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CHEMICAL CONTAMINATION OF SEDIMENTS IN THE CEDAR-ORTEGA RIVER BASIN

CHEMICAL CONTAMINATION OF SEDIMENTS IN THE CEDAR-ORTEGA RIVER BASIN

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ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
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EXECUTIVE SUMMARY

This report presents the findings of an intensive sediment quality assessment conducted within the Cedar and Ortega River Basin by the St. Johns River Water Management District from 1998 through 1999. A total of 52 sites were selected and analytically assessed for sediment quality and the presence of contaminants. Sediments were analyzed for a number of constituents of potential concern that included more than 100 organic compounds and 20 metals. The objective of the project was to determine the presence, concentration and distribution of potentially toxic organic compounds and metals, identify and evaluate the hazard posed and delineate the spatial patterns of the most problematic contaminants of concern. The resulting data were used in an assessment and evaluation of a broad range of sediment contaminants, which lead to the identification of the source areas and initiation of management efforts to remediate contamination of the Cedar-Ortega River Basin.

The lower St. Johns River has, because of its overall importance and potential for environmental damage, been the subject of several environmental studies. The SJRWMD has been sampling water, biota and sediments to determine the relationship between the biotic communities and the quality of sediments and water in the lower St. Johns River and the Cedar-Ortega River Basin, which is linked to the northern-most section of the lower St. Johns River. In the 1980's and 1990's preliminary studies were conducted to obtain baseline data on environmental quality of the lower St. Johns River, and the Cedar-Ortega River Basin was identified as an area of particular concern. Therefore a detailed environmental assessment was initiated to obtain information concerning the sediment contamination and environmental quality of the Cedar-Ortega River Basin. This report presents the information obtained by this detailed environmental and contaminant assessment of the Cedar-Ortega rivers sediments. The information will be used to guide management efforts to protect and restore the basin's natural resources.

Methods

The scope of work included measuring trace organic and trace metal contaminants in sediments from 49 sites in the Cedar-Ortega River Basin (3 additional sites were characterized only for PCB). Optimized versions of the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (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 and Conclusions

This study is the most complete sediment quality assessment to date of the Cedar-Ortega River Basin and shows that the sediments were broadly contaminated with different parts of the Basin having clearly elevated concentrations of different contaminants, as compared to the rest of the lower St. Johns River and suitable environmental reference guidelines. Although lower contaminant concentrations were typically measured in the upper parts of the Ortega River and the mouth of the Cedar-Ortega River Basin at the confluence to the St. Johns River, the sediment contamination was wide spread. There were a large number of sites that had organic and metals contaminant concentrations that exceeded the

NOAA NS&T "high" reference value. The rate of exceedances were higher than those observed in broad-based national sediment monitoring studies for, particularly, PAH, PCB, DDT, chlordane, mercury, cadmium, lead, zinc, silver, tin, and copper. These exceedances were widespread, although some of the contaminants exceeded these reference values more frequently in samples collected from specific parts of the Cedar Ortega River Basin.

The sediment contaminant concentrations were also compared to effects-based sediment quality guideline values (e.g., freshwater TEC/PEC values and coastal sediment ERL/ERM values). TEC and ERL values represent lower, more conservative, concentrations above which ecological effects may occur, while PEC/ERM values represent higher concentrations above which effects are generally likely to be observed. Highlights of these comparisons were:

Organic Contaminants

- The freshwater PEC values for total PAH, PCB, DDT, and chlordane were exceeded at 1, 9, 0, and 9 of the 49 broadly characterized surface study sites, respectively. The marine/coastal ERM values were exceeded at 0, 29, 2, and 24 surface sediment sites for total PAH, PCB, DDT, and chlordane, respectively.
- The TEC values for total PAH, total PCB, total DDT, chlordane, and dieldrin were exceeded at 45, 44, 43, 35, and 13 surface sediment sites, respectively. The ERL concentrations for total PAH, total PCB, total DDT, chlordane, and dieldrin were exceeded at 29, 48, 47, 44, and 41 surface sediment sites, respectively, and up to 28 of the surface sediment sites exceeded the ERL value for individual PAH compounds.

Metals Contaminants

- The lead concentrations exceeded the freshwater PEC at 10 of the 49 surface sediment sites. The mercury and zinc concentrations exceeded the PEC at 6 and 7 surface sediment sites, respectively.
- The mercury concentrations exceeded the marine/coastal ERM at 23 sites. The zinc, lead, and silver concentrations exceeded the freshwater ERMs at 9, 4, and 2 of the surface sediment sites, respectively.
- There were TEC and ERL exceedances for arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and/or zinc at between two and 45 of the 49 surface sediment sites. Mercury, followed by lead, zinc, cadmium, copper, and chromium had the greatest combined number of TEC/ERL exceedances.

The Cedar-Ortega River Basin is clearly widely contaminated with different organic and metals contaminants, and within the Basin there are still locations with clearly elevated concentrations, compared to the rest of the Basin.

- The upper parts of the Cedar River had very high concentrations of PCB, and also significantly elevated concentrations of DDT and phthalates, and several metals (arsenic, lead, silver, and zinc). There was a sharp increase in the contaminant signals up the river, suggesting there is a significant source of these contaminants upstream of site CED01.

- The lower part of the Cedar River, where Butcher Pen Creek enters the river and near the confluence with the Ortega River (as represented by site CED09), had significantly elevated concentrations of PAH and selected pesticides (particularly chlordane).

- The small water body in which sites ORT33 and ORT31 are located, near where Fishweir Creek discharges, and close to the mouth of the Ortega River, had elevated concentrations of chlordane, PAH, DDT, phthalates, and selected metals (e.g., lead, silver, zinc), indicating the presence of a local source.

- Elevated contaminant concentrations, although to a lesser degree than the other three locations, were also measure at site ORT19, which is located on the north side of the river near the Roosevelt Blvd. railroad bridge. The slightly elevated concentrations of PAH, mercury, and copper, in combination with the relatively site-specific PAH composition, suggests there may be a small local source of contamination.

The areas around the Cedar-Ortega River Basin are clearly exerting significant influence on the contaminant concentrations in the sediments. Although much of the contamination may be historic, the data clearly suggest that there are significant current sources of contamination. The concentrations of PCB, PAH, some of the pesticides, and several metals are very high in these sediments, whether they are compared to the lower St. Johns River, other national monitoring programs, or widely used sediment quality guidelines. The PAH and PCB compound composition is also relatively unique in the Cedar-Ortega River Basin, suggesting there may be a fairly limited number of sources.

These sediments are of poor quality, from a chemical contaminant perspective, throughout the Cedar-Ortega River Basin and there appears to be a significant potential for adverse biological impact from the measured contaminants. Although it may be difficult to predict toxicity of the chemical contaminants in Cedar-Ortega River sediments because of the high concentrations of TOC present in most sediments, a preliminary analysis revealed that all but one of the surficial sediment samples may have been toxic to aquatic organisms. The sediments of the Cedar-Ortega River Basin are widely contaminated with a variety of organic and metal contaminants, and the results from this study suggest this is an area that warrants environmental action.

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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
ERL	Effects Range-Low
ERM	Effects Range-Median
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
HCl	Hydrochloric Acid
HMW	High Molecular Weight Polycyclic Aromatic Hydrocarbon
HPLC	High Performance Liquid Chromatography
ICP/MS	Inductively Coupled Plasma/Mass Spectroscopy
LCS	Laboratory Control Sample
LEL	Lowest Effect Level
LMW	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
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
TOC	Total Organic Carbon
TS	Total Solids
TVS	Total Volatile Solids

1. INTRODUCTION

1.1 Background

The St. Johns River Water Management District (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 SJRWMD comprises approximately 12,000 square miles in northeastern Florida, or about 21 percent of the state's total area. To facilitate the planning and management of surface water, the SJRWMD is divided into ten hydrologic units or surface water basins and the boundaries of these basins approximate drainage basins delineated by the U.S. Geological Survey basins (Figure 1-1). One of the ten surface water basins, the lower St. Johns River Basin, is located in northeast Florida and represents about 22 percent of the area within the boundaries of the SJRWMD (Figure 1-1; Nos. 3A – 3K).

The lower St. Johns River Basin (LSJRB) extends from the City of Deland, in the south, to Jacksonville, in the north, where the St. Johns River empties into the Atlantic Ocean. A generalized land use distribution of the area around the lower St. Johns River Basin is shown in Figure 1-2. The LSJRB includes Jacksonville, many smaller cities, and large tracts of agricultural and forestry land. The topography is generally low and flat, with surface elevations range from sea level up to 200 feet (61 meters) in the western part of the LSJRB.

The LSJRB is sub-divided into eleven hydrologic sub-basins or watersheds (Figure 1-1; Nos. 3A – 3K). One of the major tributaries to the lower St. Johns River Basin is the Cedar-Ortega River; identified as hydrologic unit No.3D, and is located in Jacksonville, Florida. The Cedar-Ortega River Basin comprises approximately 103 square miles in western Duval County, and includes the following five major tributaries:

- Cedar River (including Wills Branch and Williamson Creek)
- Butcher Pen Creek
- McGirts Creek
- Fishing Creek
- Fishweir Creek (including Big and Little Fishweir creeks)

The Cedar River is the largest tributary to the Ortega River and drains approximately 33 square miles of west Jacksonville. The Cedar river flows from northwest to southeast, extending approximately 5 km before converging with the north flowing Ortega River. The two merged rivers travel eastward another 3 km and drain into the St. Johns River.

The eastern portion of the Cedar-Ortega River Basin is highly urbanized with predominantly medium density residential and commercial development. Urban development in the remainder of the basin is much less concentrated, with residential development, open/forest land and wetlands being the predominant land uses (Camp, Dresser, and McKee, 1992). A generalized land use distribution in the lower parts of the Cedar-Ortega River Basin is shown in Figure 1-3. Cedar-Ortega River Basin has some of the most polluted tributaries in Duval County. Industrial and domestic point sources and urban runoff are major problems that have degraded these tributaries. In turn discharges from basin have resulted in negative impacts to the St. Johns River. The Cedar River, with at least 41 discharges, has the worst water quality in the area. Point sources include discharge and/or runoff from wire, chemical and paper industries along with domestic wastewater treatment plants. There have been state water quality violations involving low dissolved oxygen concentrations, high fecal coliform bacteria numbers, and high concentrations of ammonia and other toxic wastes (Campbell *et al.*, 1993).

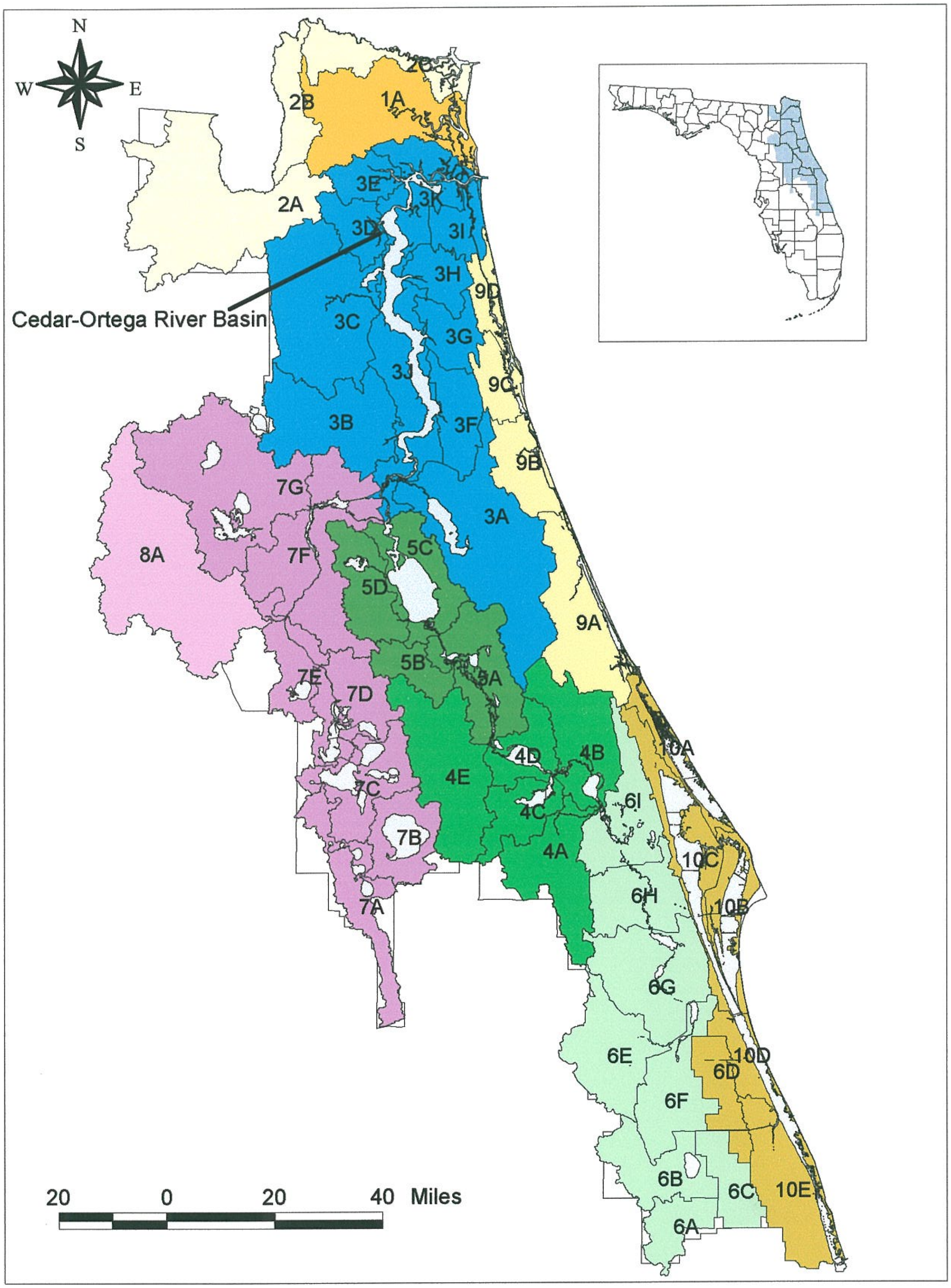

Figure 1-1. Hydrological Units in the St. Johns River Water Management District

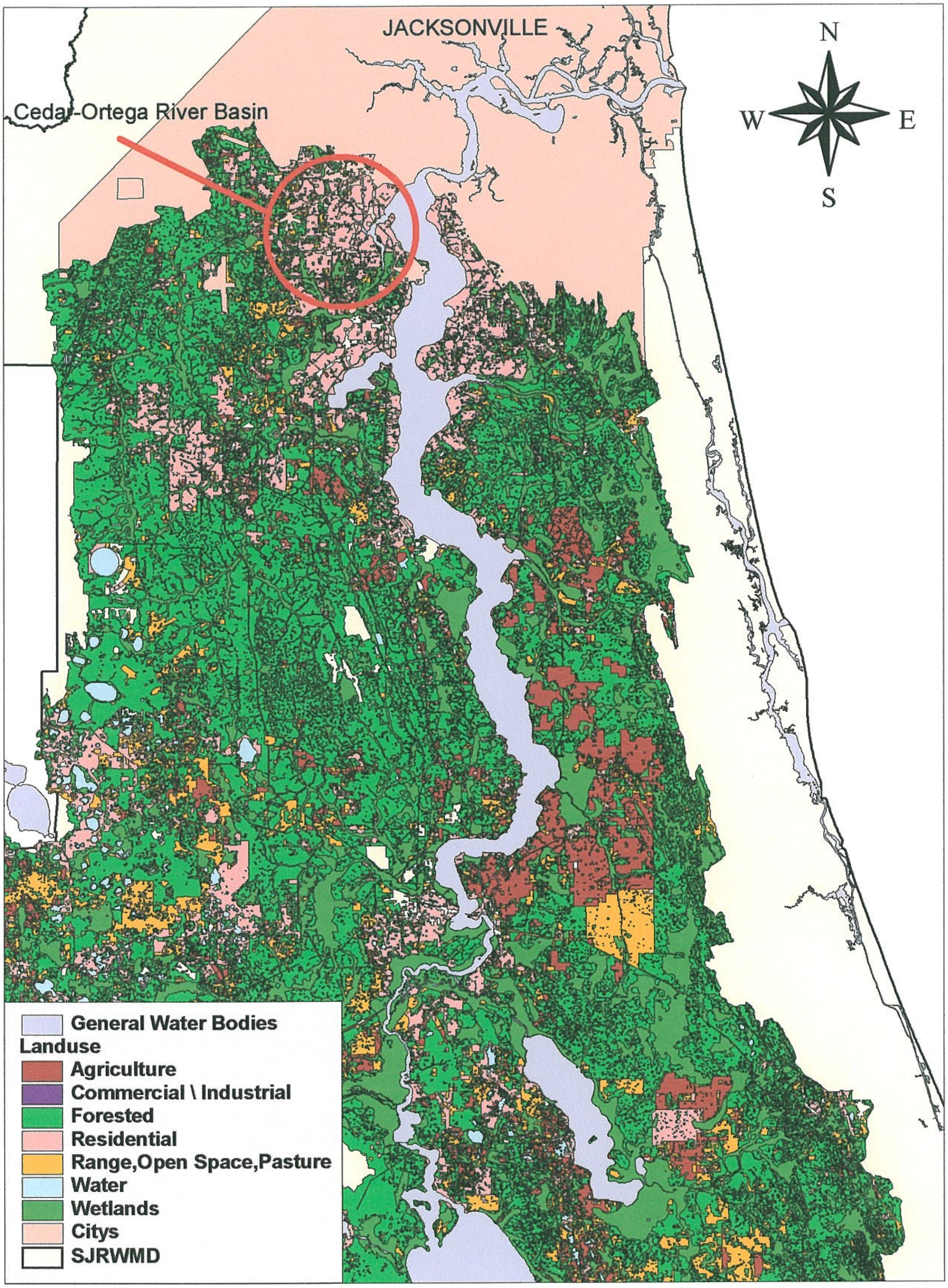

Figure 1-2. Land Uses Around the Lower St. Johns River and Cedar-Ortega River Basin

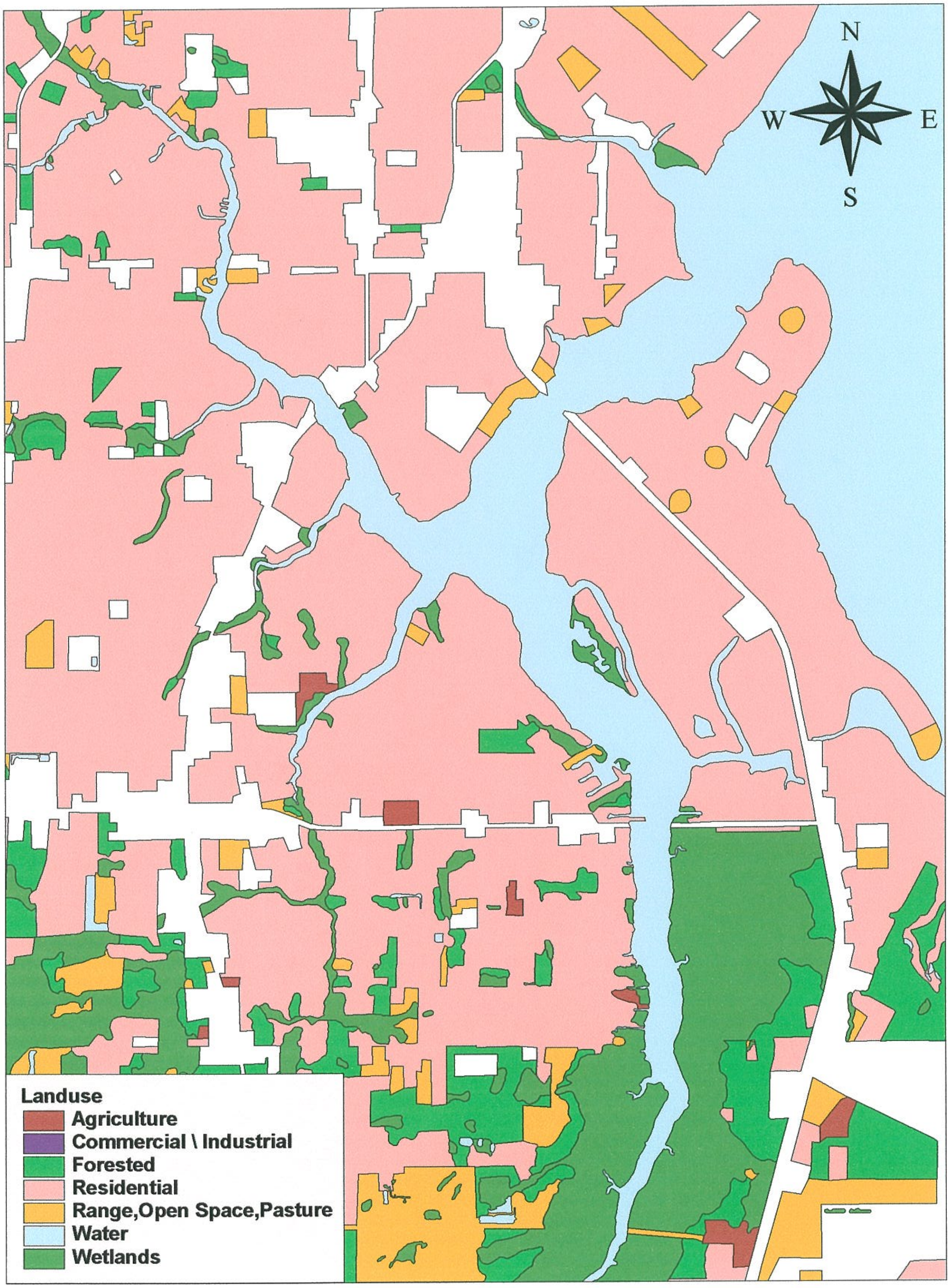

Figure 1-3. Land Uses Around the Lower Cedar-Ortega River Basin

The SJRWMD's original focus on flood control has broadened to include water supply protection, water quality protection, and environmental enhancement. In 1987, the SJRWMD was required by Florida Statute (Chap. 373.451-373.4595 F.S.) to develop and implement Surface Water Improvement and Management (SWIM) Plans for critical water bodies. To date, four water bodies have been identified for priority restoration and protection: the Indian River Lagoon, Lake Apopka, the Upper Ocklawaha River, and the lower St. Johns River. The SWIM Act required that a plan be developed to direct the restoration and improvement of the lower St. Johns River. The SWIM Plan for the lower St. Johns River (SJRWMD, 1993) has specific goals, including the restoration and protection of the health of the basin's natural systems and restoration of surface water quality to Class III or better standards. The program initiatives included monitoring of sediments for priority pollutants, including metals, hydrocarbons, pesticides and industrial chemicals known to be acutely or chronically toxic to organisms living in the river.

Restoration of the basin's water and natural systems requires knowledge of the characteristics of the river sediment. The lower St. Johns River sediments provide habitat for invertebrates and submerged aquatic vegetation, and colonization of the river bottom by plants and animals is, in part, determined by the physical-chemical characteristics of the sediments. The sediment characteristics also play an important role in determining where nutrients and contaminants become concentrated, because sediments accumulate and concentrate contaminants from the water column. 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 in sediment is therefore an essential component of an integrated and comprehensive environmental quality assessment. Assessment of the sediments for physical and chemical characteristics is needed to help provide critical information for understanding the environmental quality of the lower St. Johns, Cedar and Ortega rivers.

The St. Johns River has, because of its overall importance and potential for environmental damage, been the subject of several environmental studies. In the 1980's and 1990's preliminary studies were conducted to obtain baseline data on environmental quality of the lower St. Johns River (e.g., SJRWMD, 1993; SJRWMD, 1994), and it was identified as a water body needing particular management attention. It was soon recognized that the lower portions of the river were of particular concern (Dames and Moore, 1983; Shropp and Windom, 1987; Pierce *et al.*, 1988; FDER, 1988; Delfino *et al.*, 1991 and 1993). During these earlier investigations, the Cedar-Ortega River Basin was identified as a component of the northern-most lower St. Johns River system that had notable sediment contamination, and warranted further study. A recent study of the surface sediments in the lower St. Johns River and Cedar-Ortega River Basin (Battelle, 2004) confirmed that the Cedar-Ortega River Basin sediment contamination was of significant concern and warranted more detailed assessment.

1.2 Objectives

The project reported on in this document was conducted to better understand the sediment contamination and environmental quality of the Cedar-Ortega River Basin by performing detailed sampling and assessment of the sediments in the Basin. The primary objective of the project was to determine the presence, concentration, and distribution of potentially toxic organic compounds and metals. In addition, a preliminary assessment of the ecological implications of the measured contamination was made to guide management efforts to protect and restore the basin's natural resources.

The sediments of the lower St. Johns River have been identified as having elevated concentrations of selected organic (e.g., polycyclic aromatic hydrocarbons) and metals contaminants. In addition, the Cedar and Ortega River Basin was identified as an inadequately assessed water body with significant input to the lower St. Johns River. The Cedar Ortega River Basin had been identified as having elevated concentrations of a few identified contaminants, including polychlorinated biphenyls, but the contamination was poorly understood and other possible contaminants had not been well characterized. There was clearly a need for more thorough investigations to obtain a better understanding of the contaminant characteristics, including their magnitude and distribution.

Adverse environmental affects can potentially be observed with exposures to very low contaminant concentrations, and it was therefore critical that this sediment assessment program be performed using analytical procedures with very low limits of detection. Specialized, trace-level, analyte targeted, analytical protocols were therefore needed and applied in this project to detect subtle differences in contaminant loads at near-background concentrations.

1.3 Scope of Work

The SJRWMD staff developed an analytical program in which Battelle could assist the SJRWMD with the measurement and assessment of relevant organic and trace metal contaminants in sediments from waters of the Cedar Ortega River Basin.

Sediment sampling locations were selected and sampled by SJRWMD staff following appropriate procedures, as described in the methods section, 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 physical-chemical parameters identified as Ancillary Measurements.

The target contaminants and ancillary measures were selected based on the following considerations:

- Identification of the most important and persistent organic and metal contaminants found in sediments, as documented by major national monitoring programs conducted over the last 15 years [e.g., the U.S. EPA's Environmental Monitoring and Assessment Program (EMAP) and the National Oceanic and Atmospheric Administration's (NOAA) National Status and Trends Program (NS&T)]. In addition, selected contaminants were included based on the land use and industry characteristics of the area. Central to this theme was the selection of those organic compounds that 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-chemical parameters to aid in the interpretation of the contaminant data.

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 analyses of surface and sub-surface sediment samples collected at 52 Cedar-Ortega River sites. The report includes the following:

- Study background and objectives
- Listing of sampling locations and field sample collection methods
- The analytical methods, detection limits, and quality control program

- Analytical results of contaminant burdens by sampling location, in tabular and graphical form
- Analysis of relationships between contaminant burdens and sediment physiochemical composition
- Intercomparison of contaminant burdens among sampling sites
- A comparison of measured sediment burdens with sediment quality reference values as first-level indicators of possible risks that in-place contaminants might pose to the benthic ecological systems
- Preliminary assessment of potential ecological implications of the measured contamination
- Conclusions and recommendations

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 [b]		
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

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.)		
α-Chlordane	0.08	8081M
γ-Chlordane	0.07	8081M
Oxychlordane	0.1	8081M
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
Organic Compounds – Chlorinated Phenolics		
2-Chlorophenol	4.27	8321M
2,4-Dichlorophenol	4.78	8321M
2,6-Dichlorophenol	4.77	8321M
2,4,5-Trichlorophenol	2.59	8321M
2,4,6-Trichlorophenol	4.13	8321M
2,3,4,5-Tetrachlorophenol	8.96	8321M
2,3,4,6-Tetrachlorophenol	4.45	8321M
Pentachlorophenol	23.4	8321M
4-Chloro-3-methylphenol	7.17	8321M
2-Chloroanisole	5.16	8321M
2,4-Dichloroanisole	4.79	8321M
Pentachloroanisole	5.13	8321M
4,5-Dichloroguaiacol	4.40	8321M
3,4,5-Trichloroguaiacol	4.25	8321M
3,4,6-Trichloroguaiacol	5.33	8321M
4,5,6-Trichloroguaiacol	7.20	8321M
Tetrachloroguaiacol	11.8	8321M
4-Chlorocatechol	69.3	8321M
3,5-Dichlorocatechol	32.7	8321M
4,5-Dichlorocatechol	39.3	8321M
3,4,5-Trichlorocatechol	48.3	8321M
3,4,6-Trichlorocatechol	43.0	8321M
Tetrachlorocatechol	10.8	8321M

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

TARGET ANALYTE	Sediment MDL (mg/kg, dry weight)	Analysis Method [a]
Metals		
Aluminum (Al)	14.3 / 5.50	200.8M / 200.7
Antimony (Sb)	0.078	200.8M
Arsenic (As)	1.03	200.9M
Berylium (Be)	0.106	200.8M
Cadmium (Cd)	0.074	200.8M
Chromium (Cr)	1.0	200.8M
Cobalt (Co)	0.171	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
Thallium (Tl)	0.084	200.8M
Tin (Sn)	0.056	200.8M
Vanadium (V)	0.968	200.8M
Zinc (Zn)	3.26	200.8M
Elutriate Water Measurements		
Calcium (Ca)	0.1 µg/L	6010M
Magnesium (Mg)	0.5 µg/L	6010M
Potassium (K)	75 µg/L	6010M
Sodium (Na)	5 µg/L	6010M
Conductivity	1 µmhos/cm	9050M
Ancillary Measurements		
Total Organic Carbon (TOC)	0.01 % (dry weight)	
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)
8321M: High-performance liquid chromatography/ultra-violet detection (HPLC/UV)
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)
6010M: Inductively coupled plasma/atomic emission spectroscopy (ICP/AES)

[b] Selected samples were also analyzed by Method 8270M for the determination of 107 discrete PCB congeners, in a separate detailed PCB characterization analysis. The listing of these congeners can be found with the detailed PCB congener data in Appendix D.

2. TECHNICAL APPROACH

2.1 Site Selection

A total of 52 study sites, selected from the Cedar and Ortega River Basin (COR) and analytically assessed for sediment quality and contamination, are included in this report. Twelve (12) of these study sites are located in the lower Cedar River (CED) and 40 study sites represent the Ortega River (ORT) and the lower Basin. These study sites were selected and sampled during two sediment contaminant sampling and assessment activities in 1998 and 1999.

The study sites were selected following the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) probability based sampling design protocol (Hyland *et. al.*, 1996). The location of the Cedar-Ortega River Basin study area, relative to the lower St. Johns River, is shown in Figure 2-1. The specific locations of the 52 study sites are shown in Figure 2-2. Additional site maps are presented in Appendix A, along with information on population density, physiography, and geology.

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. A total of 52 sites were sampled, with surface sediment collected at each of these locations. Surface sediment only was collected at eight sites and sediment cores were collected at the other 44 sites. PCB was the only contaminant determined for three of the eight surface sediment sites (CED12, CED13, and CED14); the other 49 sites (44 core sites and 5 surface sediment sites) were sampled for broad-based chemical analysis and sediment characterization.

Three sediment grabs were collected at the sites that were sampled for surface-sediment only, consistent with the LSJR surface sediment monitoring protocol. A single sediment core was collected from the core sites. The three surface sediment site replicates (i.e., the surface sediment grabs) were placed in separate glass jars, and samples were chilled and shipped to the laboratory. At the laboratory, the sediment was mixed thoroughly and the individual site replicates were analyzed separately. Two of the replicates were analyzed, and the third was archived. The sediment core samples were obtained with a piston-core sampler, and replicate cores were not collected since these study sites were in close proximity to each other.

The sediment samples were collected during different sampling periods in 1998 and 1999. Quality Assurance/Quality Control procedures in compliance with the SJRWMD's Comprehensive Quality Assurance Plan (CompQAP) were followed. 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). A listing of the samples that were collected and analyzed for this study is presented in Table 2-1. This table includes an identification of the site, each individual sample that was generated and analyzed, the position of the site, the type of sample site (surface sediment only or sediment core), and the sediment depth that the sample represented. Three samples were generated for laboratory analysis from most sediment cores; two samples were generated from a few and four samples from one core, as indicated in Table 2-1.

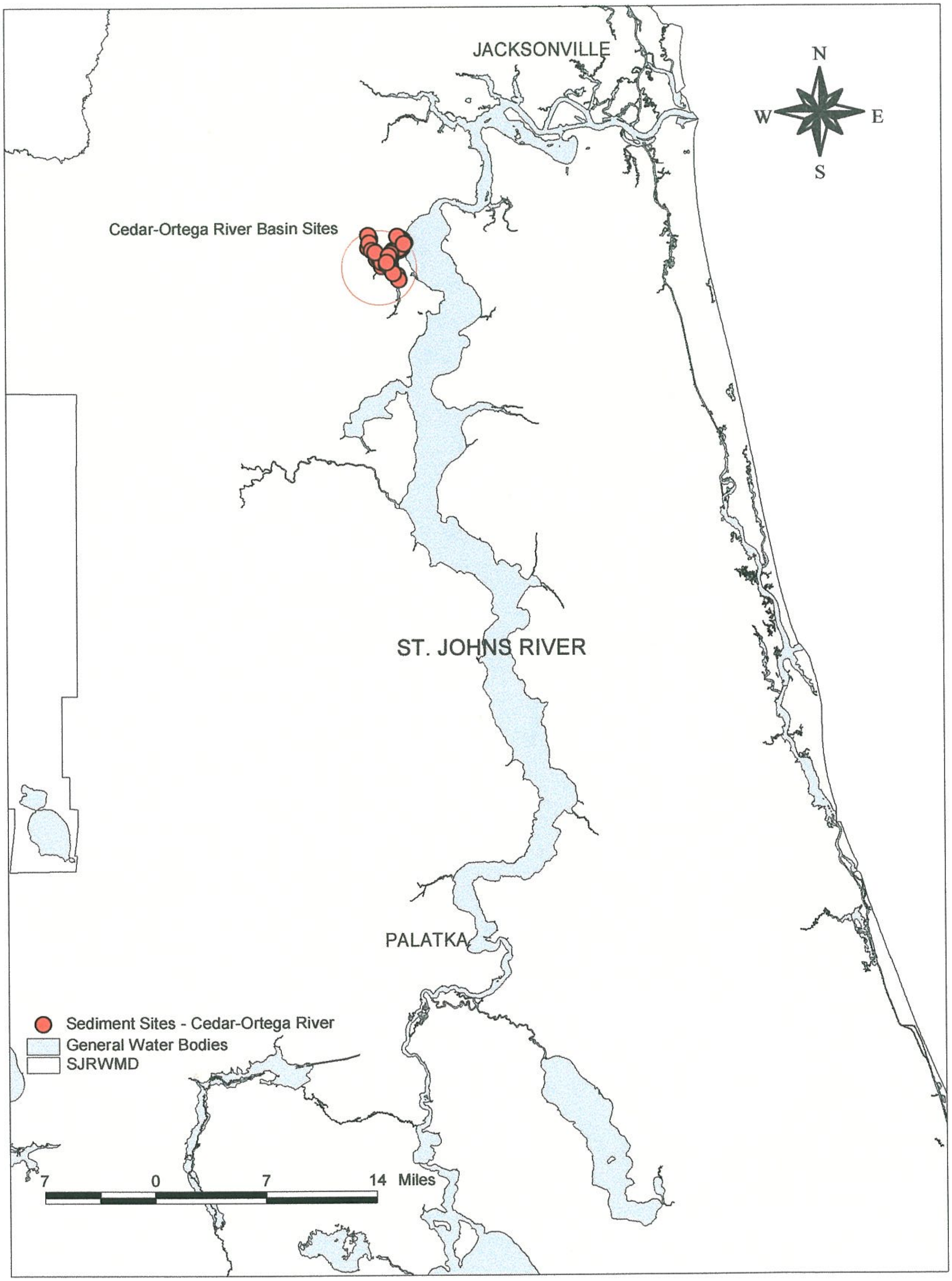

Figure 2-1. Location of the Cedar-Ortega River Basin Study Area Relative to the Lower St. Johns River

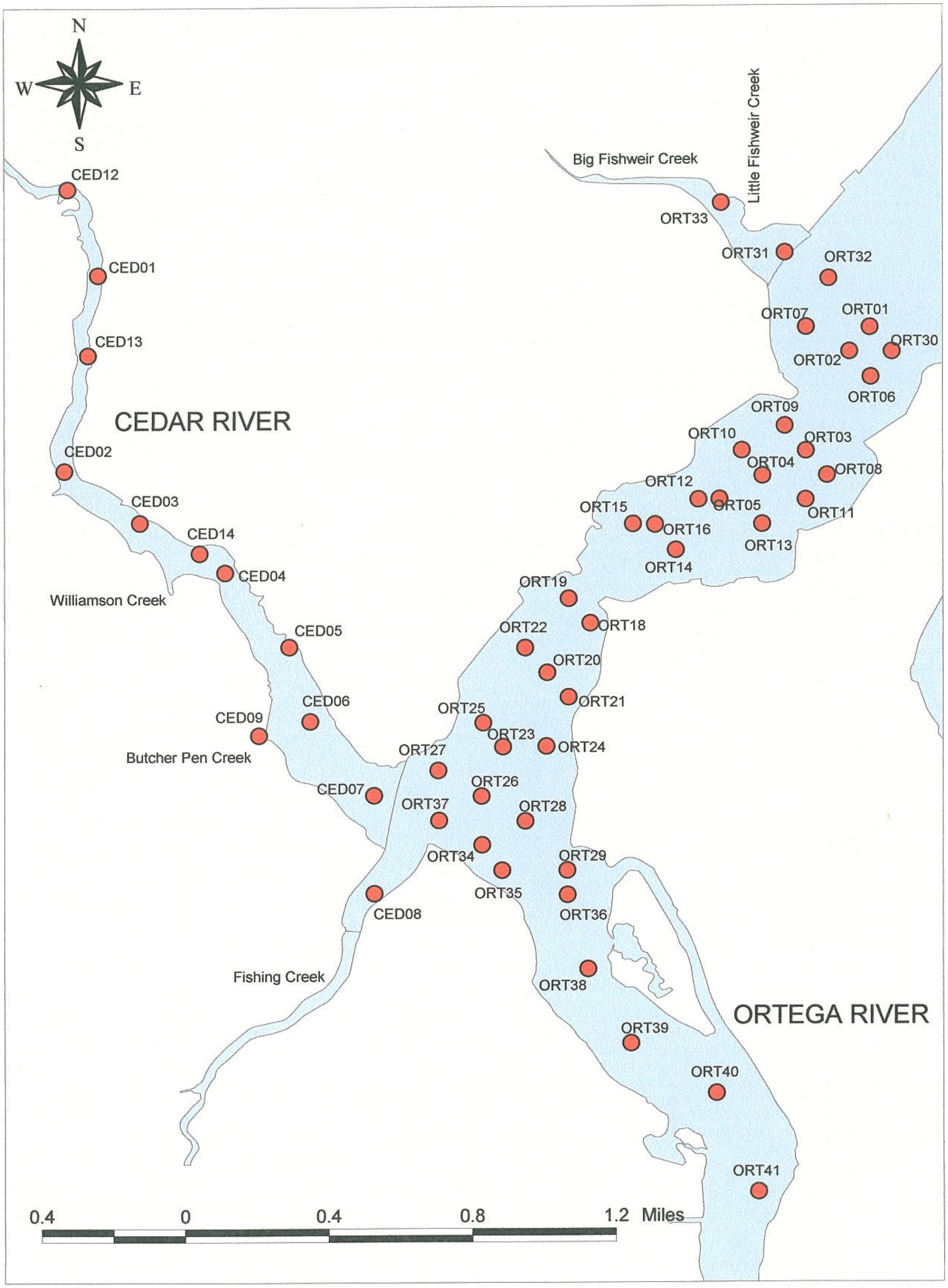

Figure 2-2. Locations of the 52 Cedar-Ortega River Basin Sampling Sites

Table 2-1. Samples Collected, Sampling Locations, and Sediment Depths Samples Represent

Sample ID Information		Location		Sample Type	Depth Sample Represents (cm)		
Site and Core Segment for Non-Surface	Field ID	LAT	LONG		From	To	Center
CED01	LSJ98SCED01SA	301710.469	814423.438	Core	0	10.5	5.25
CED01-M	LSJ98SCED01MA	301710.469	814423.438	Core	36	46	41
CED02	LSJ98SCED02SA	301641.906	814428.875	Surface	0	23	11.5
CED03	LSJ98SCED03SA	301634.406	814416.125	Core	0	6	3
CED03-M	LSJ98SCED03MA	301634.406	814416.125	Core	6	19	12.5
CED03-L	LSJ98SCED03LA	301634.406	814416.125	Core	21	37	29
CED04	LSJ98SCED04SA	301627.219	814401.750	Core	0	9	4.5
CED04-M	LSJ98SCED04MA	301627.219	814401.750	Core	12	28	20
CED04-L	LSJ98SCED04LA	301627.219	814401.750	Core	71	82	76.5
CED05	LSJ98SCED05SA	301616.438	814350.938	Surface	0	5	2.5
CED06	LSJ98SCED06SA	301605.625	814347.312	Core	0	9	4.5
CED06-M	LSJ98SCED06MA	301605.625	814347.312	Core	33	49	41
CED06-L	LSJ98SCED06LA	301605.625	814347.312	Core	84	99	91.5
CED07	LSJ98SCED07SA	301554.860	814336.594	Core	0	9	4.5
CED07-M	LSJ98SCED07MA	301554.860	814336.594	Core	21	29	25
CED07-L	LSJ98SCED07LA	301554.860	814336.594	Core	91	107	99
CED08	LSJ98SCED08SA	301540.562	814336.438	Core	0	13	6.5
CED08-M	LSJ98SCED08MA	301540.562	814336.438	Core	13	32	22.5
CED09	LSJ98SCED09SA	301603.531	814355.938	Core	0	18	9
CED09-M	LSJ98SCED09MA	301603.531	814355.938	Core	19	26	22.5
CED12	LSJ99SCED12D	301722.906	814428.562	Surface	0	10	5
CED13	LSJ99SCED13D	301658.781	814425.000	Surface	0	10	5
CED14	LSJ99SCED14D	301630.000	814406.062	Surface	0	10	5
ORT01	LSJ98SORT01SA	301703.219	814213.812	Core	0	20	10
ORT01-M	LSJ98SORT01MA	301703.219	814213.812	Core	27	37	32
ORT01-L	LSJ98SORT01LA	301703.219	814213.812	Core	97	105	101
ORT02	LSJ98SORT02SA	301659.688	814217.312	Core	0	9	4.5
ORT02-M	LSJ98SORT02MA	301659.688	814217.312	Core	11	21	16
ORT02-L	LSJ98SORT02LA	301659.688	814217.312	Core	67	78	72.5
ORT03	LSJ98SORT03SA	301645.219	814224.500	Core	0	8	4
ORT03-M	LSJ98SORT03MA	301645.219	814224.500	Core	23	32	27.5
ORT03-L	LSJ98SORT03LA	301645.219	814224.500	Core	107	116	111.5
ORT04	LSJ98SORT04SA	301641.594	814231.688	Core	0	8	4
ORT04-M	LSJ98SORT04MA	301641.594	814231.688	Core	10	22	16
ORT04-L	LSJ98SORT04LA	301641.594	814231.688	Core	49	61	55
ORT04-1	LSJ99SORT041SB	301641.562	814231.781	Core	0	7.5	3.75
ORT04-1-M	LSJ99SORT041MB	301641.562	814231.781	Core	9.5	17.5	13.5
ORT04-1-C	LSJ99SORT041CB	301641.562	814231.781	Core	29.5	39.5	34.5
ORT04-1-L	LSJ99SORT041LB	301641.562	814231.781	Core	92	102.5	97.25
ORT05	LSJ98SORT05SA	301638.125	814238.938	Core	0	10	5
ORT05-M	LSJ98SORT05MA	301638.125	814238.938	Core	45	55	50
ORT05-L	LSJ98SORT05LA	301638.125	814238.938	Core	125	135	130
ORT06	LSJ98SORT06SA	301656.063	814213.813	Core	0	8.5	4.25
ORT06-M	LSJ98SORT06MA	301656.063	814213.813	Core	26	87.5	56.75
ORT06-L	LSJ98SORT06LA	301656.063	814213.813	Core	108	117	112.5
ORT07	LSJ98SORT07SA	301703.250	814224.562	Core	0	7	3.5
ORT07-M	LSJ98SORT07MA	301703.250	814224.562	Core	8	19	13.5
ORT07-L	LSJ98SORT07LA	301703.250	814224.562	Core	30	44	37
ORT08	LSJ98SORT08SA	301641.719	814220.875	Core	0	12	6

Sample ID Information		Location		Sample Type	Depth Sample Represents (cm)		
Site and Core Segment for Non-Surface	Field ID	LAT	LONG		From	To	Center
ORT08-M	LSJ98SORT08MA	301641.719	814220.875	Core	42	58	50
ORT08-L	LSJ98SORT08LA	301641.719	814220.875	Core	182	194	188
ORT09	LSJ98SORT09SA	301648.844	814228.000	Core	0	8	4
ORT09-M	LSJ98SORT09MA	301648.844	814228.000	Core	26	36	31
ORT09-L	LSJ98SORT09LA	301648.844	814228.000	Core	122	130	126
ORT10	LSJ98SORT10SA	301645.250	814235.250	Core	0	8	4
ORT10-M	LSJ98SORT10MA	301645.250	814235.250	Core	24	34	29
ORT10-L	LSJ98SORT10LA	301645.250	814235.250	Core	125	132	128.5
ORT11	LSJ98SORT11SA	301638.094	814224.500	Core	0	11	5.5
ORT11-M	LSJ98SORT11MA	301638.094	814224.500	Core	31	43	37
ORT11-L	LSJ98SORT11LA	301638.094	814224.500	Core	113	127	120
ORT12	LSJ98SORT12SA	301638.062	814242.438	Core	0	15	7.5
ORT12-M	LSJ98SORT12MA	301638.062	814242.438	Core	32	47	39.5
ORT12-L	LSJ98SORT12LA	301638.062	814242.438	Core	113	130	121.5
ORT13	LSJ98SORT13SA	301634.531	814231.750	Core	0	7	3.5
ORT13-M	LSJ98SORT13MA	301634.531	814231.750	Core	20	30	25
ORT13-L	LSJ98SORT13LA	301634.531	814231.750	Core	126	138	132
ORT14	LSJ98SORT14SA	301630.750	814246.188	Core	0	9	4.5
ORT14-M	LSJ98SORT14MA	301630.750	814246.188	Core	23	38	30.5
ORT14-L	LSJ98SORT14LA	301630.750	814246.188	Core	73	86	79.5
ORT15	LSJ98SORT15SA	301634.531	814253.375	Core	0	14	7
ORT15-M	LSJ98SORT15MA	301634.531	814253.375	Core	29	44	36.5
ORT15-L	LSJ98SORT15LA	301634.531	814253.375	Core	86	99	92.5
ORT16	LSJ98SORT16SA	301634.438	814249.688	Core	0	11	5.5
ORT16-M	LSJ98SORT16MA	301634.438	814249.688	Core	12	27	19.5
ORT16-L	LSJ98SORT16LA	301634.438	814249.688	Core	101	116	108.5
ORT18	LSJ98SORT18SA	301620.094	814300.438	Core	0	9	4.5
ORT18-M	LSJ98SORT18MA	301620.094	814300.438	Core	9	21	15
ORT18-L	LSJ98SORT18LA	301620.094	814300.438	Core	80	94	87
ORT19	LSJ98SORT19A	301623.656	814304.125	Surface	0	10	5
ORT20	LSJ98SORT20SA	301612.875	814307.625	Core	0	9	4.5
ORT20-M	LSJ98SORT20MA	301612.875	814307.625	Core	10	25	17.5
ORT20-L	LSJ98SORT20LA	301612.875	814307.625	Core	66	79	72.5
ORT21	LSJ98SORT21SA	301609.312	814304.062	Core	0	13	6.5
ORT21-M	LSJ98SORT21MA	301609.312	814304.062	Core	28	37	32.5
ORT21-L	LSJ98SORT21LA	301609.312	814304.062	Core	78	89	83.5
ORT22	LSJ98SORT22A	301616.438	814311.375	Surface	0	10	5
ORT23	LSJ98SORT23SA	301602.031	814315.000	Core	0	10	5
ORT23-M	LSJ98SORT23MA	301602.031	814315.000	Core	23	32	27.5
ORT23-L	LSJ98SORT23LA	301602.031	814315.000	Core	91	103	97
ORT24	LSJ98SORT24SA	301602.125	814307.750	Core	0	13	6.5
ORT24-M	LSJ98SORT24MA	301602.125	814307.750	Core	37	47	42
ORT24-L	LSJ98SORT24LA	301602.125	814307.750	Core	107	116	111.5
ORT25	LSJ98SORT25SA	301605.531	814318.375	Core	0	12	6
ORT25-M	LSJ98SORT25MA	301605.531	814318.375	Core	31	40	35.5
ORT25-L	LSJ98SORT25LA	301605.531	814318.375	Core	132	140	136
ORT26	LSJ98SORT26SA	301554.812	814318.562	Core	0	10	5
ORT26-M	LSJ98SORT26MA	301554.812	814318.562	Core	24	33	28.5
ORT26-L	LSJ98SORT26LA	301554.812	814318.562	Core	94	104	99
ORT27	LSJ98SORT27SA	301558.562	814325.875	Core	0	10	5
ORT27-M	LSJ98SORT27MA	301558.562	814325.875	Core	12	22	17

Sample ID Information		Location		Sample Type	Depth Sample Represents (cm)		
Site and Core Segment for Non-Surface	Field ID	LAT	LONG		From	To	Center
ORT27-L	LSJ98SORT27LA	301558.562	814325.875	Core	47	55	51
ORT28	LSJ98SORT28SA	301551.219	814311.188	Core	0	12	6
ORT28-M	LSJ98SORT28MA	301551.219	814311.188	Core	51	61	56
ORT28-L	LSJ98SORT28LA	301551.219	814311.188	Core	117	128	122.5
ORT29	LSJ98SORT29SA	301544.062	814304.125	Core	0	8	4
ORT29-M	LSJ98SORT29MA	301544.062	814304.125	Core	28	42	35
ORT29-L	LSJ98SORT29LA	301544.062	814304.125	Core	156	166	161
ORT30	LSJ98SORT30SA	301659.719	814210.125	Core	0	8	4
ORT30-M	LSJ98SORT30MA	301659.719	814210.125	Core	49	59	54
ORT30-L	LSJ98SORT30LA	301659.719	814210.125	Core	81	90	85.5
ORT31	LSJ98SORT31SA	301714.031	814228.188	Core	0	10	5
ORT31-M	LSJ98SORT31MA	301714.031	814228.188	Core	36	45	40.5
ORT31-L	LSJ98SORT31LA	301714.031	814228.188	Core	82	89	85.5
ORT32	LSJ98SORT32SA	301710.344	814220.812	Core	0	17	8.5
ORT32-M	LSJ98SORT32MA	301710.344	814220.812	Core	35	46	40.5
ORT32-L	LSJ98SORT32LA	301710.344	814220.812	Core	89	100	94.5
ORT33	LSJ98SORT33A	301721.250	814238.938	Surface	0	10	5
ORT34	LSJ98SORT34SA	301547.688	814318.438	Core	0	8	4
ORT34-M	LSJ98SORT34MA	301547.688	814318.438	Core	13	27	20
ORT35	LSJ98SORT35SA	301544.031	814315.000	Core	0	16	8
ORT35-M	LSJ98SORT35MA	301544.031	814315.000	Core	16	28	22
ORT35-L	LSJ98SORT35LA	301544.031	814315.000	Core	53	69	61
ORT36	LSJ98SORT36SA	301540.500	814304.062	Core	0	12	6
ORT36-M	LSJ98SORT36MA	301540.500	814304.062	Core	29	38	33.5
ORT36-L	LSJ98SORT36LA	301540.500	814304.062	Core	99	109	104
ORT37	LSJ98SORT37SA	301551.250	814325.625	Core	0	10	5
ORT37-M	LSJ98SORT37MA	301551.250	814325.625	Core	59	69	64
ORT37-L	LSJ98SORT37LA	301551.250	814325.625	Core	96	106	101
ORT38	LSJ98SORT38SA	301529.688	814300.500	Core	0	11	5.5
ORT38-M	LSJ98SORT38MA	301529.688	814300.500	Core	11	22	16.5
ORT39	LSJ98SORT391SA	301518.813	814253.281	Core	0	14	7
ORT39-M	LSJ98SORT391MA	301518.813	814253.281	Core	19.5	33	26.25
ORT39-L	LSJ98SORT391LA	301518.813	814253.281	Core	75	87	81
ORT40	LSJ98SORT40SA	301511.625	814238.875	Core	0	6	3
ORT40-M	LSJ98SORT40MA	301511.625	814238.875	Core	37	46	41.5
ORT40-L	LSJ98SORT40LA	301511.625	814238.875	Core	92	100	96
ORT41	LSJ98SORT41SA	301457.219	814231.750	Core	0	3	1.5
ORT41-M	LSJ98SORT41MA	301457.219	814231.750	Core	6	14	10
ORT41-L	LSJ98SORT41LA	301457.219	814231.750	Core	46	58	52

2.2.1 Sample Collection Containers

Battelle provided 500 mL certified trace-level pre-cleaned glass jars with Teflon lined caps for samples collected for organic compound and metal analysis. Battelle was responsible for obtaining and shipping these containers, which had been cleaned in a manner that was consistent with the organic and metal contaminant analyses, to the SJRWMD.

2.2.2 Sample Collection Equipment

SJRWMD staff used Global Positioning System (GPS) equipment to locate to pre-selected sample study sites, and to record the position of the actual sample site as the sediment samples were collected. Surface sediment samples were obtained using pre-cleaned stainless steel petite Ponar dredges. 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 staff in accordance with the CompQAP.

A piston-core sampler was used for the collection of the sediment cores in the Cedar-Ortega River Basin. Pre-cleaned materials and equipment were used in the collection of the samples. The procedures followed by SJRWMD staff for the decontamination of the Lexan core liners/tubes, pistons, glass trays, and stainless steel spoons were in accordance with the CompQAP.

2.2.3 Sample Collection Procedures

Sediment collection procedures at the 52 sites involved using a SJRWMD boat. Pre-determined EMAP study site coordinates were entered into the GPS equipment and used to navigate to the sample collection site. Upon arrival at the site, a petite Ponar dredge was used for the surface sediment grab sampling. SJRWMD staff employed the following protocol for dredge usage and sediment collection:

Surface Sediment

1. Unwrapped aluminum foil from the pre-cleaned dredge, stainless steel spoon and glass tray.
2. Pre-rinsed the dredge, stainless steel spoon and glass tray with 2-propanol and deionized water.
3. Lowered the dredge into the water body until it reached the sediment. If needed, a messenger was sent down the line to trip the spring mechanism and close the jaws of the dredge.
4. Retrieved the sample and insured sample integrity and quality (e.g. grab-jaws completely closed, no sample wash-out).
5. Deposited the entire sample into a glass mixing tray.
6. Logged the position using the GPS equipment and recorded the water temperature.
7. Used a stainless steel spoon to carefully remove exterior sediment that had come into contact with the dredge jaws, sides or top. Rinsed the excess sediment from the stainless steel spoon, and then rinsed again with 2-propanol and deionized water. Selected and scooped the sample from the sediment remaining in the glass tray.
8. Promptly transferred the sediment sample into the appropriate pre-cleaned glass jar to prevent oxidation of metal ions or volatilization of organic compounds from the sample.
9. Stored the samples immediately in a cooler with wet ice. Adhered to FDEP and EPA sample handling, storage, and holding times, which obviates the need for chemical preservatives (Table 2-1).
10. Repeated this sequence for the second and third site replicate sediment sample.

Successive site replicate sediment samples were collected only after the sampling equipment was pre-cleaned following Standard Operating Procedures (SOP) for field cleaning of equipment. Field cleaning procedures included washing the dredge, stainless steel spoon, and glass tray and rinsing with deionized water, and then reagent grade 2-propanol and additional deionized water. The sample containers were filled nearly to capacity at each site and immediately placed into a cooler with wet ice. Sample collection and shipment was coordinated with the analytical laboratory (Battelle) to ensure that sample holding times were not exceeded (Table 2-2). The preservation and holding times of sediment samples for laboratory analysis followed Florida Department of Environmental Protection (FDEP) SOPs.

Table 2-2. Sediment Sample Storage and 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 Organic Carbon	Cool at 4°C	28 days

Subsurface Sediment

Subsurface sediment samples were collected using piston-core samplers, following the design by Livingstone (1955) and as modified by Fisher *et al.* (1992), to obtain undisturbed sediment samples. SJRWMD staff used a new 7.6 cm outer-diameter cellulose butyrate ("Lexan") tube for the piston-core barrel at each core sample collection location. No Lexan core tube was re-used for these trace chemical core sample collections. In addition, new pre-cleaned pistons were used for each core sample to ensure sample integrity. A clean cable was connected to the piston and then attached to the SJRWMD vessel to immobilize the piston. As the Lexan core penetrated sediment, the stationary piston created a partial vacuum and allowed soft flocculent sediment to be collected undisturbed.

Additional Lexan tubes were split lengthwise and thoroughly cleaned. These split Lexan tubes or "trays" were used to catch and retain the sediment core sample as it was extruded from the original piston-core barrel. Stainless steel spoons were used to scoop the sediment samples from these Lexan trays into pre-labeled sample collection containers.

Piston-core Sampling

1. Remove a new Lexan core barrel from wrapping sleeve.
2. Rinse the new Lexan core barrel with reagent grade 2-propanol and D.I. water.
3. Attach the core handle and insert a new, pre-cleaned piston, positioning piston inside the Lexan core barrel with the clean cable running from the piston, up the inside of the core barrel, and out the handle of the device.
4. Check depth with the Fathometer on the vessel and lowered the coring device to approximately 10 cm above the sediment surface.
5. Secure the cable attached to the piston to the vessel, to immobilize the piston.
6. Force and/or drive the piston core barrel into the sediment until insurmountable resistance is met.
7. Log the position using the GPS equipment, and record the water temperature, conductivity and salinity approximately 0.2 m beneath the water surface and 0.2 meters above the river bottom.
8. Retrieve the coring device and cap the bottom to prevent sample loss.
9. Detach the cable from the piston, and leaving the piston in place cap the top of the core barrel.
10. Measure the total sediment thickness of the core from top to bottom, and measure to any distinct layer observable through the Lexan core barrel. Measure the thickness of the flocculent layer and the total thickness of the black-organic rich surface sediments.
11. Stow the Lexan piston core barrel in an upright position aboard the vessel and maintain this upright position through the return trip.
12. Upon return at the end of the sampling day, transfer all piston core barrels to a walk-in cooler.
13. Store the piston core barrels inside the walk-in cooler in an upright position until extruded for sample extraction.

Piston-core Extraction

1. Remove piston core barrel from the walk-in cooler.
2. Re-measure the total sediment thickness of the core from top to bottom, overlying water and thickness of the flocculent layer.
3. Remove piston and siphon off any overlying water.
4. Using a pre-cleaned ramrod, carefully extrude the sediment core from the piston core barrel onto a clean Lexan tray.
5. Carefully split the extruded sediment core length-wise, and record the stratigraphy by measuring and describing the thickness of layers and the sediment heterogeneity.
6. Using a pre-cleaned stainless steel spoon, select sediment samples from within a homogeneous sediment layer for laboratory analysis and remove sample from the interior of the core. Avoid sampling sediment that may have been in contact with the piston or core barrel sides.
7. Promptly transfer sediment sample to the pre-cleaned glass jar in order to prevent oxidation of metal ions or volatilization of organic compounds from the sample.
8. Measure and record the "depth" down-core from which the sediment sample was taken.
9. Store the samples immediately in a cooler at 25 degrees C. using no chemical preservative.
10. Repeat this sequence, selecting underlying sediment from within homogeneous sediment layers for additional sediment samples.

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

2.3 Laboratory Sample Analysis Procedures

Selection of Analytical Parameters

The sediment samples were analyzed for a series of organic and trace metal contaminants, and various physical and chemical ancillary measures to support the study objectives. The analytical parameters, and the associated method detection limits (MDLs), are listed in Table 1-1. This target analyte list was developed by SJRWMD staff and includes most of the applicable contaminants from NOAA National Status &Trends (NS&T), EPA Environmental Monitoring Assessment Program (EMAP), as well as EPA's priority pollutant list, except for some polar organic compounds that do not readily accumulate in sediment or biota. All base contaminants (i.e., those listed in Table 1-1 *except* the chlorophenols) were determined in samples collected from the 49 sites primary sites; chlorophenols were also measured in surface sediment samples from 16 of these sites. PCBs only were determined in the samples from 3 sites; CED12, CED13, and CED14. A separate extended PCB congener analyte list (107 individual PCB congeners; Appendix C) was measured in selected surface and sub-surface sediment samples, to better characterize the PCB contamination. This extended set of PCB congeners represents the range of PCB contamination typically found in the environment, and comprises about 95-98% of the total PCB in most environmental samples.

This SJRWMD sediment monitoring list included all the important 2-, 3-, 4-, and 5- ring polycyclic aromatic hydrocarbons (PAH). Alkylated PAHs (e.g., methylated naphthalene and phenanthrene) were included to provide more complete data on the type of PAH contamination and assist in the identification of petrogenic contamination. Polychlorinated biphenyls (PCBs, as individual congeners) were included as target variables because these remain ubiquitous and environmentally important compounds. Several other persistent and environmentally relevant chlorinated pesticides were also included (e.g., δ-BHC, γ-BHC (lindane), methoxychlor, trans-nonachlor, chlorpyriphos, α-chlordane, and γ-chlordane) to improve the representation of each contaminant group. Chlorinated phenolic compounds (e.g., phenols, anisoles, catechols, and guaiacols) were included as environmentally relevant compounds as they are potentially related to specific industrial activities in the area.

The contaminants determined in this project include the key 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 NS&T 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 programs being conducted by national agencies (e.g., the NS&T program, the EMAP program, and the USACE dredged material assessment projects).

Selection of Analytical Methods

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. By 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 ERL and ERM 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 was needed to achieve the method performance goals required for the desired environmental quality monitoring.

Achieving meaningful detection limits for organic and trace metal contaminants for environmental quality monitoring has been of special concern to the NOAA and the U.S. EPA. Through the NOAA NS&T Program and the EPA EMAP Program, a set of analytical methods have been developed specifically to meet the low detection limit requirements necessary for successful environmental quality monitoring. Developed over the last 10 years, these methods are modifications and improvements on 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 NS&T Program, by EPA in the 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* ("Yellow Book"). The methods are also used in components of 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 analytical methods have been published in a NOAA Technical Memorandum in which Battelle scientists were principal authors (NOAA, 1998; 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) ensures 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). A large suite of chlorinated phenolic compounds was analyzed by modified EPA Method 8321, which had been optimized for the target compounds. Battelle obtained FDEP approval for the application of these specialized methods, which have been incorporated into Battelle's FDEP CompQAP. 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.

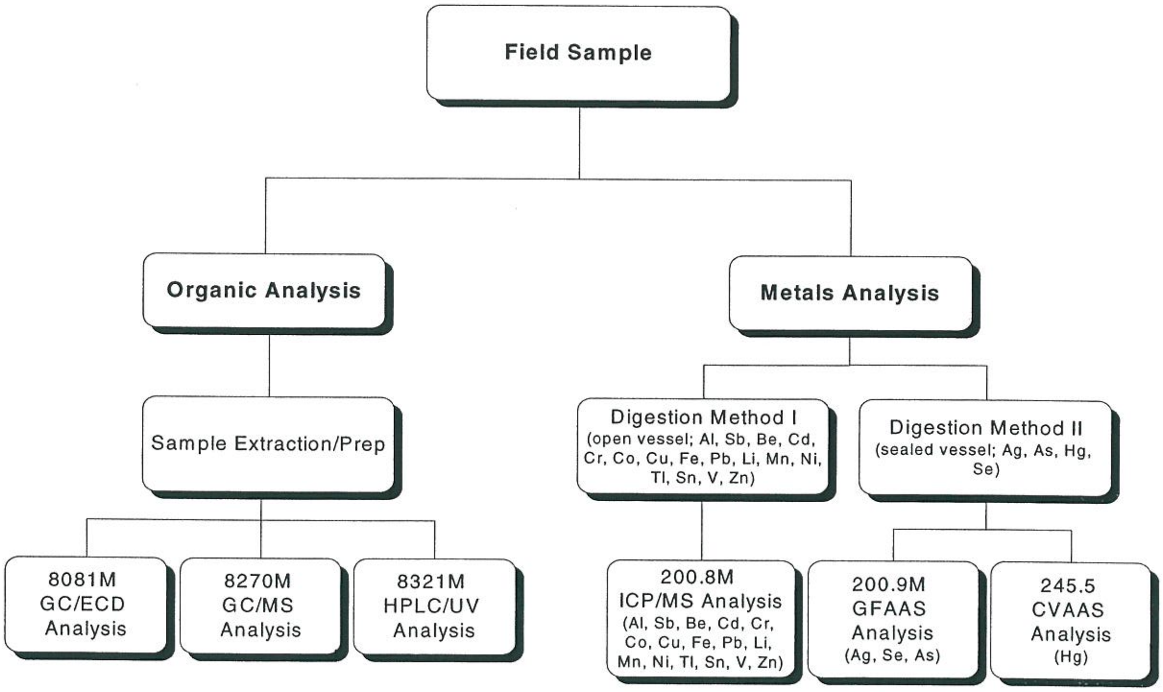

Figure 2-3. Laboratory Scheme for Organic Contaminant and Metals Analysis

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.

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, acenaphthene-d_{10} or phenanthrene-d_{10}, and chrysene-d_{12} for the 8270M analysis; PCB congeners Cl_3(34) and Cl_5(112) for the 8081M analysis)] to monitor procedural efficiency and for sample quantification. The sample was 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 process far exceeds what can be obtained with traditional, open, gravity-fed liquid chromatography columns.

Note 1: If chlorinated phenolic compounds were to be determined (this analysis was not performed on all samples), the sample was also fortified with the SIS compounds 2-fluorophenol and 3,4,5-trichlorophenol and approximately 0.4 g of ascorbic acid was mixed in with the sample prior to solvent extraction. The extract was split after the extraction, with the portion for chlorophenolic analysis put directly to HPLC/GPC cleanup (i.e., the alumina column cleanup was by-passed).

Note 2: The sub-set of 72 sediment samples that were also prepared for the detailed PCB congener characterization were extracted a second time, similarly to as described above. The differences in this preparation procedure were (1) the use of 100% hexane as the extraction solvent, (2) the substitution of the HPLC/GPC cleanup step with a sulfuric acid cleanup step, and (3) the use of PCB congener Cl_5(103) as the SIC compound and Cl_3(36) as the RIS compound.

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. If chlorophenolic compound analysis was performed, that portion of the sample was solvent exchanged to methanol, spiked with the RIS (3,4,6-tribromophenol and pentafluorophenol) and submitted for 8321M analysis.

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). This method was, separately, also used for the specialized analysis that comprised the detailed PCB congener characterization of selected samples, determining concentrations of 107 individual PCB congeners. 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 or 60-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 0.01 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., base PCB congener analysis, 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 or 6890 GC 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 temp 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.

