	5.16E-05	ND	1.37E-03	2.77E-04	0.556	9.43E-04	4.77E-04	0.0225	8.43E-07	1.49E-04	ND	ND	5.83E-05	1.31E-03
OLK	3.74E-04	3.20E-05	2.20E-03	7.50E-04	0.912	2.51E-03	4.14E-04	0.0120	1.78E-05	6.06E-04	2.49E-04	3.68E-06	5.98E-05	3.34E-03
OR908	1.19E-04	4.87E-05	5.09E-03	1.28E-03	0.337	9.52E-03	6.15E-04	0.0030	1.42E-05	6.34E-04	3.99E-05	4.40E-06	2.22E-04	7.40E-03
ORD	2.79E-04	6.79E-05	7.36E-03	4.41E-04	0.628	1.10E-03	4.44E-04	0.0058	9.79E-06	8.56E-04	3.20E-04	8.66E-06	8.38E-05	1.69E-03
PEL	1.10E-04	3.12E-05	1.63E-03	7.90E-04	0.820	4.11E-03	1.25E-03	0.0209	8.76E-06	4.09E-04	ND	1.48E-05	1.26E-04	3.66E-03
RCLSJ06	1.14E-04	4.03E-05	1.58E-03	1.20E-03	0.467	1.10E-03	5.18E-04	0.0139	1.96E-05	1.32E-03	9.18E-05	9.89E-06	9.98E-05	7.18E-03
RCLSJ10	2.43E-04	4.16E-05	1.84E-03	1.20E-03	0.601	1.19E-03	6.34E-04	0.0096	2.03E-05	1.16E-03	1.36E-04	1.06E-05	1.12E-04	6.09E-03
RCLSJ19	1.36E-04	2.21E-05	1.70E-03	9.20E-04	0.661	9.04E-04	5.21E-04	0.0035	1.23E-05	6.74E-04	1.32E-04	8.07E-06	7.79E-05	2.54E-03
SHEEL	ND	ND	1.05E-02	3.60E-03	3.050	1.57E-02	3.26E-03	0.1420	5.35E-05	7.24E-04	2.51E-04	ND	1.37E-03	2.00E-02
SIM	1.84E-04	6.17E-05	2.15E-03	6.49E-04	0.494	2.26E-03	1.07E-03	0.0086	1.67E-05	3.45E-04	1.90E-04	ND	1.83E-04	7.89E-02
SRS	2.15E-05	5.87E-06	1.23E-03	1.46E-04	0.309	5.20E-04	7.44E-04	0.0024	2.14E-06	2.05E-04	2.15E-05	3.26E-06	6.40E-05	6.57E-04
SWBPP1	4.07E-05	8.11E-05	2.64E-03	1.20E-03	0.386	2.91E-02	6.31E-04	0.0063	9.66E-06	5.84E-04	6.78E-05	2.29E-05	7.08E-04	7.32E-03
TOL	1.66E-04	ND	1.50E-03	3.80E-04	0.555	8.87E-04	9.51E-04	0.0169	6.15E-06	2.30E-04	ND	5.26E-06	9.76E-05	1.64E-03
TUBPP1	1.85E-03	9.69E-05	3.01E-03	1.53E-03	0.343	9.07E-03	1.43E-03	0.0198	2.71E-05	7.91E-04	1.01E-04	ND	1.90E-04	8.29E-03
USJ055	5.40E-05	2.01E-05	1.13E-03	4.05E-04	0.415	2.07E-03	1.32E-03	0.0049	1.19E-05	2.94E-04	7.79E-05	4.65E-06	7.12E-05	2.85E-03
USJ918	2.31E-05	4.96E-06	1.08E-03	2.07E-04	0.359	9.13E-04	7.54E-04	0.0037	7.13E-06	2.58E-04	6.62E-05	1.08E-06	5.64E-05	7.69E-04
WIN	2.15E-04	2.51E-05	9.66E-04	5.83E-04	0.207	2.44E-03	5.52E-04	0.0055	1.74E-05	3.72E-04	2.51E-04	2.69E-06	8.48E-05	3.79E-03
WIO	7.70E-05	ND	3.79E-03	1.04E-03	0.778	2.70E-03	1.87E-03	0.0363	6.62E-05	4.90E-04	ND	ND	2.83E-04	8.04E-03

Table 3-8c. Metals Data — Normalized to Grain Size

	Grain Size Normalized Metals Concentrations (mg/kg/%Mud)													
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
02235000	239	0.121	0.0177	0.66	0.255	288	0.679	0.200	2.23	0.00437	0.191	0.159	0.00072	0.0302	1.02
02236000	226	0.028	0.0028	0.375	0.102	121	0.225	0.151	2.85	0.00101	0.060	0.018	0.00065	0.0199	0.549
02238000	146	0.033	0.0222	2.19	0.728	610	0.805	0.469	31.0	0.00400	0.114	ND	0.00154	0.1469	2.02
02240800	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
02248000	1,280	0.113	ND	1.73	0.600	541	1.39	2.44	7.64	0.01625	0.488	ND	0.01500	0.0836	4.61
19010001	686	0.105	0.0068	0.930	0.240	446	3.32	0.445	7.08	0.00209	0.176	0.015	0.00178	0.1000	19.5
19010006	473	0.064	ND	1.10	0.158	162	0.870	0.198	6.21	0.00121	0.048	ND	0.00152	0.1260	0.535
19020002	772	0.160	0.0036	0.984	0.126	429	0.431	0.752	6.85	0.00133	0.222	0.011	0.00074	0.0242	1.27
20010002	111	ND	ND	0.380	0.139	104	0.190	0.277	2.99	0.00083	0.072	ND	0.00232	0.0325	0.365
20010003	277	0.023	0.0037	0.433	0.122	177	0.232	0.274	2.09	0.00111	0.135	0.015	0.00137	0.0171	0.339
20010137	985	0.110	0.0818	1.61	0.756	283	1.47	1.78	8.30	0.03230	0.434	ND	ND	0.0950	3.85
20020001	627	0.056	ND	0.910	0.259	219	0.619	0.272	5.13	0.00326	0.241	ND	0.00231	0.0682	0.842
20020012	254	0.032	ND	1.17	0.176	182	0.35	0.184	6.89	0.00176	0.100	0.072	0.00214	0.0411	0.587
20020368	612	0.500	0.0134	0.707	0.531	374	1.51	0.332	1.82	0.01136	0.280	0.097	0.00918	0.0616	1.71
20020371	1,060	0.342	0.0235	1.41	1.30	791	2.76	0.703	3.68	0.01614	0.449	0.184	0.00342	0.0937	2.29
20020377	571	0.334	0.0063	0.660	0.188	338	0.417	0.256	2.42	0.00754	0.223	0.132	ND	0.0193	0.524
20020381	456	0.256	0.0088	0.661	0.386	278	0.820	0.227	2.51	0.00680	0.217	0.087	0.00538	0.0377	0.984
20020404	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
20030373	100	0.026	ND	0.379	0.149	108	0.263	0.182	4.50	0.00147	0.063	0.018	0.00928	0.0388	0.486
20030400	104	0.028	0.0036	0.195	0.093	46	0.256	0.044	1.30	0.00282	0.056	0.023	0.00048	0.0102	0.267
20030411	831	0.057	0.0169	1.23	0.276	553	0.656	0.910	3.01	0.00544	0.330	0.039	0.00175	0.0418	1.67
20030412	58.0	0.086	0.0065	0.224	0.231	48.8	0.564	0.089	1.55	0.00143	0.061	ND	0.00066	0.0511	1.35
27010024	629	0.076	0.0029	1.02	0.162	445	0.365	0.758	2.98	0.00156	0.203	0.013	0.00121	0.0261	1.04
27010037	676	0.058	0.0087	0.902	0.287	394	0.808	0.569	9.82	0.00279	0.185	ND	0.00587	0.0451	1.51
27010579	218	0.010	ND	0.472	0.164	176	0.390	0.382	5.49	0.00190	0.073	ND	0.00333	0.0287	0.756
27010875	538	0.034	0.0053	0.563	0.138	208	0.394	0.399	4.89	0.00107	0.129	0.010	0.00173	0.0223	0.490
ASH	523	0.043	0.0066	0.606	0.189	190	0.425	0.493	1.80	0.00342	0.265	0.059	0.00126	0.0199	0.629
BLUSPA	931	0.165	0.1350	3.07	0.515	750	1.05	0.662	29.6	0.01058	0.627	0.077	ND	0.1100	2.28
BUL	390	0.021	ND	0.600	0.184	251	0.422	0.399	7.34	0.00191	0.136	ND	0.00216	0.0439	0.755

Table 3-8c (continued). Metals Data — Normalized to Grain Size

	Grain Size Normalized Metals Concentrations (mg/kg/%Mud)													
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
BWC44	82.7	0.013	0.0086	0.217	0.150	90.8	1.11	0.092	1.04	0.00132	0.067	0.013	ND	0.0332	3.25
BWCCPB	204	0.023	0.0105	0.466	0.125	183	0.283	0.215	1.98	0.00379	0.115	0.135	0.00055	0.0149	0.439
CC03	594	0.138	ND	1.04	0.598	388	1.28	2.66	6.88	0.01650	0.499	ND	0.01625	0.1563	3.79
CLD	569	0.046	0.0088	0.788	0.168	312	0.781	0.480	1.11	0.00529	0.259	0.036	0.00326	0.0330	0.708
CLW	171	0.157	ND	1.23	0.350	419	0.936	1.31	6.09	0.00814	0.228	ND	ND	0.0616	1.24
DMR	229	ND	0.0188	0.582	0.147	276	0.304	0.602	4.20	ND	0.087	ND	0.00289	0.0451	0.502
DOR	591	0.423	0.0103	0.599	0.507	368	1.22	0.312	2.15	0.00691	0.217	0.067	0.00501	0.0448	1.39
GEN	342	0.044	0.0040	0.217	0.095	44.6	0.515	0.140	0.580	0.00164	0.097	0.050	0.00054	0.0167	0.460
HAR	1,010	0.359	0.0124	1.04	0.660	482	1.91	0.413	2.70	0.01036	0.362	0.142	0.00102	0.0533	1.55
HAW	1,110	0.063	0.0110	1.43	0.210	460	1.21	0.911	3.57	0.00549	0.243	0.028	0.00220	0.0468	1.17
HOG30	298	0.036	0.0226	0.936	0.352	102	10.8	0.567	3.33	0.01060	0.212	ND	ND	0.7550	1.01
KER	413	0.083	0.0088	0.540	0.233	163	0.260	0.248	1.56	0.00179	0.212	0.106	0.00135	0.0179	0.458
LAG	85.1	0.024	0.0026	0.227	0.063	107	0.080	0.074	1.11	0.00142	0.113	0.037	0.00122	0.0083	0.130
LEO	310	0.109	0.0088	0.581	0.232	276	0.363	0.209	4.78	0.00440	0.282	0.097	0.00737	0.0235	0.546
LKWOOD	496	0.053	0.0045	0.689	0.177	301	0.452	0.355	1.82	0.00297	0.220	0.048	0.00262	0.0212	0.505
LMAC	511	0.032	0.0105	0.838	0.348	359	0.486	0.489	1.71	0.00471	0.256	0.022	0.01020	0.0374	0.990
LOL	680	0.122	0.0150	1.30	0.387	339	0.987	0.403	2.19	0.00796	0.327	0.095	0.00214	0.0329	1.92
LSJ01	788	0.102	0.0096	1.08	0.607	397	1.03	0.568	5.93	0.00517	0.265	0.020	0.00899	0.0444	2.75
LSJ05	614	0.109	0.0111	0.906	0.294	349	0.512	0.430	5.02	0.00383	0.231	0.035	0.00791	0.0495	1.57
LSJ070	471	0.089	ND	7.46	1.99	1300	5.36	1.90	52.0	0.00729	0.449	ND	0.03143	0.5543	5.93
LSJ08	685	0.121	0.0121	0.955	0.298	322	0.672	0.445	5.34	0.00575	0.250	0.043	0.01180	0.0539	1.64
LSJ087	129	0.019	0.0056	0.187	3.73	75.6	2.92	0.131	2.19	0.00988	0.053	0.009	ND	0.0442	1.14
LSJ099	223	0.016	0.0074	0.340	0.168	87.4	2.34	0.227	2.28	0.00097	0.070	ND	ND	0.0241	1.93
LSJ11	522	0.097	0.0107	0.871	0.289	294	0.642	0.390	5.39	0.00537	0.220	0.035	0.01220	0.0520	1.38
LSJ14	550	0.105	0.0087	0.843	0.278	306	0.578	0.465	4.09	0.00412	0.213	0.037	0.00676	0.0471	1.47
LSJ17	337	0.167	0.0031	0.516	0.136	228	0.215	0.276	2.22	0.00225	0.113	0.024	0.00235	0.0210	0.607
LSJ21	407	0.207	0.0055	0.499	0.193	225	0.295	0.252	3.45	0.00328	0.146	0.035	0.00299	0.0266	0.934
LSJ28	456	0.184	0.0097	0.835	0.238	514	0.565	0.326	3.27	0.00832	0.210	0.093	0.00323	0.0165	1.23
LSJ32	363	0.072	0.0069	0.660	0.214	278	0.404	0.223	1.88	0.0048	0.187	0.056	0.00274	0.0280	0.838
LSJ35	445	0.058	0.0077	0.740	0.280	309	0.511	0.273	1.54	0.0030	0.230	0.056	0.00364	0.0366	0.922

Table 3-8c (continued). Metals Data — Normalized to Grain Size

	Grain Size Normalized Metals Concentrations (mg/kg/%Mud)														
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
LSJ40	422	0.067	0.0081	1.16	0.190	350	0.503	0.286	2.67	0.0033	0.179	0.096	0.00221	0.0352	0.850
LSJ918	422	0.017	0.0039	0.505	0.071	175	0.612	0.326	3.17	0.00158	0.078	0.007	0.00049	0.0265	0.478
LSJRC17	230	0.039	0.0039	0.387	0.178	140	0.247	0.120	1.90	0.00413	0.114	0.036	0.00194	0.0224	0.503
LYC	758	0.207	0.0080	0.986	0.325	517	0.647	0.551	2.75	0.00628	0.306	0.142	0.00145	0.0317	0.705
MAT	955	0.056	0.0104	1.30	0.357	507	0.751	0.543	15.3	0.00188	0.202	ND	0.00160	0.0504	1.29
MBU	252	0.089	0.0196	0.855	0.566	151	1.52	0.184	3.11	0.00252	0.179	0.038	0.00588	0.0335	2.20
MPS	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MR312	810	0.098	0.0056	0.905	0.198	376	0.512	0.442	9.63	0.00093	0.168	0.013	0.00128	0.0322	0.913
MTC	271	0.001	0.0068	0.398	0.226	127	1.09	0.270	3.78	0.00348	0.099	0.017	0.00350	0.0324	1.45
NRI	593	0.031	ND	0.813	0.164	330	0.559	0.283	13.4	0.00050	0.088	ND	ND	0.0346	0.780
OLK	427	0.159	0.0137	0.939	0.320	389	1.07	0.176	5.12	0.00758	0.259	0.106	0.00157	0.0255	1.42
OR908	588	0.070	0.0287	3.00	0.754	198	5.60	0.362	1.79	0.00838	0.373	0.024	0.00259	0.1300	4.35
ORD	261	0.073	0.0177	1.92	0.115	164	0.287	0.116	1.50	0.00256	0.224	0.084	0.00226	0.0219	0.442
PEL	216	0.024	0.0067	0.352	0.171	177	0.890	0.271	4.52	0.00190	0.088	ND	0.00320	0.0272	0.791
RCLSJ06	520	0.059	0.0209	0.823	0.626	242	0.573	0.269	7.23	0.01020	0.688	0.048	0.00514	0.0518	3.73
RCLSJ10	457	0.111	0.0190	0.842	0.549	275	0.545	0.290	4.41	0.00929	0.529	0.062	0.00486	0.0514	2.79
RCLSJ19	873	0.119	0.0193	1.49	0.803	577	0.789	0.455	3.02	0.01070	0.588	0.115	0.00704	0.0680	2.22
SHEEL	274	ND	ND	2.87	0.988	838	4.31	0.894	38.9	0.01469	0.199	0.069	ND	0.3756	5.49
SIM	123	0.023	0.0076	0.263	0.080	60.6	0.277	0.131	1.05	0.00205	0.042	0.023	ND	0.0225	9.68
SRS	465	0.010	0.0027	0.570	0.068	144	0.242	0.346	1.12	0.00100	0.095	0.010	0.00151	0.0297	0.305
SWBPP1	459	0.019	0.0372	1.21	0.553	177	13.3	0.289	2.89	0.00444	0.268	0.031	0.01050	0.3250	3.36
TOL	650	0.108	ND	0.974	0.247	361	0.576	0.618	11.0	0.00400	0.150	ND	0.00342	0.0634	1.06
TUBPP1	157	0.291	0.0152	0.473	0.241	54.0	1.43	0.226	3.12	0.00426	0.124	0.016	ND	0.0299	1.30
USJ055	343	0.019	0.0069	0.387	0.139	142	0.711	0.453	1.67	0.00407	0.101	0.027	0.00159	0.0244	0.978
USJ918	551	0.013	0.0027	0.593	0.114	198	0.503	0.415	2.04	0.00393	0.142	0.036	0.00059	0.0311	0.424
WIN	140	0.030	0.0035	0.136	0.082	29.0	0.343	0.077	0.760	0.00245	0.052	0.035	0.00038	0.0119	0.531
WIO	295	0.023	ND	1.12	0.306	229	0.796	0.550	10.7	0.01950	0.144	ND	ND	0.0835	2.37

Table 3-8d. Metals Data — Normalized to TOC

	Metals Normalized to %TOC (mg/kg/%TOC)														
FIELD ID	Al	As	Cd	Cr	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Sn	Zn
02235000	1,080	0.547	0.080	2.99	1.16	1,310	3.08	0.907	10.1	0.0198	0.868	0.722	0.0033	0.137	4.64
02236000	3,420	0.421	0.0426	5.66	1.54	1,830	3.40	2.28	43.0	0.0153	0.906	0.268	0.0098	0.300	8.30
02238000	1,460	0.335	0.223	22.0	7.32	6,130	8.09	4.72	312	0.0402	1.15	ND	0.0155	1.48	20.3
02240800	11,000	ND	ND	21.5	9.43	2,640	15.7	39.8	64.8	0.3400	4.29	ND	0.2140	1.97	21.5
02248000	12,300	1.08	ND	16.6	5.78	5,220	13.4	23.5	73.6	0.1570	4.70	ND	0.1450	0.806	44.5
19010001	5,230	0.798	0.0514	7.08	1.83	3,400	25.3	3.39	53.9	0.0159	1.34	0.115	0.0136	0.761	149
19010006	7,760	1.04	ND	18.1	2.59	2,660	14.3	3.26	102	0.0199	0.794	ND	0.0249	2.07	8.78
19020002	5,510	1.14	0.0255	7.02	0.902	3,060	3.08	5.37	48.9	0.0095	1.58	0.080	0.0053	0.172	9.07
20010002	2,820	ND	ND	9.67	3.54	2,650	4.83	7.05	76.0	0.0210	1.84	ND	0.0590	0.827	9.30
20010003	5,070	0.429	0.0670	7.93	2.24	3,240	4.25	5.02	38.3	0.0203	2.48	0.271	0.0251	0.313	6.21
20010137	9,380	1.05	0.779	15.3	7.20	2,700	14.0	17.0	79.0	0.3080	4.13	ND	ND	0.905	36.7
20020001	2,950	0.265	ND	4.28	1.22	1,030	2.91	1.28	24.1	0.0153	1.13	ND	0.0108	0.320	3.96
20020012	5,880	0.742	ND	27.0	4.06	4,200	8.11	4.26	160	0.0406	2.31	1.66	0.0495	0.952	13.6
20020368	545	0.445	0.012	0.63	0.473	333	1.35	0.296	1.62	0.0101	0.250	0.086	0.0082	0.055	1.52
20020371	540	0.175	0.012	0.722	0.663	405	1.41	0.359	1.88	0.0083	0.229	0.094	0.0018	0.048	1.17
20020377	478	0.279	0.0053	0.553	0.157	283	0.35	0.214	2.03	0.0063	0.187	0.111	ND	0.016	0.439
20020381	374	0.210	0.0072	0.543	0.317	228	0.67	0.186	2.06	0.0056	0.178	0.071	0.0044	0.031	0.808
20020404	5,170	ND	ND	9.39	4.89	2,170	13.8	29.8	60.2	0.1280	4.74	ND	0.1110	3.13	21.9
20030373	1,190	0.313	ND	4.52	1.77	1,290	3.13	2.15	53.5	0.0176	0.747	0.220	0.1130	0.462	5.81
20030400	1,120	0.306	0.0388	2.10	0.997	495	2.75	0.467	14.0	0.0304	0.601	0.244	0.0052	0.110	2.87
20030411	1,570	0.108	0.0318	2.31	0.521	1,040	1.24	1.72	5.68	0.0103	0.623	0.074	0.0033	0.079	3.14
20030412	1,310	1.93	0.145	5.04	5.19	1,100	12.7	2.01	34.7	0.0321	1.38	ND	0.0148	1.15	30.3
27010024	8,040	0.969	0.0368	13.0	2.07	5,700	4.67	9.69	38.2	0.0200	2.60	0.163	0.0155	0.333	13.3
27010037	29,600	2.53	0.3800	39.5	12.6	17,200	35.4	24.9	430	0.1220	8.11	ND	0.2570	1.98	66.3
27010579	2,620	0.119	ND	5.68	1.98	2,110	4.69	4.60	66.0	0.0229	0.878	ND	0.0401	0.345	9.09
27010875	12,600	0.788	0.125	13.2	3.23	4,890	9.27	9.38	115	0.0251	3.03	0.227	0.0406	0.524	11.5
ASH	1,850	0.150	0.0233	2.14	0.667	671	1.50	1.74	6.36	0.0121	0.938	0.209	0.0044	0.070	2.22
BLUSPA	14,600	2.59	2.11	48.1	8.07	11,700	16.5	10.4	464	0.1660	9.82	1.20	ND	1.72	35.7
BUL	5,000	0.262	ND	7.70	2.36	3,220	5.41	5.12	94.2	0.0245	1.75	ND	0.0277	0.563	9.68

Table 3-8d (continued). Metals Data — Normalized to TOC

	Metals Normalized to %TOC (mg/kg/%TOC)													
FIELD ID	**Al**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Li**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Sn**	**Zn**
BWC44	736	0.113	0.0767	1.93	1.34	808	9.90	0.822	9.25	0.0117	0.596	0.116	ND	0.296	28.9
BWCCPB	1,510	0.173	0.078	3.46	0.929	1,360	2.10	1.60	14.7	0.0281	0.854	1.00	0.0041	0.111	3.26
CC03	2,830	0.655	ND	4.97	2.85	1,850	6.07	12.7	32.7	0.0786	2.38	ND	0.0774	0.744	18.0
CLD	1,410	0.115	0.0218	1.96	0.418	775	1.94	1.19	2.77	0.0132	0.644	0.090	0.0081	0.082	1.76
CLW	934	0.859	ND	6.72	1.91	2,290	5.12	7.15	33.3	0.0445	1.25	ND	ND	0.337	6.80
DMR	9,900	ND	0.815	25.2	6.38	11,900	13.20	26.1	182	ND	3.76	ND	0.1250	1.95	21.7
DOR	765	0.549	0.0134	0.776	0.657	477	1.58	0.404	2.79	0.0090	0.281	0.087	0.0065	0.058	1.81
GEN	3,960	0.510	0.0462	2.51	1.10	516	5.97	1.62	6.74	0.0189	1.13	0.582	0.0062	0.193	5.33
HAR	677	0.240	0.0083	0.694	0.442	323	1.28	0.277	1.81	0.0069	0.243	0.095	0.0007	0.036	1.04
HAW	3,320	0.188	0.0328	4.27	0.624	1,370	3.60	2.71	10.6	0.0164	0.723	0.083	0.0066	0.140	3.48
HOG30	4,020	0.490	0.304	12.6	4.73	1,380	145	7.63	44.9	0.1430	2.86	ND	ND	10.2	13.6
KER	915	0.184	0.0195	1.20	0.515	360	0.57	0.549	3.45	0.0040	0.468	0.234	0.0030	0.040	1.01
LAG	407	0.115	0.0123	1.09	0.302	510	0.38	0.355	5.29	0.0068	0.543	0.178	0.0058	0.040	0.623
LEO	305	0.108	0.0086	0.573	0.228	272	0.36	0.206	4.71	0.0043	0.278	0.096	0.0073	0.023	0.538
LKWOOD	1,310	0.14	0.0120	1.82	0.465	793	1.19	0.935	4.79	0.0078	0.581	0.126	0.0069	0.056	1.33
LMAC	2,430	0.153	0.0499	3.98	1.65	1,710	2.31	2.32	8.11	0.0224	1.22	0.106	0.0483	0.178	4.70
LOL	723	0.131	0.0159	1.39	0.395	356	1.03	0.428	2.24	0.0085	0.344	0.101	0.0023	0.035	2.03
LSJ01	6,630	0.858	0.0803	9.10	5.10	3,340	8.63	4.77	49.9	0.0435	2.23	0.165	0.0756	0.373	23.2
LSJ05	2,760	0.488	0.0497	4.06	1.32	1,570	2.30	1.93	22.5	0.0172	1.04	0.158	0.0355	0.222	7.05
LSJ070	3,750	0.705	ND	59.3	15.8	10,300	42.6	15.1	414	0.0580	3.57	ND	0.2500	4.41	47.2
LSJ08	2,550	0.452	0.0451	3.56	1.11	1,200	2.50	1.66	19.9	0.0214	0.933	0.158	0.0439	0.201	6.12
LSJ087	818	0.119	0.0355	1.18	23.6	478	18.50	0.83	13.9	0.0625	0.336	0.055	ND	0.279	7.23
LSJ099	3,580	0.255	0.118	5.45	2.70	1,400	37.50	3.65	36.7	0.0155	1.13	ND	ND	0.387	31.0
LSJ11	2,370	0.439	0.0486	3.96	1.31	1,330	2.92	1.77	24.5	0.0244	0.997	0.159	0.0553	0.236	6.26
LSJ14	2,280	0.438	0.036	3.50	1.15	1,270	2.40	1.93	17.0	0.0171	0.884	0.155	0.0281	0.195	6.09
LSJ17	1,960	0.972	0.0182	3.00	0.793	1,330	1.25	1.60	12.9	0.0131	0.657	0.137	0.0137	0.122	3.53
LSJ21	1,860	0.942	0.0251	2.27	0.882	1,030	1.35	1.15	15.7	0.0150	0.665	0.160	0.0136	0.121	4.26
LSJ28	1,020	0.413	0.0216	1.87	0.533	1,150	1.27	0.731	7.34	0.0186	0.470	0.209	0.0072	0.037	2.75
LSJ32	1,250	0.247	0.0239	2.28	0.737	960	1.39	0.768	6.49	0.0165	0.643	0.194	0.0095	0.097	2.89
LSJ35	1,000	0.132	0.0175	1.67	0.632	698	1.16	0.616	3.47	0.0068	0.519	0.126	0.0082	0.083	2.08

Table 3-8d (continued). Metals Data — Normalized to TOC

	Metals Normalized to %TOC (mg/kg/%TOC)													
FIELD ID	**Al**	**As**	**Cd**	**Cr**	**Cu**	**Fe**	**Pb**	**Li**	**Mn**	**Hg**	**Ni**	**Se**	**Ag**	**Sn**	**Zn**
LSJ40	956	0.151	0.0183	2.63	0.431	794	1.14	0.649	6.05	0.0074	0.406	0.219	0.0050	0.080	1.93
LSJ918	4,650	0.187	0.0429	5.56	0.786	1,930	6.74	3.59	34.9	0.0174	0.861	0.075	0.0054	0.291	5.26
LSJRC17	1,190	0.200	0.0199	2.00	0.923	724	1.28	0.622	9.86	0.0214	0.592	0.188	0.0100	0.116	2.60
LYC	727	0.199	0.0077	0.944	0.311	495	0.62	0.528	2.64	0.0060	0.293	0.139	0.0014	0.030	0.676
MAT	42,000	2.48	0.458	57.0	15.7	22,300	33.0	23.8	673	0.0827	8.88	ND	0.0701	2.21	56.5
MBU	1,910	0.674	0.149	6.49	4.30	1,140	11.6	1.40	23.6	0.0192	1.36	0.289	0.0447	0.255	16.7
MPS	14,400	ND	ND	40.0	11.1	8,740	29.3	89.1	211	0.0957	5.35	ND	ND	4.35	40.6
MR312	25,900	3.13	0.18	28.9	6.31	12,000	16.4	14.1	308	0.0296	5.36	0.410	0.0410	1.03	29.2
MTC	814	0.0044	0.0205	1.20	0.678	381	3.28	0.813	11.4	0.0105	0.297	0.050	0.0105	0.098	4.35
NRI	14,300	0.739	ND	19.6	3.97	7,960	13.5	6.82	323	0.0121	2.13	ND	ND	0.835	18.8
OLK	277	0.104	0.0089	0.61	0.208	253	0.70	0.115	3.33	0.0049	0.168	0.069	ND	0.017	0.925
OR908	1,360	0.162	0.0662	6.92	1.74	458	12.9	0.836	4.12	0.0194	0.861	0.054	0.0060	0.301	10.0
ORD	820	0.229	0.0557	6.04	0.362	515	0.90	0.364	4.72	0.0080	0.702	0.262	0.0071	0.069	1.39
PEL	1,760	0.194	0.055	2.87	1.39	1,450	7.25	2.21	36.8	0.0155	0.720	ND	0.0261	0.222	6.45
RCLSJ06	568	0.065	0.0229	0.900	0.684	265	0.63	0.294	7.90	0.0111	0.753	0.052	0.0056	0.057	4.08
RCLSJ10	499	0.121	0.0207	0.919	0.600	300	0.60	0.316	4.81	0.0101	0.577	0.068	0.0053	0.056	3.04
RCLSJ19	1,040	0.141	0.0229	1.77	0.956	687	0.94	0.542	3.59	0.0128	0.700	0.137	0.0084	0.0809	2.64
SHEEL	4,140	ND	ND	43.3	14.9	12,600	65.0	13.5	587	0.2220	3.00	1.040	ND	5.67	82.9
SIM	1,480	0.273	0.0913	3.18	0.961	732	3.35	1.58	12.7	0.0248	0.511	0.281	ND	0.271	117
SRS	12,900	0.278	0.0759	15.9	1.89	3,990	6.73	9.62	31.3	0.0277	2.65	0.278	0.0421	0.827	8.50
SWBPP1	3,590	0.146	0.291	9.48	4.32	1,390	104	2.26	22.6	0.0347	2.09	0.243	0.0821	2.54	26.3
TOL	21,500	3.57	ND	32.2	8.16	11,900	19.0	20.4	363	0.1320	4.95	ND	0.1130	2.10	35.1
TUBPP1	1,750	3.24	0.169	5.26	2.68	600	15.9	2.51	34.7	0.0473	1.38	0.176	ND	0.332	14.5
USJ055	1,520	0.0822	0.0306	1.72	0.616	631	3.15	2.01	7.40	0.0181	0.447	0.119	0.0071	0.108	4.34
USJ918	4,910	0.113	0.0244	5.29	1.02	1,760	4.48	3.70	18.2	0.0350	1.27	0.325	0.0053	0.277	3.78
WIN	2,590	0.558	0.0651	2.51	1.51	537	6.34	1.43	14.1	0.0452	0.965	0.651	0.0070	0.220	9.83
WIO	7,300	0.562	ND	27.6	7.58	5,680	19.7	13.6	265	0.4830	3.57	ND	ND	2.07	58.7

As expected, the nonanthropogenic, crustal major metals, Al, Fe, and Mn, were present at the highest concentrations in the sediments, whereas the toxic trace metals, such as As, Cd, Cr, Cu, Pb, Li, Hg, Ni, Se, Ag, Sn, and Zn, were detected at lower concentrations (Table 3-8a). The sediment metals concentrations were less variable when normalized to sediment aluminum concentrations (Table 3-8b). For instance, the Al-normalized Pb concentration in the sediment samples ranged from 0.00052 to 0.036 (unitless), a factor of approximately 70 in concentration range, as compared to the raw Pb data which varied by a factor of approximately 520 between the high and the low concentrations. Notable reductions in variability, by normalizing to Al, were also observed for Cr, Cu, Fe, Li, Mn, Hg, Ni, Se, Ag, Sn, and Zn.

Sediment metals concentrations were also less variable once the data were normalized to sediment grain size (% Mud, which is defined as the sum of the %silt and %clay) (Table 3-8c). For example, the grain-size normalized Cr concentration in the sediment samples ranged from 0.136 to 7.46 mg/kg/% mud, a factor of about 30 difference in the concentration between the high and the low sites. The raw (not normalized) Cr results showed a high-to-low site concentration difference of a factor of about 280. Significant reductions in variability, by normalizing to grain size, were also observed for Al, Cu, Fe, Pb, Mn, Hg, Ni, Ag, Sn, and Zn.

Normalizing the data to %TOC also reduced the variability for some of the sediment metals concentrations (Table 3-8d). For example, the %TOC normalized Ni concentration in the sediment samples ranged from 0.168 to 9.81 mg/kg/% TOC, a factor of 58 difference in the concentration between the high and the low sites. The raw (not normalized) Ni results revealed a high-to-low site concentration difference of a factor of about 250. Reductions in variability, by normalizing to TOC, were also observed for Al, Cr, Cu, Fe, Pb, Hg, Ni, Se, and Zn.

3.3 Results for Nutrients Analysis

Nutrient analysis results are summarized in Tables 3-9 and 3-10. Total Kjeldahl nitrogen (TKN), total phosphorus (TP), and soluble reactive phosphorus (OP) are reported in mg/kg dry weight. Nutrient analysis results are available and reported for all sediments sampling locations except the 15 LSJR sites (LSJ21, LSJ17, LSJ14, LSJ05, LSJ08, LSJ11, LSJ40, LSJ35, LSJ32, LSJ01, LSJ28, RCLSJ06, RCLSJ10, LSJRC17, and RCLSJ19).

Table 3-9. Concentration Ranges for Nutrients

	(mg/kg dry weight)	
	Min	Max
TKN	ND	48,950
TP	ND	8,070
OP	ND	68

TKN, TP, and OP concentrations were highly variable throughout the study area. The TKN concentrations measured in the study ranged from ND to 48,950 mg/kg [site LOL (Lochloosa Lake)], while the TP concentrations ranged from ND to 8,100 mg/kg [site SWBPP1 (Sweetwater Branch at Paynes Prairie)]. Unlike TKN and TP, the OP concentrations were somewhat less variable, ranging from ND to 68 mg/kg [site DOR (Lake Dora)]. Approximately 35% of the sediments analyzed (25 of 71 sites) had no detectable concentrations of OP.

Table 3-10. Nutrient Data

	Nutrient Concentration (mg/kg dry weight)		
FIELD ID	TKN	TP	OP
02235000	3,310	980	ND
02236000	2,400	336	1.0
02238000	415	34	ND
02240800	22	15	ND
02248000	75	96	ND
19010001	905	272	ND
19010006	195	30	ND
19020002	3,570	798	3.4
20010002	263	49	0.6
20010003	1,550	356	1.4
20010137	77	354	1.4
20020001	1,480	143	ND
20020012	561	202	ND
20020368	31,400	975	6.0
20020371	26,200	760	2.0
20020377	18,100	508	3.4
20020381	34,500	1,620	39.7
20020404	61	13	ND
20030373	1,098	238	0.8
20030400	2,010	387	1.0
20030411	13,500	1,220	3.1
20030412	658	54	ND
27010024	3,740	778	17.0
27010037	302	582	0.6
27010579	378	85	ND
27010875	851	250	0.7
ASH	12,400	1,490	3.0
BLUSPA	264	3,350	1.8
BUL	454	394	0.6
BWC44	3,260	251	ND
BWCCPB	3,890	297	1.3
CC03	72	82	ND
CLD	13,300	1,140	2.7
CLW	331	19	ND
DMR	89	29	ND
DOR	26,500	1,470	68.0
GEN	5,880	598	1.0
HAR	29,100	1,200	4.3
HAW	3,220	232	0.7
HOG30	233	118	0.7
KER	10,600	457	1.5
LAG	7,240	1,660	1.6
LEO	19,000	779	2.6

Table 3-10 (continued). Nutrient Data

	Nutrient Concentration (mg/kg dry weight)		
FIELD ID	TKN	TP	OP
LKWOOD	16,250	1,180	3.2
LMAC	11,800	1,160	18.3
LOL	48,950	3,065	4.2
LSJ01	NA	NA	NA
LSJ05	NA	NA	NA
LSJ070	34	12	ND
LSJ08	NA	NA	NA
LSJ087	1,400	108	ND
LSJ099	584	101	ND
LSJ11	NA	NA	NA
LSJ14	NA	NA	NA
LSJ17	NA	NA	NA
LSJ21	NA	NA	NA
LSJ28	NA	NA	NA
LSJ32	NA	NA	NA
LSJ35	NA	NA	NA
LSJ40	NA	NA	NA
LSJ918	1,580	147	ND
LSJRC17	NA	NA	NA
LYC	21,700	361	1.5
MAT	341	898	0.9
MBU	3,590	860	ND
MPS	ND	ND	ND
MR312	630	958	1.2
MTC	4,770	361	1.4
NRI	273	103	0.7
OLK	36,500	1,710	2.6
OR908	19,200	3,760	29.5
ORD	5,540	555	3.2
PEL	983	102	0.5
RCLSJ06	NA	NA	NA
RCLSJ10	NA	NA	NA
RCLSJ19	NA	NA	NA
SHEEL	141	17	ND
SIM	1,390	192	ND
SRS	1,350	152	ND
SWBPP1	1,810	8,070	3.2
TOL	84	152	0.8
TUBPP1	1,330	159	2.2
USJ055	3,460	432	1.1
USJ918	1,970	625	0.8
WIN	2,290	282	0.6
WIO	137	27	ND

NA: not analyzed.

3.4 Results for Ancillary Measurements

Total organic carbon (TOC), grain size, moisture content, total solids (TS), and total volatile solids (TVS) results are presented in Tables 3-11 and 3-12. TOC and TVS data are presented as percent dry weight. Moisture and TS data are presented as percent wet weight. The grain-size data are presented as percent distribution of sand, silt, and clay. Percent mud was determined by adding the percent silt and clay, and is used for normalizing the metals concentrations to grain size. Table 3-11 below presents the ranges of concentrations for these ancillary measurements.

Table 3-11. Ranges for Ancillary Measurements

	Min	Max
%Moisture	16.1	96.6
%TOC	0.02	45
%TS (wet weight)	3.4	83.9
%TVS (dry weight)	ND	71.2
%Sand	21	100
%Silt	ND	72
%Clay	ND	13
%Mud	ND	80

3.4.1 TOC Results

As was observed with the organic and metals contaminants, the TOC content of the sediment varied greatly, ranging from 0.023% [site MPS (Middle Prong St. Mary's River)] to 45.1% [OLK (Orange Lake)]. Low TOC concentrations are generally associated with coarse, sandy sediments (>90% sand). TOC concentrations were consistently less than 1.7% at sites with more than 90% sand. However, there was still *not* a good correlation between TOC and the sediment grain size (Figure 3-1) — many of the samples were highly non-homogeneous and significant amounts of plant debris was observed in many samples, resulting in an atypical TOC/grain size relationships. Several sites, including 20020377 and HAR (both in Lake Harris), LYC (Lake Yale), RCLSJ19 (St. Johns River at Verdiere Pt.), OLK (Orange Lake), and 20020368 (Lake Eustis) had elevated TOC concentrations with relatively high sand distribution (>70%).

3.4.2 Grain Size Results

The sediment grain-size distributions were highly variable and complex (Table 3-12). The sites included areas dominated by muddy (fine-grained, silty) sediments and others dominated by coarse sediments (primarily sand). Approximately 25% (23 of 86) of the sites had <10% mud (mud is defined as the silt plus clay fraction).

Table 3-12. Ancillary Measurement Data

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
02235000	64	4.61	35.6	16.6	79.1	18.9	2.0	20.9
02236000	62	2.35	38.4	7.2	64.5	32.9	2.6	35.5
02238000	33	0.39	67.0	1.5	95.8	3.9	ND	3.9
02240800	18	0.04	82.2	ND	99.5	ND	ND	ND
02248000	19	0.08	81.2	ND	98.9	0.8	ND	0.8
19010001	39	2.43	61.0	4.8	81.5	15.4	3.1	18.5
19010006	26	0.40	74.3	0.9	93.4	5.6	1.0	6.6
19020002	73	7.02	26.7	13.0	49.9	42.7	7.4	50.1
20010002	27	0.27	72.9	0.6	93.1	5.8	1.1	6.9
20010003	60	2.03	40.4	4.3	62.7	34.5	2.7	37.2
20010137	20	0.11	80.3	ND	98.8	1.0	ND	1.0
20020001	43	1.66	57.5	3.4	91.7	7.8	ND	7.8
20020012	33	0.57	67.2	1.6	86.9	11.2	1.9	13.1
20020368	96	33.0	4.0	59.6	70.2	29.4	ND	29.4
20020371	95	30.9	5.0	55.6	84.0	15.8	ND	15.8
20020377	94	22.8	6.1	34.7	80.7	19.1	ND	19.1
20020381	97	38.5	3.4	61.9	68.4	30.9	0.7	31.6
20020404	21	0.05	78.8	ND	99.9	ND	ND	ND
20030373	40	0.86	60.0	2.1	89.8	9.4	0.9	10.3
20030400	46	2.91	54.3	6.8	68.7	26.3	5.0	31.3
20030411	89	23.6	11.5	40.3	55.5	41.7	2.8	44.5
20030412	37	0.71	62.6	1.7	84.1	15.4	0.5	15.9
27010024	74	5.16	25.7	11.2	33.9	56.5	9.5	66.0
27010037	26	0.25	74.4	1.1	89.1	7.5	3.4	10.9
27010579	27	0.75	72.8	1.6	91.1	6.6	2.4	9.0
27010875	36	0.84	63.9	2.2	80.3	14.7	5.0	19.7
ASH	83	22.5	17.4	39.6	20.5	66.1	13.4	79.5
BLUSPA	28	0.17	72.4	0.5	97.4	2.1	0.5	2.6
BUL	28	0.69	72.4	1.8	91.3	6.8	2.0	8.8
BWC44	63	2.92	37.0	9.1	74.0	24.3	1.7	26.0
BWCCPB	70	2.95	30.0	20.0	78.1	19.9	2.0	21.9
CC03	16	0.17	83.9	0.5	99.0	0.8	ND	0.8
CLD	88	22.2	12.5	38.7	44.8	50.0	5.2	55.2
CLW	23	0.26	77.4	0.5	98.6	1.4	ND	1.4
DMR	20	0.10	80.5	ND	95.5	3.0	1.5	4.5
DOR	95	27.7	4.9	47.8	64.0	35.1	0.8	35.9
GEN	63	5.33	37.1	14.6	38.4	52.7	9.0	61.7
HAR	96	29.4	4.0	53.7	80.1	19.7	ND	19.7
HAW	67	5.64	32.7	15.1	83.2	14.5	2.3	16.8
HOG30	27	0.25	73.5	0.7	96.8	2.7	0.6	3.3
KER	87	23.5	12.9	32.4	48.1	49.6	2.4	52.0
LAG	72	11.5	28.5	19.9	45.0	49.1	5.9	55.0

Table 3-12 (continued). Ancillary Measurement Data

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
LEO	86	34.4	13.6	52.4	66.2	30.4	3.5	33.9
LKWOOD	90	21.7	9.6	34.0	42.8	55.5	1.7	57.2
LMAC	88	14.3	12.1	26.5	32.1	65.4	2.5	67.9
LOL	96	34.2	3.9	57.8	62.9	36.6	0.6	37.1
LSJ01	77	7.30	23.3	14.3	38.6	54.8	6.6	61.4
LSJ05	84	15.4	15.9	23.7	30.9	63.8	5.3	69.1
LSJ070	19	0.09	81.3	ND	99.1	0.7	ND	0.7
LSJ08	83	15.7	17.1	21.4	41.7	53.0	5.3	58.3
LSJ087	45	2.53	55.4	7.8	84.1	14.3	1.7	16.0
LSJ099	24	0.94	76.2	2.1	84.9	11.9	3.2	15.1
LSJ11	84	17.4	16.5	22.7	21.2	71.7	7.1	78.8
LSJ14	86	18.1	14.2	26.3	25.1	68.3	6.6	74.9
LSJ17	75	10.7	24.7	15.8	37.6	57.6	4.8	62.4
LSJ21	80	11.1	19.7	18.4	49.3	47.3	3.3	50.6
LSJ28	79	12.5	21.1	21.6	72.1	26.2	1.7	27.9
LSJ32	83	14.9	17.2	25.3	48.9	47.7	3.5	51.2
LSJ35	90	25.2	10.2	40.9	43.2	54.5	2.3	56.8
LSJ40	87	21.7	13.2	36.8	51.0	46.3	2.8	49.1
LSJ918	52	1.87	47.7	7.8	79.4	17.5	3.1	20.6
LSJRC17	65	7.22	35.0	10.5	62.7	35.1	2.3	37.4
LYC	94	21.6	6.1	44.1	79.0	20.7	ND	20.7
MAT	26	0.21	73.8	1.6	90.6	6.5	2.9	9.4
MBU	70	2.91	30.0	9.8	77.9	21.3	0.8	22.1
MPS	17	0.02	83.4	ND	99.9	ND	ND	ND
MR312	39	0.76	61.3	2.4	75.8	17.9	6.3	24.2
MTC	72	8.18	27.7	21.2	75.4	22.2	2.4	24.6
NRI	33	0.41	66.7	1.3	90.2	7.8	2.0	9.8
OLK	96	45.1	4.2	71.2	70.7	28.5	0.8	29.3
OR908	92	20.1	7.9	35.7	53.6	44.8	1.6	46.4
ORD	76	8.73	23.8	16.4	72.6	25.5	1.9	27.4
PEL	46	2.11	53.8	5.0	82.8	15.4	1.8	17.2
RCLSJ06	89	39.6	10.9	58.2	56.7	40.0	3.3	43.3
RCLSJ10	88	33.4	12.4	50.5	63.6	34.6	1.8	36.4
RCLSJ19	86	24.5	13.8	39.9	70.8	27.6	1.5	29.1
SHEEL	24	0.11	76.0	ND	98.1	1.6	ND	1.6
SIM	45	2.31	54.7	7.5	72.2	24.5	3.4	27.9
SRS	46	1.33	54.1	3.7	63.0	28.7	8.3	37.0
SWBPP1	52	3.29	48.2	7.2	74.3	21.7	4.0	25.7
TOL	22	0.12	78.3	ND	96.2	2.9	0.9	3.8
TUBPP1	44	0.74	56.0	4.2	91.8	7.7	0.5	8.2
USJ055	62	5.23	37.7	13.0	76.7	21.0	2.2	23.2
USJ918	58	3.97	41.6	8.4	64.6	29.5	5.9	35.4
WIN	46	1.72	54.2	5.7	68.2	27.7	4.1	31.8
WIO	31	0.11	69.1	ND	97.5	2.0	0.6	2.6

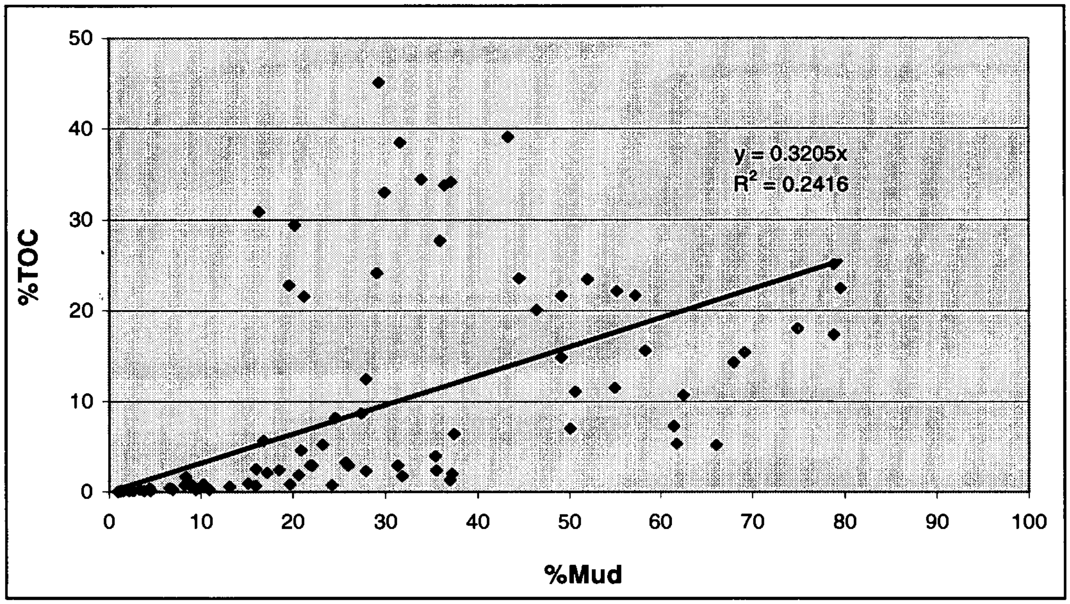


Figure 3-1. %TOC versus %Mud

The ternary grain size plot presented in Figure 3-2 shows the grain size composition of each sample as characterized by a continuum of grain-size distributions. Other than the subset of sites with <10% mud, distinct grouping(s) of sediment grain size are not apparent from this analysis. Overall, the grain size composition is variable throughout the area and ranged from 0% to 80% mud [site ASH (Lake Ashby)] and from approximately 20% [site ASH (Lake Ashby)] to 100 % sand [site 20020404 (Orange Creek)] sand. Percent silt and clay range from 0% to 71.7% [site LSJ11 (St. Johns River at Mandarin Pt.)] and 0% to 13.4% [site ASH (Lake Ashby)], respectively.

3.4.3 Sediment Moisture Content, Total Solids, and Total Volatile Solids

Sediment moisture content, TS, and TVS also varied greatly for the sediment samples. Moisture, TS, and TVS content were characterized by a range of distributions, with no obvious groupings of sediment types. Percent moisture content ranges from 16.1% [site CC03 (Crane Creek)] to 96.6% [site 20020381 (Lake Griffin)]. TS and TVS concentrations range from 3.4% [site 20020381 (Lake Griffin)] to 83.9% [site CC03 (Crane Creek)], and ND to 71.2% [site OLK (Orange Lake)], respectively.

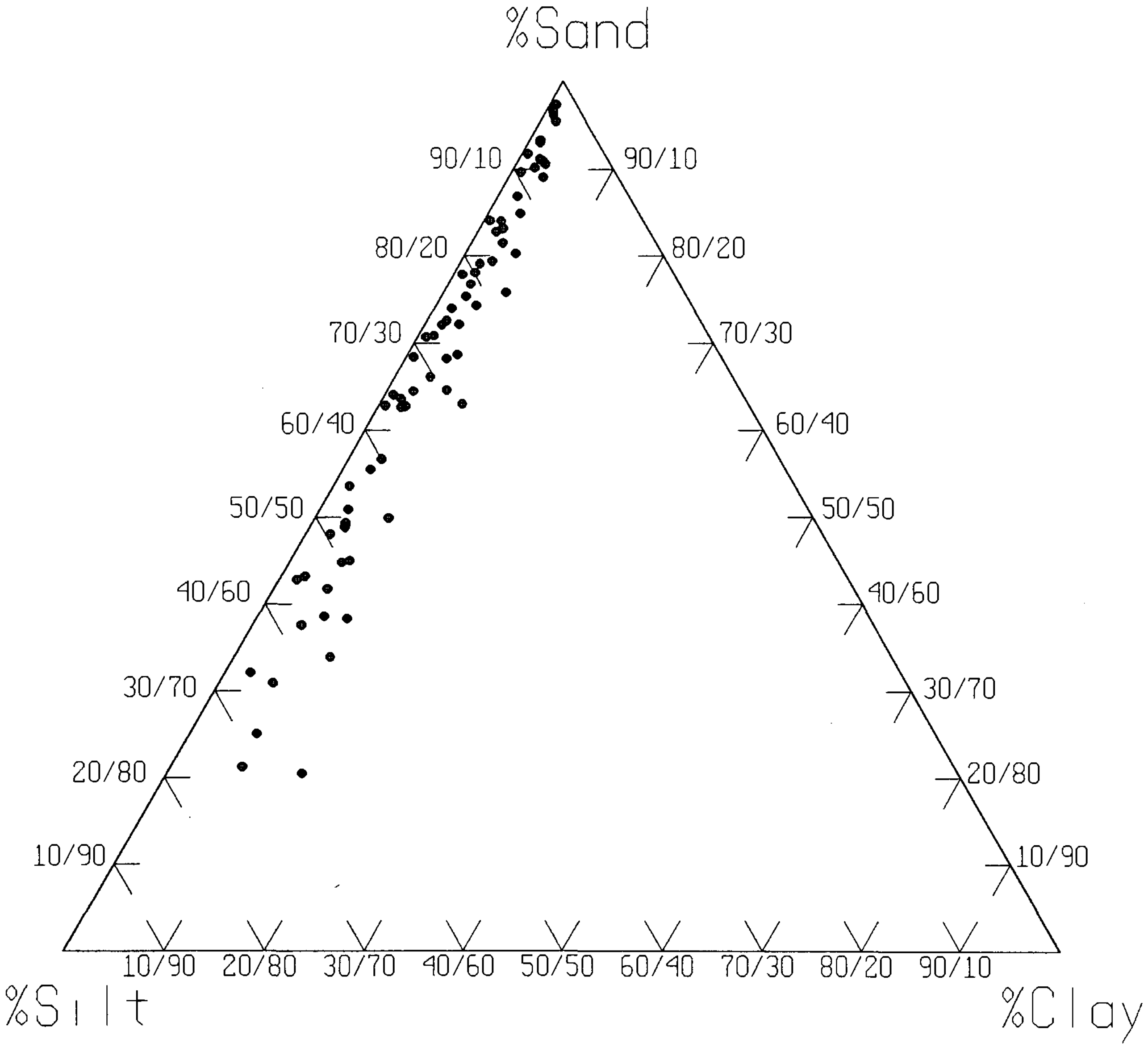


Figure 3-2. Graphical Presentation of Grain Size Data — % Sand, % Silt, and %Clay

4. DISCUSSION

The samples collected in this study cover a large range of water body types (creeks, rivers, lakes, and coastal) and either one of two identifiable general land use types, urban or rural. The majority of the samples are from predominately rural settings. The major urban setting include the portion of the St. Johns River located in the southern sectors of Jacksonville. Other water bodies classified as urban are associated with smaller cities and towns. The presentation below focuses on three aspects of the contaminants in the SJRWMD sediments. These include 1) the contaminant distribution within the SJRWMD, including general relationships to water body types and separation of concentrations in rural and urban settings, 2) general relationships between and among the various contaminants and the parameters that are major factors controlling contaminant distribution in sediments, and 3) the potential of measured concentrations to cause impact to the water bodies.

4.1 Organic Compound Contaminant Levels

Organic Contaminants Investigated

The major classes of organic compounds analyzed were polycyclic aromatic hydrocarbons (PAH), phthalates, polychlorinated biphenyls (PCBs), a group of other chlorinated organic compounds, and a series of chlorinated pesticides (DDTs, BHCs, and chlordane). These groups of compounds were categorized in Sections 3.1.1 and 3.1.2.

PAH are among the most widespread and important organic contaminants. PAH are ubiquitous trace components of terrestrial, aquatic, and marine environments. PAH are composed of two or more fused benzene (aromatic) rings. Naphthalene ($C_{10}H_8$), which consists of two fused aromatic rings, is the lowest molecular weight PAH. PAH with up to nine rings have been identified in the heavy residual fractions of crude oil and in coal tars.

PAH may be formed by four different mechanisms (Neff, 1979):

- Very rapid, high temperature (e.g., 700°C) incomplete combustion (pyrolysis) of organic matter (e.g., combustion of fossil fuels)
- Very slow (e.g., millions of years) rearrangement and transformation of organic matter at moderate temperatures of 100–300°C to form fossil fuels (coal and petroleum)
- Relatively rapid (days to years) transformation of certain pigments and sterols in soils and sediments
- Direct biosynthesis by organisms

The last two processes appear not to be quantitatively important sources of PAH in the environment and result in the production of very simple assemblages of PAH. Examples of these assemblages include perylene and certain C_2 and C_3 alkyl phenanthrenes (retene).

Coal and petroleum are rich sources of PAH. Coal generally is considered an aromatic material. Most of the PAH in coal is tightly bound in the coal structure and is not readily leached out. Nevertheless, a substantial fraction of the total PAH in sediments from industrial bays and estuaries may be derived from coal dust (Tripp, *et al.*, 1981).

Typical crude petroleum may contain from 0.2 to more than 7 percent PAH. The abundance of aromatic hydrocarbons in petroleum decreases markedly with increasing molecular weight. In most cases, the 1-ring (benzenes) through 3-ring (phenanthrenes) aromatics account for at least 90 percent of the aromatic hydrocarbons that can be resolved in crude petroleum.

The aromatic hydrocarbons in coal and petroleum usually contain one or more alkyl hydrocarbon chains containing one or more carbon atoms. As a general rule, these alkyl aromatics are more abundant than the parent compounds in petroleum. Homologues with two to five alkyl carbons usually are more abundant than less or more highly alkylated homologues.

A major source of PAH containing three or more aromatic rings in the environment is combustion of organic matter (Neff, *et al.*, 1979). Combustion of any organic material, including fossil fuels, will generate a wide variety of PAH. The PAH assemblages produced by pyrolysis of organic matter are complex, and, unlike the assemblages in petroleum, are dominated by 4-, 5-, and 6-ring PAH. In pyrogenic PAH assemblages, the dominant compound in each homologous series is the unalkylated parent compound or a homologue with only one or two alkyl carbons. In contrast, as mentioned above, in petrogenic PAH assemblages, the relative abundance of compounds in each homologous series increases to a maximum for the homologues containing three to four, and occasionally five, alkyl carbons. However, the relative distribution for the different alkyl homologues varies significantly for different crude and refined petroleum products.

Another important, though localized, source of PAH in the aquatic environment is creosote, coal tars, and related materials derived from the high-temperature carbonization of coal and petroleum. These materials are derived from high-temperature processing of fossil fuels, and so the PAH contained in them have some of the properties of both pyrogenic and petrogenic PAH assemblages. Asphalt and tar, used to pave roads and parking lots and to waterproof the roofs of houses, also are byproducts of petroleum and contain abundant PAH. Paved road surfaces often contain high concentrations of PAHs, derived from a combination of deposition of exhaust soot from vehicles, wear of tires releasing carbon black, which is rich in pyrogenic PAHs, and wear of the asphalt pavement. PAH washed by rain from road surfaces often reaches the aquatic environment in runoff from land, particularly through storm drains and combined sewer overflows.

It has been proposed that PAH of pyrogenic and petrogenic origin have a different behavior in the aquatic environment (Farrington, *et al.*, 1986). PAH of pyrogenic origin are mostly tightly bound to soot particles owing to the high-temperature formation process and are not readily desorbed and bioaccumulated by aquatic organisms. Crude and refined petroleum products enter the aquatic environment in soluble, colloidal, bulk, or more loosely bound form and, therefore, are more mobile and available for uptake and bioaccumulation. PAH from creosote and other solid tar-derived products seem to have a behavior intermediate between those of pyrogenic and petrogenic PAH (Hugget *et al.*, 1987).

The phthalate esters are also ubiquitous in the environment. Phthalates are typically not considered to cause adverse effects to the same degree as many of the other compounds that were analyzed, but they are among the most widely used industrial chemicals (major components of most plastics), and are part of our daily life and, therefore, are introduced into the environment from countless sources. They are also common laboratory contaminants, particularly bis(2-ethylhexyl)phthalate and di-N-butylphthalate. The "other industrial chlorinated compounds" are a group of chlorinated low molecular weight organic compounds (e.g., chlorinated benzenes) that are also widely used in many industrial applications.

PCBs are used less today than they were in the past, but are a very persistent class of chlorinated hydrocarbons that remain of significant environmental concern and are found throughout the environment. Similarly, the concentrations of several persistent chlorinated pesticides, such as DDT and its degradation products DDD and DDE, chlordane, and BHCs, were studied.

Distribution and Urbanization Impacts

The organic contaminant concentrations varied greatly throughout the study area (Tables 3-3, 3-6 and Appendices B, C, and F). Some of the variability can likely be attributed to anthropogenic sources, while others are more a reflection of the bulk composition of the sediment.

The total PAH concentrations in the sediments are presented in Figure 4-1, and are also displayed on a map in Figure 4-2. Additional supplemental bar charts of organic contaminant concentrations are compiled in Appendix F, and maps illustrating the general geographical distribution of the contaminants can be found in Appendix K. The sites in the bar graph (and in all similar bar graphs in this report) are sorted by the type of aquatic environment (river, lake, creek, and coastal), as indicated in Figure 4-1. Additionally, within each aquatic class the sites are sorted by listing the urban sites first (counting from the top of the graph) and then the rural sites.

The highest PAH concentrations were found at the river sites, which is probably a result of many of these sites being located in the St. Johns River near the urban areas of southern Jacksonville. A few of the creek sites also had higher PAH concentrations than most other sites [e.g., MBU (Ocklawaha River at Moss Bluff), SWBPP1 (Sweetwater Branch at Paynes Prairie), and ORD (Ocklawaha River downstream of SR 40)]. The majority of the sites had total PAH concentrations below 2,000 μg/kg dry weight; 15 of the 86 sites had concentrations above 2,000 μg/kg and only one site had a sediment total PAH concentration above 10,000 μg/kg dry weight — the LSJ01 (Lower St. Johns River at Ortega River) sediment sample had 13,800 μg/kg total PAH. Nine of the sites had high molecular weight PAH above 2,000 μg/kg and four had low molecular weight PAH above 2,000 μg/kg.

Non-polar organic contaminants have an affinity for the organic matter in the sediment, and tend to concentrate in organic-rich sediments to a higher degree than in low organic content sediments, given the same concentrations and conditions in the water phase. It can therefore be useful to normalize the organic contaminant data to the TOC content of the sediment for data analysis purposes. The normalization can help ascertain if elevated levels of organic contaminants could be the result of significant nearby sources of anthropogenic organic contaminants (both non-normalized and TOC-normalized levels are typically elevated), or if it is primarily a sediment concentration effect (elevated TOC-normalized levels, but the non-normalized levels are not elevated). Additionally, the TOC-normalized concentrations are a better indicator of bioavailable organic contaminants (i.e., organic contaminants tightly bound to organic matter, or particulates, are less bioavailable than less bound compounds).