8321M — HPLC/UV Instrumental Analysis

The Method 8321M analysis was performed for the analysis of the chlorophenolic compounds (chlorinated phenols, anisoles, catechols, and guaiacols) using high-performance liquid chromatography with ultraviolet detection. (HPLC/UV) using a Hewlett-Packard 1050 HPLC system fitted with a programmable multiple wavelength UV detector. Chromatographic separation was carried out on a 250 mm × 4.6-mm i.d., 5 µm particle size, C18 column (Hypersil BDS) using gradient elution.

The resolution of the target analytes in a set of standard runs was reviewed prior to field sample analysis, and minor adjustments (e.g., to gradient program time lines, temperature) made to maintain optimum chromatography for the target compounds. The detector was programmed to provide the needed sensitivity for the different target compounds. A 10 µL sample extract was injected, and the column was maintained at 28 °C A flow rate of 1 mL/min was used, and the following conditions:

Mobile Phase and Gradient Program:	*Time (min)*	*%Methanol*	*%Water*
	0	50	50
	21	85	15
	24	100	0
	31	100	0
	32	50	50
Programmable UV Detector Settings:	*Time (min)*	*λA*	*λB*
	0	272	260
	8	280	265
	14	285	—
	23	260	280

Wavelength A data are for quantification. Wavelength B data may be used for confirmation.

The instrumental analysis method used a 5-point calibration curve with an approximate analyte concentration range of 0.5 to 10 µg/mL. 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, 8081M, and 8321M — 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 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 NS&T 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 20 metals (MDLs are listed in Table 1-1): aluminum (Al), arsenic (As), antimony (Sb), berylium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), lithium (Li), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), thallium (Tl), tin (Sn), vanadium (V), and zinc (Zn). The general laboratory sample analysis scheme is summarized in Figure 2-2, 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, Sb, Be, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Ni, Tl, Sn, V, 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 manganese.

A second digestion method was used to achieve optimum recovery of mercury, a relatively volatile element that is lost in an evaporative digestion method when the sample is taken to dryness, and of arsenic, selenium, and silver. There would also be significant loss of mercury 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 silver, arsenic, selenium and mercury. 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 mercury.

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 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, Sb, Be, Cd, Cr, Co, Cu, Fe, Pb, Li, Mn, Ni, Tl, Sn, V, 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 of mercury. 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 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. Total organic carbon (TOC) was 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 (e.g., 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, however, 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 sample within that spherical size range. Within rounding error, the sum of volume percents from all size ranges total 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:

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

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.

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

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 2-2 are included in the appendices (Appendix F).

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.

2.3.4 Elutriate/Pore Water Analysis

Sample Preparation

The sediment to be used for the elutriate/pore-water analysis was subsampled from the original sample for determination of key metal concentrations and conductivity. Approximately 150 to 200 g of sediment was placed into a 250-mL centrifuge jar for each sample. The jar was centrifuged (maximum of 10,000 RPM) to bring the water to the top. The water was filtered using a 0.45 µm membrane filter (e.g., Polysulfon, or equivalent) and the sample was split and submitted for conductivity and ICP analysis.

The split for conductivity measurement was stored refrigerated at approximately 4°C until analysis, and the measurement was performed within 24 hours of filtration. The sample split designated for ICP analysis was preserved by adding 1 µL reagent grade nitric acid per mL of sample.

9050M — Conductivity Analysis

The conductivity measurements were performed in accordance with Battelle SOP 3-161, *Use of the Cole Parmer TDSTESTR 20 Conductivity Meter*. A Cole Parmer TDS Testr20 was calibrated with standard solutions at the low end of the expected sample conductivity (typically in the range from 500 to 5,000 µmhos/cm). The validity of the calibration was checked with an independent check standard no less frequently than every 10 samples.

6010M — ICP Analysis

The sample preparation, instrumental analysis, and instrument operation for the major metals analysis were performed using the procedures described in Battelle SOP 3-277 *Determination of Metals by Inductively Coupled Plasma/Atomic Emission Spectrometry* and SOP 3-152 *Operation of Perkin Elmer Optima 3000 Inductively Coupled Plasma Atomic Emission Spectrometer*. A Perkin Elmer Optima 3000 inductively coupled plasma (ICP) atomic emission spectrometer (AES) was employed for the analysis, and was calibrated with at least 3 calibration levels, covering the expected concentration range of the samples. The validity of the calibration was checked with an independent check standard no less frequently than every 10 samples. The filtered aqueous samples were direct-injected onto the ICP/AES, and concentrations of calcium, magnesium, potassium, and sodium were determined. Samples with concentrations outside the calibration range were diluted and re-analyzed.

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 a n umber of state and federal programs, including for the Florida State DEP, Commonwealth of Massachusetts DEP, New Jersey DEP, New York State DEC, California 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 analysis of sediments and tissues for PCBs, pesticides, PAH, and metals.

Several components of this QA 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. Battelle's FDEP CompQAP is reviewed and updated with the FDEP annually.

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 (laboratory control sample)
- 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 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.

- *Procedural (Method) Blanks* (PB) were prepared, processed, and analyzed with each analytical batch of 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 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 the sample matrix.

- *Matrix Spikes/Matrix Spike Duplicate* (MS/MSD) samples were processed and analyzed with each batch of samples for trace metals and organic compound analysis. 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 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 collected and processed for each surface sediment site. Field duplicates incorporated the precision in the field sampling with the analytical precision. In addition, laboratory duplicate analysis (replicate analysis of the *same* field sample) was performed with each batch of metals, TOC, and grain size analysis.

- *Standard Reference Materials* (SRMs) were processed and analyzed with each analytical batch of 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.

The quality control data quality objectives (DQOs) are presented in Table 2-4. The complete data for all quality control samples have been reported to the SJRWMD along with the field sample data. The 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 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. In general, these QC sample results verified that sample processing and analytical procedures were well in control.

Table 2-4. Laboratory Analysis Data Quality Objectives

QC Measurement	Frequency	Acceptability Limits	Corrective Action
ORGANIC CONTAMINANTS			
Method	8270Mod (PAH, phthalates, kepone) 8081Mod (PCB, Pesticide) 8321Mod (Phenolics)		Deviations will be documented.
Procedural blank	1 per 20 samples	<3 × MDL (qualify if < MDL)	Reextraction or reanalysis, and/or justification documented.
SRM[1]	1 per 20 samples	<35% (or 65-135% recovery) of/relative to 95% confidence intervals. Applies to parameters with certified values >5 × MDL	Reextraction or reanalysis and/or justification documented.
MS/MSD	1 per 20 samples	30-130% recovery[2], <30% RPD[3]. Applies to parameters with spikes >5 × background.	Reextraction or reanalysis and/or justification documented.
BS (LCS)	1 per 20 samples	30-130% recovery[2]	Reextraction or reanalysis and/or justification documented.
Surrogate recovery	8270M: 3 per sample 8081M: 2 per sample 8321M: 2 per sample	30-130% recovery[4]	Reextraction or reanalysis and/or justification documented.
Instrument calibration	Initial calibration	8270M: <25% RSD[5] each analytes and <15% RSD average all analytes. 8081M and 8321M: r^2: 0.995,	Reanalyze or justification documented.
	Continuing calibration checks	<25% PD individual analytes and <15% PD avg all analytes	Remedial maintenance, new initial calibration, or reanalysis documented and justified.
TOTAL ORGANIC CARBON			
Method	Standard Methods (9060)		Deviations will be documented.
Procedural blank	1 per 20 samples	<5 × MDL	TOC sample concentrations will be blank subtracted.
Laboratory control spike	1 per 20 samples	<10% of certified/acceptance value	Reanalysis and/or justification documented.
Duplicates	1 per 20 samples	<20% RPD if conc. <0.20% <10% RPD if conc. >0.20%	Reanalysis and/or justification documented.
Instrument calibration	Continuing checks	± 5% true value	Remedial maintenance, new initial calibration, reanalyze samples at discretion of analyst and Task Leader. Documented and justified.

Table 2-3 (continued). Laboratory Analysis Data Quality Objectives

QC Measurement	Frequency	Acceptability Limits	Corrective Action
TRACE AND MAJOR METALS			
Method	200.8Mod, 200.9Mod, and 245.5		Deviations will be
Procedural blank	1 per 20 samples	<3 × MDL (qualify if < MDL)	Reextraction, reanalysis, or blank subtraction documented.
SRM	1 per 20 samples	70-130% recovery versus certified value	Reextraction or reanalysis and/or justification documented.
MS	1 per 20 samples	70-130% recovery. Applies to parameters with spikes >5 × background.	Reextraction or reanalysis and/or justification documented.
Duplicate	1 per 20 samples	<20% RPD[3]	Reextraction or reanalysis and/or justification documented
BS	1 per 20 samples	70-130% recovery; <30% RPD	Reextraction or reanalysis and/or justification documented.
Instrument calibration	Initial calibration Continuing calibration checks	r^2 0.99 <15% PD individual analytes	Reanalysis or justification documented. Remedial maintenance, new initial calibration, or reanalysis documented and justified.
GRAIN SIZE			
Method	Fraunhofer		Deviations will be documented.
Duplicates	1 per 20 samples	<20% RPD for sand, silt, clay[6]	Reanalysis documented.

[1] Certified values for sediment SRM are available for selected PAH, PCB, pesticides, and metals. DQO apply when the consensus/certified value is >5 × MDL.

[2] % recovery (MS/MSD) = [((MS concentration – Background concentration) × (MS dry weight)) / spike amount] × 100. MS/MSD criteria apply when spiking level >5 × background level.

[3] Relative Percent Difference (RPD)(%) = [(|replicate 1 – replicate 2| × 2) / (replicate 1 + replicate 2)] × 100. DQO applies when the concentration is >5 × MDL.

[4] One PAH SIS may exceed acceptability limits only after other data quality indicators are reviewed.

[5] Relative Standard Deviation (RSD) = [(standard deviation of the response factors)/mean response factor] ×100

[6] No criteria for gravel fraction.

3. RESULTS

This section summarizes the results of the organic compound, metals, and geophysical analyses. It is divided into the following three sections: Section 3.1 includes organic compound analyses ([polycyclic aromatic hydrocarbons (PAH), phthalate esters, polychlorinated biphenyl (PCB), pesticides, other chlorinated compounds, and chlorinated phenolic compounds), Section 3.2 includes metals analyses (major metals and trace metals), Section 3.3 includes geophysical (ancillary) analyses (total organic carbon (TOC), grain size, moisture content, total solids (TS), total volatile solids (TVS), and elutriate metals). This Results section is primarily intended to provide a presentation of the data, including some key summary statistics, without detailed discussions of the data. The data are analyzed and discussed in more detail in the Discussion section (Section 4).

Section 3 presents the data in summary format. The detailed sediment chemistry results for each site and each measured parameter are reported in Appendix B through H. The data tables in the appendices, and the summary data in the main body of the report, are organized alphanumerically by site name. All chemistry data presented and discussed in this report 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, and provides for a more reliable data comparison. 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.

All organic contaminant data are presented as surrogate corrected data in this report. Target compounds are corrected for the recovery of a representative surrogate compound in the sample. The main purpose of the correction is to account for sample loss that may have occurred during sample processing. Surrogate correction is widely applied in environmental monitoring programs (e.g., NOAA NS&T Program and EPA EMAP) and is a generally accepted technique to generate data that better represent the contaminant concentration in the original field sample than non-corrected data.

3.1 Results for Organic Compound Analysis

This subsection presents the results of the organic compound analysis and is divided into four sections; the results from the base Method 8270M analyses (PAH and phthalate results), the base Method 8081M analyses (base PCB, pesticide, and other chlorinated compound results), the detailed 107 PCB congener analyses, and the Method 8321M analyses (chlorophenolic compound results). Individual concentrations for a total of 116 base organic compounds were determined in this study (Table 1-1). In addition, a total of 107 PCB congeners were determined in the detailed PCB characterization analysis of a sub-set of samples. The analytical data for each individual compound are listed in Appendix B (Method 8270M analytes), Appendix C (Method 8081M analytes), Appendix D (Detailed 107 PCB Congener analytes), and Appendix E (Method 8321M 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 most of this report. Individual organic compounds are discussed when the data review revealed them to be of particular interest.

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 total organic carbon (TOC) content of the sediment for data analysis purposes, and both normalized (as µg/g TOC) and non-normalized organic contaminant data are presented in this report. 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, a review of both the non-normalized and TOC-normalized concentrations can provide a first-level indication of the bioavailable organic contamination (i.e., organic contaminants tightly bound to organic matter, or particulates, are generally less bioavailable than compounds in sandy, low-TOC, sediment). Although the TOC measurement will include hydrocarbons and other contaminants that may be used in the normalization process, these compounds are negligible compared to the majority of the bulk organic material measured in the TOC analysis and do not significantly impact the normalization (e.g., petroleum hydrocarbons and other anthropogenic organic compounds may together constitute a few tens or hundreds of mg/kg of the organic material in these samples, compared to an overall TOC that averaged about 10% for these samples).

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. The chloronaphthalenes, isophorone, and kepone data were reviewed. These compounds were typically not detected at notable levels in the sediment samples, are thus of little concern, and are therefore not elaborated on in this report; the results for these compounds are briefly discussed at the end of section 3.1.1. For presentation and discussion purposes this report focuses on the 30 PAH and phthalate compounds, which are categorized as (1) low molecular weight PAH (LMW), (2) high molecular weight PAH (HMW), (3) total PAH, and (4) total phthalate. Table 3-1 lists the analytes that comprise each group.

LMW PAH are frequently associated with refined and unrefined petroleum products. HMW PAH are primarily derived from the combustion of fossil fuels or as principal components of creosote-type formulations or coal tar handling/processing. 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.

Table 3-1. Aromatic Hydrocarbon and Phthalate Groups

LMW PAH (Low PAH; Σ of)	HMW PAH (High PAH; Σ of)	Total PAH (Σ of)	Total Phthalate (Σ of)
Naphthalene	Fluoranthene	Low PAH	Dimethylphthalate
2-Methylnaphthalene	Pyrene	High PAH	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		

A summary of the median values and ranges of concentrations of selected classes of aromatic organic compounds is listed in Table 3-2. A summary of the concentration data for each site is presented in Table 3-3. These data are presented both non-normalized and normalized to TOC. The data for each Method 8270M compound are presented in Appendix B.

Table 3-2. Concentration Ranges for PAH and Phthalates

	Not Normalized (µg/kg dry weight)			Normalized to TOC (µg/g TOC)		
	Median	Min	Max	Median	Min	Max
Cedar-Ortega River Basin Sites – Surface Sediments						
Total PAH	4,840	560	29,800	32.8	5.78	353
Low PAH (LMW)	366	26.5	1,150	2.87	2.07	36.3
High PAH (HMW)	4,230	478	28,600	29.2	5.57	332
Total Phthalate	280	56.4	2,570	1.88	0.477	38.6
Cedar-Ortega River Basin Sites – Sub-surface Sediments						
Total PAH	2,260	185	20,800	16.0	2.54	183
Low PAH (LMW)	123	5.23	1,050	0.741	0.072	8.53
High PAH (HMW)	2,283	180	19,800	15.2	2.46	175
Total Phthalate	80.9	13.7	4,400	0.587	0.121	34.3

PAH – Total PAH

The median surface sediment total PAH concentration was 4,840 µg/kg. The data indicate that the PAH concentrations were somewhat variable in the COR sediment samples; surface sediment total PAH concentrations ranged from 560 (site ORT30) to 29,800 µg/kg (site CED09) at the COR sites. The sub-surface PAH concentrations were generally a little lower for most COR sites, with a median total PAH concentration of 2,260 µg/kg. However, the sub-surface data were more variable than the surface sediment data and include the results for a number of "deep" samples that were clearly deposited at a time when there was lower anthropogenic contaminant loading in the COR Basin. It should also be noted that the sub-surface organic contaminant data for ORT04 (samples ORT04-M and ORT04-L) appear surprisingly elevated, compared to the surface ORT04 sample and the samples from the surrounding sites, and should probably be considered unreliable. A core was re-collected at this location at a later time, and analyzed for PCB only, and those data indicated low levels of sub-surface contamination (comparable to the surrounding sites) and that the data for the initial core were probably not representative of this location.

The majority of the COR sites had surface sediment total PAH concentrations *above* 2,000 µg/kg dry weight; 43 of the 49 sites listed in Table 3-3 had concentrations above 2,000 µg/kg and eight sites (CED02, CED03, CED04, CED06, CED09, ORT25, ORT31, and ORT33) had a sediment total PAH concentration above 10,000 µg/kg dry weight.

The sample data were analyzed against 2 standard deviations from their medians to determine sites with significantly higher concentrations than the medians. Three of the COR sites had surface sediment total PAH concentrations above 14,900 µg/kg (median concentration + 2 standard deviations). These sites were CED04 (16,000 µg/kg), CED09 (29,800 µg/kg), and ORT33 (15,200 µg/kg). The highest sub-surface PAH concentrations were generally measured at the sites with the highest surface sediment concentrations, with the one exception for site ORT04 that was described above.

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

FIELD ID	Not Normalized (µg/kg dry weight)				Normalized to TOC (µg/g TOC)			
	Total PAH	Low PAH	High PAH	Total Phthalates	Total PAH	Low PAH	High PAH	Total Phthalates
Cedar-Ortega River Basin Sites – Surface Sediments								
CED01	5,510	544	4,960	1,200	83.9	8.30	75.6	18.3
CED02	12,400	594	11,900	1,460	116	5.55	111	13.6
CED03	10,400	498	9,900	1,690	92.9	4.44	88.4	15.1
CED04	16,000	766	15,200	2,570	112	5.39	107	18.1
CED05	2,200	119	2,090	2,380	29.6	1.60	28.0	31.9
CED06	13,700	623	13,100	391	102	4.65	97.6	2.92
CED07	8,310	412	7,890	199	66.4	3.29	63.2	1.60
CED08	7,600	366	7,230	1,010	53.5	2.58	50.9	7.13
CED09	29,800	1,150	28,600	684	250	9.69	240	5.74
ORT01	2,620	304	2,320	77.2	25.0	2.90	22.1	0.735
ORT02	962	51.6	910	136	9.88	0.530	9.35	1.40
ORT03	899	27.7	871	205	7.75	0.239	7.51	1.77
ORT04	2,190	261	1,930	221	18.5	2.22	16.3	1.87
ORT05	3,240	575	2,660	66.7	25.9	4.60	21.3	0.534
ORT06	2,130	239	1,890	393	21.4	2.37	19.0	3.66
ORT07	5,280	486	4,800	529	38.8	3.57	35.3	3.89
ORT08	2,180	207	1,970	95.4	18.6	1.77	16.9	0.815
ORT09	3,940	579	3,360	338	43.7	6.43	37.3	3.76
ORT10	4,020	486	3,530	1,010	31.1	3.77	27.4	7.81
ORT11	2,930	260	2,670	183	22.9	2.03	20.9	1.43
ORT12	5,600	488	5,110	566	43.1	3.76	39.3	4.36
ORT13	5,270	680	4,590	454	36.1	4.66	31.4	3.11
ORT14	1,880	234	1,650	181	17.1	2.13	15.0	1.64
ORT15	7,070	534	6,530	262	45.0	3.40	41.6	1.67
ORT16	4,460	488	3,970	242	32.8	3.59	29.2	1.78
ORT18	4,840	625	4,210	699	37.8	4.88	32.9	5.46
ORT19	8,150	1,030	7,120	327	288	36.3	252	11.6
ORT20	1,770	62.8	1,710	182	16.1	0.571	15.5	1.65
ORT21	3,900	310	3,590	106	31.2	2.48	28.7	0.850
ORT22	5,470	405	5,070	624	46.0	3.40	42.6	5.24
ORT23	3,970	294	3,680	84.2	28.4	2.10	26.3	0.601
ORT24	5,760	491	5,270	280	38.7	3.30	35.4	1.88
ORT25	12,300	702	11,600	359	78.3	4.47	73.8	2.29
ORT26	6,830	433	6,400	269	45.2	2.87	42.4	1.78
ORT27	8,380	410	7,970	570	57.4	2.81	54.6	3.91
ORT28	5,020	326	4,690	205	31.2	2.02	29.2	1.27
ORT29	739	26.5	713	61.0	5.78	0.207	5.57	0.477
ORT30	560	81.1	478	56.4	24.1	3.50	20.6	2.43
ORT31	11,100	742	10,400	476	90.5	6.04	84.4	3.87
ORT32	6,310	433	5,870	146	55.3	3.80	51.5	1.28
ORT33	15,200	915	14,300	1,670	353	21.2	332	38.6
ORT34	4,180	288	3,900	361	25.2	1.74	23.5	2.17
ORT35	3,910	224	3,690	75.4	28.8	1.65	27.1	0.554
ORT36	4,010	219	3,790	958	24.2	1.32	22.8	5.77

FIELD ID	Not Normalized (µg/kg dry weight)				Normalized to TOC (µg/g TOC)			
	Total PAH	Low PAH	High PAH	Total Phthalates	Total PAH	Low PAH	High PAH	Total Phthalates
ORT37	6,660	358	6,300	153	45.6	2.45	43.2	1.05
ORT38	5,150	327	4,820	111	33.6	2.14	31.5	0.725
ORT39	4,180	205	3,980	303	22.8	1.12	21.7	1.61
ORT40	4,860	290	4,570	187	29.5	1.76	27.7	1.13
ORT41	2,030	78.1	1,950	291	9.40	0.362	9.04	1.35
Cedar-Ortega River Basin Sites – Sub-surface Sediments								
CED01-M	6,080	542	5,540	149	83.1	7.41	75.7	2.03
CED03-M	816	39.4	777	92.3	6.58	0.318	6.26	0.745
CED03-L	11,900	569	11,400	4,400	93.3	4.44	88.8	34.3
CED04-M	9,570	481	9,090	2,640	67.4	3.38	64.0	18.6
CED04-L	8,320	514	7,810	475	46.0	2.84	43.1	2.62
CED06-M	3,110	139	2,970	32.0	36.3	1.63	34.7	0.374
CED06-L	2,580	18.6	2,560	44.8	13.2	0.095	13.1	0.229
CED07-M	5,210	302	4,910	78.6	38.9	2.25	36.6	0.587
CED07-L	1,960	33	1,930	32.3	11.8	0.201	11.6	0.195
CED08-M	4,470	222	4,250	97.4	37.6	1.87	35.7	0.818
CED09-M	20,500	869	19,600	510	183	7.76	175	4.55
ORT01-M	2,910	345	2,570	82.0	22.8	2.70	20.1	0.641
ORT01-L	759	23.5	736	30.5	7.30	0.226	7.08	0.293
ORT02-M	2,520	234	2,280	148	23.1	2.15	20.9	1.36
ORT02-L	1,080	21.5	1,060	73.7	10.4	0.207	10.2	0.709
ORT03-M	1,260	22.0	1,230	41.5	9.23	0.161	9.07	0.305
ORT03-L	1,070	16.3	1,060	27.8	9.32	0.142	9.18	0.242
ORT04-M	5,220	767	4,450	230	40.8	5.99	34.8	1.80
ORT04-L	20,800	972	19,800	3,470	182	8.53	174	30.4
ORT05-M	1,380	38.7	1,340	34.1	9.45	0.265	9.19	0.233
ORT05-L	1,340	17.8	1,320	39.0	10.1	0.135	10.0	0.295
ORT06-M	1,380	139.0	1,240	80.9	12.4	1.25	11.1	0.726
ORT06-L	878	23.6	854	90.1	9.43	0.253	9.17	0.967
ORT07-M	5,350	464	4,890	478	39.1	3.39	35.7	3.49
ORT07-L	4,880	479	4,400	379	32.1	3.15	28.9	2.50
ORT08-M	1,560	152	1,400	71.4	15.3	1.49	13.8	0.700
ORT08-L	1,240	15.7	1,230	23.9	13.3	0.168	13.1	0.256
ORT09-M	3,330	391	2,940	65.1	25.2	2.96	22.2	0.493
ORT09-L	797	20.3	777	57.1	8.00	0.204	7.80	0.573
ORT10-M	4,970	627	4,340	175	35.2	4.45	30.8	1.24
ORT10-L	1,170	26.9	1,140	32.6	8.82	0.203	8.62	0.247
ORT11-M	5,090	493	4,600	1,260	38.0	3.68	34.3	9.40
ORT11-L	1,280	20.5	1,260	44.0	12.1	0.193	11.9	0.415
ORT12-M	8,390	1046	7,350	161	57.9	7.22	50.7	1.11
ORT12-L	1,500	21.2	1,480	169	11.6	0.165	11.4	337
ORT13-M	5,370	729	4,650	160	35.4	4.79	30.6	1.06
ORT13-L	1,210	166	1,040	66	7.58	1.04	6.54	0.416
ORT14-M	1,790	168	1,620	362	18.9	1.78	17.2	3.83
ORT14-L	1,870	33.8	1,830	138	15.3	0.277	15.0	1.13

FIELD ID	Not Normalized (µg/kg dry weight)				Normalized to TOC (µg/g TOC)			
	Total PAH	Low PAH	High PAH	Total Phthalates	Total PAH	Low PAH	High PAH	Total Phthalates
ORT15-M	7,740	552	7,180	745	49.6	3.54	46.1	4.78
ORT15-L	5,880	528	5,350	139	38.2	3.43	34.7	0.902
ORT16-M	6,980	773	6,200	490	50.9	5.64	45.3	3.57
ORT16-L	2,020	34.2	1,980	175	14.6	0.248	14.4	1.27
ORT18-M	5,210	899	4,310	122	46.9	8.10	38.8	707.8
ORT18-L	1,800	31.1	1,770	140	14.8	0.255	14.5	1.15
ORT20-M	1,980	50.1	1,930	194	13.6	0.343	13.2	1.33
ORT20-L	2,140	27.6	2,110	111	17.8	0.23	17.6	0.928
ORT21-M	5,150	449	4,700	67.5	35.0	3.06	32.0	0.459
ORT21-L	2,080	39.8	2,040	32.5	16.8	0.321	16.4	0.262
ORT23-M	3,440	283	3,160	30.7	22.9	1.89	21.0	0.204
ORT23-L	2,360	17.5	2,350	28.4	17.6	0.13	17.5	0.212
ORT24-M	1,570	78.0	1,490	40.1	10.8	0.538	10.3	0.277
ORT24-L	1,890	17.7	1,870	19.2	11.9	0.112	11.8	0.121
ORT25-M	5,560	351	5,210	97.7	36.6	2.31	34.2	0.643
ORT25-L	3,180	25.0	3,160	24.5	22.2	0.175	22.1	0.172
ORT26-M	3,470	237	3,230	46.5	21.1	1.45	19.7	0.283
ORT26-L	1,660	22.3	1,630	30.5	11.3	0.152	11.1	0.207
ORT27-M	4,620	251	4,370	125	30.2	1.64	28.5	0.814
ORT27-L	552	23.2	529	19.0	7.74	0.325	7.41	0.266
ORT28-M	4,320	278	4,040	48.1	30.6	1.97	28.7	0.341
ORT28-L	2,410	24.0	2,390	36.7	14.7	0.146	14.6	0.224
ORT29-M	981	102	878	34.7	6.37	0.665	5.70	0.226
ORT29-L	1,820	12.7	1,810	33.9	14.7	0.102	14.6	0.273
ORT30-M	343	6.27	337	648	10.2	0.187	10.0	19.3
ORT30-L	185	5.23	180	16.5	2.54	0.072	2.46	0.226
ORT31-M	8,170	521	7,640	64.5	73.6	4.70	68.9	0.581
ORT31-L	695	12.4	682	101	11.2	0.201	11.0	1.63
ORT32-M	4,130	269	3,860	25.2	38.6	2.52	36.0	0.235
ORT32-L	473	15.7	458	13.7	11.2	0.371	10.8	0.323
ORT34-M	2,160	140	2,020	154	13.9	0.901	13.0	0.995
ORT35-M	4,990	272	4,720	107	38.1	2.07	36.0	0.815
ORT35-L	1,530	40.1	1,490	28.1	9.44	0.247	9.19	0.173
ORT36-M	4,010	210	3,800	90.0	26.9	1.41	25.5	0.604
ORT36-L	2,150	28.9	2,120	36.2	13.5	0.182	13.3	0.228
ORT37-M	2,480	123	2,360	48.7	16.0	0.792	15.2	0.314
ORT37-L	2,210	74.3	2,140	48.9	18.0	0.604	17.4	0.398
ORT38-M	1,340	94.3	1,240	284	7.91	0.558	7.35	1.68
ORT39-M	3,900	255	3,640	140	20.4	1.34	19.1	0.733
ORT39-L	2,590	42.4	2,550	148	14.1	0.230	13.9	0.803
ORT40-M	2,610	150	2,460	86.1	12.9	0.741	12.1	0.424
ORT40-L	1,980	26.8	1,950	77.3	10.1	0.136	9.92	0.392
ORT41-M	5,930	305	5,630	212	26.2	1.35	24.9	0.937
ORT41-L	1,970	28.3	1,940	97.0	9.69	0.140	9.55	0.478

PAH – LMW PAH

The concentration of LMW PAH (Low PAH), the primarily petrogenic PAH, ranged from 26.5 (site ORT29) to 1,150 µg/kg (site CED09) in COR basin surface sediment samples. The sub-surface sediments had a similar LMW PAH concentration range (5.2 to 1,050 µg/kg). Two of the COR sites had surface sediment LMW PAH concentrations above 863 µg/kg (median concentration + 2 standard deviations). These sites were CED09 (1,150 µg/kg) and ORT19 (1,030 µg/kg).

PAH – HMW PAH

The concentration of HMW PAH (High PAH), the primarily pyrogenic PAH, were generally significantly higher than the LMW PAH, and ranged from 478 (site ORT30) to 28,600 µg/kg (site CED09) for the COR surface sediment samples. The sub-surface sediment HMW PAH concentration ranged from 180 to 19,800 µg/kg. The relatively elevated HMW PAH was notable; the COR surface sediment median HMW PAH concentration was about 12 times higher than the median LMW PAH concentration.

Three of the COR sites had surface sediment HMW PAH concentrations above the median concentration + 2 standard deviations (13,900 µg/kg). These sites were CED04 (15,200 µg/kg), CED09 (28,600 µg/kg), and ORT33 (14,300 µg/kg). The variability in the sediment PAH concentrations remained high even after the PAH data were normalized to sediment TOC content (Tables 3-2 and 3-3). For instance, the TOC-normalized surface sediment HMW PAH concentration ranged from 5.57 (site ORT29) to 332 µg/g TOC (site ORT33) for the COR Basin sites.

Phthalate Esters and Other Method 8270M Compounds

The phthalate concentrations were, by and large, lower than the PAH concentrations. The total phthalate concentration in the COR surface sediment ranged from 56.4 (site ORT30) to 2,570 µg/kg (site CED04). Analysis of the data against 2 standard deviations from their medians was performed to determine those sites that had significantly elevated concentrations, compared with the medians for these general locations. Five of the COR sites had total phthalate concentrations above 1,420 µg/kg (median concentration + 2 standard deviations); sites CED02 (1,460 µg/kg), CED03 (1,690 µg/kg), CED04 (2,570 µg/kg), CED05 (2,380 µg/kg), and ORT33 (1,670 µg/kg).

Two of the COR sub-surface sediment samples (ORT12-L and ORT18-M) had uncommonly and unrealistically high concentrations of one of the six phthalates [bis(2-ethylhexyl)phthalate; 43,300 and 78,400 µg/kg, respectively], particularly when considering the concentrations in the rest of the core and surrounding samples. This suggests that the samples might have contained a small piece of plastic from the field, rather than high concentrations of sediment-associated molecular-level phthalates. The two site replicate outlier data points were therefore omitted for the reporting in Tables 3-2 and 3-3. They were, however, included in the data tables in Appendix B, to allow for a complete data evaluation.

The variability in the sediment phthalate concentrations remained high even after the data were normalized to sediment TOC content (Tables 3-2 and 3-3). For instance, the TOC-normalized total phthalate concentration ranged from 0.477 (site ORT29) to 38.6 µg/g TOC (site ORT33) for the COR Basin sites.

Four other compounds, 2-chloronaphthalene, 1-chloronaphthalene, isophorone, and kepone were also analyzed using Method 8270M and reported with the PAH data (Appendix B), but are not classified as PAH or phthalate and therefore are not included in the total PAH or total phthalate calculations. The chloronaphthalenes (1- and 2-) were detected least frequently of these additional compounds, but isophorone and kepone were also rarely detected at environmentally relevant concentrations. In fact, 1-chloronaphthalene was not detected in any of the COR samples and 2-chloronaphthalene was detected at trace levels in only 5 of the 140 samples. Isophorone, which is primarily used in metals coatings and paints, and plastic adhesives, was detected at low concentrations in less than half of the COR samples. Kepone, a rarely used insecticide, was not detected at any of the COR sites.

3.1.2 PCB, Pesticide, and Other Chlorinated Compound Results

The sediment samples were analyzed for 61 base chlorinated compounds (23 individual PCB congeners, 30 pesticides, and 8 other chlorinated compounds) using Method 8081M. In addition, a sub-set of the samples was analyzed for a total of 107 individual PCB congeners, for a detailed PCB characterization. Table 3-4 below shows the analytes that are summarized as separate groups/classes for presentation and discussion purposes. The base analytes are categorized as (1) sum of PCB congeners, (2) total DDT compounds, (3) total chlordanes, (4) total benzene hexachlorides [(BHCs), which includes the pesticide lindane (γ-BHC)], (5) total endosulfans, and (6) total other industrial chlorinated compounds. Total DDT, DDE, and DDD compounds, each as sums of their 4,4'- and 2,4'-isomers, were also determined to further characterize the DDT contamination. It should be noted that for this report, all seven individual target compounds that are often considered chlordane compounds have been used for the summation. However, in some earlier reports (e.g., Battelle, 2004) only the three primary chlordane compounds (α-chlordane, γ-chlordane, and oxychlordane) were used; the three primary chlordane congeners generally, but not always, constitute >90% of the sum of the seven congeners.

The data for the additional pesticides that were determined, but are not captured in these compound summations, were also reviewed and were, for the most part, of less environmental significance. However, the review of these other analyzed pesticides is briefly discussed below.

Table 3-5 presents the median concentrations and 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 date in Table 3-6 is based on the Method 8081M analysis, and the data for each Method 8081M compound are presented in Appendix C. The complete data set from the analyses of the extended list of 107 PCB congeners, including a listing of the congeners, is compiled in Appendix D.

Table 3-4. Chlorinated Organic Compound Groups

Sum of PCBs (Σ of)		Total DDTs (Σ of)	Total Chlordanes (Σ of)	Total BHCs (Σ of)	Total Endosulfans (Σ of)	Total Other Chlorinated Compounds (Other Chloros; Σ of)
Cl_2(8)	Cl_3(18)	2,4'-DDT	*α*-Chlordane	α-BHC	Endosulfan I	1,3-Dichlorobenzene
Cl_3(28)	Cl_4(52)	4,4'-DDT	γ-Chlordane	β-BHC	Endosulfan II	1,4-Dichlorobenzene
Cl_4(44)	Cl_4(66)	2,4'-DDE	Oxychlordane	γ-BHC	Endosulfan sulfate	1,2-Dichlorobenzene
Cl_4(77)	Cl_5(110)	4,4'-DDE	*trans*-Nonachlor	δ-BHC		1,2,4-Trichlorobenzene
Cl_5(101)	Cl_5(118)	2,4'-DDD	*cis*-Nonachlor			1,2,4,5-Tetrachlrorobenzene
Cl_6(153)	Cl_5(105)	2,4'-DDD	Heptachlor			Hexachloroethane
Cl_6(138)	Cl_5(126)		Heptachlor epoxide			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. Concentration Ranges for Selected Chlorinated Organic Compounds

	Not Normalized (µg/kg dry weight)			Normalized to TOC (µg/g TOC)		
	Median	Min	Max	Median	Min	Max
Cedar-Ortega River Basin Sites – Surface Sediments						
Σ 23 PCB Compounds	147	3.76	3,930	1.11	0.128	64.8
Σ DDT Compounds	14.8	0.93	87.8	0.116	0.010	1.34
DDTs	2.70	ND	16.4	0.023	ND	0.379
DDEs	5.53	ND	33.0	0.044	ND	0.502
DDDs	5.71	0.23	52.2	0.040	0.0026	0.796
Σ Chlordanes	6.71	ND	94.9	0.047	ND	1.74
Σ BHCs	0.89	ND	6.60	0.008	ND	0.050
Σ Endosulfans	2.04	ND	29.0	0.016	ND	0.442
Σ Other Chloros	24.9	0.12	136	0.196	0.0009	0.872
Cedar-Ortega River Basin Sites – Sub-surface Sediments						
Σ 23 PCB Compounds	18.0	0.28	3,580	0.125	0.0019	28.0
Σ DDT Compounds	4.26	ND	79.3	0.0306	ND	1.08
DDTs	1.49	ND	7.11	0.0118	ND	0.0558
DDEs	0.58	ND	69.6	0.0033	ND	0.951
DDDs	1.46	ND	30.3	0.0107	ND	0.266
ΣChlordanes	0.20	ND	46.7	0.0018	ND	0.417
Σ BHCs	1.08	ND	6.1	0.0077	ND	0.0342
Σ Endosulfans	0.45	ND	15.0	0.0034	ND	0.132
Σ Other Chloros	18.8	ND	107	0.137	ND	0.778

PCB (base analysis of 23 PCB congeners)

The base 23 PCB congeners that were determined for all samples in this project are widely used for PCB contaminant monitoring in a variety of national (e.g., NOAA NS&T Program and EPA EMAP Program) and regional monitoring programs, and provide a broad general assessment of the PCB contamination. These congeners 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), as determined in the NOAA NS&T program. A set of samples in this project were separately processed and analyzed for a detailed PCB congener characterization by quantifying more than 100 congeners, as discussed below.

The sum of the 23 PCB congener concentrations in the surface sediments ranged from 3.76 (site ORT30) to 3,930 µg/kg (site CED01) at the COR Basin sites, based on the Method 8081M analysis (Table 3-5 and Table 3-6)[1]. The median PCB concentrations were 147 µg/kg for the surface sediments and 18 µg/kg for the sub-surface COR sediment samples. The sub-surface PCB concentrations were more variable, with high concentrations at several Cedar River locations, while many deeper core samples had low PCB concentrations. The unexpectedly high concentrations of PCB (and other contaminants) in samples ORT04-M and ORT04-L (Table 3-6) was investigated through re-sampling of this location (as sample ORT04-1). The re-analysis indicated significantly lower concentrations of PCB (Table 3-7) that was more comparable to the surrounding locations, suggesting that the original ORT04 data may be unreliable.

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[1] Note that in the Lower St. Johns River and Cedar-Ortega River Basin report (Battelle, 2001) the sum of the congeners did not include PCB08, and there are therefore minor differences in the congener sums.

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

FIELD ID	Not Normalized (µg/kg dry weight)									Normalized to TOC (µg/g TOC)								
	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros
Cedar-Ortega River Basin Sites – Surface Sediments																		
CED01	3,930	87.8	2.62	33.0	52.2	7.21	ND	29.0	37.6	64.8	1.34	0.0400	0.502	0.796	0.119	ND	0.442	0.574
CED02	2,300	31.2	3.63	8.86	18.7	20.2	4.94	9.04	33.4	21.5	0.292	0.0339	0.0828	0.175	0.189	0.0462	0.0845	0.312
CED03	912	18.7	0.73	10.5	7.46	17.4	ND	3.65	6.31	8.14	0.167	0.0066	0.0938	0.0666	0.155	ND	0.0326	0.0563
CED04	1121	20.2	1.05	9.74	9.38	20.7	ND	3.21	0.12	7.89	0.142	0.0074	0.0686	0.0660	0.146	ND	0.0226	0.0009
CED05	121	9.00	1.10	5.47	2.44	9.45	1.30	2.43	31.9	1.63	0.121	0.0147	0.0735	0.0327	0.127	0.0175	0.0327	0.428
CED06	489	23.4	4.79	10.1	8.53	33.5	1.63	6.96	26.7	3.65	0.175	0.0358	0.0751	0.0636	0.250	0.0122	0.0519	0.199
CED07	690	12.1	4.12	4.39	3.63	16.3	1.85	4.28	36.1	4.89	0.0972	0.0330	0.0351	0.0291	0.115	0.0148	0.0342	0.289
CED08	154	13.1	2.70	4.74	5.64	21.8	ND	0.95	35.2	1.08	0.0921	0.0190	0.0334	0.0397	0.154	ND	0.0067	0.248
CED09	380	36.1	5.51	18.8	11.7	78.3	0.55	5.81	26.2	3.19	0.303	0.0463	0.158	0.0987	0.658	0.0046	0.0488	0.220
ORT01	173	10.6	2.41	4.74	3.43	0.72	3.41	3.07	57.0	1.65	0.101	0.0229	0.0451	0.0326	0.0068	0.0325	0.0293	0.543
ORT02	12.5	1.85	0.60	0.45	0.79	0.02	0.10	ND	8.52	0.128	0.0190	0.0062	0.0047	0.0081	0.0002	0.0010	ND	0.0874
ORT03	74.3	1.16	0.86	ND	0.31	ND	1.82	0.19	53.5	0.640	0.0100	0.0074	ND	0.0026	ND	0.0156	0.0016	0.462
ORT04	33.0	5.52	1.11	1.96	2.44	0.97	0.18	0.19	11.9	0.280	0.0468	0.0095	0.0166	0.0207	0.0082	0.0015	0.0016	0.101
ORT05	156	9.78	2.56	3.56	3.66	ND	ND	2.33	96.3	1.25	0.0782	0.0205	0.0285	0.0293	ND	ND	0.0186	0.771
ORT06	73.8	7.54	1.42	3.62	2.51	1.15	1.28	1.12	30.2	0.727	0.0761	0.0143	0.0363	0.0255	0.0113	0.0123	0.0106	0.278
ORT07	284	45.8	8.65	16.5	20.6	7.93	0.22	1.79	8.69	2.09	0.336	0.0636	0.121	0.151	0.0583	0.0016	0.0132	0.0639
ORT08	82.7	11.1	1.96	4.54	4.63	2.07	ND	1.30	24.9	0.707	0.0951	0.0167	0.0388	0.0395	0.0177	ND	0.0111	0.213
ORT09	170	15.8	3.93	7.48	4.38	3.68	2.68	3.99	13.7	1.88	0.175	0.0436	0.0831	0.0487	0.0409	0.0298	0.0443	0.152
ORT10	216	9.47	2.67	3.20	3.60	3.67	1.77	2.38	26.8	1.68	0.0734	0.0207	0.0248	0.0279	0.0285	0.0137	0.0185	0.208
ORT11	81.0	11.0	1.11	6.65	3.23	2.68	0.32	2.61	53.0	0.633	0.0858	0.0087	0.0519	0.0252	0.0210	0.0025	0.0204	0.414
ORT12	147	15.8	4.45	5.21	6.17	4.93	0.5	3.72	113	1.13	0.122	0.0342	0.0400	0.0475	0.0379	0.0039	0.0286	0.872
ORT13	220	20.8	6.44	7.92	6.44	5.21	ND	4.43	67.4	1.51	0.142	0.0441	0.0542	0.0441	0.0357	ND	0.0303	0.461
ORT14	17.5	4.54	1.75	0.81	1.98	0.19	0.48	ND	2.60	0.159	0.0413	0.0159	0.0073	0.0180	0.0018	0.0043	ND	0.0236
ORT15	171	22.9	6.06	6.13	10.7	11.9	ND	0.89	74.3	1.09	0.146	0.0386	0.0391	0.0679	0.0755	ND	0.0057	0.473
ORT16	140	15.8	4.09	5.03	6.68	3.47	1.18	0.67	4.05	1.03	0.116	0.0301	0.0370	0.0491	0.0255	0.0087	0.0049	0.0298
ORT18	168	8.05	1.71	3.03	3.31	4.13	0.99	0.33	3.59	1.31	0.0629	0.0133	0.0237	0.0259	0.0322	0.0077	0.0025	0.028
ORT19	209	11.7	1.24	2.16	8.26	2.61	ND	1.24	5.54	7.40	0.413	0.0440	0.0765	0.292	0.0925	ND	0.0439	0.196
ORT20	18.9	2.93	1.24	0.56	1.13	0.54	0.51	0.07	3.12	0.172	0.0266	0.0112	0.0051	0.0103	0.0049	0.0046	0.0007	0.0284

FIELD ID	Not Normalized (µg/kg dry weight)									Normalized to TOC (µg/g TOC)								
	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros
ORT21	124	13.6	3.74	5.53	4.37	4.34	1.35	1.26	27.0	0.989	0.109	0.0299	0.0442	0.0349	0.0347	0.0108	0.0101	0.216
ORT22	193	14.0	1.18	5.35	7.43	7.89	0.61	1.14	5.57	1.63	0.117	0.0100	0.0450	0.0624	0.0663	0.0051	0.0096	0.0468
ORT23	134	14.8	2.62	6.00	6.18	6.22	6.64	2.78	40.2	0.959	0.106	0.0187	0.0429	0.0442	0.0444	0.0474	0.0199	0.287
ORT24	166	27.0	8.04	11.5	7.46	10.3	2.11	2.37	42.4	1.11	0.181	0.0539	0.0769	0.0501	0.0689	0.0142	0.0159	0.285
ORT25	354	25.1	7.54	9.15	8.39	32.2	2.28	7.78	19.7	2.25	0.160	0.0480	0.0583	0.0535	0.205	0.0145	0.0496	0.125
ORT26	276	21.6	6.51	8.60	6.49	12.7	1.58	2.44	29.8	1.83	0.143	0.0431	0.0569	0.0430	0.0844	0.0104	0.0162	0.197
ORT27	487	17.2	3.28	6.49	7.44	13.8	ND	3.11	35.5	3.34	0.118	0.0225	0.0445	0.0510	0.0948	ND	0.0213	0.243
ORT28	136	19.9	7.49	6.74	5.71	12.6	1.84	2.01	12.9	0.847	0.124	0.0465	0.0419	0.0355	0.0782	0.0114	0.0125	0.0799
ORT29	52.4	2.28	0.83	0.26	1.19	2.28	0.27	ND	10.9	0.410	0.0178	0.0065	0.0020	0.0093	0.0178	0.0021	ND	0.0851
ORT30	3.76	0.93	ND	0.70	0.23	ND	0.40	0.32	19.0	0.162	0.0402	ND	0.0302	0.0100	ND	0.0172	0.0139	0.818
ORT31	133	35.2	5.41	23.1	6.66	94.9	2.67	2.04	19.7	1.08	0.286	0.0440	0.188	0.0542	0.772	0.0217	0.0166	0.161
ORT32	108	27.4	5.25	11.5	10.6	28.3	2.02	2.69	17.8	0.949	0.240	0.0460	0.101	0.0934	0.248	0.0177	0.0236	0.156
ORT33	87.9	51.4	16.4	16.4	18.7	75.1	0.63	0.07	6.03	2.04	1.19	0.379	0.380	0.434	1.74	0.0146	0.0017	0.140
ORT34	118	12.9	2.30	5.51	5.09	4.29	0.89	0.44	3.25	0.710	0.0777	0.0139	0.0332	0.0307	0.0258	0.0054	0.0026	0.0196
ORT35	92.3	11.7	3.69	4.89	3.15	5.48	1.54	2.33	18.7	0.678	0.0860	0.0271	0.0360	0.0232	0.0403	0.0113	0.0172	0.137
ORT36	105	19.2	8.32	6.35	4.52	7.49	1.51	1.41	16.7	0.634	0.116	0.0501	0.0383	0.0272	0.0451	0.0091	0.0085	0.101
ORT37	317	17.3	3.32	7.64	6.30	15.6	1.69	3.75	26.1	2.17	0.118	0.0227	0.0523	0.0432	0.107	0.0116	0.0257	0.179
ORT38	143	37.6	7.97	22.6	6.97	5.37	ND	3.90	62.0	0.932	0.246	0.0521	0.148	0.0456	0.0351	ND	0.0255	0.405
ORT39	216	25.0	3.88	11.7	9.47	5.74	1.31	0.39	15.9	1.18	0.137	0.0212	0.0640	0.0518	0.0312	0.0072	0.0021	0.0878
ORT40	128	7.43	1.14	3.84	2.45	7.93	2.62	2.65	136	0.776	0.0450	0.0069	0.0233	0.0149	0.0480	0.0159	0.0161	0.822
ORT41	92.4	9.78	1.31	4.71	3.76	1.50	0.66	0.23	5.66	0.428	0.0453	0.0061	0.0218	0.0174	0.0069	0.0031	0.0011	0.0262
Cedar-Ortega River Basin Sites – Sub-Surface Sediments																		
CED01-M	225	79.3	3.06	69.6	6.65	10.3	1.16	5.58	27.2	3.08	1.08	0.0418	0.951	0.0908	0.140	0.0158	0.0763	0.371
CED03-M	0.97	0.43	ND	ND	0.43	ND	0.05	ND	0.20	0.0079	0.0035	ND	ND	0.0035	ND	0.0004	ND	0.0016
CED03-L	3,580	36.7	ND	14.6	22.1	19.1	ND	9.00	ND	28.0	0.287	ND	0.114	0.173	0.149	ND	0.0703	ND
CED04-M	1,810	33.3	6.08	6.44	20.8	12.8	1.10	4.21	8.46	12.8	0.235	0.0428	0.0454	0.147	0.0901	0.0077	0.0297	0.0596
CED04-L	114	37.2	1.89	27.0	8.29	5.36	0.25	0.54	9.98	0.629	0.205	0.0104	0.149	0.0458	0.0296	0.0014	0.0030	0.0552
CED06-M	108	24.0	1.36	16.2	6.45	13.5	1.73	2.19	22.4	1.27	0.280	0.0160	0.189	0.0754	0.158	0.0203	0.0256	0.261
CED06-L	7.37	1.45	0.81	ND	0.64	ND	1.55	0.17	19.5	0.0376	0.0074	0.0041	ND	0.0033	ND	0.0079	0.0009	0.0996
CED07-M	819	18.7	7.11	4.66	6.93	11.8	2.02	3.78	32.3	6.12	0.140	0.0531	0.0348	0.0517	0.088	0.0151	0.0282	0.241
CED07-L	3.55	2.35	1.45	ND	0.90	ND	1.69	ND	33.2	0.0214	0.0142	0.0087	ND	0.0054	ND	0.0102	ND	0.200

FIELD ID	Not Normalized (µg/kg dry weight)									Normalized to TOC (µg/g TOC)								
	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros
CED08-M	141	12.8	3.50	5.01	4.33	16.1	0.91	1.34	13.0	1.19	0.108	0.0294	0.0421	0.0363	0.135	0.0076	0.0112	0.110
CED09-M	509	31.0	2.51	18.6	9.85	46.7	ND	1.82	50.0	4.54	0.276	0.0224	0.166	0.0879	0.417	ND	0.0163	0.447
ORT01-M	66.5	10.9	3.18	3.92	3.80	ND	ND	2.86	77.3	0.519	0.0852	0.0248	0.0306	0.0297	ND	ND	0.0223	0.604
ORT01-L	1.29	1.16	1.16	ND	ND	ND	ND	ND	27.9	0.0124	0.0112	0.0112	ND	ND	ND	ND	ND	0.268
ORT02-M	55.4	5.39	0.27	2.27	2.85	1.08	2.32	ND	2.16	0.508	0.0495	0.0025	0.0208	0.0261	0.0099	0.0213	ND	0.0198
ORT02-L	2.81	ND	ND	ND	ND	ND	1.92	ND	2.24	0.0270	ND	ND	ND	ND	ND	0.0185	ND	0.0216
ORT03-M	28.2	2.09	2.09	ND	ND	ND	2.80	0.28	36.5	0.207	0.0153	0.0153	ND	ND	ND	0.0206	0.002	0.268
ORT03-L	4.15	1.45	0.77	ND	0.69	ND	2.21	0.45	70.6	0.0361	0.0126	0.0067	ND	0.0060	ND	0.0192	0.0039	0.614
ORT04-M	185	23.6	3.76	11.0	8.80	2.07	0.92	1.95	12.4	1.44	0.184	0.0293	0.0863	0.0687	0.0162	0.0072	0.0152	0.0968
ORT04-L	1,616	46.4	ND	16.1	30.3	32.0	ND	15.0	34.9	14.2	0.407	ND	0.141	0.266	0.281	ND	0.132	0.306
ORT05-M	25.5	3.20	2.31	ND	0.89	0.49	ND	0.54	28.3	0.174	0.0219	0.0158	ND	0.0061	0.0033	ND	0.0037	0.194
ORT05-L	52.4	3.25	1.84	ND	1.41	ND	2.83	ND	99.6	0.397	0.0246	0.0139	ND	0.0107	ND	0.0214	ND	0.754
ORT06-M	14.0	3.41	1.05	1.98	2.76	0.20	1.06	0.16	25.8	0.125	0.0306	0.0094	0.0177	0.0247	0.0018	0.0095	0.0014	0.232
ORT06-L	1.99	1.16	0.92	ND	0.70	0.13	1.08	ND	32.6	0.0214	0.0125	0.0099	ND	0.0075	0.0014	0.0116	ND	0.350
ORT07-M	117	31.3	4.45	7.52	19.3	8.99	1.28	1.55	0.31	0.854	0.228	0.0325	0.0549	0.141	0.0656	0.0093	0.0113	0.0023
ORT07-L	178	33.6	1.91	9.83	21.9	5.98	1.39	ND	5.61	1.17	0.221	0.0126	0.0647	0.144	0.0394	0.0091	ND	0.0369
ORT08-M	52.8	7.76	1.91	2.31	3.55	0.87	0.55	0.28	17.8	0.517	0.0761	0.0187	0.0226	0.0348	0.0085	0.0054	0.0027	0.174
ORT08-L	1.24	ND	ND	ND	ND	ND	0.28	ND	13.6	0.0133	ND	ND	ND	ND	ND	0.0029	ND	0.145
ORT09-M	80.4	7.12	ND	3.41	3.71	2.02	3.48	3.81	28.5	0.609	0.0539	ND	0.0258	0.0281	0.0153	0.0264	0.0289	0.216
ORT09-L	3.28	0.89	ND	ND	0.89	ND	2.78	0.40	4.84	0.0329	0.0089	ND	ND	0.0089	ND	0.0279	0.0040	0.0486
ORT10-M	359	18.9	5.22	5.51	8.15	4.70	ND	5.11	107	2.54	0.134	0.0370	0.0391	0.0578	0.0333	ND	0.0362	0.759
ORT10-L	26.7	1.56	1.56	ND	ND	ND	1.81	0.32	46.0	0.202	0.0118	0.0118	ND	ND	ND	0.0137	0.0024	0.349
ORT11-M	145	28.7	6.08	16.6	5.98	1.87	ND	5.13	52.7	1.08	0.214	0.0454	0.124	0.0446	0.0139	ND	0.0383	0.393
ORT11-L	1.58	ND	ND	ND	ND	0.26	1.80	0.24	35.3	0.0149	ND	ND	ND	ND	0.0024	0.0170	0.0022	0.333
ORT12-M	221	19.7	1.82	7.86	10.0	5.69	0.57	6.30	88.3	1.53	0.136	0.0126	0.0542	0.0691	0.0392	0.0039	0.0435	0.609
ORT12-L	3.60	0	ND	0.28	ND	ND	1.55	0.25	18.0	0.0279	0.0022	ND	0.0022	ND	ND	0.0120	0.0019	0.140
ORT13-M	235	33.5	5.71	18.0	9.80	2.95	5.20	7.27	59.7	1.54	0.220	0.0376	0.118	0.0645	0.0194	0.0342	0.0478	0.393
ORT13-L	6.57	0.22	ND	0.22	ND	ND	0.97	0.72	54.7	0.0413	0.0014	ND	0.0014	ND	ND	0.0061	0.0045	0.344
ORT14-M	2.38	0.79	ND	0.30	0.49	ND	1.86	ND	0.14	0.0252	0.0084	ND	0.0032	0.0052	ND	0.0197	ND	0.0015
ORT14-L	2.07	0.55	ND	ND	0.55	ND	ND	ND	0.20	0.0170	0.0045	ND	ND	0.0045	ND	ND	ND	0.0016
ORT15-M	342	25.0	3.88	9.18	12.0	7.49	ND	3.91	50.6	2.20	0.161	0.0249	0.0589	0.0768	0.0480	ND	0.0251	0.325

FIELD ID	Not Normalized (µg/kg dry weight)									Normalized to TOC (µg/g TOC)								
	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros
ORT15-L	218	17.5	4.54	ND	13.0	4.23	ND	2.81	40.2	1.41	0.114	0.0295	ND	0.0843	0.0275	ND	0.0183	0.261
ORT16-M	224	15.2	0.64	6.04	8.51	4.30	0.29	1.17	0.20	1.63	0.111	0.0047	0.0441	0.0621	0.0314	0.0021	0.0085	0.0015
ORT16-L	10.4	0.98	ND	ND	0.98	ND	ND	ND	5.89	0.0751	0.0071	ND	ND	0.0071	ND	ND	ND	0.0427
ORT18-M	189	21.1	1.49	8.56	11.1	3.85	1.59	1.22	3.31	1.70	0.190	0.0135	0.0771	0.0999	0.0346	0.0144	0.0110	0.0299
ORT18-L	8.66	0.72	ND	ND	0.72	ND	ND	ND	6.71	0.0710	0.0059	ND	ND	0.0059	ND	ND	ND	0.055
ORT20-M	6.48	0.91	ND	0.29	0.62	ND	ND	ND	8.13	0.0444	0.0062	ND	0.0020	0.0043	ND	ND	ND	0.0557
ORT20-L	1.95	0.81	ND	ND	0.81	ND	ND	ND	3.84	0.0163	0.0067	ND	ND	0.0067	ND	ND	ND	0.032
ORT21-M	288	16.8	3.64	7.05	6.05	7.65	2.32	1.91	40.7	1.96	0.114	0.0248	0.0480	0.0412	0.0520	0.0158	0.0130	0.277
ORT21-L	16.3	7.00	4.37	0.58	2.05	0.33	0.83	ND	18.8	0.132	0.0564	0.0352	0.0047	0.0165	0.0026	0.0067	ND	0.152
ORT23-M	71.3	10.9	2.74	4.51	3.61	1.04	1.68	2.37	23.8	0.475	0.0724	0.0183	0.0301	0.0240	0.0069	0.0112	0.0158	0.159
ORT23-L	3.47	0.71	0.71	ND	ND	ND	0.99	ND	1.11	0.0259	0.0053	0.0053	ND	ND	ND	0.0074	ND	0.0083
ORT24-M	5.57	5.52	2.60	1.44	1.48	ND	1.69	0.25	21.6	0.0384	0.0381	0.0180	0.0099	0.0102	ND	0.0117	0.0017	0.149
ORT24-L	0.47	4.26	2.81	ND	1.46	ND	1.18	ND	12.8	0.0030	0.0268	0.0177	ND	0.0092	ND	0.0074	ND	0.0804
ORT25-M	362	14.8	3.00	6.09	5.70	8.36	2.16	2.14	20.9	2.38	0.0973	0.0197	0.0401	0.0375	0.0550	0.0142	0.0141	0.137
ORT25-L	3.16	0.75	0.75	ND	ND	ND	1.12	0.59	14.4	0.0221	0.0052	0.0052	ND	ND	ND	0.0078	0.0042	0.101
ORT26-M	18.0	10.1	5.43	2.52	2.19	ND	1.09	0.55	25.3	0.110	0.0618	0.0331	0.0154	0.0134	ND	0.0066	0.0034	0.155
ORT26-L	0.28	3.06	3.06	ND	ND	ND	1.08	ND	20.8	0.0019	0.0208	0.0208	ND	ND	ND	0.0074	ND	0.142
ORT27-M	493	14.9	2.71	4.80	7.42	7.93	0.71	2.04	42.1	3.22	0.0976	0.0177	0.0314	0.0485	0.0518	0.0047	0.0134	0.275
ORT27-L	31.9	1.65	0.45	0.22	0.98	1.36	0.08	ND	7.89	0.447	0.0230	0.0063	0.0030	0.0137	0.0190	0.0011	ND	0.111
ORT28-M	125	19.9	5.90	8.95	5.01	4.41	1.36	1.68	17.6	0.884	0.141	0.0418	0.0635	0.0356	0.0313	0.0097	0.0119	0.125
ORT28-L	1.43	2.81	2.29	ND	0.53	ND	1.53	ND	0.55	0.0087	0.0172	0.0139	ND	0.0032	ND	0.0093	ND	0.0034
ORT29-M	4.33	0.89	ND	ND	0.89	ND	ND	ND	7.25	0.0281	0.0058	ND	ND	0.0058	ND	ND	ND	0.0471
ORT29-L	5.04	0.69	0.69	ND	ND	ND	0.28	ND	13.7	0.0407	0.0056	0.0056	ND	ND	ND	0.0022	ND	0.110
ORT30-M	2.50	ND	ND	ND	ND	ND	0.43	1.15	26.1	0.0745	ND	ND	ND	ND	ND	0.0127	0.0344	0.778
ORT30-L	7.19	ND	ND	ND	ND	ND	0.44	0.14	36.9	0.0985	ND	ND	ND	ND	ND	0.0060	0.0019	0.505
ORT31-M	12.9	12.7	6.19	1.34	5.21	3.49	1.15	2.79	0.46	0.116	0.115	0.0558	0.0121	0.0469	0.0315	0.0104	0.0252	0.0042
ORT31-L	2.01	0.91	0.91	ND	ND	0.45	0.97	ND	7.38	0.0325	0.0147	0.0147	ND	ND	0.0072	0.0156	ND	0.119
ORT32-M	4.39	4.26	3.18	ND	1.08	ND	1.33	1.79	6.32	0.0410	0.0398	0.0297	ND	0.0101	ND	0.0124	0.0167	0.059
ORT32-L	0.81	1.68	1.35	ND	0.33	ND	0.59	ND	5.43	0.0191	0.0397	0.0318	ND	0.0079	ND	0.0139	ND	0.128
ORT34-M	7.96	4.67	1.19	1.80	1.67	ND	0.12	ND	0.14	0.0514	0.0301	0.0077	0.0116	0.0108	ND	0.0007	ND	0.0009
ORT35-M	162	15.5	3.64	7.09	4.82	7.15	1.65	3.23	30.2	1.24	0.119	0.0278	0.0541	0.0368	0.0546	0.0126	0.0246	0.231

FIELD ID	Not Normalized (µg/kg dry weight)									Normalized to TOC (µg/g TOC)								
	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros	Sum PCBs	Sum DDTs	DDT	DDE	DDD	Chlor-danes	BHCs	Endo-sulfans	Other Chloros
ORT35-L	4.11	2.31	1.40	ND	0.91	0.57	1.54	0.89	1.38	0.0254	0.0143	0.0086	ND	0.0056	0.0035	0.0095	0.0055	0.0085
ORT36-M	56.0	16.6	4.49	8.52	3.60	1.51	1.05	0.93	8.72	0.376	0.111	0.0301	0.0572	0.0242	0.0102	0.0070	0.0063	0.0585
ORT36-L	5.00	1.49	1.49	ND	ND	ND	ND	ND	19.7	0.0314	0.0093	0.0093	ND	ND	ND	ND	ND	0.124
ORT37-M	36.0	4.47	2.28	1.16	1.04	3.21	0.83	0.45	21.3	0.232	0.0289	0.0147	0.0075	0.0067	0.0207	0.0053	0.0029	0.137
ORT37-L	25.7	4.11	2.59	0.71	0.82	3.74	1.26	0.27	18.1	0.209	0.0334	0.0210	0.0057	0.0067	0.0304	0.0103	0.0022	0.147
ORT38-M	8.42	1.39	ND	ND	1.39	ND	1.88	1.58	24.6	0.0498	0.0082	ND	ND	0.0082	ND	0.0111	0.0094	0.145
ORT39-M	193	36.1	3.69	19.0	13.5	2.94	0.45	1.47	9.33	1.01	0.189	0.0193	0.0993	0.0706	0.0154	0.0023	0.0077	0.0488
ORT39-L	1.90	2.93	ND	0.61	2.32	0.04	ND	ND	22.6	0.0104	0.0159	ND	0.0033	0.0126	0.0002	ND	ND	0.123
ORT40-M	18.4	29.3	ND	19.0	10.3	ND	1.51	4.55	87.5	0.0908	0.144	ND	0.0938	0.0506	ND	0.0074	0.0224	0.431
ORT40-L	10.8	2.07	1.87	0.20	ND	ND	2.40	1.41	42.8	0.0546	0.0105	0.0095	0.0010	ND	ND	0.0122	0.0072	0.217
ORT41-M	111	48.7	ND	27.8	20.8	7.64	6.11	3.37	4.47	0.493	0.215	ND	0.123	0.0921	0.0338	0.0270	0.0149	0.0198
ORT41-L	2.55	ND	ND	ND	ND	ND	3.53	ND	7.29	0.0126	ND	ND	ND	ND	ND	0.0174	ND	0.0359

[a] Note that in the Lower St. Johns River and Cedar-Ortega River Basin report (Battelle, 2001) the sum of the PCB congeners did not include PCB08, and there are therefore minor differences in the Sum PCBs. Also, the chlordanes was based on the three primary chlordane compounds in the earlier report, and is based on seven chlordane compounds in this report (including the three primary compounds), resulting in some differences; the three primary compounds generally constitute >90% of the sum of the seven compounds.

Analysis of the COR surface sediment PCB data against 2 standard deviations from the median was performed to identify sites with notably elevated concentrations, relative to the other sites. Two of the COR sites, CED01 and CED02 (3,930 and 2,300 µg/kg, respectively), had a sum of the 23 PCB congener concentrations above 2,040 µg/kg (median concentration + 2 standard deviations); the PCB concentrations were clearly broadly elevated at the COR sites. The GC/MS analysis of 107 PCB congeners (discussed further below) indicates that surface sediments at CED02 and CED12 likely also have PCB concentrations greater than the median + 2 standard deviations; sites CED12, CED01, and CED02 are all sites upstream in the Cedar River.

PCB (detailed analysis of 107 PCB congeners)
A set of samples were selected for re-processing and re-analysis in the laboratory for a detailed PCB congener characterization by quantifying the concentrations of 107 individual PCB congeners. These congeners had been carefully selected to be representative of most environmental contamination and original PCB source material (i.e., Aroclor formulations) and comprise about 95-99% of the total PCB in most environmental samples and all PCB formulations. A total of 21 of the 23 base PCB congeners were also included in this long list of PCB congeners. The two that were not included (PCB77 and PCB126) are coplanar congeners that need specialized techniques to be accurately determined, and the data reported for those two congeners should be considered less reliable than the rest. Additionally, the concentrations of those two congeners are also typically very minor, compared to the rest (generally constitute well below 1% of the total, and are often not detected at all). The GC/MS analysis is recognized to provide more reliable data (e.g., less potential for interferences and false positives, among other characteristics) than the GC/ECD analysis (Method 8081M), and the GC/MS data should therefore be used for most data analysis and interpretation, when available.

The total PCB concentrations of the surface and sub-surface sediment samples are summarized in Table 3-7. The detailed data, with results for the 107 individual PCB congeners, is presented in Appendix D. Using the GC/MS analysis data it was determined that the base PCB congener set, on average, represented 42% of the sum of the 107 PCB congeners in the COR samples (it ranged from 40 to 45% for most samples). Therefore, although the 107 PCB congeners were not measured for all samples, the total PCB could be estimated by multiplying the sum of the base PCB congener concentrations by 2.4. For this data set, using the 2.4 multiplier provided a more accurate, location-specific, estimate than the general NOAA NS&T figure of 2.0. For the samples that were included in the detailed PCB congener characterization, the total PCB was estimated as the sum of the 107 PCB congener concentrations. For the samples that were not included in the detailed PCB congener characterization by GC/MS analysis, the total PCB was estimated by multiplying the sum of the 23 PCB congeners from the GC/ECD analysis (Method 8081M; data in Table 3-6) by 2.4.