The TOC normalized PAH concentration distribution (Appendix F) has a slightly different appearance than the non-normalized distribution, with several sites appearing elevated even though their non-normalized concentrations were low [e.g., sites 20010137 (Little Wekiva River) and MAT (Matanzas River at Washington Oaks)]. This is clearly a reflection of a very low TOC content of these sediments and not of PAH concentrations that are of real concern — it is important to view all the related data as a whole; non-normalized and normalized contaminant data along with the bulk sediment characterization data. After considering all the PAH and sediment characteristics data, the sites that appear to have the most significant concentrations of PAH include LSJ01 (Lower St. Johns River at Ortega River — the St. Johns River site closest to Jacksonville) and other sites in the northern parts of this river, creek sites MBU (Ocklawaha River at Moss Bluff) and SWBPP1 (Sweetwater Branch at Paynes Prairie), site 20030412 (Kingsley Lake), and, to a lesser degree, sites ORD (Ocklawaha River downstream of SR 40) and OR908 (Bivens Arm West). These are a combination of urban and rural sites.

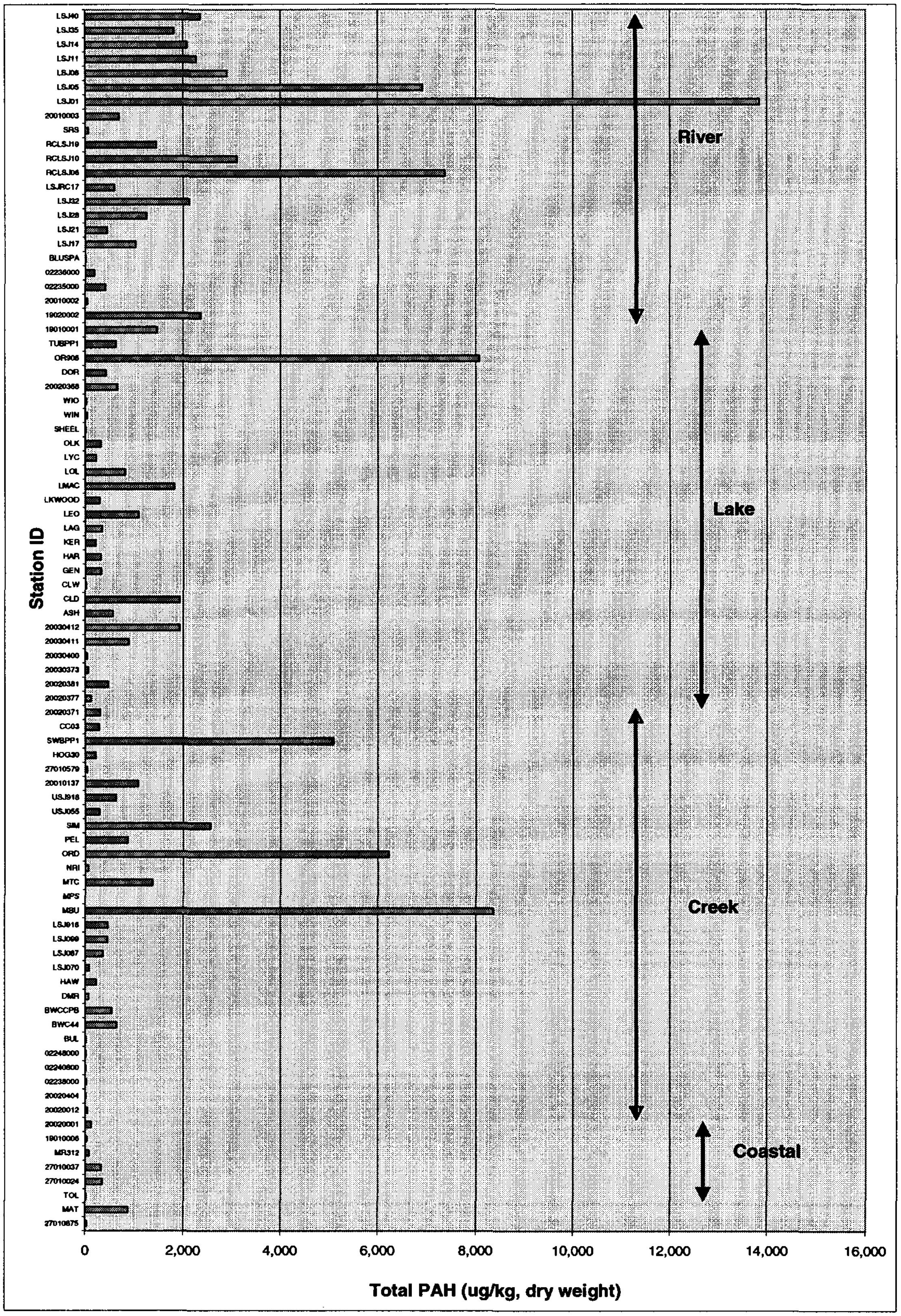


Figure 4-1. Total PAH Concentrations

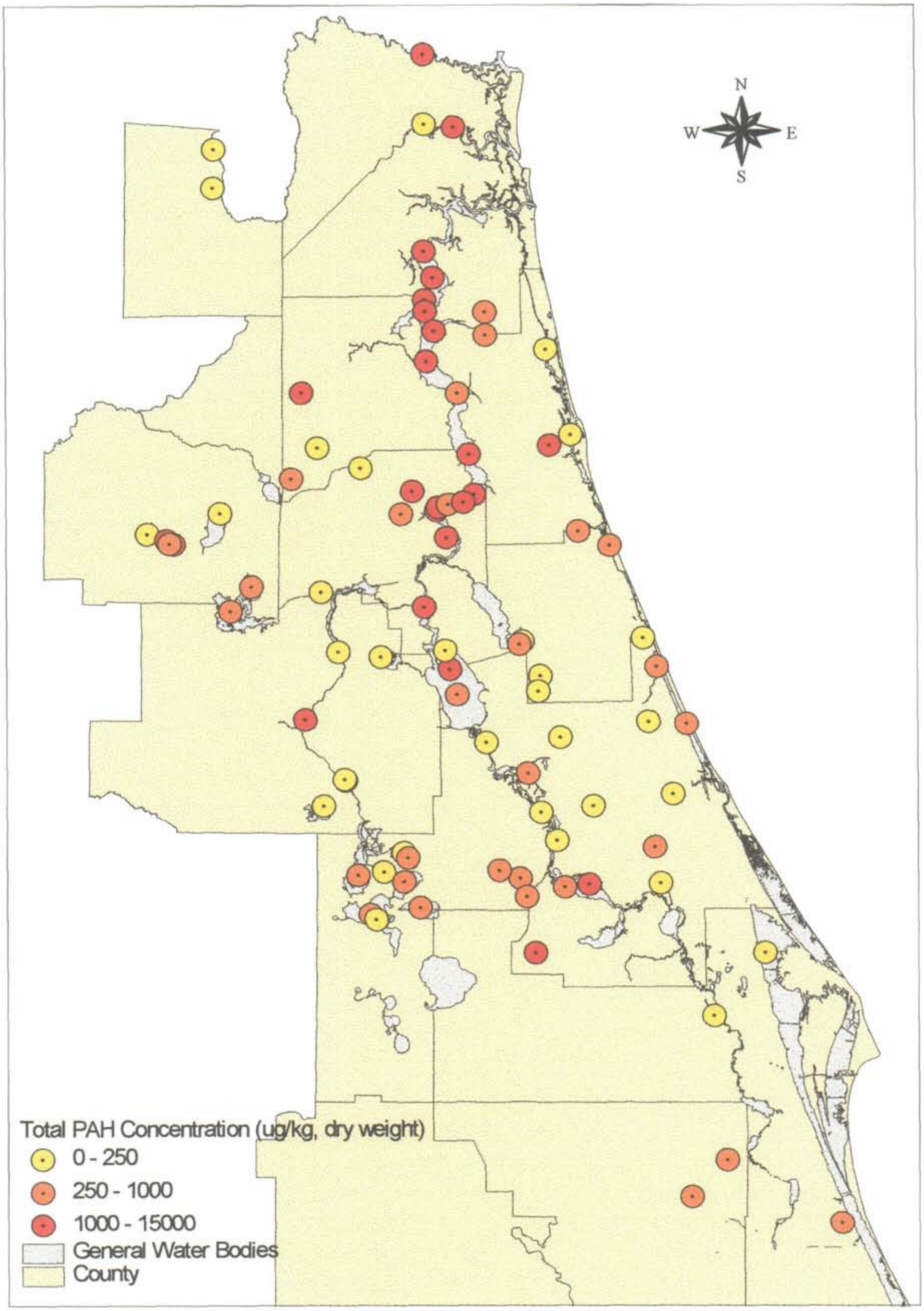


Figure 4-2. Map Displaying Total PAH Concentrations

The PAH concentrations measured in this study were generally within an expected range, and most urban sites had PAH concentrations comparable to or lower than concentrations measured for urban coastal sediments elsewhere in the U.S. Concentrations of total PAHs (sum of only 8 parent PAH compounds) in surficial sediments from western Lake Erie near the mouth of the River Raisin, Michigan, ranged from 530 to 3,750 µg/kg (Eadie, *et al.*, 1982). Concentrations of total PAH in surficial sediments from offshore lake Michigan range from 200 to 12,000 µg/kg (Helfrich and Armstrong, 1986; Zhang *et al.*, 1993). PAH concentrations in sediments tend to decrease with distance from the shore.

In 1990, total PAH concentrations of approximately 600 to 66,000 µg/kg were measured in Dorchester Bay sediment. Dorchester Bay is within Massachusetts Bay, and about 5-7 miles south of central Boston. In 1994 the same Dorchester Bay stations were resampled, and sediment was also collected at several other Boston Harbor locations (Battelle, 1995). This time the total PAH concentrations in the surface sediment ranged from 500 to 128,000 µg/kg, and for 12 of the 14 stations the concentrations were between 700 and 40,000 µg/kg. The highest sediment PAH concentrations were measured near combined sewer overflow (CSO) discharge locations in both the 1990 and 1994 studies. Concentrations of total PAH in sediments from Boston Harbor, Massachusetts, ranged from 48 to 718,000 µg/kg in a mid 1980s sediment profile (Shiaris and Jambard-Sweet, 1986).

A total of 60 sites were sampled in a 1990 survey of sediment contamination of Long Island Sound (Battelle, 1991a). The samples were mostly collected away from urban locations, and total PAH concentrations ranged from about 700 to 22,000 µg/kg, and averaged about 6,000 µg/kg. At remote reference locations in Long Island Sound the total PAH concentrations ranged from 2,200 to 2,600 µg/kg.

A large number of surface sediment and sediment core samples were collected at various locations in lower Narragansett Bay in 1993 (Battelle, 1994). The total PAH in the surface sediment ranged from below 1,000 µg/kg at the reference locations to approximately 30,000 µg/kg for locations with no identified impact from PAH point source contamination; 58,000 µg/kg was measured at a location near a known source of PAH input. Surface sediment total PAH concentrations ranging from 1,700 to 40,700 µg/kg were recently measured at 18 sites throughout Presque Isle Bay, in Erie, Pennsylvania (Battelle, 1997).

PAH concentrations in sediment cores tend to increase with depth to a maxima at depths corresponding to the 1960s to 1970s, and then decrease as the sediment represents earlier deposition. It is widely accepted that the dramatic increase in PAH fluxes observed in sediment in the North American aquatic environment from the early to mid 1900's is a direct result of the acceleration of industrial activities and other increases in the use of fossil fuels. Several studies have shown that anthropogenic inputs of PAH in urban areas of North America generally peaked some time between 1950 and 1980 (Gustafsson *et al.*, 1997; Simcik *et al.*, 1996; Furlong, *et al.*, 1987), although there are clearly regional differences. In a detailed study of the characteristics of PAH deposition in Lake Michigan sediment, cores were collected from the northern part of the lake to the south (Simcik *et al.*, 1996). The data showed that the accumulation of PAH increased sharply starting around 1900, reached a maximum and a plateau between 1940 and 1970, and has since begun a gradual decline. However, the decline in PAH input is not dramatic, and is still undetectable in many systems. In a similar study of sediment cores from the Upper Mystic Lake (a small lake near Boston, Massachusetts), inputs of pyrogenic PAH were determined to have peaked around 1960, leveled off, and began and slow decline around 1970 (Gustafsson *et al.*, 1997). The dramatic increase in PAH is generally attributed to the onset of coal combustion and later use of other fossil fuels, while a slight decline in recent years is thought to have resulted from a shift from coal to oil and gas use, and to implementation of various pollution control measures, particularly removal of particulate matter (soot) from stack gases.

The "high" concentration (geometric mean plus one standard deviation of National Status and Trends Program site means) of total PAH in sediments from U.S. National Status and Trends monitoring sites, including the Great lakes, is 2,180 µg/kg (Daskalakis and O'Connor, 1995) based on the same 24 PAH compounds that were measured in this study. "High" concentrations for low molecular weight PAH (2- and 3-ring PAH) and high molecular weight PAH (4- through 6-ring PAH) are set at 450 µg/kg and 1,730 µg/kg, respectively, reflecting the greater abundance and persistence of pyrogenic (from combustion products, mostly high molecular weight PAH) than petrogenic (from petroleum products, mostly lower molecular weight PAH) PAH. Approximately 23% of coastal sediments monitored in various U.S. monitoring programs, including some in the Great Lakes, contain concentrations of total low and high molecular weight PAH equal to or greater than the corresponding National Status and Trends "high" values. A total of 13 of the 86 SJRWMD sites (15% of the sites) sampled in this study had total PAH concentrations that exceeded the NOAA "high" concentrations, and most of these were only slightly above the NOAA value.

The phthalate data showed no clear relationship between concentrations and the aquatic system from which they were collected. Only eight sites had total phthalate concentrations in excess of 1,000 µg/kg, and all were below 2,000 µg/kg. The TOC-normalized data indicate that the sites with the highest phthalate concentrations generally had fairly high TOC content — MBU (Ocklawaha River at Moss Bluff) was the only site that appeared somewhat elevated compared to the rest of the sites after review of both sets of data. Similarly, the concentration of other chlorinated industrial compounds appeared to be moderate after analyzing the entire data set. There were some slightly elevated sites in the St. Johns River [e.g., RCLSJ19 (St. Johns River at Verdiere Pt.), LSJ05 (St. Johns River at NASJAX), LSJ08 (St. Johns River at Orange Pt.), LSJ11 (St. Johns River at Mandarin Pt.)] and at a few lake locations [sites OLK (Orange Lake) and LOL (Lochloosa Lake)]; only five sites had total other chlorinated compound concentrations that were greater than 50 µg/kg, and all were below 150 µg/kg.

The sum of the PCB congener concentrations were highest at the St. Johns River sites [e.g., LSJ01 (Lower St. Johns River at Ortega River), RCLSJ06 (St Johns River at Rice Creek), LSJ08 (St. Johns River at Orange Pt.), and LSJ11 (St. Johns River at Mandarin Pt.)] and a few lake sites [OR908 (Bivens Arm West), HAR and 20020377 (both in Lake Harris), 20020368 (Lake Eustis), 20020371 (Lake Yale), and 20020381 (Lake Griffin)], when considering both the non-normalized (Appendix F) and TOC-normalized data (Figures 4-3 and 4-4). The sum of the PCB congener concentrations was between 50 and 200 µg/kg for 16 of the 86 sites, and below 50 µg/kg for the rest of the sites. These data can be compared with sediment concentrations from 66 to 233 µg/kg for three Boston Harbor/Massachusetts Bay sites sampled in the NOAA Mussel Watch Program in the late 1980's, and a range of 9 to 80 µg/kg for five Massachusetts sites outside Massachusetts Bay (Battelle, 1990, 1991b, 1992). The congeners that were determined in this study, and in the NOAA Mussel Watch Program, typically constitute approximately 40-60% of the total PCB in most environmental samples, so a good estimate of the true total PCB can be obtained by multiplying the sum of the congeners by two.

The chlorinated pesticide concentrations have a somewhat different geographic distribution than the compounds discussed so far, which is consistent with their more focused use and distribution (Appendices F and K). The sum of the DDT class of compounds (DDT and its degradation products DDD and DDE) were measured at a concentration greater than 20 µg/kg at 9 of the 86 sites, and the concentration was just above 100 µg/kg at two sites. The sites that had somewhat elevated concentrations of the DDT compounds, as compared to the rest of the sites, include sites CLD (Lake Disston), DOR (Lake Dora), OR908 (Bivens Arm West), 20020368 (Lake Eustis), HAR (Lake Harris), LMAC (Lake Monroe), ASH (Lake Ashby), and some of the St. Johns River sites [e.g., LSJ01 (Lower St. Johns River at Ortega River) and LSJ28 (St. Johns River at CM 33)]; this is a combination of river, lake, and creek, and urban and rural sites.

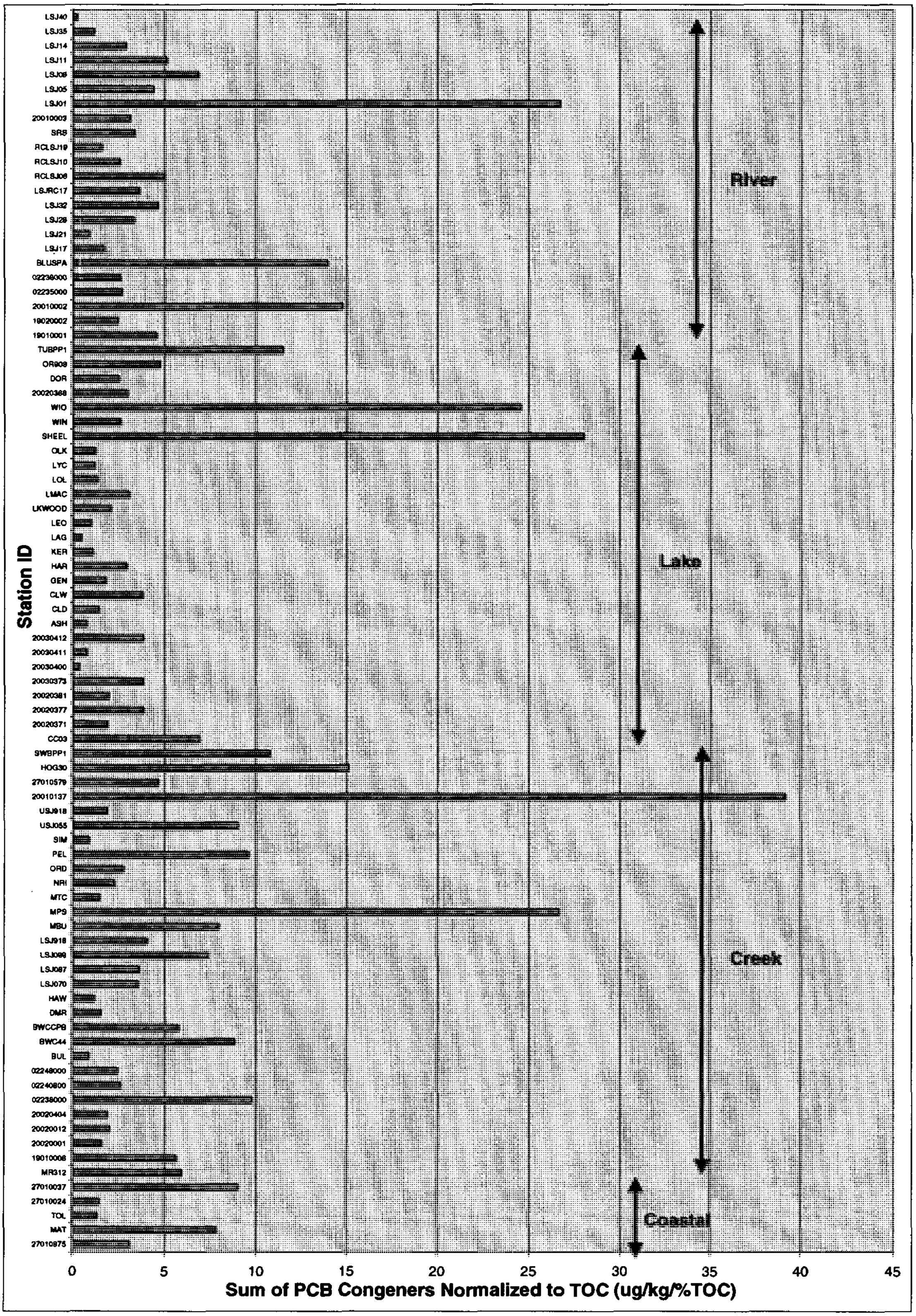


Figure 4-3. TOC Normalized Sum of PCB Congener Concentrations

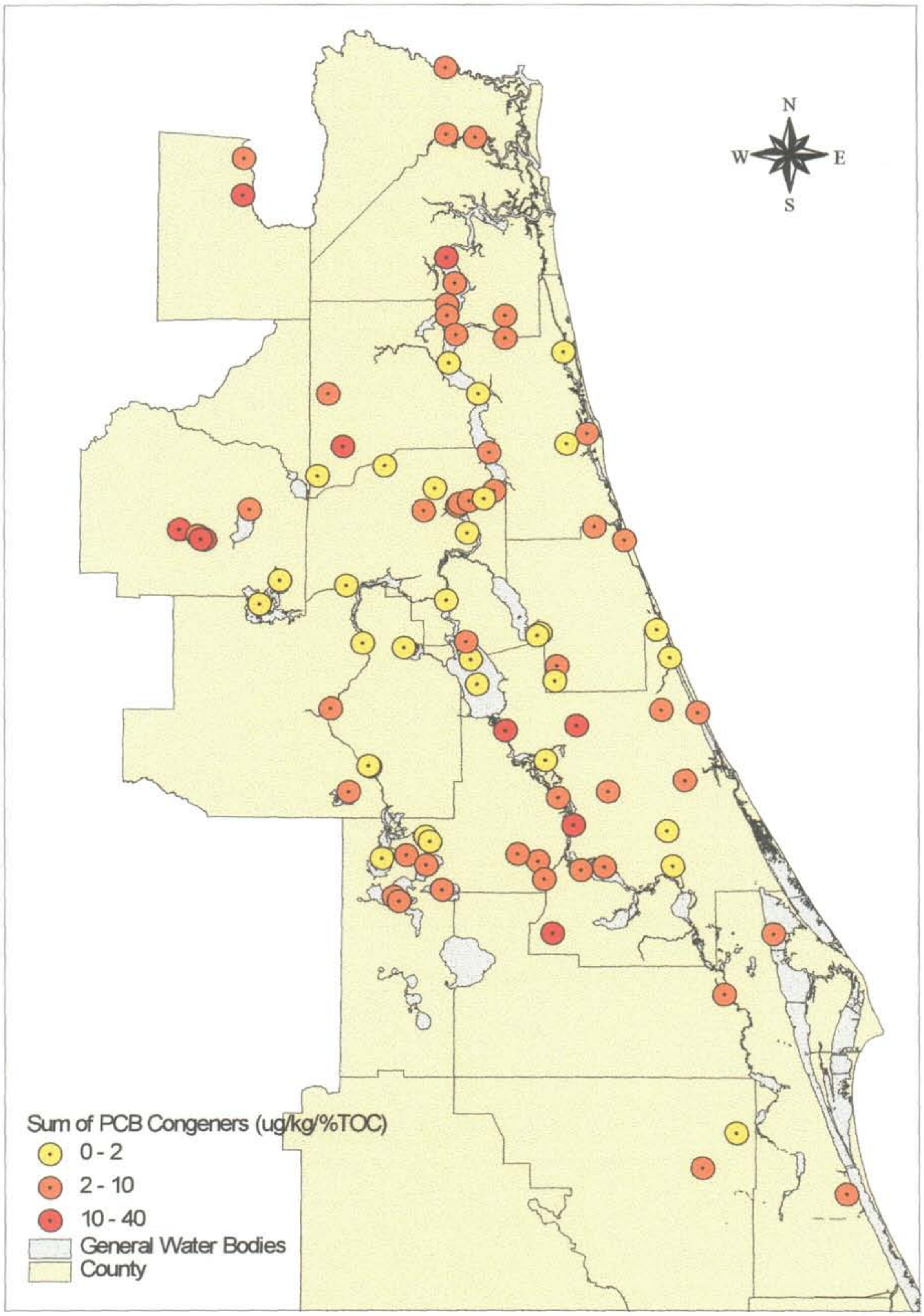


Figure 4-4. Map Displaying TOC Normalized Sum of PCB Congener Concentrations

A few sites with total DDT compound concentrations above 10 µg/kg had an uncommonly high proportion of DDT relative to DDE and DDD [HAW (Haw Creek at Dead Lake), LOL (Lochloosa Lake), BWCCPB (Blackwater Creek), LSJ01 (Lower St. Johns River at Ortega River), RCLSJ06 (St. Johns River at Rice Creek), and RCLSJ10 (St. Johns River near Rice Creek)]. DDE is the degradation product that typically constitutes most of the sum of the DDT compounds in the environment. The elevated relative amounts of DDT suggests that there may be recent DDT inputs to these areas, or that the DDT has not been degrading the way this compound usually does. The DDT compound concentrations measured in this study can be compared to 24 to 58 µg/kg for three NOAA Massachusetts sites located near urban areas and to 1 to 9 µg/kg for the more rural sites (Battelle, 1990, 1991b, 1992).

Chlordane concentrations were below 6 µg/kg in all samples, and between 2 and 6 µg/kg at 10 of the 86 sites. The pesticide chlordane was determined to be elevated at some of the sites that also had elevated DDT [CLD (Lake Disston), OR908 (Bivens Arm West) and some St. Johns River sites], but also elevated at some other sites [e.g., LEO (Lake George at M 4 & M 5), SWBPP1 (Sweetwater Branch at Paynes Prairie), CC03 (Crane Creek), MAT (Matanzas River at Washington Oaks), 19020002 (Nassau River at US 17), and 20010137 (Little Wekiva River)]. BHC concentrations were between 2 and 10 µg/kg in 10 of the samples, with the rest having concentrations below 2 µg/kg. The BHCs (which include the pesticide lindane) were elevated in a number of the St. Johns River sites [e.g., RCLSJ06 (St Johns River at Rice Creek), RCLSJ10 (St. Johns River near Rice Creek)] and LEO (Lake George at M 4 & M 5), but also at LMAC (Lake Monroe) and KER (Lake Kerr) and, to a lesser degree, at some other lake and creek sites [e.g., 20030411 (Crescent Lake), SWBPP1 (Sweetwater Branch at Paynes Prairie), and ORD (Ocklawaha River downstream of SR 40)]. However, the chlordane and BHC concentrations were generally quite low and fairly uniform (particularly the BHC concentrations), and there was no chlordane or BHC detected at nearly half the sites.

Potential Hot Spots

When discussing potential hot spots, this particular study can be used as the primary frame of reference, or one can include data from other comparable locations throughout the country. Because there are limited data from other studies and locations that can be considered truly comparable, this section will focus on data generated in this study. The reader should be aware that significantly elevated concentrations relative to other study sites do not necessarily indicate environmental concern — it could simply mean that most sites have relatively low contaminant concentrations. It should also be cautioned that this data set includes samples from a large number of different environments, with very different natural conditions, sediment characteristics, ecology, geology etc. These numerous and important differences between the sites clearly makes it impossible to quantitatively assess the significance of the relative contamination among sites — an assessment that is often possible to perform with data from sites that are within the same general environment.

The contaminant concentrations are clearly higher at many of the St. Johns River sites than at other sites in this study. Elevated PAH, PCB, chlorinated industrial compounds, DDT, and chlordane was measured in most of the sites in the northern parts of the St. Johns River, with LSJ01 (Lower St. Johns River at Ortega River) frequently having the highest concentrations. This suggests that many of these contaminants are coming from activities in and around Jacksonville. Elevated PCBs and other chlorinated compounds were also detected in other parts of the St. Johns River, such as the sites near Rice Creek [e.g., RCLSJ19 (St. Johns River at Verdiere Pt.), RCLSJ06 (St Johns River at Rice Creek), LSJRC17 (St. Johns River at CM 41), and LSJ32 (St. Johns River at CM 38)]. Other locations with elevated concentrations of several types of organic contaminants include site OR908 (Bivens Arm West) and SWBPP1 (Sweetwater Branch at Paynes Prairie), with elevated PAH, PCB, chlordane, and DDT. These sites are both located on the south side of Gainesville. Site MBU (Ocklawaha River at Moss Bluff) had elevated PAH and phthalates. Individual contaminants were elevated at different separate sites, as described earlier. For instance, several of the sites in the mid-Florida lakes (sites HAR and 20020377 in Lake Harris, site 20020368 in Lake Eustis, site 20020381 in Lake Griffin, and site 20020371 in Lake Yale) had notably elevated PCB. The DDT concentrations were higher at sites CLD (Lake Disston) and DOR (Lake Dora), also in the mid-Florida lakes region, than at other sites. Site LEO (Lake George at M 4 & 5) had high concentration of the pesticides chlordane and BHC (which includes lindane), and also relatively high DDT concentrations.

Contaminant Composition

The relative composition of the different PAH compounds varied some from site-to-site, but the dominant PAH at most locations were the four- and five-ring PAH. These PAH are mostly associated with pyrogenic sources, although lower molecular weight PAH, with likely petrogenic origin, are present at lower concentrations. The pyrogenic PAH (high molecular weight PAH) constitute between 60 and 80% of the total PAH at most locations (Figure 4-5). The relatively consistent proportion of petrogenic to pyrogenic PAH in the surface sediment indicate a similarity in the sources, or types of sources, of the PAH contamination. Figure 4-6 shows the PAH composition of selected samples. The PAH composition of selected reference samples and petroleum products are compiled in Appendix G.

Most samples had a PAH composition similar to those of OR908 (Bivens Arm West) and MBU (Ocklawaha River at Moss Bluff), which are comparable to the PAH composition in the NIST SRM 1941 sediment and soot (Appendix G). The SRM sediment is a reference material that was collected in an east coast estuarine environment and is considered to be a good representation of typical background PAH derived primarily from pyrogenic sources. Sample 19020002 (Nassau River at US 17) is presented as an example of one of the few samples that had PAH of mostly petrogenic composition. ORD (Ocklawaha River downstream of SR 40) has a highly unusual PAH composition with acenaphthene and fluorene constituting approximately 90% of the total PAH — this sample does not have a common petrogenic or pyrogenic PAH composition.

The high molecular weight PAH distribution in most sediment samples is characteristic of PAH inputs primarily from combustion sources, or hydrocarbon materials containing a mixture of high molecular weight of pyrogenic and petrogenic PAHs (e.g., coal and coke tar, coal gasification tars, carbon black, creosote, and, to some degree, asphalt). Low concentrations of petrogenic PAH (e.g., alkylated naphthalenes, phenanthrenes) are also present in many of the samples, suggesting some contribution from weathered petroleum products.

The concentrations of DDT and its degradation products DDD and DDE are listed in Table 3-6, along with the total concentration of these DDT compounds. Various environmental conditions (primarily oxygen supply) dictate the rate of DDT degradation, and the relative amounts of DDD and DDE that are formed. Figure 4-7 shows the relative concentrations of DDT, DDD, and DDE at selected sites. The concentration of DDE was higher than both the DDD and DDT concentrations in most samples, just as it is in most sediments around the US, as determined in the NOAA Mussel Watch Project (Battelle, 1990, 1991b, 1992). However, as discussed above, some sites had proportionately higher concentrations of DDT than what is most commonly found in sediments, suggesting more recent inputs of DDT and/or slower DDT degradation.

Indicators of Potential Effects

One useful way to evaluate concentrations of contaminants in sediments is to compare the concentrations to effects-based sediment quality guideline values. Effects range-low (ER-L) and effects range-medium (ER-M) values are the most commonly used and referenced sediment quality guidelines. ER-L and ER-M values were initially developed by scientists at NOAA (Long *et. al.*, 1991), and were later revised after compiling additional data (Long *et. al.*, 1995). These are scientifically derived values of potential for biological effects due to sediment-sorbed contaminants.