The total PCB concentrations in the surface sediments ranged from 9.0 (site ORT30) to 42,900 µg/kg (site CED12). The sub-surface total PCB concentrations ranged from less than 1 µg/kg (samples ORT04-1-L, ORT05-L, and ORT26-L) to 11,200 µg/kg (site CED03-L). Sample CED03-L, which had the highest sub-surface PCB concentration, was collected at a relatively shallow sediment depth (center-point of 29 cm; Table 2-1), compared to the surrounding sample cores and most "low" segment samples, and therefore does not represent the PCB concentrations at a significant depth at this location. The detailed PCB congener analysis included surface sediments from 3 sites in the Cedar River that were not analyzed for other contaminants (sites CED12, CED13, and CED14; Figure 2-2). Those sites were added to provide a better characterization of the PCB contamination in the Cedar River. The most upstream site (CED12) had the highest surface sediment PCB concentrations, and the Cedar River sites, in general, clearly had the highest surface and sub-surface PCB concentrations.

Table 3-7. Total PCB Concentration Based on the Analysis of 107 PCB Congeners

Surface Sediment	
Site/Sample	**Total PCB (µg/kg, dry wt.)**
CED01	9,980
CED02	11,500
CED03	2,320
CED04	3,040
CED05	643
CED06	1,120
CED07	1,271
CED08	330
CED09	817
CED12	42,900
CED13	993
CED14	581
ORT01	175
ORT02[a]	30.0
ORT03[a]	178
ORT04-1	43.9
ORT05	88.6
ORT06[a]	177
ORT07	137
ORT08[a]	199
ORT09	119
ORT10	177
ORT11[a]	194
ORT12[a]	352
ORT13	167
ORT14[a]	42.0
ORT15[a]	411
ORT16	106
ORT18	115
ORT19[a]	502
ORT20	45.0
ORT21	183
ORT22[a]	464
ORT23[a]	322
ORT24	186
ORT25	441
ORT26	335
ORT27	525
ORT28	175
ORT29[a]	126
ORT30[a]	9.01
ORT31	307
ORT32[a]	260
ORT33[a]	211
ORT34[a]	283
ORT35	114
ORT36	115

Sub-Surface Sediment Samples			
Site/Sample	**Total PCB (µg/kg, dry wt.)**	**Site/Sample**	**Total PCB (µg/kg, dry wt.)**
CED01-M	471	ORT24-M[a]	13.4
CED03-M	2,930	ORT24-L[a]	1.13
CED03-L	11,200	ORT25-M	376
CED04-M	7,650	ORT25-L[a]	7.57
CED04-L	158	ORT26-M[a]	43.2
CED06-M	257	ORT26-L[a]	0.67
CED06-L[a]	17.7	ORT27-M	684
CED07-M	1,450	ORT27-L	111
CED07-L[a]	8.53	ORT28-M	112
CED08-M	296	ORT28-L[a]	3.43
CED09-M	1,030	ORT29-M[a]	10.4
ORT01-M	12.2	ORT29-L[a]	12.1
ORT01-L	3.08	ORT30-M[a]	6.01
ORT02-M[a]	133	ORT30-L[a]	17.3
ORT02-L[a]	6.74	ORT31-M[a]	31.0
ORT03-M[a]	67.7	ORT31-L[a]	4.83
ORT03-L[a]	10.0	ORT32-M[a]	10.5
ORT04-1-M	34.8	ORT32-L[a]	1.94
ORT04-1-C	2.24	ORT34-M[a]	19.1
ORT04-1-L	0.54	ORT35-M	389
ORT05-M	1.48	ORT35-L	9.87
ORT05-L	0.22	ORT36-M[a]	134
ORT06-M[a]	33.6	ORT36-L[a]	12.0
ORT06-L[a]	4.79	ORT37-M[a]	86.4
ORT07-M	138	ORT37-L[a]	61.7
ORT07-L	174	ORT38-M[a]	20.2
ORT08-M[a]	127	ORT39-M[a]	464
ORT08-L[a]	2.99	ORT39-L[a]	4.57
ORT09-M[a]	193	ORT40-M[a]	44.2
ORT09-L[a]	7.86	ORT40-L[a]	25.8
ORT10-M	386	ORT41-M[a]	267
ORT10-L[a]	64.0	ORT41-L[a]	6.13
ORT11-M[a]	348		
ORT11-L[a]	3.79		
ORT12-M[a]	531		
ORT12-L[a]	8.65		
ORT13-M	279		
ORT13-L[a]	15.8		
ORT14-M[a]	5.71		
ORT14-L[a]	4.97		
ORT15-M[a]	454		
ORT15-L[a]	348		
ORT16-M[a]	536		
ORT16-L[a]	24.9		
ORT18-M[a]	453		
ORT18-L[a]	20.8		
ORT20-M[a]	15.5		

Surface Sediment	
Site/Sample	Total PCB (µg/kg, dry wt.)
ORT37	432
ORT38	116
ORT39	325
ORT40	191
ORT41 [a]	222

Sub-Surface Sediment Samples			
Site/Sample	Total PCB (µg/kg, dry wt.)	Site/Sample	Total PCB (µg/kg, dry wt.)
ORT20-L [a]	4.68		
ORT21-M	216		
ORT21-L	11.0		
ORT23-M [a]	171		
ORT23-L [a]	8.33		

[a] Total PCB concentration was calculated using the GC/ECD based PCB congener data; sample was *not* included in the GC/MS 107 PCB congener analysis.

Pesticides - DDTs

The median total DDT concentration was 14.8 µg/kg for the COR surface sediment samples. The concentration was 4.26 µg/kg for the sub-surface sediment samples. The total DDT concentration ranged from 0.93 (site ORT30) to 87.8 µg/kg (site CED01) in the COR surface sediments sites, and from ND to 79.3 µg/kg in the sub-surface sediments. The apparently elevated concentrations of DDT (as well as other pesticides, such as chlordane and endosulfans) in the sub-surface samples from site ORT04 may, as discussed in the PCB section above, be unreliable results, and should be considered with caution. Investigation of concentrations of DDT and its degradation products DDD and DDE reveal that the greatest concentration of DDT compounds was typically found as DDD or DDE; the original pesticide compound (DDT) was less frequently the predominant DDT constituent.

An analysis of the DDT concentrations against 2 standard deviations from their medians was performed to establish which sites had elevated concentrations, compared to the rest of the COR study sites. Three of the COR sites, CED01 (87.8 µg/kg), ORT07 (45.8 µg/kg), and ORT33 (51.4 µg/kg), had surface sediment total DDT concentrations above 44.7 µg/kg (median concentration + 2 standard deviations). The DDT concentrations were clearly highest in the Cedar River and Fishweir Creek areas.

Pesticides – Chlordanes, BHCs, Endosulfans, and other Chlorinated Pesticides

Concentrations of the other chlorinated pesticides, such as chlordane, BHC and endosulfan, were generally significantly lower than total DDT, and their concentration ranges were also smaller. Exceptions were observed at some locations (CED06, CED09, ORT31, and ORT33), where the chlordane concentrations were higher than the DDT concentrations. Although a few of the "cleanest" COR sites had no chlordane detected, sites such as CED09, ORT31, and ORT33 had 78.3, 94.9, and 75.1 µg/kg of total chlordane, respectively, in the surface sediments. The surface sediment median total chlordane concentration was 6.7 µg/kg. The sub-surface chlordane concentration were lower than the surface sediment concentrations; the median sub-surface total chlordane concentration was 0.2 µg/kg, and only 2 sub-surface samples had a total chlordane concentration above 20 µg/kg. The BHC and endosulfan concentrations were lower than the chlordane concentrations; the BHC and endosulfan median concentrations were 0.89 and 2.04 µg/kg, respectively.

The concentrations of the other pesticides that were analyzed, but were not included in the base pesticide data presentation (e.g, aldrin, dieldrin, chlorpyriphos, endrin, hexachlorobenzene, mirex, and methoxychlor), were, for the most part, quite low, compared to the major pesticide classes of compounds. Dieldrin was most widely detected of these additional pesticides, but consistently at concentrations below 10 µg/kg and generally at a concentration that was well below the DDT and chlordane concentrations. The surface sediments collected at ORT33 had the highest dieldrin concentrations. Toxaphene was not detected in any samples.

Other Chlorinated Compounds

The concentrations of total other chlorinated compounds ranged from less than to 1 µg/kg to 136 µg/kg (site ORT40) in the surface sediments from the Cedar-Ortega River Basin. The sub-surface sediments had similar, relatively low, concentrations of other chlorinated compounds as the surface sediments. The variability of the sediment concentrations of chlorinated compounds was reduced somewhat when the data were normalized to sediment TOC content (Tables 3-5 and 3-6), but the contaminant concentrations still covered a fairly wide range in magnitude.

3.1.3 Chlorophenolic Compound Results

Selected surface sediment samples were analyzed for 23 chlorinated compounds using method 8321M; 9 individual chlorinated phenols, 3 chlorinated anisoles, 5 guaiacols, and 6 catechols. This analysis was not performed on sub-surface sediment samples because of these compound's relatively high polarity and lower persistence; they would not be expected to be present at high levels in historic sediments. Table 3-8 lists the analytes that comprise each of these sub-groups of chlorinated phenolic compounds. Chlorinated phenols and anisoles are widely used industrial compounds, being a component and/or by-product of many industrial processes. Guaiacols and catechols are also more commonly considered industrial by-products, and are often associated with pulp and paper industry activities.

Table 3-8. Chlorinated Phenolic Compound Groups

Total Chlorophenolics	Total Phenols (Σ of)	Total Anisoles (Σ of)	Total Guaiacols (Σ of)	Total Catechols (Σ of)
Σ Phenols	2-Chlorophenol	2-Chloroanisole	4,5-Dichloroguaiacol	4-Chlorocatechol
Σ Anisoles	2,4-Dichlorophenol	2,4-Dichloroanisole	3,4,5-Trichloroguaiacol	3,5-Dichlorocatechol
Σ Guaiacols	2,6-Dichlorophenol	Pentachloroanisole	3,4,6-Trichloroguaiacol	4,5-Dichlorocatechol
Σ Catechols	2,4,5-Trichlorophenol		4,5,6-Trichloroguaiacol	3,4,5-Trichlorocatechol
	2,4,6-Trichlorophenol		Tetrachloroguaiacol	3,4,6-Trichlorocatechol
	2,3,4,5-Tetrachlorophenol			Tetrachlorocatechol
	2,3,4,6-Tetrachlorophenol			
	Pentachlorophenol			
	4-Chloro-3-methylphenol			

Table 3-9 presents the concentration ranges of chlorinated compounds found at the sampling locations, and the data for the individual sites are presented in Table 3-10. The complete data for each of the individual chlorophenolic compounds are presented in Appendix E.

Table 3-9. Concentration Ranges for Chlorinated Phenolic Compounds

	Not Normalized (µg/kg dry weight)			Normalized to TOC (µg/g TOC)		
	Median	Min	Max	Median	Min	Max
Cedar-Ortega River Basin Sites – Surface Sediments						
Total Chlorophenolics	5,240	1,400	22,100	52.0	ND	155
Σ Phenols	1,190	305	6,310	7.89	ND	123
Σ Anisoles	150	ND	376	1.18	ND	4.88
Σ Guaiacols	62.3	ND	4,360	0.58	ND	32.0
Σ Catechols	3,378	ND	15,100	30.1	ND	106

The data indicate that the chlorinated phenolic compound concentrations were highly variable in the sediments. The total chlorophenolic compound concentrations in the surface sediments at the COR sites ranged from 1,400 (site CED03) to 22,100 µg/kg (site CED04) at the COR sites; the highest and lowest concentrations were measured at two adjacent sites. The median concentration was 5,240 µg/kg for Cedar-Ortega River Basin. All sites had measurable concentrations of phenols. The samples from the majority of these sites also contained anisoles, guaiacols, and catechols.

Table 3-10. Organic Contaminant Summary Data — Chlorinated Phenolics

FIELD ID	Not Normalized (µg/kg dry weight)					Normalized to TOC (µg/g TOC)				
	Total Phenols	Total Anisoles	Total Guaiacols	Total Catechols	Total CPs	Total Phenols	Total Anisoles	Total Guaiacols	Total Catechols	Total CPs
Cedar-Ortega River Basin Sites (Surface Sediments)										
CED03	1,020	202	43.1	136	1,400	9.07	1.80	0.385	1.22	12.5
CED04	6,310	358	345	15,100	22,100	44.4	2.52	2.43	106	155
ORT02	653	376	57.9	1960	3,050	6.71	3.86	0.595	20.1	31.3
ORT04	1,680	152	122	ND	1,950	14.2	1.28	1.03	ND	16.5
ORT06	570	ND	ND	4,800	5,370	6.12	ND	ND	51.5	57.6
ORT07	4,280	163	166	514	5,120	31.5	1.19	1.22	3.78	37.7
ORT14	305	ND	ND	5,230	5,530	2.77	ND	ND	47.5	50.3
ORT16	513	ND	4,350	7,610	12,500	3.77	ND	32.0	56.0	91.8
ORT18	850	ND	1,670	6,840	9,360	6.64	ND	13.0	53.4	73.1
ORT19	3,480	138	207	425	4,250	123	4.88	7.34	15.0	150
ORT20	338	ND	ND	5,590	5,930	3.07	ND	ND	50.8	53.9
ORT22	2,850	149	66.6	620	3,680	23.9	1.25	0.560	5.21	30.9
ORT33	3,290	190	402	802	4,680	76.2	4.4	9.31	18.6	108
ORT34	4,710	ND	ND	8,760	13,500	28.4	ND	ND	52.8	81.1
ORT39	635	220	ND	7,580	8,430	3.36	1.16	ND	40.1	44.6
ORT41	1,370	190	ND	ND	1560	6.36	0.878	ND	ND	7.24

Only one of the COR sites (CED04; 22,100 µg/kg) had a surface sediment total chlorophenolic concentration above the COR reference value of 16,100 µg/kg (median concentration + 2 standard deviations). However, this is as much an indication of significant variability (i.e., high standard deviation) as it is of few sites with notably elevated chlorophenolic concentrations. The phenols or catechols contributed the largest proportion of the total chlorophenolic concentration.

There were a few instances of surprisingly high individual compound concentrations that did not follow an anticipated compound composition pattern. For instance, relatively high levels of tetrachlorocatechol were detected at CED04, ORT06, ORT14, and ORT20, among others, when few or no commonly related compounds were identified. Similarly, elevated levels of tetrachloroguaiacol and/or pentachloroanisole were detected at site ORT16 and ORT18, and pentachlorophenol at CED04 and ORT34. These unexpected data may be real measured concentrations, the composition of which is not understood at this time, or it could be contributed by non-analyte sample matrix components. These target compounds were particularly challenging to resolve in the analytical procedure, especially in the high-organic complex sample matrices that were encountered with many of these samples.

The analytical method that was used for the chlorophenolic analysis was intended to provide a first-level screening analysis of a broad range of compounds simultaneously, with the intent to identify locations and/or compounds that may warrant more detailed investigation. Since the method accommodated chlorinated phenolic compounds with highly varying chemical characteristics, it could not be optimized for a specific class of compounds and there was a significant potential for matrix contributions (i.e., non-analyte matrix contribution to measured compounds, and even false positives). The chlorophenolic data should therefore be used with caution. However, the analysis served its intended purpose in identifying locations and compounds that may be of concern, and these data can form the basis for further studies that should use more targeted and specific analytical methods (e.g., GC/MS or LC/MS).

3.2 Results for Metals Analysis

The sediment metals concentrations were determined for 20 elements. Three of the metals (aluminum, iron, and manganese) are considered major metals and are naturally abundant in most geological formations. The other 17 metals that were analyzed are potentially environmental contaminants of concern. These 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. Lithium is also sometimes used as a geological "marker" and may be used to normalize metals data for subsequent data analysis. The use of data normalizers, and the relationships between metal contaminants and common normalizers such as the major crustal elements, grain size, and total organic carbon, is discussed in more detail below.

Relationships Among Metals and Data Normalization

Metals distributions are controlled by several factors in sediments. These include the grain size, the amount of organic carbon, and the water column concentration and proximity to contaminant sources. During the initial data analysis process, the sediment contaminant metal concentrations were plotted versus the 1) sediment major metals concentrations, 2) grain size, and 3) TOC, in order to determine which normalizing parameter was most suitable for this sample set. Normalizing metals concentrations to aluminum is the most common approach for differentiating anthropogenic contamination from metals naturally occurring in the geology of the sediment, although iron, manganese, and/or lithium normalization can also be useful.

Normalizing to grain size [using the fines (silt + clay) fraction, such as %mud] is also frequently done to determine anthropogenic contamination, because of 1) the natural geological abundance differences and 2) the fact that many metals adhere/associate with 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, including mercury, may bind to organic matter of the sediment, and TOC normalizing the metals data may therefore also be appropriate.

Comparison of the aluminum concentrations to the fine-grained (silt + clay), or mud, fraction of the sediments revealed a general, but fairly weak, correspondence in this system (Figure 3-1). Similar variability was observed when the TOC content was used to compare to the aluminum concentrations, and when the other crustal elements were used instead of aluminum. Some of the variability may relate to the very high amount of TOC in many of the sediment samples (>10% in most surface sediments and >15% at a large number of sites); many of these sediments were comprised of significant proportions of organic non-geological material.

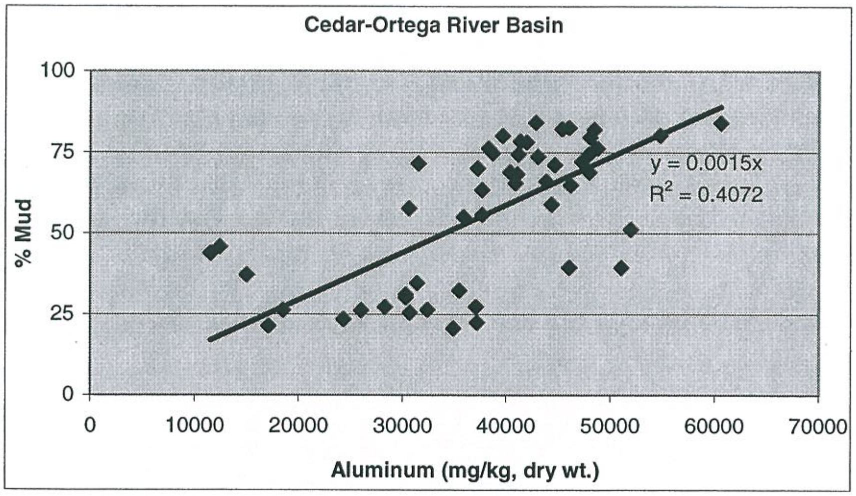


Figure 3-1. Grain Size (% Mud) versus Aluminum Concentrations of Surface Sediment Samples

The toxic metals concentrations also generally increased with the aluminum content, but the correspondence was more variable than one might expect (Figure 3-2). The relationship was particularly weak between the toxic metal concentration and grain size and TOC (Figures 3-3 and 3-4), and it became evident that metal contamination was best identified using normalization to one of the crustal elements. The relationship between a number of toxic metals and aluminum, iron, manganese, and lithium was therefore investigated. Lithium, though sometimes considered a potential contaminant, is sometimes used as a geological marker, and has been found to be useful for data normalizing in certain environments. Of the four elements, aluminum co-varied most consistently with the contaminant metals, and was therefore chosen as the primary normalized for the metals data assessment.

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 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* (Section 3.3.1). This presentation demonstrates 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. the grain size of the sediments exerted very little control over TOC accumulation). The high TOC values were also consistent with observation of samples with notable amounts of detritus, undegraded, or only partially degraded, vegetative debris that probably skewed the grain size and elevated the TOC content in many samples. Aluminum normalization provided better correlation to the other metal concentrations than grain size or TOC normalization, and better than what the other major metals provided.

Measured Metal Concentrations

The ranges of major and trace metal concentrations varied widely within the study area (see summary Table 3-11). The data from the metals analyses of sediment samples are summarized for each of the COR sites in Tables 3-12a through 3-12d; Table 3-12a contains the non-normalized metals data (which are also presented in Appendix F), Table 3-12b the aluminum normalized data, Table 3-12c the grain size normalized data, and Table 3-12d the TOC normalized data. Tables 3-12b through 3-12d present the normalized data for the potential metal contaminants; the 3 major crustal elements (aluminum, iron, and manganese) are not included in these three tables. These non-normalized and aluminum normalized data tables (Tables 3-12a and 3-12b), and the summary table (Table 3-11), include both the surface and sub-surface data. The grain-size and TOC normalized data are only presented for the surface sediment samples (Tables 3-12c and 3-12d).

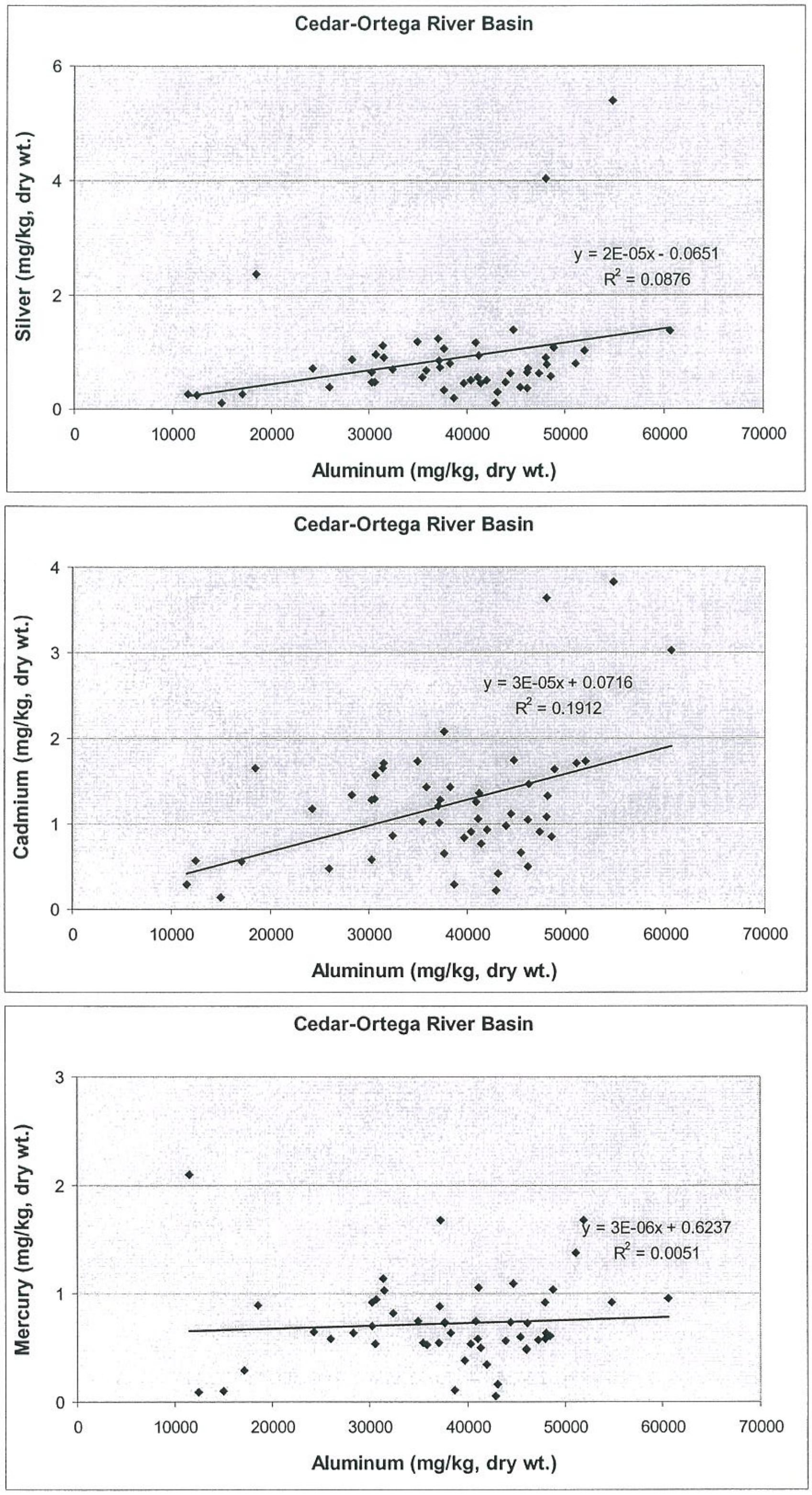


Figure 3-2. Silver, Cadmium, and Mercury Concentrations versus Aluminum Concentration of Surface Sediment Samples

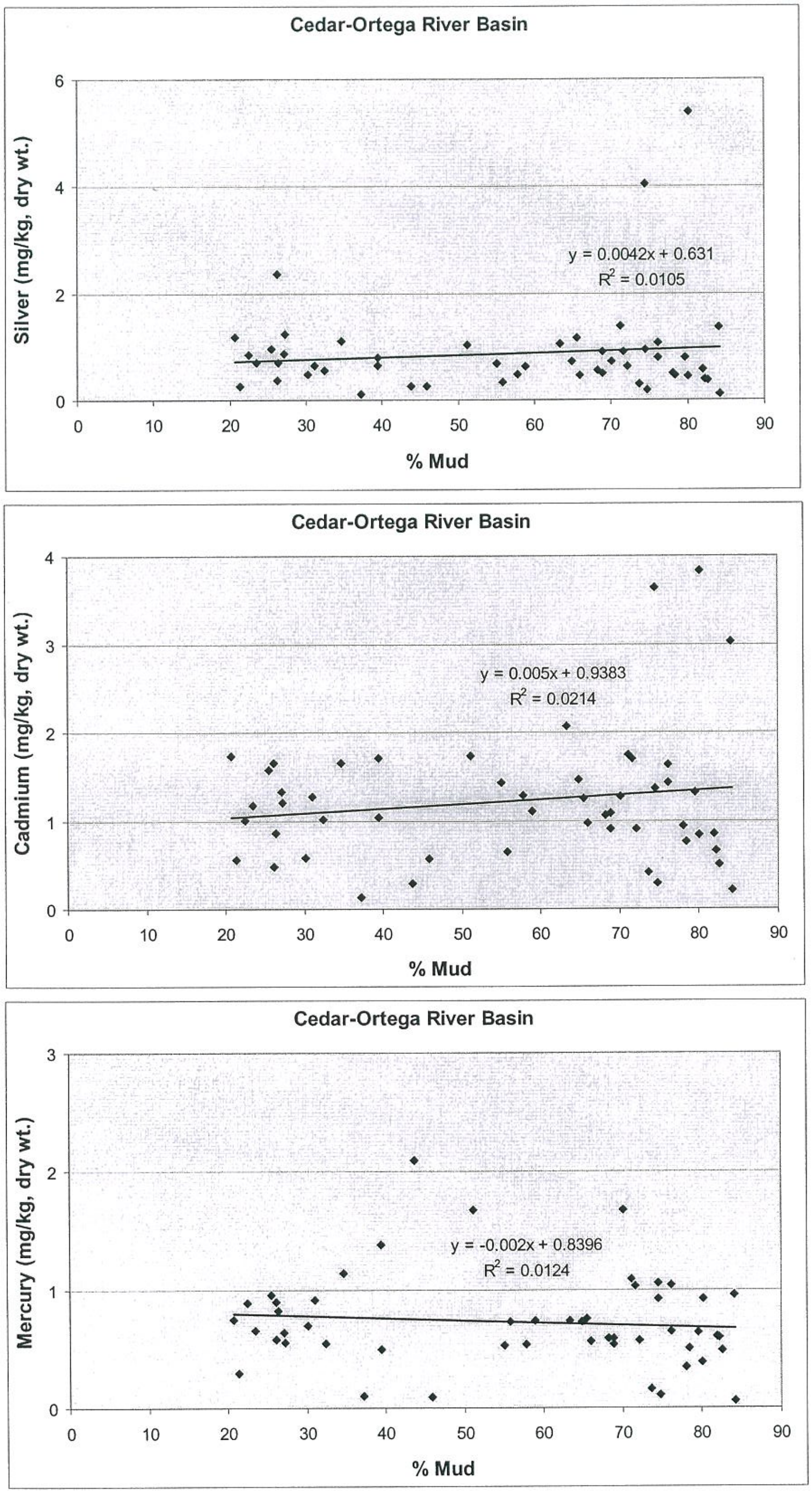


Figure 3-3. Silver, Cadmium, and Mercury Concentrations versus Grain Size of Surface Sediment Samples

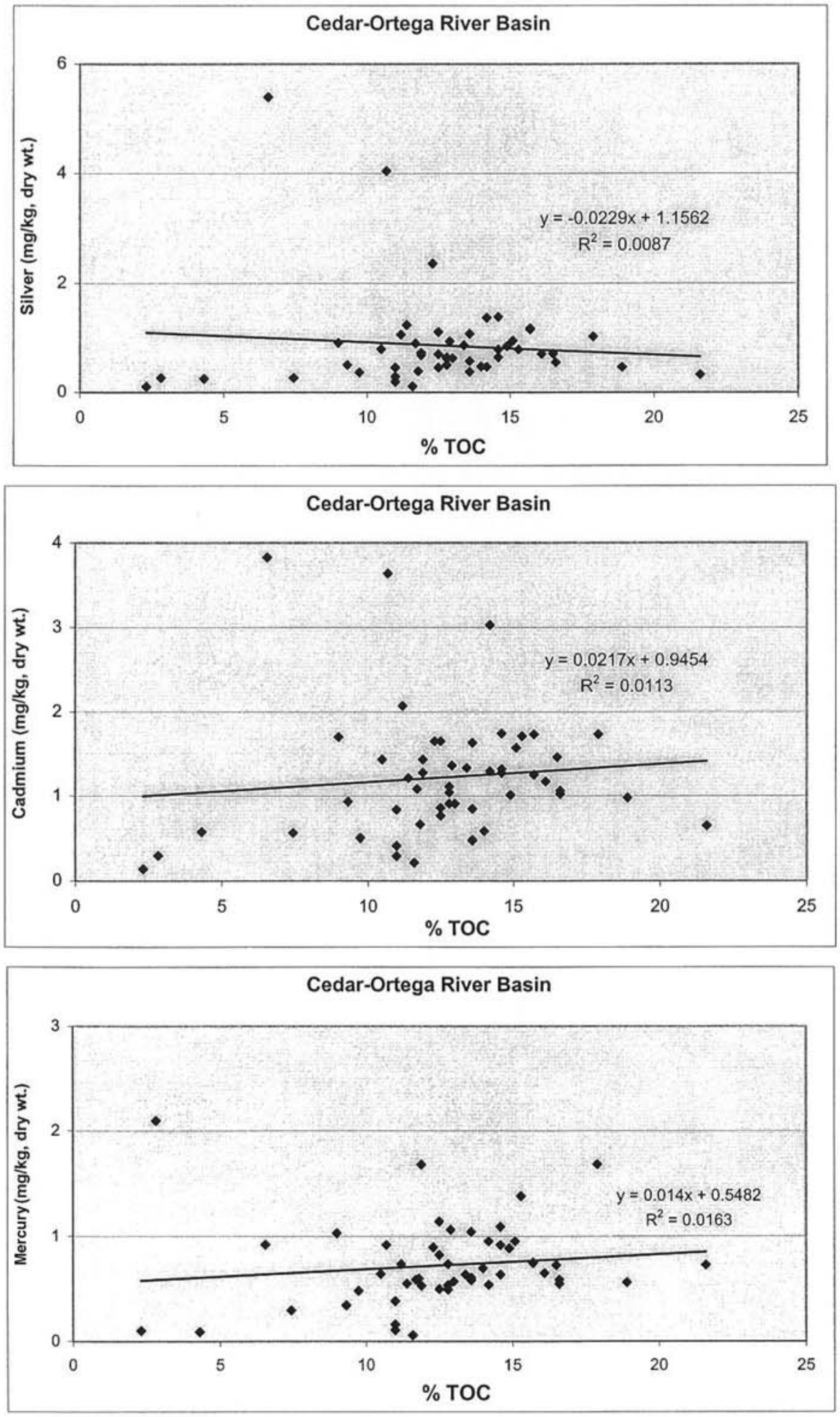


Figure 3-4. Silver, Cadmium, and Mercury Concentrations versus TOC Content of Surface Sediment Samples

Table 3-11. Concentration Ranges for Major and Trace Metals

	Not Normalized (raw) (mg/kg dry weight)			Normalized to Al		
	Median	Min	Max	Median	Min	Max
Cedar-Ortega River Basin Sites – Surface Sediments						
Major Metals						
Aluminum (Al)	39,700	11,600	60,600	1	1	1
Iron (Fe)	27,600	8,070	36,600	7.16E-04	4.80E-01	1.14
Manganese (Mn)	166	96	270	4.32E-03	1.95E-03	1.00E-02
Trace Metals						
Antimony (Sb)	0.339	0.093	1.20	8.50E-06	2.30E-06	3.08E-05
Arsenic (As)	5.09	1.36	24.5	1.42E-04	4.71E-05	4.47E-04
Beryllium (Be)	0.975	0.008	3.18	2.89E-05	6.80E-07	9.42E-05
Cadmium (Cd)	1.11	0.139	3.83	3.06E-05	5.01E-06	8.92E-05
Chromium (Cr)	57.1	15.5	96.0	1.44E-03	1.06E-03	3.07E-03
Cobalt (Co)	4.59	1.48	7.42	1.13E-04	9.00E-05	1.96E-04
Copper (Cu)	32.2	4.88	104	9.05E-04	1.23E-04	7.95E-03
Lead (Pb)	69.5	10.1	384	1.82E-03	4.80E-01	1.14E+00
Lithium (Li)	33.0	11.5	54.0	8.36E-04	4.32E-04	1.29E-03
Mercury (Hg)	0.642	0.057	2.10	1.68E-05	1.33E-06	1.81E-04
Nickel (Ni)	15.2	4.30	23.9	3.81E-04	2.87E-04	7.73E-04
Selenium (Se)	1.69	0.246	3.28	4.45E-05	1.98E-05	8.40E-05
Silver (Ag)	0.683	0.107	5.39	1.88E-05	2.52E-06	1.28E-04
Thallium (Tl)	0.353	0.122	0.510	8.82E-06	6.73E-06	2.38E-05
Tin (Sn)	4.27	1.07	15.7	1.21E-04	2.89E-05	3.10E-04
Vanadium (V)	54.2	17.8	72.3	1.38E-03	1.09E-03	2.58E-03
Zinc (Zn)	189	47.1	2,050	5.04E-03	1.10E-03	3.74E-02
Cedar-Ortega River Basin Sites – Sub-surface Sediments						
Major Metals						
Aluminum (Al)	42,800	5,710	57,900	1	1	1
Iron (Fe)	28,600	8,200	37,300	0.732	0.459	1.44
Manganese (Mn)	148	83.8	294	3.79E-03	2.74E-03	1.75E-02
Trace Metals						
Antimony (Sb)	0.233	0.031	1.12	6.84E-06	6.67E-07	2.50E-05
Arsenic (As)	3.95	1.29	13.9	1.09E-04	5.11E-05	2.71E-04
Beryllium (Be)	0.952	ND	3.44	2.54E-05	ND	9.05E-05
Cadmium (Cd)	0.383	ND	3.67	1.28E-05	ND	8.63E-05
Chromium (Cr)	55.1	13.8	105	1.43E-03	8.35E-04	2.46E-03
Cobalt (Co)	4.55	1.14	8.25	1.11E-04	8.43E-05	2.13E-04
Copper (Cu)	9.90	2.30	107	3.08E-04	1.11E-04	2.27E-03
Lead (Pb)	18.4	4.47	420	6.13E-04	2.12E-04	8.28E-03
Lithium (Li)	33.6	3.62	55.6	8.62E-04	6.12E-04	1.16E-03
Mercury (Hg)	0.363	0.031	4.29	9.66E-06	1.06E-06	7.47E-05
Nickel (Ni)	14.0	2.71	27.4	3.45E-04	2.61E-04	6.10E-04

	Not Normalized (raw) (mg/kg dry weight)			Normalized to Al		
	Median	Min	Max	Median	Min	Max
Selenium (Se)	1.59	0.615	2.96	4.02E-05	2.68E-05	1.13E-04
Silver (Ag)	0.232	0.020	2.97	7.04E-06	6.55E-07	9.40E-05
Thallium (Tl)	0.362	0.162	0.623	8.60E-06	5.94E-06	2.84E-05
Tin (Sn)	1.56	0.410	14.8	5.01E-05	1.86E-05	3.91E-04
Vanadium (V)	53.3	13.4	77.6	1.31E-03	1.01E-03	2.35E-03
Zinc (Zn)	79.9	9.80	1,440	1.99E-03	6.98E-04	3.06E-02

As expected, the nonanthropogenic, crustal major metals, aluminum, iron, and manganese, were present at the highest concentrations in the sediments, whereas the potentially toxic trace metals, such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, and silver were detected at lower concentrations (Tables 3-11 and 3-12a). The sediment metals concentrations were generally somewhat less variable when normalized to sediment aluminum concentrations (Tables 3-11 and 3-12b). For instance, the Al-normalized cadmium concentration in the COR surface sediment samples ranged from 0.00000501 to 0.0000892 (unitless), a factor of approximately 18 in concentration range, as compared to the non-normalized cadmium data which ranged by a factor of approximately 28 between the high and the low concentrations. Some reductions in variability, by normalizing to aluminum, were observed for most samples and most other metals.

However, the data normalization did not significantly reduce the observed sample-to-sample variability, indicating that the differences were mainly driven by true contaminant loadings and that the sediment physico-chemical characteristics were relatively uniform in these sediment. The sediment metals concentrations were not notably less variable once the data were normalized to sediment grain size (% Mud, also referred to as % Fines, which is defined as the sum of the %silt and %clay) or TOC (Tables 3-12c and 2-12d). For instance, the grain-size normalized chromium concentration in the surface sediment samples ranged from 0.630 to 25.6 mg/kg/% mud, a factor of about 40 difference in the concentration between the high and the low sites. The non-normalized chromium results showed a high-to-low site concentration difference of a factor of about 44.

Based solely on the effects-based sediment quality guideline values (discussed further in Section 4), specifically the effects range-median (ERM) values, one would expect the abundance of the following non-crustal metals to be approximately as follows:

Zn > Cr > Cu > Pb > As > Ni > Cd > Ag > Hg

Comparison of the surface sediment median metal concentrations in the Cedar-Ortega River Basin Sites (Table 3-11) indicate that the abundance of the metals followed a similar trend to the ERM relationship, with a few exceptions. Lead concentrations were higher than both chromium and copper concentrations, on average, and nickel concentrations were higher than arsenic. The median metals concentrations in the Cedar-Ortega River surface sediments were in the following order:

Zn > Pb > Cr > Cu > Ni > As > Cd > Ag > Hg

Table 3-12a. Metals Data — Non-Normalized

FIELD ID	Non-Normalized Metals Concentrations (mg/kg, dry weight)																			
	Al	Sb	As	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
Cedar-Ortega River Basin Sites – Surface Sediments																				
CED01	54,800	1.20	24.5	0.340	3.83	96.0	5.96	83.1	28,900	268	23.7	107	0.921	22.8	3.28	5.39	0.376	15.7	72.3	2,050
CED02	48,000	1.13	15.1	0.777	3.64	93.9	7.42	104	36,600	384	31.8	151	0.918	23.9	2.30	4.04	0.464	14.9	69.8	1,430
CED03	37,700	0.686	6.23	1.06	2.07	52.6	5.40	65.5	21,400	176	26.5	143	0.738	16.5	1.70	1.06	0.424	6.88	46.2	608
CED04	60,600	0.846	8.61	0.796	3.03	81.0	6.54	88.1	29,100	315	52.1	175	0.953	22.6	1.64	1.37	0.498	12.2	65.8	796
CED05	17,100	0.208	1.73	1.61	0.559	22.6	2.56	13.7	15,300	58.9	13.5	96.3	0.294	7.31	0.813	0.263	0.226	3.04	27.5	151
CED06	28,300	0.584	5.50	1.13	1.33	57.5	4.60	54.0	26,500	144	23.0	143	0.638	15.1	1.49	0.868	0.355	7.54	43.7	449
CED07	31,400	0.355	5.16	0.845	1.65	66.4	4.72	56.8	30,200	157	24.7	152	1.14	16.6	1.68	1.11	0.369	6.71	46.3	423
CED08	30,600	0.461	2.85	0.413	1.29	48.9	3.95	45.8	24,300	84.1	25.0	127	0.538	14.0	2.13	0.471	0.318	5.12	42.5	286
CED09	35,900	0.588	5.01	0.360	1.43	51.7	4.02	52.5	21,300	149	27.0	126	0.530	15.0	2.01	0.683	0.295	5.34	45.1	523
ORT01	38,300	0.279	5.36	2.15	1.43	58.2	4.06	21.5	29,100	52.0	32.0	170	0.642	13.8	1.51	0.799	0.343	4.14	52.8	112
ORT02	46,100	0.244	3.81	1.45	0.503	54.8	4.86	10.5	27,200	16.8	38.6	180	0.482	14.4	1.56	0.367	0.420	1.60	59.9	52.6
ORT03	42,900	0.099	4.18	2.69	0.215	50.8	4.24	5.29	32,200	11.7	33.5	160	0.057	12.7	1.97	0.108	0.337	1.24	54.6	58.2
ORT04	45,400	0.239	4.35	1.27	0.661	54.6	4.92	13.8	26,900	23.5	39.8	172	0.598	15.2	1.71	0.386	0.420	1.92	58.7	65.1
ORT05	41,400	0.189	4.36	2.32	0.762	53.6	4.30	18.9	35,200	40.7	35.2	165	0.499	13.6	2.02	0.456	0.345	3.06	54.6	108
ORT06	40,900	0.222	4.39	1.74	0.884	57.8	4.21	15.3	26,500	29.4	39.2	174	0.364	13.5	1.67	0.476	0.325	2.68	55.8	80.9
ORT07	48,800	0.617	7.37	1.41	1.63	74.9	5.92	54.9	28,400	90.2	39.9	270	1.04	20.9	1.94	1.08	0.447	5.51	70.3	229
ORT08	48,000	0.341	5.47	0.506	1.08	65.7	4.63	24.9	34,100	47.0	35.9	189	0.588	16.7	2.67	0.903	0.352	3.98	58.8	172
ORT09	31,500	0.343	6.37	2.70	1.70	58.7	4.10	28.5	29,300	63.2	33.3	170	1.03	13.8	1.53	0.911	0.351	6.18	56.1	234
ORT10	41,200	0.276	6.50	2.40	1.36	59.5	4.40	37.0	31,700	69.8	32.2	205	1.06	14.8	1.73	0.942	0.359	5.19	55.0	189
ORT11	46,100	0.299	6.78	2.34	1.04	63.1	4.95	26.0	33,100	55.1	33.2	199	0.492	16.0	1.65	0.646	0.400	4.27	63.5	219
ORT12	47,300	0.293	6.59	2.07	0.906	62.0	4.85	44.6	35,400	62.7	34.8	185	0.571	15.8	1.84	0.629	0.403	4.36	61.3	155
ORT13	48,100	0.318	6.66	2.97	1.32	66.1	5.06	38.2	34,500	82.7	36.9	207	0.638	17.1	1.76	0.791	0.403	5.30	63.3	248
ORT14	43,100	0.162	3.20	0.833	0.413	51.5	4.59	10.9	27,000	17.5	51.8	167	0.161	13.7	1.46	0.289	0.362	1.59	55.9	47.6
ORT15	40,900	0.501	10.2	1.05	1.25	68.5	5.33	101	29,300	74.3	33.7	249	0.751	18.5	2.84	1.16	0.351	5.51	60.3	315
ORT16	48,500	0.258	4.09	0.683	0.844	60.1	4.84	31.7	27,400	49.1	52.0	179	0.607	15.9	1.67	0.574	0.376	3.09	59.4	127
ORT18	40,400	0.303	3.73	0.679	0.908	50.2	4.36	29.0	23,900	56.5	42.6	185	0.536	14.1	1.29	0.501	0.323	3.28	51.0	140
ORT19	11,600	0.339	2.87	0.008	0.296	15.5	1.67	91.9	8,360	51.9	14.9	116	2.10	4.40	0.503	0.266	0.122	2.92	17.8	134
ORT20	38,700	0.186	3.33	0.590	0.291	41.4	4.23	12.5	23,900	18.3	43.7	148	0.105	12.3	1.26	0.191	0.308	1.16	48.4	47.1
ORT21	32,400	0.259	4.63	1.27	0.855	56.9	3.98	30.3	25,900	69.5	25.2	154	0.822	13.9	1.69	0.704	0.286	3.95	45.2	137

FIELD ID	Non-Normalized Metals Concentrations (mg/kg, dry weight)																			
	Al	Sb	As	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT22	37,300	0.403	6.51	0.846	1.28	54.1	4.61	80.8	24,600	78.7	37.5	239	1.68	15.3	1.39	0.728	0.334	4.51	52.1	366
ORT23	30,300	0.246	4.61	1.17	0.580	56.3	4.09	26.3	27,600	51.5	34.5	151	0.698	13.7	1.47	0.474	0.262	3.02	46.8	189
ORT24	37,200	0.353	6.61	1.22	1.01	66.4	4.71	50.3	29,700	89.0	31.7	195	0.885	16.8	1.89	0.851	0.328	5.09	53.4	233
ORT25	34,900	0.797	6.95	1.39	1.73	80.6	5.77	85.3	31,100	133	30.7	228	0.746	20.1	2.25	1.18	0.508	6.58	67.2	520
ORT26	30,700	0.560	5.38	1.16	1.57	70.8	5.04	58.7	30,300	107	28.2	203	0.952	18.0	1.89	0.953	0.474	5.80	57.6	251
ORT27	44,700	0.649	6.12	0.702	1.74	71.4	4.84	71.4	36,100	133	31.2	191	1.09	18.7	2.60	1.39	0.375	7.77	52.4	587
ORT28	24,300	0.472	7.54	0.764	1.17	58.2	4.37	51.4	25,200	76.9	27.2	205	0.650	15.5	2.04	0.706	0.405	4.27	50.9	327
ORT29	44,400	0.339	2.09	0.572	1.11	55.9	4.31	27.8	26,600	57.3	34.3	151	0.737	15.9	1.83	0.625	0.299	4.17	49.2	125
ORT30	15,000	0.093	1.36	1.33	0.139	18.5	1.48	4.88	10,600	10.1	11.5	100	0.101	4.30	0.410	0.107	0.137	1.07	26.8	75.5
ORT31	18,500	0.570	5.07	0.935	1.65	56.8	3.62	42.2	21,100	243	21.5	172	0.896	14.3	1.48	2.36	0.441	5.36	47.8	274
ORT32	37,100	0.522	6.60	0.906	1.21	64.0	4.52	42.4	24,200	98.1	25.7	217	0.551	15.7	1.65	1.24	0.437	5.03	56.2	187
ORT33	12,500	0.333	1.81	0.975	0.571	16.8	1.63	21.8	8,070	86.6	15.3	101	0.089	5.10	0.246	0.251	0.144	2.22	21.8	217
ORT34	41,100	0.304	3.31	0.719	1.06	53.8	4.73	33.1	27,200	66.2	50.0	172	0.587	15.2	1.44	0.551	0.349	3.94	53.0	181
ORT35	26,000	0.258	5.09	0.806	0.478	48.3	3.65	28.3	23,500	53.2	27.2	139	0.582	12.3	1.67	0.375	0.232	3.15	40.4	140
ORT36	35,500	0.390	5.12	0.595	1.02	57.1	4.36	32.1	26,400	64.2	26.2	159	0.547	14.8	1.92	0.554	0.428	3.73	50.1	148
ORT37	30,300	0.534	5.13	0.836	1.27	63.5	4.68	48.2	30,300	101	25.5	166	0.917	16.3	1.85	0.649	0.510	5.42	48.3	248
ORT38	51,100	0.354	7.89	2.34	1.71	60.8	4.60	29.1	32,000	71.3	33.0	142	1.38	15.4	1.65	0.792	0.372	6.65	59.8	154
ORT39	48,000	0.351	4.14	0.512	1.35	65.1	5.00	27.0	28,800	66.2	42.7	139	1.12	17.7	1.74	0.746	0.357	4.53	56.0	184
ORT40	46,200	0.289	4.78	3.18	1.46	56.9	4.40	41.8	30,100	98.4	34.0	147	0.725	16.2	1.44	0.712	0.331	6.13	54.2	276
ORT41	37,700	0.315	3.02	1.19	0.647	40.0	4.29	19.2	23,900	28.7	37.5	115	0.728	13.0	1.71	0.325	0.335	1.99	44.2	80.3
Cedar-Ortega River Basin Sites – Sub-Surface Sediments																				
CED01-M	33,500	0.837	6.73	0.382	2.89	56.3	3.88	38.9	17,900	70.0	20.5	101	1.21	12.9	1.90	1.37	0.290	13.1	43.8	241
CED03-M	54,700	0.963	6.83	0.744	2.58	68.6	6.12	92.5	25,100	258	38.7	172	0.835	19.6	1.61	1.44	0.441	9.38	57.9	731
CED03-L	47,100	1.12	11.7	0.952	3.67	94.3	8.02	107	29,200	390	46.3	158	1.18	25.7	1.98	2.14	0.548	13.0	71.2	1,440
CED04-M	57,900	1.00	13.9	0.930	3.67	105	8.25	98.2	36,000	420	51.9	192	1.12	27.4	2.11	2.19	0.623	14.8	77.6	1,310
CED04-L	45,600	0.537	5.52	0.607	1.66	64.4	5.29	37.3	26,700	92.3	47.5	160	1.15	16.2	1.42	0.816	0.449	7.60	59.4	353
CED06-M	24,900	0.195	2.96	0.533	0.562	42.4	3.63	15.8	21,800	46.2	18.7	115	0.576	12.0	1.27	0.393	0.251	3.23	33.2	116
CED06-L	25,900	0.038	3.50	0.862	ND	37.9	4.32	4.88	23,700	9.57	25.4	95.5	0.098	10.9	1.66	0.042	0.231	0.719	34.0	22.1
CED07-M	31,800	0.315	5.22	0.483	1.45	63.2	4.59	33.5	29,600	116	25.0	128	1.56	16.4	1.63	0.943	0.338	6.25	43.7	340
CED07-L	29,400	0.063	3.21	0.705	ND	42.1	4.20	4.97	24,900	10.4	25.3	134	0.128	11.0	1.50	0.039	0.288	0.834	40.6	28.3
CED08-M	21,500	0.245	2.52	1.23	0.621	37.4	3.03	26.5	20,500	87.6	16.9	108	0.549	9.73	1.21	2.02	0.233	3.73	29.9	209
CED09-M	29,400	0.566	3.50	0.540	1.51	50.3	3.74	51.2	22,200	174	27.8	129	0.648	14.4	1.80	0.678	0.302	5.96	42.4	488

FIELD ID	Non-Normalized Metals Concentrations (mg/kg, dry weight)																		
	Al	Sb	As	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT01-M	42,400	0.243	5.53	2.68	1.31	55.4	3.97	16.6	31,500	35.9	33.6	156	0.575	13.3	1.70	0.677	0.360	4.19	53.3	92.1
ORT01-L	42,400	0.109	3.89	2.87	0.194	51.0	4.30	5.15	32,600	11.4	32.2	157	0.045	12.5	2.02	0.107	0.350	1.29	55.9	41.1
ORT02-M	45,300	0.218	4.03	0.747	0.972	56.3	4.62	17.0	26,900	34.8	46.5	185	0.755	14.8	1.70	0.474	0.380	2.82	59.0	313
ORT02-L	52,800	0.146	4.48	0.777	0.314	61.1	5.29	9.25	30,500	14.4	52.9	207	0.549	15.9	1.81	0.210	0.428	1.31	67.8	44.0
ORT03-M	45,000	0.100	4.25	2.36	0.227	53.1	4.55	5.24	33,800	11.4	37.5	155	0.059	13.7	1.70	0.119	0.360	1.24	56.5	39.8
ORT03-L	44,400	0.087	4.05	3.44	0.197	53.3	4.57	5.26	32,800	11.5	36.2	147	0.055	13.6	1.45	0.105	0.380	1.28	56.7	41.7
ORT04-M	54,100	0.370	5.87	0.653	2.21	73.0	5.06	87.2	28,600	75.4	48.8	205	1.80	18.0	1.85	1.11	0.384	5.50	63.5	187
ORT04-L	57,500	0.173	3.95	0.872	0.278	56.0	4.85	8.53	28,600	18.4	51.4	186	0.454	15.0	1.59	0.192	0.373	1.13	61.3	42.7
ORT05-M	48,300	0.100	3.74	2.45	0.253	55.2	4.66	6.04	36,000	13.5	40.0	156	0.072	14.6	1.48	0.106	0.382	1.37	59.3	42.9
ORT05-L	47,100	0.095	3.21	2.43	0.233	55.6	5.02	5.67	34,800	12.3	37.8	133	0.050	14.5	1.26	0.103	0.402	1.45	60.5	44.8
ORT06-M	43,900	0.192	4.63	1.91	0.613	63.7	4.64	11.6	30,800	20.5	42.2	177	0.258	14.7	1.45	0.321	0.358	2.20	61.1	85.7
ORT06-L	46,400	0.131	4.03	2.04	0.241	60.5	4.91	7.24	31,000	11.7	42.2	202	0.070	14.8	1.45	0.164	0.361	1.30	63.8	77.4
ORT07-M	53,400	0.438	7.62	0.936	1.30	80.0	6.30	59.2	31,100	93.1	55.3	294	1.08	21.9	2.14	0.957	0.459	5.47	76.1	232
ORT07-L	49,100	0.457	7.18	0.966	1.71	77.3	5.93	48.6	29,400	94.0	52.6	264	1.04	20.4	1.59	1.18	0.424	5.35	71.9	214
ORT08-M	43,600	0.404	3.86	0.154	0.680	53.5	3.97	14.8	25,600	28.7	28.0	149	0.421	13.6	1.83	0.527	0.315	2.82	49.8	78.9
ORT08-L	53,700	0.245	4.05	0.814	0.269	60.7	5.31	7.55	31,100	11.4	35.9	148	0.106	15.1	1.56	0.035	0.386	1.43	62.9	41.4
ORT09-M	40,200	0.192	4.40	2.73	0.516	49.3	3.89	14.1	29,500	34.3	34.4	141	0.398	12.5	1.25	0.344	0.344	3.10	52.0	79.9
ORT09-L	35,700	0.088	3.51	2.33	0.143	43.1	3.47	4.13	26,200	9.32	30.4	120	0.044	10.5	1.47	0.079	0.270	1.00	47.8	32.0
ORT10-M	46,000	0.316	6.26	2.85	2.17	73.8	5.01	47.2	36,700	106	36.4	211	1.48	18.2	2.28	1.40	0.407	7.16	61.7	214
ORT10-L	40,000	0.100	3.59	2.92	0.212	48.1	4.00	5.17	32,000	11.2	35.6	133	0.069	12.2	1.28	0.114	0.335	1.23	52.3	38.5
ORT11-M	46,300	0.340	6.77	2.36	2.090	67.7	4.64	24.3	34,200	59.6	34.0	177	1.24	15.7	1.63	0.926	0.405	5.80	59.9	124
ORT11-L	44,000	0.109	4.23	2.22	0.212	50.4	4.39	5.43	32,200	12.0	31.9	151	0.075	12.8	1.20	0.132	0.379	1.31	55.1	42.2
ORT12-M	47,300	0.363	8.60	2.46	1.40	70.1	5.22	66.3	35,000	99.9	35.6	223	0.896	18.4	1.68	0.942	0.408	6.70	65.0	225
ORT12-L	47,900	0.105	4.07	2.10	0.258	55.1	4.69	5.38	35,000	12.0	36.0	142	0.083	14.2	1.87	0.099	0.389	1.35	61.4	41.5
ORT13-M	47,700	0.443	7.79	2.65	2.76	75.0	4.87	31.8	34,400	82.6	37.9	178	1.500	17.2	1.71	1.37	0.395	7.27	60.6	161
ORT13-L	47,100	0.105	4.21	2.37	0.241	53.0	4.58	5.40	34,200	11.6	37.9	148	0.061	13.8	1.49	0.098	0.362	1.30	55.9	41.0
ORT14-M	48,900	0.148	4.21	1.10	0.322	60.4	5.03	9.22	28,900	13.5	42.5	191	0.121	14.9	1.66	0.232	0.393	1.38	60.8	133
ORT14-L	47,400	0.174	3.45	1.05	0.330	62.7	5.24	8.49	31,400	12.7	43.8	167	0.115	15.6	1.61	0.210	0.403	1.27	60.6	108
ORT15-M	44,000	0.518	7.36	0.797	1.85	76.6	5.20	98.4	31,900	122	33.5	210	2.30	19.7	2.78	1.68	0.389	7.54	59.8	288
ORT15-L	57,400	0.666	7.81	0.854	3.16	86.3	5.15	45.6	31,000	86.0	41.5	157	4.29	18.9	2.96	2.97	0.384	8.08	62.4	206
ORT16-M	52,900	0.436	7.21	1.10	1.73	83.2	5.86	78.1	32,600	103	47.0	265	1.30	21.0	1.79	1.06	0.472	6.92	68.7	442
ORT16-L	48,700	0.166	3.41	1.17	0.394	63.2	5.28	9.25	31,200	12.4	48.4	162	0.084	15.8	1.65	0.235	0.391	1.24	62.2	105

FIELD ID	Non-Normalized Metals Concentrations (mg/kg, dry weight)																			
	Al	Sb	As	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT18-M	37,700	0.347	5.17	0.847	1.23	60.2	4.29	45.0	23,900	78.3	33.9	204	0.803	15.4	1.67	0.770	0.360	4.79	51.0	221
ORT18-L	44,400	0.138	3.98	0.836	0.329	57.5	4.79	8.35	29,800	11.4	43.7	177	0.113	14.4	1.46	0.194	0.349	1.25	56.7	109
ORT20-M	48,400	0.127	3.80	0.782	0.322	64.3	5.28	9.27	31,700	12.4	51.7	178	0.103	15.8	1.49	0.205	0.385	1.32	60.7	101
ORT20-L	50,900	0.162	4.29	0.993	0.371	65.0	5.76	8.96	32,700	13.0	48.1	180	0.084	16.4	1.47	0.207	0.420	1.28	66.9	103
ORT21-M	35,000	0.358	4.91	1.27	1.65	71.2	4.32	31.6	28,200	92.3	32.1	150	1.70	16.2	1.84	1.66	0.322	5.39	50.9	168
ORT21-L	28,000	0.094	3.10	1.21	ND	41.2	3.63	6.50	23,700	17.2	23.3	106	0.137	10.4	1.45	0.257	0.244	1.13	38.0	35.4
ORT23-M	32,900	0.137	3.69	0.633	0.310	53.5	4.15	13.7	28,400	32.3	28.5	135	0.715	13.1	1.90	0.270	0.293	2.41	46.1	73.8
ORT23-L	24,200	0.074	2.44	0.631	ND	37.4	3.45	4.63	21,600	9.25	25.3	107	0.112	9.44	1.27	0.270	0.222	0.788	34.5	26.5
ORT24-M	32,400	0.275	3.95	1.35	0.400	59.0	4.39	8.21	27,500	14.8	29.0	145	0.217	13.7	1.47	0.077	0.368	1.51	55.2	38.2
ORT24-L	26,200	0.316	2.06	1.10	0.383	47.2	3.99	5.92	24,200	10.1	23.0	126	0.094	11.9	1.34	0.049	0.425	1.11	44.6	24.7
ORT25-M	31,300	0.504	5.56	1.55	1.7	76.9	5.11	59.2	30,600	130	32.2	179	1.28	19.1	2.05	1.26	0.460	6.41	60.4	262
ORT25-L	34,700	0.312	2.76	1.42	0.339	54.8	5.14	6.95	28,300	12.1	31.0	117	0.083	14.1	1.21	0.055	0.442	1.23	53.5	33.2
ORT26-M	30,800	0.582	4.51	0.894	0.655	55.1	4.44	12.8	27,300	29.0	23.2	138	0.468	13.6	1.47	0.242	0.462	2.63	51.2	51.6
ORT26-L	24,800	0.268	3.41	0.764	0.339	47.6	4.04	5.86	24,800	10.5	26.2	125	0.131	12.3	1.74	0.048	0.376	1.09	45.5	26.5
ORT27-M	42,800	0.462	6.27	0.600	1.81	73.9	5.22	60.7	37,300	120	32.7	176	1.29	19.9	2.32	1.37	0.403	8.24	54.9	404
ORT27-L	18,700	0.130	2.33	0.018	0.191	20.1	3.99	4.78	12,700	8.64	15.9	83.8	0.132	5.40	1.10	0.056	0.163	0.783	20.4	26.7
ORT28-M	25,100	0.374	4.35	0.953	1.01	57.4	4.17	22.2	26,400	61.5	29.2	136	0.758	14.0	1.83	0.608	0.398	3.57	49.7	116
ORT28-L	27,000	0.243	3.09	1.15	0.346	52.7	4.50	6.29	27,500	11.9	27.9	110	0.109	13.6	1.70	0.225	0.389	1.19	49.6	31.1
ORT29-M	43,200	0.252	3.41	0.527	0.327	45.8	4.08	10.1	25,800	17.9	32.4	120	0.277	13.0	1.98	0.130	0.291	2.02	45.4	49.4
ORT29-L	36,100	0.240	2.51	0.288	0.199	37.4	4.16	5.86	24,300	8.25	25.2	132	0.069	11.1	1.57	0.029	0.248	0.947	39.3	25.2
ORT30-M	20,100	0.075	1.29	1.82	0.070	24.7	1.86	2.30	14,100	6.07	15.4	102	0.031	5.70	0.615	0.044	0.165	0.690	33.4	22.5
ORT30-L	38,400	0.094	3.73	2.35	0.156	45.5	3.66	4.25	28,200	10.1	26.7	149	0.055	10.9	1.43	0.097	0.314	1.15	50.9	37.5
ORT31-M	19,300	0.295	3.24	1.39	0.490	41.2	3.11	15.4	20,100	34.3	19.1	129	0.444	9.61	1.38	0.198	0.418	3.04	38.7	87.7
ORT31-L	5,710	0.139	1.40	ND	0.160	13.8	1.14	2.33	8,200	4.47	3.62	100	0.094	2.71	0.643	0.020	0.162	0.410	13.4	9.8
ORT32-M	30,000	0.265	3.33	0.694	0.374	45.0	3.14	9.51	20,400	22.6	19.0	119	0.303	10.1	1.49	0.194	0.399	2.41	42.7	48.0
ORT32-L	20,300	0.223	2.19	0.515	0.271	33.0	2.40	3.90	14,600	8.56	14.1	113	0.062	7.00	0.860	0.145	0.301	0.811	31.4	22.3
ORT34-M	45,100	0.233	3.74	0.741	0.667	56.5	4.87	14.0	28,300	25.4	45.9	167	0.363	14.5	1.46	0.346	0.345	2.70	56.2	113
ORT35-M	26,200	0.255	7.11	0.779	0.868	53.6	3.78	46.9	25,100	80.7	29.9	163	0.782	14.1	2.13	0.673	0.243	4.51	42.6	216
ORT35-L	24,100	0.119	2.34	0.552	ND	34.5	3.11	46.3	21,100	9.83	21.6	104	0.129	8.64	1.04	0.038	0.191	0.808	32.9	25.3
ORT36-M	36,900	0.356	5.22	1.20	0.895	55.7	4.38	16.9	25,900	40.8	29.7	134	0.598	14.0	1.87	0.464	0.408	3.36	51.0	91.6
ORT36-L	32,600	0.238	3.11	0.951	0.359	47.1	4.04	5.74	25,200	11.0	27.9	113	0.096	12.4	1.50	0.055	0.372	1.09	45.7	30.1
ORT37-M	25,300	0.175	3.00	0.607	0.089	40.3	3.35	9.90	22,800	23.1	23.6	109	0.384	10.3	1.46	0.168	0.232	1.56	35.5	63.3

FIELD ID	Non-Normalized Metals Concentrations (mg/kg, dry weight)																		
	Al	Sb	As	Be	Cd	Cr	Co	Cu	Fe	Pb	Li	Mn	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT37-L	25,800	0.134	2.98	0.989	0.099	41.0	3.57	7.95	23,700	17.5	25.0	110	0.196	10.4	1.45	0.091	0.230	1.12	36.9	48.6
ORT38-M	43,100	0.192	4.93	1.86	0.635	49.6	4.41	10.3	32,000	26.4	32.8	123	0.441	13.1	1.46	0.249	0.312	2.44	52.8	65.4
ORT39-M	50,600	0.387	4.34	0.654	1.40	64.9	5.09	24.6	29,700	55.6	40.7	149	1.09	17.2	2.04	0.644	0.343	4.60	57.2	196
ORT39-L	45,500	0.157	3.18	0.892	0.454	53.9	5.20	8.42	30,200	11.3	50.6	151	0.103	14.9	1.28	0.184	0.310	1.14	56.1	87.8
ORT40-M	46,300	0.031	2.76	3.19	1.06	51.4	4.55	14.7	32,200	38.4	36.4	129	0.631	13.9	1.45	0.326	0.335	3.00	52.7	92.6
ORT40-L	42,600	0.127	3.61	3.09	0.275	44.5	4.45	5.06	32,400	10.5	36.7	119	0.073	12.7	1.49	0.193	0.297	1.16	50.6	36.3
ORT41-M	42,400	0.356	3.87	0.746	1.15	47.3	4.72	20.4	25,700	61.9	49.3	131	1.12	15.3	1.95	0.455	0.321	4.06	51.9	145
ORT41-L	49,700	0.177	2.54	0.648	0.343	41.5	4.70	7.60	27,100	11.5	55.6	136	0.580	13.2	1.76	0.150	0.295	0.924	50.0	49.7