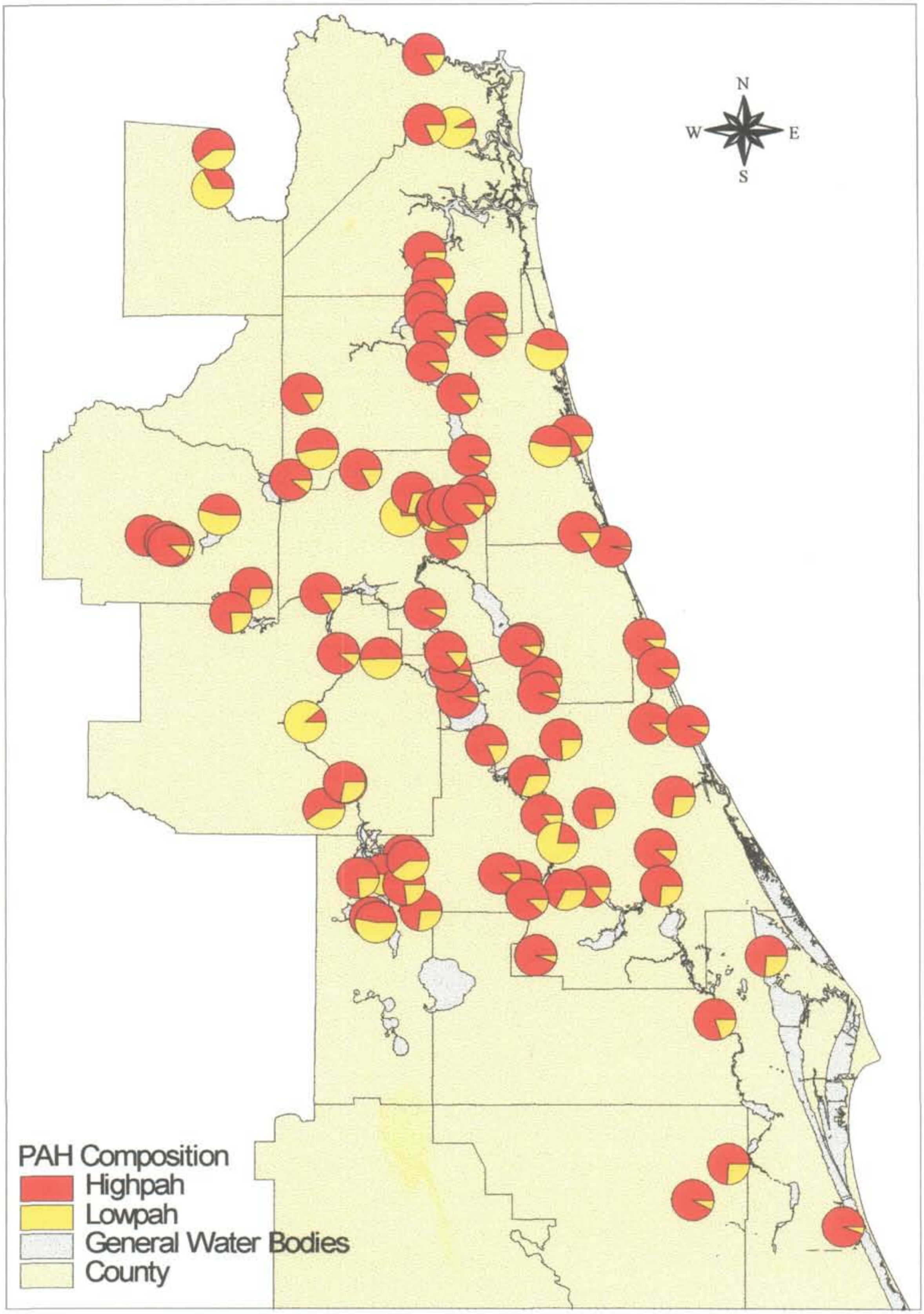
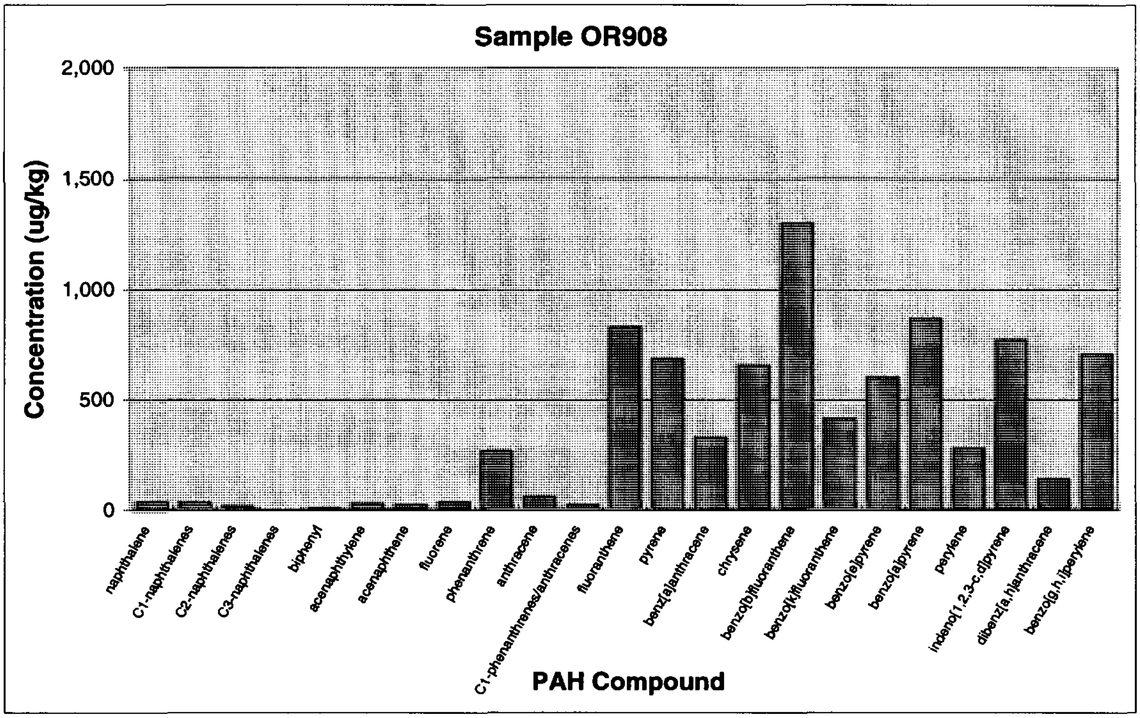


Figure 4-5. Map Displaying Relative Composition of High- and Low-Molecular Weight PAH



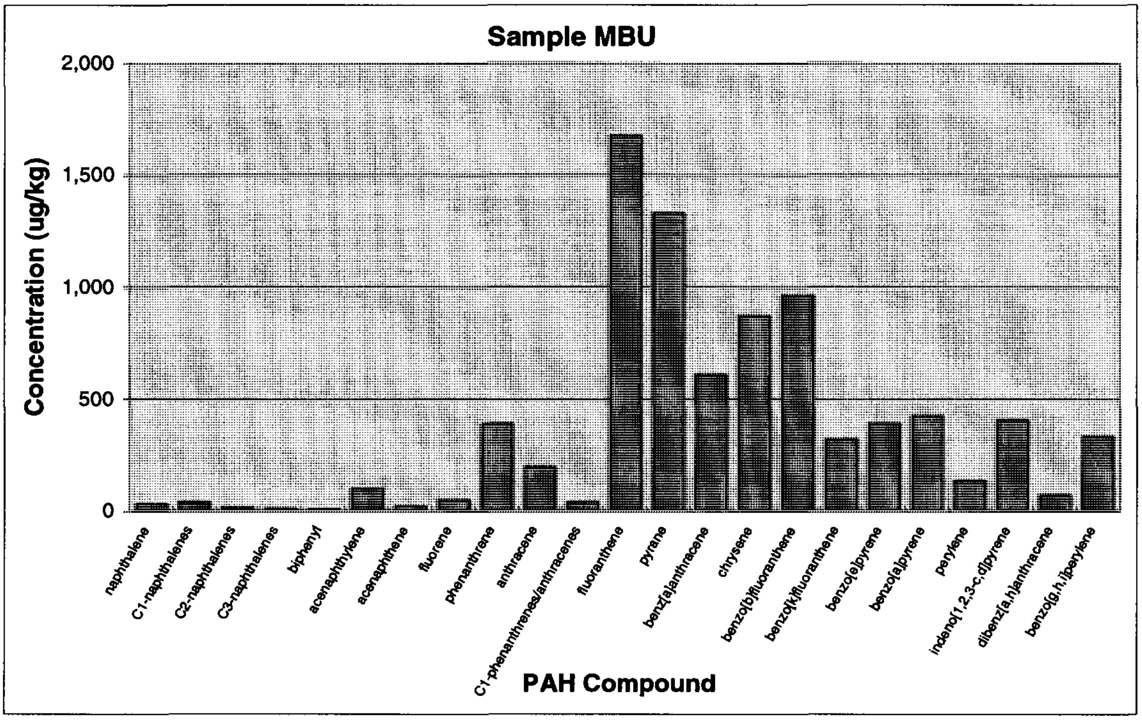
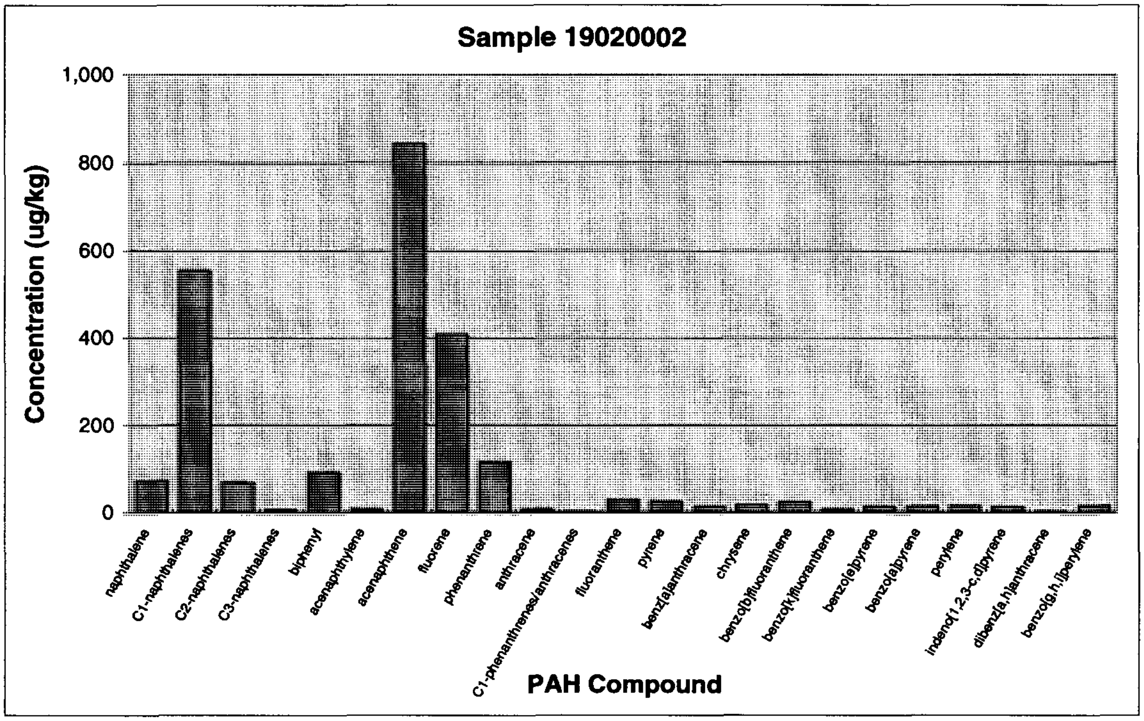


Figure 4-6. PAH Composition of Selected Samples



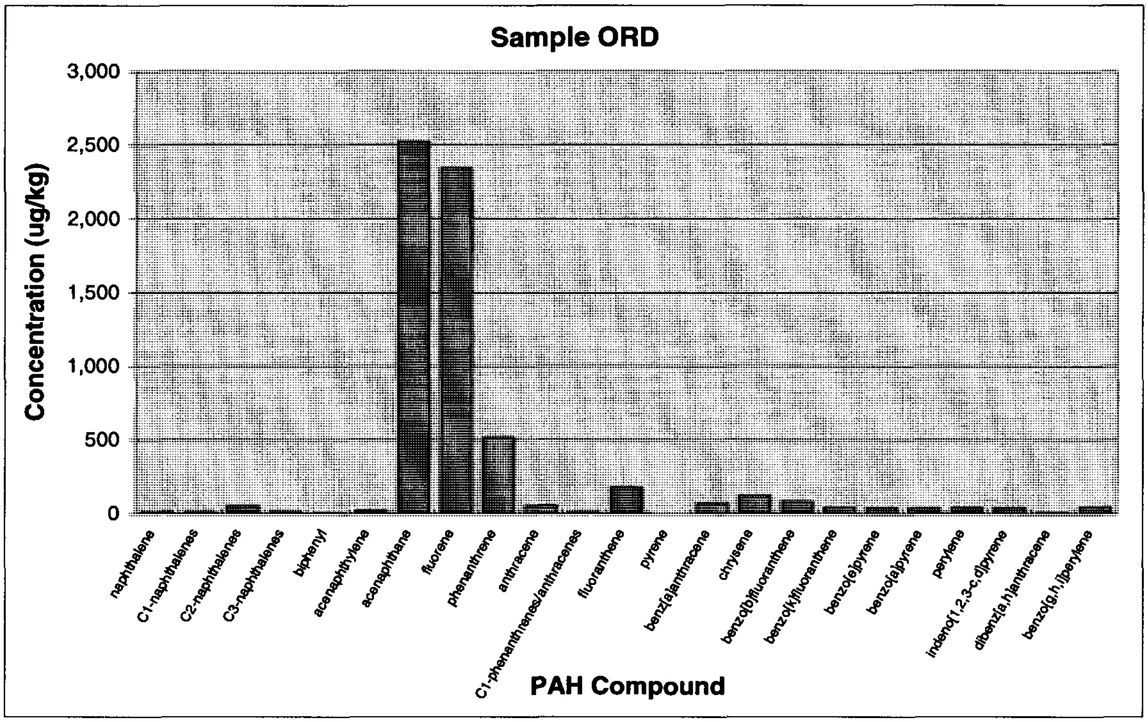


Figure 4-6 (continued). PAH Composition of Selected Samples

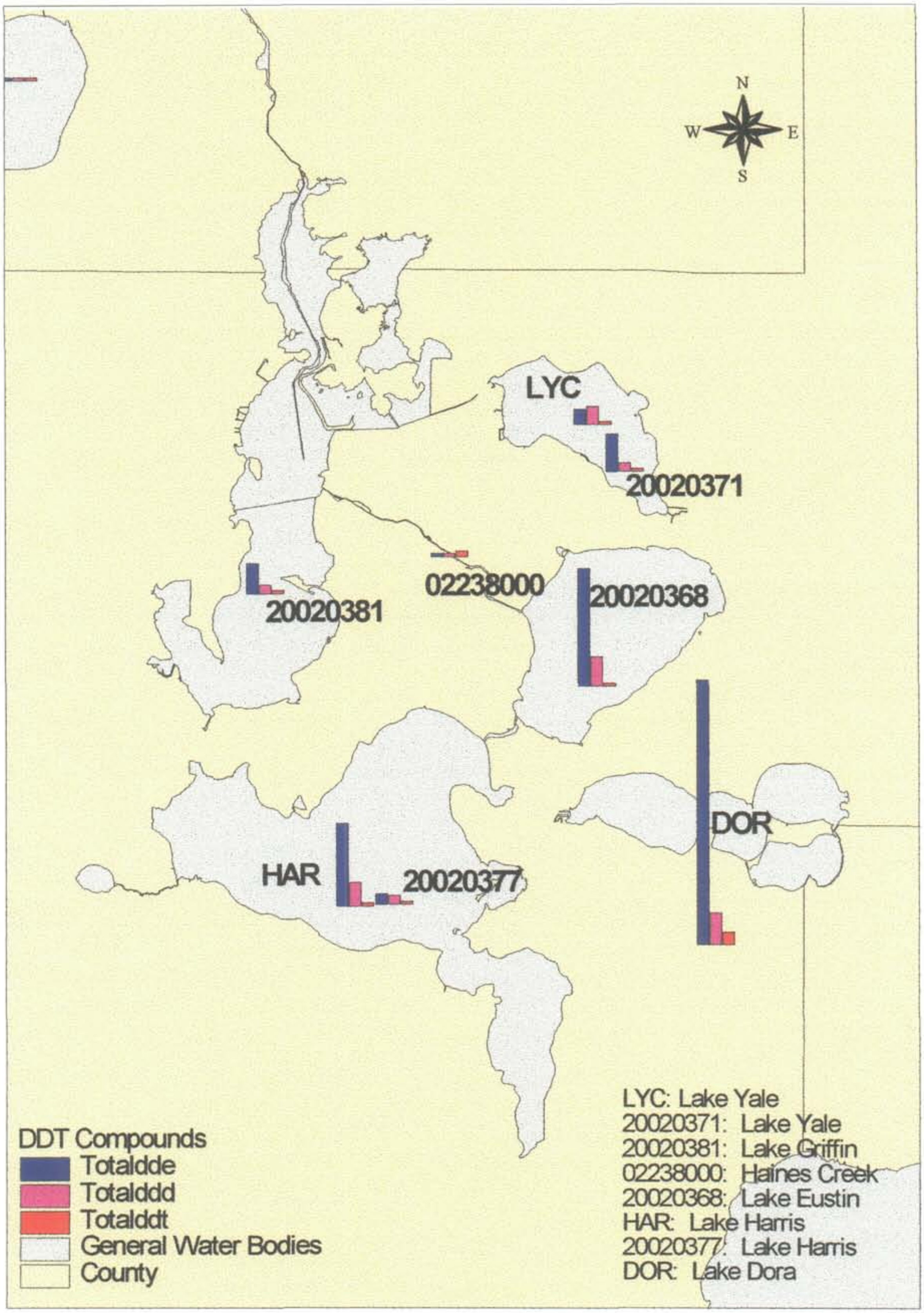


Figure 4-7. Map Displaying Relative Composition of DDT and its Key Degradation Products

The degree of confidence in the accuracy and representativeness of the ER-L and ER-M values is highly variable. There is, for instance, typically more confidence in the PAH guidance values than in those for PCB or most toxic metals. These reference values are screening tools that were developed to evaluate the potential for biological impact. However, although these values were not intended as sediment quality criteria, and should not be used as such, they can be useful as a semiquantitative point of reference for reviewing sediment data.

The ER-L and ER-M guideline values delineate three concentration ranges for a particular chemical (Long *et. al.*, 1995). The concentration below the ER-L value represents a minimal-effect range; a range representing conditions in which effects would rarely be observed. Concentrations between the ER-L and ER-M represent a possible-effects range within which effects would occasionally occur, and the concentrations above the ER-M value represent a probable-effects range where effects would be expected to frequently occur.

Guidelines similar to the more widely accepted and used ER-L and ER-M values have also been published specifically for sediments in Florida systems. MacDonald *et al.* (1996) published threshold effects levels (TEL) and probable effect levels (PEL) for Florida coastal water sediments using a weight-of-evidence approach. The TELs and PELs were determined similarly to the ER-Ls and ER-Ms. The three ranges of contaminant concentrations represent sediment levels that rarely, occasionally, and frequently are associated with adverse biological effects, but the TEL/PEL values are typically lower than the ER-L/ER-M values because the testing regime used in their development to generate actual sediment quality guidelines. An additional set of sediment quality guidelines have been developed for the freshwater systems in the province of Ontario (Persaud *et al.*, 1993); it uses lowest effects levels (LELs), which indicate a level of contamination which has an effect on less than 5% of the sediment-dwelling organisms studied. LEL values are generally comparable to ER-Ls.

Sediment ER-L, ER-M, TEL, PEL, and LEL values are summarized in Table 4-1. The ER-L/ER-M and TEL/PEL values were developed for coastal sediments, and it is unclear how they translate to fresh water systems. The LELs are intended for freshwater systems in Ontario and compare well with the ER-Ls, suggesting there is little impact due to differences between coastal and freshwater sediments. For several of the contaminants there is probably little reason to suspect differences in bioavailability based strictly on whether the sediment is from a fresh or salt water system, while for other contaminants, particularly for some of the toxic metals, it may play a more significant role. However, these sediment quality guidelines were developed base on data from toxicity testing with a wide range of testing scenarios and systems, and a significant degree of broad based general application was incorporated. Another note of caution in applying ER-L and ER-Ms is that it may be important to realize that these sediment quality guidelines do not satisfactorily account for multiple contaminants or any contaminant interactions that may affect the biota that are exposed to a complex suite of contaminants simultaneously.

Table 4-2 summarizes the number of sites that exceeded the sediment ER-L, ER-M, TEL, and PEL values for selected parameters listed in Table 4-1. Graphs with total PAH, total PCB, and sum of the DDT compound concentrations are presented in Figures 4-8, 4-9, and 4-10, respectively, along with the ER-L and ER-M reference values. Additional plots with ER-L/ER-M references are presented in Appendix J. The organic contaminant and data are not normalized to TOC content for the sediment quality guideline comparisons, because the sediment quality guidelines were developed using non-normalized data. Similarly, non-normalized data are used for the metals data evaluation against sediment quality guidelines, to be consistent with how those ER-L/ER-Ms were derived. However, it may be important to further study the natural organic matter of the sediments, and how this may control and/or affect the toxicity and bioavailability of contaminants, particularly when considering how high the organic content is of many of these sediments.

Table 4-1. Sediment ER-L, ER-M, TEL, PEL, and LEL Values

Contaminant	ER-L[a] (mg/kg for metals and µg/kg for organics)	ER-M[b] (mg/kg for metals and µg/kg for organics)	TEL[c] (mg/kg for metals and µg/kg for organics)	PEL[d] (mg/kg for metals and µg/kg for organics)	LEL[e] (mg/kg for metals and µg/kg for organics)
As	8.2	70	7.24	41.6	6
Cd	1.2	9.6	0.68	4.21	0.6
Cr	81	370	52.3	160	26
Cu	34	270	18.7	108	16
Pb	46.7	218	30.2	112	31
Hg	0.15	0.71	0.13	0.7	0.2
Ni	20.9	51.6	15.9	42.8	16
Ag	1	3.70	0.73	1.77	NA
Zn	150	410	124	271	120
Total PCB	22.7	180	21.6	189	70
Total DDT	1.58	46.1	3.89	51.7	7
p,p'-DDE	2.2	27	2.07	374	5
Lindane	NA[f]	NA	0.32	0.99	3
Chlordane	NA	NA	2.26	4.79	7
Low PAH	552	3,160	312	1,442	NA
High PAH	1,700	9,600	655	6,676	NA
Total PAH	4,022	44,792	1,684	16,770	4,000
Acenaphthene	16	500	6.71	88.9	NA
Acenaphthylene	44	640	5.87	128	NA
Anthracene	85.3	1100	46.9	245	220
Fluorene	19	540	21.2	144	190
Naphthalene	160	2,100	34.6	391	NA
2-Methylnaphthalene	70	670	20.2	201	NA
Phenanthrene	240	1,500	86.7	544	560
Benz(a)anthracene	261	1,600	74.8	693	320
Benzo(a)pyrene	430	1,600	88.8	763	370
Chrysene	384	2,800	108	846	340
Dibenzo(a,h)anthracene	63.4	260	6.22	135	60
Fluoranthene	600	5,100	113	1,494	750
Pyrene	665	2,600	153	1,398	490

[a] ER-L: Exceeds Effects Range Low (Long *et al.*, 1995)
[b] ER-M: Exceeds Effects Range Level Median (Long *et al.*, 1995)
[c] TEL: Threshold Effect Level (MacDonald *et al.*, 1996)
[d] PEL: Probable effect level (MacDonald *et al.*, 1996)
[e] LEL: Lowest effect level, (Persaud *et al.*, 1993)
[f] NA: not applicable. There is no ER-L, ER-M, or LEL for this parameter.

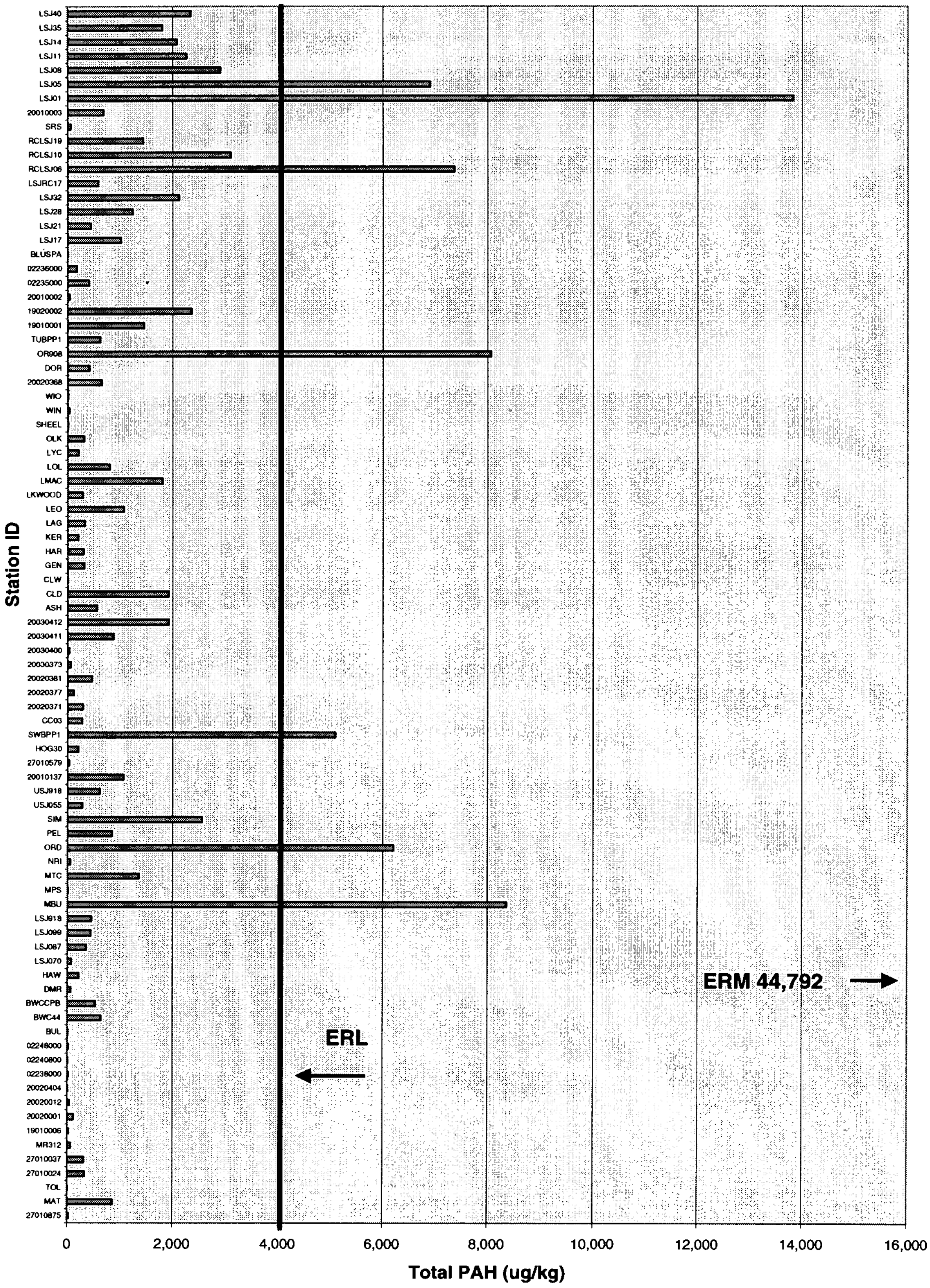


Figure 4-8. Total PAH Concentrations and ER-L/ER-M Values

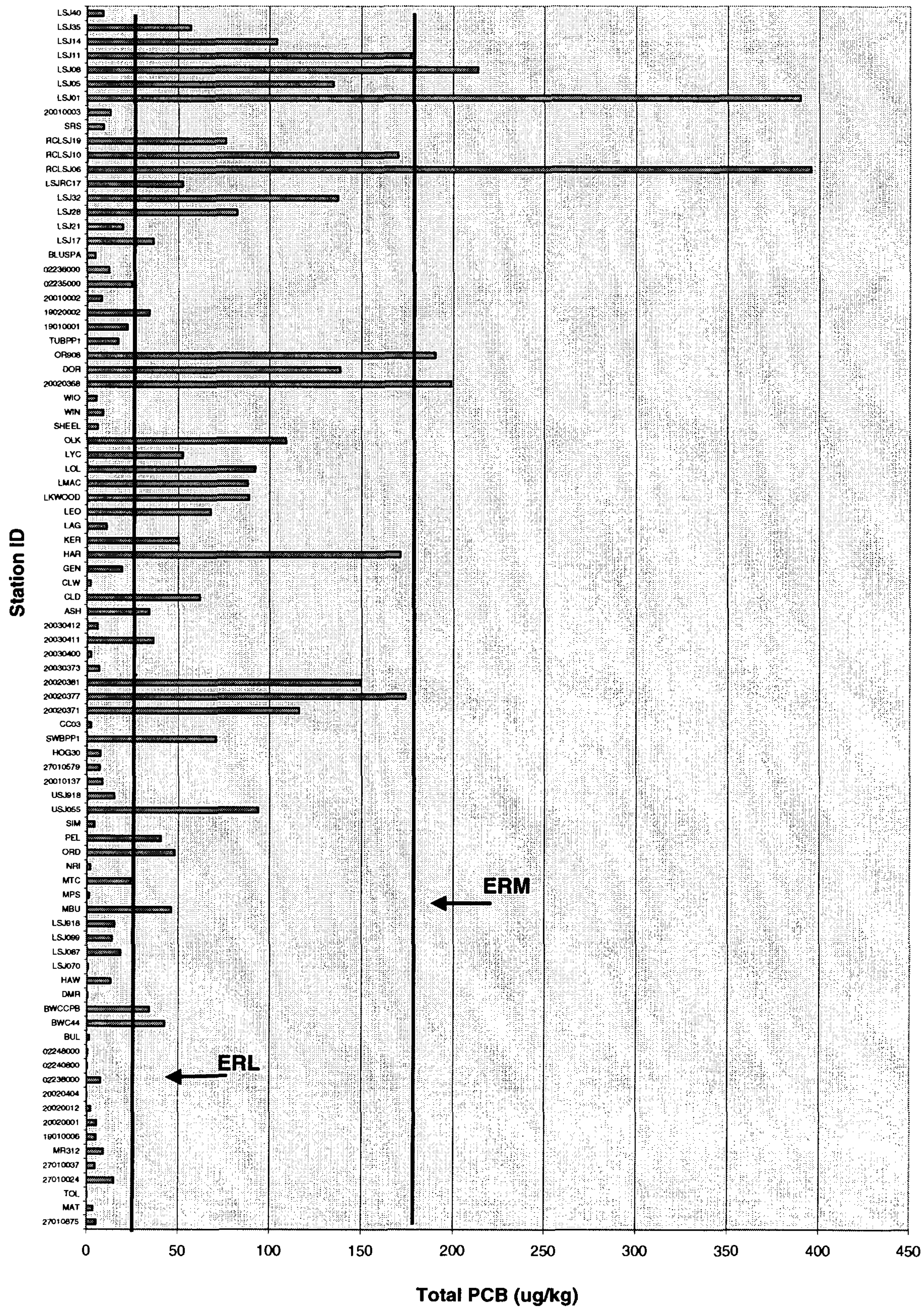


Figure 4-9. Total PCB Concentrations and ER-L/ER-M Values

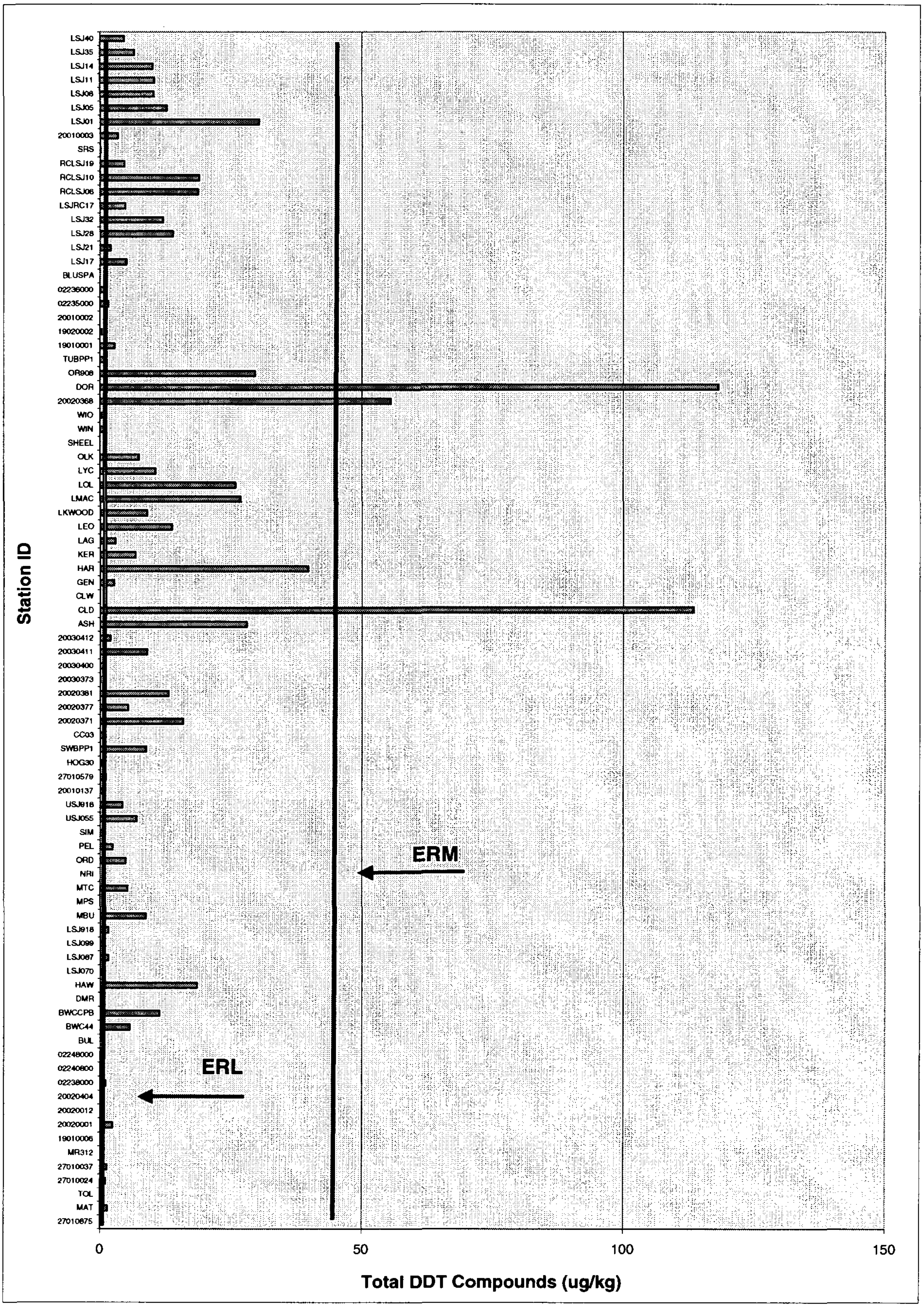


Figure 4-10. Sum of the DDT Compound Concentrations and ER-L/ER-M Values

Table 4-2. Number of Sites with Sediment ER-L, ER-M, TEL, and PEL Exceedances

Contaminant	Number of Exceedances [a]			
	ER-L	ER-M	TEL	PEL
As	4 (5%) [a]	0 (0%)	9 (10%)	0 (0%)
Cd	1 (1%)	0 (0%)	9 (10%)	0 (0%)
Cr	1 (1%)	0 (0%)	11 (13%)	0 (0%)
Cu	3 (3%)	0 (0%)	11 (13%)	0 (0%)
Pb	6 (7%)	2 (2%)	22 (26%)	2 (2%)
Hg	28 (33%)	0 (0%)	33 (38%)	0 (0%)
Ni	2 (2%)	0 (0%)	10 (12%)	0 (0%)
Ag	0 (0%)	0 (0%)	1 (1%)	0 (0%)
Zn	5 (6%)	0 (0%)	5 (6%)	0 (0%)
Total PCB	40 (47%)	5 (6%)	41 (48%)	5 (6%)
Total DDT	49 (57%)	3 (3%)	40 (47%)	3 (3%)
Lindane	NA [b]	NA	26 (30%)	19 (22%)
Chlordane	NA	NA	8 (9%)	2 (2%)
Low PAH	9 (10%)	2 (2%)	14 (16%)	4 (5%)
High PAH	14 (16%)	1 (1%)	27 (31%)	3 (3%)
Total PAH	7 (8%)	0 (0%)	19 (22%)	0 (0%)

[a] The percentage of all 86 sites that exceeded the guidance value is listed in parenthesis.

[b] NA: Not applicable. There are no ER-L or ER-M values for these parameters.

The total PAH concentration exceeded the ER-L value for seven sites; three sites in the Lower St. Johns River (sites LSJ01, LSJ05, and RCLSJ06), two sites near Gainesville (sites OR908 and SWBPP1), and two sites in the Ocklawaha River (sites MBU and ORD). No sites had PAH concentrations that came close to the ER-M value. The high molecular weight PAH concentration exceeded the ER-L for 14 of the 86 sites, and there were one ER-M exceedance (LSJ01; Lower St. Johns River at Ortega River). Nine of the sites exceeded the low molecular weight PAH ER-L and two exceeded the ER-M (sites LSJ01 and ORD). Note that the PAH compounds used to compute the low- and high-molecular weight PAH ER-L/ER-M values (Long *et. al.*, 1995) are slightly different from what is most commonly used for similar summations, and from what is used in this report (see Table 3-1), but the differences are small and have no impact on the overall conclusions.

The total PCB ER-L was exceeded for 40 of the 86 sites, and there were five PCB ER-M exceedances; two in the Lower St. Johns River (sites LSJ01, LSJR08, RCLSJ06), one near Gainesville (site OR908), and one in Lake Eustis (site 20020368). The total PCB was determined by multiplying the sum of the PCB congeners by two, because, as discussed earlier, the congeners determined in this study typically constitute 40-60% of the total PCB in most sediment.

The ER-L for total DDT was exceeded for a number of samples (at 49 of the 86 sites), but there were only three ER-M exceedances. The sites with ER-M exceedances, were CLD (Lake Disston), DOR (Lake Dora), and 20020368 (Lake Eustis). Site LSJ01 (Lower St. Johns River at Ortega River), HAR (Lake Harris), and OR908 (Bivens Arm West) also had significant concentrations of the DDT compounds, on both a TOC-normalized and non-normalized basis (as is used for sediment quality guideline comparisons).

4.2 Metal Contaminant Levels

Distribution and Urbanization Impacts. There was a broad range in the metal concentrations of the SJRWMD sediments, and the levels were also spatially variable. An example of this range and variability was seen in the aluminum concentrations (Figure 4-11). Aluminum is a major metal primarily associated with mineral components of sediments. It is frequently used to normalize variability in metals concentrations that arise from differences in the grain size composition and geology of sediments. Through normalization, naturally occurring metal concentrations can often be separated from those resulting from anthropogenic activities. Bar charts depicting the non-normalized and aluminum-, grain size-, and TOC-normalized metals concentrations for all sites are compiled in Appendix H.

Aluminum concentrations in the sediments ranged from a low of 239 mg/kg to a high of 48,400 mg/kg, or a 200-fold difference between the lowest and highest concentrations. The range is typical of systems that have highly variable grain size distributions as found in this set of samples. Comparison of the aluminum concentrations to the fraction of fine-grained sediments (mud) in these sediments showed a general correspondence (Figure 4-12). The fraction of mud in these samples ranges from less than 1% to 80%. Because grain size is a major factor controlling metals distribution (along with geology, organic carbon, and proximity to sources), the interrelationships between the metals and grain size, as well as TOC, were explored.

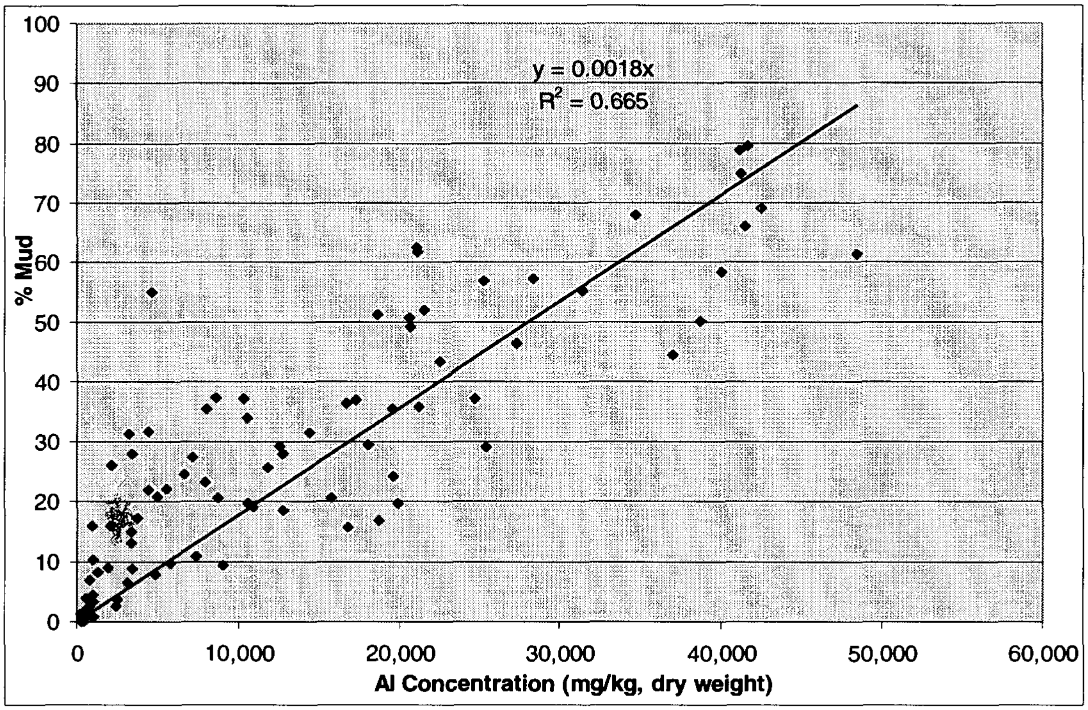


Figure 4-12. %Mud versus Aluminum Concentration

As observed in the aluminum distribution, the other major metals associated with crustal materials (minerals) also displayed a large range in concentration. Iron concentrations ranged from 111 to 29,400 ppm, manganese from 2.7 to 425 ppm, and lithium from 1.3 to 50 ppm. There was a 263-, 157-, and 38-fold difference between the maximum and minimum concentrations of each of these elements, respectively. Of these major metals, lithium showed the lowest relative range within the sediments.

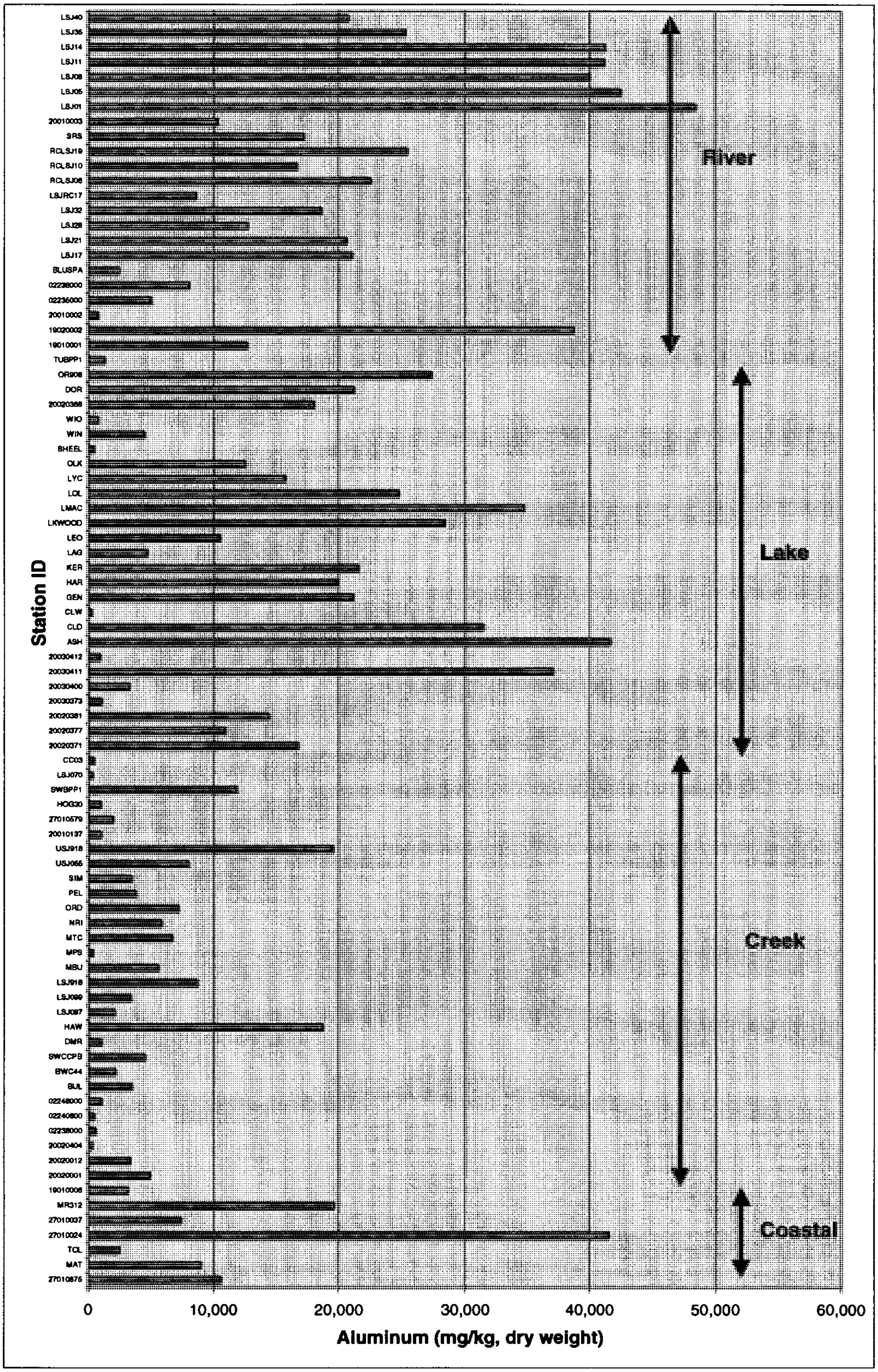


Figure 4-11. Aluminum Concentrations

Interrelationships among these elements were generally weaker because of the variability in the ranges and may only be diagnostic of different sediment types under sophisticated statistical analysis. Aluminum was found to be the most suitable major metal normalizer.

During the initial data analysis process, the metal concentrations were plotted versus the sediment aluminum concentration, the grain size, and the TOC, in order to determine which normalizing parameter was most suitable for this sample set. Examples of these plots are presented in Figures 4-13, 4-14, and 4-15, and a complete set of the plots is compiled in Appendix H. Normalizing metals concentrations to aluminum is the most common approach for differentiating anthropogenic contamination from metals naturally occurring in the geology of the sediment. Normalizing to grain size (using the fine fraction, such as %mud) is also frequently done to determine anthropogenic contamination, because many metals adhere/associate with to the fine particulates of the sediment, which would add a concentration effect similar to what is often observed with TOC and organic contaminants. Similarly, it has also been demonstrated that some metals bind to organic matter of the sediment, and TOC normalizing the metals data may therefore also be appropriate.

However, because of the very different sources of sediments in this study, the standard normalizing procedures were not as useful as in many other studies. For instance, aluminum normalization is a powerful method when the sediments originate in the same or very similar geological formations, where the natural variability in metal concentrations track well with the variability in the aluminum (which is generally related to grain size) — if the base sediment geology is similar, the relative concentration of a metal of interest and aluminum remains about the same, unless there are anthropogenic sources. It is then easy to detect outliers (i.e., contaminated sites) by simply comparing the aluminum normalized data, or reviewing X-Y plots of the metal of interest versus aluminum. Log transformation is sometimes used in these data analysis plots, which tends to "flatten out" the data, reducing outliers, but this did not improve the confidence in the analysis of this data set. Aluminum normalized metals data plots, and X-Y plots for metals versus aluminum, can be found for all metals in Appendix H.

Aluminum normalization was the most useful normalizing procedure for this sample set, providing better correlation to the other metal concentrations than both grain size and TOC normalizing (Figures 4-13, 4-14, and 4-15). Additionally, these relationships combined with the aluminum to grain size relationship (Figure 4-12) suggested that aluminum may be an acceptable normalizing parameter for this data set. The correspondence between metals concentrations and grain size (Figure 4-14) and TOC concentrations (Figure 4-15) was generally weak. Mercury was one metal that did appear to exhibit some correspondence to the TOC level of the sediment. The other metals tended to display substantial variability in the correspondence to both grain size and TOC concentrations in sediments. However, even the aluminum normalizing should be used with caution with this data set, and both non- and aluminum-normalized data (and grain size and TOC) should be reviewed together to best understand the situation. The potential sources and environments in which these samples were collected were too diverse to effectively apply the standard normalization tools.

As shown below in Table 4-3, the trace metals concentrations were also quite variable in the system. Differences between high and low values ranged from 16 fold for cadmium to as large as 520 fold for lead. Variability in the relative difference between the high and low values can be related to many factors including the proximity to sources, subtle differences in the factors controlling concentrations (e.g., TOC, grain size), and the redox state of the sediments.

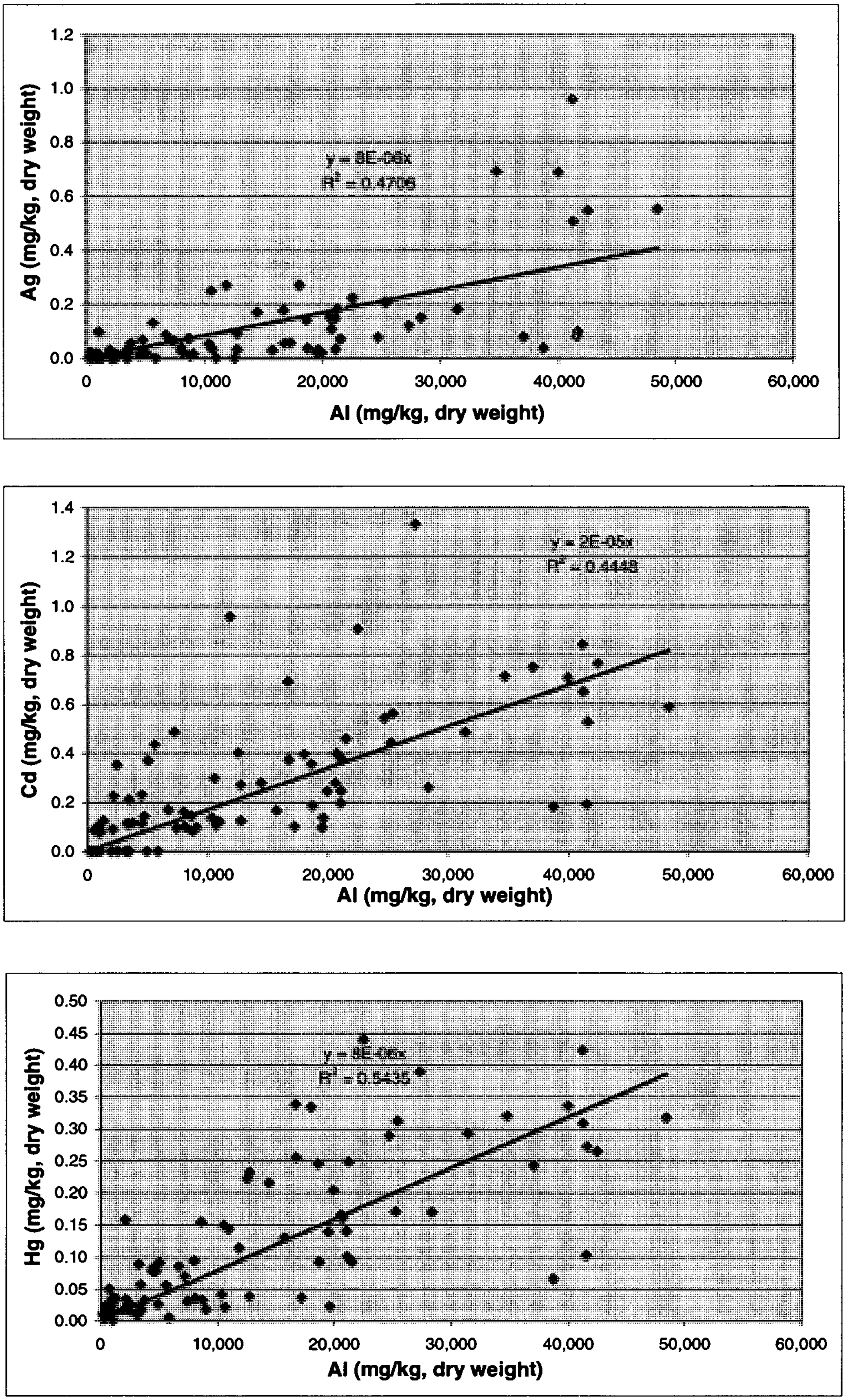


Figure 4-13. Silver, Cadmium, and Mercury versus Aluminum Concentration of Sediments

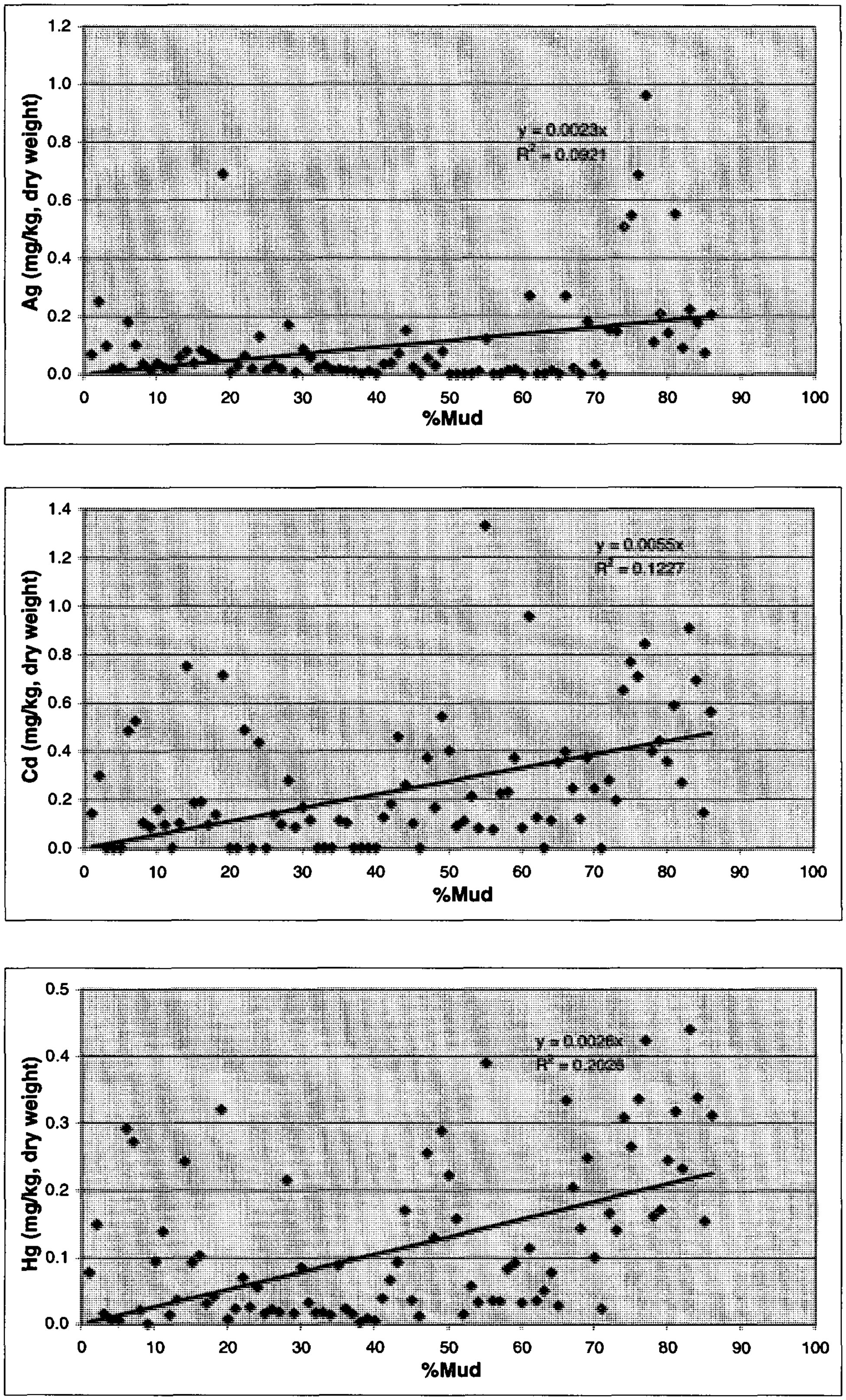


Figure 4-14. Silver, Cadmium, and Mercury Concentrations versus Grain Size of Sediments

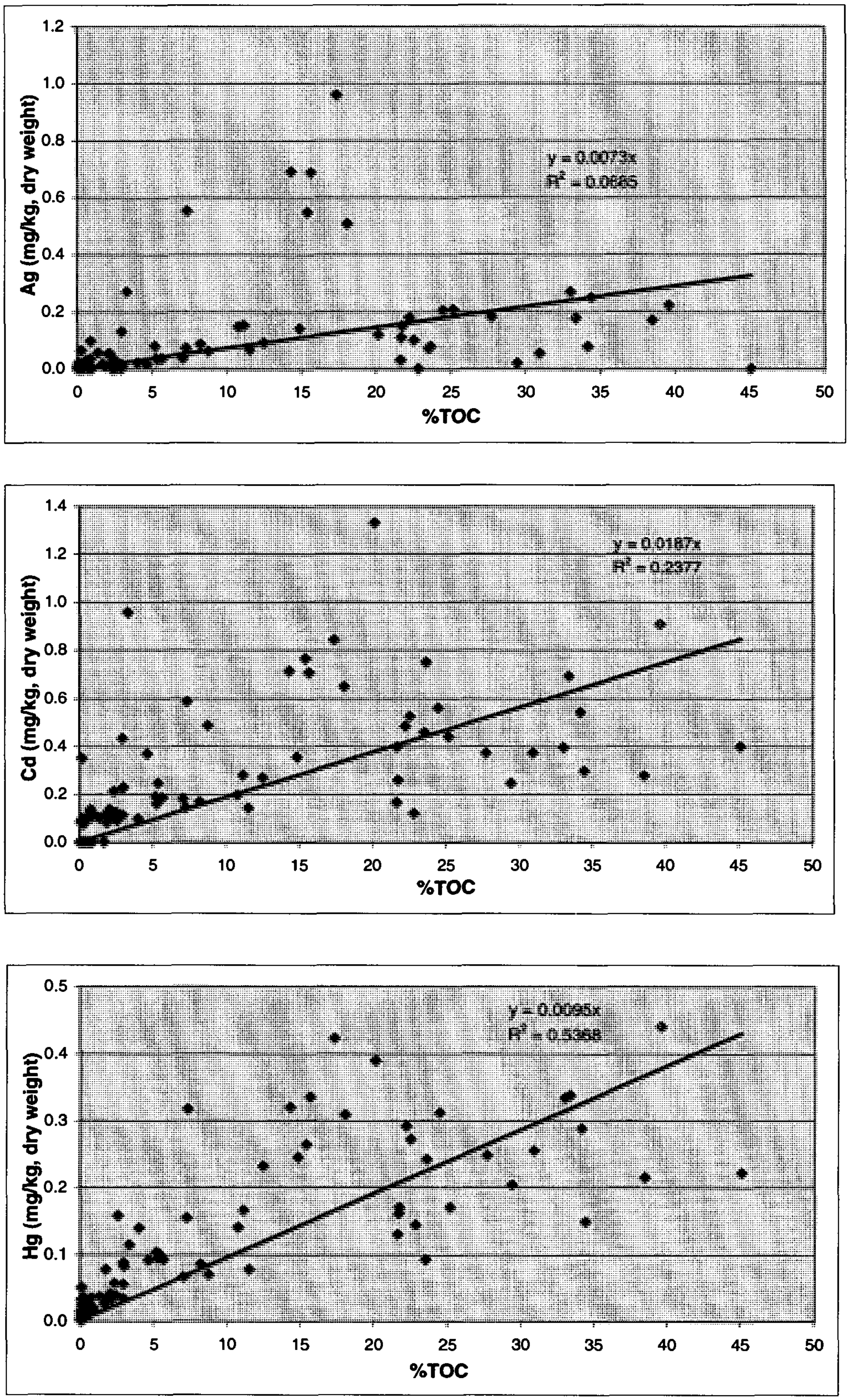


Figure 4-15. Silver, Cadmium, and Mercury Concentrations versus TOC Content of Sediments

Table 4-3. Concentration Range of Metals and Relative Difference

Metal	Minimum ppm [a]	Maximum ppm	Relative Difference Factor
As	0.036	15.2	422
Cd	0.080	1.3	16
Cr	0.51	139	273
Cu	0.26	60	230
Pb	0.66	343	520
Hg	0.0022	0.44	200
Ni	0.12	29.8	248
Se	0.11	5.51	50
Ag	0.006	0.96	160
Sn	0.067	8.35	125
Zn	0.90	361	400

[a] Minimum *detected* concentration. As, Cd, Hg, Se, and Ag were not detected in all samples.

Geographically, and generally speaking, samples with low toxic metals concentrations tended to be associated with creeks, which are generally sandier in nature (Figure 4-16), rather than the other water body types (rivers, lakes, and coastal areas). The sediments from the rivers and lakes tended to be muddier than from the creeks and coastal areas, although sediments from all locations were found to have a significant but variable fraction of sand. One caveat in these data and the apparent grain size distributions is the fact that many of the samples, especially those from the lakes and rivers, were very rich in organic matter (Figure 4-17) and included undegraded vegetative material that contributed to the coarse fraction in the grain size distribution. Therefore, the grain size data should be considered carefully, and for many samples does not represent the true distribution of mineral grains in the sediments. Although sediments in the system with the highest sand content tended to be predominantly associated with the creeks, there were exceptions in every water body type.

The trace metals distributions followed the pattern established by the major elements; lowest concentrations were generally associated with the sandy sediment types and the highest with the finer grained, organic rich, lake and river sediments. For some metals, such as lead and copper, substantial differences between the lake, river, and creek sediments were not evident. For other metals, such as silver, selenium, and mercury, the differences between water body types appeared to be more distinct (Figures 4-18a,b; 4-19a,b, and 4-20a,b). For example, mercury concentrations above 0.15 mg/kg were not evident in the creeks or coastal sediments while concentrations above 0.15 mg/kg were frequently observed in the lake and river sediments (Figure 4-20a). However, the relationship was less distinct when reviewing the aluminum normalized data for the purposes of displaying metal concentrations above those that may be attributed to crustal abundance (Figure 4-20b).