Table 3-12b. Metals Data — Normalized to Aluminum

FIELD ID	Aluminum Normalized Metals Concentrations																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
Cedar-Ortega River Basin Sites – Surface Sediments																	
CED01	2.19E-05	4.47E-04	6.20E-06	6.99E-05	1.75E-03	1.09E-04	1.52E-03	4.89E-03	4.32E-04	1.68E-05	4.16E-04	5.99E-05	9.84E-05	6.86E-06	2.86E-04	1.32E-03	3.74E-02
CED02	2.35E-05	3.15E-04	1.62E-05	7.58E-05	1.96E-03	1.55E-04	2.17E-03	8.00E-03	6.63E-04	1.91E-05	4.98E-04	4.79E-05	8.42E-05	9.67E-06	3.10E-04	1.45E-03	2.98E-02
CED03	1.82E-05	1.65E-04	2.81E-05	5.49E-05	1.40E-03	1.43E-04	1.74E-03	4.67E-03	7.03E-04	1.96E-05	4.38E-04	4.51E-05	2.81E-05	1.12E-05	1.82E-04	1.23E-03	1.61E-02
CED04	1.40E-05	1.42E-04	1.31E-05	5.00E-05	1.34E-03	1.08E-04	1.45E-03	5.20E-03	8.60E-04	1.57E-05	3.73E-04	2.71E-05	2.26E-05	8.22E-06	2.01E-04	1.09E-03	1.31E-02
CED05	1.22E-05	1.01E-04	9.42E-05	3.27E-05	1.32E-03	1.50E-04	8.01E-04	3.44E-03	7.89E-04	1.72E-05	4.27E-04	4.75E-05	1.54E-05	1.32E-05	1.78E-04	1.61E-03	8.83E-03
CED06	2.06E-05	1.94E-04	3.99E-05	4.70E-05	2.03E-03	1.63E-04	1.91E-03	5.09E-03	8.13E-04	2.25E-05	5.34E-04	5.27E-05	3.07E-05	1.25E-05	2.66E-04	1.54E-03	1.59E-02
CED07	1.13E-05	1.64E-04	2.69E-05	5.25E-05	2.11E-03	1.50E-04	1.81E-03	5.00E-03	7.87E-04	3.63E-05	5.29E-04	5.35E-05	3.54E-05	1.18E-05	2.14E-04	1.47E-03	1.35E-02
CED08	1.51E-05	9.31E-05	1.35E-05	4.22E-05	1.60E-03	1.29E-04	1.50E-03	2.75E-03	8.17E-04	1.76E-05	4.58E-04	6.96E-05	1.54E-05	1.04E-05	1.67E-04	1.39E-03	9.35E-03
CED09	1.64E-05	1.40E-04	1.00E-05	3.98E-05	1.44E-03	1.12E-04	1.46E-03	4.15E-03	7.52E-04	1.48E-05	4.18E-04	5.60E-05	1.90E-05	8.22E-06	1.49E-04	1.26E-03	1.46E-02
ORT01	7.28E-06	1.40E-04	5.61E-05	3.73E-05	1.52E-03	1.06E-04	5.61E-04	1.36E-03	8.36E-04	1.68E-05	3.60E-04	3.94E-05	2.09E-05	8.96E-06	1.08E-04	1.38E-03	2.92E-03
ORT02	5.29E-06	8.26E-05	3.15E-05	1.09E-05	1.19E-03	1.05E-04	2.28E-04	3.64E-04	8.37E-04	1.05E-05	3.12E-04	3.38E-05	7.96E-06	9.11E-06	3.47E-05	1.30E-03	1.14E-03
ORT03	2.30E-06	9.74E-05	6.27E-05	5.01E-06	1.18E-03	9.88E-05	1.23E-04	2.73E-04	7.81E-04	1.33E-06	2.96E-04	4.59E-05	2.52E-06	7.86E-06	2.89E-05	1.27E-03	1.36E-03
ORT04	5.26E-06	9.58E-05	2.80E-05	1.46E-05	1.20E-03	1.08E-04	3.04E-04	5.18E-04	8.77E-04	1.32E-05	3.35E-04	3.77E-05	8.50E-06	9.25E-06	4.23E-05	1.29E-03	1.43E-03
ORT05	4.57E-06	1.05E-04	5.60E-05	1.84E-05	1.29E-03	1.04E-04	4.57E-04	9.83E-04	8.50E-04	1.21E-05	3.29E-04	4.88E-05	1.10E-05	8.33E-06	7.39E-05	1.32E-03	2.61E-03
ORT06	5.44E-06	1.08E-04	4.33E-05	2.16E-05	1.42E-03	1.03E-04	3.74E-04	7.19E-04	9.60E-04	8.93E-06	3.31E-04	4.10E-05	1.17E-05	7.94E-06	6.58E-05	1.37E-03	1.99E-03
ORT07	1.26E-05	1.51E-04	2.89E-05	3.34E-05	1.53E-03	1.21E-04	1.13E-03	1.85E-03	8.18E-04	2.13E-05	4.28E-04	3.98E-05	2.21E-05	9.16E-06	1.13E-04	1.44E-03	4.69E-03
ORT08	7.10E-06	1.14E-04	1.05E-05	2.25E-05	1.37E-03	9.65E-05	5.19E-04	9.79E-04	7.48E-04	1.23E-05	3.48E-04	5.56E-05	1.88E-05	7.33E-06	8.29E-05	1.23E-03	3.58E-03
ORT09	1.09E-05	2.02E-04	8.57E-05	5.40E-05	1.86E-03	1.30E-04	9.05E-04	2.01E-03	1.06E-03	3.27E-05	4.38E-04	4.86E-05	2.89E-05	1.11E-05	1.96E-04	1.78E-03	7.43E-03
ORT10	6.70E-06	1.58E-04	5.83E-05	3.30E-05	1.44E-03	1.07E-04	8.98E-04	1.69E-03	7.82E-04	2.57E-05	3.59E-04	4.20E-05	2.29E-05	8.71E-06	1.26E-04	1.33E-03	4.59E-03
ORT11	6.49E-06	1.47E-04	5.08E-05	2.26E-05	1.37E-03	1.07E-04	5.64E-04	1.20E-03	7.20E-04	1.07E-05	3.47E-04	3.58E-05	1.40E-05	8.68E-06	9.26E-05	1.38E-03	4.75E-03
ORT12	6.19E-06	1.39E-04	4.38E-05	1.92E-05	1.31E-03	1.03E-04	9.43E-04	1.33E-03	7.36E-04	1.21E-05	3.34E-04	3.89E-05	1.33E-05	8.52E-06	9.22E-05	1.30E-03	3.28E-03
ORT13	6.61E-06	1.38E-04	6.17E-05	2.74E-05	1.37E-03	1.05E-04	7.94E-04	1.72E-03	7.67E-04	1.33E-05	3.56E-04	3.66E-05	1.64E-05	8.38E-06	1.10E-04	1.32E-03	5.16E-03
ORT14	3.76E-06	7.42E-05	1.93E-05	9.58E-06	1.19E-03	1.06E-04	2.53E-04	4.06E-04	1.20E-03	3.74E-06	3.18E-04	3.39E-05	6.71E-06	8.40E-06	3.69E-05	1.30E-03	1.10E-03
ORT15	1.22E-05	2.49E-04	2.57E-05	3.06E-05	1.67E-03	1.30E-04	2.47E-03	1.82E-03	8.24E-04	1.84E-05	4.52E-04	6.94E-05	2.84E-05	8.58E-06	1.35E-04	1.47E-03	7.70E-03
ORT16	5.32E-06	8.43E-05	1.41E-05	1.74E-05	1.24E-03	9.98E-05	6.54E-04	1.01E-03	1.07E-03	1.25E-05	3.28E-04	3.44E-05	1.18E-05	7.75E-06	6.37E-05	1.22E-03	2.62E-03
ORT18	7.50E-06	9.23E-05	1.68E-05	2.25E-05	1.24E-03	1.08E-04	7.18E-04	1.40E-03	1.05E-03	1.33E-05	3.49E-04	3.19E-05	1.24E-05	8.00E-06	8.12E-05	1.26E-03	3.47E-03
ORT19	2.94E-05	2.48E-04	6.80E-07	2.56E-05	1.34E-03	1.44E-04	7.95E-03	4.49E-03	1.29E-03	1.81E-04	3.81E-04	4.35E-05	2.30E-05	1.06E-05	2.53E-04	1.54E-03	1.16E-02
ORT20	4.81E-06	8.60E-05	1.52E-05	7.52E-06	1.07E-03	1.09E-04	3.23E-04	4.73E-04	1.13E-03	2.71E-06	3.18E-04	3.26E-05	4.94E-06	7.96E-06	3.00E-05	1.25E-03	1.22E-03
ORT21	7.99E-06	1.43E-04	3.92E-05	2.64E-05	1.76E-03	1.23E-04	9.35E-04	2.15E-03	7.78E-04	2.54E-05	4.29E-04	5.22E-05	2.17E-05	8.83E-06	1.22E-04	1.40E-03	4.23E-03

FIELD ID	Aluminum Normalized Metals Concentrations																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT22	1.08E-05	1.75E-04	2.27E-05	3.42E-05	1.45E-03	1.24E-04	2.17E-03	2.11E-03	1.01E-03	4.50E-05	4.09E-04	3.73E-05	1.95E-05	8.97E-06	1.21E-04	1.40E-03	9.83E-03
ORT23	8.12E-06	1.52E-04	3.86E-05	1.91E-05	1.86E-03	1.35E-04	8.68E-04	1.70E-03	1.14E-03	2.30E-05	4.52E-04	4.85E-05	1.56E-05	8.65E-06	9.97E-05	1.54E-03	6.24E-03
ORT24	9.49E-06	1.78E-04	3.28E-05	2.72E-05	1.78E-03	1.27E-04	1.35E-03	2.39E-03	8.52E-04	2.38E-05	4.52E-04	5.08E-05	2.29E-05	8.82E-06	1.37E-04	1.44E-03	6.26E-03
ORT25	2.28E-05	1.99E-04	3.98E-05	4.96E-05	2.31E-03	1.65E-04	2.44E-03	3.81E-03	8.80E-04	2.14E-05	5.76E-04	6.45E-05	3.38E-05	1.46E-05	1.89E-04	1.93E-03	1.49E-02
ORT26	1.82E-05	1.75E-04	3.78E-05	5.11E-05	2.31E-03	1.64E-04	1.91E-03	3.49E-03	9.19E-04	3.10E-05	5.86E-04	6.16E-05	3.10E-05	1.54E-05	1.89E-04	1.88E-03	8.18E-03
ORT27	1.45E-05	1.37E-04	1.57E-05	3.89E-05	1.60E-03	1.08E-04	1.60E-03	2.98E-03	6.98E-04	2.44E-05	4.18E-04	5.82E-05	3.11E-05	8.39E-06	1.74E-04	1.17E-03	1.31E-02
ORT28	1.94E-05	3.10E-04	3.14E-05	4.81E-05	2.40E-03	1.80E-04	2.12E-03	3.16E-03	1.12E-03	2.67E-05	6.38E-04	8.40E-05	2.91E-05	1.67E-05	1.76E-04	2.09E-03	1.35E-02
ORT29	7.64E-06	4.71E-05	1.29E-05	2.50E-05	1.26E-03	9.71E-05	6.26E-04	1.29E-03	7.73E-04	1.66E-05	3.58E-04	4.12E-05	1.41E-05	6.73E-06	9.39E-05	1.11E-03	2.82E-03
ORT30	6.21E-06	9.07E-05	8.87E-05	9.27E-06	1.23E-03	9.87E-05	3.25E-04	6.73E-04	7.67E-04	6.73E-06	2.87E-04	2.73E-05	7.13E-06	9.13E-06	7.13E-05	1.79E-03	5.03E-03
ORT31	3.08E-05	2.74E-04	5.05E-05	8.92E-05	3.07E-03	1.96E-04	2.28E-03	1.31E-02	1.16E-03	4.84E-05	7.73E-04	8.00E-05	1.28E-04	2.38E-05	2.90E-04	2.58E-03	1.48E-02
ORT32	1.41E-05	1.78E-04	2.44E-05	3.26E-05	1.73E-03	1.22E-04	1.14E-03	2.64E-03	6.93E-04	1.49E-05	4.23E-04	4.45E-05	3.34E-05	1.18E-05	1.36E-04	1.51E-03	5.04E-03
ORT33	2.67E-05	1.45E-04	7.83E-05	4.59E-05	1.35E-03	1.31E-04	1.75E-03	6.95E-03	1.23E-03	7.15E-06	4.10E-04	1.98E-05	2.02E-05	1.15E-05	1.78E-04	1.75E-03	1.74E-02
ORT34	7.40E-06	8.05E-05	1.75E-05	2.58E-05	1.31E-03	1.15E-04	8.05E-04	1.61E-03	1.22E-03	1.43E-05	3.70E-04	3.50E-05	1.34E-05	8.49E-06	9.59E-05	1.29E-03	4.40E-03
ORT35	9.92E-06	1.96E-04	3.10E-05	1.84E-05	1.86E-03	1.40E-04	1.09E-03	2.05E-03	1.05E-03	2.24E-05	4.73E-04	6.42E-05	1.44E-05	8.92E-06	1.21E-04	1.55E-03	5.38E-03
ORT36	1.10E-05	1.44E-04	1.68E-05	2.87E-05	1.61E-03	1.23E-04	9.04E-04	1.81E-03	7.38E-04	1.54E-05	4.17E-04	5.41E-05	1.56E-05	1.21E-05	1.05E-04	1.41E-03	4.17E-03
ORT37	1.76E-05	1.69E-04	2.76E-05	4.19E-05	2.10E-03	1.54E-04	1.59E-03	3.33E-03	8.42E-04	3.03E-05	5.38E-04	6.11E-05	2.14E-05	1.68E-05	1.79E-04	1.59E-03	8.18E-03
ORT38	6.93E-06	1.54E-04	4.58E-05	3.35E-05	1.19E-03	9.00E-05	5.69E-04	1.40E-03	6.46E-04	2.70E-05	3.01E-04	3.23E-05	1.55E-05	7.28E-06	1.30E-04	1.17E-03	3.01E-03
ORT39	7.21E-06	8.62E-05	1.10E-05	2.78E-05	1.35E-03	1.05E-04	5.57E-04	1.37E-03	9.17E-04	2.26E-05	3.68E-04	3.59E-05	1.52E-05	7.51E-06	9.29E-05	1.18E-03	3.79E-03
ORT40	6.26E-06	1.03E-04	6.88E-05	3.16E-05	1.23E-03	9.52E-05	9.05E-04	2.13E-03	7.36E-04	1.57E-05	3.51E-04	3.12E-05	1.54E-05	7.16E-06	1.33E-04	1.17E-03	5.97E-03
ORT41	8.36E-06	8.01E-05	3.16E-05	1.72E-05	1.06E-03	1.14E-04	5.09E-04	7.61E-04	9.95E-04	1.93E-05	3.45E-04	4.54E-05	8.62E-06	8.89E-06	5.28E-05	1.17E-03	2.13E-03
Cedar-Ortega River Basin Sites – Sub-Surface Sediments																	
CED01-M	2.50E-05	2.01E-04	1.14E-05	8.63E-05	1.68E-03	1.16E-04	1.16E-03	2.09E-03	6.12E-04	3.61E-05	3.85E-04	5.67E-05	4.09E-05	8.66E-06	3.91E-04	1.31E-03	7.19E-03
CED03-M	1.76E-05	1.25E-04	1.36E-05	4.72E-05	1.25E-03	1.12E-04	1.69E-03	4.72E-03	7.07E-04	1.53E-05	3.58E-04	2.94E-05	2.63E-05	8.06E-06	1.71E-04	1.06E-03	1.34E-02
CED03-L	2.38E-05	2.48E-04	2.02E-05	7.79E-05	2.00E-03	1.70E-04	2.27E-03	8.28E-03	9.83E-04	2.51E-05	5.46E-04	4.20E-05	4.54E-05	1.16E-05	2.76E-04	1.51E-03	3.06E-02
CED04-M	1.73E-05	2.40E-04	1.61E-05	6.34E-05	1.81E-03	1.42E-04	1.70E-03	7.25E-03	8.96E-04	1.93E-05	4.73E-04	3.64E-05	3.78E-05	1.08E-05	2.56E-04	1.34E-03	2.26E-02
CED04-L	1.18E-05	1.21E-04	1.33E-05	3.64E-05	1.41E-03	1.16E-04	8.18E-04	2.02E-03	1.04E-03	2.52E-05	3.55E-04	3.11E-05	1.79E-05	9.85E-06	1.67E-04	1.30E-03	7.74E-03
CED06-M	7.83E-06	1.19E-04	2.14E-05	2.26E-05	1.70E-03	1.46E-04	6.35E-04	1.86E-03	7.51E-04	2.31E-05	4.82E-04	5.10E-05	1.58E-05	1.01E-05	1.30E-04	1.33E-03	4.66E-03
CED06-L	1.46E-06	1.35E-04	3.33E-05	ND	1.46E-03	1.67E-04	1.88E-04	3.69E-04	9.81E-04	3.78E-06	4.21E-04	6.41E-05	1.61E-06	8.92E-06	2.78E-05	1.31E-03	8.53E-04
CED07-M	9.91E-06	1.64E-04	1.52E-05	4.56E-05	1.99E-03	1.44E-04	1.05E-03	3.65E-03	7.86E-04	4.91E-05	5.16E-04	5.13E-05	2.97E-05	1.06E-05	1.97E-04	1.37E-03	1.07E-02
CED07-L	2.15E-06	1.09E-04	2.40E-05	ND	1.43E-03	1.43E-04	1.69E-04	3.54E-04	8.61E-04	4.35E-06	3.74E-04	5.10E-05	1.33E-06	9.80E-06	2.84E-05	1.38E-03	9.63E-04
CED08-M	1.14E-05	1.17E-04	5.72E-05	2.89E-05	1.74E-03	1.41E-04	1.23E-03	4.07E-03	7.86E-04	2.55E-05	4.53E-04	5.63E-05	9.40E-05	1.08E-05	1.73E-04	1.39E-03	9.72E-03
CED09-M	1.93E-05	1.19E-04	1.84E-05	5.14E-05	1.71E-03	1.27E-04	1.74E-03	5.92E-03	9.46E-04	2.20E-05	4.90E-04	6.12E-05	2.31E-05	1.03E-05	2.03E-04	1.44E-03	1.66E-02

FIELD ID	Aluminum Normalized Metals Concentrations																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT01-M	5.73E-06	1.30E-04	6.32E-05	3.09E-05	1.31E-03	9.36E-05	3.92E-04	8.47E-04	7.92E-04	1.36E-05	3.14E-04	4.01E-05	1.60E-05	8.49E-06	9.88E-05	1.26E-03	2.17E-03
ORT01-L	2.57E-06	9.17E-05	6.77E-05	4.58E-06	1.20E-03	1.01E-04	1.21E-04	2.69E-04	7.59E-04	1.07E-06	2.95E-04	4.76E-05	2.52E-06	8.25E-06	3.04E-05	1.32E-03	9.69E-04
ORT02-M	4.81E-06	8.90E-05	1.65E-05	2.15E-05	1.24E-03	1.02E-04	3.75E-04	7.68E-04	1.03E-03	1.67E-05	3.27E-04	3.75E-05	1.05E-05	8.39E-06	6.23E-05	1.30E-03	6.91E-03
ORT02-L	2.77E-06	8.48E-05	1.47E-05	5.95E-06	1.16E-03	1.00E-04	1.75E-04	2.73E-04	1.00E-03	1.04E-05	3.01E-04	3.43E-05	3.98E-06	8.11E-06	2.48E-05	1.28E-03	8.33E-04
ORT03-M	2.21E-06	9.44E-05	5.24E-05	5.04E-06	1.18E-03	1.01E-04	1.16E-04	2.53E-04	8.33E-04	1.31E-06	3.04E-04	3.78E-05	2.64E-06	8.00E-06	2.76E-05	1.26E-03	8.84E-04
ORT03-L	1.96E-06	9.12E-05	7.75E-05	4.44E-06	1.20E-03	1.03E-04	1.18E-04	2.59E-04	8.15E-04	1.24E-06	3.06E-04	3.27E-05	2.36E-06	8.56E-06	2.88E-05	1.28E-03	9.39E-04
ORT04-M	6.84E-06	1.09E-04	1.21E-05	4.09E-05	1.35E-03	9.35E-05	1.61E-03	1.39E-03	9.02E-04	3.33E-05	3.33E-04	3.42E-05	2.05E-05	7.10E-06	1.02E-04	1.17E-03	3.46E-03
ORT04-L	3.01E-06	6.87E-05	1.52E-05	4.83E-06	9.74E-04	8.43E-05	1.48E-04	3.20E-04	8.94E-04	7.90E-06	2.61E-04	2.77E-05	3.34E-06	6.49E-06	1.97E-05	1.07E-03	7.43E-04
ORT05-M	2.06E-06	7.74E-05	5.07E-05	5.24E-06	1.14E-03	9.65E-05	1.25E-04	2.80E-04	8.28E-04	1.48E-06	3.02E-04	3.06E-05	2.19E-06	7.91E-06	2.84E-05	1.23E-03	8.88E-04
ORT05-L	2.01E-06	6.82E-05	5.16E-05	4.95E-06	1.18E-03	1.07E-04	1.20E-04	2.61E-04	8.03E-04	1.06E-06	3.08E-04	2.68E-05	2.19E-06	8.54E-06	3.08E-05	1.28E-03	9.51E-04
ORT06-M	4.36E-06	1.05E-04	4.36E-05	1.40E-05	1.45E-03	1.06E-04	2.65E-04	4.67E-04	9.61E-04	5.87E-06	3.35E-04	3.29E-05	7.31E-06	8.15E-06	5.01E-05	1.39E-03	1.95E-03
ORT06-L	2.83E-06	8.67E-05	4.39E-05	5.19E-06	1.30E-03	1.06E-04	1.56E-04	2.52E-04	9.08E-04	1.50E-06	3.19E-04	3.13E-05	3.53E-06	7.77E-06	2.80E-05	1.38E-03	1.67E-03
ORT07-M	8.20E-06	1.43E-04	1.75E-05	2.43E-05	1.50E-03	1.18E-04	1.11E-03	1.74E-03	1.04E-03	2.02E-05	4.10E-04	4.01E-05	1.79E-05	8.60E-06	1.02E-04	1.43E-03	4.34E-03
ORT07-L	9.31E-06	1.46E-04	1.97E-05	3.48E-05	1.57E-03	1.21E-04	9.90E-04	1.91E-03	1.07E-03	2.12E-05	4.15E-04	3.24E-05	2.40E-05	8.64E-06	1.09E-04	1.46E-03	4.36E-03
ORT08-M	9.27E-06	8.85E-05	3.53E-06	1.56E-05	1.23E-03	9.11E-05	3.39E-04	6.58E-04	6.42E-04	9.66E-06	3.12E-04	4.20E-05	1.21E-05	7.22E-06	6.47E-05	1.14E-03	1.81E-03
ORT08-L	4.56E-06	7.54E-05	1.52E-05	5.01E-06	1.13E-03	9.89E-05	1.41E-04	2.12E-04	6.69E-04	1.97E-06	2.81E-04	2.91E-05	6.55E-07	7.19E-06	2.66E-05	1.17E-03	7.71E-04
ORT09-M	4.78E-06	1.09E-04	6.79E-05	1.28E-05	1.23E-03	9.68E-05	3.51E-04	8.53E-04	8.56E-04	9.90E-06	3.11E-04	3.11E-05	8.56E-06	8.56E-06	7.71E-05	1.29E-03	1.99E-03
ORT09-L	2.47E-06	9.83E-05	6.53E-05	4.01E-06	1.21E-03	9.72E-05	1.16E-04	2.61E-04	8.52E-04	1.22E-06	2.94E-04	4.12E-05	2.22E-06	7.56E-06	2.79E-05	1.34E-03	8.96E-04
ORT10-M	6.87E-06	1.36E-04	6.20E-05	4.72E-05	1.60E-03	1.09E-04	1.03E-03	2.30E-03	7.91E-04	3.22E-05	3.96E-04	4.96E-05	3.04E-05	8.85E-06	1.56E-04	1.34E-03	4.65E-03
ORT10-L	2.50E-06	8.98E-05	7.30E-05	5.30E-06	1.20E-03	1.00E-04	1.29E-04	2.80E-04	8.90E-04	1.73E-06	3.05E-04	3.20E-05	2.85E-06	8.38E-06	3.08E-05	1.31E-03	9.63E-04
ORT11-M	7.34E-06	1.46E-04	5.10E-05	4.51E-05	1.46E-03	1.00E-04	5.25E-04	1.29E-03	7.34E-04	2.68E-05	3.39E-04	3.52E-05	2.00E-05	8.75E-06	1.25E-04	1.29E-03	2.68E-03
ORT11-L	2.48E-06	9.61E-05	5.05E-05	4.82E-06	1.15E-03	9.98E-05	1.23E-04	2.73E-04	7.25E-04	1.71E-06	2.91E-04	2.73E-05	3.00E-06	8.61E-06	2.98E-05	1.25E-03	9.59E-04
ORT12-M	7.67E-06	1.82E-04	5.20E-05	2.96E-05	1.48E-03	1.10E-04	1.40E-03	2.11E-03	7.53E-04	1.89E-05	3.89E-04	3.55E-05	1.99E-05	8.63E-06	1.42E-04	1.37E-03	4.76E-03
ORT12-L	2.19E-06	8.50E-05	4.38E-05	5.39E-06	1.15E-03	9.79E-05	1.12E-04	2.51E-04	7.52E-04	1.73E-06	2.96E-04	3.90E-05	2.06E-06	8.12E-06	2.82E-05	1.28E-03	8.66E-04
ORT13-M	9.29E-06	1.63E-04	5.56E-05	5.79E-05	1.57E-03	1.02E-04	6.67E-04	1.73E-03	7.95E-04	3.14E-05	3.61E-04	3.58E-05	2.87E-05	8.28E-06	1.52E-04	1.27E-03	3.38E-03
ORT13-L	2.23E-06	8.94E-05	5.03E-05	5.12E-06	1.13E-03	9.72E-05	1.15E-04	2.46E-04	8.05E-04	1.30E-06	2.93E-04	3.16E-05	2.08E-06	7.69E-06	2.76E-05	1.19E-03	8.70E-04
ORT14-M	3.03E-06	8.61E-05	2.25E-05	6.58E-06	1.24E-03	1.03E-04	1.89E-04	2.76E-04	8.69E-04	2.47E-06	3.05E-04	3.39E-05	4.74E-06	8.04E-06	2.82E-05	1.24E-03	2.72E-03
ORT14-L	3.67E-06	7.28E-05	2.22E-05	6.96E-06	1.32E-03	1.11E-04	1.79E-04	2.68E-04	9.24E-04	2.43E-06	3.29E-04	3.40E-05	4.43E-06	8.50E-06	2.68E-05	1.28E-03	2.28E-03
ORT15-M	1.18E-05	1.67E-04	1.81E-05	4.20E-05	1.74E-03	1.18E-04	2.24E-03	2.77E-03	7.61E-04	5.23E-05	4.48E-04	6.32E-05	3.82E-05	8.84E-06	1.71E-04	1.36E-03	6.55E-03
ORT15-L	1.16E-05	1.36E-04	1.49E-05	5.51E-05	1.50E-03	8.97E-05	7.94E-04	1.50E-03	7.23E-04	7.47E-05	3.29E-04	5.16E-05	5.17E-05	6.69E-06	1.41E-04	1.09E-03	3.59E-03
ORT16-M	8.24E-06	1.36E-04	2.08E-05	3.27E-05	1.57E-03	1.11E-04	1.48E-03	1.95E-03	8.88E-04	2.46E-05	3.97E-04	3.38E-05	2.00E-05	8.92E-06	1.31E-04	1.30E-03	8.36E-03
ORT16-L	3.41E-06	7.00E-05	2.40E-05	8.09E-06	1.30E-03	1.08E-04	1.90E-04	2.55E-04	9.94E-04	1.73E-06	3.24E-04	3.39E-05	4.83E-06	8.03E-06	2.55E-05	1.28E-03	2.16E-03

FIELD ID	Aluminum Normalized Metals Concentrations																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT18-M	9.20E-06	1.37E-04	2.25E-05	3.26E-05	1.60E-03	1.14E-04	1.19E-03	2.08E-03	8.99E-04	2.13E-05	4.08E-04	4.43E-05	2.04E-05	9.55E-06	1.27E-04	1.35E-03	5.86E-03
ORT18-L	3.11E-06	8.96E-05	1.88E-05	7.41E-06	1.30E-03	1.08E-04	1.88E-04	2.57E-04	9.84E-04	2.55E-06	3.24E-04	3.29E-05	4.37E-06	7.86E-06	2.82E-05	1.28E-03	2.45E-03
ORT20-M	2.62E-06	7.85E-05	1.62E-05	6.65E-06	1.33E-03	1.09E-04	1.92E-04	2.56E-04	1.07E-03	2.13E-06	3.26E-04	3.08E-05	4.24E-06	7.95E-06	2.73E-05	1.25E-03	2.09E-03
ORT20-L	3.18E-06	8.43E-05	1.95E-05	7.29E-06	1.28E-03	1.13E-04	1.76E-04	2.55E-04	9.45E-04	1.65E-06	3.22E-04	2.89E-05	4.07E-06	8.25E-06	2.51E-05	1.31E-03	2.02E-03
ORT21-M	1.02E-05	1.40E-04	3.63E-05	4.71E-05	2.03E-03	1.23E-04	9.03E-04	2.64E-03	9.17E-04	4.86E-05	4.63E-04	5.26E-05	4.74E-05	9.20E-06	1.54E-04	1.45E-03	4.80E-03
ORT21-L	3.37E-06	1.11E-04	4.32E-05	ND	1.47E-03	1.30E-04	2.32E-04	6.14E-04	8.32E-04	4.89E-06	3.71E-04	5.18E-05	9.18E-06	8.71E-06	4.04E-05	1.36E-03	1.26E-03
ORT23-M	4.16E-06	1.12E-04	1.92E-05	9.42E-06	1.63E-03	1.26E-04	4.16E-04	9.82E-04	8.66E-04	2.17E-05	3.98E-04	5.78E-05	8.21E-06	8.91E-06	7.33E-05	1.40E-03	2.24E-03
ORT23-L	3.07E-06	1.01E-04	2.61E-05	ND	1.55E-03	1.43E-04	1.91E-04	3.82E-04	1.05E-03	4.63E-06	3.90E-04	5.25E-05	1.12E-05	9.17E-06	3.26E-05	1.43E-03	1.10E-03
ORT24-M	8.49E-06	1.22E-04	4.17E-05	1.23E-05	1.82E-03	1.35E-04	2.53E-04	4.57E-04	8.95E-04	6.70E-06	4.23E-04	4.54E-05	2.36E-06	1.14E-05	4.66E-05	1.70E-03	1.18E-03
ORT24-L	1.21E-05	7.86E-05	4.20E-05	1.46E-05	1.80E-03	1.52E-04	2.26E-04	3.85E-04	8.78E-04	3.59E-06	4.54E-04	5.11E-05	1.87E-06	1.62E-05	4.24E-05	1.70E-03	9.43E-04
ORT25-M	1.61E-05	1.78E-04	4.95E-05	5.53E-05	2.46E-03	1.63E-04	1.89E-03	4.15E-03	1.03E-03	4.09E-05	6.10E-04	6.55E-05	4.03E-05	1.47E-05	2.05E-04	1.93E-03	8.37E-03
ORT25-L	8.99E-06	7.95E-05	4.09E-05	9.77E-06	1.58E-03	1.48E-04	2.00E-04	3.49E-04	8.93E-04	2.39E-06	4.06E-04	3.49E-05	1.59E-06	1.27E-05	3.54E-05	1.54E-03	9.57E-04
ORT26-M	1.89E-05	1.46E-04	2.90E-05	2.13E-05	1.79E-03	1.44E-04	4.16E-04	9.42E-04	7.53E-04	1.52E-05	4.42E-04	4.77E-05	7.86E-06	1.50E-05	8.54E-05	1.66E-03	1.68E-03
ORT26-L	1.08E-05	1.38E-04	3.08E-05	1.37E-05	1.92E-03	1.63E-04	2.36E-04	4.23E-04	1.06E-03	5.28E-06	4.96E-04	7.02E-05	1.93E-06	1.52E-05	4.40E-05	1.83E-03	1.07E-03
ORT27-M	1.08E-05	1.46E-04	1.40E-05	4.23E-05	1.73E-03	1.22E-04	1.42E-03	2.80E-03	7.64E-04	3.01E-05	4.65E-04	5.42E-05	3.20E-05	9.42E-06	1.93E-04	1.28E-03	9.44E-03
ORT27-L	6.95E-06	1.25E-04	9.84E-07	1.02E-05	1.07E-03	2.13E-04	2.56E-04	4.62E-04	8.50E-04	7.06E-06	2.89E-04	5.88E-05	3.01E-06	8.72E-06	4.19E-05	1.09E-03	1.43E-03
ORT28-M	1.49E-05	1.73E-04	3.80E-05	4.02E-05	2.29E-03	1.66E-04	8.84E-04	2.45E-03	1.16E-03	3.02E-05	5.58E-04	7.29E-05	2.42E-05	1.59E-05	1.42E-04	1.98E-03	4.62E-03
ORT28-L	9.00E-06	1.14E-04	4.26E-05	1.28E-05	1.95E-03	1.67E-04	2.33E-04	4.41E-04	1.03E-03	4.04E-06	5.04E-04	6.30E-05	8.33E-06	1.44E-05	4.41E-05	1.84E-03	1.15E-03
ORT29-M	5.83E-06	7.89E-05	1.22E-05	7.57E-06	1.06E-03	9.44E-05	2.34E-04	4.14E-04	7.50E-04	6.41E-06	3.01E-04	4.58E-05	3.01E-06	6.74E-06	4.68E-05	1.05E-03	1.14E-03
ORT29-L	6.65E-06	6.95E-05	7.98E-06	5.51E-06	1.04E-03	1.15E-04	1.62E-04	2.29E-04	6.98E-04	1.91E-06	3.07E-04	4.35E-05	8.03E-07	6.87E-06	2.62E-05	1.09E-03	6.98E-04
ORT30-M	3.73E-06	6.42E-05	9.05E-05	3.50E-06	1.23E-03	9.25E-05	1.14E-04	3.02E-04	7.66E-04	1.56E-06	2.84E-04	3.06E-05	2.17E-06	8.21E-06	3.43E-05	1.66E-03	1.12E-03
ORT30-L	2.45E-06	9.71E-05	6.12E-05	4.06E-06	1.18E-03	9.53E-05	1.11E-04	2.63E-04	6.95E-04	1.43E-06	2.84E-04	3.72E-05	2.52E-06	8.18E-06	2.99E-05	1.33E-03	9.77E-04
ORT31-M	1.53E-05	1.68E-04	7.20E-05	2.54E-05	2.13E-03	1.61E-04	7.98E-04	1.78E-03	9.90E-04	2.30E-05	4.98E-04	7.15E-05	1.03E-05	2.17E-05	1.58E-04	2.01E-03	4.54E-03
ORT31-L	2.43E-05	2.45E-04	ND	2.80E-05	2.42E-03	2.00E-04	4.08E-04	7.83E-04	6.34E-04	1.65E-05	4.75E-04	1.13E-04	3.43E-06	2.84E-05	7.18E-05	2.35E-03	1.71E-03
ORT32-M	8.83E-06	1.11E-04	2.31E-05	1.25E-05	1.50E-03	1.05E-04	3.17E-04	7.53E-04	6.33E-04	1.01E-05	3.37E-04	4.97E-05	6.47E-06	1.33E-05	8.03E-05	1.42E-03	1.60E-03
ORT32-L	1.10E-05	1.08E-04	2.54E-05	1.33E-05	1.63E-03	1.18E-04	1.92E-04	4.22E-04	6.95E-04	3.06E-06	3.45E-04	4.24E-05	7.14E-06	1.48E-05	4.00E-05	1.55E-03	1.10E-03
ORT34-M	5.17E-06	8.29E-05	1.64E-05	1.48E-05	1.25E-03	1.08E-04	3.10E-04	5.63E-04	1.02E-03	8.05E-06	3.22E-04	3.24E-05	7.67E-06	7.65E-06	5.99E-05	1.25E-03	2.51E-03
ORT35-M	9.73E-06	2.71E-04	2.97E-05	3.31E-05	2.05E-03	1.44E-04	1.79E-03	3.08E-03	1.14E-03	2.98E-05	5.38E-04	8.13E-05	2.57E-05	9.27E-06	1.72E-04	1.63E-03	8.24E-03
ORT35-L	4.94E-06	9.71E-05	2.29E-05	ND	1.43E-03	1.29E-04	1.92E-03	4.08E-04	8.96E-04	5.35E-06	3.59E-04	4.32E-05	1.58E-06	7.93E-06	3.35E-05	1.37E-03	1.05E-03
ORT36-M	9.65E-06	1.41E-04	3.25E-05	2.43E-05	1.51E-03	1.19E-04	4.58E-04	1.11E-03	8.05E-04	1.62E-05	3.79E-04	5.07E-05	1.26E-05	1.11E-05	9.11E-05	1.38E-03	2.48E-03
ORT36-L	7.30E-06	9.54E-05	2.92E-05	1.10E-05	1.44E-03	1.24E-04	1.76E-04	3.37E-04	8.56E-04	2.94E-06	3.80E-04	4.60E-05	1.68E-06	1.14E-05	3.34E-05	1.40E-03	9.23E-04
ORT37-M	6.92E-06	1.19E-04	2.40E-05	3.52E-06	1.59E-03	1.32E-04	3.91E-04	9.13E-04	9.33E-04	1.52E-05	4.07E-04	5.77E-05	6.64E-06	9.17E-06	6.17E-05	1.40E-03	2.50E-03

FIELD ID	Aluminum Normalized Metals Concentrations																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT37-L	5.19E-06	1.16E-04	3.83E-05	3.85E-06	1.59E-03	1.38E-04	3.08E-04	6.78E-04	9.69E-04	7.60E-06	4.03E-04	5.62E-05	3.53E-06	8.91E-06	4.34E-05	1.43E-03	1.88E-03
ORT38-M	4.45E-06	1.14E-04	4.32E-05	1.47E-05	1.15E-03	1.02E-04	2.39E-04	6.13E-04	7.61E-04	1.02E-05	3.04E-04	3.39E-05	5.78E-06	7.24E-06	5.66E-05	1.23E-03	1.52E-03
ORT39-M	7.64E-06	8.57E-05	1.29E-05	2.77E-05	1.28E-03	1.00E-04	4.86E-04	1.10E-03	8.04E-04	2.16E-05	3.40E-04	4.02E-05	1.27E-05	6.77E-06	9.08E-05	1.13E-03	3.87E-03
ORT39-L	3.45E-06	6.99E-05	1.96E-05	9.98E-06	1.18E-03	1.14E-04	1.85E-04	2.48E-04	1.11E-03	2.26E-06	3.27E-04	2.81E-05	4.04E-06	6.81E-06	2.51E-05	1.23E-03	1.93E-03
ORT40-M	6.67E-07	5.96E-05	6.89E-05	2.29E-05	1.11E-03	9.83E-05	3.17E-04	8.29E-04	7.86E-04	1.36E-05	3.00E-04	3.13E-05	7.04E-06	7.24E-06	6.48E-05	1.14E-03	2.00E-03
ORT40-L	2.98E-06	8.47E-05	7.25E-05	6.46E-06	1.04E-03	1.04E-04	1.19E-04	2.46E-04	8.62E-04	1.71E-06	2.98E-04	3.50E-05	4.53E-06	6.97E-06	2.72E-05	1.19E-03	8.52E-04
ORT41-M	8.40E-06	9.13E-05	1.76E-05	2.71E-05	1.12E-03	1.11E-04	4.81E-04	1.46E-03	1.16E-03	2.64E-05	3.61E-04	4.60E-05	1.07E-05	7.57E-06	9.58E-05	1.22E-03	3.42E-03
ORT41-L	3.56E-06	5.11E-05	1.30E-05	6.90E-06	8.35E-04	9.46E-05	1.53E-04	2.31E-04	1.12E-03	1.17E-05	2.66E-04	3.54E-05	3.02E-06	5.94E-06	1.86E-05	1.01E-03	1.00E-03

Table 3-12c. Metals Data — Normalized to Grain Size (% Mud)

FIELD ID	Grain Size Normalized Metals Concentrations (mg/kg/%Mud)																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
Cedar-Ortega River Basin Sites																	
CED01	1.50E-02	3.05E-01	4.24E-03	4.78E-02	1.20	7.43E-02	1.04	3.34	0.296	1.15E-02	0.284	4.09E-02	6.72E-02	4.69E-03	1.96E-01	0.901	25.6
CED02	1.52E-02	2.03E-01	1.04E-02	4.89E-02	1.26	9.96E-02	1.40	5.15	0.427	1.23E-02	0.321	3.09E-02	5.42E-02	6.23E-03	2.00E-01	0.937	19.2
CED03	1.08E-02	9.83E-02	1.67E-02	3.26E-02	0.830	8.52E-02	1.03	2.78	0.418	1.16E-02	0.260	2.68E-02	1.67E-02	6.69E-03	1.09E-01	0.729	9.59
CED04	1.01E-02	1.02E-01	9.46E-03	3.60E-02	0.963	7.78E-02	1.05	3.75	0.620	1.13E-02	0.269	1.95E-02	1.63E-02	5.92E-03	1.45E-01	0.782	9.46
CED05	9.72E-03	8.08E-02	7.52E-02	2.61E-02	1.06	1.20E-01	0.640	2.75	0.631	1.37E-02	0.342	3.80E-02	1.23E-02	1.06E-02	1.42E-01	1.29	7.06
CED06	2.15E-02	2.02E-01	4.15E-02	4.89E-02	2.11	1.69E-01	1.99	5.29	0.846	2.35E-02	0.555	5.48E-02	3.19E-02	1.31E-02	2.77E-01	1.61	16.5
CED07	1.02E-02	1.49E-01	2.44E-02	4.76E-02	1.91	1.36E-01	1.64	4.52	0.712	3.29E-02	0.478	4.84E-02	3.20E-02	1.06E-02	1.93E-01	1.33	12.2
CED08	7.98E-03	4.93E-02	7.15E-03	2.23E-02	0.846	6.83E-02	0.792	1.46	0.433	9.31E-03	0.242	3.69E-02	8.15E-03	5.50E-03	8.86E-02	0.735	4.95
CED09	1.07E-02	9.09E-02	6.53E-03	2.60E-02	0.938	7.30E-02	0.953	2.70	0.490	9.62E-03	0.272	3.65E-02	1.24E-02	5.35E-03	9.69E-02	0.819	9.49
ORT01	3.66E-03	7.03E-02	2.82E-02	1.88E-02	0.764	5.33E-02	0.282	0.682	0.420	8.43E-03	0.181	1.98E-02	1.05E-02	4.50E-03	5.43E-02	0.693	1.47
ORT02	2.95E-03	4.61E-02	1.76E-02	6.09E-03	0.663	5.88E-02	0.127	0.203	0.467	5.84E-03	0.174	1.89E-02	4.44E-03	5.08E-03	1.94E-02	0.725	0.637
ORT03	1.17E-03	4.96E-02	3.19E-02	2.55E-03	0.603	5.04E-02	0.063	0.139	0.398	6.78E-04	0.151	2.34E-02	1.28E-03	4.00E-03	1.47E-02	0.648	0.691
ORT04	2.91E-03	5.29E-02	1.55E-02	8.04E-03	0.664	5.99E-02	0.168	0.286	0.484	7.27E-03	0.185	2.08E-02	4.70E-03	5.11E-03	2.34E-02	0.714	0.792
ORT05	2.41E-03	5.56E-02	2.96E-02	9.72E-03	0.684	5.48E-02	0.241	0.519	0.449	6.36E-03	0.173	2.58E-02	5.82E-03	4.40E-03	3.90E-02	0.696	1.38
ORT06	2.81E-03	5.54E-02	2.19E-02	1.12E-02	0.731	5.32E-02	0.194	0.371	0.497	4.60E-03	0.171	2.11E-02	6.02E-03	4.11E-03	3.38E-02	0.706	1.02
ORT07	8.10E-03	9.67E-02	1.85E-02	2.14E-02	0.983	7.77E-02	0.720	1.18	0.524	1.36E-02	0.274	2.55E-02	1.42E-02	5.87E-03	7.23E-02	0.923	3.01
ORT08	4.95E-03	7.94E-02	7.34E-03	1.57E-02	0.954	6.72E-02	0.361	0.682	0.521	8.53E-03	0.242	3.88E-02	1.31E-02	5.11E-03	5.78E-02	0.853	2.50
ORT09	4.79E-03	8.90E-02	3.77E-02	2.37E-02	0.820	5.73E-02	0.398	0.883	0.465	1.44E-02	0.193	2.14E-02	1.27E-02	4.90E-03	8.63E-02	0.784	3.27
ORT10	3.70E-03	8.72E-02	3.22E-02	1.83E-02	0.799	5.91E-02	0.497	0.937	0.432	1.42E-02	0.199	2.32E-02	1.26E-02	4.82E-03	6.97E-02	0.738	2.54
ORT11	7.57E-03	1.72E-01	5.92E-02	2.63E-02	1.60	1.25E-01	0.658	1.39	0.841	1.25E-02	0.405	4.18E-02	1.64E-02	1.01E-02	1.08E-01	1.61	5.54
ORT12	4.06E-03	9.14E-02	2.87E-02	1.26E-02	0.860	6.73E-02	0.619	0.87	0.483	7.92E-03	0.219	2.55E-02	8.72E-03	5.59E-03	6.05E-02	0.850	2.15
ORT13	3.99E-03	8.37E-02	3.73E-02	1.66E-02	0.830	6.36E-02	0.480	1.04	0.464	8.02E-03	0.215	2.21E-02	9.94E-03	5.06E-03	6.66E-02	0.795	3.12
ORT14	2.20E-03	4.34E-02	1.13E-02	5.60E-03	0.699	6.23E-02	0.148	0.237	0.703	2.18E-03	0.186	1.98E-02	3.92E-03	4.91E-03	2.16E-02	0.758	0.646
ORT15	7.65E-03	1.56E-01	1.60E-02	1.91E-02	1.05	8.14E-02	1.54	1.13	0.515	1.15E-02	0.282	4.34E-02	1.77E-02	5.36E-03	8.41E-02	0.921	4.81
ORT16	3.15E-03	4.99E-02	8.33E-03	1.03E-02	0.733	5.90E-02	0.387	0.599	0.634	7.40E-03	0.194	2.04E-02	7.00E-03	4.59E-03	3.77E-02	0.724	1.55
ORT18	4.40E-03	5.41E-02	9.85E-03	1.32E-02	0.729	6.33E-02	0.421	0.820	0.618	7.78E-03	0.205	1.87E-02	7.27E-03	4.69E-03	4.76E-02	0.740	2.03
ORT19	7.74E-03	6.55E-02	1.79E-04	6.75E-03	0.354	3.80E-02	2.10	1.18	0.339	4.78E-02	0.100	1.15E-02	6.06E-03	2.79E-03	6.67E-02	0.406	3.06
ORT20	2.49E-03	4.45E-02	7.89E-03	3.89E-03	0.553	5.66E-02	0.167	0.245	0.584	1.40E-03	0.164	1.68E-02	2.55E-03	4.12E-03	1.55E-02	0.647	0.630
ORT21	9.81E-03	1.75E-01	4.81E-02	3.24E-02	2.16	1.51E-01	1.15	2.63	0.955	3.11E-02	0.527	6.40E-02	2.67E-02	1.08E-02	1.50E-01	1.71	5.19

FIELD ID	Grain Size Normalized Metals Concentrations (mg/kg/%Mud)																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT22	5.75E-03	9.29E-02	1.21E-02	1.82E-02	0.772	6.57E-02	1.15	1.12	0.534	2.39E-02	0.218	1.98E-02	1.04E-02	4.76E-03	6.43E-02	0.743	5.22
ORT23	8.15E-03	1.53E-01	3.87E-02	1.92E-02	1.86	1.35E-01	0.871	1.71	1.14	2.31E-02	0.454	4.87E-02	1.57E-02	8.68E-03	1.00E-01	1.55	6.26
ORT24	1.57E-02	2.94E-01	5.42E-02	4.49E-02	2.95	2.09E-01	2.24	3.96	1.41	3.93E-02	0.747	8.40E-02	3.78E-02	1.46E-02	2.26E-01	2.37	10.4
ORT25	3.85E-02	3.36E-01	6.71E-02	8.36E-02	3.89	2.79E-01	4.12	6.43	1.48	3.60E-02	0.971	1.09E-01	5.70E-02	2.45E-02	3.18E-01	3.25	25.1
ORT26	2.20E-02	2.11E-01	4.55E-02	6.16E-02	2.78	1.98E-01	2.30	4.20	1.11	3.73E-02	0.706	7.41E-02	3.74E-02	1.86E-02	2.27E-01	2.26	9.84
ORT27	9.12E-03	8.60E-02	9.86E-03	2.44E-02	1.00	6.80E-02	1.00	1.87	0.438	1.53E-02	0.263	3.65E-02	1.95E-02	5.27E-03	1.09E-01	0.736	8.24
ORT28	2.01E-02	3.21E-01	3.25E-02	4.98E-02	2.48	1.86E-01	2.19	3.27	1.16	2.77E-02	0.660	8.68E-02	3.00E-02	1.72E-02	1.82E-01	2.17	13.9
ORT29	5.76E-03	3.55E-02	9.71E-03	1.88E-02	0.949	7.32E-02	0.472	0.973	0.582	1.25E-02	0.270	3.11E-02	1.06E-02	5.08E-03	7.08E-02	0.835	2.12
ORT30	2.50E-03	3.66E-02	3.58E-02	3.74E-03	0.497	3.98E-02	0.131	0.272	0.309	2.72E-03	0.116	1.10E-02	2.88E-03	3.68E-03	2.88E-02	0.720	2.03
ORT31	2.18E-02	1.94E-01	3.57E-02	6.30E-02	2.17	1.38E-01	1.61	9.27	0.821	3.42E-02	0.546	5.65E-02	9.01E-02	1.68E-02	2.05E-01	1.82	10.5
ORT32	1.91E-02	2.42E-01	3.32E-02	4.43E-02	2.34	1.66E-01	1.55	3.59	0.941	2.02E-02	0.575	6.04E-02	4.54E-02	1.60E-02	1.84E-01	2.06	6.85
ORT33	7.26E-03	3.94E-02	2.13E-02	1.25E-02	0.365	3.54E-02	0.474	1.89	0.334	1.94E-03	0.111	5.37E-03	5.47E-03	3.13E-03	4.84E-02	0.475	4.73
ORT34	4.45E-03	4.85E-02	1.05E-02	1.55E-02	0.788	6.93E-02	0.485	0.969	0.732	8.59E-03	0.223	2.11E-02	8.07E-03	5.11E-03	5.77E-02	0.776	2.65
ORT35	9.85E-03	1.94E-01	3.08E-02	1.82E-02	1.84	1.39E-01	1.08	2.03	1.04	2.22E-02	0.469	6.37E-02	1.43E-02	8.85E-03	1.20E-01	1.54	5.34
ORT36	1.20E-02	1.58E-01	1.84E-02	3.15E-02	1.76	1.35E-01	0.991	1.98	0.809	1.69E-02	0.457	5.93E-02	1.71E-02	1.32E-02	1.15E-01	1.55	4.57
ORT37	1.72E-02	1.65E-01	2.69E-02	4.08E-02	2.04	1.50E-01	1.55	3.25	0.820	2.95E-02	0.524	5.95E-02	2.09E-02	1.64E-02	1.74E-01	1.55	7.97
ORT38	8.96E-03	2.00E-01	5.92E-02	4.33E-02	1.54	1.16E-01	0.737	1.81	0.835	3.49E-02	0.390	4.18E-02	2.01E-02	9.42E-03	1.68E-01	1.51	3.90
ORT39	6.29E-03	7.26E-02	8.56E-03	2.43E-02	1.157	8.67E-02	0.479	1.174	0.716	2.07E-02	0.310	3.08E-02	1.36E-02	6.18E-03	8.14E-02	0.977	3.27
ORT40	4.45E-03	7.37E-02	4.90E-02	2.25E-02	0.877	6.78E-02	0.644	1.52	0.524	1.12E-02	0.250	2.22E-02	1.10E-02	5.10E-03	9.45E-02	0.835	4.25
ORT41	5.65E-03	5.41E-02	2.13E-02	1.16E-02	0.717	7.69E-02	0.344	0.514	0.672	1.30E-02	0.233	3.06E-02	5.82E-03	6.00E-03	3.57E-02	0.792	1.44

Table 3-12d. Metals Data — Normalized to Total Organic Carbon

FIELD ID	TOC Normalized Metals Concentrations (mg/g TOC)																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
Cedar-Ortega River Basin Sites																	
CED01	0.0198	0.404	0.00561	0.0631	1.58	0.0983	1.37	4.42	0.391	0.0152	0.376	0.0541	0.0889	0.00620	0.259	1.19	33.8
CED02	0.0106	0.141	0.00726	0.0340	0.878	0.0693	0.972	3.59	0.297	0.00858	0.223	0.0215	0.0378	0.00434	0.139	0.652	13.4
CED03	0.00613	0.0556	0.00946	0.0185	0.470	0.0482	0.585	1.57	0.237	0.00659	0.147	0.0152	0.00946	0.00379	0.0614	0.413	5.43
CED04	0.00596	0.0606	0.00561	0.0213	0.570	0.0461	0.620	2.22	0.367	0.00671	0.159	0.0115	0.00965	0.00351	0.0859	0.463	5.61
CED05	0.00280	0.0233	0.0216	0.00751	0.304	0.0344	0.184	0.792	0.181	0.00395	0.0983	0.0109	0.00353	0.00304	0.0409	0.370	2.03
CED06	0.00436	0.0410	0.00843	0.00993	0.429	0.0343	0.403	1.07	0.172	0.00476	0.113	0.0111	0.00648	0.00265	0.0563	0.326	3.35
CED07	0.00252	0.0366	0.00599	0.0117	0.471	0.0335	0.403	1.11	0.175	0.00809	0.118	0.0119	0.00787	0.00262	0.0476	0.328	3.00
CED08	0.00325	0.0201	0.00291	0.00908	0.344	0.0278	0.323	0.592	0.176	0.00379	0.0986	0.0150	0.00332	0.00224	0.0361	0.299	2.01
CED09	0.00494	0.0421	0.00303	0.0120	0.434	0.0338	0.441	1.25	0.227	0.00445	0.126	0.0169	0.00574	0.00248	0.0449	0.379	4.39
ORT01	0.00266	0.0510	0.0205	0.0136	0.554	0.0387	0.205	0.495	0.305	0.00611	0.131	0.0144	0.00761	0.00327	0.0394	0.503	1.07
ORT02	0.00251	0.0391	0.0149	0.00516	0.563	0.0499	0.108	0.172	0.396	0.00495	0.148	0.0160	0.00377	0.00431	0.0164	0.615	0.540
ORT03	0.00085	0.0360	0.0232	0.00185	0.438	0.0366	0.0456	0.101	0.289	0.00049	0.109	0.0170	0.00093	0.00291	0.0107	0.471	0.502
ORT04	0.00203	0.0369	0.0108	0.00560	0.463	0.0417	0.117	0.199	0.337	0.00507	0.129	0.0145	0.00327	0.00356	0.0163	0.497	0.552
ORT05	0.00151	0.0349	0.0186	0.00610	0.429	0.0344	0.151	0.326	0.282	0.00399	0.109	0.0162	0.00365	0.00276	0.0245	0.437	0.864
ORT06	0.00219	0.0432	0.0171	0.00870	0.569	0.0414	0.151	0.289	0.386	0.00358	0.133	0.0164	0.00469	0.00319	0.0263	0.549	0.796
ORT07	0.00454	0.0542	0.0104	0.0120	0.551	0.0435	0.404	0.663	0.293	0.00765	0.154	0.0143	0.00794	0.00329	0.0405	0.517	1.68
ORT08	0.00291	0.0468	0.00432	0.00923	0.562	0.0396	0.213	0.402	0.307	0.00503	0.143	0.0228	0.00772	0.00301	0.0340	0.503	1.47
ORT09	0.00381	0.0708	0.0300	0.0189	0.652	0.0456	0.317	0.702	0.370	0.0114	0.153	0.0170	0.0101	0.00390	0.0687	0.623	2.60
ORT10	0.00214	0.0504	0.0186	0.0105	0.461	0.0341	0.287	0.541	0.250	0.00822	0.115	0.0134	0.00730	0.00278	0.0402	0.426	1.47
ORT11	0.00234	0.0530	0.0183	0.00813	0.493	0.0387	0.203	0.430	0.259	0.00384	0.125	0.0129	0.00505	0.00313	0.0334	0.496	1.71
ORT12	0.00225	0.0507	0.0159	0.00697	0.477	0.0373	0.343	0.482	0.268	0.00439	0.122	0.0142	0.00484	0.00310	0.0335	0.472	1.19
ORT13	0.00218	0.0456	0.0203	0.00904	0.453	0.0347	0.262	0.566	0.253	0.00437	0.117	0.0121	0.00542	0.00276	0.0363	0.434	1.70
ORT14	0.00147	0.0291	0.00757	0.00375	0.468	0.0417	0.0990	0.159	0.471	0.00146	0.125	0.0133	0.00263	0.00329	0.0145	0.508	0.433
ORT15	0.00319	0.0650	0.00669	0.00796	0.436	0.0339	0.643	0.473	0.215	0.00478	0.118	0.0181	0.00739	0.00224	0.0351	0.384	2.01
ORT16	0.00190	0.0301	0.00502	0.00621	0.442	0.0356	0.233	0.361	0.382	0.00446	0.117	0.0123	0.00422	0.00276	0.0227	0.437	0.934
ORT18	0.00237	0.0291	0.00530	0.00709	0.392	0.0341	0.227	0.441	0.333	0.00419	0.110	0.0101	0.00391	0.00252	0.0256	0.398	1.09
ORT19	0.0120	0.102	0.00056	0.0105	0.549	0.0589	3.25	1.84	0.526	0.0742	0.156	0.0178	0.00940	0.00432	0.103	0.630	4.75
ORT20	0.00169	0.0303	0.00536	0.00265	0.376	0.0385	0.114	0.166	0.397	0.00095	0.112	0.0115	0.00174	0.00280	0.0105	0.440	0.428
ORT21	0.00207	0.0370	0.01016	0.00684	0.455	0.0318	0.242	0.556	0.202	0.00658	0.111	0.0135	0.00563	0.00229	0.0316	0.362	1.10

FIELD ID	TOC Normalized Metals Concentrations (mg/g TOC)																
	Sb	As	Be	Cd	Cr	Co	Cu	Pb	Li	Hg	Ni	Se	Ag	Tl	Sn	V	Zn
ORT22	0.00339	0.0547	0.00711	0.0107	0.455	0.0387	0.679	0.661	0.315	0.0141	0.128	0.0117	0.00611	0.00281	0.0379	0.438	3.08
ORT23	0.00176	0.0329	0.00836	0.00414	0.402	0.0292	0.188	0.368	0.246	0.00499	0.0979	0.0105	0.00339	0.00187	0.0216	0.334	1.35
ORT24	0.00237	0.0444	0.00819	0.00678	0.446	0.0316	0.338	0.597	0.213	0.00594	0.113	0.0127	0.00571	0.00220	0.0342	0.358	1.56
ORT25	0.00508	0.0443	0.00885	0.0110	0.513	0.0368	0.543	0.847	0.196	0.00475	0.128	0.0143	0.00752	0.00324	0.0419	0.428	3.31
ORT26	0.00371	0.0356	0.00768	0.0104	0.469	0.0334	0.389	0.709	0.187	0.00630	0.119	0.0125	0.00631	0.00314	0.0384	0.381	1.66
ORT27	0.00445	0.0419	0.00481	0.0119	0.489	0.0332	0.489	0.911	0.214	0.00747	0.128	0.0178	0.00952	0.00257	0.0532	0.359	4.02
ORT28	0.00293	0.0468	0.00475	0.00727	0.361	0.0271	0.319	0.478	0.169	0.00404	0.0963	0.0127	0.00439	0.00252	0.0265	0.316	2.03
ORT29	0.00265	0.0163	0.00447	0.00867	0.437	0.0337	0.217	0.448	0.268	0.00576	0.124	0.0143	0.00488	0.00234	0.0326	0.384	0.977
ORT30	0.00401	0.0586	0.0573	0.00599	0.797	0.0638	0.210	0.435	0.496	0.00435	0.185	0.0177	0.00461	0.00591	0.0461	1.16	3.25
ORT31	0.00463	0.0412	0.00760	0.0134	0.462	0.0294	0.343	1.98	0.175	0.00728	0.116	0.0120	0.0192	0.00359	0.0436	0.389	2.23
ORT32	0.00458	0.0579	0.00795	0.0106	0.561	0.0396	0.372	0.861	0.225	0.00483	0.138	0.0145	0.0109	0.00383	0.0441	0.493	1.64
ORT33	0.00772	0.0418	0.04519	0.01323	0.388	0.0377	0.504	2.01	0.355	0.00206	0.118	0.0114	0.00582	0.00333	0.0514	0.505	5.03
ORT34	0.00183	0.0199	0.00433	0.00639	0.324	0.0285	0.199	0.399	0.301	0.00354	0.0916	0.00867	0.00332	0.00210	0.0237	0.319	1.09
ORT35	0.00190	0.0374	0.00593	0.00351	0.355	0.0268	0.208	0.391	0.200	0.00428	0.0904	0.0123	0.00276	0.00171	0.0232	0.297	1.03
ORT36	0.00235	0.0308	0.00358	0.00614	0.344	0.0263	0.193	0.387	0.158	0.00330	0.0892	0.0116	0.00334	0.00258	0.0225	0.302	0.892
ORT37	0.00366	0.0351	0.00573	0.00870	0.435	0.0321	0.330	0.692	0.175	0.00628	0.112	0.0127	0.00445	0.00349	0.0371	0.331	1.70
ORT38	0.00231	0.0516	0.0153	0.0112	0.397	0.0301	0.190	0.466	0.216	0.00902	0.101	0.0108	0.00518	0.00243	0.0435	0.391	1.01
ORT39	0.00191	0.0225	0.00278	0.00735	0.354	0.0271	0.146	0.360	0.232	0.00609	0.0959	0.00943	0.00405	0.00194	0.0246	0.304	1.00
ORT40	0.00175	0.0290	0.0193	0.00885	0.345	0.0267	0.253	0.596	0.206	0.00439	0.0982	0.00873	0.00432	0.00201	0.0372	0.328	1.67
ORT41	0.00146	0.0140	0.00551	0.00300	0.185	0.0199	0.0889	0.133	0.174	0.00337	0.0602	0.00792	0.00150	0.00155	0.00921	0.205	0.372

3.3 Results for Ancillary Measurements

The total organic carbon (TOC), grain size, moisture content, total solids (TS), and total volatile solids (TVS) results are presented in Tables 3-13 and 3-14, and in Appendix G. Sediment elutriate results are presented in Tables 3-15 and 3-16, and Appendix G. 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 silt and clay.