Similarly, silver concentrations in coastal and creek sediments were consistently below 0.1 mg/kg except at one urbanized creek sediment site [SWBPP1 (Sweetwater Branch at Paynes Prairie)]. In contrast, silver concentrations were above 0.1 mg/kg in several lake and river samples. Distinct in the silver data is the group of five river samples that have silver above 0.4 mg /kg and one lake sample [LMAC (Lake Monroe)] that exceeded this level. The group of 5 samples is from the southern Jacksonville portion of the St. Johns River.

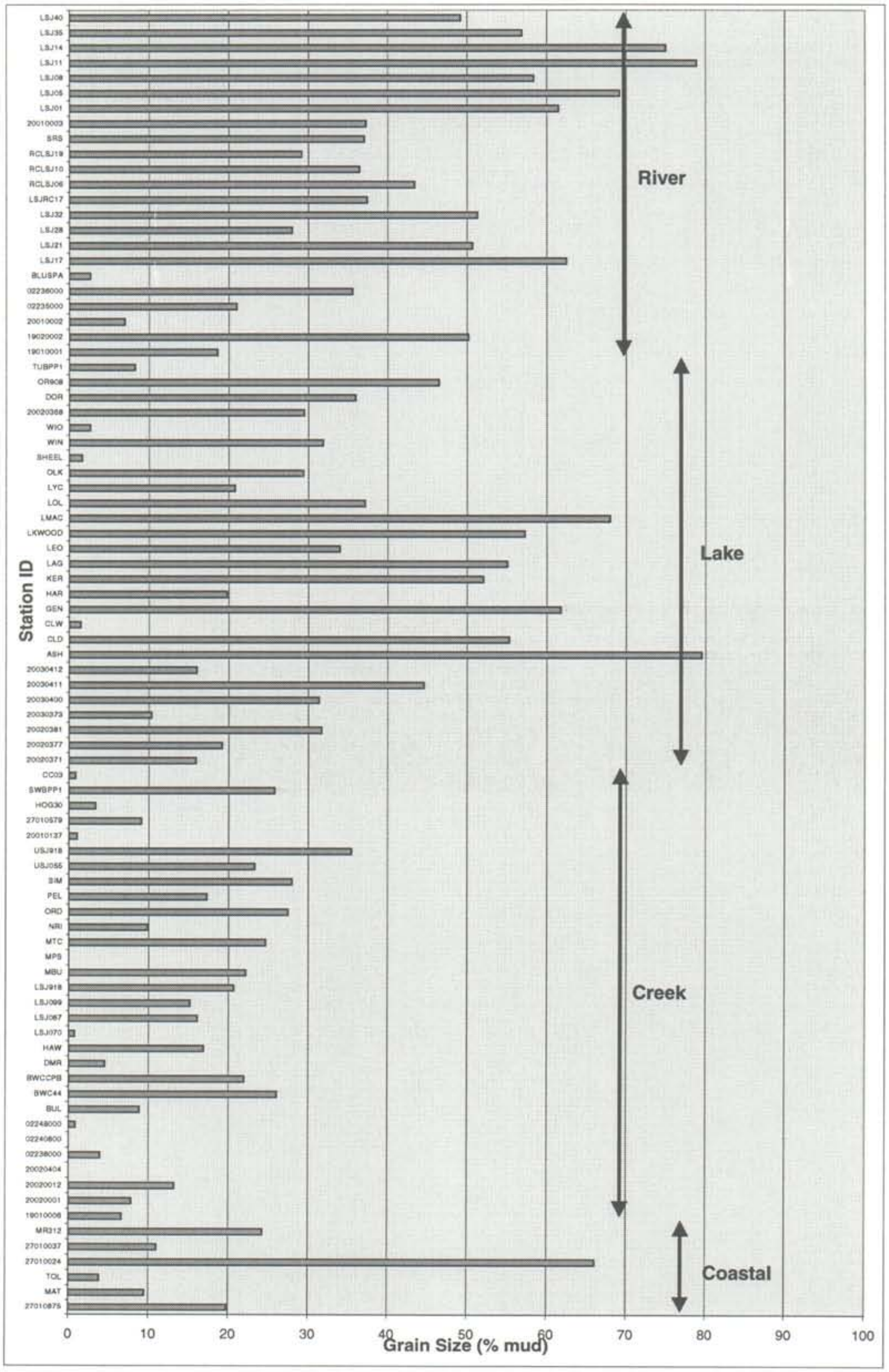


Figure 4-16. Grain Size (%Mud) of Sediments

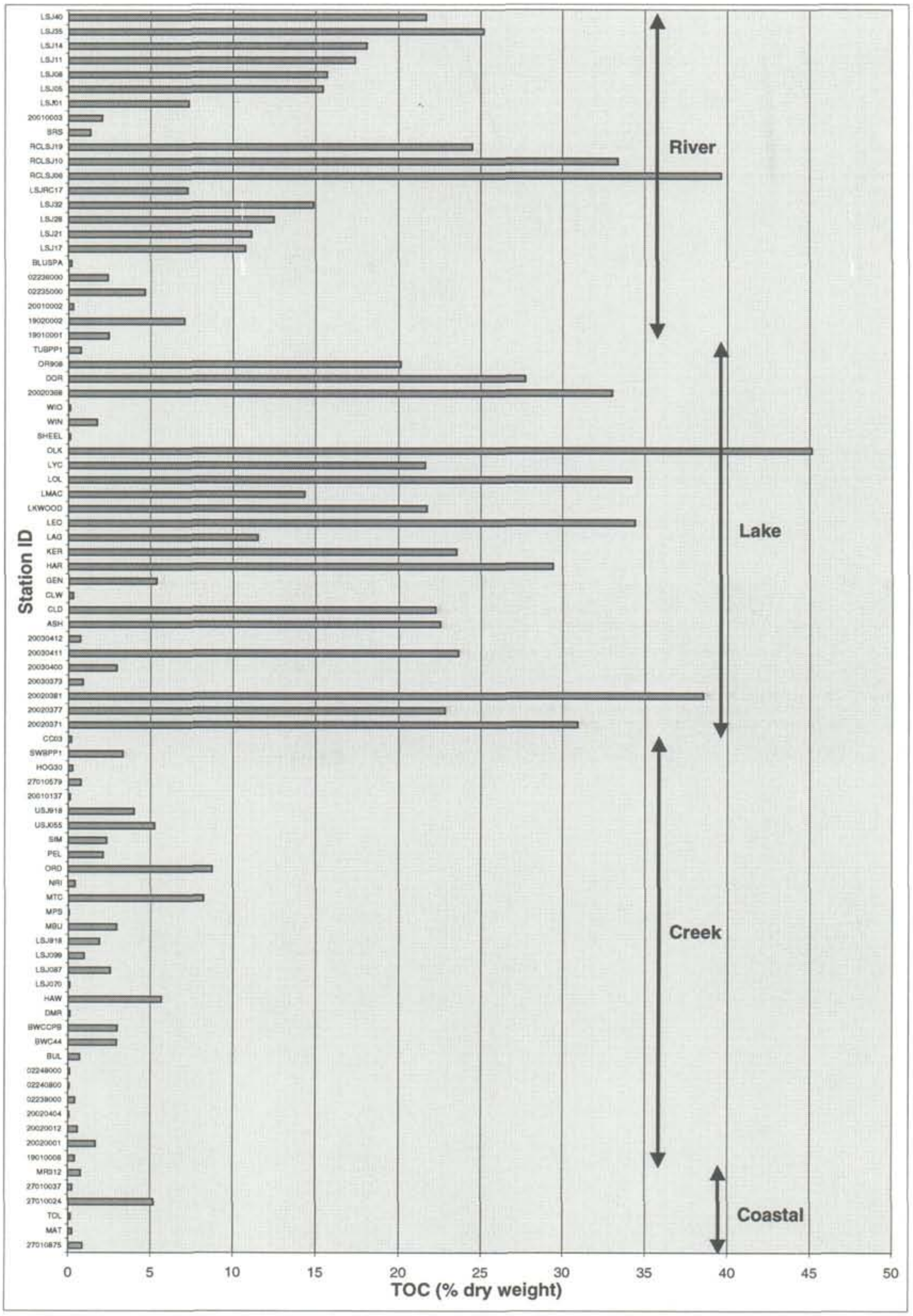


Figure 4-17. Total Organic Carbon (TOC) of Sediments

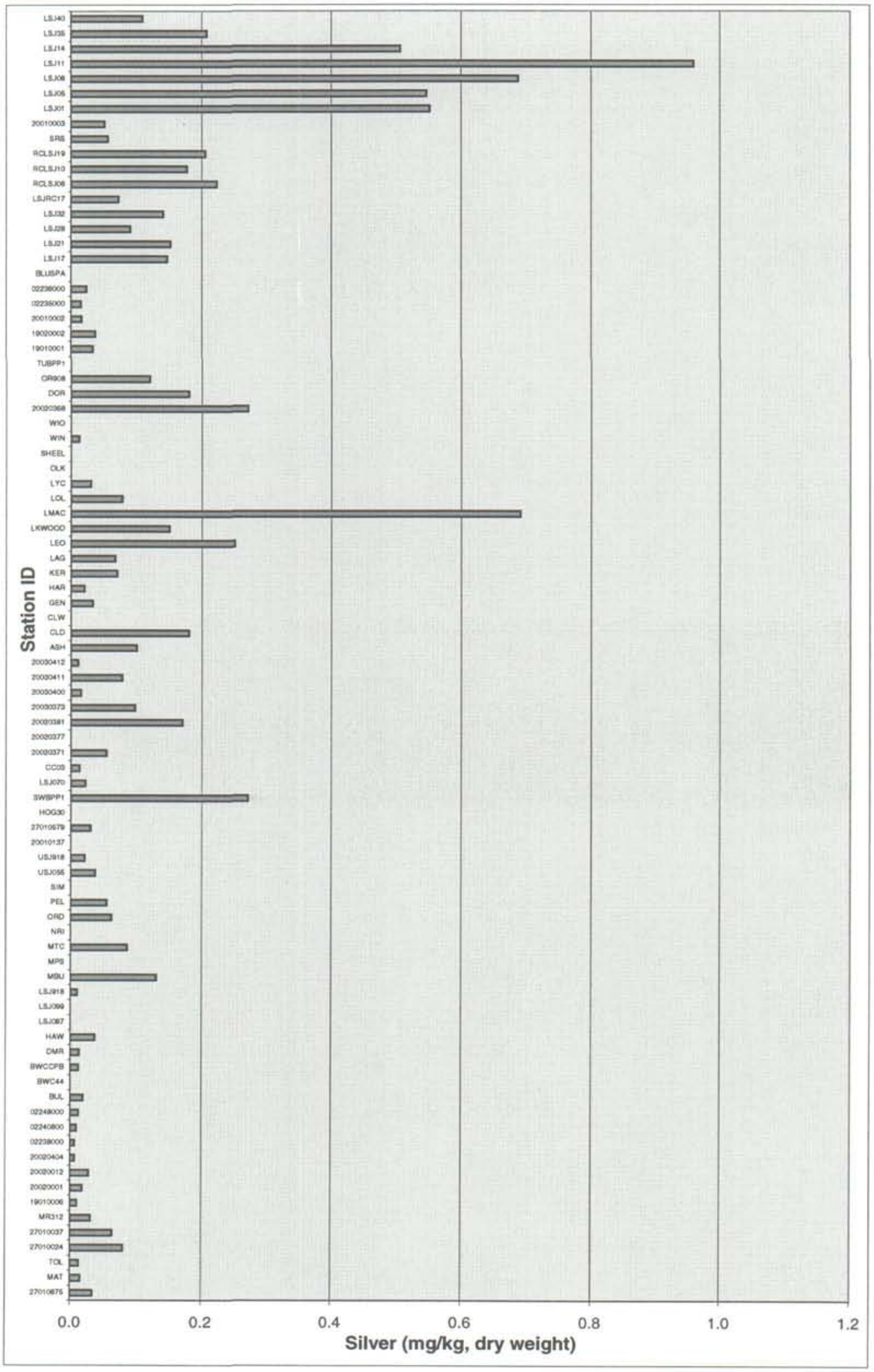


Figure 4-18. Silver Concentrations of Sediments
(a) Non-Normalized

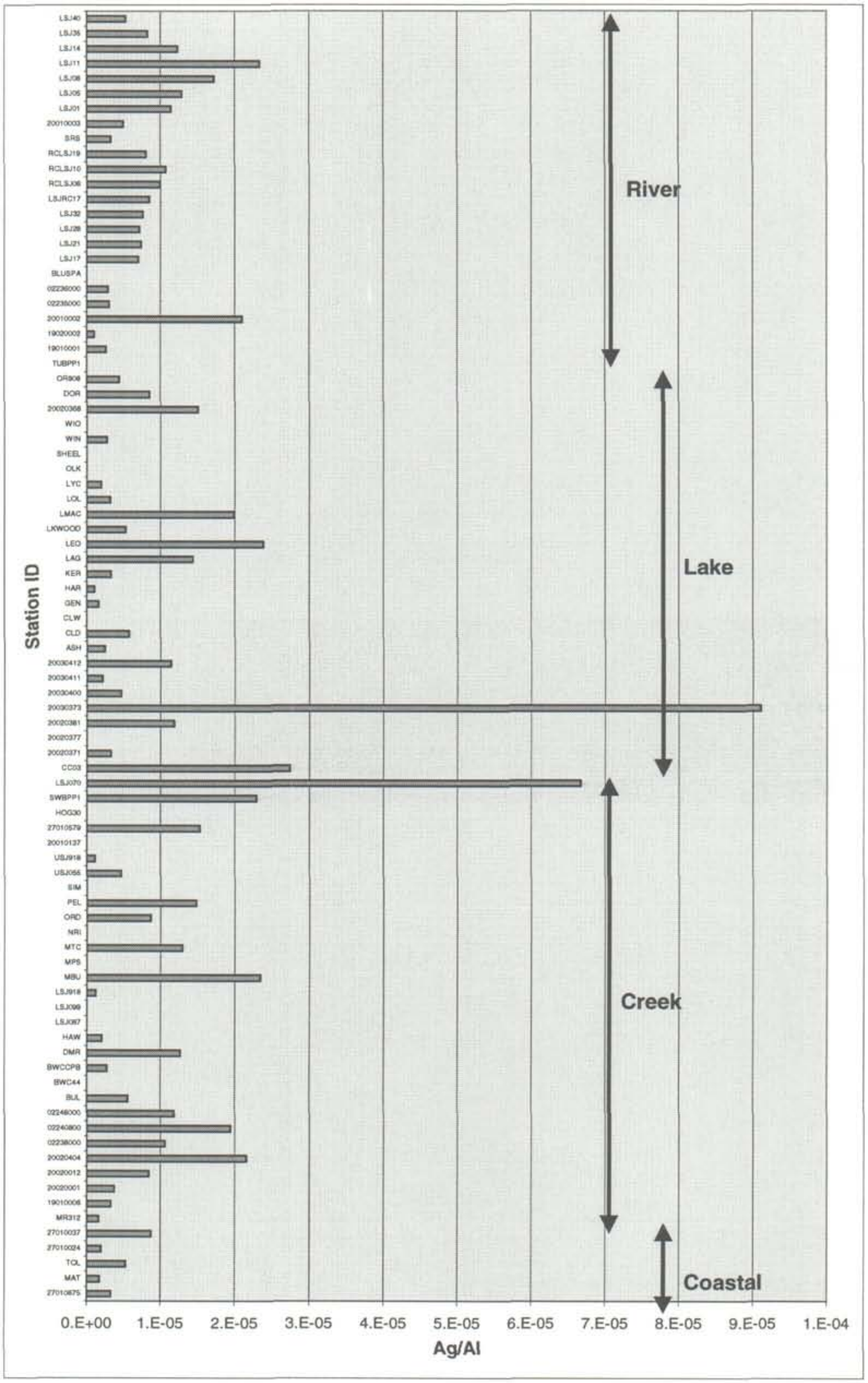


Figure 4-18. Silver Concentrations of Sediments
(b) Normalized to Aluminum

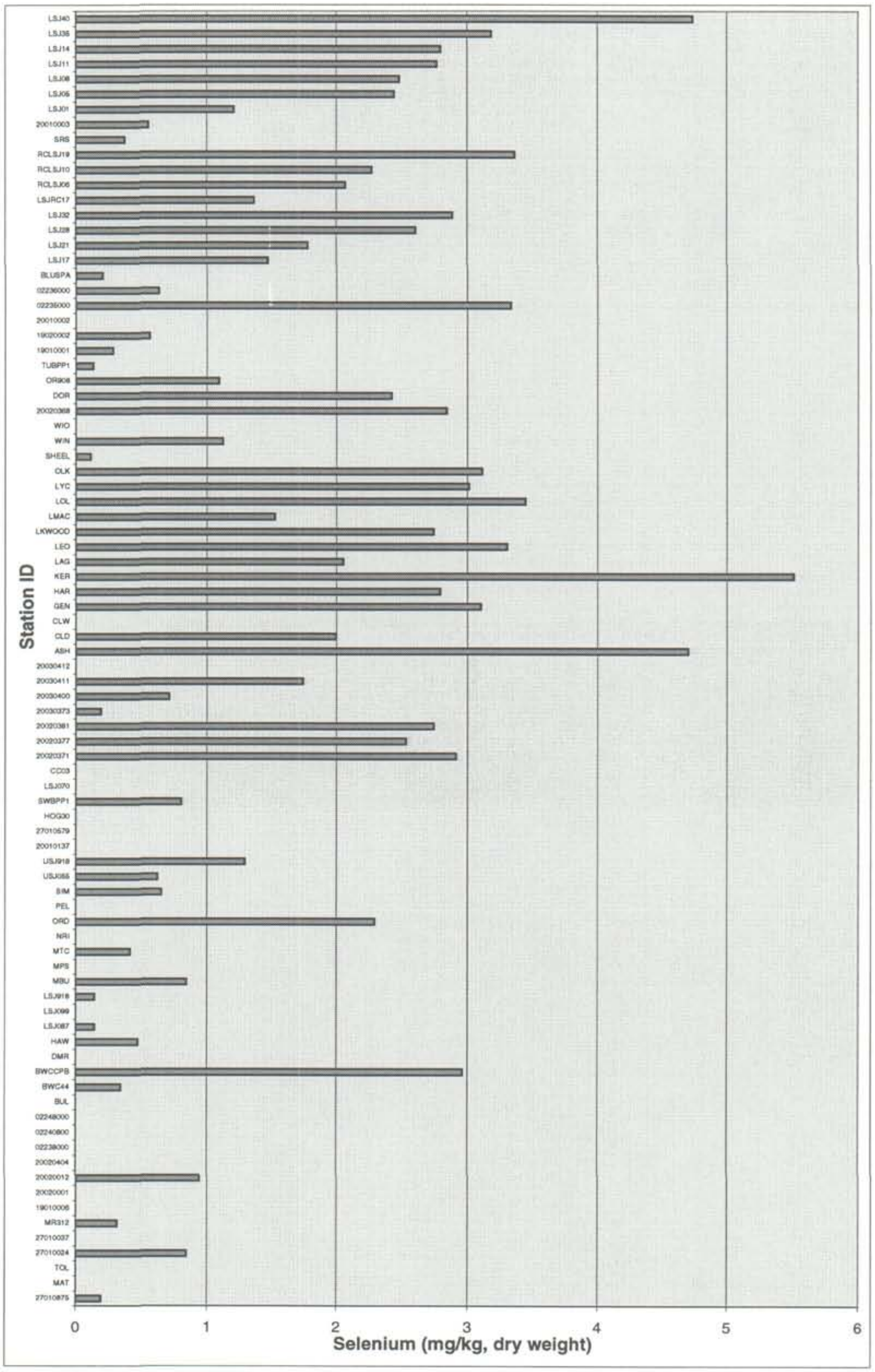


Figure 4-19. Selenium Concentrations of Sediments
(a) Non-Normalized

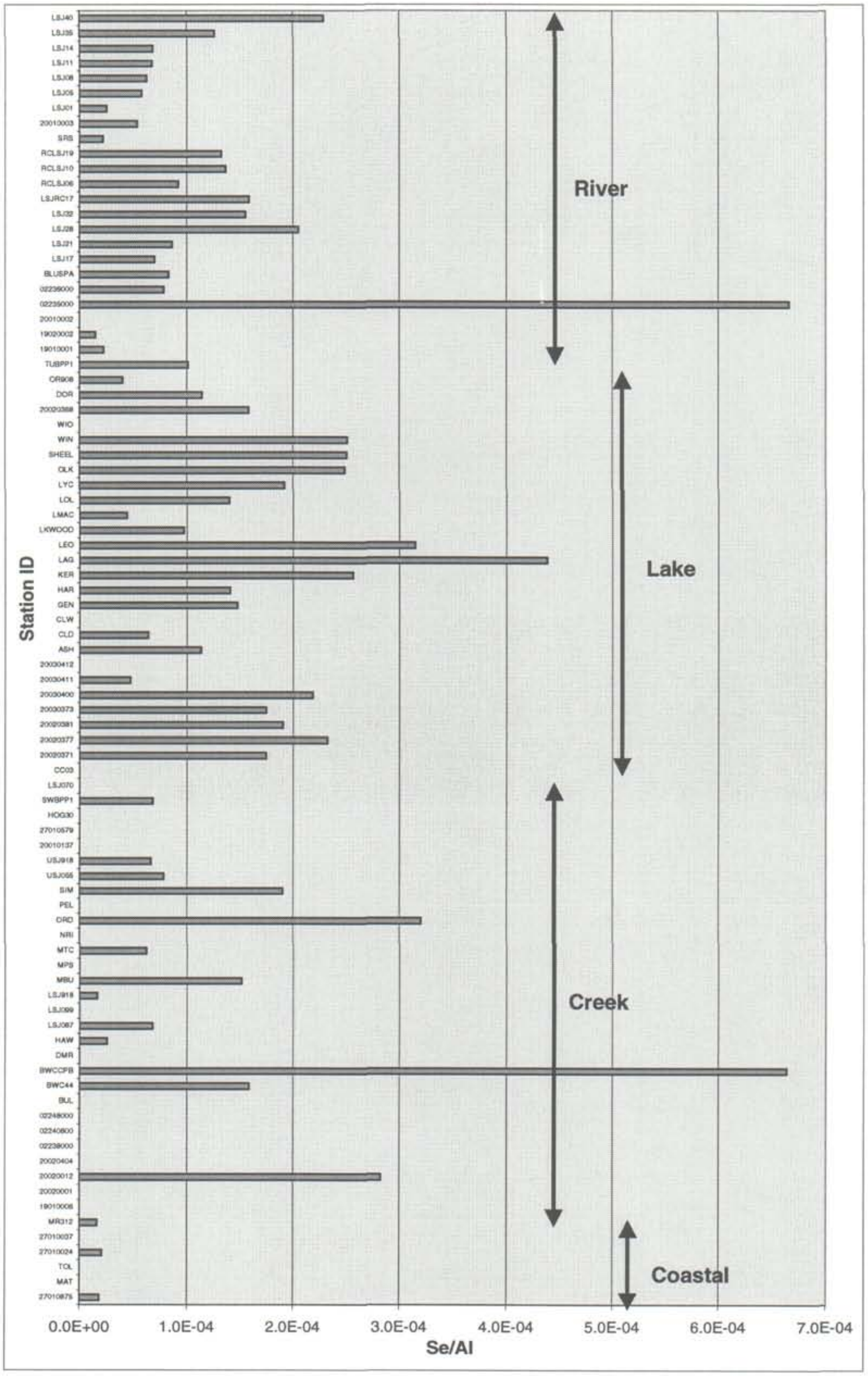


Figure 4-19. Selenium Concentrations of Sediments
(b) Normalized to Aluminum

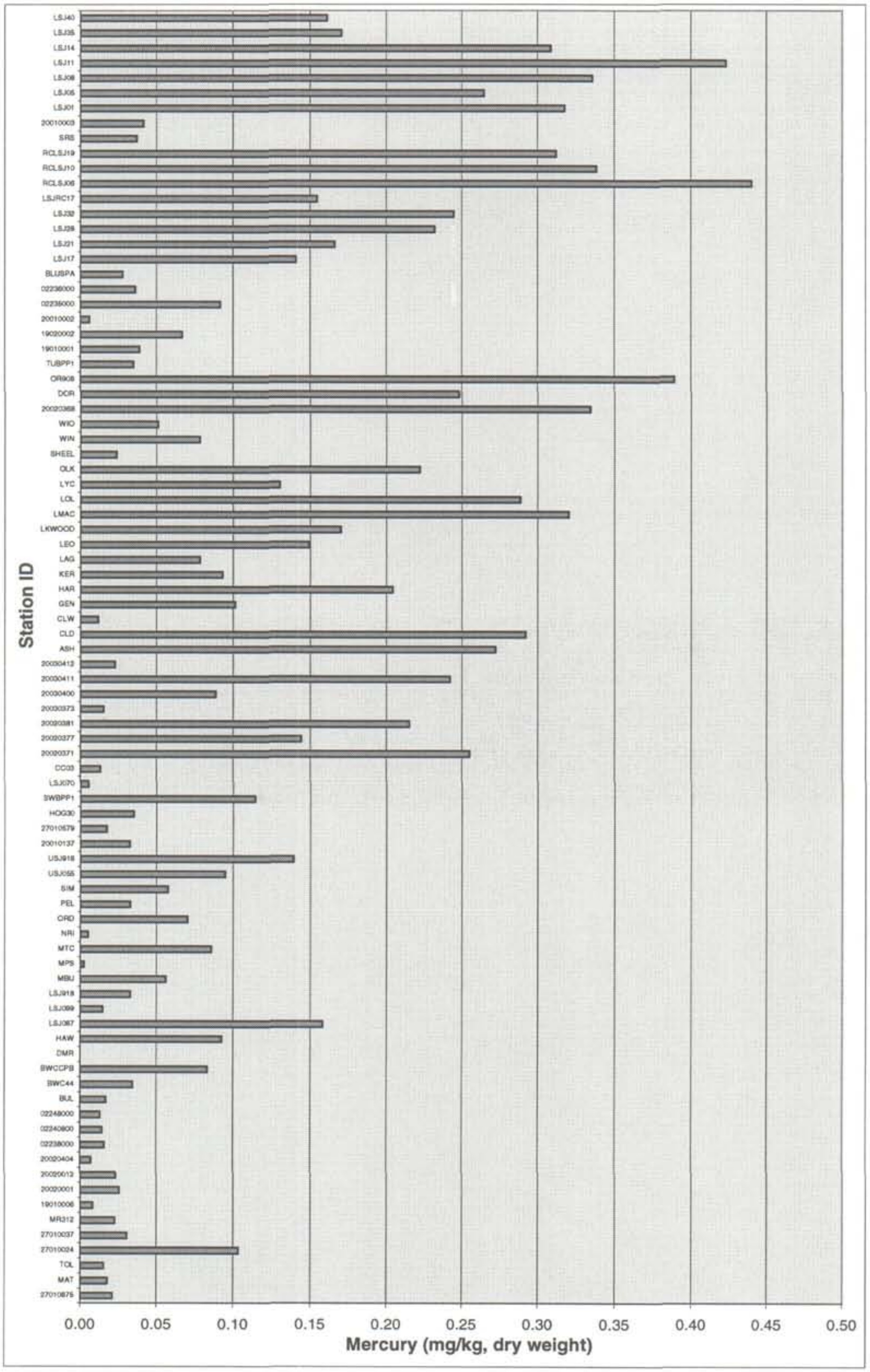


Figure 4-20. Mercury Concentrations of Sediments
(a) Non-Normalized

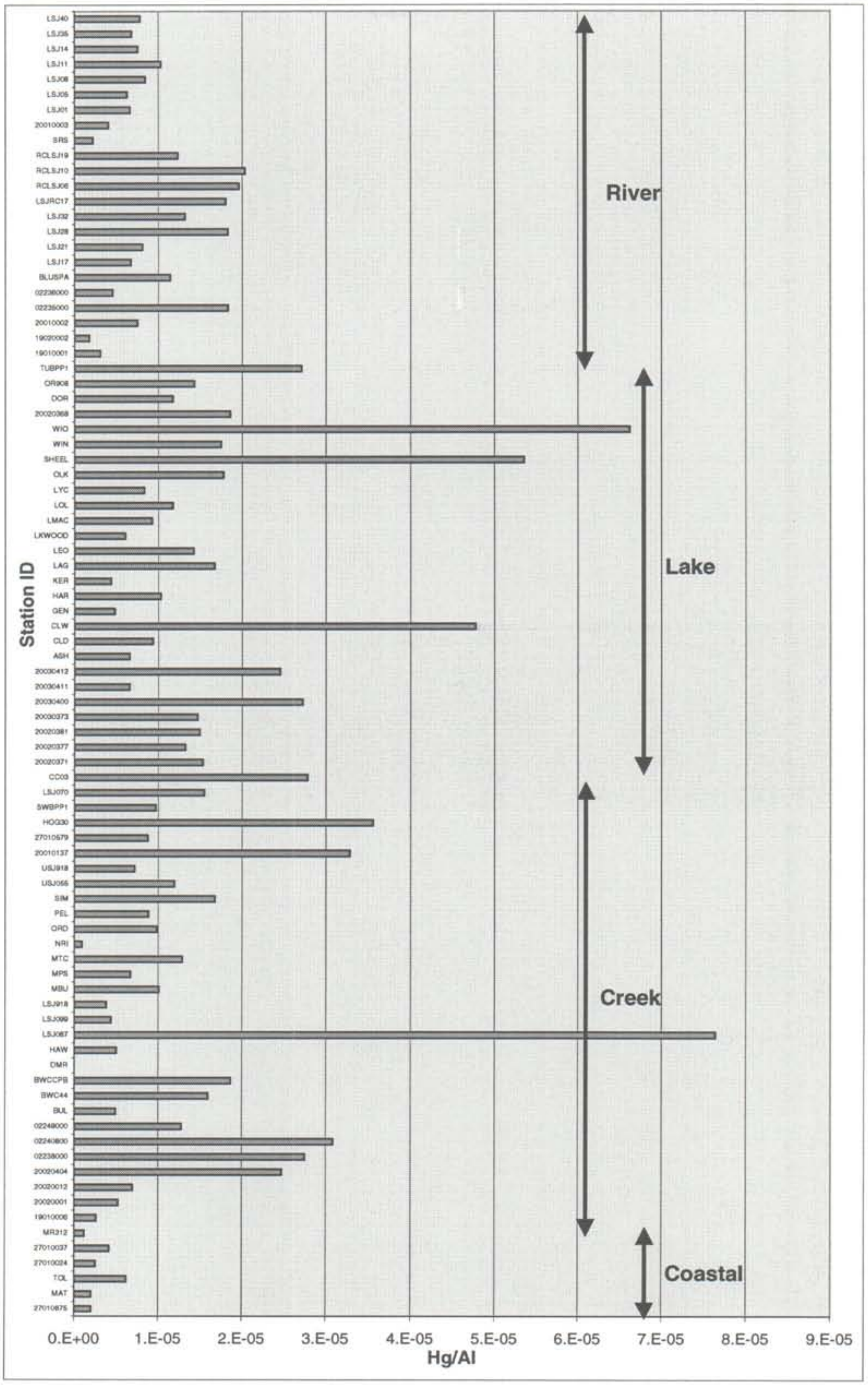


Figure 4-20. Mercury Concentrations of Sediments
(b) Normalized to Aluminum

One factor that may influence the relative magnitude of these metals between urban and rural areas is the amount of mud in the sediments. Examination of Figure 4-16 suggests that the urbanized portion of the St. Johns River may have slightly more mud than the other portions of this river and other rivers within the system. However, without more data specifically collected to address this idea, the observation is speculative.

While many urban samples had higher metals concentrations than rural sites, there were several samples classified as urban that had low metals concentrations. Thus, definitive separation of urban influences on the sediments would require more sophisticated statistical tools, and more site-specific information, to determine if this general observation is valid. Central to this assessment would be a definitive characterization of the water body type and land use characteristics associated with each sediment sample.

Potential Hot Spots. While the above evaluation suggests that broad, contiguous areas with elevated metals concentrations are limited within the SJRWMD (primarily the St. Johns River area near Jacksonville), there are several locations that appear to have unusually high metal concentrations relative to the overall sample set. Determination of whether or not these locations constitute hot spots of concern depends on an evaluation of other factors, such as proximity to localized specific sources, which are not available to this assessment.

There was a striking spatial similarity in the relative concentration of different trace metal contaminants in the study area. In the case of essentially every trace metal contaminant, the same spatial picture emerged — contaminant concentrations were elevated in parts of the northern regions of the study area [sites LSJ01 (Lower St. Johns River at Ortega River), LSJ05 (St. Johns River at NASJAX), LSJ08 (St. Johns River at Orange Pt.), LSJ11 (St. Johns River at Mandarin Pt.), LSJ14 (St. Johns River at Julington Creek), and sometimes 19010001 (St. Mary's River at US 17) and 19020002 (Nassau River at US 17)], in the west, central region [sites LOL (Lochloosa Lake), OLK (Orange Lake), OR908 (Bivens Arm West), SWBPP1 (Sweetwater Branch at Paynes Prairie)], at select sites in the southeastern region [sites 20020381 (Lake Griffin), 20020368 (Lake Eustis), DOR (Lake Dora), HAR (Lake Harris)], and at select sites located in the central regions of the study area [sites LSJ21 (St. Johns River at Palm Cove), LSJ28 (St. Johns River at CM 33), LSJ32 (St. Johns River at CM 38), RCLSJ19 (St. Johns River at Verdiere Pt.), SIM (Simms Creek)]. These sites were generally located near urban areas and/or major water bodies. Lower concentrations of trace metal contaminants were generally found at sites located between the central and western regions of the study area [sites SHEEL (Lake Sheelar), 20030400 (Georges Lake), 20020404 (Orange Creek), 20020012 (Ocklawaha River at SR 316), LAG (Lake George at M 9), 20010002 (St. Johns River at Hwy 40), and BLUSPA (Blue Springs)] and at sites located along the eastern border of the study area [sites BUL, 27010579 (Tomoka River at 11:th St.), 27010037 (Halifax River), 02248000]. To illustrate this point, the geographical distribution of non-normalized and aluminum-normalized mercury concentrations is presented in Figure 4-21, and a similar presentation of the lead data is shown in Figure 4-22. Additional mapped metals contaminant data are compiled in Appendix K.

The mercury and lead concentrations emerged as two metals of potential concern in parts of the District, and the mercury distribution was comparable to that of many other metals, while a few notable lead hot spots were identified. As considered below, the different high metals measurements were not always consistent among samples. For example, high lead concentrations (>250 ppm) that were more than 5 times higher than those measured in the remaining sediments were measured for SWBPP1 (Sweetwater Branch at Paynes Prairie) and OR908 (Bivens Arm West). High cadmium and tin concentrations (relative to the other samples in the data set) were also measured at these two locations. Other metals did not show consistent or unusually elevated concentrations at these two sites, although, the mercury, copper, and chromium concentrations were high at OR908 (Bivens Arm West).

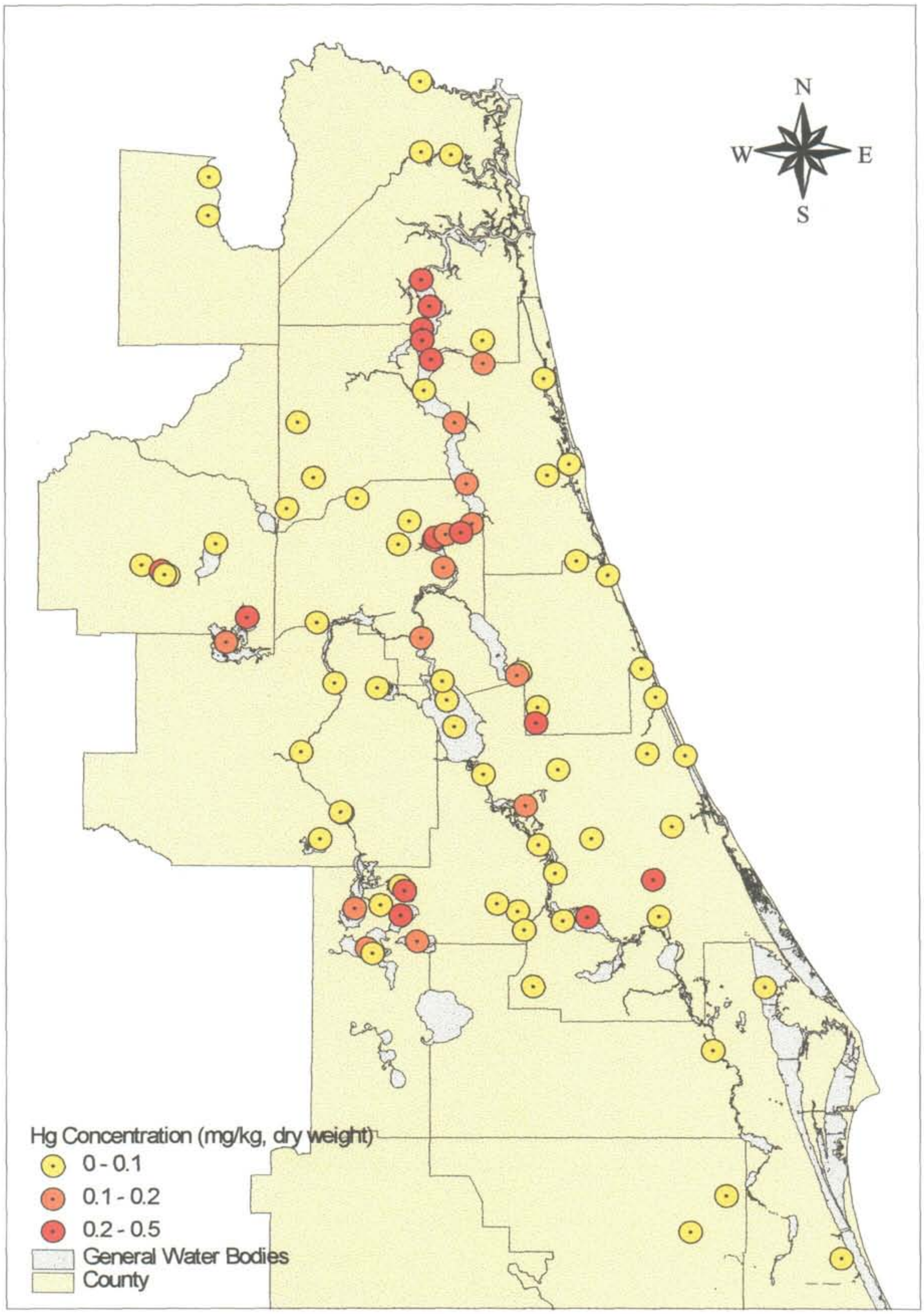


Figure 4-21. Map Displaying Mercury Concentrations — (a) Non-Normalized

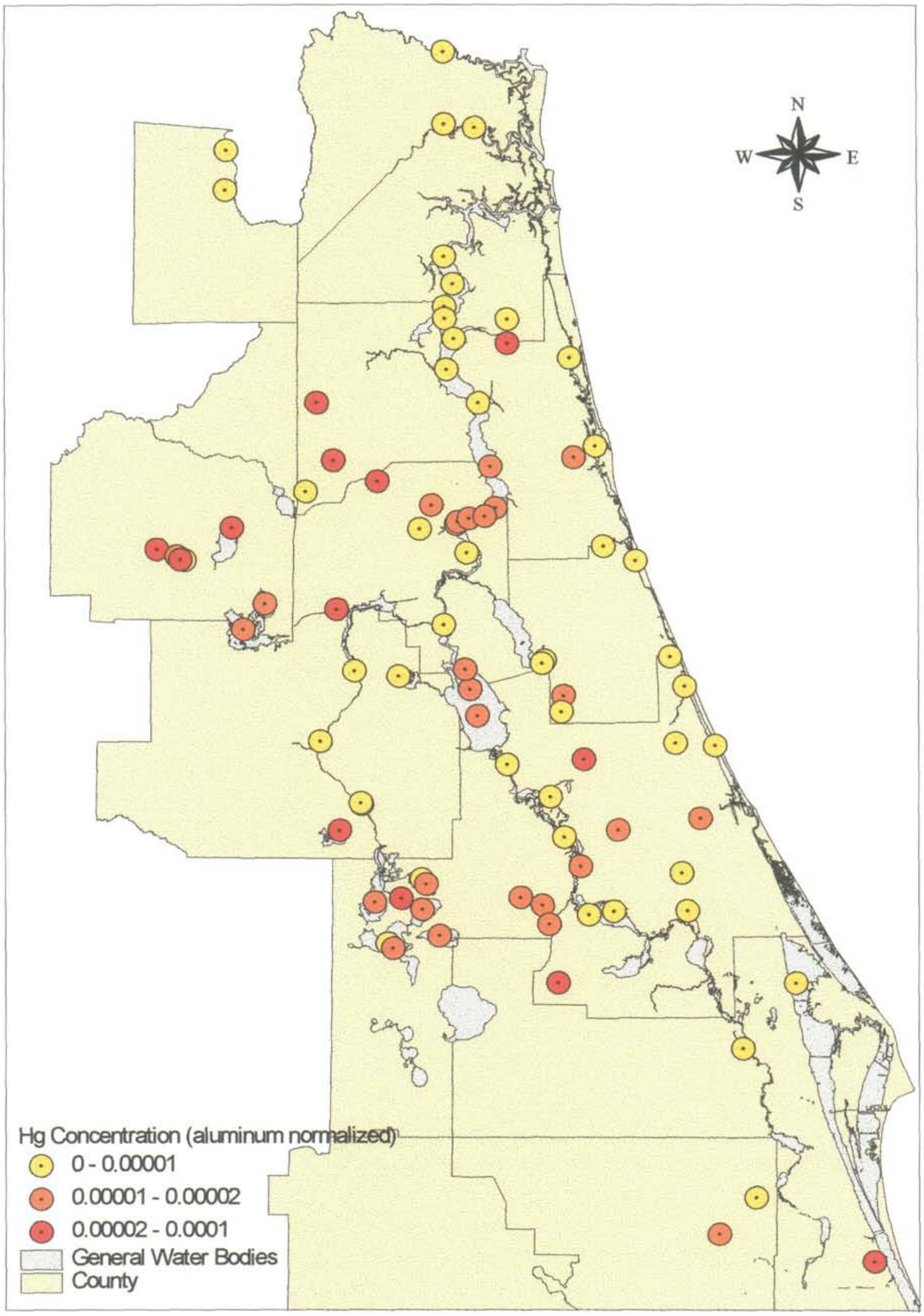


Figure 4-21. Map Displaying Mercury Concentrations — (b) Normalized to Aluminum

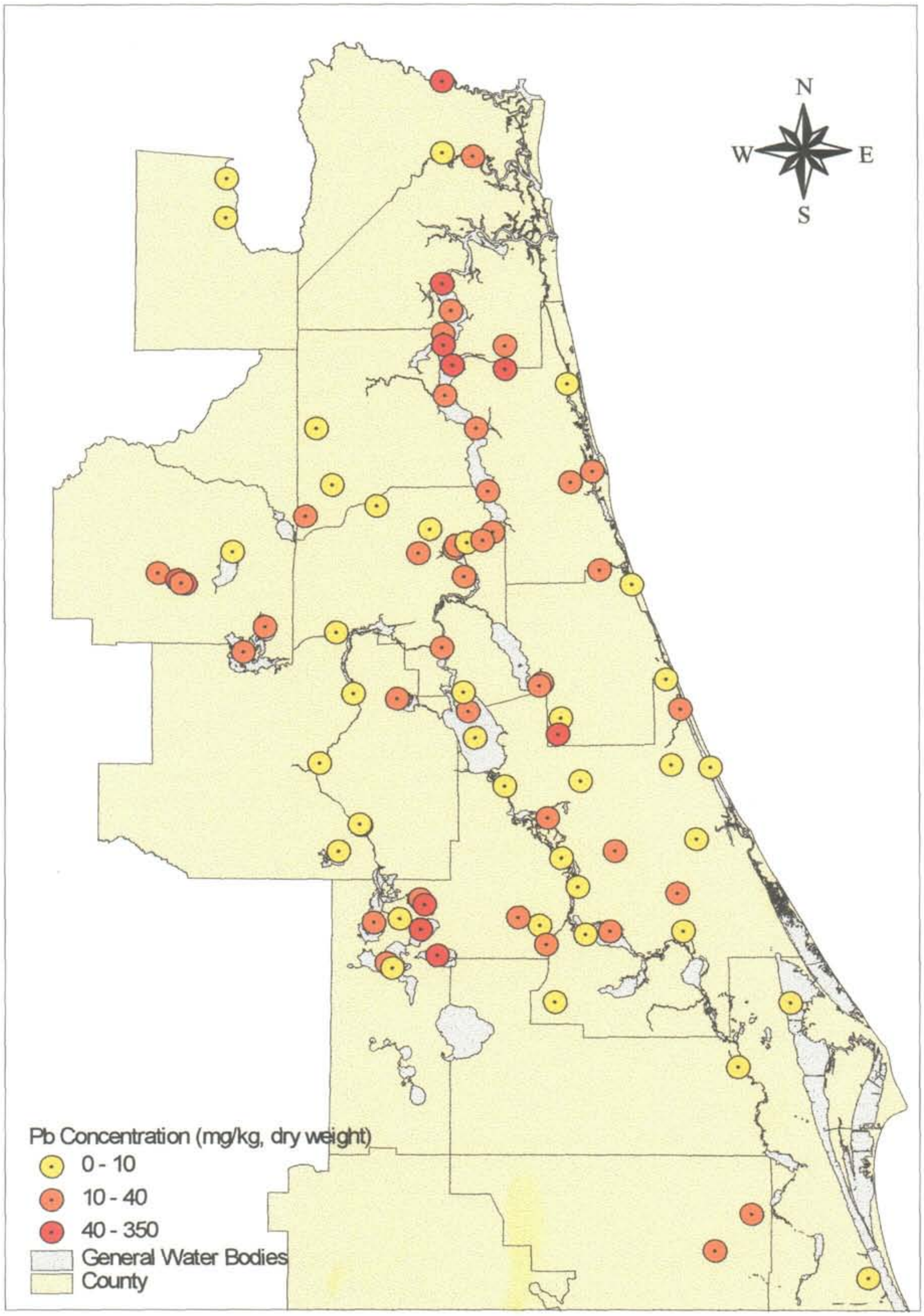


Figure 4-22. Map Displaying Lead Concentrations — (a) Non-Normalized

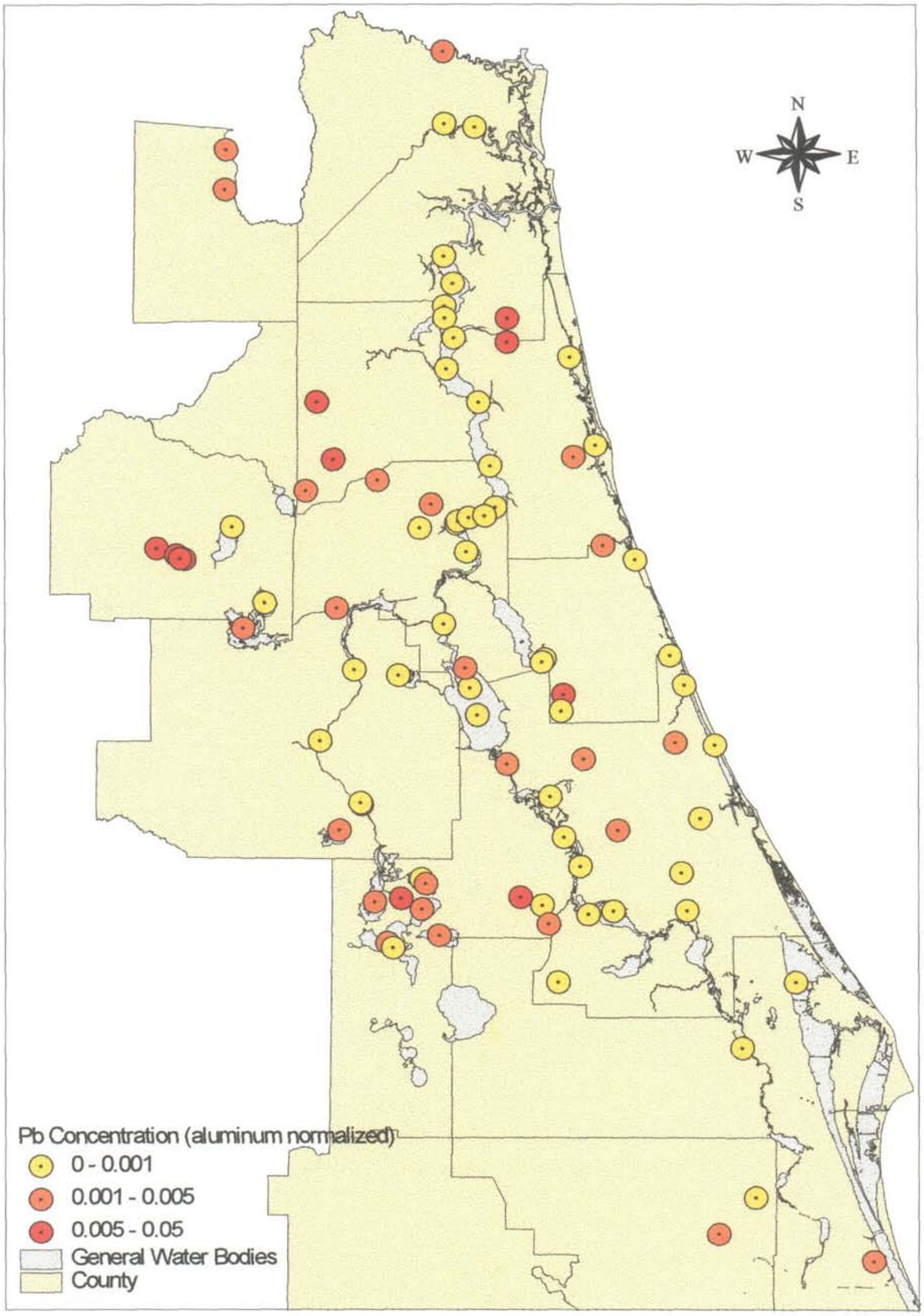


Figure 4-22. Map Displaying Lead Concentrations — (b) Normalized to Aluminum

Arsenic was elevated in Lake Eustis and Lake Dora, which are proximal to each other and within an urbanized area. Copper was high at LSJ087 (Durbin Creek) and nickel was high at RCLSJ06 (St Johns River at Rice Creek). Zinc concentrations were above 250 mg/kg at two sites [19010001 (St. Marys River at US 17) and SIM (Simms Creek)].

Correspondence Among Metals: Metals distributions are controlled by several factors in sediments. These include the grain size and level of organic carbon and the proximity to sources. Comparison of the aluminum concentrations to the fine-grained, or mud, fraction of the sediments reveals a general, but weak, correspondence in this system (Figure 4-12). The other metals concentrations also generally increased with the mud fraction (or aluminum), but the correspondence was not as strong as might be expected. Some of the variability may relate to the extremely high amount of TOC in many of the sediments, especially in the lakes where TOC frequently was higher than 20 % and as much as 40% of the sediments (Figure 4-17). Areas of very high TOC (>20%) were confined to a few general areas (Figure 4-23)

In addition to the correspondence with aluminum, there is usually a strong correlation between TOC and fraction of mud within sediments. This correspondence was examined for the SJRWMD sediments in this study to determine if there were any unusual features within this system relating to this common paradigm. The exercise showed the correspondence between the fraction of Mud and level of TOC in the sediments to be generally *very poor* (Figure 3-1), and did not follow the commonly observed relationship. Similarly, the correspondence between aluminum and TOC was weak. Striking in the relationship shown in Figure 3-1 is the apparent correspondence between TOC and mud fraction in those sediments with TOC under 2.5% and the complete lack of correspondence between these two parameters in sediments with TOC greater than 2.5%. This presentation demonstrated that many of the sediments were highly enriched in organic carbon and that accumulation of TOC in these sediments was independent of sediment grain size (e.g. grain size of the sediments exerts very little control over TOC accumulation). The high values were also consistent with observation of samples with significant amounts of undegraded, or only partially degraded, vegetative debris that probably skewed the grain size and elevated the TOC content in many samples.

The sediments that had low TOC concentrations were generally found in the creeks and coastal areas; the highest concentrations were associated with the lakes. While sediments from the rivers showed a large range in TOC concentration, the highest values did not reach the levels seen in the lakes.

As discussed earlier, aluminum normalization generally provided better correlation to the other metal concentrations than grain size or TOC normalization. Most metals displayed substantial variability in the correspondence to both grain size and TOC concentrations in sediments. Such variability can occur when there is an excess of one component over the other, such that associations driven by geochemical process are overridden. However, the relationship between individual metals and TOC suggests elevated levels of certain metals in several samples, compared to the general relationship observed for the system. For example, an examination of the silver to TOC relationships reveals a subset of samples with enriched silver concentrations compared to most of the samples (Figure 4-15 and Appendix H). Similarly, a subset of samples show higher arsenic, iron, manganese, chromium, copper, lead, and tin relative to the general TOC relationships observed in the samples. Determination of the locations of these samples shows that they are generally consistent among these metals and are located in the St. Johns River near Jacksonville. Considered together the data from these samples [LSJ01 (Lower St. Johns River at Ortega River), LSJ05 (St. Johns River at NASJAX), LSJ08 (St. Johns River at Orange Pt.), LSJ11 (St. Johns River at Mandarin Pt.), and LSJ14 (St. Johns River at Julington Creek)] suggest this area has a slightly different pattern in its metals chemistry. Because these sediments are proximal to Jacksonville, the data suggests that anthropogenic activity may be causing them to differentiate from the more general interrelationships observed in the SJRWMD.

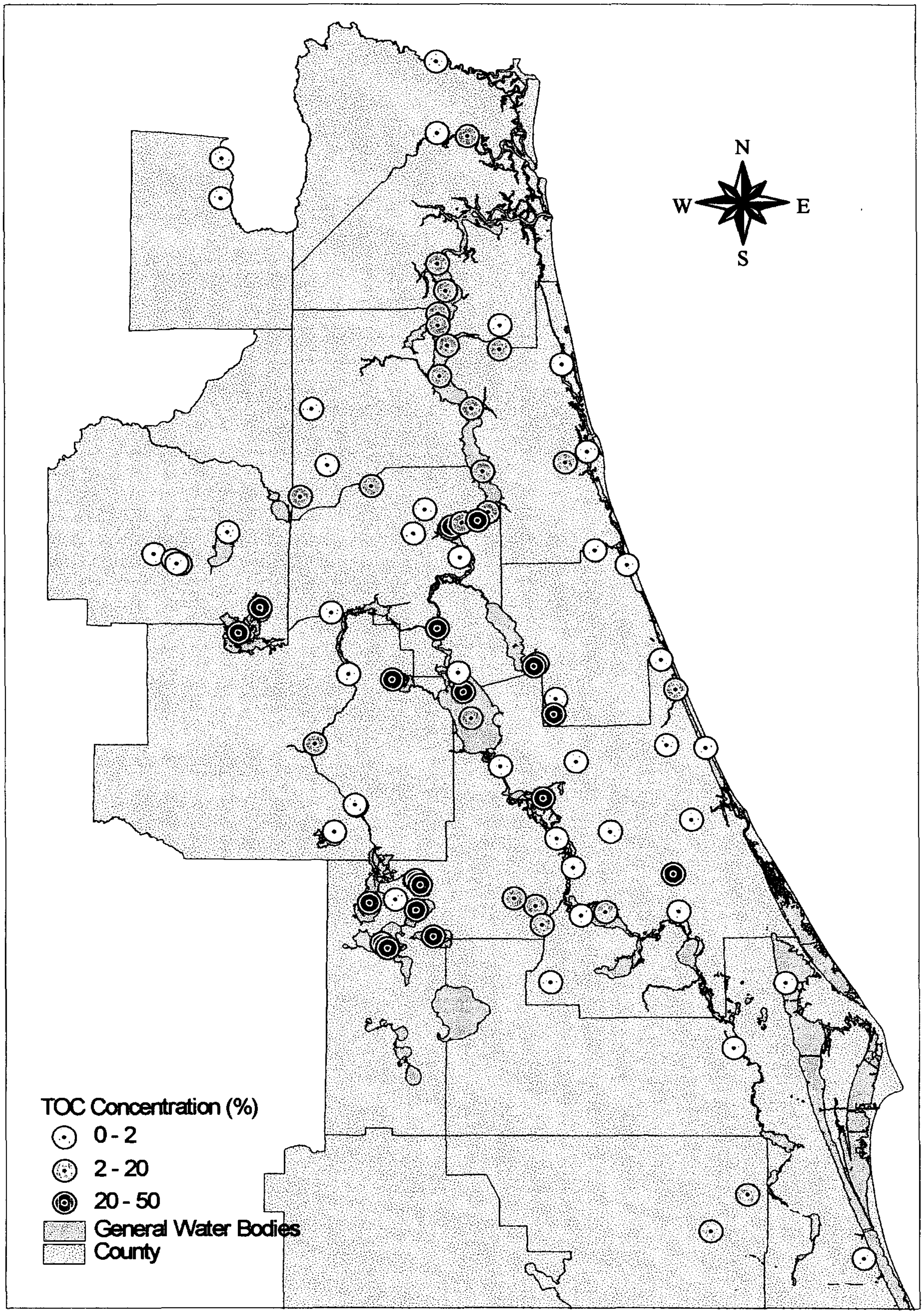


Figure 4-23. Map Displaying Total Organic Carbon Content of Sediments

Indicators of Potential Effects. Figure 4-24 presents the mercury data relative to the ER-L and ER-M values (Long *et al.*, 1995), and Figure 4-25 presents this information for lead. Similar figures for the other 7 metals that are typically of environmental concern, and for which there are published ER-L and ER-M values, are compiled in Appendix J. The numerical values of the ER-L, ER-M, TEL and PEL indicators vary with the metal (Table 4-1). Even though these values were developed primarily for marine sediments, and are thus not directly transferable to fresh water systems, they can be used to evaluate areas that may have potential impacts and that potentially should be examined further with other data to determine whether or not environmentally detrimental impacts are present. Furthermore, the somewhat less frequently used and references LEL values, which were developed for freshwater sediments, are quite comparable to the ER-L values.

For this evaluation, the metals concentrations in the sediments were compared to both the ER-L/ER-M and TEL/PEL indicators (see Tables 4-1 and 4-2). Relatively few ER-L/ER-M exceedances were noted. Mercury had the largest number of exceedances (Figure 4-24 and Appendix J). Lead exceeded the ER-L value at 6 locations and the ER-M value at 2 locations (Figure 4-25). The only site showing more than 3 ER-L exceedances was OR908 (Bivens Arm West), with 6 ER-L exceedances. Otherwise, exceedances were limited to 1 to 3 per site, for those that had any exceedances at all, and, except for mercury, there were only between 0 and 6 ER-L exceedances among all 86 sites for the different metals.

The comparison shows that few sites have more than 1 or 2 TEL exceedances and that metal PEL values were exceeded at only two sites [OR908 (Bivens Arm West) and SWBPP1 (Sweetwater Branch at Paynes Prairie)] and then only for lead (Table 4-2). Exceedance of 1 to 3 TEL metals values was observed in a scattering of sites throughout the system. Only a few sites had 4 or more metal TELs exceeded. These included LMAC (Lake Monroe), OR908 (Bivens Arm West), LSJ01 (Lower St. Johns River at Ortega River), LSJ11 (St. Johns River at Mandarin Pt.), LSJ08 (St. Johns River at Orange Pt.), LSJ05 (St. Johns River at NASJAX), LSJ14 (St. Johns River at Julington Creek), RCLSJ06 (St. Johns River at Rice Creek), and RCLSJ10 (St. Johns River near Rice Creek). The metal that most frequently exceeded the TEL was mercury (in 33 of the 86 samples) followed by lead (22 of 86 sites). Silver was the metal that least frequently exceeded the TEL (1 sample) with zinc having the second to the fewest metal TEL exceedances. Other than mercury, and to a lesser degree lead, the data set shows a remarkable lack of notable ER-L and TEL exceedances and leaves the impression of relatively limited potential for biological impact from metals.

The application of these sediment quality guidelines should be made with caution, particularly for toxic metals. Firstly, most of the guidelines were developed for individual parameters and do not incorporate additive or interactive effects due to multiple toxic components. Secondly, the potential of metals to cause adverse biological effects depends greatly on the characteristics of the sediment and how the metals are associated with the sediment (i.e., how available the metals are to possible receptors). The bioavailability of the metals depends on the grain size and the amount of TOC in the sediment — finer grain sediment and high TOC typically bind the metals more tightly making them less available. A high acid volatile sulfide (AVS) concentration in the sediment also appears to reduce the bioavailability of certain toxic metals, including cadmium, copper, nickel, lead, and zinc (DiToro *et al.*; 1990 and 1992).