Table 3-13. Ranges for Ancillary Measurements

	Median	Min	Max
Cedar-Ortega River Basin Sites – Surface Sediments			
%Moisture	77.8	55.2	84.1
%TOC	12.5	2.3	21.6
%TS (wet weight)	22.2	15.9	44.8
%TVS (dry weight)	20.6	5.5	29.9
%Sand	34.4	15.9	79.3
%Silt	58.0	19.1	75.9
%Clay	6.4	1.6	23.7
%Mud	65.8	20.7	84.2
Cedar-Ortega River Basin Sites – Sub-Surface Sediments			
%Moisture	78.0	56.6	82.4
%TOC	13.4	3.4	22.6
%TS (wet weight)	22.0	17.6	43.4
%TVS (dry weight)	21.6	8.5	33.6
%Sand	37.0	12.7	76.3
%Silt	57.2	21.5	79.1
%Clay	6.0	1.6	12.9
%Mud	63.1	23.7	87.3

Table 3-14. Ancillary Measurement Summary Data

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
Cedar-Ortega River Basin Sites – Surface Sediments								
CED01	64.8	6.6	35.2	16.2	19.8	56.5	23.7	80.2
CED02	71.1	10.7	28.9	21.8	25.6	61.6	12.9	74.5
CED03	74.8	11.2	25.2	19.2	36.7	56.3	7.1	63.4
CED04	80.6	14.2	19.4	23.4	15.9	73.8	10.3	84.1
CED05	73.9	7.4	26.1	17.7	78.5	19.8	1.6	21.4
CED06	71.6	13.4	28.4	23.1	72.9	24.7	2.5	27.2
CED07	74.2	12.5	25.8	24.5	65.3	31.1	3.6	34.7
CED08	64.7	14.2	35.3	21.7	42.2	49.6	8.2	57.8
CED09	69.9	11.9	30.1	21.7	44.9	47.8	7.3	55.1
CED12	67.4	9.01	32.6	15.8	21.7	59.8	18.5	78.3
CED13	65.7	6.31	34.3	12.6	65.1	30.5	4.4	34.9
CED14	62.3	4.34	37.7	9.4	49.1	45.4	5.6	51.0
ORT01	78.9	10.5	21.1	18.5	23.8	69.7	6.5	76.2
ORT02	74.5	9.7	25.5	17.6	17.3	73.6	9.0	82.6
ORT03	78.5	11.6	21.5	19.0	15.9	75.9	8.3	84.2
ORT04	76.8	11.8	23.2	20.1	17.8	73.5	8.7	82.2

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
ORT04-1	78.6	11.9	21.4	20.3	19.5	72.6	8.0	80.6
ORT05	78.6	12.5	21.4	21.3	21.6	71.0	7.4	78.4
ORT06	76.1	10.2	24.0	17.2	20.9	71.4	7.8	79.1
ORT07	82.3	13.6	17.7	22.4	23.8	69.9	6.3	76.2
ORT08	75.7	11.7	24.3	20.1	31.1	62.6	6.3	68.9
ORT09	78.2	9.0	21.8	19.4	28.4	65.2	6.4	71.6
ORT10	80.8	12.9	19.2	22.0	25.5	67.9	6.6	74.5
ORT11	80.6	12.8	19.4	23.5	60.5	36.5	3.0	39.5
ORT12	81.2	13.0	18.8	22.2	27.9	65.4	6.7	72.1
ORT13	81.4	14.6	18.6	23.8	20.4	71.7	7.9	79.6
ORT14	78.2	11.0	21.8	19.8	26.3	67.5	6.2	73.7
ORT15	78.8	15.7	21.2	25.1	34.6	59.1	6.4	65.5
ORT16	79.3	13.6	20.7	19.9	18.0	73.9	8.1	82.0
ORT18	78.5	12.8	21.5	19.9	31.2	62.4	6.5	68.9
ORT19	58.5	2.8	41.6	6.3	56.2	39.7	4.1	43.8
ORT20	76.4	11.0	23.6	19.8	25.2	67.8	7.0	74.8
ORT21	72.9	12.5	27.1	18.1	73.6	24.2	2.2	26.4
ORT22	81.0	11.9	19.0	18.4	30.0	64.9	5.3	70.1
ORT23	72.8	14.0	27.2	20.4	69.8	26.9	3.3	30.2
ORT24	78.0	14.9	22.0	25.3	77.6	20.8	1.7	22.5
ORT25	77.9	15.7	22.1	27.5	79.3	19.1	1.6	20.7
ORT26	79.4	15.1	20.6	24.9	74.5	23.7	1.8	25.5
ORT27	73.2	14.6	26.8	25.2	28.8	62.9	8.3	71.2
ORT28	80.3	16.1	19.7	25.3	76.5	21.7	1.8	23.5
ORT29	73.0	12.8	27.0	20.4	41.1	52.4	6.5	58.9
ORT30	55.2	2.3	44.8	5.5	62.8	34.1	3.1	37.2
ORT31	73.3	12.3	26.7	19.6	73.8	24.4	1.8	26.2
ORT32	74.5	11.4	25.5	20.5	72.7	25.5	1.8	27.3
ORT33	58.9	4.3	41.2	7.5	54.2	42.2	3.7	45.9
ORT34	79.7	16.6	20.3	23.7	31.7	61.7	6.6	68.3
ORT35	77.7	13.6	22.3	23.5	73.9	23.5	2.7	26.2
ORT36	76.7	16.6	23.3	28.5	67.6	29.1	3.3	32.4
ORT37	79.2	14.6	20.8	25.0	68.9	28.8	2.3	31.1
ORT38	79.9	15.3	20.1	27.2	60.4	35.6	3.9	39.5
ORT39	79.6	18.4	20.4	29.5	41.5	52.3	6.4	58.6
ORT40	84.1	16.5	15.9	28.2	35.1	57.3	7.6	64.9
ORT41	83.1	21.6	16.9	27.7	44.2	50.8	5.0	55.8
Cedar-Ortega River Basin Sites – Sub-Surface Sediments								
CED01-M	66.6	7.3	33.4	16.8	45.0	42.1	12.9	55.0
CED03-M	75.1	12.4	24.9	15.8	27.7	64.1	8.3	72.4
CED03-L	73.8	12.8	26.2	16.6	22.9	66.5	10.6	77.1
CED04-M	75.4	14.2	24.6	20.8	15.2	71.9	12.9	84.8
CED04-L	78.2	18.1	21.8	21.6	15.3	73.7	11.0	84.7
CED06-M	74.4	8.6	25.6	18.0	69.1	28.5	2.4	30.9
CED06-L	81.5	19.6	18.5	25.3	68.7	29.3	2.0	31.3
CED07-M	74.4	13.4	25.6	24.3	66.2	30.5	3.3	33.8
CED07-L	79.9	16.6	20.1	21.4	73.5	24.6	1.9	26.5
CED08-M	66.9	11.9	33.1	18.1	71.3	26.0	2.7	28.7
CED09-M	70.5	11.2	29.5	20.8	51.7	43.1	5.2	48.3

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
ORT01-M	75.5	12.8	24.5	19.0	21.4	71.1	7.6	78.7
ORT01-L	74.4	10.4	25.6	15.5	15.2	75.6	9.2	84.8
ORT02-M	77.9	10.9	22.1	18.4	21.5	71.5	7.0	78.5
ORT02-L	74.9	10.4	25.1	16.2	13.6	77.5	8.9	86.4
ORT03-M	78.9	13.6	21.1	22.5	13.1	78.4	8.5	86.9
ORT03-L	77.2	11.5	22.8	19.1	15.4	76.0	8.6	84.6
ORT04-M	78.8	12.8	21.2	18.2	23.3	69.9	6.8	76.7
ORT04-L	78.0	11.4	22.0	16.6	15.0	77.2	7.8	85.0
ORT04-1-M	78.6	13.1	21.4	22.0	16.6	76.2	7.2	80.2
ORT04-1-C	77.7	10.9	22.4	20.9	15.4	77.3	7.4	84.6
ORT04-1-L	77.6	12.2	22.5	21.2	19.1	72.3	8.6	80.9
ORT05-M	79.7	14.6	20.3	22.6	12.7	79.1	8.2	87.3
ORT05-L	77.1	13.2	22.9	21.9	13.5	78.1	8.4	86.5
ORT06-M	69.6	11.2	30.5	33.6	15.8	76.3	8.0	84.3
ORT06-L	76.3	9.3	23.8	17.4	12.7	78.5	8.7	87.2
ORT07-M	82.1	13.7	17.9	20.5	20.1	73.3	6.6	79.9
ORT07-L	81.8	15.2	18.2	23.0	17.7	75.9	6.4	82.3
ORT08-M	76.8	10.2	23.2	20.7	34.5	60.8	4.7	65.5
ORT08-L	73.8	9.4	26.2	16.5	18.7	72.6	8.7	81.3
ORT09-M	78.9	13.2	21.1	20.5	24.5	69.5	6.0	75.5
ORT09-L	74.3	10.0	25.7	18.2	17.8	73.4	8.9	82.3
ORT10-M	81.1	14.1	18.9	22.0	21.3	71.8	6.9	78.7
ORT10-L	75.3	13.2	24.7	20.4	25.7	67.0	7.3	74.3
ORT11-M	79.2	13.4	20.8	22.3	57.2	39.2	3.5	42.7
ORT11-L	75.9	10.6	24.1	17.8	59.0	37.5	3.5	41.0
ORT12-M	81.3	14.5	18.7	25.3	49.7	46.6	3.8	50.4
ORT12-L	78.2	12.9	21.8	20.7	40.8	53.8	5.4	59.2
ORT13-M	79.1	15.2	20.9	24.3	18.4	73.6	8.1	81.7
ORT13-L	79.5	15.9	20.5	24.4	17.4	74.5	8.0	82.5
ORT14-M	80.2	9.5	19.8	16.8	19.0	75.1	6.0	81.1
ORT14-L	79.8	12.2	20.2	18.8	18.2	74.6	7.2	81.8
ORT15-M	77.9	15.6	22.1	24.0	48.1	47.7	4.2	51.9
ORT15-L	76.4	15.4	23.6	24.8	25.0	66.9	8.1	75.0
ORT16-M	82.4	13.7	17.6	21.1	20.3	73.0	6.7	79.7
ORT16-L	79.2	13.8	20.8	20.9	16.0	76.5	7.6	84.1
ORT18-M	77.4	11.1	22.6	17.0	34.7	59.1	6.2	65.3
ORT18-L	79.1	12.2	20.9	20.0	18.6	73.5	7.8	81.3
ORT20-M	81.0	14.6	19.0	22.1	20.3	73.5	6.2	79.7
ORT20-L	78.1	12.0	21.9	21.0	22.6	70.4	7.1	77.5
ORT21-M	77.5	14.7	22.5	22.6	74.0	24.1	1.9	26.0
ORT21-L	78.1	12.4	21.9	23.4	67.2	30.7	2.2	32.9
ORT23-M	77.4	15.0	22.6	21.6	63.7	33.5	2.8	36.3
ORT23-L	76.0	13.4	24.0	17.5	57.0	39.1	3.9	43.0
ORT24-M	77.5	14.5	22.5	22.4	72.9	25.3	1.8	27.1
ORT24-L	76.8	15.9	23.2	22.9	75.5	23.0	1.6	24.6
ORT25-M	78.1	15.2	21.9	26.7	74.8	23.4	1.9	25.3
ORT25-L	78.0	14.3	22.0	24.8	68.9	29.1	2.0	31.1
ORT26-M	78.2	16.4	21.8	26.6	67.8	29.9	2.3	32.2
ORT26-L	78.2	14.7	21.8	26.9	69.6	28.5	1.9	30.4

FIELD ID	%Moisture	%TOC	%TS (wet wt)	%TVS (dry wt)	%Sand	%Silt	%Clay	%Mud
ORT27-M	73.0	15.3	27.0	22.1	34.0	58.2	7.8	66.0
ORT27-L	63.6	7.1	36.4	13.8	54.8	41.5	3.7	45.2
ORT28-M	79.2	14.1	20.8	24.0	71.0	27.0	2.0	29.0
ORT28-L	81.1	16.4	18.9	30.7	58.3	38.8	2.9	41.7
ORT29-M	78.0	15.4	22.0	27.4	39.2	56.2	4.6	60.8
ORT29-L	76.8	12.4	23.2	25.2	43.2	52.3	4.5	56.8
ORT30-M	57.2	3.4	42.8	8.5	54.4	40.4	5.2	45.6
ORT30-L	69.2	7.3	30.8	16.4	56.4	39.3	4.3	43.6
ORT31-M	75.8	11.1	24.2	21.1	76.0	22.3	1.7	24.0
ORT31-L	56.6	6.2	43.4	15.4	71.2	25.1	3.7	28.8
ORT32-M	76.2	10.7	23.8	17.9	58.8	38.4	2.8	41.2
ORT32-L	65.0	4.2	35.0	10.8	69.6	27.8	2.6	30.4
ORT34-M	78.6	15.5	21.4	19.2	24.5	68.9	6.6	75.5
ORT35-M	78.9	13.1	21.1	23.6	76.3	21.5	2.2	23.7
ORT35-L	76.9	16.2	23.1	24.0	67.8	29.7	2.4	32.1
ORT36-M	80.0	14.9	20.0	24.7	74.3	23.9	1.8	25.7
ORT36-L	81.5	15.9	18.5	27.5	71.5	26.7	1.8	28.5
ORT37-M	79.7	15.5	20.3	22.2	69.0	29.1	1.9	31.0
ORT37-L	78.8	12.3	21.2	21.6	71.0	27.2	1.9	29.1
ORT38-M	80.1	16.9	19.9	28.0	72.2	25.9	1.9	27.8
ORT39-M	80.0	19.1	20.0	30.7	41.2	52.7	6.1	58.8
ORT39-L	81.4	18.4	18.6	25.1	27.6	66.4	6.1	72.5
ORT40-M	82.1	20.3	17.9	32.9	25.2	67.8	6.9	74.7
ORT40-L	81.6	19.7	18.4	31.3	23.4	70.3	6.3	76.6
ORT41-M	82.2	22.6	17.8	32.4	46.0	48.6	5.5	54.1
ORT41-L	82.0	20.3	18.0	32.4	40.4	54.5	5.1	59.6

3.3.1 TOC Results

The TOC concentrations for the COR surface sediment samples are illustrated in Figure 3-5. With the exception for a few low-TOC content samples (ORT19, ORT30, and ORT33), the TOC concentration was relatively uniform in the COR surface and sub-surface sediments. The TOC content of the surface sediments ranged from 2.3% (site ORT30) to 21.6% (ORT41), and the median concentration was 12.5%. The median TOC content of the sub-surface sediments was 13.4%. Low TOC concentrations are generally associated with coarse, sandy sediments (>80% sand), but this was not the observation with the COR samples. There was not a good correlation between TOC and the sediment grain size (Figure 3-6), possibly because the samples had relatively high and relatively uniform TOC content, indicating a relatively uniform and significant loading of organic carbon to the Cedar-Ortega River Basin sediments.

3.3.2 Grain Size Results

The sediment grain-size distribution was more variable and complex than the TOC content (Table 3-14; Figures 3-6 and 3-7). The sites included areas dominated by muddy (fine-grained, silty) sediments and a few others dominated by coarse sediments (primarily sand). The grain size composition can be characterized as a continuum of grain-size distributions. Overall, the grain size composition was variable throughout the area; the surface sediment composition ranged from 20% to 84% mud and from approximately 16% to 79% sand. The sub-surface sediment had a similar composition.

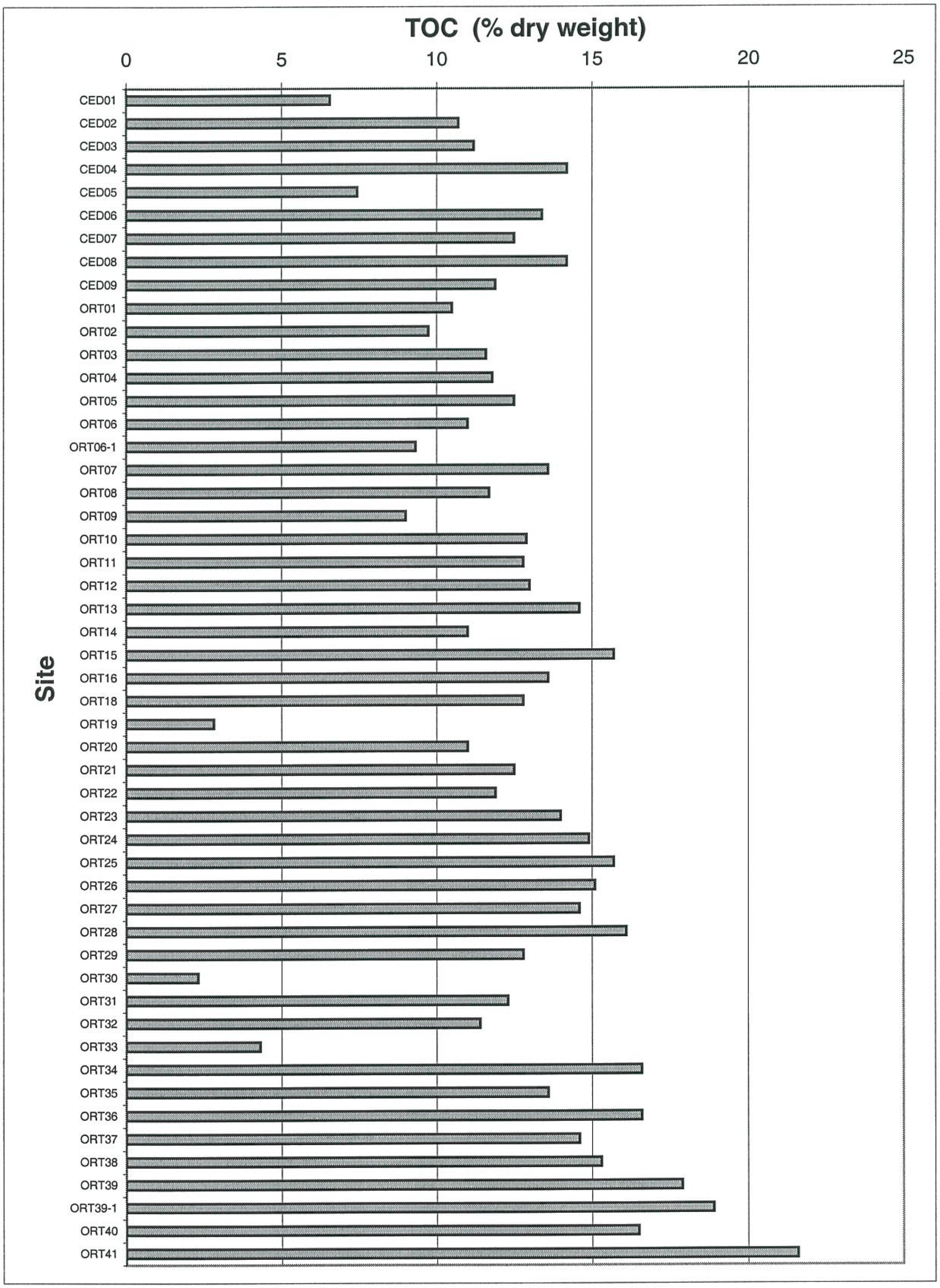


Figure 3-5. Total Organic Carbon (%TOC) Content of Surface Sediment Samples

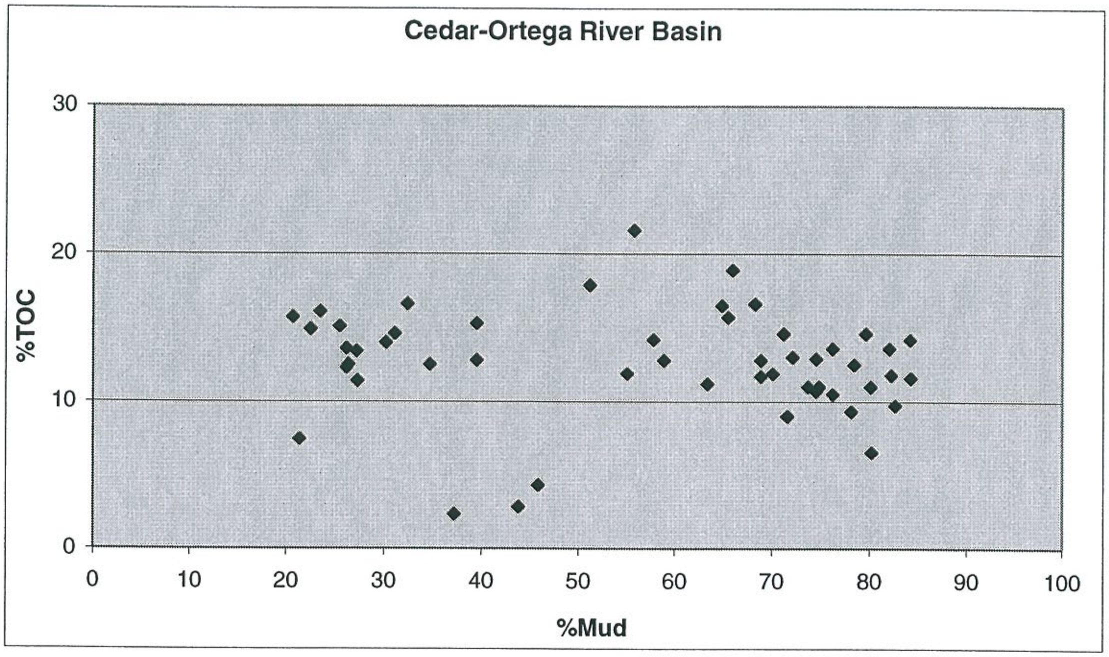


Figure 3-6. %TOC versus %Mud of Surface Sediment Samples

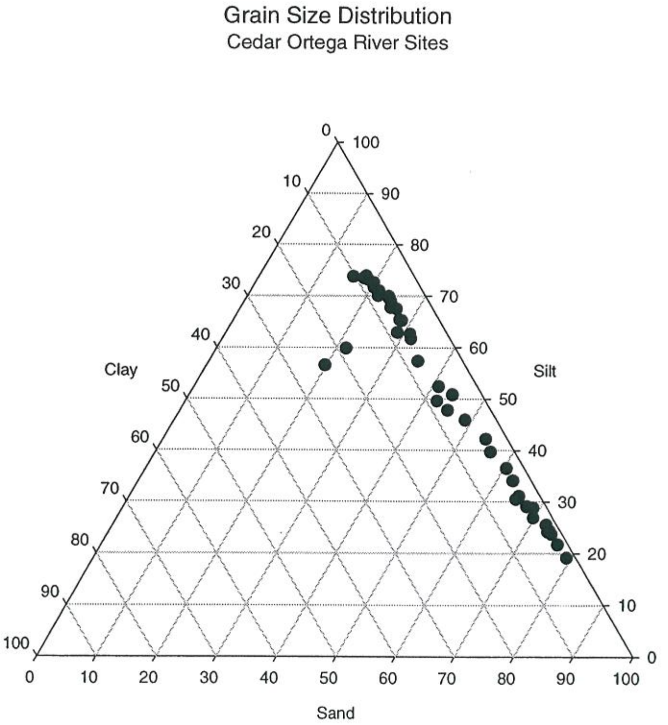


Figure 3-7. Grain Size Distribution of Surface Sediment Samples

The sediments were, for the most part, fairly fine in consistency. The median mud content was 65.8% for the COR surface sediments and 63.1% for the sub-surface sediments. However, most of the fine grain material, or mud, was comprised of silt; the clay content was generally low (mostly less than 10% clay). None of the COR sediment samples had less than 20% mud and the Cedar-Ortega samples were, on average, more fine grain than the lower St. Johns River samples (Battelle, 2004).

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

Sediment moisture content, TS, and TVS varied somewhat for the sediment samples. Moisture, TS, and TVS content were characterized by a range of distributions, with no obvious groupings of sediment types. The percent moisture content ranged from 55% to 84% in the surface sediments, and from 57% to 82% in the sub-surface sediments. TS and TVS concentrations range from 16% to 45%, and 5.5 to 30%, respectively, in the surface sediment. The moisture content was, on average, more uniform among the COR sites than among the LSJR sites (Battelle, 2004).

3.3.4 Elutriate Metals

Elutriate samples were only isolated and analyzed from surface sediments, and only from a selected sub-set of the surface sediment samples. Calcium, magnesium, potassium, and sodium concentrations in elutriate waters isolated from the sediments from the COR sites ranged from 36,400 to 78,900 µg/L, 40,800 to 112,000 µg/L, 14,200 to 36,300 µg/L, and 208,000 to 869,000 µg/L, respectively. The elutriate sample metals concentrations (Ca, Mg, K, and Na), and the conductivity, were less variable in the COR sediments than in the LSJR sediments (Battelle, 2004); none of the Cedar-Ortega River Basin samples had elutriate metals concentrations that were more than twice the median value.

Table 3-15. Concentration Ranges for Sediment Elutriate Major Metals

	Median (µg/L)	Min (µg/L)	Max (µg/L)
Cedar Ortega River Basin Sites (surface sediments)			
Calcium	54,400	36,400	78,900
Magnesium	57,300	40,800	112,000
Potassium	23,400	14,200	36,300
Sodium	473,000	208,000	869,000
Conductivity[1]	2,770	678	5,100

[1] Conductivity measured in units of µmhoms/cm.

Table 3-16. Sediment Elutriate Major Metals and Conductivity Summary Data

FIELD ID	Calcium (µg/L)	Magnesium (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Conductivity (µmhoms/cm)
Cedar Ortega River Basin Sites (surface sediments)					
CED01	52,500	55,300	15,900	358,000	2,450
CED02	63,500	72,800	23,700	572,000	3,340
CED06	71,300	42,200	16,400	301,000	1,930
CED07	53,800	51,100	25,700	473,000	678
CED08	52,500	40,800	14,800	208,000	1,560
CED09	41,900	42,400	14,200	241,000	1,550

FIELD ID	Calcium (µg/L)	Magnesium (µg/L)	Potassium (µg/L)	Sodium (µg/L)	Conductivity (µmhoms/cm)
ORT08	75,600	112,000	32,700	869,000	5,100
ORT15	40,400	52,800	18,600	368,000	2,160
ORT21	52,600	60,500	27,300	541,000	3,160
ORT23	69,500	65,300	27,700	571,000	3,280
ORT25	51,750	49,700	17,600	327,000	2,025
ORT26	47,000	62,900	25,900	499,000	2,820
ORT27	65,800	93,800	27,700	705,000	4,020
ORT28	36,400	46,300	19,200	344,000	2,000
ORT29	60,900	52,700	20,500	394,000	2,550
ORT31	63,700	59,800	27,900	513,000	5,100
ORT32	61,200	105,000	36,300	868,000	4,740
ORT35	54,900	56,300	22,600	453,000	2,710
ORT36	62,800	77,300	24,900	564,000	3,390
ORT37	48,900	58,300	21,400	472,000	2,820
ORT39	78,900	97,400	29,100	699,000	4,220

4. DISCUSSION

The samples collected in this study were from the Cedar-Ortega River (COR) Basin (Figures 2-1 and 2-2). Most of the samples were collected in a 2 mile long and 1,000 to 2,000 ft. wide segment of the basin, below the confluence of the Cedar and Ortega rivers and down to the mouth at the confluence with the lower St. Johns River. Samples were also collected to about 1 mile upstream in the Ortega River and to about 2 miles upstream in the Cedar River, where that river was no more than about 150 ft. wide.

The predominant land use types are wetlands, forest, and agriculture along the main stem of the lower St. Johns River (Figures 1-2 and 1-3, and Appendix A), while the area within several miles of the Cedar-Ortega River Basin is primarily urban/residential. Of course, and as discussed in Section 1, the St. Johns and Cedar-Ortega rivers drain large areas, and the near-shore land use is only part of what impacts the contaminant characteristics of these river systems.

The presentation below focuses on three aspects of the sediment contamination. These include 1) the general contaminant concentrations, distribution, and composition in the study area, and how the measured contaminant levels compare to those reported for other aquatic systems around the country, 2) identification of geographically unique contaminant profiles and a summary of possible "hot spots", and 3) the potential of measured concentrations to cause impact to the water bodies. This data assessment presents separate discussions of the organic compound and metals contaminants. A general discussion of the potential ecological implications of the observed contamination is also provided.

4.1 Organic Compound Contamination

4.1.1 Organic Contaminants — Review/Overview

The major classes of organic compounds analyzed were polycyclic aromatic hydrocarbons (PAH), phthalates, polychlorinated biphenyls (PCBs), a group of other chlorinated industrial organic compounds, a series of chlorinated pesticides (e.g., DDTs, chlordane, BHCs, and endosulfans), and selected classes of chlorinated phenolic compounds (chlorinated phenols, anisoles, guiaiacols, and catechols). These groups of compounds were categorized, and the analytical results presented, in Sections 3.1.1, 3.1.2, and 3.1.3.

PAH. 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 from two to six ring [e.g., benzo(g,h,i)perylene] are most commonly monitored as environmental contaminants, and this was the molecular weight range included in this project.

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 oils 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 origins 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 between those of pyrogenic and petrogenic PAH (Hugget *et al.*, 1987).

Phthalate Esters. The phthalate ester compounds are also ubiquitous in the environment. Phthalates are typically not considered to cause adverse effects to the same degree as many of the other organic compounds that were analyzed, but they are among the most widely used industrial chemicals (e.g., 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, in particular bis(2-ethylhexyl)phthalate and di-N-butylphthalate.

Industrial Chlorinated Compounds. The "other industrial chlorinated compounds" are a group of chlorinated, relatively low molecular weight, organic compounds. These compounds include di, tri, and tetrachlorinated benzenes, and they are also widely used in many industrial processes and applications.

PCB and Chlorinated Pesticides. PCBs have been widely used in a number of industries. Although they are used less today than they were in the past, they are a highly persistent class of chlorinated hydrocarbons that remain of significant environmental concern and are found throughout our environment. Similarly, the concentrations of several persistent and once widely used chlorinated pesticides, such as DDT and its degradation products DDD and DDE, chlordane, BHCs, and endosulfans, were studied. The manufacturing and broad uses of these compounds has either been stopped or severely limited. However, endosulfan, for instance, is still being permitted for use as an insecticide on tobacco, fruits, and vegetables, and for wood preservation, BHC compounds are used in small-scale pest control (e.g., ticks, fleas), and stockpiles of banned pesticides are still a concern. Nonetheless, the majority of the PCB and chlorinated pesticides that are detected in the environment today were introduced more than 20 years ago.

Chlorophenolic Compounds.
The chlorinated phenolic compounds are a combination of chemicals primarily used in industrial processes and process byproducts. The chlorinated phenol target analytes and the anisoles are widely used industrial compounds, being a component and/or byproduct of many industrial processes. Guaiacols and catechols are most commonly considered industrial byproducts, and are often associated with pulp and paper industry activities. These compounds are, for the most part, relatively polar compounds, and do not tend to persist in historic sediments or bioaccumulate to the degree that most of the other organic contaminants do. These chlorinated phenolic compounds therefore, were only measured in the surface sediment samples.

4.1.2 Organic Compounds — Contaminant Concentrations and Distribution

The data from the Cedar-Ortega River Basin sampling were presented in Section 3. Table 4-1 summarizes similar data for the 77 lower St. Johns River surface sediment sites reported in Battelle, 2004, for comparison purposes. The lower St. Johns River sediment data were generated using identical methods as those used to generate the Cedar-Ortega River Basin data, and can therefore be directly and confidently compared.

Table 4-1. Summary of Contaminant Concentration Data for Lower St. Johns River Surface Sediment Samples (Battelle, 2004)

	Not Normalized (µg/kg dry weight for organics; mg/kg dry weight for metals)			Normalized [to TOC (µg/g TOC) for organics; to aluminum for metals]		
	Median	**Min**	**Max**	**Median**	**Min**	**Max**
Organic Contaminants						
Total PAH	1,300	10.7	13,800	10.8	1.69	190
Low PAH (LMW)	177	3.23	3,190	1.62	0.168	43.7
High PAH (HMW)	1,130	7.48	10,700	9.52	1.52	146
Total Phthalate	162	12.3	1,710	1.86	0.294	32.5
Σ23 PCB Compounds	26.9	0.09	257	0.245	0.012	2.71
ΣDDT Compounds	5.81	ND	30.3	0.047	ND	0.416
DDTs	1.25	ND	15.5	0.012	ND	0.143
DDEs	1.79	ND	7.23	0.016	ND	0.138
DDDs	2.13	ND	13.3	0.016	ND	0.182
ΣChlordanes [a]	0.38	ND	4.11	0.005	ND	0.292
Σ BHCs	0.67	ND	5.77	0.007	ND	0.098
Σ Endosulfans	0.68	ND	16.6	0.008	ND	0.145
Σ Other Chloros	16.6	ND	152	0.205	ND	7.86
Total Chlorophenolics	2,500	ND	13,800	26.1	ND	1,070
Σ Phenols	952	ND	5,530	9.36	ND	317
Σ Anisoles	ND	ND	2,710	ND	ND	120
Σ Guaiacols	753	ND	7,260	6.83	ND	610
Σ Catechols	161	ND	11,500	1.86	ND	64.5
Metals						
Major Metals						
Aluminum (Al)	20,800	637	54,450	1	1	1
Iron (Fe)	14,300	ND	32,700	0.637	ND	2.20
Manganese (Mn)	119	20.8	485	7.29E-03	2.84E-03	7.38E-02
Trace Metals						
Antimony (Sb)	0.235	0.046	0.953	1.18E-05	7.08E-06	1.43E-04
Arsenic (As)	3.46	0.120	13.2	1.64E-04	4.49E-05	6.56E-04
Beryllium (Be)	0.486	ND	1.65	2.39E-05	ND	4.92E-04
Cadmium (Cd)	0.401	ND	1.41	1.75E-05	ND	1.14E-04
Chromium (Cr)	38.0	2.97	91.8	1.69E-03	7.59E-04	6.23E-03
Cobalt (Co)	2.18	0.158	5.97	1.08E-04	6.75E-05	4.29E-04
Copper (Cu)	11.4	0.664	62.0	5.76E-04	1.99E-04	1.56E-03
Lead (Pb)	20.9	0.311	94.7	1.04E-03	3.62E-04	3.21E-03
Lithium (Li)	13.4	1.42	45.0	7.00E-04	3.98E-04	4.72E-03
Mercury (Hg)	0.214	0.008	0.859	8.40E-06	1.12E-06	2.22E-04
Nickel (Ni)	9.54	0.314	29.8	4.20E-04	1.70E-04	1.32E-03
Selenium (Se)	2.03	ND	4.74	8.53E-05	ND	4.18E-04
Silver (Ag)	0.165	ND	1.06	9.56E-06	ND	7.12E-05
Thallium (Tl)	0.290	ND	0.511	1.45E-05	ND	1.30E-04
Tin (Sn)	1.55	0.204	6.21	8.24E-05	3.29E-05	6.40E-04
Vanadium (V)	36.4	3.84	87.3	1.63E-03	7.77E-04	1.10E-02
Zinc (Zn)	57.1	2.09	241	2.72E-03	8.49E-04	1.49E-02

[a] The ΣChlordanes data for the LSJR is based on the sum of the 3 main chlordane compounds (α-chlordane, γ-chlordane, and oxychlordane), while for the COR (Tables 3-5 and 3-6) it is based on all chlordane compounds listed in Table 3-4.

The organic contaminant concentrations were, generally, less variable in the Cedar-Ortega River Basin than in the lower St. Johns River (Tables 3-2, 3-5, 3-9, and 4-1). However, the sediments in the Cedar-Ortega River Basin had, overall, higher concentrations of many organic contaminants than the lower St. Johns River. Some of the variability that was observed can likely be attributed to anthropogenic sources, while others are more a reflection of the bulk composition of the sediment and the different contaminant concentration potential of the sediments, and of contaminant transport and depositional characteristics.

PAH

COR Concentrations Measured in this Study

The total PAH concentrations in the sediments are presented in Table 3-3, and Figures 4-1 (non-normalized) and 4-2 (TOC-normalized). The PAH data are also displayed on a map in Figure 4-3. Additional bar charts with organic contaminant concentrations are compiled in Appendix I, and maps illustrating the general geographical distribution of the contaminants can be found in Appendix Q. The sites in the bar graph are sorted alphabetically by site name, as indicated in Figure 4-1.

The highest surface sediment PAH concentrations were measured at site CED09 (29,800 µg/kg total PAH), the nearby sites in the middle segment of the Cedar River, and site ORT33 (15,200 µg/kg total PAH). The PAH concentrations were, generally, much higher at the Cedar-Ortega River Basin sites than at the lower St. Johns River sites (Tables 3-2 and 4-1); the median surface sediment total PAH concentration was 4,840 µg/kg for COR, which is about three times higher than what was measured for the LSJR sites. A total of 44 of the 49 COR sites (90% of the sites) had surface sediment total PAH concentrations above 2,000 µg/kg dry weight, while only 22 of the 77 LSJR sites (29% of the sites) described in Battelle, 2004, had a PAH concentration that exceeded 2,000 µg/kg.

It is often useful to also normalize organic contaminant data to the TOC content of the sediment, and review both the non-normalized and TOC-normalized data, to help determine if elevated levels of organic contaminants may be from nearby sources. A review of both the non-normalized and TOC-normalized concentrations can also provide information related to the bioavailability of the organic contaminant (i.e., organic contaminants tightly bound to organic matter, or particulates, are less bioavailable than less tightly bound compounds).

The TOC normalized PAH concentration distribution (Figure 4-2) was fairly similar to the non-normalized distribution, with only a few sites appearing elevated even though their non-normalized concentrations were more moderate (e.g., site ORT19). This is a reflection of a lower TOC content of these sediments and not of PAH concentration that is of greater concern than those of surrounding sites — 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. This similarity in the contaminant pattern for non-normalized and TOC-normalized PAH data is a reflection of the TOC content being fairly similar in these sediments. After considering all the PAH and sediment characteristics data, the sites and areas that appear to have the most elevated surface sediment concentrations of PAH are CED09, CED04, ORT33, ORT31, ORT19, and, generally, the Cedar River (Figure 4-3).

Figure 4-4 shows the total PAH concentration for the 3 samples (surface, center, and lower) from sediment cores collected at 13 selected locations. The sites represented in Figure 4-4 are ordered from the most upstream in the Cedar River (CED01), moving down the Cedar River, through the downstream part of the Basin, to the last site before it empties into the lower St. Johns River (ORT01). Figure 4-5 shows similar information for 3 cores, but also includes information on the sediment depth that the samples represent, and these data are displayed in Figure 4-6 using 3-dimensional visualization and extrapolations of all surface and sub-surface sediment PAH data.

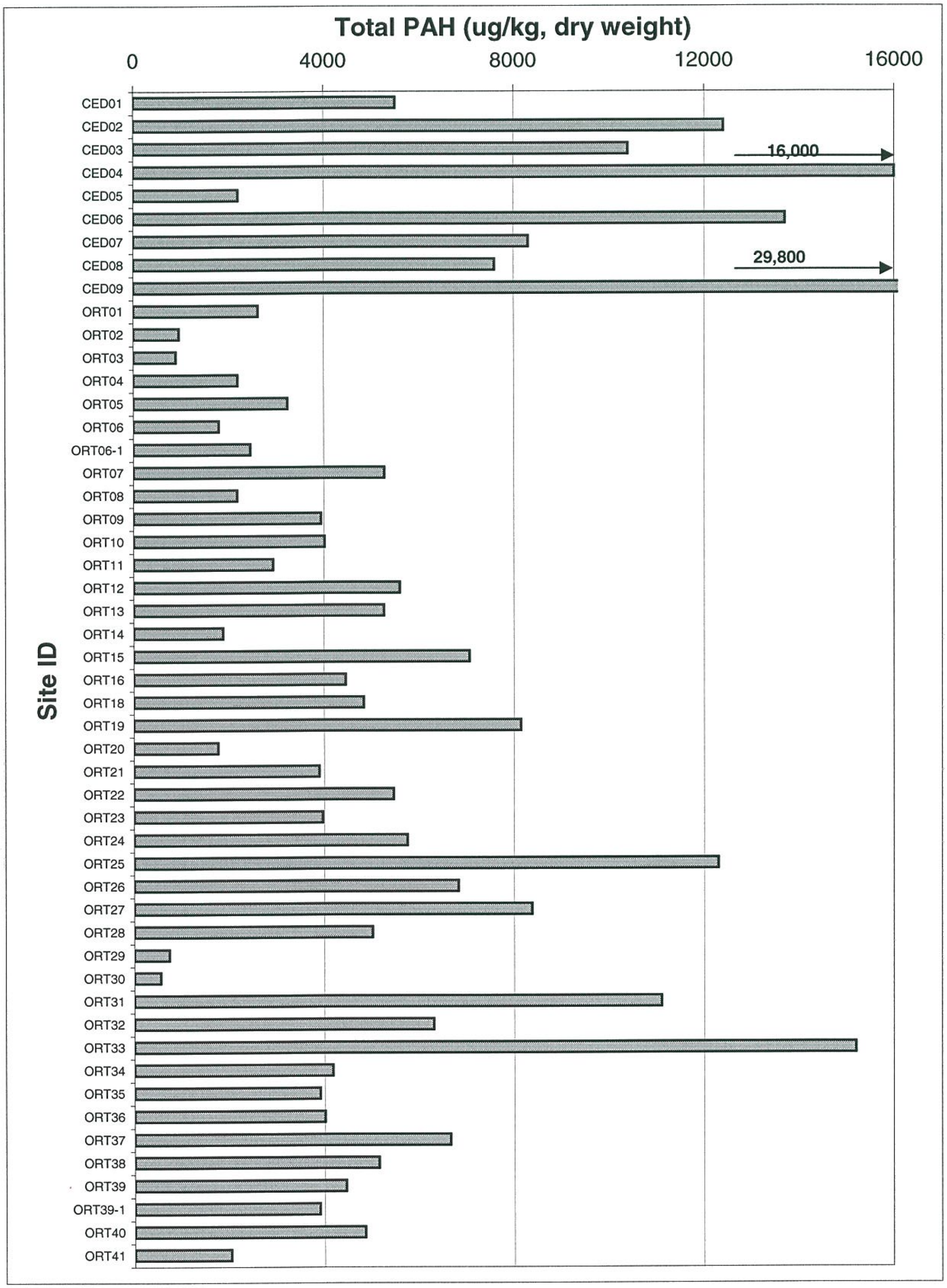


Figure 4-1. Total PAH Concentrations of Surface Sediment Samples

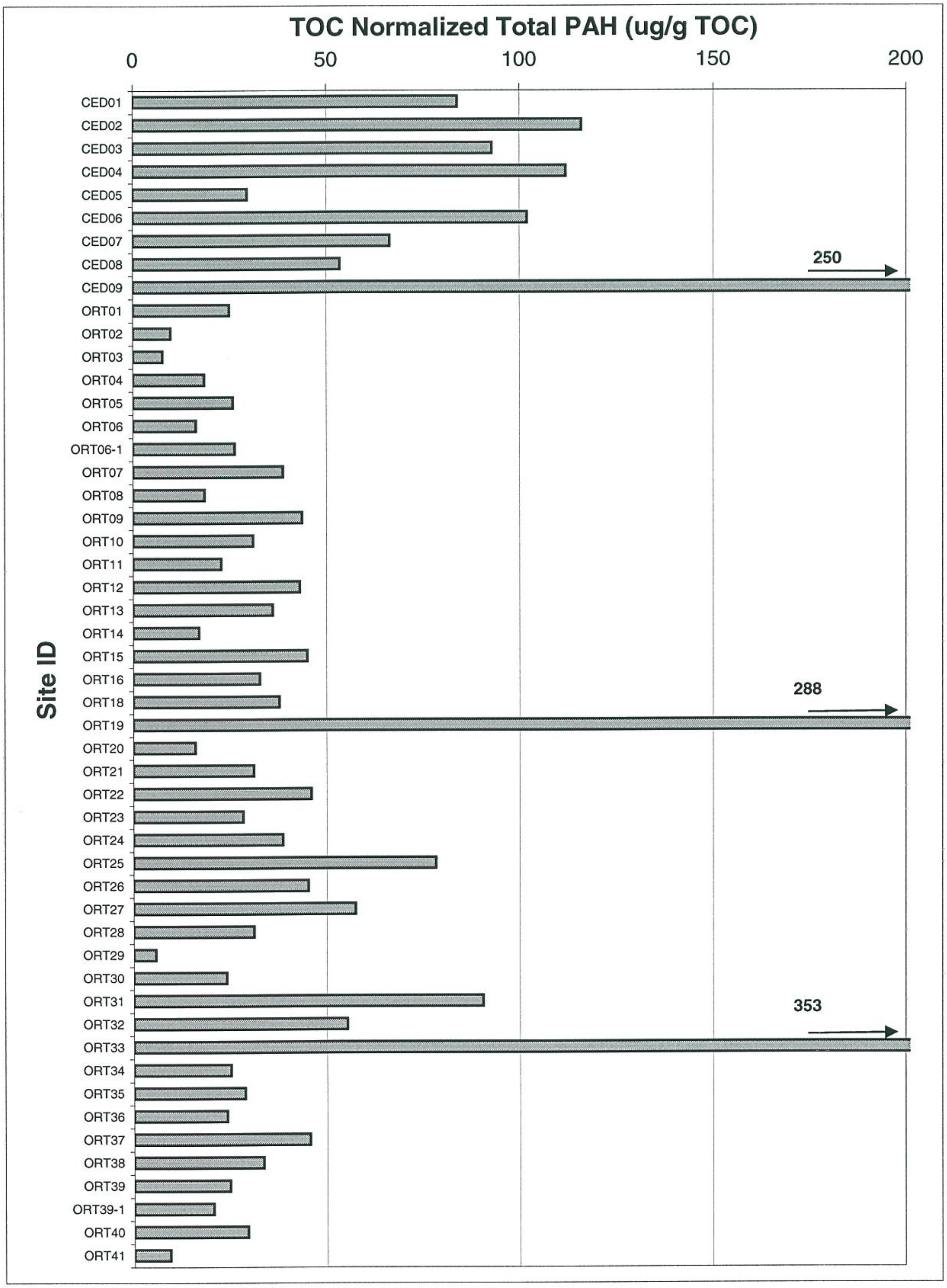


Figure 4-2. TOC-Normalized Total PAH Concentrations of Surface Sediment Samples

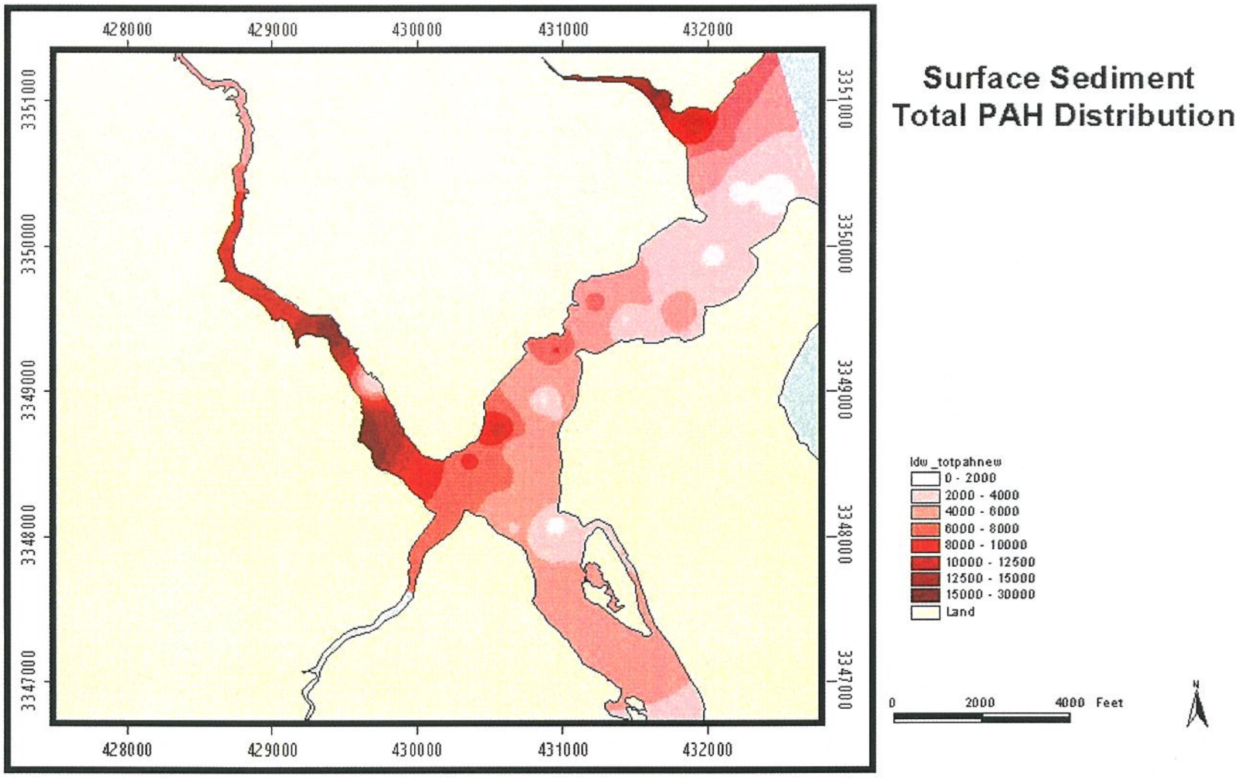


Figure 4-3. Extrapolated Surface Sediment Total PAH Concentrations

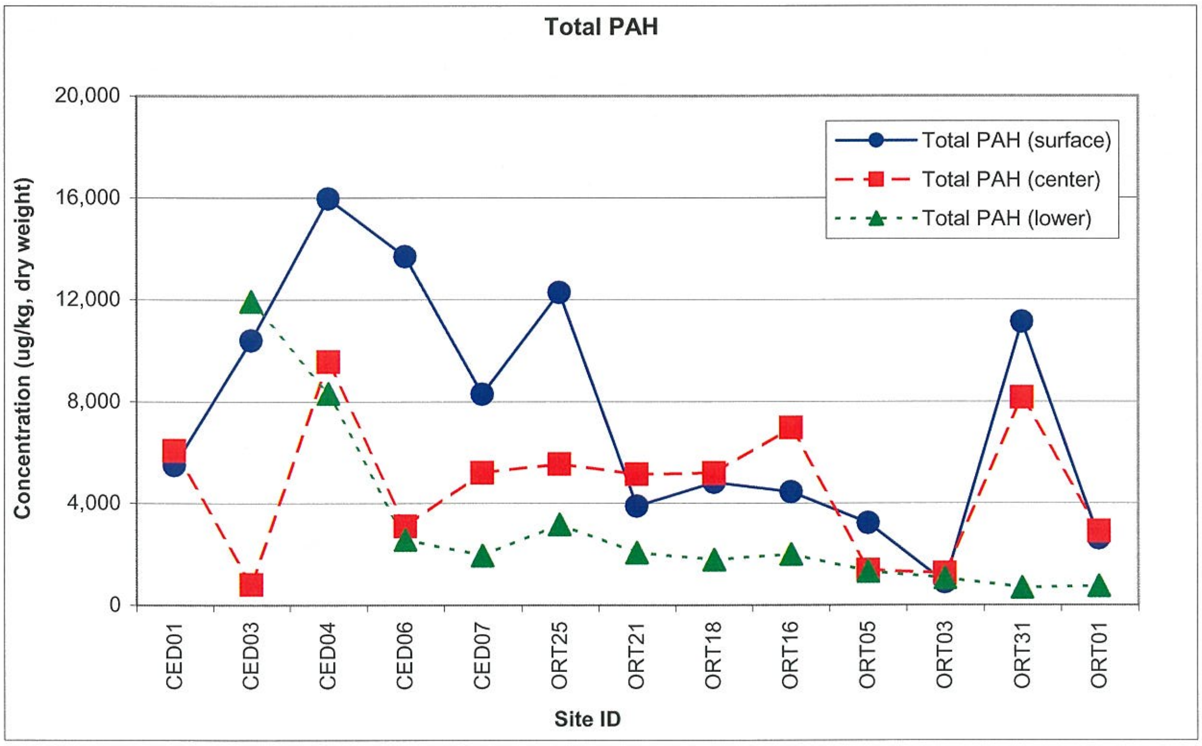


Figure 4-4. Total PAH Concentrations at Different Sediment Depths at Selected Sites

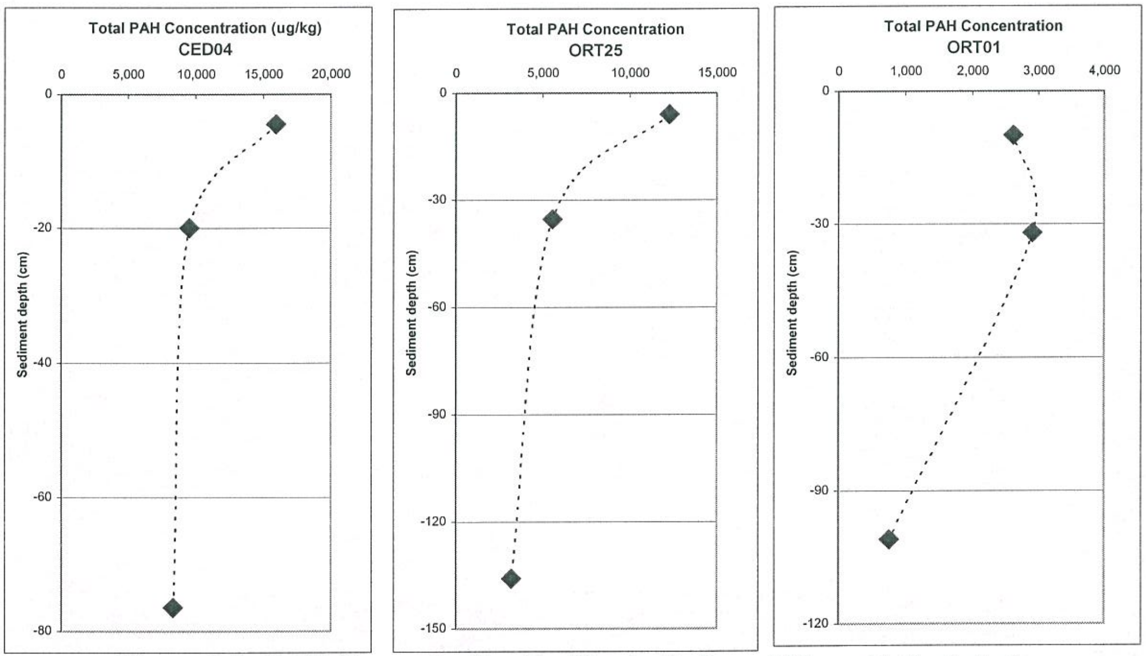


Figure 4-5. PAH Concentration Profiles in Sediment Cores Collected at Sites CED04, ORT25, and ORT01

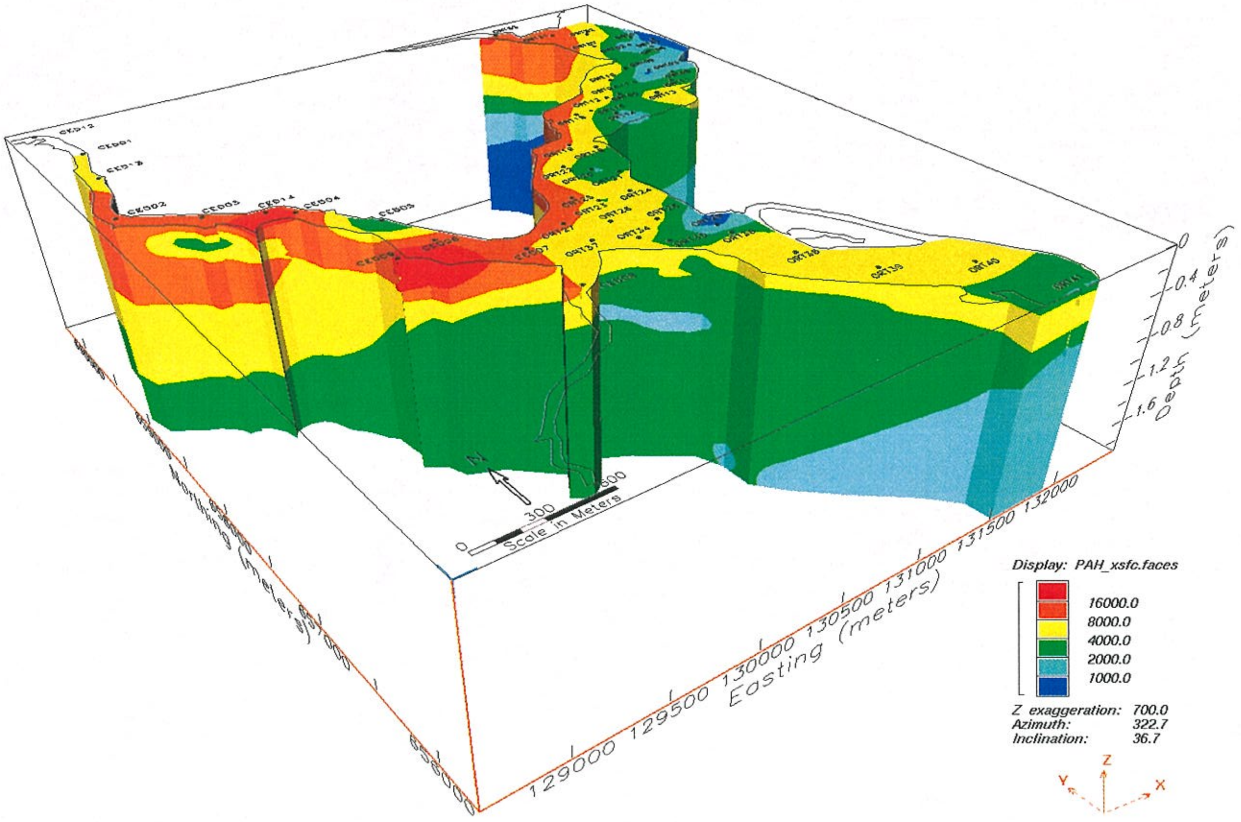


Figure 4-6. 3-D Visualization of the Total PAH Concentration in the Cedar-Ortega River Basin

The sediment PAH concentrations typically decreased with sediment depth. However, the PAH concentrations of many sub-surface sediments were comparable to the surface sediment PAH concentrations, depending on the depth at which the sample was collected and the location. There appears to be a fair amount of variability in the PAH concentrations in the sediment from the top 30-50cm, with the surface sediment generally having the highest concentration but the near-surface often having similar and sometimes having different (mostly lower) PAH concentrations. The PAH concentrations were generally below 3,000 µg/kg in sediments collected at a depth of 50-100cm, or deeper (except in the most contaminated areas).

The observed fluctuations in near-surface PAH sediment concentrations may partly be due to effects of depositional and turbation characteristics. The total PAH concentration is also significantly affected by unusually high concentrations of perylene in many of these samples, which can misrepresent the PAH contamination; perylene is primarily a product of biosynthesis, and not the result of typical PAH contamination such as from petroleum or combustion sources, and can become significant in organic-rich sediments, such as these. The elevated concentrations of PAH in the surface and near-surface sediments indicate that there are significant current sources of PAH, and the PAH concentrations in the sediment samples from greater depth indicate that there has been significant inputs of high-molecular weight PAH to these sediments for quite some time (at least for several decades). Data from sediment core age dating were not available for this report — such data could make it possible to determine the approximate year the sediments were deposited at different depths.

COR Concentrations Compared to Other Studies
The PAH concentrations were generally higher at the COR sites than at the LSJR sites that had earlier been investigated by the District (Battelle, 2004), with a median surface sediment total PAH concentration of 4,840 and 1,300 µg/kg, respectively (Tables 3-2 and 4-1). Most of the LSJR sites had surface sediment total PAH concentrations below 2,000 µg/kg; 22 of the 77 sites had concentrations above 2,000 µg/kg and only one site had a total PAH concentration above 10,000 µg/kg. However, the majority of the COR sites - 43 of the 49 sites - had surface sediment total PAH concentrations *above* 2,000 µg/kg. Sites CED02, CED03, CED04, CED06, CED09, ORT25, ORT31, and ORT33 had a sediment total PAH concentration above 10,000 µg/kg. The relatively elevated HMW PAH, compared to LMW PAH, was much more evident with the COR samples than the LSJR samples, indicating a greater contribution from a pyrogenic source of PAH to the COR sediments. The COR surface sediment median HMW PAH concentrations were about 12 times higher than the median LMW PAH concentrations, while the difference was about a factor of 6 for the LSJR samples.

The PAH concentrations measured in this study were generally higher than one might typically expect for most urban or near-urban locations. Total PAH concentrations (sum of 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 coastal or lake 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 the concentrations were between 700 and 40,000 µg/kg for 12 of the 14 stations. 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 in this study. The concentrations ranged from 2,200 to 2,600 µg/kg at remote reference locations in the Sound.

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, in general, increase with depth to a maximum concentration at depths corresponding to the 1960s to 1970s, and then decrease as the sediment represents earlier deposition (Gustafsson *et al.*, 1997; Simcik *et al.*, 1996). 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 a change 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. Recent significant improvements in source control include better removal of particulate matter (soot) from stack gases and more effective control of sewerage discharges, combined sewerage overflow, and storm water systems.

Sediment contaminant data can be compared to the NS&T/MW (National Status and Trends/Mussel Watch) "high" values, which are useful reference values determined statistically using the NS&T/MW monitoring program dataset (Table 4-2; Daskalakis and O'Connor, 1995). The listed reference values were set as the geometric mean plus one standard deviation, using the NS&T U.S. coastal monitoring program sediment site data. Daskalakis and O'Connor (1995) compiled a comprehensive Coastal Sediment Database (COSED) of chemical contaminant concentrations in US sediments, and this is a useful reference for contaminant concentrations measured around the country and what would typically be considered elevated concentrations.

The NS&T/MW "high" value for Total PAH is 2,180 µg/kg, and is based on the same 24 PAH compounds that were measured in this study. NS&T/MW "high" values for low MW PAH (LMW, 2- and 3-ring PAH) and high MW PAH (HMW, 4- through 6-ring PAH) are 450 µg/kg and 1,730 µg/kg, respectively. These values reflect the greater abundance and persistence of pyrogenic PAH (from combustion products, mostly HMW PAH) than petrogenic PAH (from petroleum products, mostly LMW PAH).

Table 4-2. Number and Percentage of Sites with Surface Sediment NS&T/MW "High" Value Exceedances

		Number of Exceedances				
	NS&T/MW 'High' Value [a]	% NS&T/MW 'High' Exceedances in COSED Dataset			% NS&T/MW 'High' Exceedances in This Study	
		NS&T/MW Sites	EMAP Sites	All COSED Sites	COR Sites	LSJR Sites
Study/Site Information						
Random		No [b]	Yes			
Total # of sites		224	500	3878	49	77
Parameter						
Ag	0.52	16	8	22	65	14
As	13	13	8	18	4	1
Cd	0.54	16	12	31	86	38
Cr	125	14	3	11	0	0
Cu	42	18	10	25	41	3
Hg	0.22	15	12	30	90	48
Ni	42	13	5	11	0	0
Pb	45	13	12	23	80	12
Sb	2.1	15	1	8	0	0
Se	0.92	14	16	15	92	71
Sn	4	12	17	20	57	8
Zn	135	15	17	22	73	16
High MW PAH	1730	18	9	23	86	30
Low MW PAH	450	17	12	22	39	17
Total PAH	2180	14	2	6	82	25
Total Chlordane	4.5	14	2	8	59	0
Total Dieldrin	2.9	13	1	6	0	0
Total DDT	22	18	9	23	25	1
Total PCBs	80	15	5	15	90	32

[a] "High" concentrations are in µg/kg for organic contaminants and mg/kg for metals. From Daskalakis and O'Connor (1995).
[b] Not random, but representative sites. Percentages are based on number of sites analyzed for the particular chemical, a number usually less than the total number of sites. EMAP: Environmental Monitoring and Assessment Program; NS&T/MW: National Status and Trends, Mussel Watch Program.

The data in Table 4-2 indicate that between 2 and 14% of coastal sediments monitored in various U.S. monitoring programs (NST&MW sites, EMAP sites, and all COSED sites; 14%, 2%, and 6%, respectively) contain concentrations of total PAH equal to or greater than the corresponding NS&T/MW "high" value. In comparison, approximately 82% of the Cedar-Ortega River Basin surface sediment sites sampled in this study had total PAH concentrations that exceeded the NOAA "high" concentration of 2,180 µg/kg. In addition, approximately 39% and 86% of the COR sites exceed the NS&T/MW "high" values for Low MW PAH and High MW PAH, respectively, which is also well above the 9 to 23% observed for the other listed programs. This is an exceedance rate that is clearly much higher than observed in any of the national sediment monitoring program data sets listed in Table 4-2, including the lower St. Johns River in general, and the observed exceedances are widespread, geographically. However, the Cedar-Ortega River Basin is also likely more impacted by industry and urban environments than the average U.S. coastal location.

Phthalates
The phthalate data showed a range in surface sediment concentrations that, on average, were about twice as high as in the lower St. Johns River (Tables 3-2, 3-3, and 4-1). Elevated phthalate concentrations were measured at sites from CED01 through CED05 in the Cedar River and at ORT33 — the geographical distribution of the phthalate contamination was similar to that of PAH. Eight of the 49 COR sites had surface sediment total phthalate concentrations over 1,000 μg/kg (only two of the 77 LSJR sites exceeded 1,000 μg/kg), and the highest was just above 2,500 μg/kg (CED04). The TOC-normalized data indicate that the sites identified with the highest non-normalized surface sediment phthalate concentrations are indeed likely near potential sources of these contaminants because the concentrations remained similarly elevated relative to the rest of the sites, both non- and TOC-normalized. The sub-surface sediment phthalate concentrations were generally lower than the surface sediment concentrations, similarly to what was observed for PAH, with the highest sub-surface concentrations in the sediments at sites in the middle-segment of the Cedar River.

Industrial Chlorinated Compounds
The concentrations of total other chlorinated industrial compounds (i.e., the chlorinated benzene) ranged from less than 1 μg/kg to 136 μg/kg in Cedar-Ortega River Basin surface sediment, which was comparable to the range measured in the sediments from lower St. Johns River. These contaminants exhibited a highly variable contaminant distribution, with no clear geographical relationship. Among the highest concentrations were measured at a site in the southern branch of the Ortega River (site ORT40), but the two sites closest to ORT40 had among the lowest industrial chlorinated compound concentrations of all sites, confounding the interpretation and reliability of these data. There was no obvious relationship between surface sediment and sub-surface sediment concentrations of these contaminants. These compounds are among the most water-soluble and mobile of the chlorinated compounds determined in this project, and tend to be transported in the water column, away from sources, and concentrate in areas of high TOC more than discretely near the source, potentially causing less predictable and more variable data. The TOC-normalized data for the other chlorinated compounds show relatively little concentration difference along the river.

PCB
COR Concentrations Measured in this Study
The surface sediment PCB concentrations were, generally, much higher at the COR sites than at the LSJR sites reported in Battelle (2004); the median concentration was five times higher (Table 3-5). The PCB concentrations were highest in the Cedar River (e.g., sites CED01, CED02, CED03), and there was a clear trend of gradually decreasing PCB concentrations down the Cedar River (Figure 4-7, and Appendices C, D, and I). Three surface sediment sites (CED12, CED13, and CED14) were sampled for PCB analysis only (and TOC and grain size), to better characterize the PCB in the Cedar River. An increase in PCB loading was observed moving up stream of site CED01 to site CED12, which was the site farthest up the river. This suggests that there is a source of PCB upstream of CED01.

A selected set of samples that had been analyze for PCB (and pesticides and other chlorinated compounds) using Method 8081M (Table 3-6) were also re-extracted and re-analyzed by GC/MS using PCB-targeted sample preparation and instrumental analysis methods. Three additional samples (surface sediments from CED12, CED13, and CED14) were collected for the detailed PCB congener analysis, for a total of 72 samples used in the detailed congener assessment. The PCB-targeted method is less susceptible to matrix interference than the Method 8081M GC/ECD analysis, and the data from the GC/MS analysis should be considered the most reliable PCB data (which was supported by excellent quality control data results). A suite of 107 individual PCB congeners were determined in those samples; congeners representing >95% of the total PCB in all Aroclor formulations and most environmental samples. A total PCB could therefore confidently be determined by adding up the individual concentrations of the 107 PCB congeners (Table 3-7). The data for each of the 107 PCB

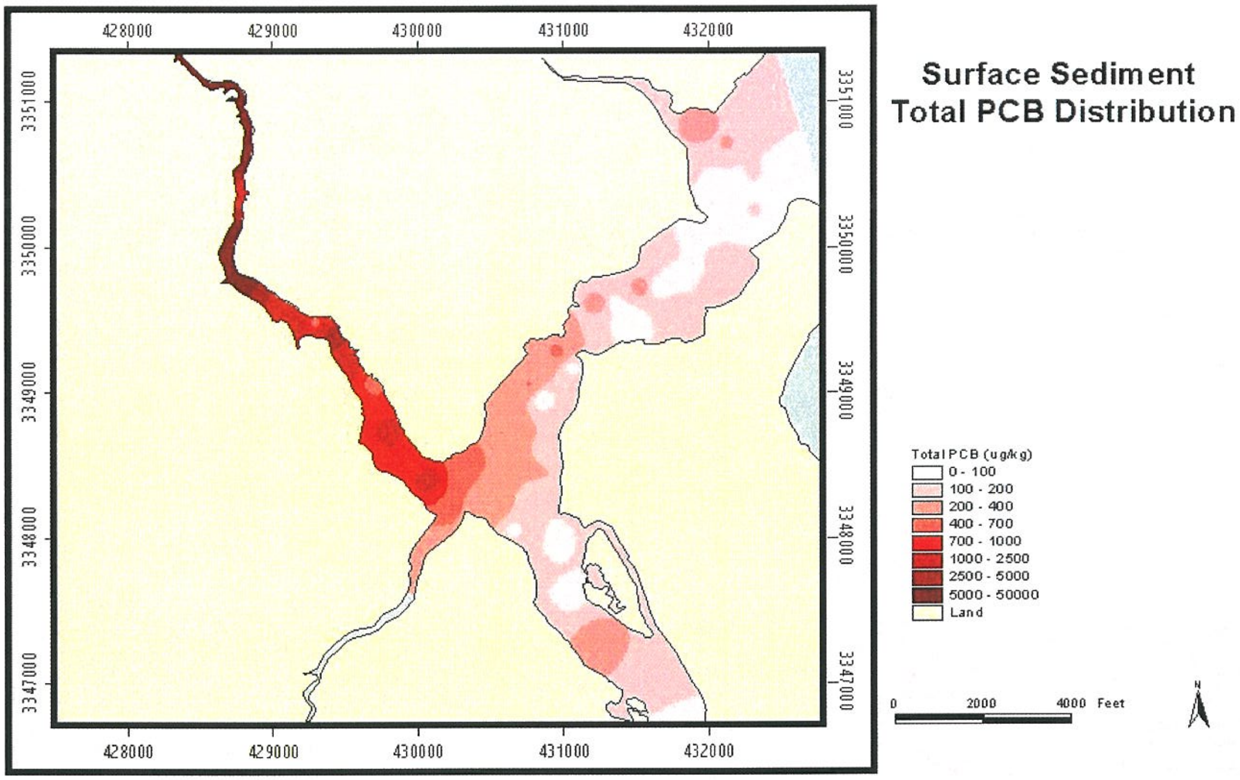


Figure 4-7. Extrapolated Surface Sediment Total PCB Concentrations

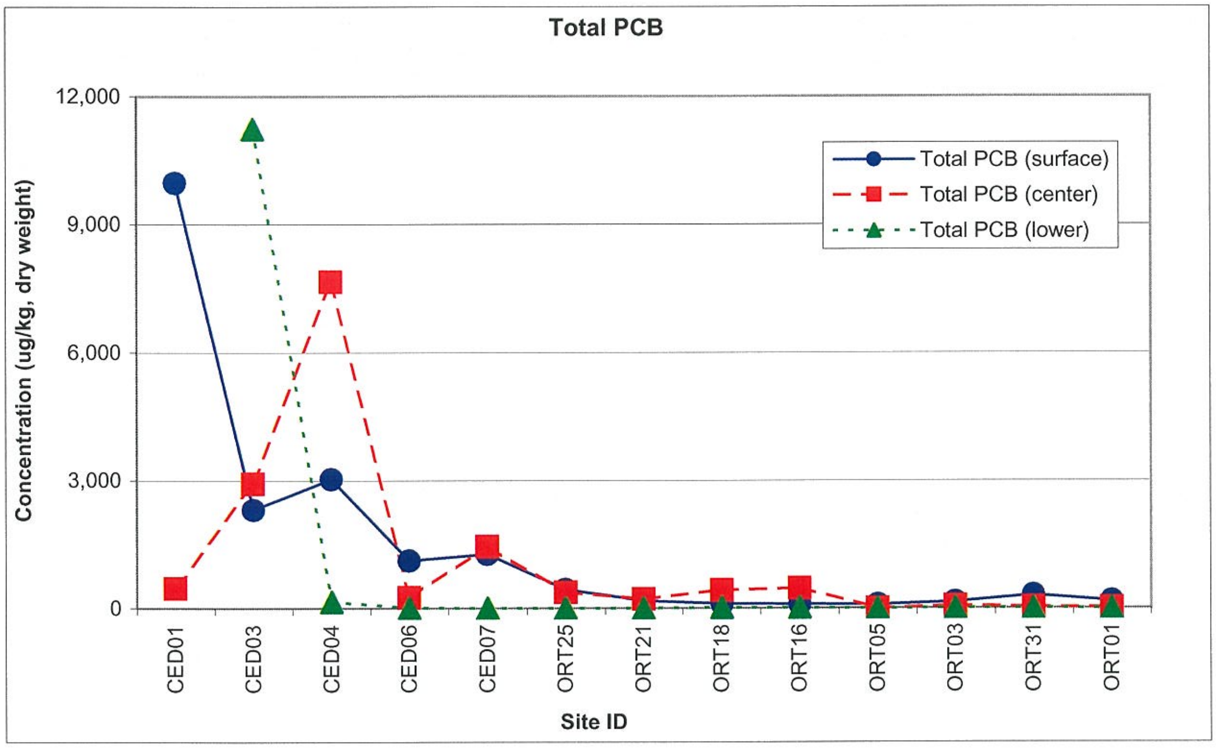


Figure 4-8. Total PCB Concentrations at Different Sediment Depths at Selected Sites

congeners are also reported, in Appendix D. Samples that were not re-analyzed using the detailed PCB congener method had their total PCB content determined using the data from the Method 8081M analysis, by applying a multiplication factor (2.4) to the sum of the concentrations of the 23 PCB congeners that were common to both the GC/ECD and GC/MS analyses, as described in Section 3.1.2. The total PCB concentrations for all surface and sub-surface samples are presented in Table 3-7. These are the PCB data that were used for any total PCB sediment reference value comparisons.

The general PCB contaminant distribution within the Cedar-Ortega River Basin was confirmed with the high reliability detailed congener work and total PCB determinations (Table 3-7 and Figure 4-7), and subtle differences in PCB congener composition and transformation could be determined using the detailed congener data (Appendix D). The Cedar River clearly had the highest PCB concentrations, and the concentrations increased the further upstream the samples were collected; the most upstream sample (collected at site CED12) had the highest PCB concentration, suggesting that there may be even higher PCB concentrations, and a significant source of PCB, upstream of CED12.

The sediment PCB concentrations typically decreased with sediment depth (Figures 4-8, 4-9, and 4-10). Please note that the plots in Figure 4-9 are each based on three data points; the dashed line does not represent actual measured concentrations. For instance, it is unknown what the PCB concentration is between 20cm depth and 80cm depth at site CED04; it may actually be higher at a depth of 25cm or 30cm than it is in the sample that represents 20cm. However, the data suggest that, in general, the sediments that were deposited in recent earlier times appear to have higher PCB concentrations than the surface sediments. Since there are differences in the depths from which the samples were collected, and sediment age information is not available, it is difficult to directly compare sub-surface sediment data between the different sites. Nonetheless, it appears that sediments in the middle segment of the Cedar River (e.g., sites CED03, CED04, CED07, and CED09) may have a higher PCB concentration at depths of 15-30cm than at the surface. The subsurface samples from CED01 and CED06 had lower PCB concentrations than the surface sediments, but the middle-segment samples from those cores were from a greater depth (both were from 41cm), and may not be comparable to the ~20cm deep data for the other locations. Although they were lower in overall PCB concentration, the subsurface sediments from the lower parts of the basin (past the confluence of the Cedar and Ortega rivers) followed similar concentration patterns, with higher concentrations in the middle segment sample (from 15-30cm) than in the surface sediment (e.g., ORT10, ORT13, ORT21, ORT27, and ORT35). These data suggest that there may have been higher PCB loadings at the time when the sediments at 15-30cm depth were deposited in the Cedar-Ortega River Basin than today's loadings. However, the sediment deposition characteristics, including the sediment transport/deposition mechanisms, historical storm and other major sediment turbation events, and generally the age of the sediments at different depths, is not available, so the historical PCB loadings cannot be fully interpreted.

The elevated concentrations of PCB in the surface and near-surface sediments indicate that there for some time has been, and there continues to be, significant sources of PCB contaminating the sediments of the Cedar-Ortega River Basin. Although the PCB concentrations increase significantly upstream in the Cedar River, there are clearly highly contaminated sediments throughout the Cedar River (Figure 4-10). The more contaminated sediments in the lower part of the basin appear to be depositing along the northern side of the Ortega River.

COR Concentrations Compared to Other Studies

The PCB concentrations were, generally, much higher in the Cedar-Ortega River than in the main stem of the lower St. Johns River. Only 3 of the 77 LSJR sites had a surface sediment PCB concentration higher than the median concentration for the COR sites. The sum of the base target PCB congener concentrations was below 50 µg/kg for only five of the 49 widely analyzed COR surface sediment sites (Table 3-6), between 50 and 250 µg/kg for 33 sites, and above 250 µg/kg for 12 of the sites.

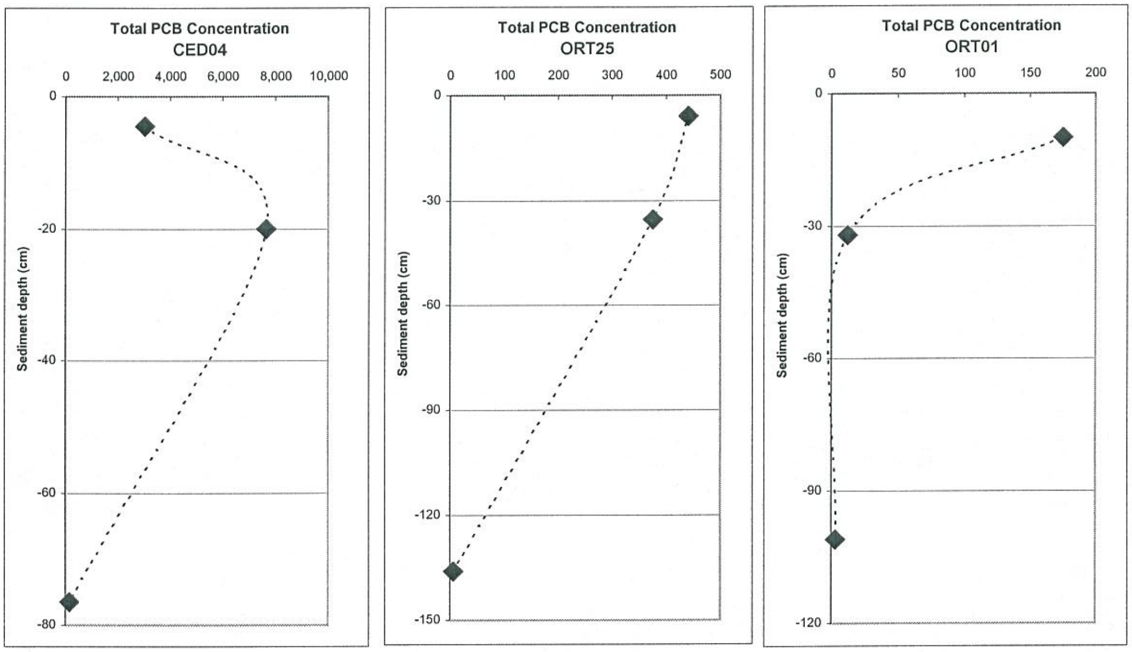


Figure 4-9. PCB Concentration Profiles in Sediment Cores Collected at Sites CED04, ORT25, and ORT01

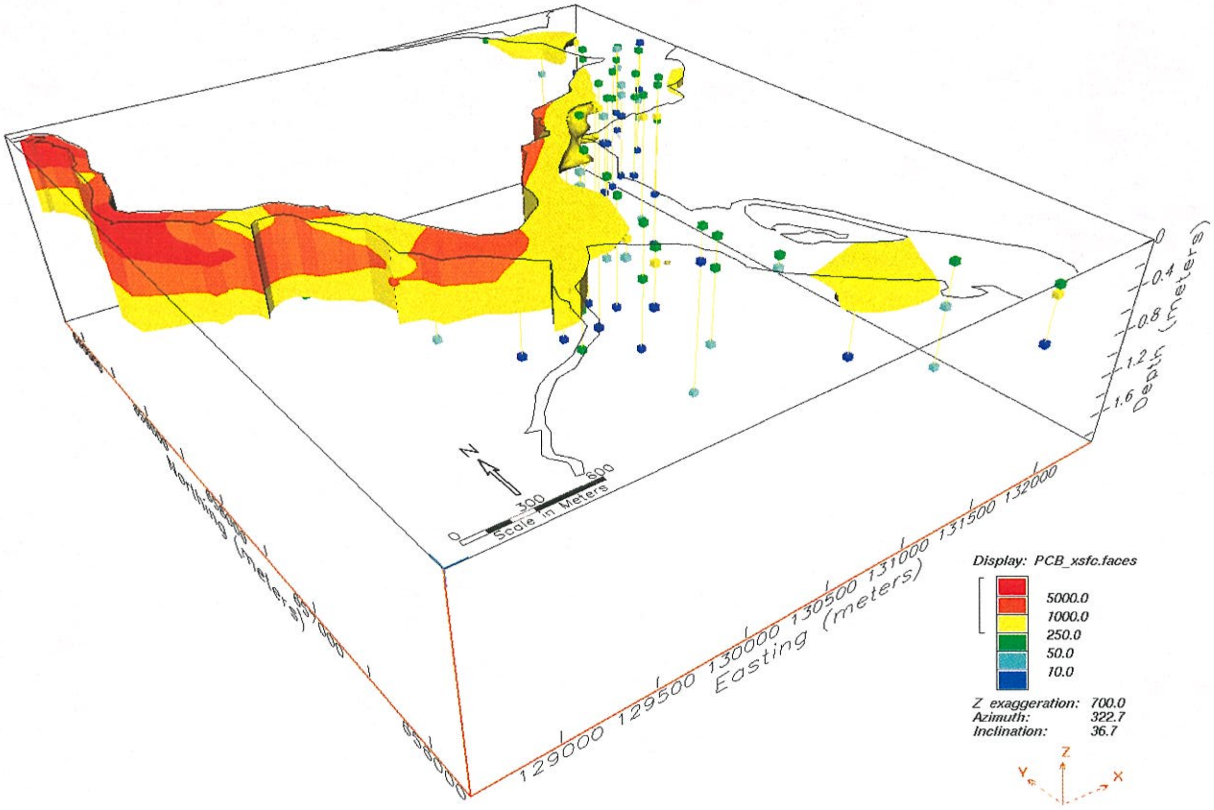


Figure 4-10. 3-D Visualization of Sediment Total PCB Concentration Estimated to be Above 250 µg/kg in the Cedar-Ortega River Basin

These data can be compared with concentrations from 66 to 233 µg/kg for three Boston Harbor/Massachusetts Bay sediment 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) — two programs that used the same base PCB congener analytes for the analysis. A total of 47 (90%) of the 52 Cedar-Ortega River surface sediment PCB samples had total PCB concentrations (Table 3-7) higher than the NOAA "high" concentration of 80 µg/kg (Table 4-2); 15% of the NS&T and 15% of all COSED sites exceeded this reference value. The PCB concentrations appear to, like the PAH concentrations, be significantly higher in the Cedar-Ortega River Basin than can be expected in a typical cross-section of the country.

Pesticides - DDTs

COR Concentrations Measured in this Study

The concentrations of DDT, and its degradation products DDD and DDE, are listed in Table 3-6, along with the total concentration as the sum of these DDT compounds. The chlorinated pesticide concentrations had a somewhat different geographic distribution than the more urban and industrial-linked PAH, phthalate, and PCB compounds. In addition, the contaminant pattern varied somewhat from pesticide to pesticide compound. The DDT concentrations were highest in the Cedar River (e.g., sites CED01, CED02, CED03), and there was a clear trend of gradually decreasing DDT concentrations down the Cedar River (Figure 4-11, and Appendices C and I). Elevated concentrations were also measured in the Fishweir Creek area (e.g., sites ORT31 and ORT33). A total of 16 of the 49 COR sites had surface sediment concentration of the sum of the DDT class of compounds higher than 20 µg/kg (only two of the 77 LSJR sites exceeded this concentration), and the highest concentration was just above 80 µg/kg (CED01). Sites CED01 and ORT33 were the two sites with the most significantly elevated surface sediment DDT concentrations, compared to the rest of the sites, and the concentrations decreased notably away from these location.

The sediment DDT concentrations typically decreased with sediment depth, and the deep sediments consistently had lower concentrations than the surface sediments. However, the DDT concentrations in the near-surface sediments (e.g, less than 30cm depth) were comparable to, and in many cases higher than, the surface sediment DDT concentrations, much like was observed for PCB (Table 3-6). The total DDT concentrations were generally below 10 µg/kg in sediments collected at a depth of 50-100cm, or deeper, except at the most contaminated areas (e.g., CED04). These data suggest that, like for PCB, there may have been higher DDT loadings at the time when the sediments at 15-30cm depth were deposited in the Cedar-Ortega River Basin than today's loadings. However, the sediment deposition characteristics and age of the sediments at different depths was not available, so the historical DDT loadings were not fully interpreted.

COR Concentrations Compared to Other Studies

The median total DDT concentration for the COR sites was about a factor of 3 higher than for the LSJR samples, again demonstrating that the Cedar-Ortega River Basin sites were generally more contaminated than the LSJR main stem sites. However, the DDT concentrations at the COR sites were generally comparable to, or slightly higher than, what has been observed in many national monitoring programs. For example, 25% of the COR surface sediment samples had DDT concentrations that exceeded the NS&T/MW "high" value of 22 µg/kg (Table 4-2), while only 18% of the NS&T/MW and 23% of the COSED sites exceeded this value. The DDT compound concentrations measured in the COR surface sediment were also comparable to the 24 to 58 µg/kg measured at three NOAA Massachusetts surface sediment sites located near urban areas; concentrations were 1 to 9 µg/kg for the more rural Massachusetts NOAA sites (Battelle, 1990, 1991b, 1992).

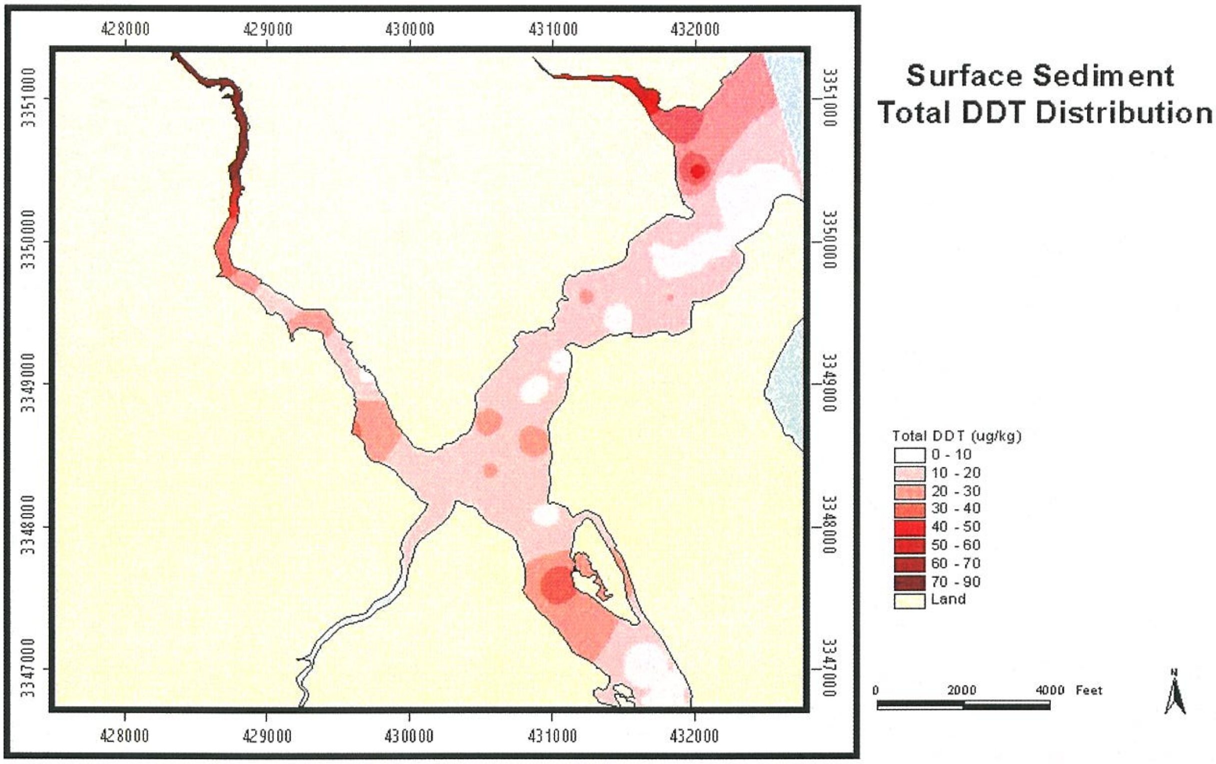


Figure 4-11. Extrapolated Surface Sediment Total DDT Concentrations

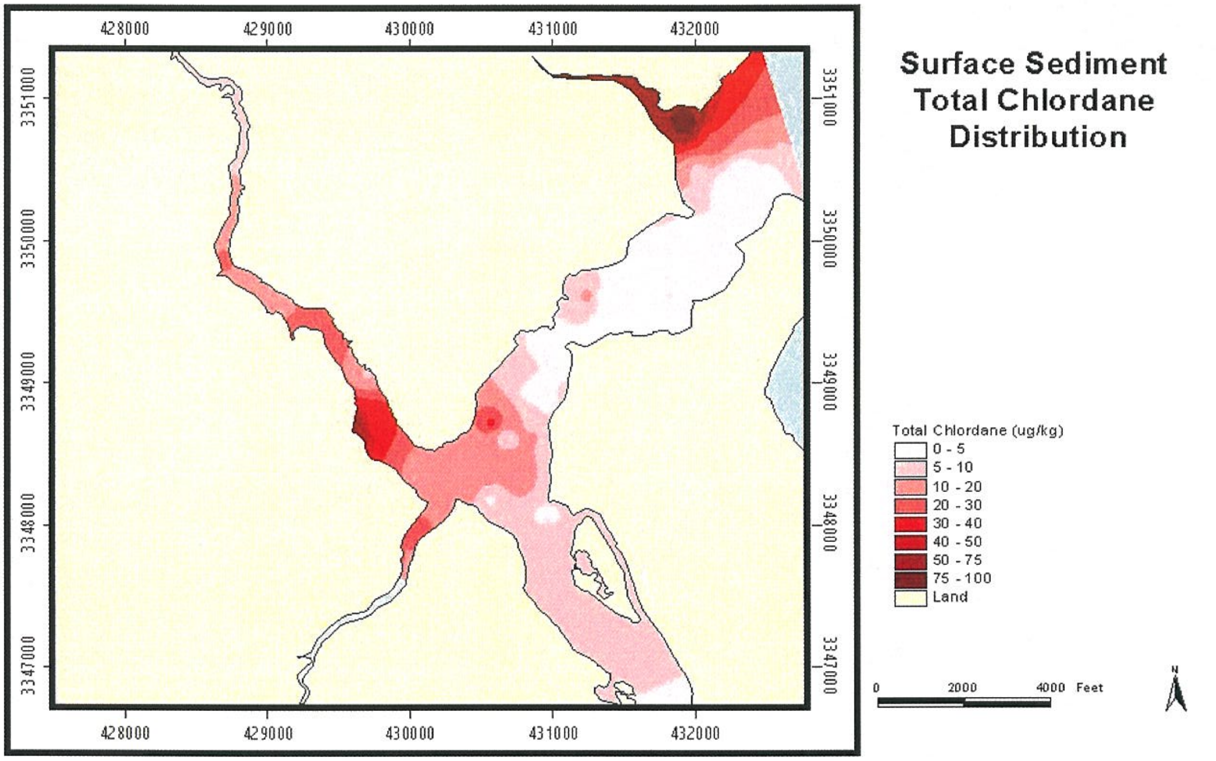


Figure 4-12. Extrapolated Surface Sediment Total Chlordane Concentrations

Pesticides – Other Chlorinated Pesticides

The chlordane concentrations were, generally, a little lower than the DDT concentrations, but they were significantly higher in the COR than in the near-by LSJR. The median chlordane concentration was more than 10 times higher in the COR than in the LSJR, and the highest chlordane concentration measured in the COR (85.4 µg/kg at ORT31) was 20 times higher than the highest concentration measured in the St. Johns River. The chlordane concentration was elevated at several of the sites that also had elevated DDT (sites ORT31 and ORT33, and some Cedar River sites), but the contaminant distribution was more similar to what was observed for PAH. High chlordane concentrations were measured at ORT33 and nearby (e.g., ORT31), at CED09, and, though slightly lower, up the Cedar River (Figure 4-12). Like PAH, and unlike PCB and DDT, the chlordane concentrations were higher in the sediments from the lower part of the Cedar River (near CED09 and CED06) than in the upper part of the river. The chlordane concentrations at the COR sites were notably higher than what has typically been observed in national monitoring programs; 59% of the sites exceeded the NS&T/MW "high" value of 4.5 µg/kg (Table 4-2), while 14% of the NS&T/MW and 8% of all COSED sites exceeded this value.

Not only did the surface sediment chlordane and PAH concentrations have a similar distribution, but so did much of the sub-surface sediment. Some of the near-surface chlordane concentrations were higher than the surface sediment concentrations (e.g., at CED07, ORT10, ORT21, and ORT35), but, for the most part, there was a gradual decline in the chlordane concentrations with sediment depth. The chlordane compounds either have less persistence in the COR sediments than some other contaminants, or there has, in recent years, been an increase in the loading of this contaminant to the COR sediments. Although the use of chlordane was banned for most purposes in 1983 it was used to control termites until 1988, after which there was no approved use of chlordane in the US. However, because of the relatively slow degradation and low mobility of chlordane, high concentrations of this pesticide are still being measured in many urban environments where chlordane usage was high to control termites.

The BHC and endosulfan concentrations were lower than the chlordane and DDT concentrations, in both surface and sub-surface sediment. The BHC concentrations were similar to what they were in the St. Johns River; the surface sediment BHC concentration was between 2 and 6 µg/kg at 9 of the 49 sites (the highest was for site ORT23), with the rest having concentrations below 2 µg/kg. There was no distinct geographical pattern to the BHC concentrations. The endosulfan concentrations were higher than the BHC concentrations, and the concentrations at the COR sites were somewhat higher than at comparable LSJR locations. Elevated levels of endosulfan were measured in the upper parts of the Cedar River, and signals above the general area were also detected at sites CED09 and ORT25.

Chlorophenolic Compounds

The chlorophenolic compound concentrations varied greatly across the Cedar-Ortega River Basin, and it was difficult to distinguish a clear geographical pattern (Table 3-10 and Appendices E and I). Chlorophenolic compounds were only measured in surface sediment samples, and only in surface sediments from a few selected locations. The two Cedar River sites (CED03 and CED04) appeared to have elevated concentrations of some of the chlorophenolics, while the central basin sites seemed to have higher concentrations of other, related, compounds. The elevated concentrations were not always consistent across chlorophenolic compound classes (i.e., chlorinated phenols, anisoles, catechols, guiaiacols), and scattered sites across the study area had sporadic elevated chlorophenolic compound concentrations. Chlorinated phenols were detected at all locations; the presence of this broadly used (and highly mobile) class of compounds was wide spread. Anisoles and guaiacols were detected at about half of the sites, and catechols were detected at close to 90% of the sites. However, the lack of correlation between guaiacols and catechols detections was surprising, considering that these classes of compounds most often co-exist in areas that may experience environmental contamination from pulp and paper industry.

As discussed in Section 3.1.3, the analytical method that was developed for the chlorophenolic compound analysis in this project was intended to provide a first-level screening analysis of a broad range of compounds simultaneously, with the intent to identify locations and/or compounds that may warrant more detailed investigation. Battelle's quality assurance and quality control program results demonstrated adequate recoveries of these chlorophenolic compounds, and Battelle is confident in the reported results as intended screening level data. However, since the method accommodated chlorinated phenolic compounds with highly varying chemical characteristics, it could not be optimized for a specific class of compounds and there was a significant potential for matrix interference (i.e., non-analyte matrix contribution to measured target compounds, and false positives). The chlorophenolic data should therefore be used with caution, keeping in mind the intended use of these results.

4.1.3 Organic Compounds — Contaminant Composition

PAH

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, were also present at significantly lower concentrations. This predominance of high-molecular weight PAH was even more apparent in the Cedar-Ortega River than it was in the St. Johns River, and was very striking. The average relationship was about 14 times more HMW than LMW PAH in the COR surface sediment (Figure 4-13), as compared to an average ratio of 3:1 for the LSJR sites (Battelle, 2004). The pyrogenic PAH (HMW) constituted over 90% of the total PAH at many locations (Figure 4-14).

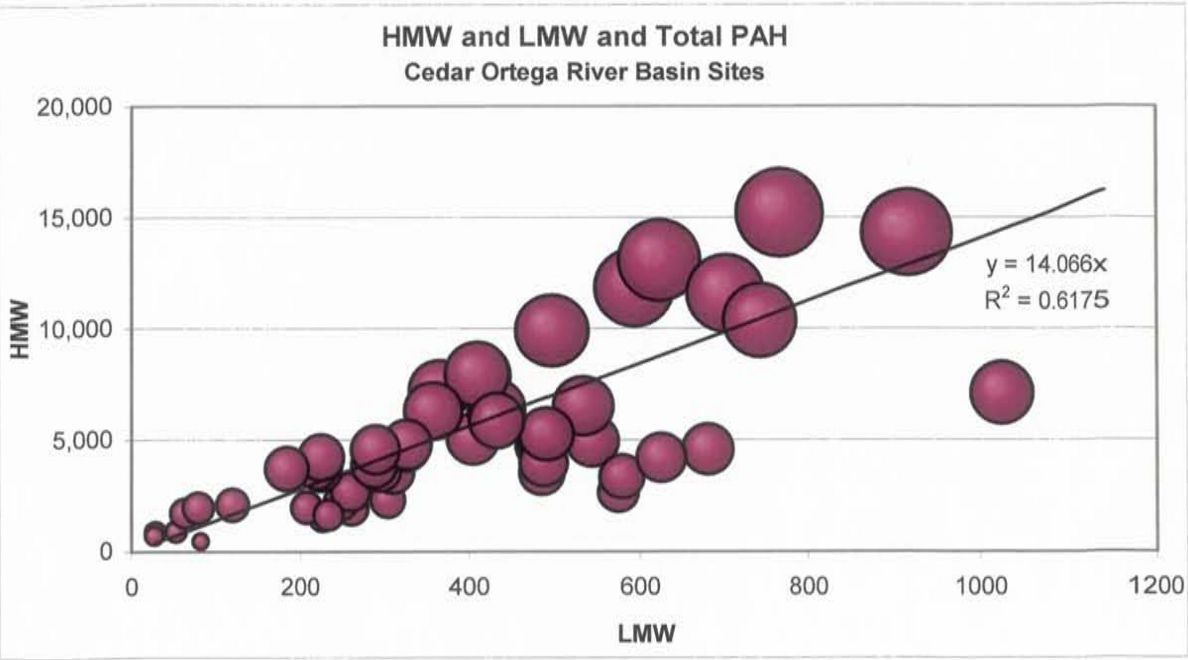


Figure 4-13. Relative Composition of High- and Low-Molecular Weight PAH and Total PAH Concentration in Surface Sediment Samples

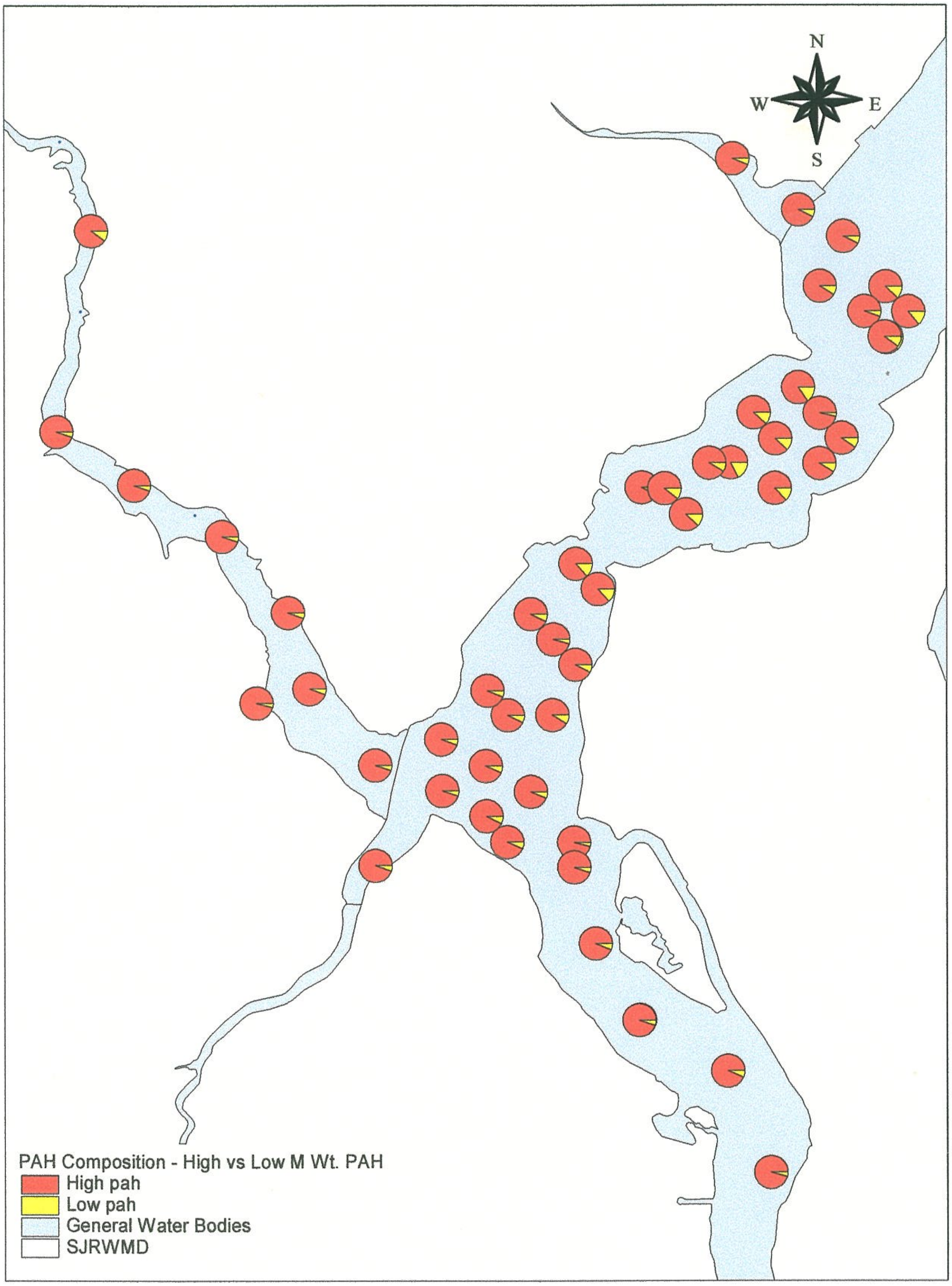


Figure 4-14. Map Displaying Relative Concentrations of Low- and High-Molecular Weight PAH in Surface Sediment Samples

The samples with the highest PAH concentrations also had the highest proportion of high molecular weight PAH. The PAH in the surface sediments at site CED09 (the sample with the highest PAH concentration), and the nearby CED06, were comprised of 96% HMW PAH (a high:low ratio of about 25:1). The highly contaminated sediments in Fishweir Creek also had more than 90% HMW PAH. The relatively consistent proportion of pyrogenic to petrogenic PAH in the surface sediment indicate a similarity in the sources, or types of sources, of the PAH contamination, at least for most of the locations. This signal of predominance of high-molecular weight PAH is particularly strong in the area where Butcher Pen Creek meets the Cedar River, and at the nearby sites, suggesting there is a significant input of a mostly HMW PAH in this area that may be the major source of PAH in the lower Cedar River and much of the lower part of the Cedar-Ortega River Basin. Site ORT19 is one location that had, proportionately, more LMW than other locations (a high:low PAH ratio of 7:1), suggesting there may be a local source of some PAH from a material with a different hydrocarbon composition (e.g., proportionality more LWM PAH, such as in oils, fuels, or other petrogenic materials).

Figure 4-15 shows the PAH composition of selected samples; the composition of the surface, middle, and lower section of four cores is presented (cores from CED03, CED04, CED27, and CED31). The PAH composition of selected reference samples and petroleum products are compiled in Appendix J. Most samples had a PAH composition similar to that of ORT31. The composition of CED03, CED04, and ORT27 is actually very similar to the composition of most other samples, except for the greater contributions of perylene. Perylene is sometimes a relatively significant PAH in, particularly, some of the lower concentration and high organic content samples. Perylene is not primarily derived from petrogenic or pyrogenic sources; most is formed through the natural decay of plant material in anoxic layers of the sediment, and perylene is not considered an important environmental contaminant. Therefore, considering the high organic content of these sediments, it is understandable that perylene present at substantial concentrations in these sediments, particularly in the deeper sediments where biogenic processes have had time to act on the natural organic matter and the conditions are anaerobic. However, the concentration of perylene is uncommonly high in many of these sediments (e.g., up to 3,000 µg/kg, or 30-40% of the total PAH, in sub-surface sediments from CED03 and CED04).
The PAH composition of most samples is somewhat different than what is most commonly observed for urban sediments. The PAH in most urban environment sediments are primarily derived from urban and street runoff, and atmospheric deposition, of combustion products (i.e., pyrogenic PAH). Uncombusted, or partially combusted, petroleum products and oils often also contribute to the PAH signature, but to a lesser degree. The PAH distribution of the NIST SRM 1941 sediment and soot (Appendix J) is a common urban signature, and considered to be a good representation of typical background PAH derived primarily from pyrogenic sources, including atmospheric deposition, stormwater runoff and other urban discharges. The unique HMW distribution in most of the COR sediment samples is characteristic of PAH inputs primarily from hydrocarbon materials containing predominantly HMWs (e.g., the type of PAH that are dominant in coal and coke tar, coal gasification tars, carbon black, creosote, and, to some degree, asphalt; Appendix J).

The PAH composition was not significantly different in the sub-surface sediments than in the surface sediments (Figure 4-15), except that the older sediments generally contained more perylene than the surface sediments, as discussed earlier. Some of the sub-surface samples had greater proportions of fluoranthene, pyrene, and mid-molecular weight PAH (e.g., sample CED03-Mid, but also some –Low samples), and therefore more of an appearance of traditional urban/industrial runoff and atmospheric deposition (i.e., more like the reference sample SRM1941). The PAH composition in the these sediments indicate that the Cedar-Ortega River Basin sediments have received PAH from fossil fuel combustion, and related urban and industrial activities, for a long time, and that the input has increased in recent history, consistent with the population growth and urban development of the general area.

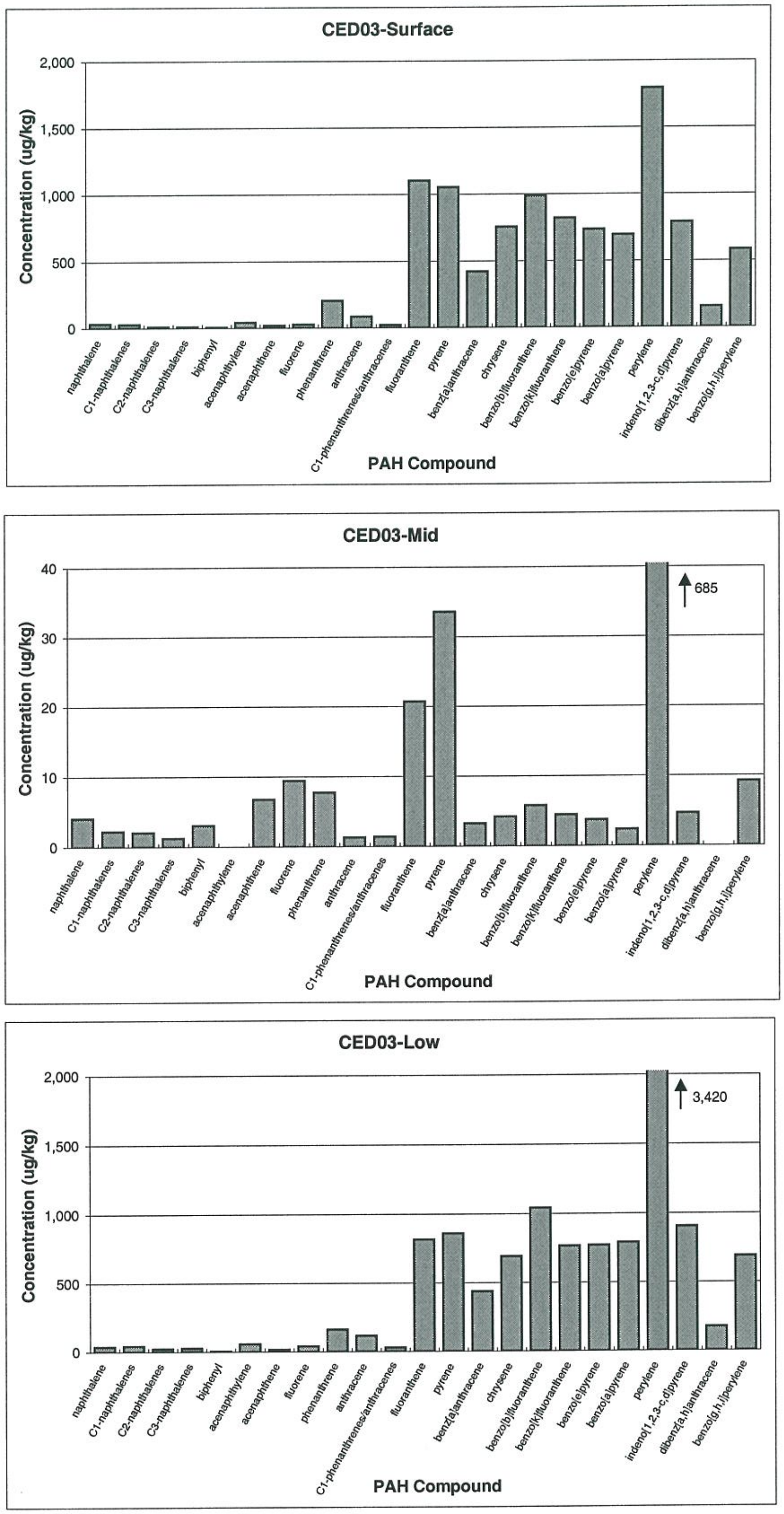


Figure 4-15. PAH Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27 and ORT31

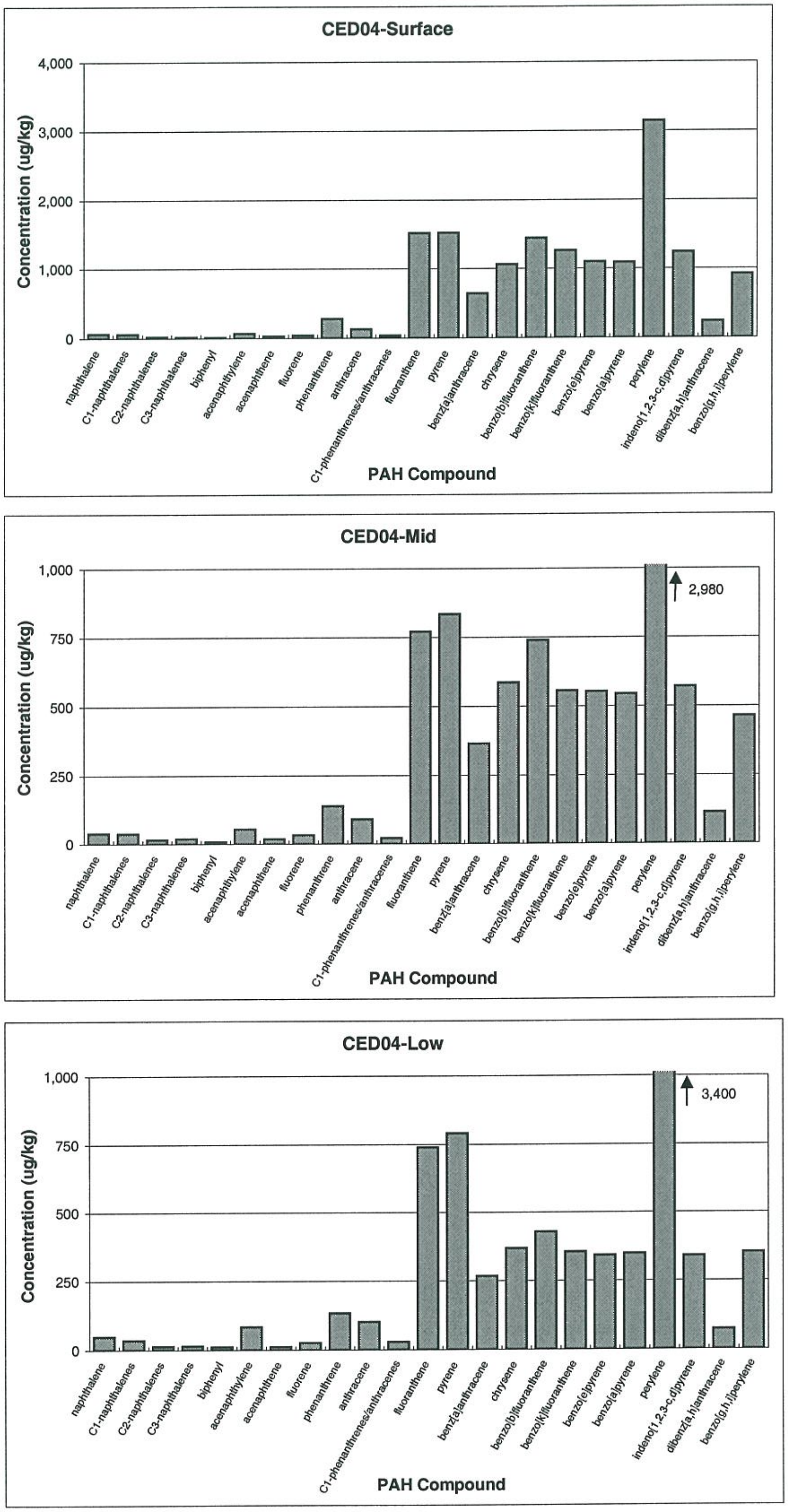
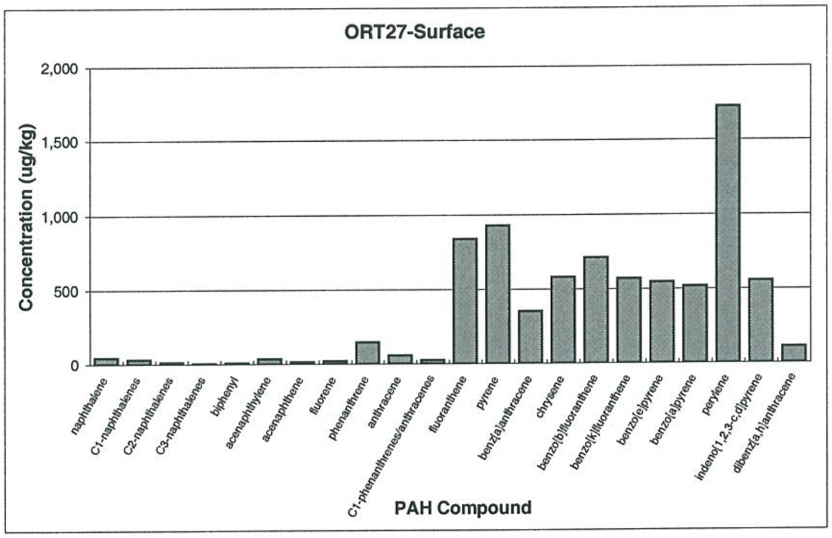
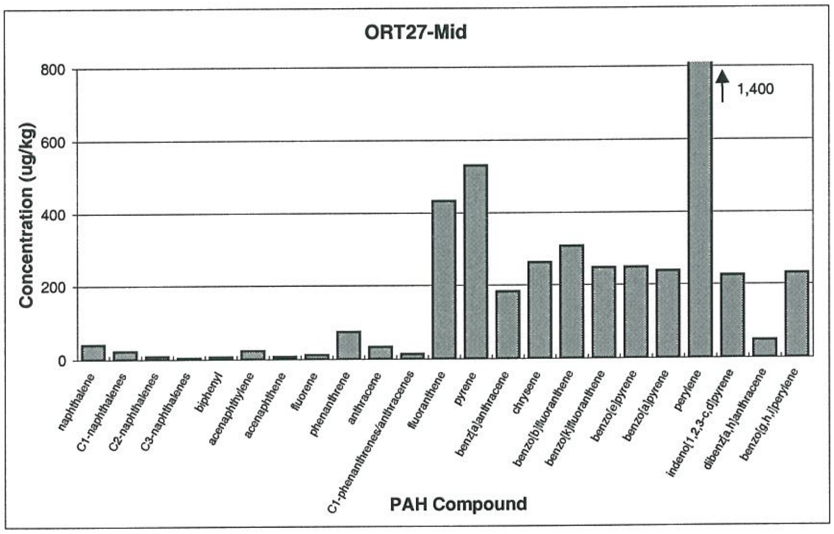


Figure 4-15 (cont.). PAH Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27 and ORT31





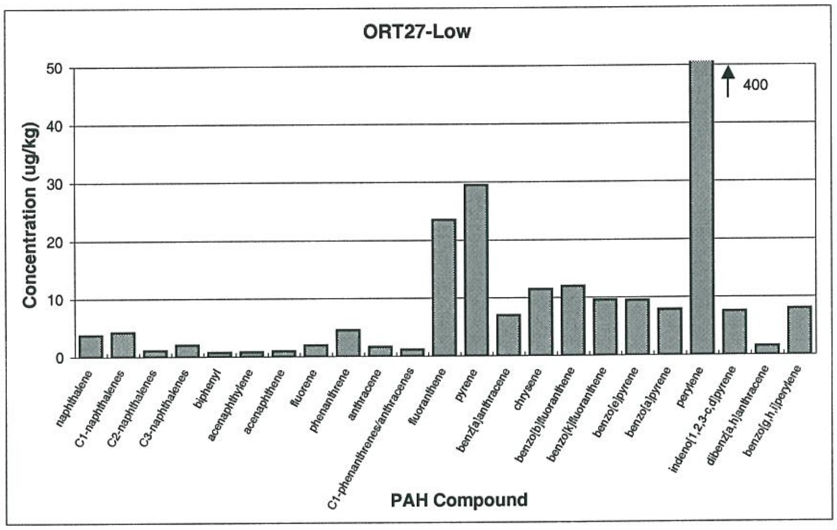
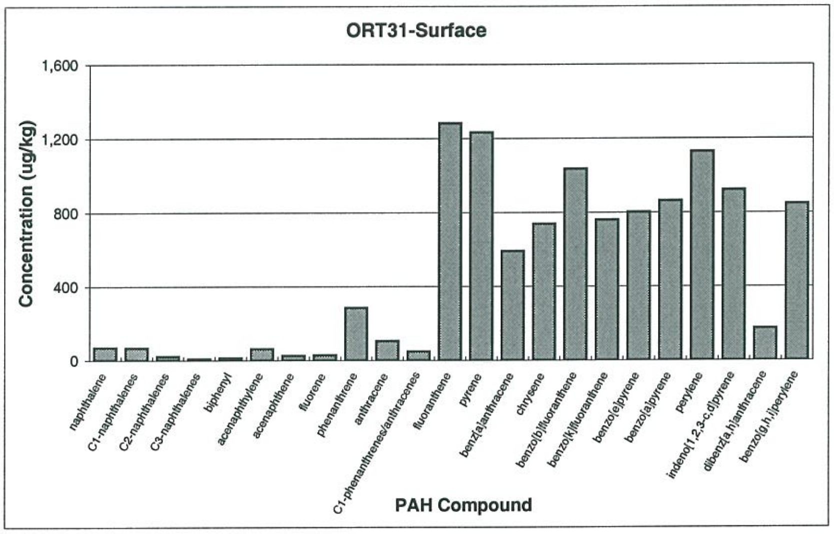
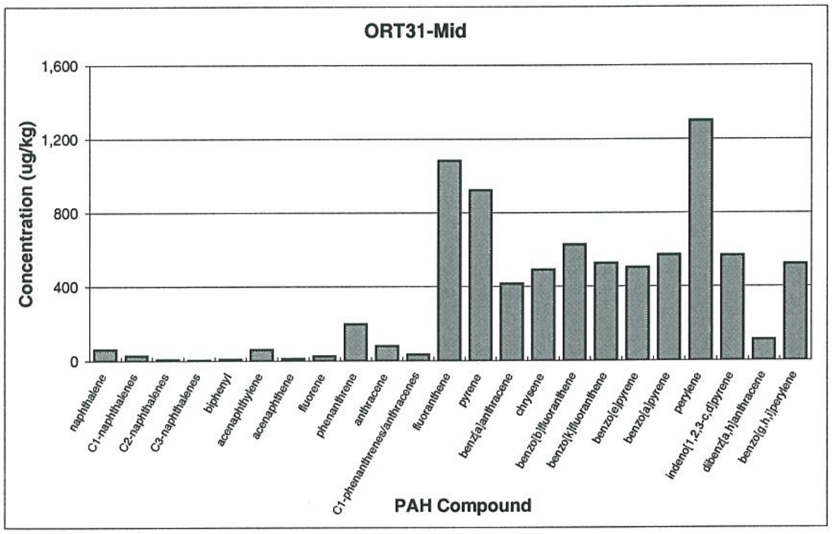


Figure 4-15 (cont.). PAH Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27 and ORT31


ORT31-Surface


ORT31-Mid

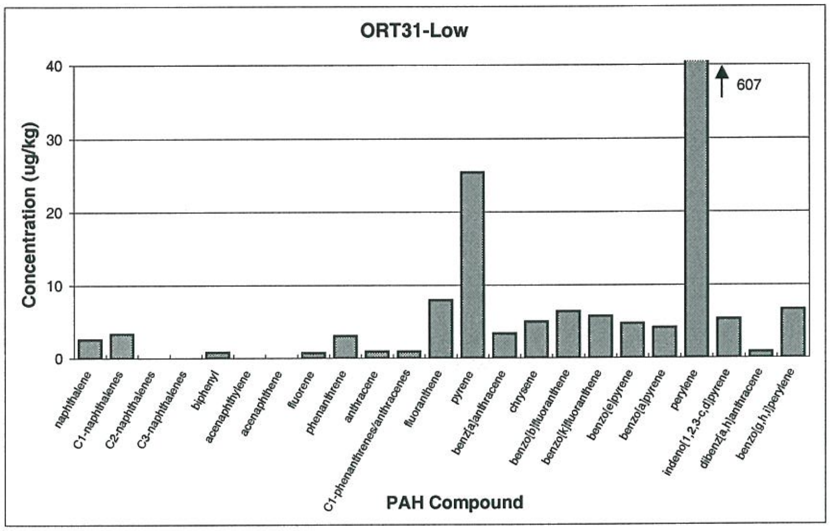

ORT31-Low

Figure 4-15 (cont.). PAH Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27 and ORT31

The surface and near-surface sediments had a slightly different PAH composition than most urban sediments. This could be because of relatively unique local fossil fuel combustion patterns (e.g., power generated from coal, gas, or petroleum that is different from many other places), or it could be because of major source of the PAH from local industrial activities. For instance, coal tar and gasification tar processing by-product (e.g., coal tar pitch), have a PAH composition that is similar to what was observed in much of the Cedar-Ortega River Basin. However, without a better understanding of the historical industrial and power generating activities in the area, it is difficult to link the contamination to an origin. This historical information, in combination with a more detailed study of the PAH composition of the sediments and potential source areas (e.g., Butcher Pen Creek and Fishweir Creek) and source materials, would further the understanding of the significant PAH contamination in this area.

The surface sediment PAH data were analyzed using an exploratory principal component analysis (PCA)[1] to further characterize the composition and contaminant similarity and dissimilarity in the area (Figure 4-16). The PCA exploratory technique is used to help recognize groups of samples that share similar PAH composition (i.e., similar *relative* PAH compound concentrations) and those that have clearly different composition. Prior to the PCA analysis the PAH compound data were normalized to the total concentration in each sample in order to eliminated influences caused by concentration alone. The goal of these analyses is to identify difference and similarities between samples based on PAH pattern recognition, and therefore other influential factors need to be removed. Normalized data for different potential source materials (those presented in Appendix J) were also included in the data set. The PAH compound composition (as depicted by the PCA analysis output in Figure 4-16) were different in the Cedar-Ortega River Basin than in the nearby lower St. Johns River, and also varied, to some degree, within the Cedar-Ortega River Basin, indicating the presence of local source(s).

The high concentration surface sediment samples from the middle and lower part of the Cedar River (i.e., near Butcher Pen Creek) clustered together and closer to coal tar pitch than other types of hydrocarbon materials. The other samples were slightly separated in the PCA analysis, appearing more like traditional urban/industrial runoff, such as represented by SRM1941 and soot. However, the PAH composition is not dramatically different within the Cedar-Ortega River Basin, and the differences that are observed may mainly be the result of selective adsorption/dissolution/deposition of PAH interacting with the water column and suspended particulates as they are transported down the river. For instance, the higher molecular weight PAH would tend to associate with particles more quickly and tightly than the lower molecular weight PAH, which could explain subtle compositional changes illustrated with the lower PCA plot in Figure 4-16; the sediments near a potential source at Butcher Pen Creek are enriched in the higher molecular weight PAH, while the further downstream samples have, relatively, somewhat less of the high molecular weight PAH.

PCB

The PCB composition was relatively uniform across the COR sites (Figure 4-17), and can be compared to those of the original PCB source material (Aroclor formulations; Appendix K). The samples that had significant concentrations of PCB had a PCB composition that was dominated by tetrachlorobiphenyl PCB congeners, followed by tri- and pentachlorobiphenyl congeners. This was a level of chlorination and molecular weight composition that most closely resembled that of a combination of mid-molecular weight Aroclor formulations (e.g., Aroclors 1248 and 1242), with some contribution of higher molecular weight material (e.g., Aroclor 1254).

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[1] Principal component analysis (PCA) analysis is a data exploratory and analysis tools designed to explore large data sets, focusing on the variability between samples. PCA produces graphical depictions of relationships between samples and variables (e.g., PAH compounds or PCB congeners) based on pattern recognition. These techniques were used to help recognize groups of samples that share similar contaminant composition (i.e., similar relative PAH and PCB compound concentrations) and those that have clearly different composition. Samples which visually "cluster" are chemically similar, and may have similar source(s) of the contamination.

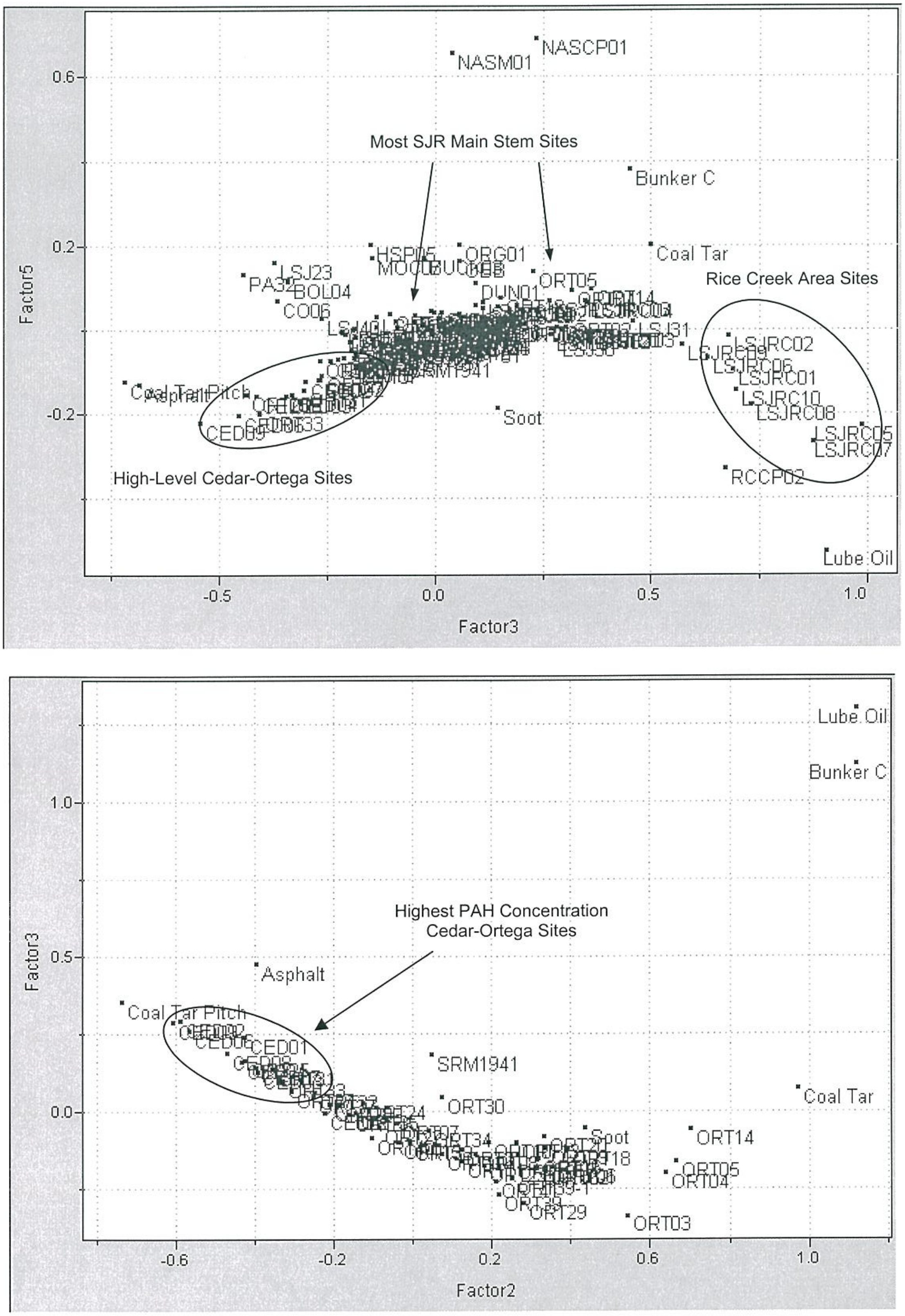


Figure 4-16. Principal Component Analysis (PCA) of Sediment PAH Data: Using Data for LSJR and COR Sites (top) and COR Sites Only (bottom)

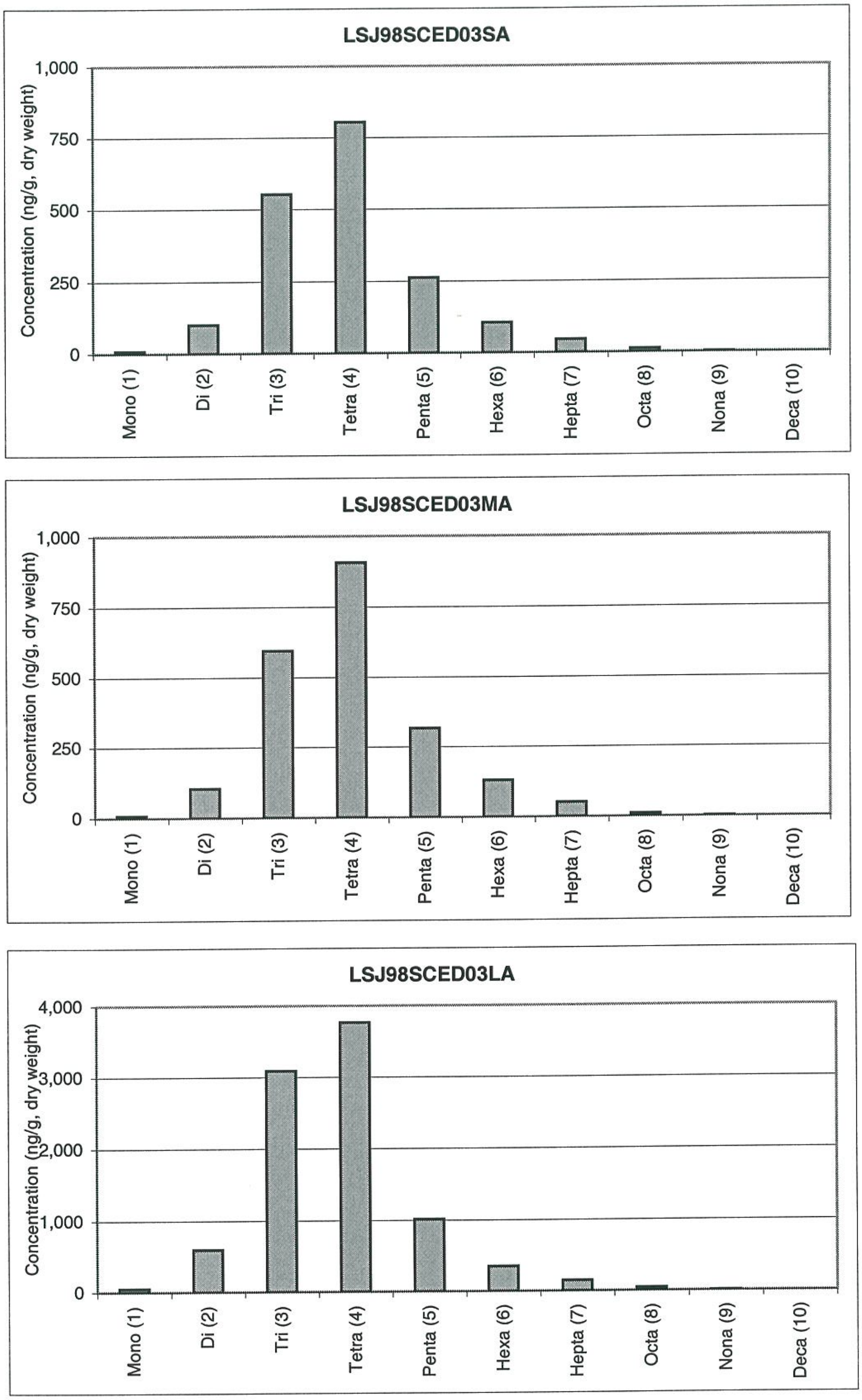
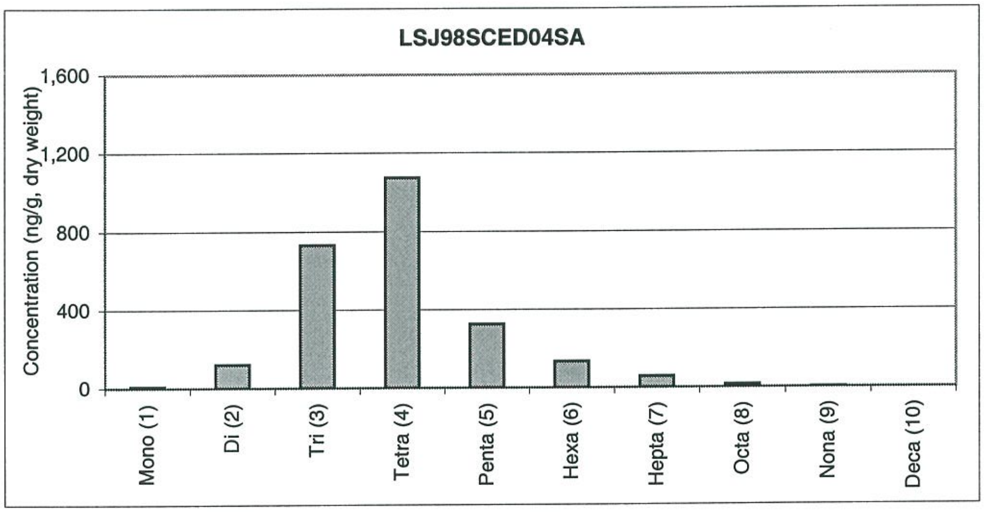
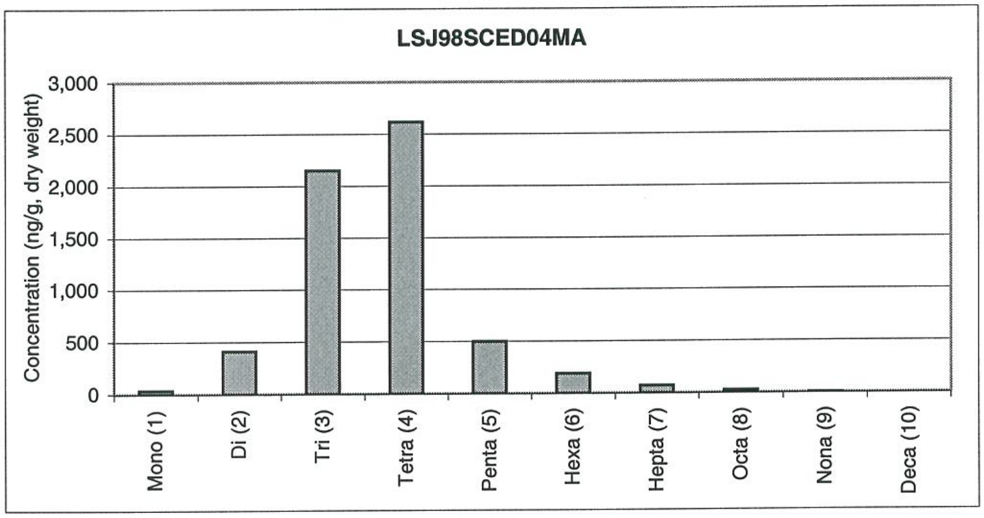


Figure 4-17. PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(a) PCB Homologue Composition