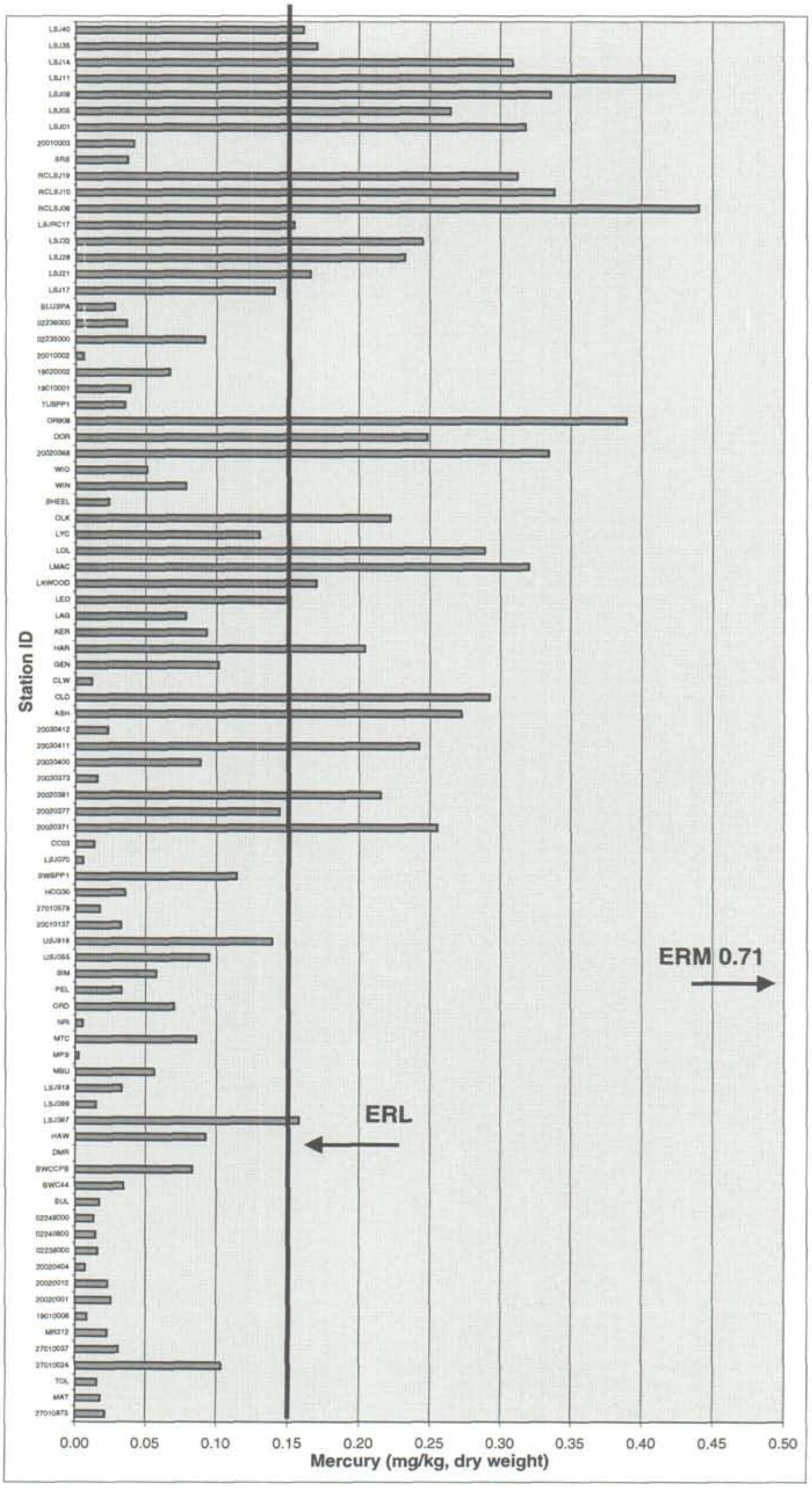


Figure 4-24. Sediment Mercury Concentrations and ER-L/ER-M Values

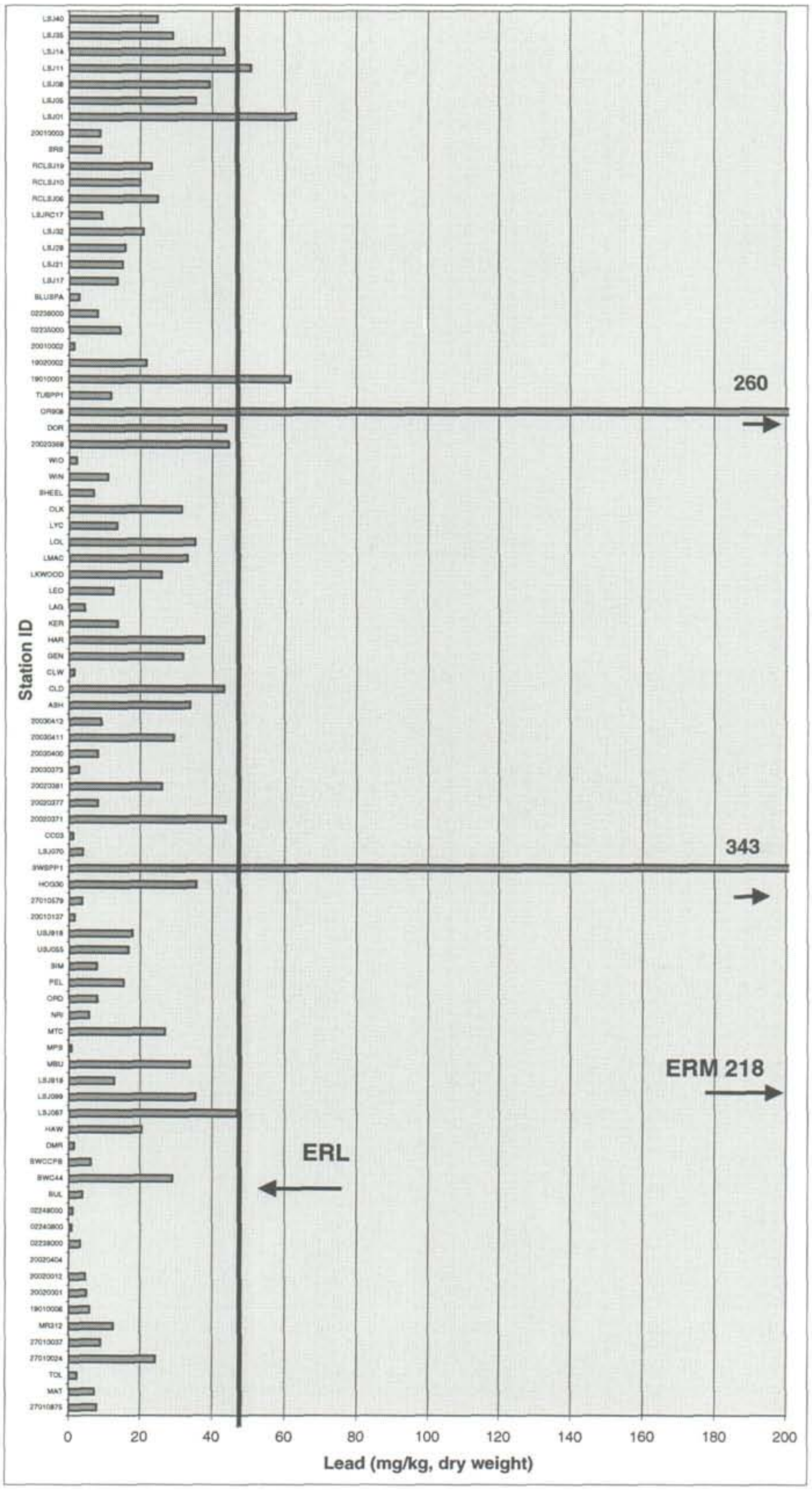


Figure 4-25. Sediment Lead Concentrations and ER-L/ER-M Values

4.3 Nutrient Levels

Nutrient (TKN, TP, OP) concentrations were generally highest in the lake samples (Figure 4-26) although considerable variability was evident within each sediment type. There was also a remarkable correlation between the TKN and TOC content of the sediments (Figure 4-27) — no such relationship was observed for TP or OP versus TOC, or for any of the nutrients when plotted versus %mud. The TKN to TOC relationship suggests that the majority of the nitrogen originates with the organic material in the sediments, and not as anthropogenic inputs of nutrients. However, because of the large amounts of organic matter in many of these sediments, smaller anthropogenic contributions might not be discerned. The maximum TKN concentrations reached in the lakes was generally at least two times, and often more than 10 times, the TKN concentrations measured in the coastal, creek or river sediments. It should be noted that nutrient measurements were made on very few river samples, and a comparison between this sediment source and the others is therefore tenuous at best. The TKN concentrations in the coastal, creek, and river environments were generally comparable, but variable. A similar general pattern was observed for TP (Figure 4-28), although there were river samples that had TP concentrations that were similar to those measured in the lakes. The creek samples generally had the lowest total phosphorus concentrations. A notable exception was site SWBPP1 (Sweetwater Branch at Paynes Prairie) which had the highest TP concentration (8,000 mg/kg). This sampling site is located in a small creek/branch, downstream of the discharge from the wastewater treatment plant in the City of Gainesville.

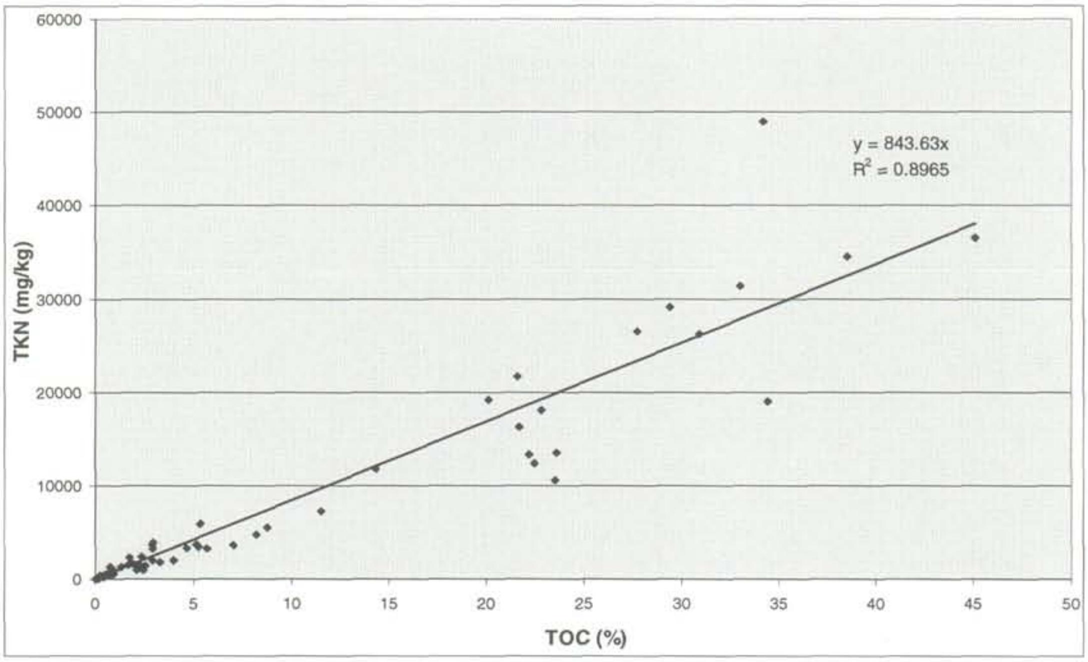


Figure 4-27. TKN versus TOC Concentration

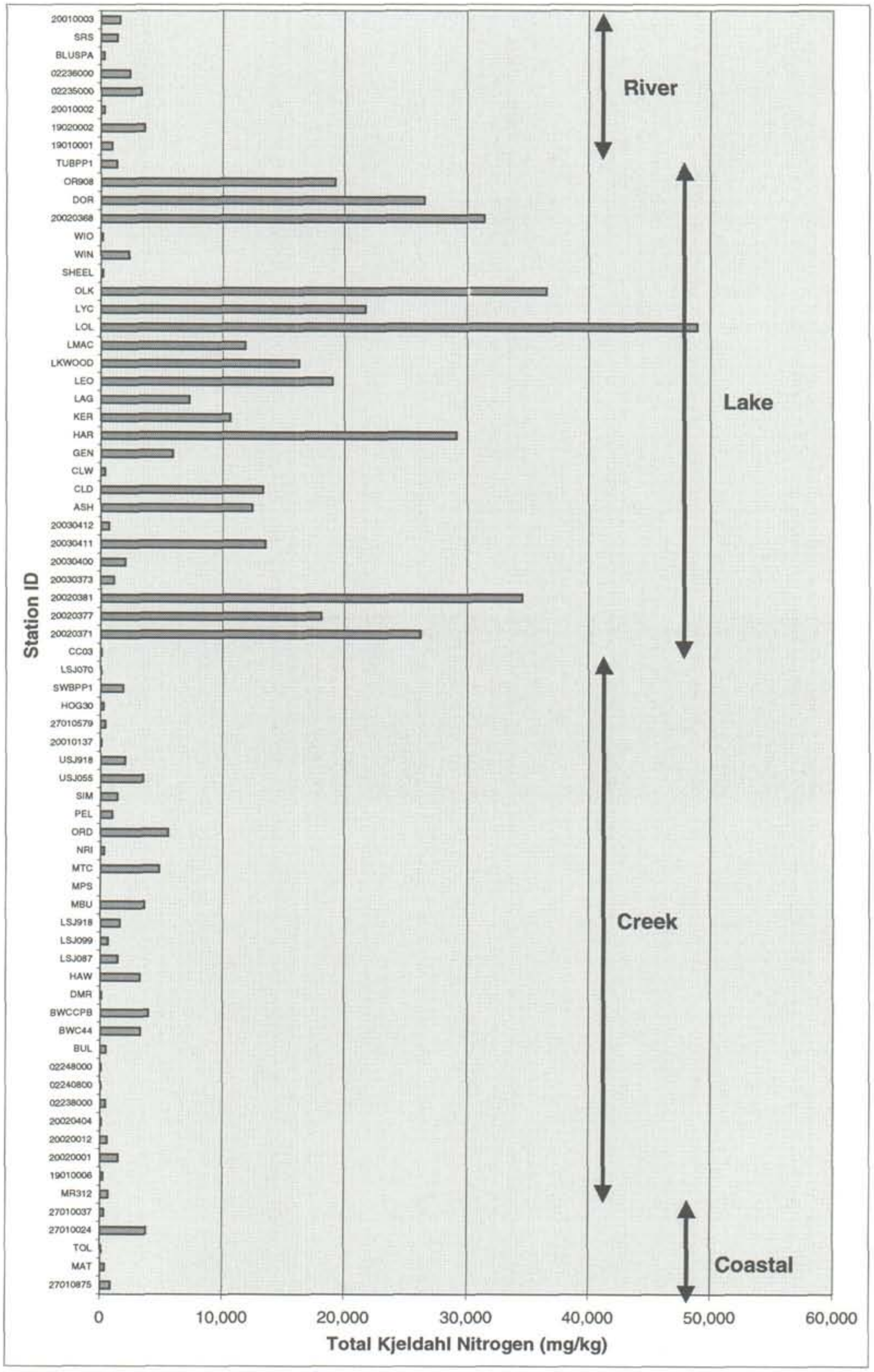


Figure 4-26. TKN Concentrations

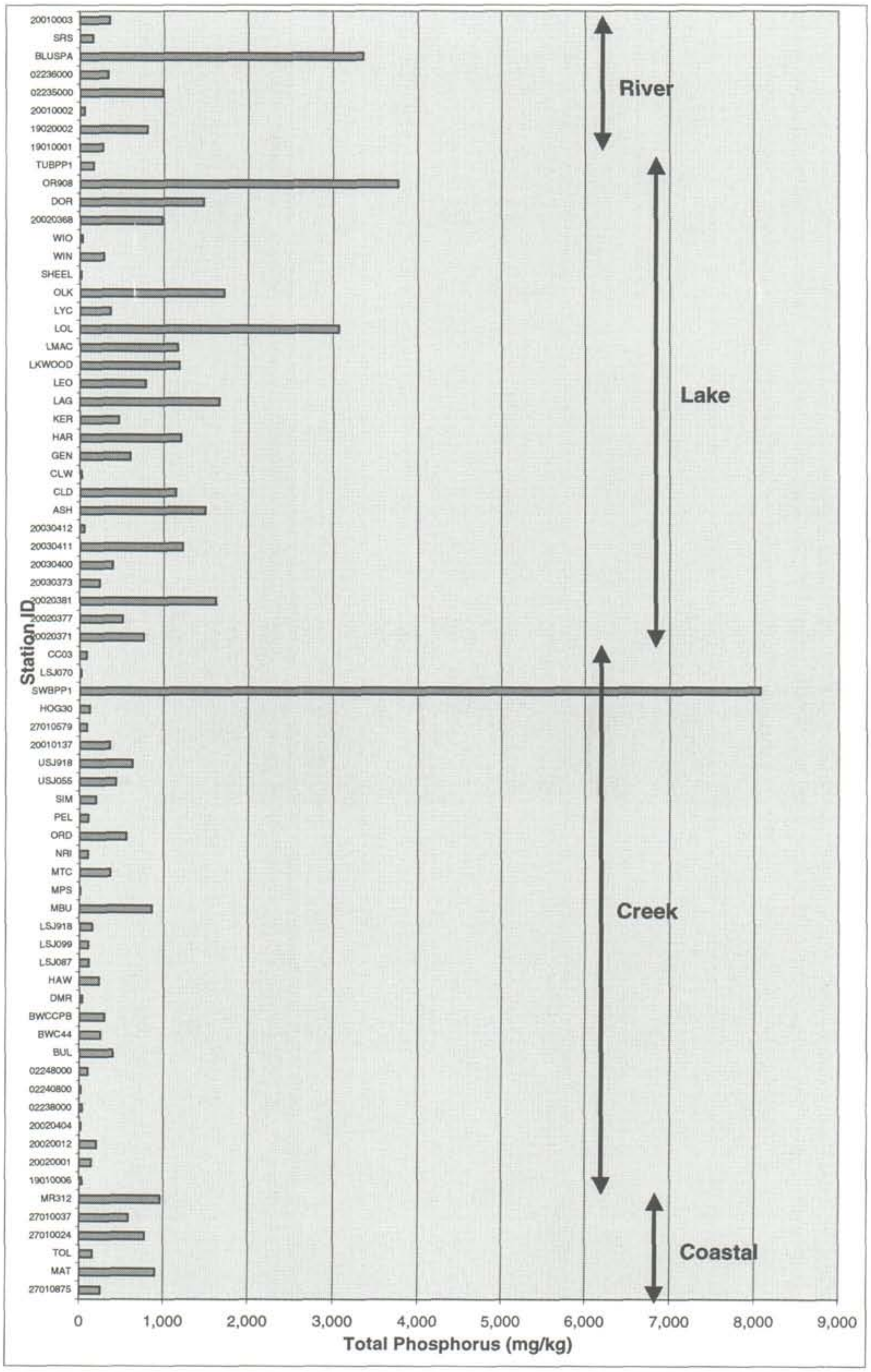


Figure 4-28. TP Concentrations

Although orthophosphate was a small fraction of the total phosphorus in these sediments, the distribution pattern was similar to that observed for the other nutrient measurements; the highest concentrations were observed in the lake sediments. The OP level in the other areas were uniformly low (less than 1 mg/kg dry weight), and was generally less than 1 percent of the TP measured in the samples (Figure 4-29). Occasionally, OP contributed 1 to 4 %, and as much as 10% in one sample [MPS (Middle Prong St. Mary's River)], of the total phosphorus in the samples. There was little difference in the ratio of ortho- to total-phosphorus among the four sediment types. Many samples in the lake sites had nitrogen to phosphorus ratios that were similar to the other water bodies (Figure 4-30). However, there were a number of lake samples that had N/P ratios greater than 10, indicating that the nitrogen per unit phosphate was often higher in the lake sediments, as compared to the other sediment types.

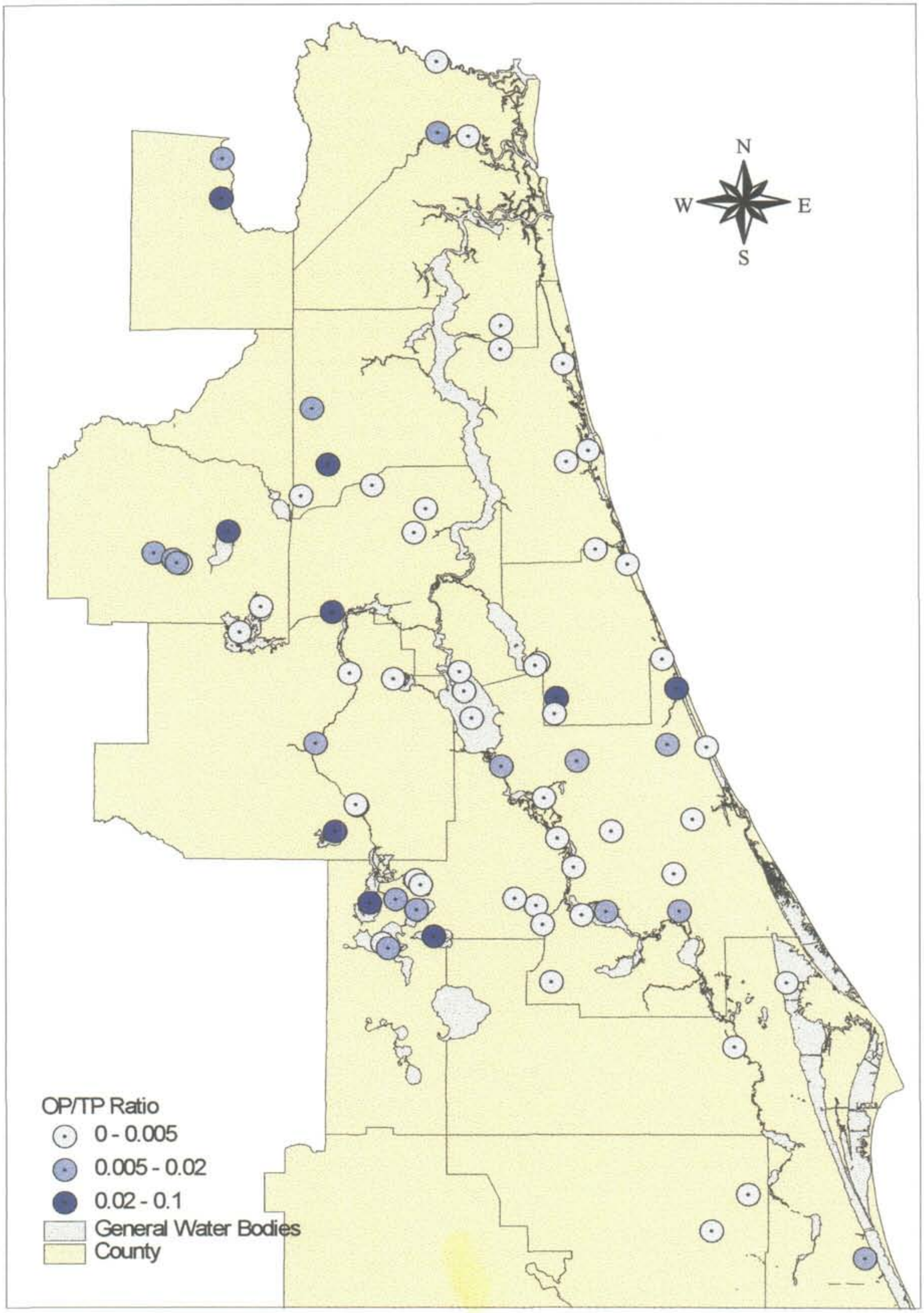


Figure 4-29. Map Displaying the OP/TP Concentration Ratio

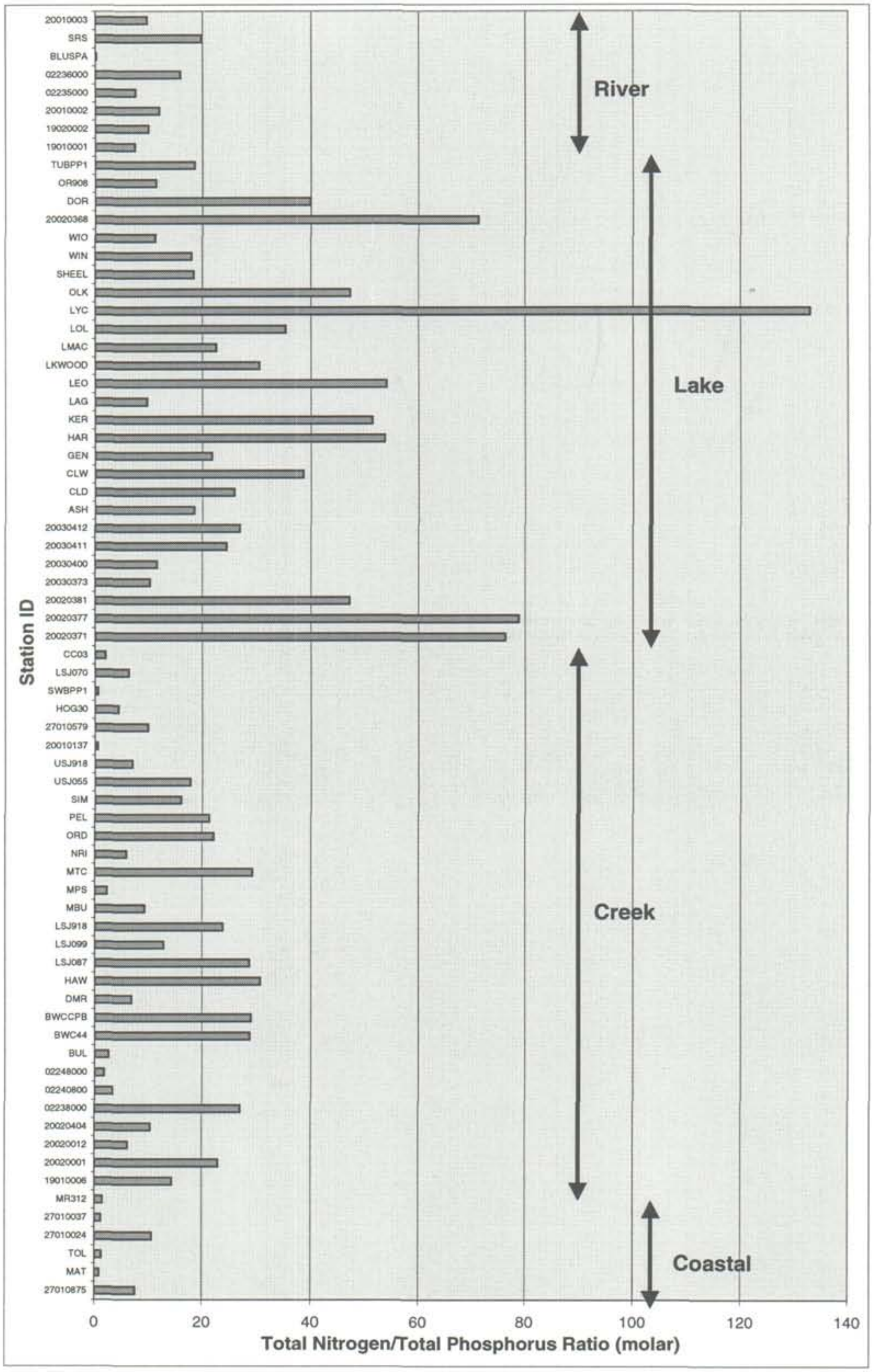


Figure 4-30. TKN/TP Concentration Ratio

5. CONCLUSION

Overall there was no clear or easily discernible diagnostic in the organic contaminant and metals data that unequivocally points to a substantial anthropogenic signal in most of the samples examined. There were several isolated areas with elevated concentrations of contaminants when compared to the rest of the sites, but, generally, the quality of the sedimentary environment in the areas surveyed appears to be quite good, based on the data that were generated. It must be cautioned that the sampling program was quite limited, and the representativeness of the samples has not been demonstrated.

Generally, the data were quite variable, indicating differences in contaminant concentrations and also in the natural composition of the sample matrices. The metals, for instance, generally showed an increase in concentration as the grain size of the sediments decreased, but the nature of these sediments made it difficult to apply standard data normalization procedures. Many of the sediments were very high in organic carbon, but much of this was undegraded plant debris that is not completely available as an organic source for "binding" contaminants. This plant debris also contributed disproportionately to the coarser fractions in the grain size determinations, and the grain size data did therefore not always provide reliable information on the grain size of the mineral component of the sediment. Furthermore, the 86 sites that were investigated represent many different environments, with different geology and natural processes, and can therefore not be directly compared as if they were from similar locations.

Specific water body type "signals" were evident in some of the data, but a hard and fast rule could not be developed to classify environmental quality based on the water body type. At the most basic level, it appears that the lakes and rivers had collected the largest concentrations of most contaminants. Differences among the sources of these contaminants likely does account for some of the differences in the distribution pattern. Some contaminants, such as PAH and mercury, have a large atmospheric source component in addition to being in runoff and other discharges that also must be considered. In contrast, most other metals, PCB, and pesticides are introduced to the environment primarily through point sources, or local non-point runoff. Contaminants with substantial atmospheric sources will tend to be spread more uniformly within a watershed when contrasted to pollutants with more localized and less distributed source functions.

Large urbanized areas appear to be exerting some influence on the contaminant concentrations in the sediments, although definitive conclusions cannot be drawn until more samples are evaluated, and/or statistically analyzed, to ensure the inherent variability in the system is accounted for. Differences between urban and rural areas are subtle and sophisticated statistics may be required to separate the two.

A few general locations with elevated concentrations of a number of organic and metal contaminants were identified, and they include:

- The Lower St. Johns River area near Jacksonville. Elevated concentrations of most contaminants were found in this area, most notably PAH, PCB, and toxic metals.

- The Middle St. Johns River area near Rice Creek. Elevated concentrations of PCB and other chlorinated industrial compounds were found in this area, as were moderate levels of relatively undegraded DDT.

- The water bodies sampled on the south side of Gainesville [OR908 (Bivens Arm West) and SWBPP1 (Sweetwater Branch at Paynes Prairie)]. These sites had elevated concentrations of PAH, PCB, metals (most notably lead), chlordane, and DDT, and the total phosphorus levels were very high at SWBPP1.

- The mid-Florida lakes region, and other lakes. Several of the mid-Florida lakes, including Lake Harris, Lake Eustin, and Lake Griffin had high concentrations of PCB and several metals, and the DDT concentrations were high in Lake Dora. Away from this region, Lake Disston had very high concentrations of DDT and elevated chlordane, and Lake George had elevated concentrations of several chlorinated pesticides (e.g., chlordane, BHCs, and DDT).

The potential for biological impact from the measured contaminants generally appears to be low, based on the ER-L and TEL comparison approach, and is consistent with the generally low to moderate organic contaminant and metals concentrations measured in most of these sediments. With the possible exception for the locations indicated above, the potential for biological impact is likely low, based on the ER-L/ER-M assessment method.

Recommendations

- Sophisticated data analysis and statistical tools, such as multivariate cluster analysis and/or principal component analysis (PCA), may be applied to various parts of the data set in an attempt to distinguish more subtle differences in contaminant concentrations by aquatic system type, urban/rural, and various land use types. A more complete land use and location analysis may be valuable in an attempt to explain some of the isolated contaminant elevations that were observed.

  However, the general objective of this study was met — to obtain a solid broad based, general, status estimate of the quality of the sediment in water bodies throughout the SJRWMD. Specific areas that may warrant further investigation were identified. The data generated in this study may be inappropriate for further in-depth quantitative analysis, considering the diverse nature of the sampling locations and the limited statistical basis for the sampling regime.

- The study described in this report has provided a rough idea of the status of the quality of the sediments of the aquatic systems in the areas sampled. This study has provided a wealth of general screening data that are a valuable foundation for future work and environmental planning. However, the representativeness of the data is not well understood because of the low numbers of samples that were collected at each site, and because a single site composite was analyzed to represent each location. It would be useful to perform a small study in a few different locations to test the representativeness using a more statistically rigorous sampling and analysis scheme.

- A few areas of potential concern have been identified, and the findings may warrant more rigorous investigations of these locations. Site-focused studies should include a sound sampling and analysis plan that will ensure that the data can be confidently used in statistical and other interpretive analyses. Additionally, the target analyte list can be reduced and focused to effectively address the issues at any particular location.

  Such location-specific investigations would not have the complicating factors due to the diverse nature of the sampling locations that were observed in this study, and site-to-site comparisons could be performed, and potential contaminant sources possibly identified. The items discussed in the first two recommendations could be incorporated and addressed.

A large set of Lower and Middle St. Johns River sediment data are currently being generated for the SJRWMD, and additional sampling may therefore not be required for these areas. The other areas of potential concern, the south Gainesville locations, the mid-Florida Lakes, Lake Disston, and Lake George, may warrant additional focused sampling efforts.

- Follow-up assessment to determine the trends in the environmental contaminant loadings at the 86 sites may be very useful to support environmental management. However, sediment contaminants concentrations do not change rapidly (and the rate of change depends on a number of factors, such a rate of deposition, bioturbation etc.), so large-scale follow-up trends monitoring may not be useful for another 3-5 years.
- This report provides a wealth of quality environmental monitoring data that could be a valuable resource for environmental planers and scientist around the country. It would therefore be good if this information could become more widely distributed and available, such as by publishing the results in technical journals, presenting it at technical and non-technical meetings, and possibly by making it available over the Internet (e.g., though an ArcView or other map-based interface).

6. REFERENCES

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