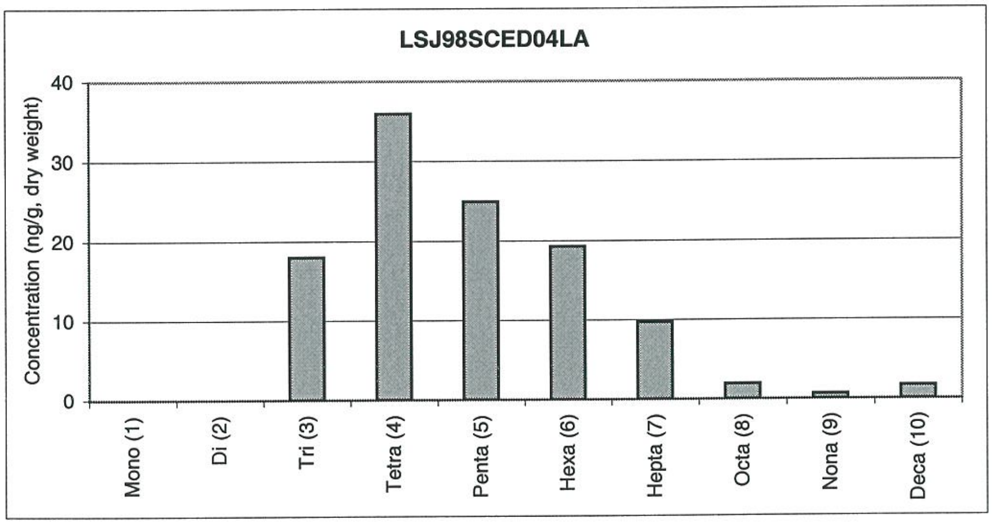
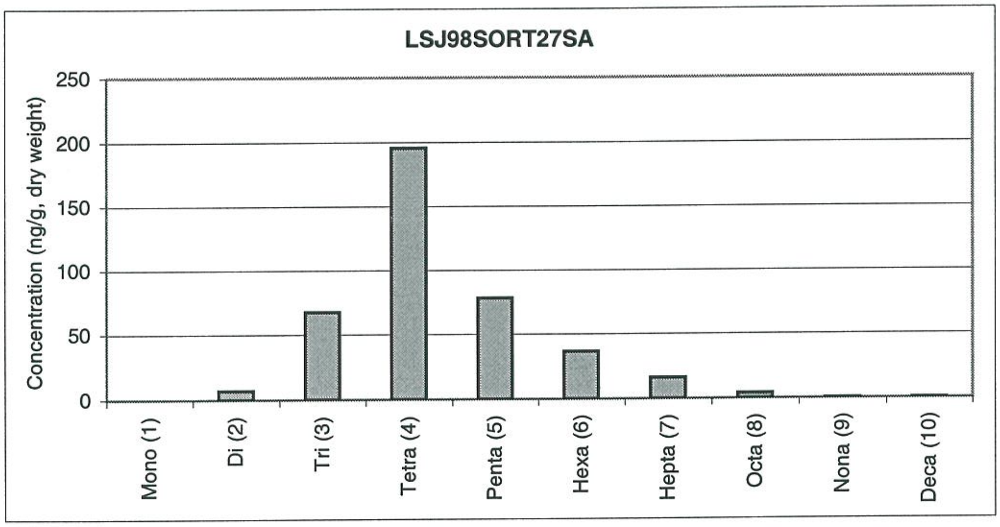
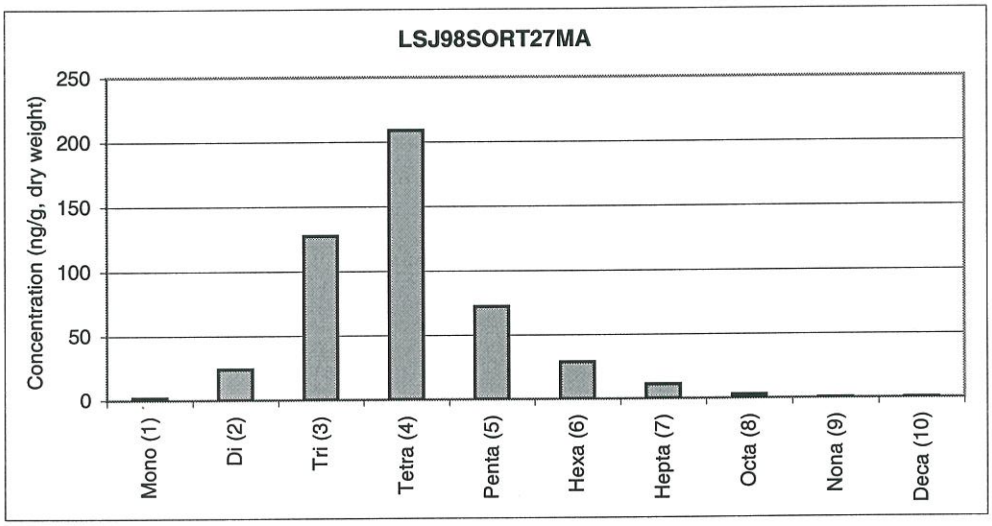


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(a) PCB Homologue Composition





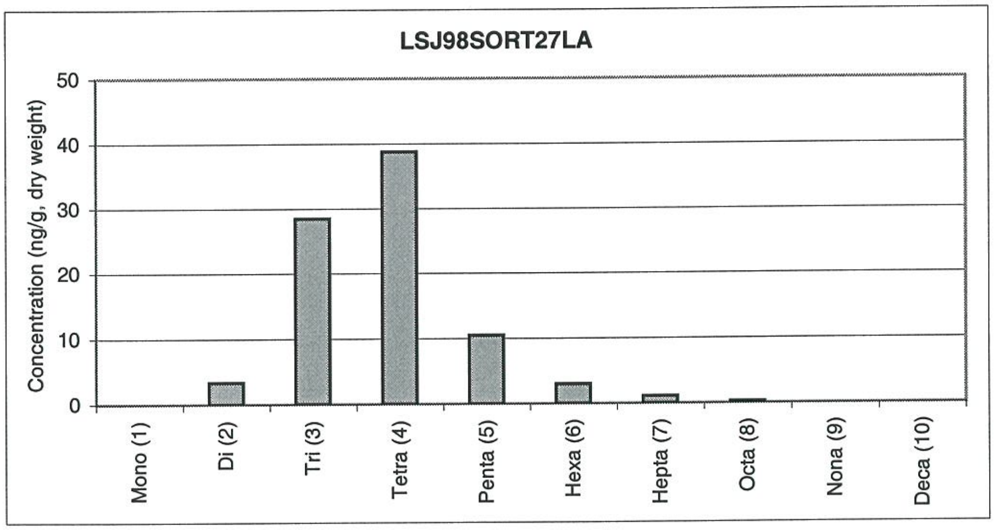


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(a) PCB Homologue Composition

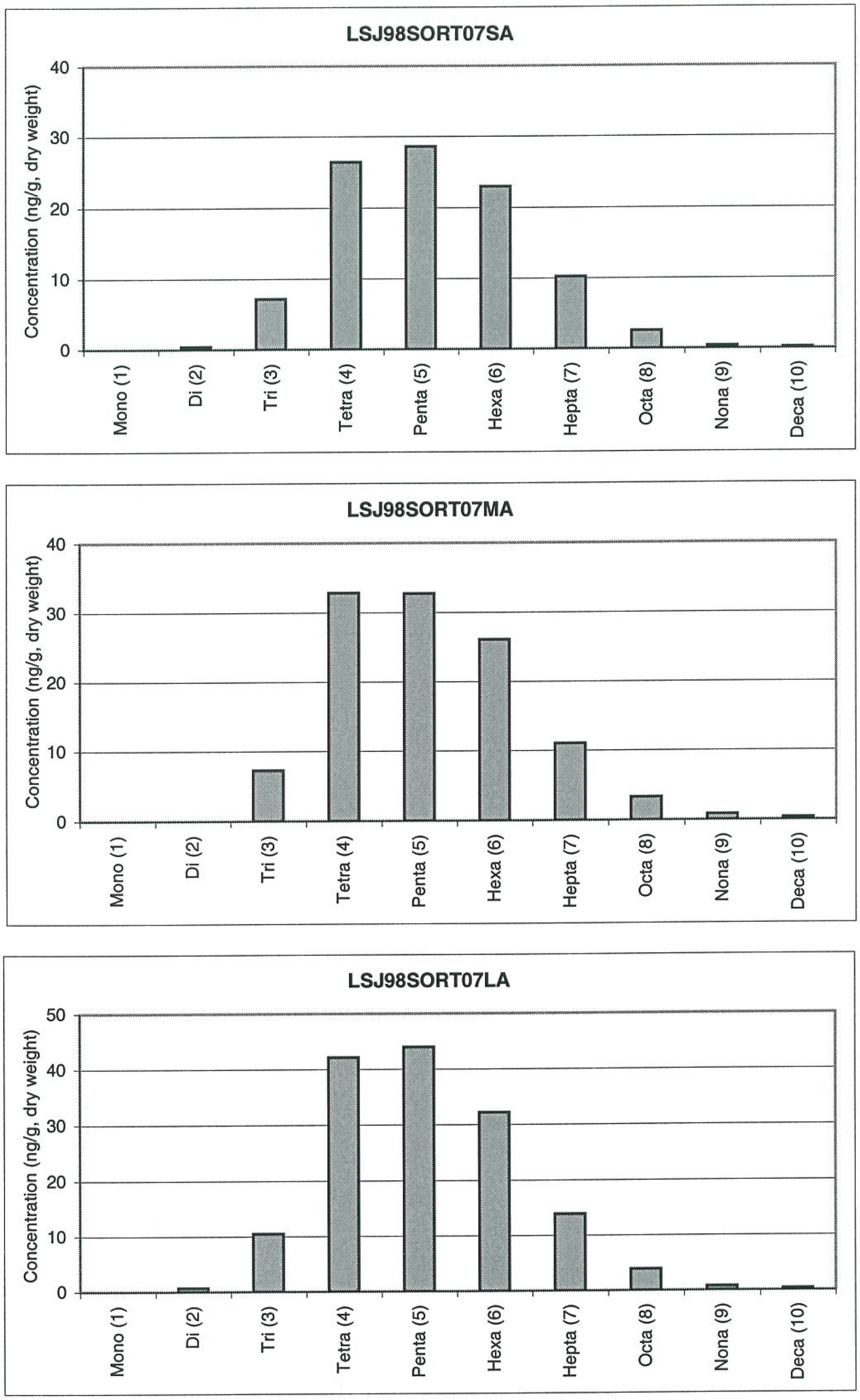


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(a) PCB Homologue Composition

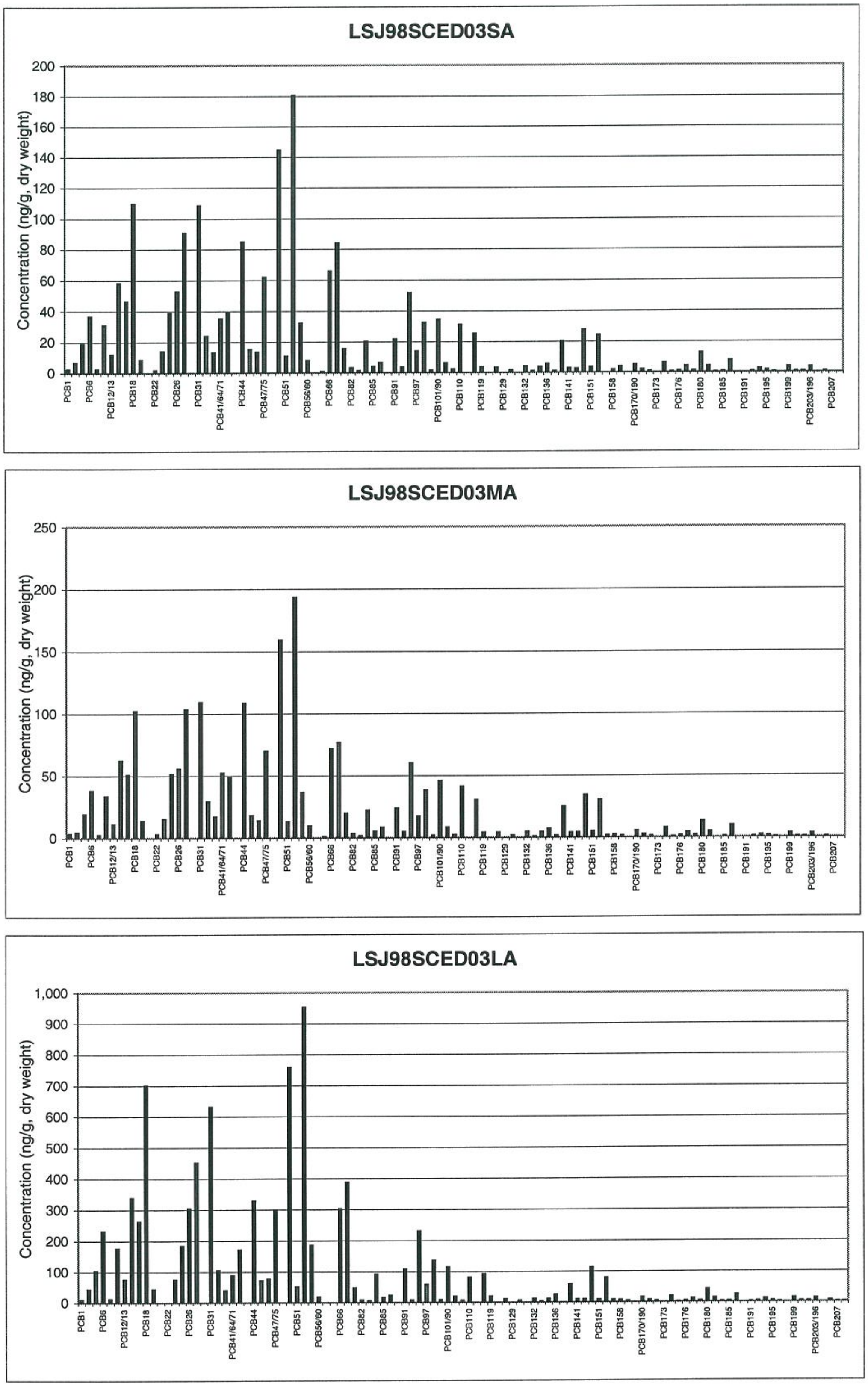


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(b) 107 PCB Congener Composition

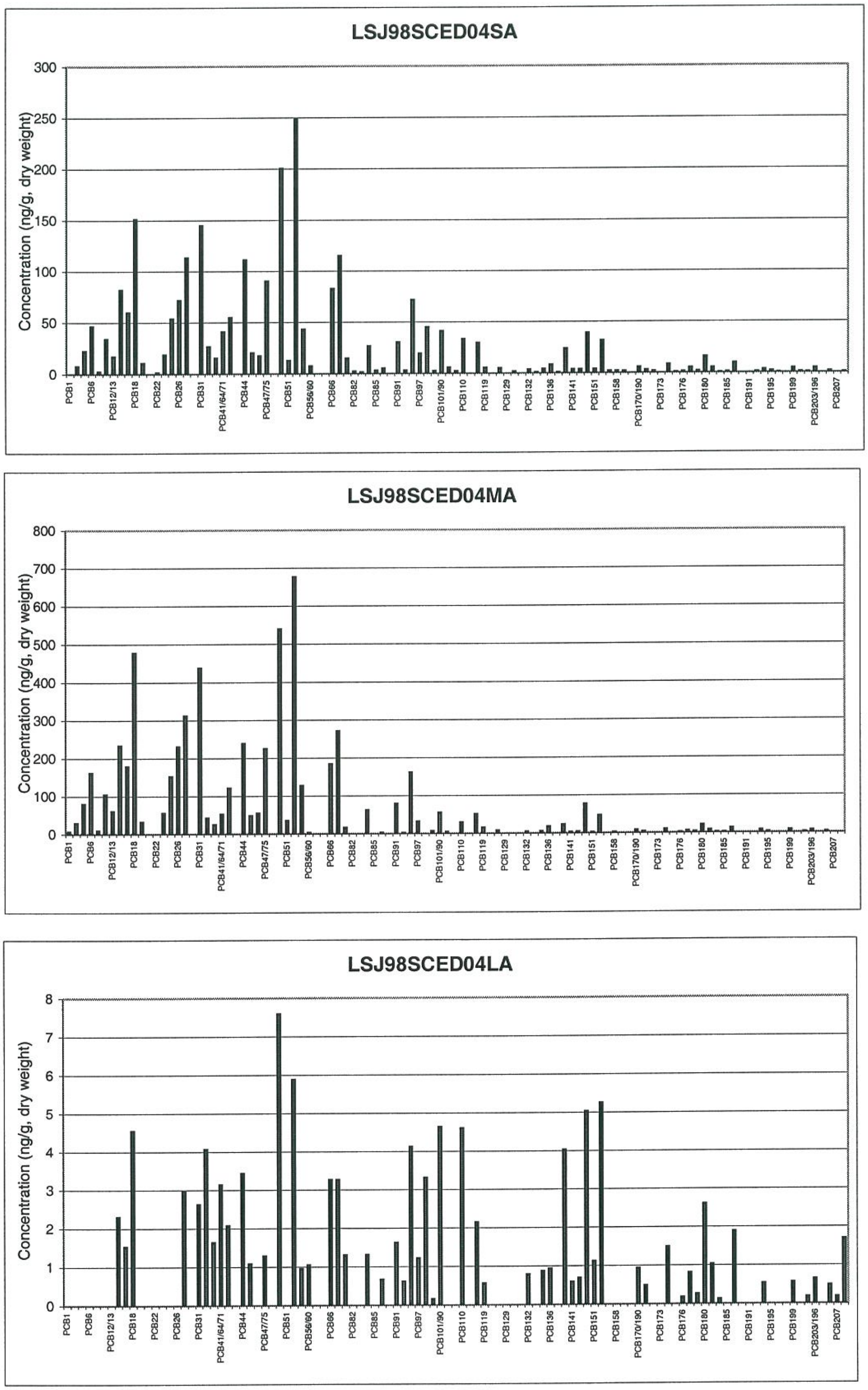


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(b) 107 PCB Congener Composition

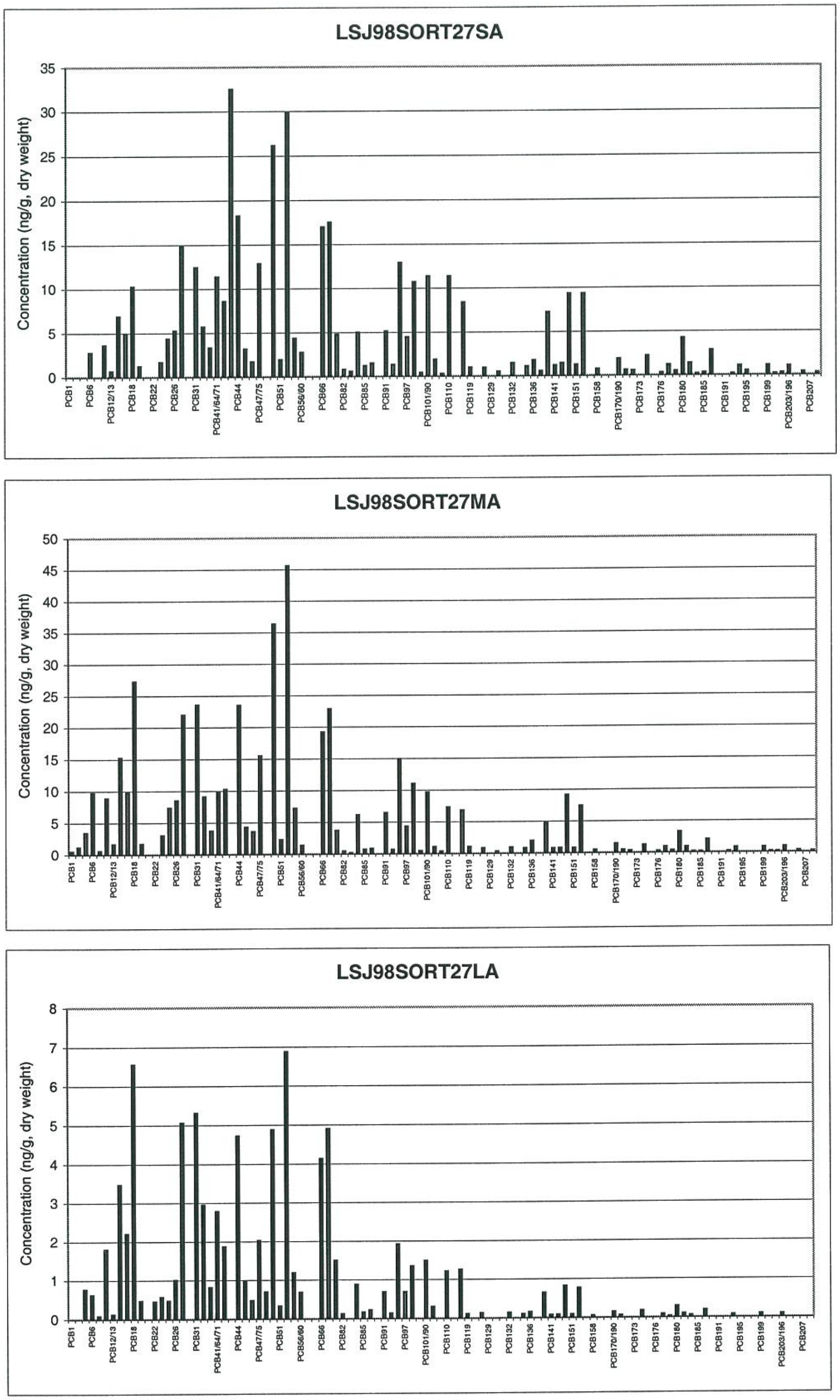


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(b) 107 PCB Congener Composition

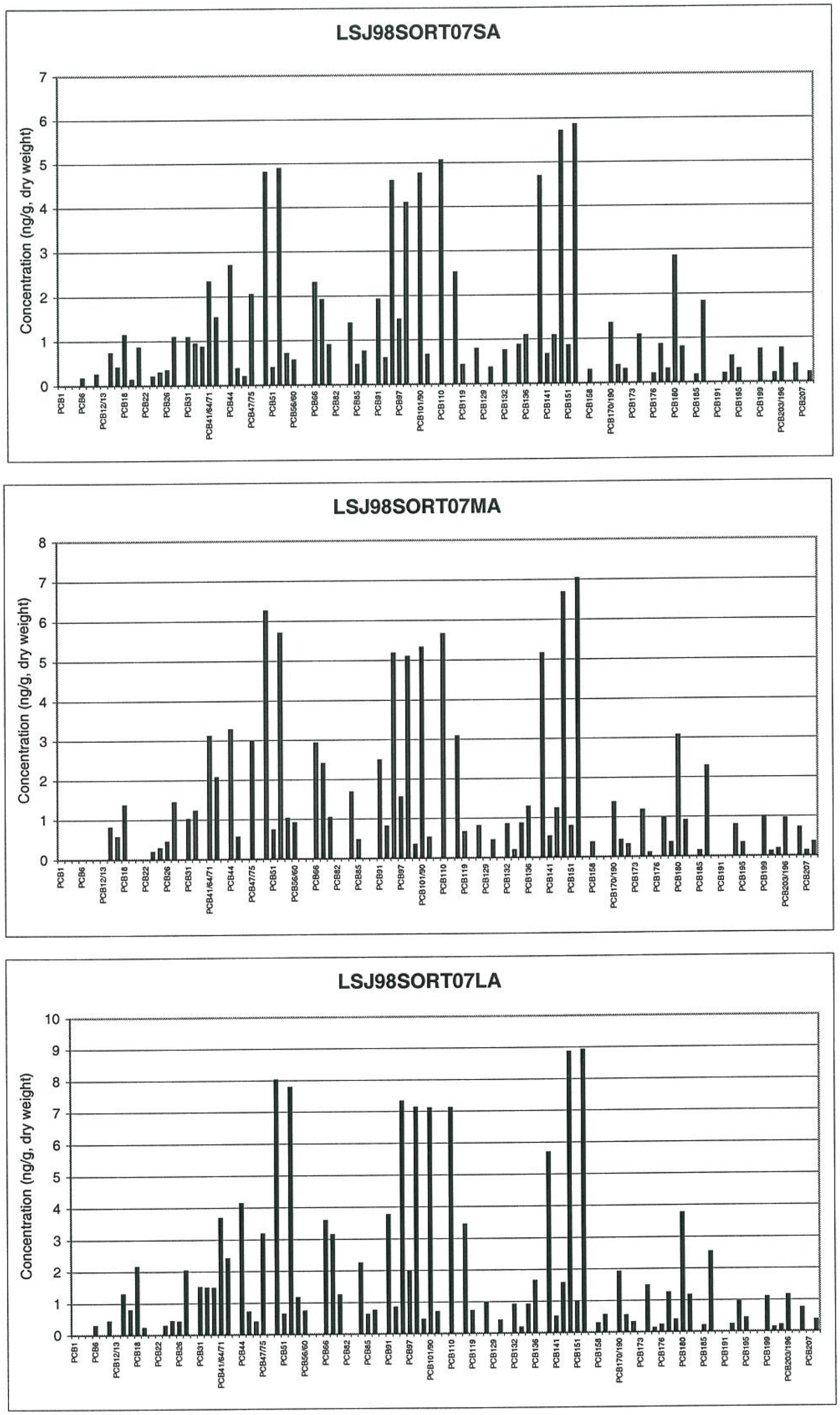
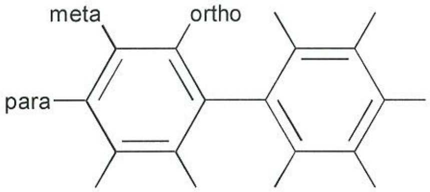


Figure 4-17 (cont.). PCB Composition of Surface and Sub-Surface Sediment Samples from Sites CED03, CED04, ORT27, and ORT07
(b) 107 PCB Congener Composition

A PCB congener is a biphenyl molecule with between one and ten chlorines in the ten available positions. There are four ortho-positions, four meta-positions, and two para-positions where there can be chlorines. Congeners with no chlorines in the ortho position are called non-ortho, or coplanar, PCBs and are the most toxicologically and environmentally important PCB congeners because of their potential to cause adverse effects. This results in a total of 209 possible PCB congeners, but most Aroclor formulations only contain 50-60 congeners (there are different combinations of congeners for different Aroclors), and only a little over 100 congeners are commonly found in the environment. Although the total PCB concentration declined rapidly going down the Cedar River, traditional anaerobic microbial degradation of the PCB was not readily observed in these sediments. Anaerobic microbial dechlorination of PCBs is one of the most important environmental processes for dechlorinating/degrading PCBs in the environment. The meta and para position chlorines are most readily removed during this process, and there tends to become a build-up of ortho-substituted congeners. PCB congeners PCB4 and PCB19 have all their chlorines in the ortho position, and if there is significant microbial dechlorination these congeners generally increase in relative concentration. PCB congeners PCB44 and PCB118 are congeners that are present at high concentrations in Aroclors 1242, 1248, and 1254 and have chlorines in the meta and para positions that are readily removed during microbial dechlorination processes; these congeners therefore tend to decline in concentration relative to the rest of the PCB if there is a significant amount of anaerobic dechlorination occurring. These dechlorination processes were not observed in the surface or subsurface sediments in the Cedar-Ortega River Basin; the relative concentrations of PCB4, PCB19, PCB44, and PCB118 remained highly constant in these sediments (Figure 4-18) and the overall PCB compositional pattern was not altered notably over time (i.e., with depth; Figure 4-17).



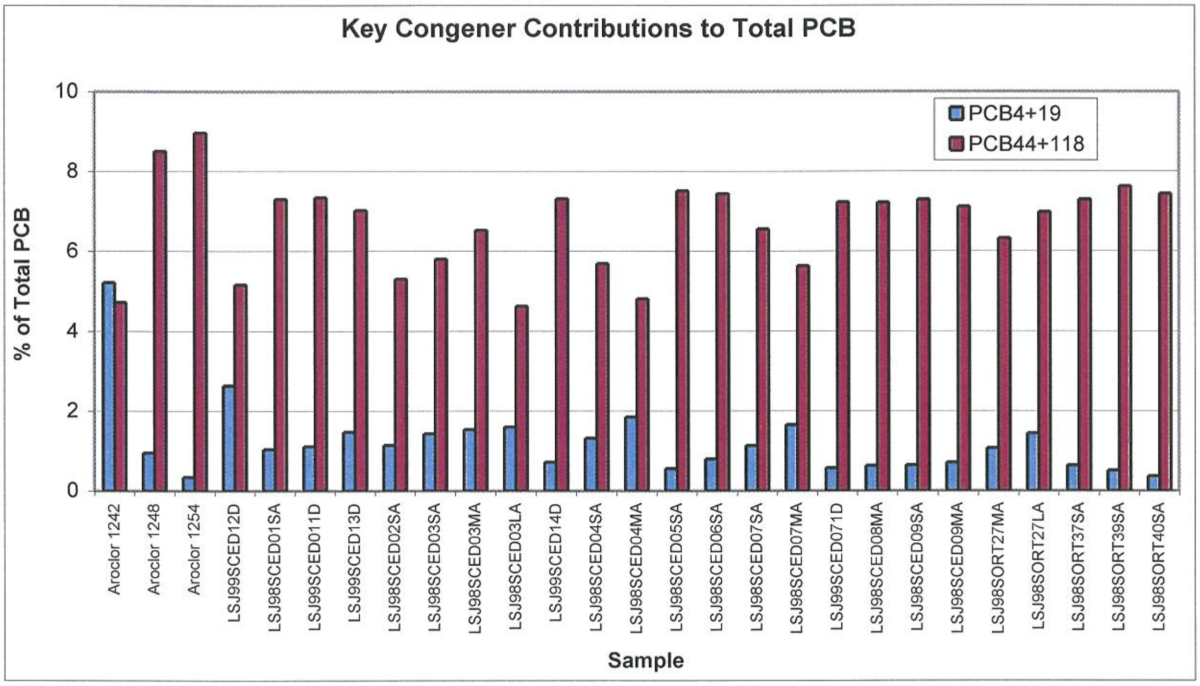


Figure 4-18. PCB Congeners 4+19 and PCB Congeners 44+118 Contributions to the Total PCB Concentration in Surface and Sub-Surface Sediment Samples

A PCA analysis was also performed using the PCB data, with PCB Aroclor reference materials included in the data processing for comparison purposes. The PCB composition, and PCA plot, indicated that the PCB composition of the St. Johns River sediments were similar to what is commonly observed in US sediments that are not near a PCB point-source; a PCB composition that most closely resembles Aroclor 1254, with some higher contributions from more chlorinated Aroclors (e.g., Aroclor 1260) and some from less chlorinated Aroclors (e.g., Aroclors 1248 and/or 1242). Such PCB patterns are indicative of the Aroclor formulations that were most widely used in the U.S., and this is a fairly typical PCB composition for aquatic environments that have a number of potential sources of PCB or originate in a source where the most common Aroclors were used.

A few of the sediments in the Cedar-Ortega River Basin had a PCB composition comparable to that of the lower St. Johns River, but most had a lower molecular weight composition (relatively more PCB congeners of a lower level of chlorination). The surface sediments collected in the highly contaminated Cedar River clustered together in the PCA analysis (Figure 4-19), with a PCB congener composition that appeared to be a combination of Aroclor 1242 and Aroclor 1248, with a greater resemblance to Aroclor 1242 the further upstream the sample was collected. The samples from the lower part of the basin had a congener composition that was in the molecular weight range between Aroclor 1248 and Aroclor 1254, and resembled Aroclor 1254 more and more the closer to the confluence of the Ortega and lower St. Johns River the sample was collected. However, it should be pointed out that the overall PCB congener *pattern* of the sediments from the lower Basin did not closely resemble Aroclor 1254, as if there was a source of Aroclor 1254, but contained congeners of the molecular weight range that more closely resembled Aroclor 1254. These congeners could actually be residual congeners that originated with higher or lower molecular weight Aroclor formulations, depending on the environmental fate and transport mechanisms they had been subjected to. For instance, it is possible that as Aroclor 1242/1248-type of PCB congeners travel down the Cedar-Ortega River system the higher molecular weight congeners more closely associate with organic matter and solids, settle into the sediments. Through dissolution and resuspension, the lower molecular weight (more water soluble less tightly bound) congeners would then travel out of the Basin more readily, while the higher molecular weigh congeners are more closely associated with the sediments and travel less slowly down the system, proportionately concentrating in the sediments with travel distance. In addition, there may be other, smaller, sources of the commonly used higher molecular weight PCB formulations in the lower part of the basin.

Pesticides - DDTs

The concentrations of DDT, and its degradation products DDD and DDE, are presented in Table 3-6, along with the total concentration of these DDT compounds. Figure 4-20 shows the relative concentrations of DDT, DDD, and DDE at selected sites. Various environmental conditions (primarily oxygen supply) dictate the rate of DDT degradation, and the relative amounts of DDD and DDE that are formed. The concentration of DDD was higher than both the DDE and DDT concentrations in most samples, just as it is in many sediments around the US (Battelle, 1990, 1991b, 1992), but there were also a number of sites at which DDE was most abundant, suggesting varying oxygen supply conditions of the sediments (aerobic vs anaerobic conditions). In addition, site ORT33, and some of the sites towards the middle part of the study area (the main Basin area), had proportionately higher concentrations of DDT than what was found in most sediments, and very similar concentrations of all three components, suggesting more recent inputs of DDT in the Fishweir Creek area and/or slower DDT degradation. The DDT compound composition in the subsurface sediments was also dominated by DDD and/or DDE, but the environmental conditions that control the DDT degradation appeared to be somewhat variable, with some locations having DDD as the dominant degradation product in the surface sediment and DDE in the sub-surface sediment (e.g., CED01) while other locations were dominated by DDE at the surface and by DDD at greater depth (e.g., CED03).

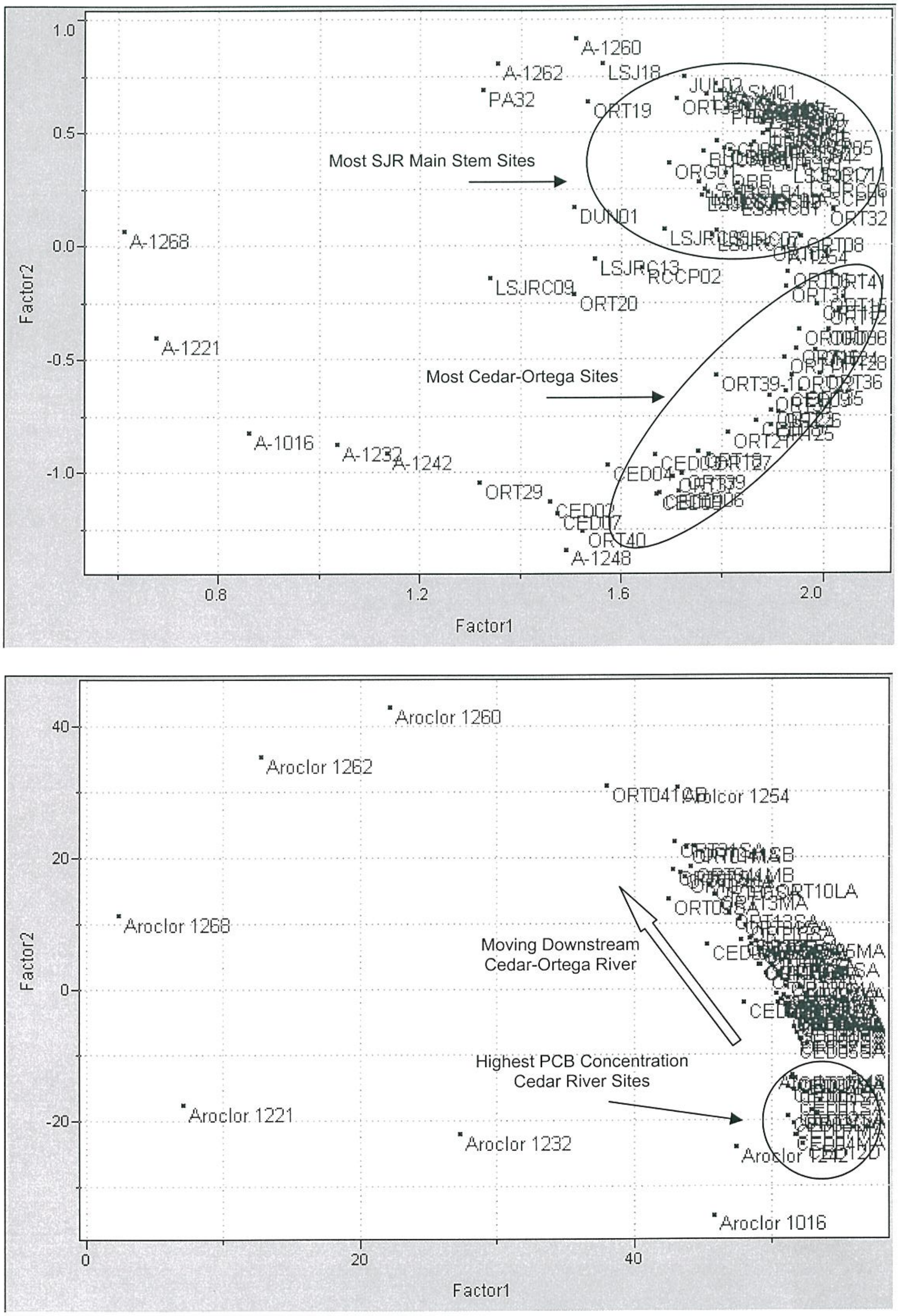


Figure 4-19. Principal Component Analysis (PCA) of Sediment PCB Data: Using 23 PCB Congener Data for LSJR and COR Sites (top) and PCB Homologue Data for COR Sites (bottom)

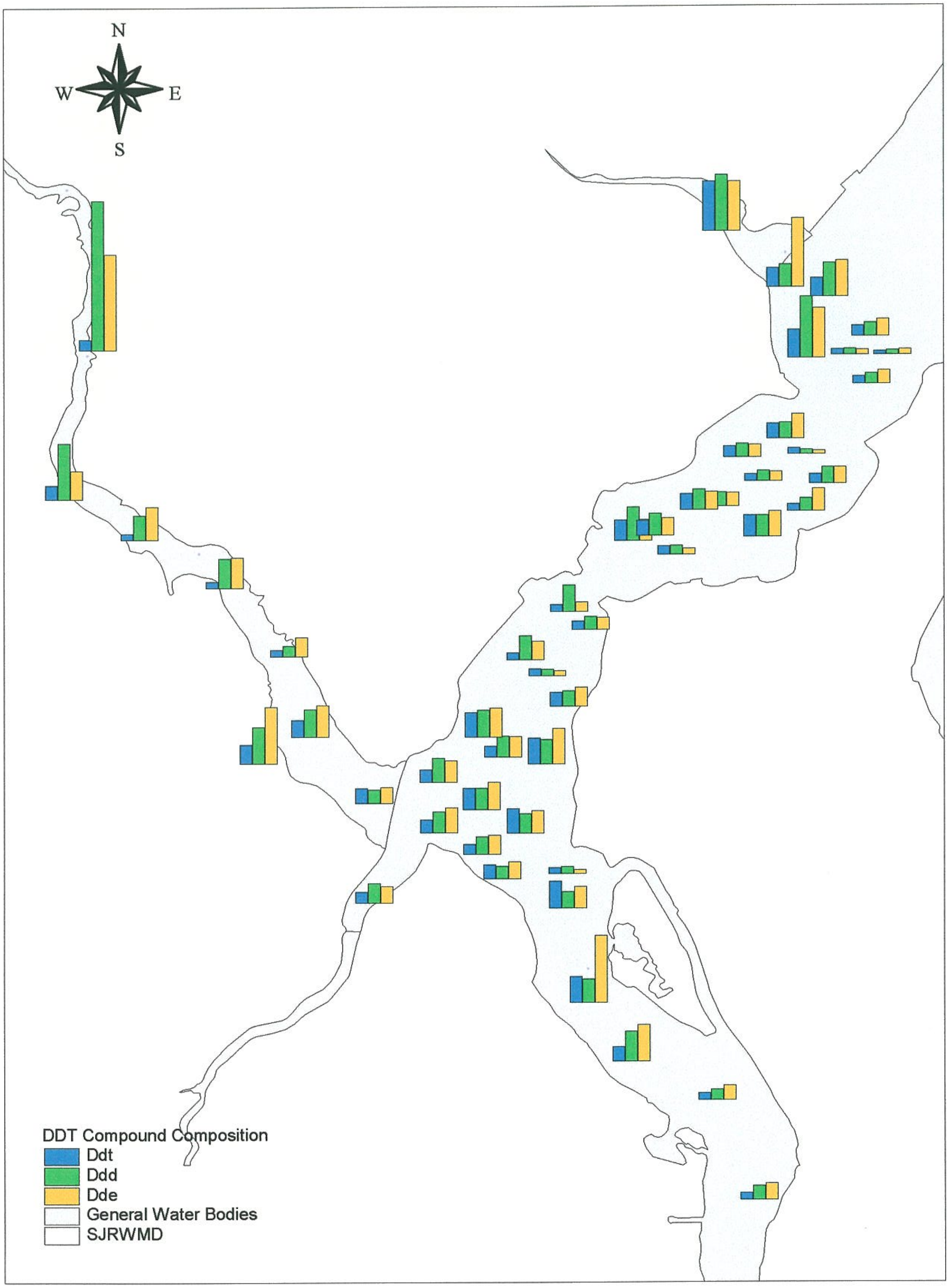


Figure 4-20. Map Displaying Relative Composition of DDT and Its Key Degradation Products in Surface Sediments from Selected Sites

4.1.4 Organic Compounds — Potential Hot Spots

This particular study can be used as the primary frame of reference when discussing potential hot spots, or one can include data from other comparable locations throughout the country to put the entire study area into perspective. Contaminant concentrations were earlier in this section compared to data generated in various other national monitoring programs (Table 4-2), but 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. Conversely, low relative concentrations does not necessarily mean that the contamination is not of concern, it could just mean that the higher reference concentration is extremely high.

The contaminant profiles vary from contaminant-to-contaminant, but there are a few clear geographical distribution characteristics. Following a review of the data, three general areas emerge as the primary potential hot spots: (1) the upper part of the Cedar River, (2) the area around ORT33/ORT31 (Fishweir Creek area), and (3) the lower part of the Cedar River near CED09 (Butcher Pen Creek area). Some elevated contamination was also measured along the north shore of the lower Basin (at ORT19).

The Cedar River, in general, and the upper parts in particular, had elevated concentrations of a number of organic contaminants, as compared to the rest of the Cedar-Ortega River Basin. This is particularly the case for the PCB contamination (Figures 4-7 and 4-10), but also DDT (Figure 4-11) and phthalates. The high phthalate concentrations are fairly wide spread across the central part of the Cedar River, with a subtle increase in concentration going downstream, suggesting the input may be historic (or episodic) and the measured concentrations are mostly related to depositional characteristics. The PCB and DDT concentrations increase upstream, suggesting there may be a current source of these contaminants upstream of site CED01. The PCB contamination is particularly high throughout most of the Basin, and the contaminant concentrations increase dramatically up the Cedar River. The overall PCB contamination levels, and PCB composition, that was observed for the Cedar-Ortega River Basin suggests that the primary source of this contaminant for the entire basin may be somewhere up the Cedar River, and the sub-surface sediment concentrations indicate that there has been significant inputs of PCB and DDT to the upper Cedar River for a long time.

The concentrations of chlordane (Figure 4-12), PAH (Figures 4-3 and 4-6), DDT (Figure 4-11), and phthalate are significantly elevated at site ORT33, and to a lesser degree at ORT31, relative to most of the Cedar-Ortega River Basin. There appears to be a contaminant gradient towards the south for this area, with most measured contaminant concentrations decreasing from ORT33 to ORT31 to ORT32. These data suggest that the small water body that enters the mouth of the Ortega River by sites ORT31 and ORT32 receive elevated amounts of these contaminants from local source(s). Several small creeks (Big Fishweir Creek and Little Fishweir Creek) and other urban/residential runoff discharges enter into this water body (Figure 2-2).

The PAH and chlordane concentrations were elevated at site CED09 (where Butcher Pen Creek flows into the Cedar River), and the surrounding area. The DDT and endosulfan concentrations were also somewhat higher in the Butcher Pen Creek area than most parts of the COR area. The PAH and chlordane concentrations were also elevated, but to a lesser degree, up the Cedar River, particularly up to site CED02. This suggests that the source of this contamination is mainly (1) in the lower part of the river (e.g., Butcher Pen Creek) or (2) the contamination is primarily historic from upstream source(s) and has been deposited in these lower parts of the Cedar River. A contaminant transport *up* the Cedar River (e.g., from CED09 to CED02) would be unlikely, except for minor tidally influenced fluctuations, and the source(s) of particularly the PAH contamination could be more wide spread. This is consistent with the generally high levels of PAH in the Cedar-Ortega River Basin, and the overall similarity in PAH composition. However, the area around Butcher Pen Creek appears to be an area that warrants additional study. Butcher Pen Creek discharges into the Cedar River at CED09, and the potential for this creek contributing contaminants, and potential upstream sources, should be investigating more closely, in addition to determining the transport/depositional mechanisms associated with other parts of the Cedar River and other part of the Basin.

Site ORT19, near the north shore of the central part of the main Basin area and below an automobile (Roosevelt Blvd) and railroad bridge, was one site that had somewhat elevated concentrations of several contaminants, and may be impacted by a local relatively small source. The PAH concentrations are particularly elevated at this location, and the composition of the PAH is slightly different at this location, suggesting there may be local source(s).

4.1.5 Organic Compounds — Indicators of Potential Effects

In the following section concentrations of contaminants in surface sediments are compared to effects-based sediment quality guideline (SQG) values. The data assessment focuses on the surface sediments because these are the sediments that are most widely exposed to the aquatic biotic life of the Basin, and are therefore most likely to cause any potential environmental harm. In addition, the near-surface sediments, which may be mixed with surface sediments under different environmental conditions, generally had contaminant concentrations that were comparable to the surface sediments concentrations.

Effects range-low (ERL) and effects range-median (ERM) values are the most commonly used and referenced sediment quality guidelines. They were initially developed by scientists at NOAA (Long and Morgan, 1990) and were later revised after compiling additional data (Long *et. al.*, 1995). These are scientifically derived values of potential for biological effects from sediment-sorbed contaminants. The ERL and ERM guideline values delineate three concentration ranges for a particular chemical (Long *et. al.*, 1995). The concentration below the ERL value represents a minimal-effect range; a range representing conditions in which ecologic and toxic effects are rarely expected. Concentrations between the ERL and ERM represent a possible-effects range within which effects would occasionally occur, and the concentrations above the ERM value represent a probable-effects range where effects would be expected to frequently occur.

Guidelines similar to the widely accepted and used ERL and ERM values have also been published specifically for sediments in Florida systems (MacDonald *et al.*, 1996; FDEP, 1994). MacDonald published threshold effects levels (TEL) and probable effect levels (PEL) for Florida coastal water sediments using a weight-of-evidence approach. These TELs and PELs were determined similarly to the ERLs and ERMs, and, like ERLs and ERMs, were developed based on coastal/salt-water sediment data. 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 ERL/ERM values because of the testing regime used in their development.

The ERL/ERM and Florida TEL/PEL values were developed for coastal sediments, and it is unclear how they translate to fresh water systems. An additional set of TEL/PEL sediment quality guidelines has been developed for freshwater systems (Smith, *et. al.*, 1996; CCME, 1995). These guidelines were based on much of the approach taken by MacDonald for developing marine/estuarine sediment quality guidelines for Florida. Freshwater sediment guidelines may be particularly important for evaluating metals contamination in freshwater sediments, because salinity may have a marked effect on the speciation and bioavailability of some metals in sediments. However, Long and MacDonald (1998) concluded that saltwater sediment quality guidelines are comparable to those derived with similar methods, but different databases, for freshwater sediments, particularly for organic contaminants.

After a careful review of current SQG information it became evident that a set of freshwater sediment quality guidelines that have only recently become availability are more applicable to this work than the ERL/ERM and TEL/PEL values; the threshold effects concentration (TEC) and probable effects concentration (PEC) values developed by MacDonald *et. al.* (2000). The TEC represents the concentration below which sediment toxicity would not be expected to be observed and the PEC the concentration above which sediment toxicity would likely occur.

The TEC and PEC values were developed specifically for freshwater systems by MacDonald *et. al.* (2000). MacDonald had earlier contributed to the development of TEL and PEL values for Florida coastal water sediments. MacDonald is also developing freshwater sediment quality guidelines for the State of Florida, and those are expected to be much like theses TEC and PEC values that he published in 2000. These new TEC and PEC values were developed using a very large dataset, including appropriate information used earlier to establish other SQG values. The TEC and PEC sediment quality guidelines values were developed using a *consensus-based* approach, and are thus recognized as defensible and widely applicable.

The TEC and PEC values are the latest and, because of how they were developed, the most robust freshwater sediment quality guidelines available. The Cedar-Ortega River Basin aquatic system, although partly tidally influenced, has salinity that is more like fresh than marine/coastal water (which typically has a salinity of about 30 ppt). The salinity is the key difference between freshwater and marine systems that influence the availability and toxicity of sediment contaminants. The TEC and PEC values were developed specifically for freshwater sediments and are therefore also the most applicable SQGs for assessing the potential toxicity of the Cedar-Ortega River Basin sediments.

The representativeness of sediment quality guideline values is sometimes hotly debated. There is, for instance, typically more confidence in the PAH ERL and ERM guidance values than in those for PCB or most toxic metals. Although it is widely recognized that the organic content of the sediment can greatly influence the availability of organic contaminants to the surrounding biota, current sediment quality guideline values are based on concentration data that are not normalized to organic content. Similarly, the potential for metals to cause adverse biological effects depends greatly on the characteristics of the sediment and how the metals are associated with the sediment. In addition, the sediment quality guidelines were developed based 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; a significant "error margin" should therefore be used in the application of these values. Another note of caution in applying sediment quality guidelines is that they may not satisfactorily describe or account for multiple contaminants, or contaminant interactions, that may affect the biota that are exposed to a complex suite of contaminants simultaneously.

Consequently, the application of sediment quality guidelines should be made with caution. These reference values are *screening* tools that were developed to evaluate the general 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 freshwater sediment TEC and PEC values, and the marine/coastal ERL and ERM values, are summarized in Table 4-3. The TEC and PEC values were given the greatest weight in the sediment quality assessment, but the widely used ERL and ERM values were also considered. The freshwater and marine/coastal sediment TEL and PEL values are summarized in Table 4-4, for reference and to facilitate additional data comparison.

Table 4-3. Freshwater Sediment TEC and PEC Values, and Marine/Estuarine Sediment ERL and ERM Values

Contaminant	Freshwater		Marine/Estuarine	
	TEC[a] (mg/kg for metals and µg/kg for organics)	PEC[b] (mg/kg for metals and µg/kg for organics)	ERL[c] (mg/kg for metals and µg/kg for organics)	ERM[d] (mg/kg for metals and µg/kg for organics)
As	9.79	33.0	8.2	70
Cd	0.99	4.98	1.2	9.6
Cr	43.4	111	81	370
Cu	31.6	149	34	270
Pb	35.8	128	46.7	218
Hg	0.18	1.06	0.15	0.71
Ni	22.7	48.6	20.9	51.6
Ag	NA[e]	NA	1	3.70
Zn	121	459	150	410
Total PCB	59.8	676	22.7	180
Total DDT	5.28	572	1.58	46.1
DDE	3.16	31.3	2.2	27
DDD	4.88	28.0	2	20
DDT	4.16	62.9	1	7
Chlordane	3.24	17.6	0.5	6
Dieldrin	1.90	61.8	0.02	8
Endrin	2.22	207	0.02	45
Lindane	2.37	4.99	NA	NA
Heptachlor epoxide	2.47	16.0	NA	NA
Total PAH	1,610	22,800	4,022	44,792
Low PAH	NA	NA	552	3,160
High PAH	NA	NA	1,700	9,600
Acenaphthene	NA	NA	16	500
Acenaphthylene	NA	NA	44	640
Anthracene	57.2	845	85.3	1100
Fluorene	77.4	536	19	540
Naphthalene	176	561	160	2,100
2-Methylnaphthalene	NA	NA	70	670
Phenanthrene	204	1,170	240	1,500
Benz(a)anthracene	108	1,050	261	1,600
Benzo(a)pyrene	150	1,450	430	1,600
Chrysene	166	1,290	384	2,800
Dibenzo(a,h)anthracene	33.0	NA	63.4	260
Fluoranthene	423	2,230	600	5,100
Pyrene	195	1,520	665	2,600

[a] TEC: Threshold Effects Concentration (MacDonald *et al*., 2000).

[b] PEC: Probable Effects Concentration (MacDonald *et al*., 2000).

[c] ERL: Effects Range Low (Long *et al*., 1995; Long & Morgan, 1990, for DDD, DDT, chlordane, dieldrin and endrin).

[d] ERM: Effects Range Median (Long *et al*., 1995; Long & Morgan, 1990, for DDD, DDT, chlordane, dieldrin, and endrin).

[e] NA: not applicable. There is no TEC or PEC or ERL or ERM for this parameter.

Table 4-4. Freshwater and Marine/Estuarine Sediment TEL and PEL Values

Contaminant	Freshwater		Marine/Estuarine	
	TEL[a] (mg/kg for metals and µg/kg for organics)	PEL[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)
As	5.9	17	7.24	41.6
Cd	0.60	3.5	0.68	4.21
Cr	37.3	90	52.3	160
Cu	35.7	197	18.7	108
Pb	35	91.3	30.2	112
Hg	0.17	0.49	0.13	0.7
Ni	18	35.9	15.9	42.8
Ag	NA[e]	NA	0.73	1.77
Zn	123	315	124	271
Total PCB	34.1	277	21.6	189
Total DDT	6.98	4,450	3.89	51.7
DDE	1.42	6.75	2.07	374
DDD	3.54	8.51	1.22	7.81
DDT	NA	NA	1.19	4.77
Chlordane	4.5	8.9	2.26	4.79
Dieldrin	2.85	6.67	0.72	4.3
Endrin	2.67	62.4	NA	NA
Lindane	0.94	1.38	0.32	0.99
Heptachlor epoxide	0.6	2.74	NA	NA
Total PAH	NA	NA	1,684	16,770
Low PAH	NA	NA	312	1,442
High PAH	NA	NA	655	6,676
Acenaphthene	NA	NA	6.71	88.9
Acenaphthylene	NA	NA	5.87	128
Anthracene	NA	NA	46.9	245
Fluorene	NA	NA	21.2	144
Naphthalene	NA	NA	34.6	391
2-Methylnaphthalene	NA	NA	20.2	201
Phenanthrene	41.9	515	86.7	544
Benz(a)anthracene	31.7	385	74.8	693
Benzo(a)pyrene	31.9	782	88.8	763
Chrysene	57.1	862	108	846
Dibenzo(a,h)anthracene	NA	NA	6.22	135
Fluoranthene	111	2,355	113	1,494
Pyrene	53	875	153	1,398

[a] TEL: Threshold Effect Level (Smith *et al.*, 1996)

[b] PEL: Probable Effect level (Smith *et al.*, 1996; CCME, 1995)

[c] TEL: Threshold Effect Level (MacDonald *et al.*, 1996; FDEP, 1994)

[d] PEL: Probable Effect level (MacDonald *et al.*, 1996; FDEP, 1994)

[e] NA: not applicable. There is no TEL or PEL for this parameter.

Table 4-5 summarizes the number of sites that exceeded the freshwater TEC/PEC and the marine ERL/ERM values. The assessment of Cedar-Ortega River Basin sediment quality guideline exceedances focuses on the TEC/PEC values because they are the most robust freshwater sediment quality guidelines available. However, comparisons to ERL and ERM values were also performed because they are the most widely used sediment quality guideline values. Graphs with contaminant concentrations, along with the TEC/PEC and ERL/ERM references are presented in Appendix P. Non-normalized data are used for all organic and metals sediment quality guideline comparisons.

It is clear that there can be differences in the contaminant assessment conclusions depending on which sediment quality guidelines (SQGs) one uses. Additionally, the high TOC concentrations in many of these samples actually contributes to "holding" the organic contaminants, making them less available to cause environmental harm. It is therefore important to consider both TOC- and non-normalized data, and the TEC/PEC and ERL/ERM values, for an overall SQG-related contaminant assessment.

PAH

The assessment of sediment quality guideline exceedances focused on the freshwater TEC/PEC values (the sediment quality guidelines most applicable to Cedar-Ortega River Basin sediment), but the coastal/marine ERL/ERM values (the most widely used sediment quality guidelines) were also used. TEC exceedances for total PAH occurred at 45 (92%) of the 49 COR sites (Table 4-5; Figure 4-21). The PEC value for total PAH was exceeded at one of the COR sites. The ERL value for total PAH, low PAH, and high PAH was exceed at 29 (60%), 12 (24%), and 44 (90%) of the 49 COR sites, respectively. The HMW PAH (e.g., fluoranthene, benzo(a)pyrene) were the PAH that contributed the most to PAH sediment quality guideline exceedances and are the PAH generally considered to have the greatest potential for adverse chronic effects (e.g., carcinogens, teratogens), but they are generally less acutely toxic than lower molecular weight PAH and also less mobile in the environment. Note that the PAH compounds used to compute the low- and high-molecular weight PAH ERL/ERM values (Long *et. al.*, 1995) are slightly different from what is commonly used for similar summations, and from what is used in this report, but the differences are small and have no impact on the overall exceedance rate or conclusions.

PCB

The surface sediment PCB data reported in Table 3-7 were used for this assessment. There were numerous TEC/PEC and ERL/ERM total PCB exceedances (Table 4-5 and Figure 4-22). The total PCB TEC and PEC values were exceeded at 44 (90%) and 9 (18%) of the 49 broadly characterized COR sites, respectively. The ERL and ERM values were exceeded at 48 (98%) and 29 (59%)[2] of the COR sites, respectively. In addition, the three sites that were sampled for PCB only (CED12, CED13, and CED14) all had surface sediment PCB concentrations that exceeded all the TEC/PEC and ERL/ERM values. The total PCB concentration at CED01 exceeded the PEC value by a factor of 15, and the TEC was exceeded by a factor of 167; the surface sediment from the next, and most, upstream site (CED12) had even higher PCB concentrations. PCB sediment quality guideline exceedances were observed for sediments to a considerable sediment depth (Figure 4-23), consistent with the surface- and sub-surface PCB concentrations discussed earlier. A large amount of the sediment in the Cedar-Ortega River Basin had PCB concentrations that were above even the higher PEC and ERM values. PCB appears to be the organic contaminant with the greatest potential for environmental effects in the Cedar-Ortega River Basin, based on these sediment quality guideline comparisons.

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[2] Note that this number of ERM exceedances is lower than indicated in the earlier the Lower St. Johns River and Cedar-Ortega River Basin report (Battelle, 2004); 29 vs 42 site exceedances. This discrepancy is partly because there were two more sites included in the earlier report, but mainly due to differences in analytical methods that result in slightly different total PCB concentrations (See Section 3.1.2). Most of the total PCB data used in this report (Table 3-7) are based on the more reliable GC/MS analysis, while all the data in the earlier report are based on GC/ECD analysis, and many of the samples had total PCB concentrations near the PCB ERM value.

Table 4-5. Number and Percentage of Cedar-Ortega River Basin Sites with Surface Sediment TEC, PEC, ERL, and ERM Exceedances

Contaminant	Number of Sediment Quality Guideline Exceedances [a]			
	Freshwater Guidelines		Marine/Coastal Guidelines	
	TEC	PEC	ERL	ERM
Metals				
As	3 (6%)	0 (0%)	4 (8%) [a]	0 (0%)
Cd	31 (63%)	0 (0%)	24 (49%)	0 (0%)
Cr	43 (88%)	0 (0%)	3 (6%)	0 (0%)
Cu	27 (55%)	0 (0%)	24 (49%)	0 (0%)
Pb	41 (84%)	10 (20%)	40 (82%)	4 (8%)
Hg	44 (90%)	6 (12%)	45 (92%)	23 (47%)
Ni	2 (4%)	0 (0%)	4 (8%)	0 (0%)
Ag	NA	NA	11 (22%)	2 (4%)
Zn	39 (80%)	7 (14%)	32 (65%)	9 (18%)
Organic Compound Classes				
Total PAH	45 (92%)	1 (2%)	29 (60%)	0 (0%)
Low PAH	NA	NA	12 (24%)	0 (0%)
High PAH	NA	NA	44 (90%)	8 (16%)
Total PCB	44 (90%)	9 (18%)	48 (98%)	29 (59%)
Total DDT	43 (88%)	0 (0%)	47 (96%)	2 (4%)
Chlordane	35 (71%)	9 (18%)	44 (90%)	24 (49%)
Individual Organic Compounds				
Acenaphthene	NA	NA	20 (41%)	0 (0%)
Acenaphthylene	NA	NA	13 (27%)	0 (0%)
Anthracene	26 (52%)	0 (0%)	15 (31%)	0 (0%)
Fluorene	0 (0%)	0 (0%)	28 (57%)	0 (0%)
Naphthalene	2 (4%)	0 (0%)	3 (6%)	0 (0%)
2-Methylnaphthalene	NA	NA	1 (2%)	0 (0%)
Phenanthrene	8 (16%)	0 (0%)	7 (14%)	0 (0%)
Benz(a)anthracene	36 (72%)	1 (2%)	17 (35%)	0 (0%)
Benzo(a)pyrene	31 (62%)	1 (2%)	13 (27%)	1 (2%)
Chrysene	36 (72%)	2 (4%)	15 (31%)	0 (0%)
Dibenzo(a,h)anthracene	34 (68%)	NA	21 (43%)	2 (4%)
Fluoranthene	26 (52%)	2 (4%)	17 (35%)	0 (0%)
Pyrene	42 (84%)	3 (6%)	20 (41%)	0 (0%)
p,p'-DDE	40 (80%)	1 (2%)	43 (88%)	1 (2%)
p,p'-DDD	27 (54%)	1 (2%)	44 (90%)	2 (4%)
p,p'-DDT	12 (24%)	0 (0%)	46 (94%)	7 (14%)
Dieldrin	13 (27%)	0 (0%)	41 (84%)	0 (0%)
Endrin	2 (4%)	0 (0%)	NA	NA
Lindane	4 (8%)	0 (0%)	NA	NA
Heptachlor epoxide	1 (2%)	0 (0%)	NA	NA

[a] The percentage of the 49 broadly assessed Cedar-Ortega River sites that exceeded the guidance values are listed in parenthesis. The 3 sites assessed for PCB only (CED12, CED13, and CED14) exceeded all listed PCB sediment quality guideline values.

[b] NA: not applicable. There is no TEC, PEC, ERL, or ERM value for this parameter in this sediment type.

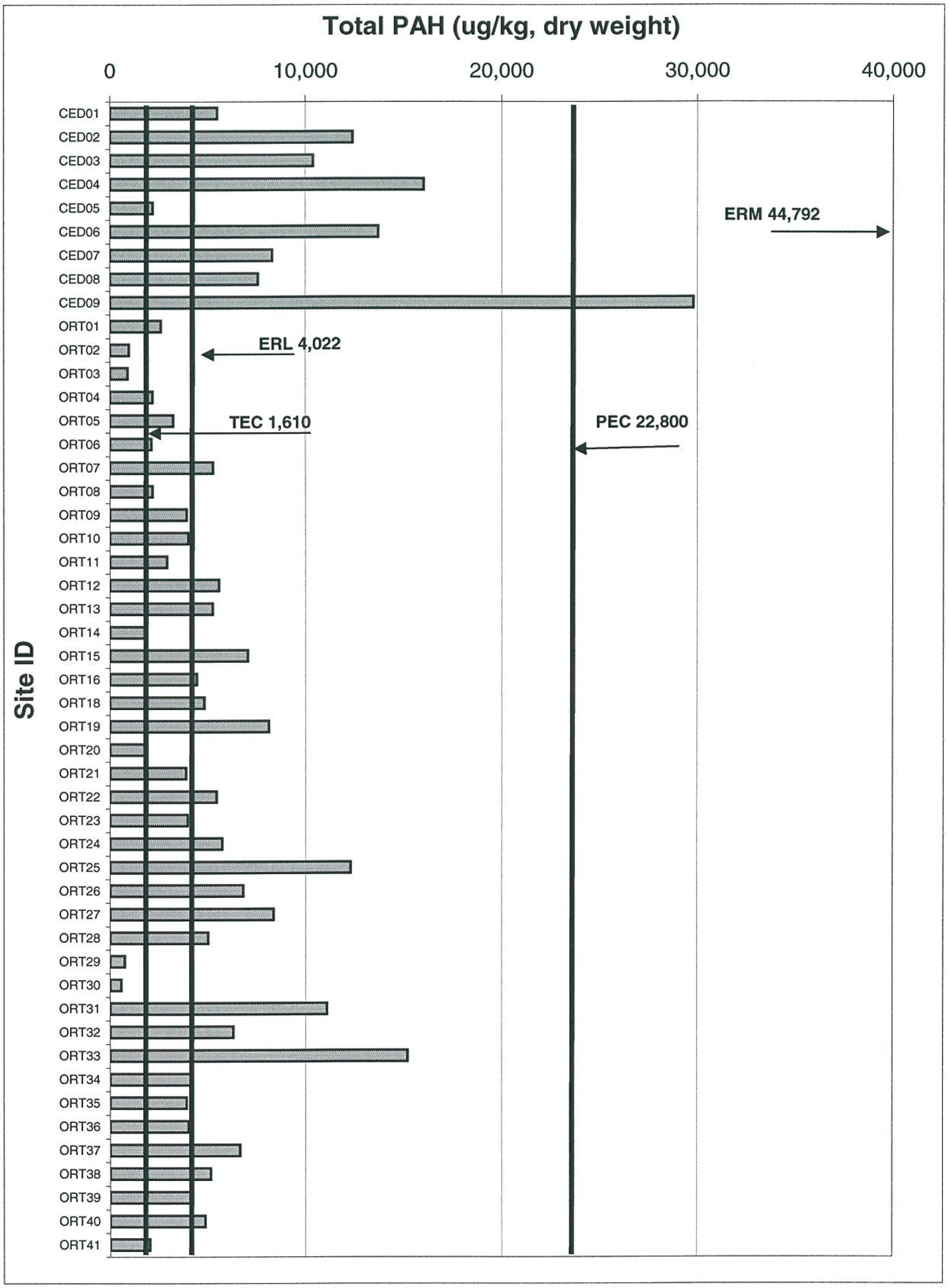


Figure 4-21. Surface Sediment Total PAH Concentrations and SQG Values

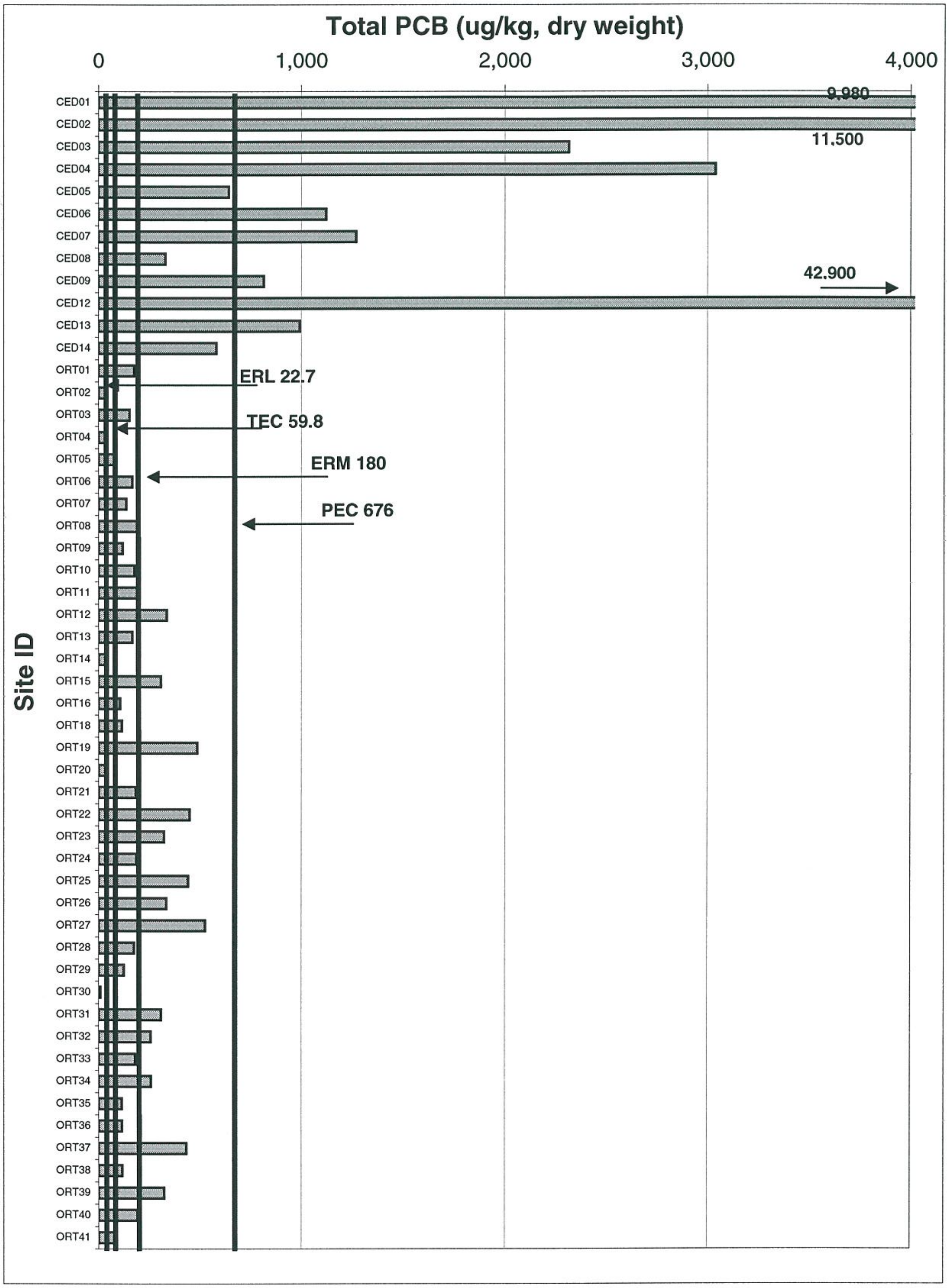


Figure 4-22. Surface Sediment Total-PCB Concentrations and SQG Values

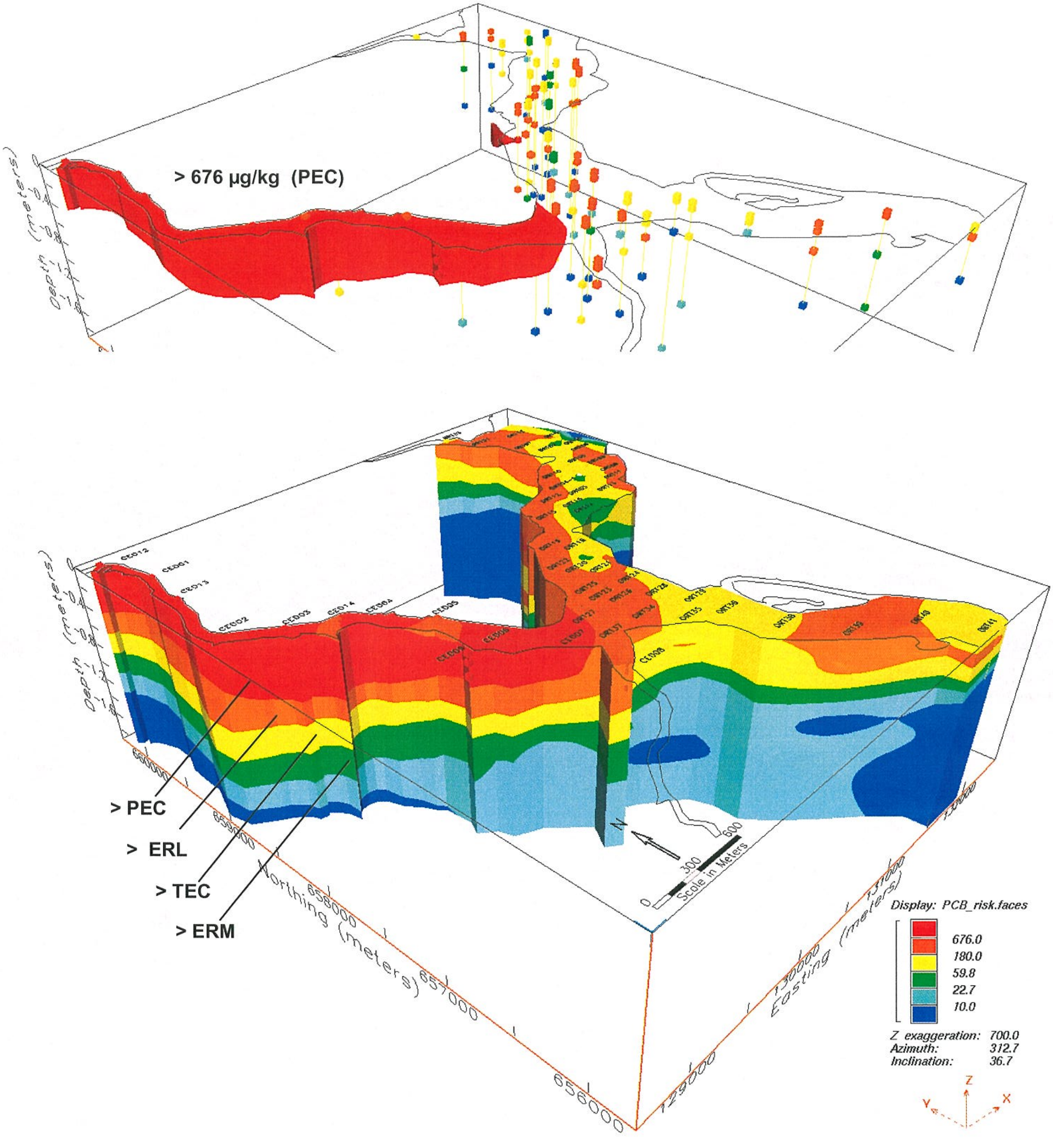


Figure 4-23. 3-D Visualization of the Surface and Subsurface Sediment PCB Concentrations in the Cedar-Ortega River Basin, Relative to Sediment Quality Guidelines

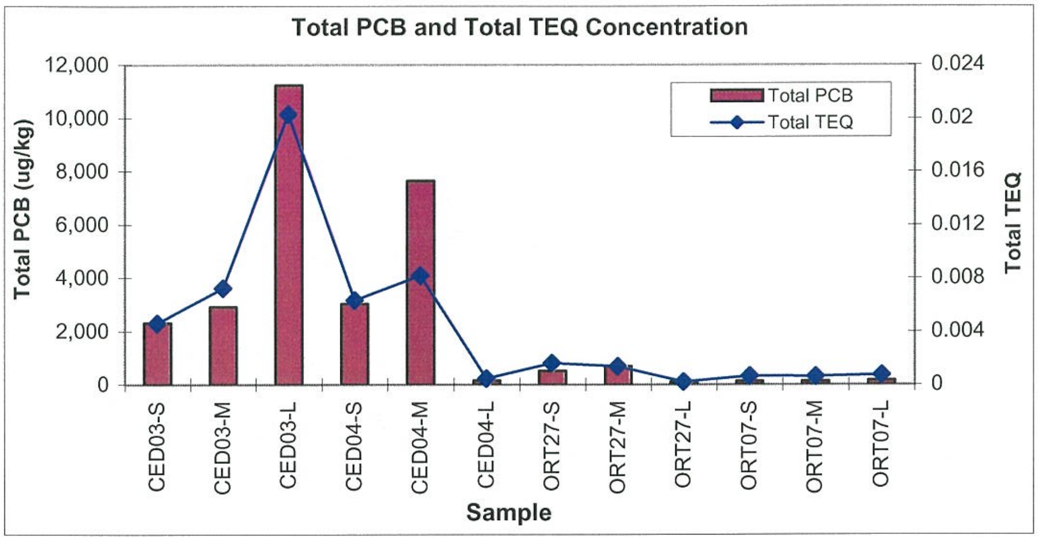
Some PCB congeners have significantly higher toxicity than other congeners, and congener-based risks are increasingly being used in PCB contaminant assessments. Congeners with no chlorines in the *ortho* positions, and all in the *meta* or *para* positions (Section 4.1.3), are called coplanar PCB congeners and are recognized to have the greatest potential to cause harm to biota. This is followed by selected congeners with one chlorine in the *ortho* and the rest in the *meta* and *para* positions (mono-ortho substituted congeners). The World Health Organization (WHO) has identified 13 PCB congeners of particular environmental concern (Table 4-6), and has assigned toxic equivalency factors (TEFs) to the congeners relative to the dioxin compound 2,3,7,8-TCDD. PCB126 is the congener with the highest TEF; a TEF of 0.1, which indicates a toxic equivalence that is one tenth that of 2,3,7,8-TCDD.

Table 4-6. World Health Organization (WHO) List of Dioxin-like Congeners and Their Toxic Equivalency Factors

PCB Congener		Toxic Equivalency Factor (relative to 2,3,7,8-TCDD)
Congener Number (IUPAC)	Congener "Type" (chlorine substitution characteristics)	
9 Congeners Included in this Project		
PCB105	Mono-ortho substituted	0.00010
PCB114	Mono-ortho substituted	0.00050
PCB118	Mono-ortho substituted	0.00010
PCB156	Mono-ortho substituted	0.00050
PCB167	Mono-ortho substituted	0.00001
PCB169	Non-ortho substituted (coplanar)	0.01000
PCB170	Di-ortho substituted	0.00010
PCB180	Di-ortho substituted	0.00001
PCB189	Mono-ortho substituted	0.00010
4 Additional WHO Congeners		
PCB77	Non-ortho substituted (coplanar)	0.00050
PCB123	Mono-ortho substituted	0.00010
PCB126	Non-ortho substituted (coplanar)	0.10000
PCB157	Mono-ortho substituted	0.00050

Nine of the 13 WHO toxic congeners were determined in the detailed PCB congener analysis in this project (Table 4-6). The other 4 congeners require special laboratory processing and analysis specific to these congeners to obtain reliable analytical data. Using the concentrations established for these nine target congeners, and applying the appropriate TEFs listed in Table 4-6, toxic equivalencies (TEQ) specific to these congeners were calculated. The TEQs and total PCB concentrations for each segment of the sediment core collected at sites CED03, CED04, ORT27, and ORT07 are presented in Figure 4-24, along with a plot showing the total PCB concentrations and the TEQ/total PCB concentration ratio.

Of the nine WHO congeners that were determined in this project, PCB118 consistently contributed the most to the overall TEQ, followed by PCB156, PCB105, and PCB170. The TEQ tracked differences in the overall PCB concentrations in the core. This is what can be expected for PCB that is not going through microbial anaerobic dechlorination, which is a process that preferentially removes meta- and para-position chlorines from the PCB molecule (see section 4.1.3). As a consequence, sediments that are going through such dechlorination processes may exhibit "detoxification" of the PCB contamination with sediment depth (age), and a decline in the TEQ/total PCB ratio. This is clearly not the case with the Cedar-Ortega River Basin sediments, in which dechlorination does not appear to be occurring and there is no reduction in PCB toxicity over time that can be attributable to the molecular composition of the PCB. For instance, the total PCB concentrations of the samples from the core collected at site CED03 ranged from 2,320 to 11,200 µg/kg (a factor of 4.8), and the TEQ ranged from 0.0046 to 0.0203 (a factor of 4.4); the TEQ and total PCB correlated very well (Figure 4-25), indicating no reduction in toxicity and no change in the PCB composition of the environmentally important WHO congeners.



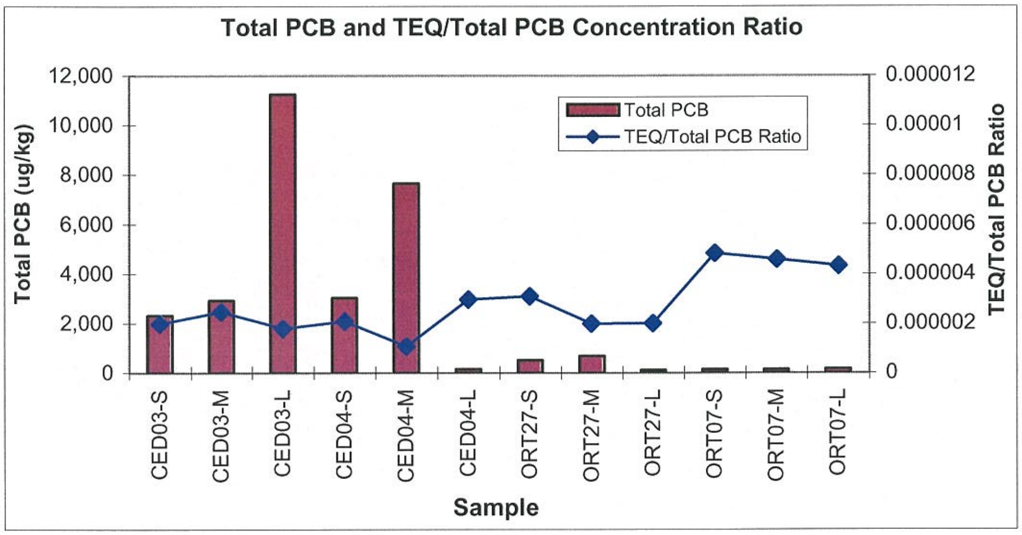


Figure 4-24. Total PCB and Total TEQ (top) and Total PCB and Total TEQ/PCB Ratio (bottom) for Selected Sediment Core Samples

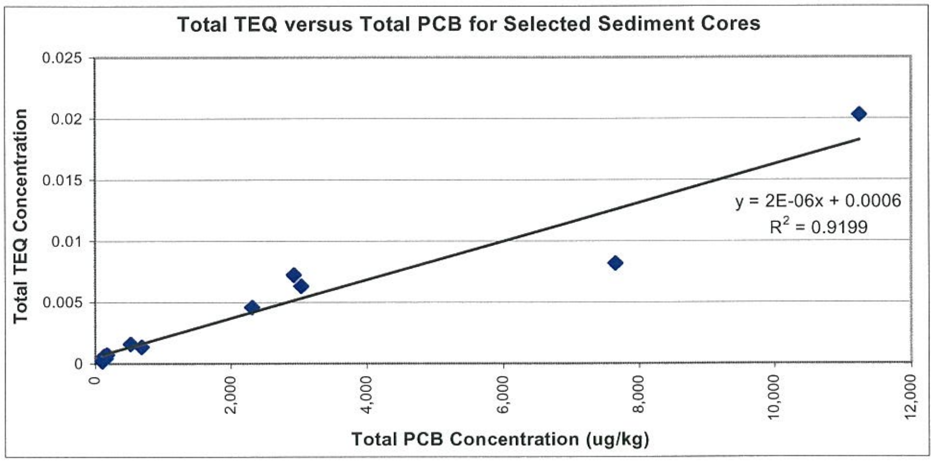


Figure 4-25. Total PCB versus Total TEQ Concentration for Selected Sediment Core Samples

Pesticides - DDTs
The TEC for total DDT was exceeded at 43 (88%) sites and the ERL was exceeded at 47 (96%) of the 49 sites (Figure 4-26). The PEC for total DDT was not exceeded at any of the 49 COR sites and the ERM was exceeded at 2 (CED01 and ORT33) the COR sites. Sites CED01 and ORT33 exceeded these sediment quality guideline values by the greatest amounts; the sediment DDT concentrations for site CED01 exceeded the ERM value by about a factor of 2. The individual p,p'-DDE, p,p'-DDD, and p,p'-DDT compound concentrations exceed the TEC values at 40 (80%), 27 (54%), and 12 (24%) of the COR sites, respectively. PEC values for the p,p'-DDE, p,p'-DDD, and p,p'-DDT compound were exceeded at 1 (2%), 1 (2%), and none of the COR sites, respectively. Freshwater ERL and ERM values for p,p'-DDE were exceeded at 43 (88%) and 1 (2%) of the COR sites, respectively. CED01 and ORT33 were clearly the sites in the Cedar-Ortega River Basin with the most significant DDT compound contamination, from a sediment quality perspective.

Pesticides – Other Chlorinated Pesticides
There were a number of chlordane, dieldrin, and lindane sediment quality guideline exceedances in the Cedar-Ortega River Basin. Chlordane concentrations exceeded the TEC value at 35 (71%) of the 49 sites and the ERL value was exceeded at 44 (90%) of the sites (Figure 4-27). The chlordane PEC value was exceeded at 9 of the COR sites and the ERM value was exceeded at 24 (49%) of the sites. The most significant sediment quality guideline exceedances for chlordane were observed at the sites near Fishweir Creek and Butcher Pen Creek.

Dieldrin concentrations exceeded the TEC value at only 13 (27%) of the 49 sites but the ERL value was exceeded at 41 (84%) of the sites. However, the ERL reference value for dieldrin is considered less reliable than most other values (Long and Morgan, 1990); the ERL value for dieldrin is about a factor of 10 lower than the TEC value. The dieldrin PEC or ERM values were not exceeded at any of the COR sites. The concentration of lindane was above both the TEC value at four (8%) of the 49 sites, and they were, geographically, distributed throughout the Basin. There were no lindane PEC exceedances. The concentrations of lindane at these 4 sites with TEC exceedances were, generally, within a factor of 2 of the reference value. There are no ERL or ERM reference values for lindane.

4.2 Metal Contamination

4.2.1 Metals — Contaminant Concentrations and Distribution

The important relationships between metals, the general physico-chemical characteristics of sediments (e.g., TOC and grain size), and how those relate to the interpretation of metals data, were discussed in Section 3.2. The physico-chemical data analyses described in Section 3.2 was performed with the COR sample data, and the metals data were therefore handled as earlier described for interpretation and presentation purposes.

COR Concentrations Measured in this Study
There was a fairly broad range in the metal concentrations of the Cedar-Ortega River Basin sediments and the levels were also spatially variable. An example of this range and variability, which was not as great as in the St. Johns River, was seen in the aluminum concentrations (Figure 4-28). Aluminum is a major metal primarily associated with the 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- and grain size-normalized metals data are compiled in Appendix L.

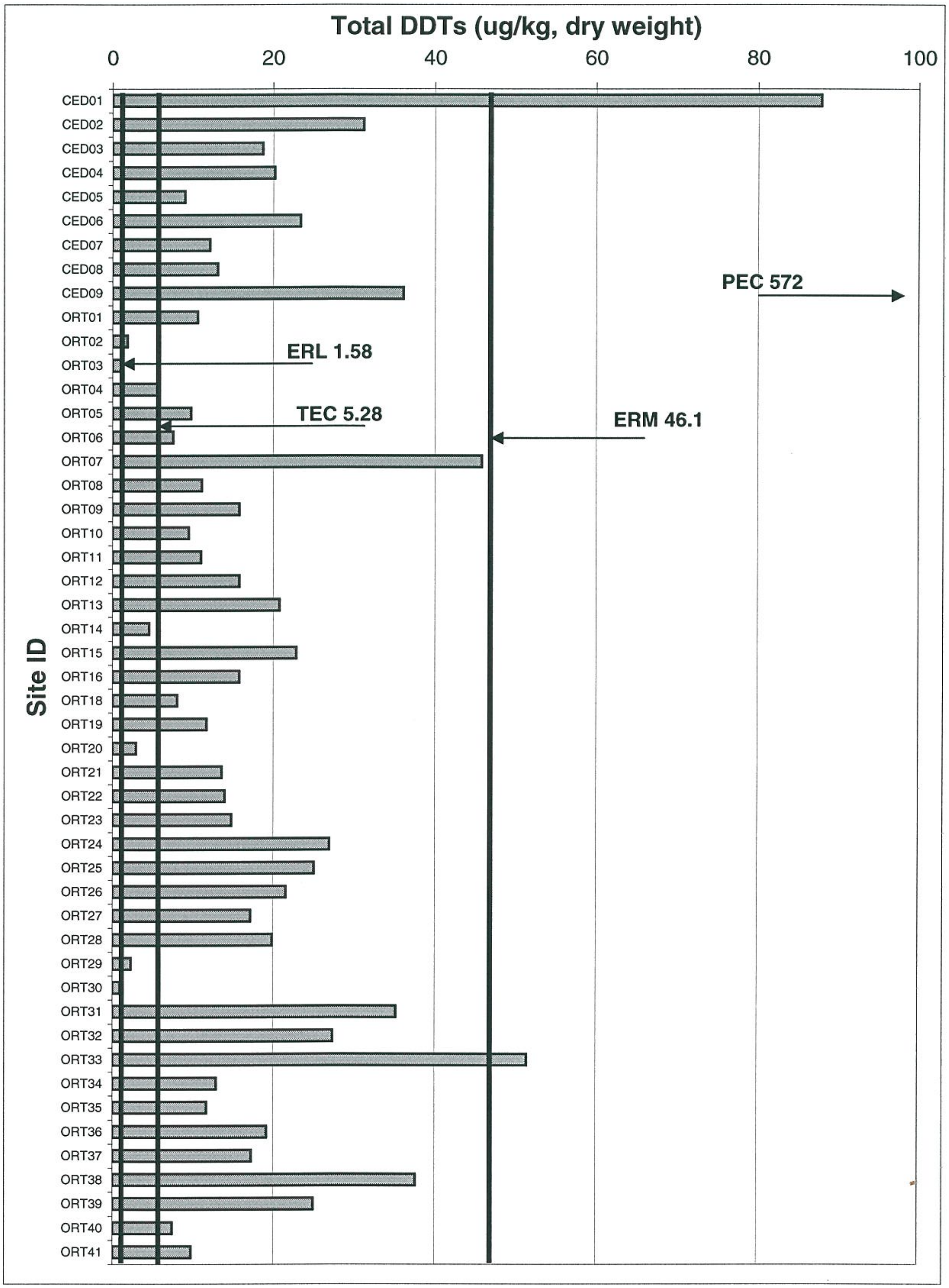


Figure 4-26. Surface Sediment Total DDT Concentrations and SQG Values

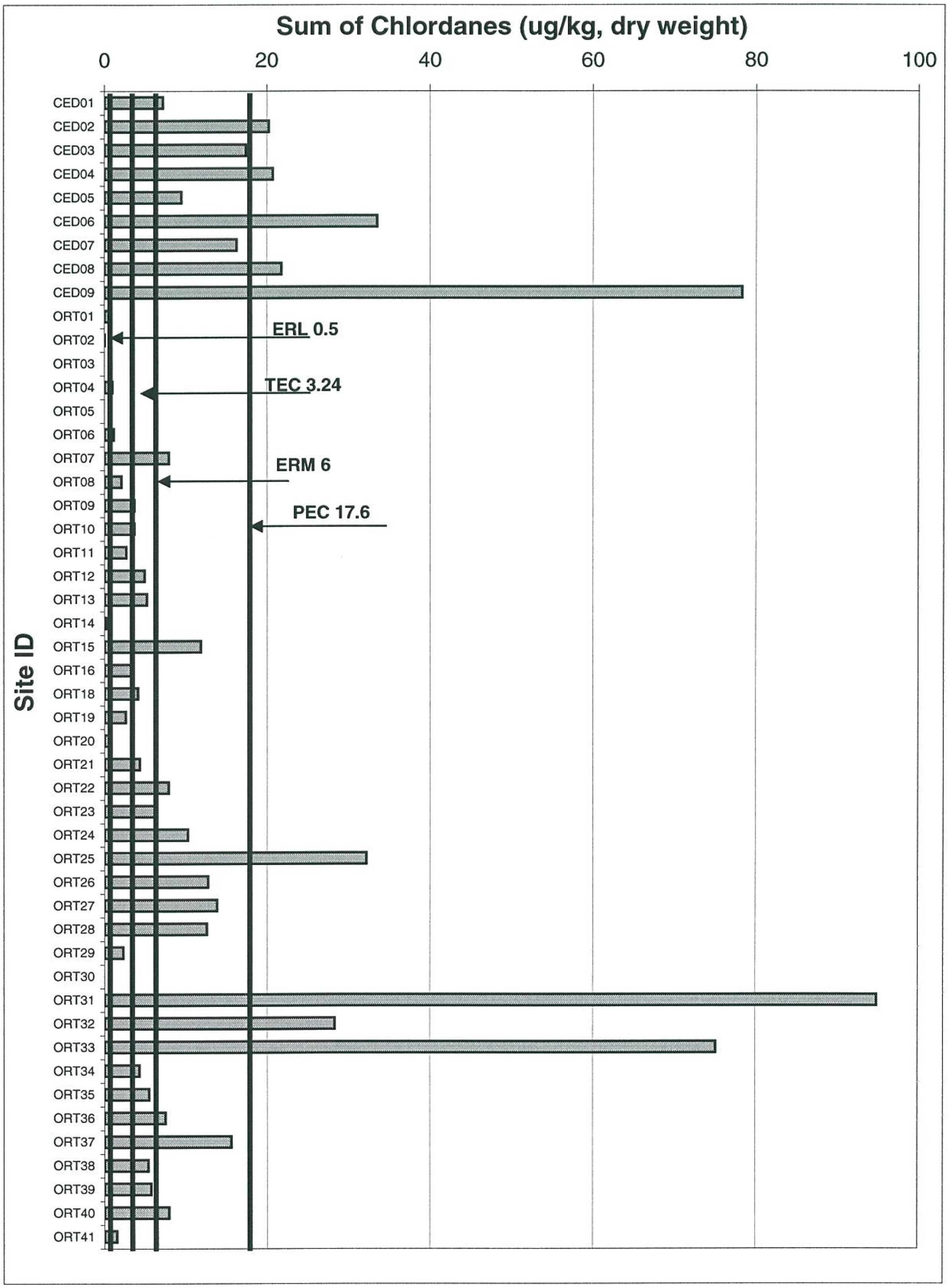


Figure 4-27. Surface Sediment Total Chlordane Concentrations and SQG Values

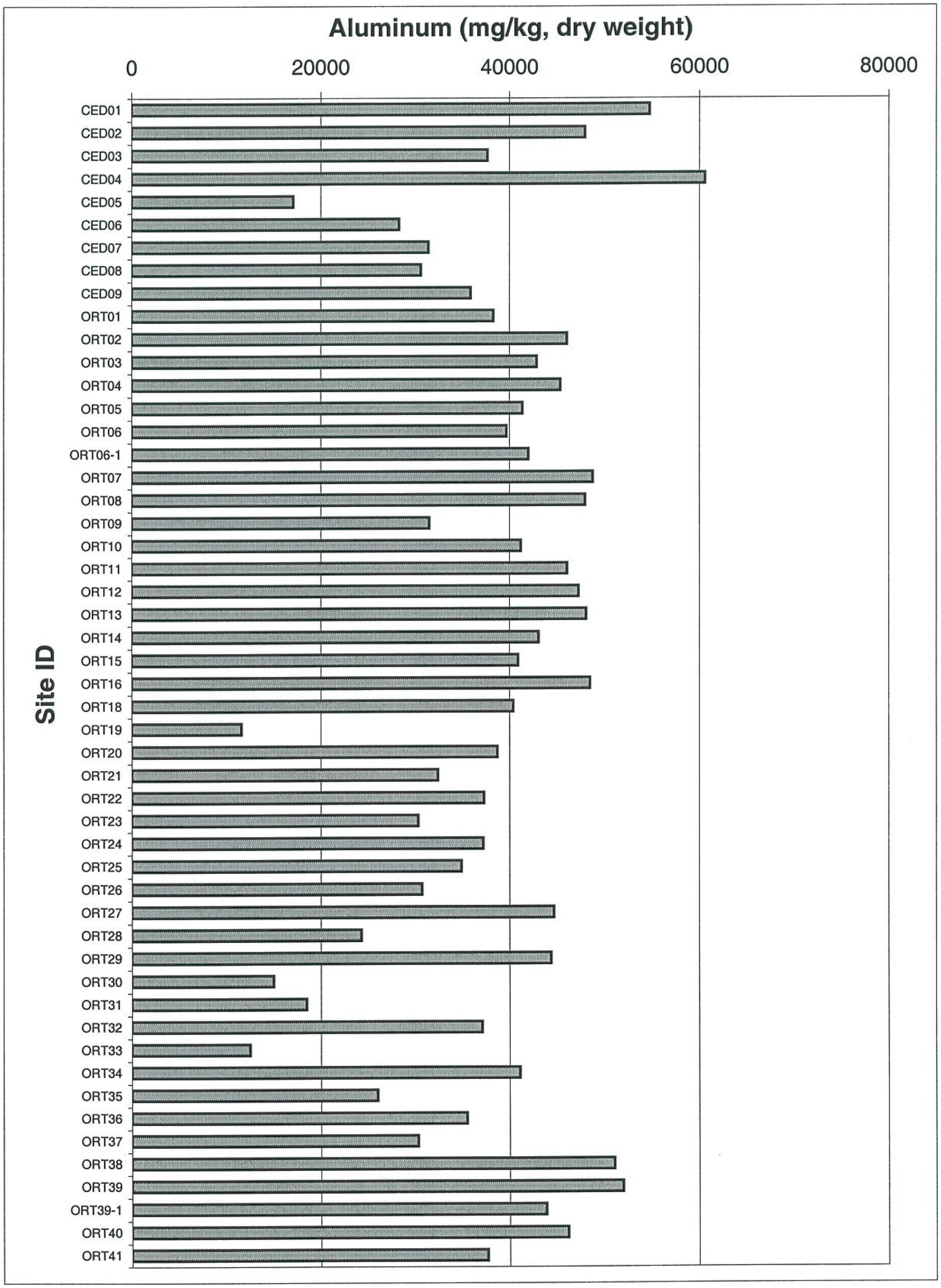


Figure 4-28. Aluminum Concentrations of Surface Sediment Samples

Aluminum concentrations ranged from a low of 11,600 mg/kg to a high of 60,600 mg/kg in the Cedar-Ortega River Basin surface sediments, or about a 5-fold difference between the lowest and highest sediment concentrations (as compared to a 100-fold difference in the St. Johns River). Most samples had aluminum concentrations that were within a factor of two of each other. A small range like this is typical of systems that have modestly variable grain size distributions and are of similar geological origin. The other major metals associated with crustal materials (minerals) also displayed a similarly fairly small range in concentration. Iron surface sediment concentrations, for instance, ranged from 8,070 to 36,600 ppm, manganese from 96 to 270 ppm, and lithium from 11.5 to 54 ppm. There was a 3- to 5-fold difference between the maximum and minimum concentrations of these elements.

As shown in Tables 3-11 and 3-12, the toxic metals concentrations were notably more variable in the Cedar-Ortega River Basin than were the crustal element concentrations, indicating metal contamination. Differences between high and low values ranged from 4-fold for thallium and vanadium to 100-fold for silver and 400-fold for beryllium. Some of the toxic metals did not exhibit a large concentration range, but were still likely of potential concern; they were just more uniformly elevated. 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. However, there were also subtle geographical patterns to some of the metal contaminant profiles that could be attributable to potential sources because the percent mud did not exhibit a discernable geographical pattern (Appendix M). Because of this relative uniformity in percent mud and aluminum, normalizing the data to aluminum content (the normalization procedure that was determined to best represent this data set) did not notably alter the contaminant distribution picture (Figure 4-29).

There were less discrete contaminant signals and patterns for most metals than there were for key organic contaminants, and many metals followed a similar contaminant distribution trend. The concentrations of several metals, including antimony, arsenic, chromium, copper, lead, silver, tin, and zinc appeared to be somewhat elevated in the upper parts of the Cedar River, with declining concentrations closer to the confluence with the Ortega River (Figures 4-30, 4-31, 4-32, 4-33 and Appendices L and Q). Some of these metals (e.g., lead and silver) were also elevated at sites near Fishweir Creek, and copper concentrations appear to be somewhat elevated in the sediments near ORT19 (located at the north side of the Roosevelt Blvd bridge). The magnitude of the elevation varied by metal, but was generally smaller than for the major organic contaminants, even when a geographical pattern was evident. Most areas with elevated metals levels had concentrations that were less than 10 times above the concentrations of the "cleaner" parts of the Basin.

Other metals were detected at concentrations that were either more constant throughout the area (e.g., cadmium, cobalt, lithium, nickel, selenium, and thallium) or somewhat variable but with contaminant concentrations varying within a fairly small concentration range [e.g., mercury (Figure 4-34) and vanadium]. These metals exhibited, for the most part, no clear geographical pattern, whether the data were reviewed normalized to aluminum or not (i.e., the metals concentrations were mostly driven by the natural geology or for other reasons correlated with grain size).

Several of these contaminant signals were evident when both the normalized and non-normalized data had been reviewed. The copper, lead, silver, and zinc concentrations appear to be significantly elevated in the northern section of the Cedar River (e.g., sites CED01 and CED02), and the lead, silver, and zinc concentrations were also elevated at sites ORT31 and/or ORT33. These Cedar and Ortega River locations were also identified to have elevated concentrations of several key organic contaminants, as discussed earlier. Mercury and copper appeared to be elevated at site ORT19, along the northern shore of the main section of the Basin, where there also was a PAH contamination profile that was a little different from the rest of the area.

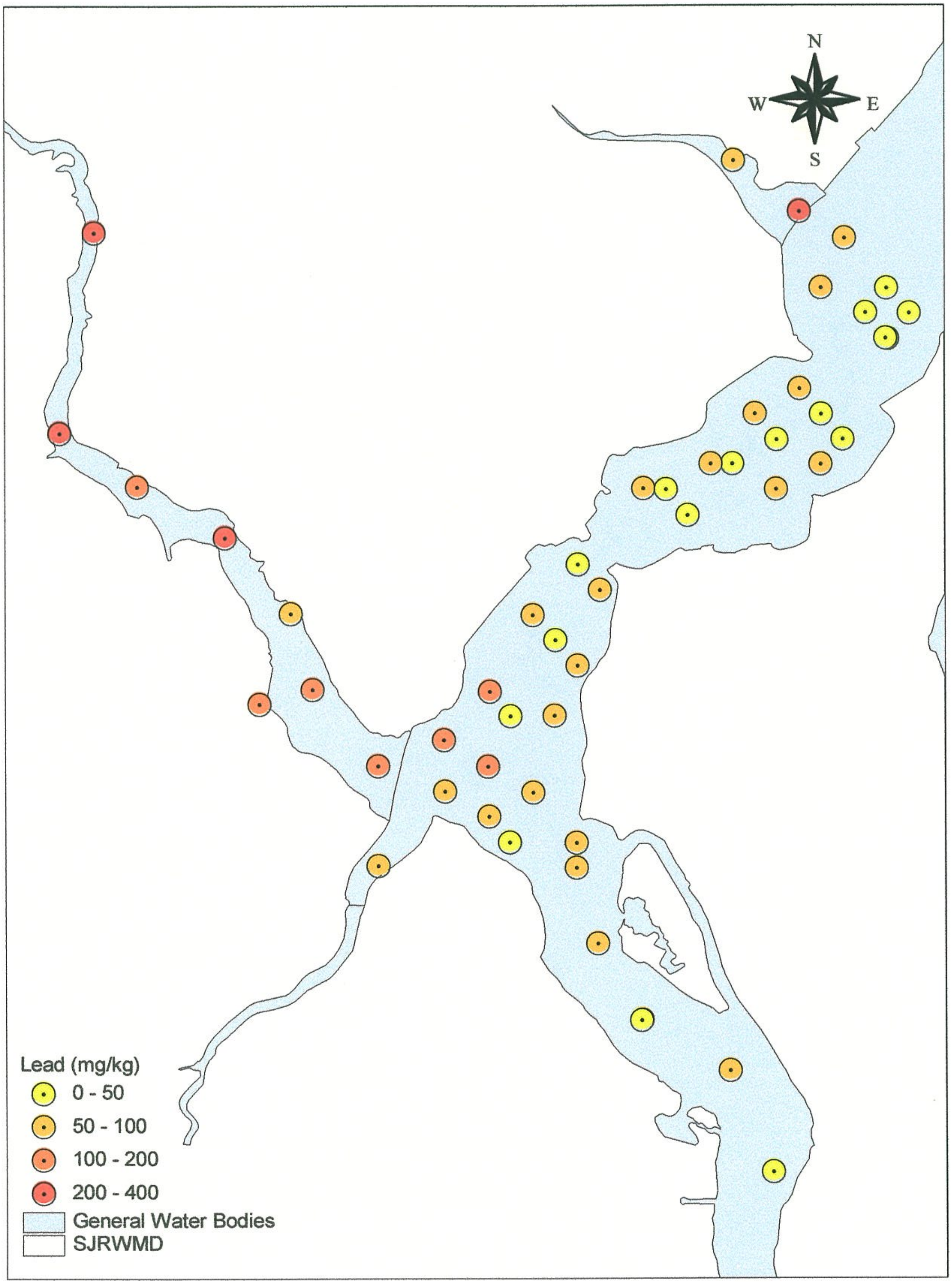


Figure 4-29. Map Displaying Surface Sediment Lead (Pb) Concentrations
(a) Non-Normalized

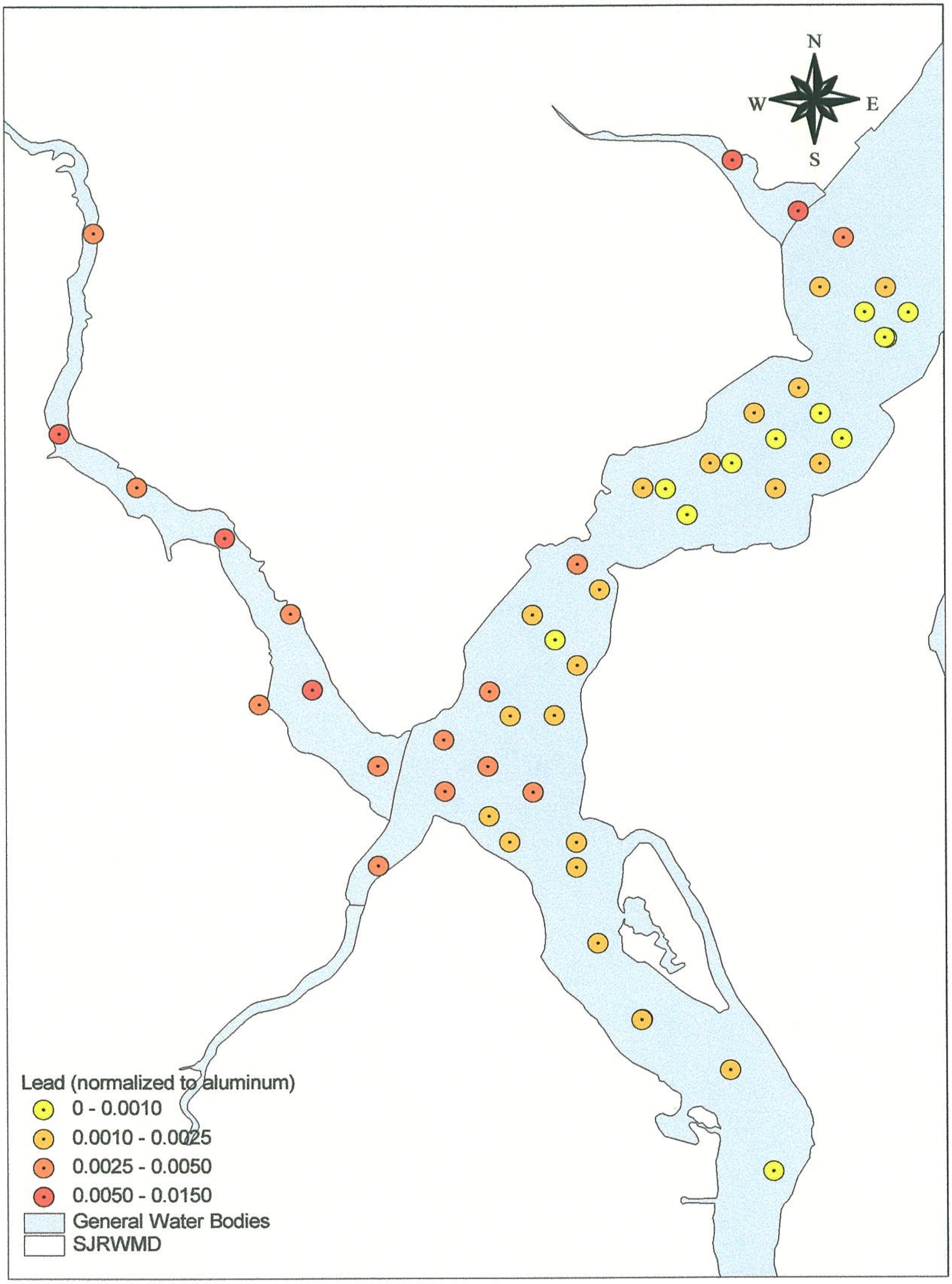


Figure 4-29 (cont.). Map Displaying Surface Sediment Lead (Pb) Concentrations (b) Normalized to Aluminum

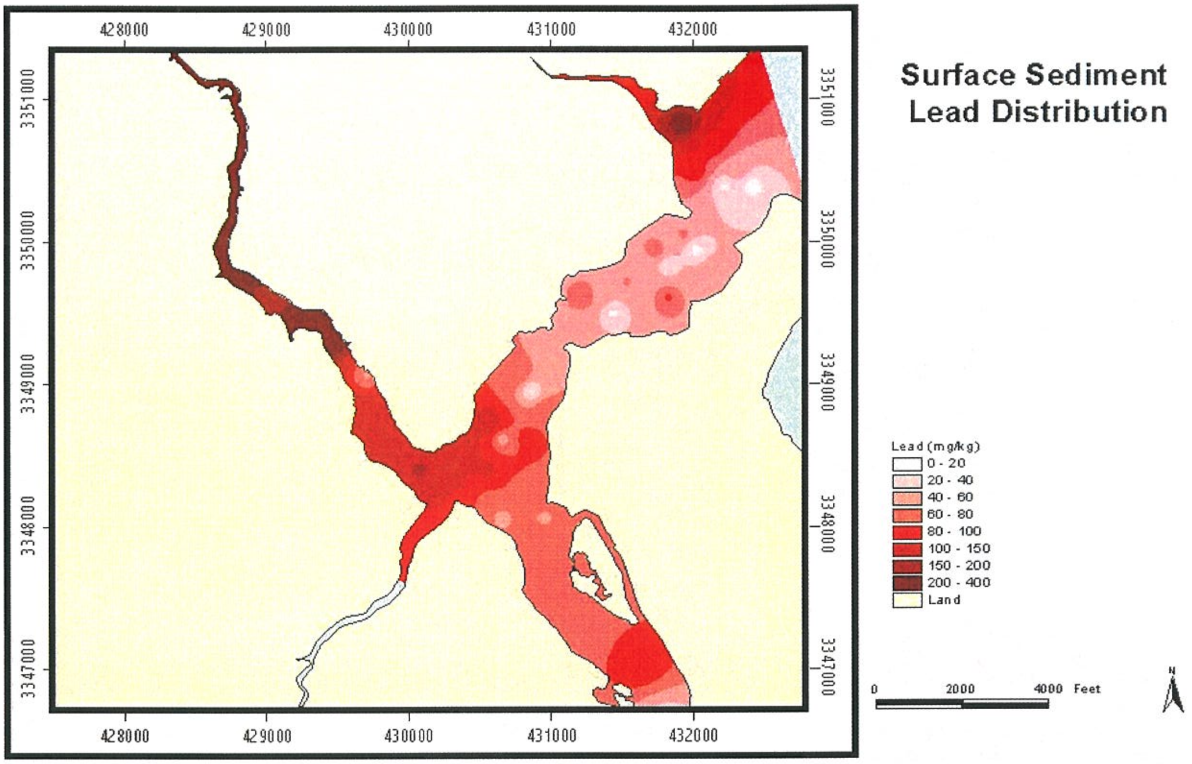


Figure 4-30. Extrapolated Surface Sediment Lead (Pb) Concentrations

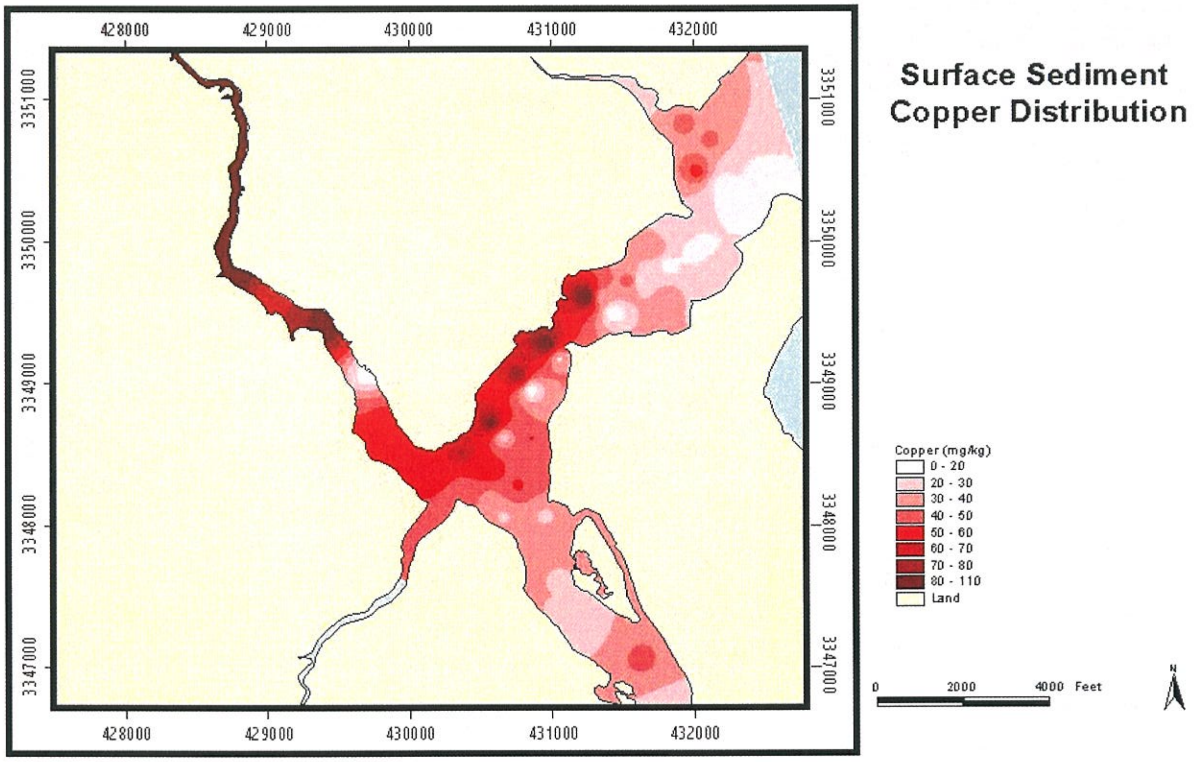


Figure 4-31. Extrapolated Surface Sediment Copper (Cu) Concentrations

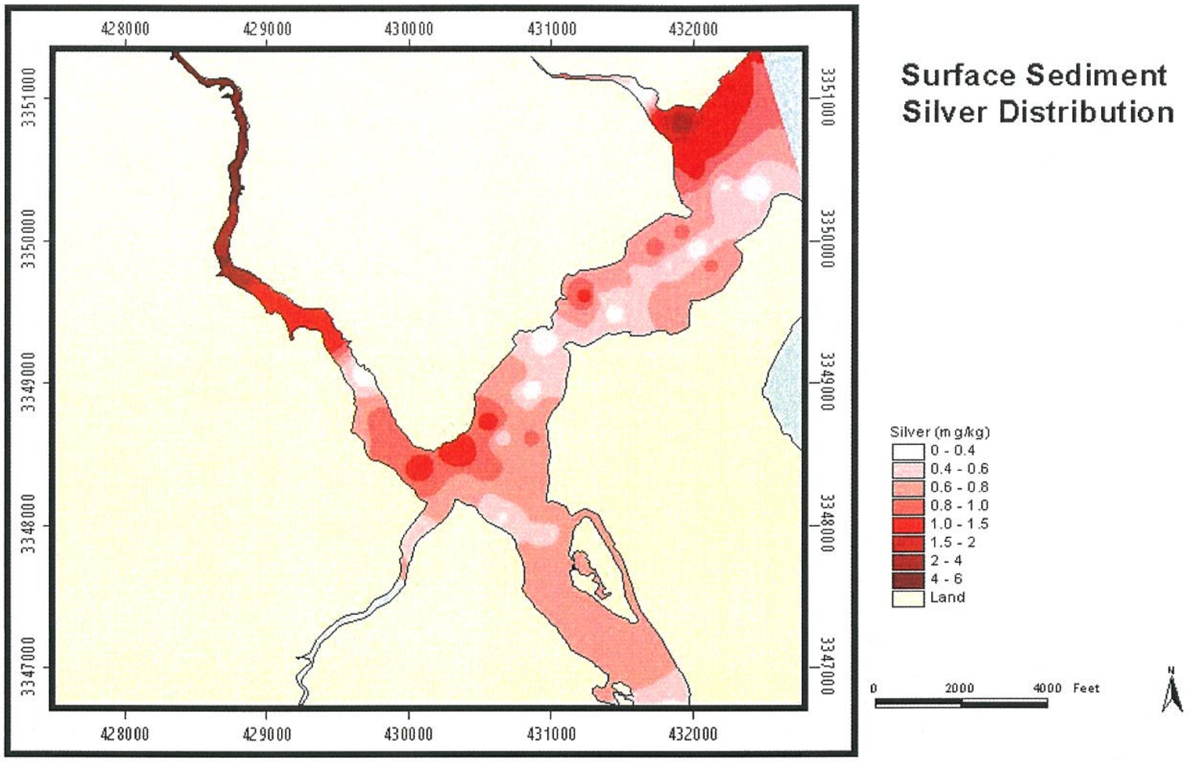


Figure 4-32. Extrapolated Surface Sediment Silver (Ag) Concentrations

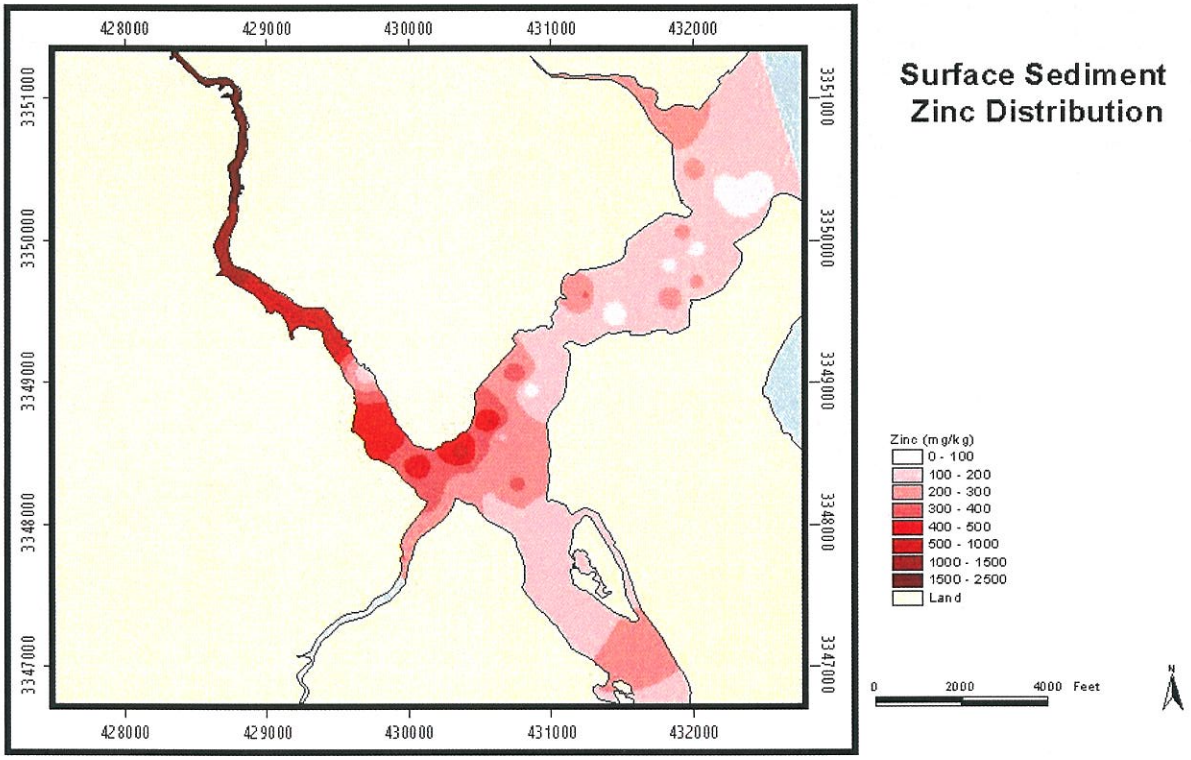


Figure 4-33. Extrapolated Surface Sediment Zinc (Zn) Concentrations

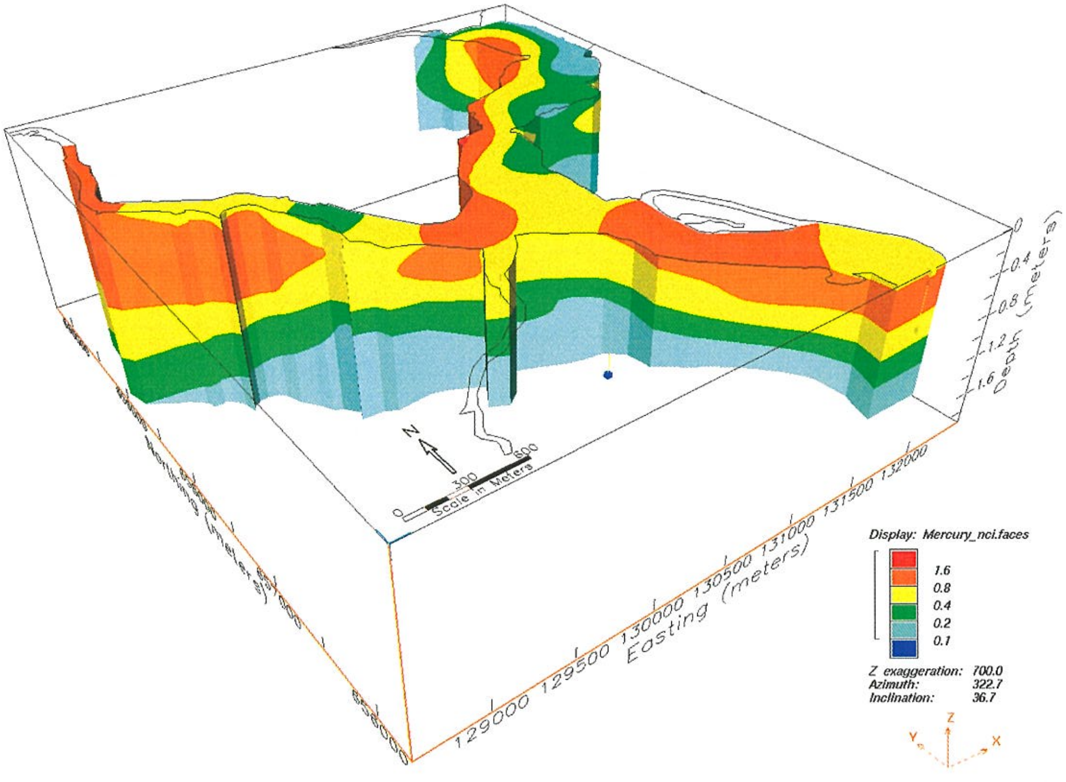


Figure 4-34. 3-D Visualization of the Mercury Concentration in the Cedar-Ortega River Basin

The sub-surface sediment metals concentrations typically decreased down-stream (Figure 4-35) and with sediment depth (Figure 4-36) for the metals that had elevated surface sediment concentrations in the Cedar River. However, the toxic metals concentrations in most of the *near-surface* sub-surface sediments were comparable to the surface sediment metals concentrations, and, similarly to PCB and DDT, some near-surface sediments had the highest concentrations, indicating high historic loadings. Lead, mercury, and zinc, for instance, were present at higher concentrations in most of the 10-30cm deep sediments than in the surface sediment (Figures 4-34, 4-35, 4-36, and Table 3-12), possibly reflecting a small decline in the loadings of these toxic metals. The phasing out of leaded gasoline has eliminated one significant source of lead in our environment. Many other industrial processes have changed, reducing the creation of metals pollution from specific processes.

COR Concentrations Compared to Other Studies

Several of the metals measured in this study, were present at higher concentrations in the Cedar-Ortega River Basin than in the lower St. Johns River and other national monitoring programs (Tables 4-1 and 4-2). The median concentration of copper, lead, mercury, silver, tin, and zinc were approximately three times higher in the COR surface sediments than in the surface sediment samples from the LSJR.

A relatively large proportion of the sediment sites had surface sediment cadmium, copper, lead, mercury, selenium, silver, tin, and zinc concentrations that exceeded the NS&T/MW "high" value; these metals exceeded the reference value at 86%, 41%, 80%, 90%, 92%, 65%, 57%, and 73% of the COR sites, respectively, compared to 31%, 25%, 23%, 30%, 15%, 22%, 20%, and 22%, respectively, for all COSED sites. There were fewer exceedances for the NS&T/MW sediment sites (between 12% and 18%, for these metals) than the COSED sites.

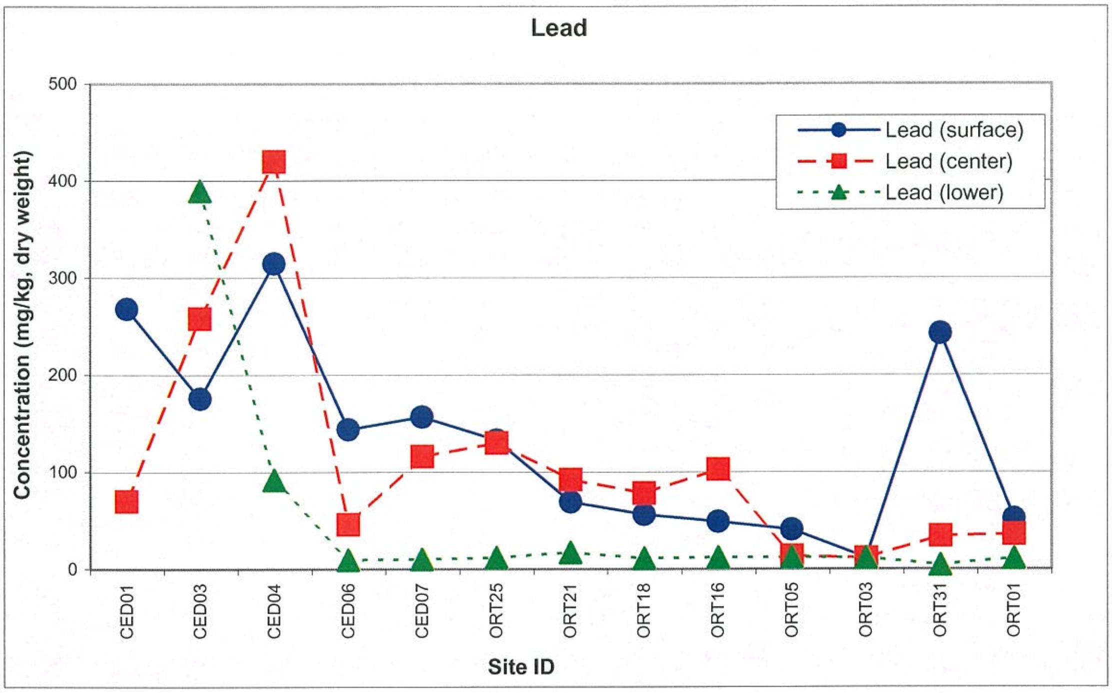


Figure 4-35. Lead (Pb) Concentrations at Different Sediment Depths at Selected Sites

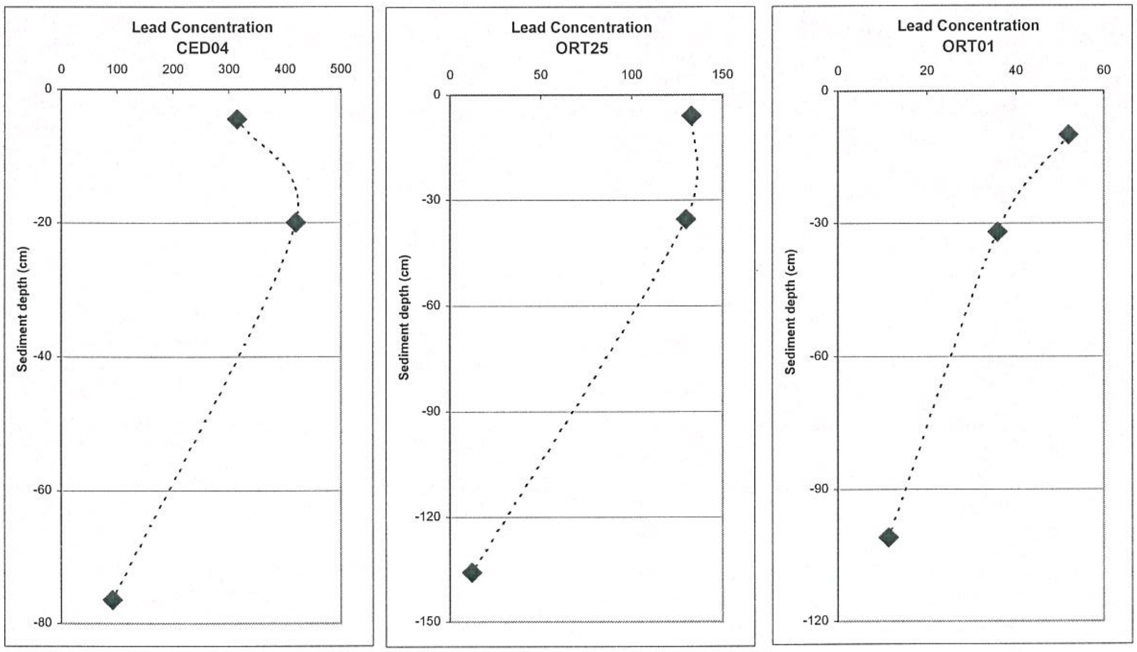


Figure 4-36. Lead Concentration Profiles in Sediment Cores Collected at Sites CED04, ORT25, and ORT01

There were no, or fewer, NS&T/MW "high" value exceedances for arsenic, chromium, nickel, antimony for the COR sites than there were in the NS&T/MW and COSED data sets. The fairly high rate of exceedances for many metals may, partly, be due to differences in the geology of the sediments; the Cedar-Ortega River sediments may be naturally more enriched in these metals than the average U.S. coastal sediment. Another factor could be the relatively fine grain size of these sediment, as compared to most coastal sediment (the NOAA "high" values are based on non-normalized data), resulting in a naturally elevated metals concentrations as compared to coarser grain size sediments. Additionally, mercury results are difficult to dependably compare with historical data because significantly more reliable analytical methods were used in this study than were available for most historical monitoring programs. A major evolution in analytical methods has also occurred for other trace metals, but is particularly significant for mercury. However, the very high rate of exceedance for many metals, in addition to the significantly higher rate of exceedance as compared to the St. Johns River, clearly suggests that the Cedar-Ortega River Basin has notably elevated concentrations of many toxic metals (e.g., cadmium, chromium, copper, lead, mercury, silver, and zinc).

4.2.2 Metals — Potential Hot Spots

The contaminant concentration evaluations described earlier suggest that there are parts of the Cedar-Ortega River Basin that have elevated concentrations of selected metals, as compared to other parts of the study area, just as there are for organic contaminants. These include areas in the upper parts of the Cedar River and around sites ORT31, ORT33, and ORT19. The northern parts of the Cedar River (e.g., CED01 and CED02) had higher concentrations of several metals (e.g., copper, lead, and zinc) than other parts of the Basin, and these concentrations declined down stream. The PCB and DDT concentrations had a similar contaminant distribution, suggesting there may be current, related or unrelated, source(s) of these metals and organic contaminants upstream of site CED01.

The area around ORT31 and ORT33 (Fishweir Creek area) also had significantly higher concentrations of some metals (e.g., lead and silver, and, to a lesser degree, zinc) than most other parts of the Basin, but more so at site ORT31 than at the northern-most site (ORT33) where the most significant elevation of organic contaminants was observed. This could mean that much of the organic contamination that is observed is coming from Big Fishweir Creek (and also maybe Little Fishweir Creek), while most of the metals contamination may originate in Little Fishweir Creek or other runoff and discharges. These data suggest that this small water body that enters the mouth of the Ortega River by ORT31/ORT32 receives elevated amounts of a number of metals and organic contaminants from local source(s). Several small creeks (e.g., Big Fishweir Creek and Little Fish Creek) and other urban/residential runoff discharges enter into this water body.

Site ORT19, near the north side of the Roosevelt Blvd bridge along the north shore of the central part of the main Basin area, is a site that had elevated concentrations of copper and mercury, and may be impacted by a local source. These metals are not dramatically elevated at other locations in the central parts of the Basin, so there is clearly a site-specific signal to this contamination. The PAH concentrations were also particularly elevated at this location, and the composition of the PAH was slightly different at this location, all suggesting that there may be local source(s) of PAH, copper, and mercury contamination.

4.2.3 Metals — Indicators of Potential Effects

The surface sediment metals contaminant data were compared to sediment quality guidelines to identify areas that may potentially be ecologically impacted by chemical contaminants, much like what was done for the organic contaminant data. For this evaluation, the sediment metals concentrations were compared to both the freshwater TEC/PEC and marine/coastal ERL/ERM indicators (Tables 4-3 and 4-4). The results of this data comparison are summarized in Table 4-5. Figure 4-37 presents the lead data relative to the TEC/PEC and ERL/ERM values, and Figure 4-38 presents this information for mercury. Similar figures for the other seven metals that are typically of environmental concern, and for which there are published TEC/PEC and ERL/ERM values, are compiled in Appendix P.

There were many more metals sediment quality guideline exceedances in the Cedar-Ortega River Basin than the St. Johns River (Battelle, 2004). There were a relatively limited number of PEC exceedances; the PEC for lead was exceeded at ten sites (e.g., CED01, CED02, CED04, and ORT31), mercury at six sites (e.g., ORT19, ORT22, ORT38, and ORT39), and zinc at seven sites (mostly in the Cedar River). There were no PEC exceedances for arsenic, cadmium, chromium, copper, or nickel. There are no TEC/PEC reference values for silver, but this metal was detected at concentrations that exceeded the ERM at two locations (CED01 and CED02). There were significantly more exceedances of the more conservative, and lower, TEC and ERL values, as is evident from the figures in Appendix P and the summary data in Table 4-5; all metals had some TEC and ERL exceedances. Mercury had the largest number of TEC (and ERL) exceedances; 90% of the sites exceeded the mercury TEC, followed by chromium (88% of the sites), lead (84% of the sites), zinc (80% of the sites), and copper (55% of the sites). The reliability of using the mercury ERL (or TEC) value to assess potential risk is often particularly hotly debated at scientific meetings, and it should certainly only be used as a general guideline and only as a component of a more comprehensive environmental quality assessment.
The sites with the most metals TEC and ERL exceedances were CED01 and CED02 (all metals with TEC and ERL values exceeded these measures) followed by CED04. Many sites had five or more TEC and ERL metals exceedances. The sediment quality guideline exceedances were concentrated in or near the Cedar River, and also the Big Fishweir Creek area, for several of the metals with notable exceedances (e.g., copper, lead, silver, and zinc), indicating that the sediment quality issues may be originating in sources upstream of these locations. There were also a large number of sediment quality guideline exceedances for mercury and cadmium, but the contaminant concentrations and sediment quality exceedances were more broadly distributed throughout the Cedar Ortega River Basin for these two metals. This data set shows a significant amount of sediment quality guideline exceedances for the Cedar-Ortega River Basin, resulting in an impression of a fairly wide spread potential for biological impact from metals in the study area.

As mentioned previously, the application of these sediment quality guidelines should be made with caution, particularly for toxic metals. Most of the guidelines were developed for individual parameters and do not incorporate additive or interactive effects due to multiple toxic components. In addition, 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).

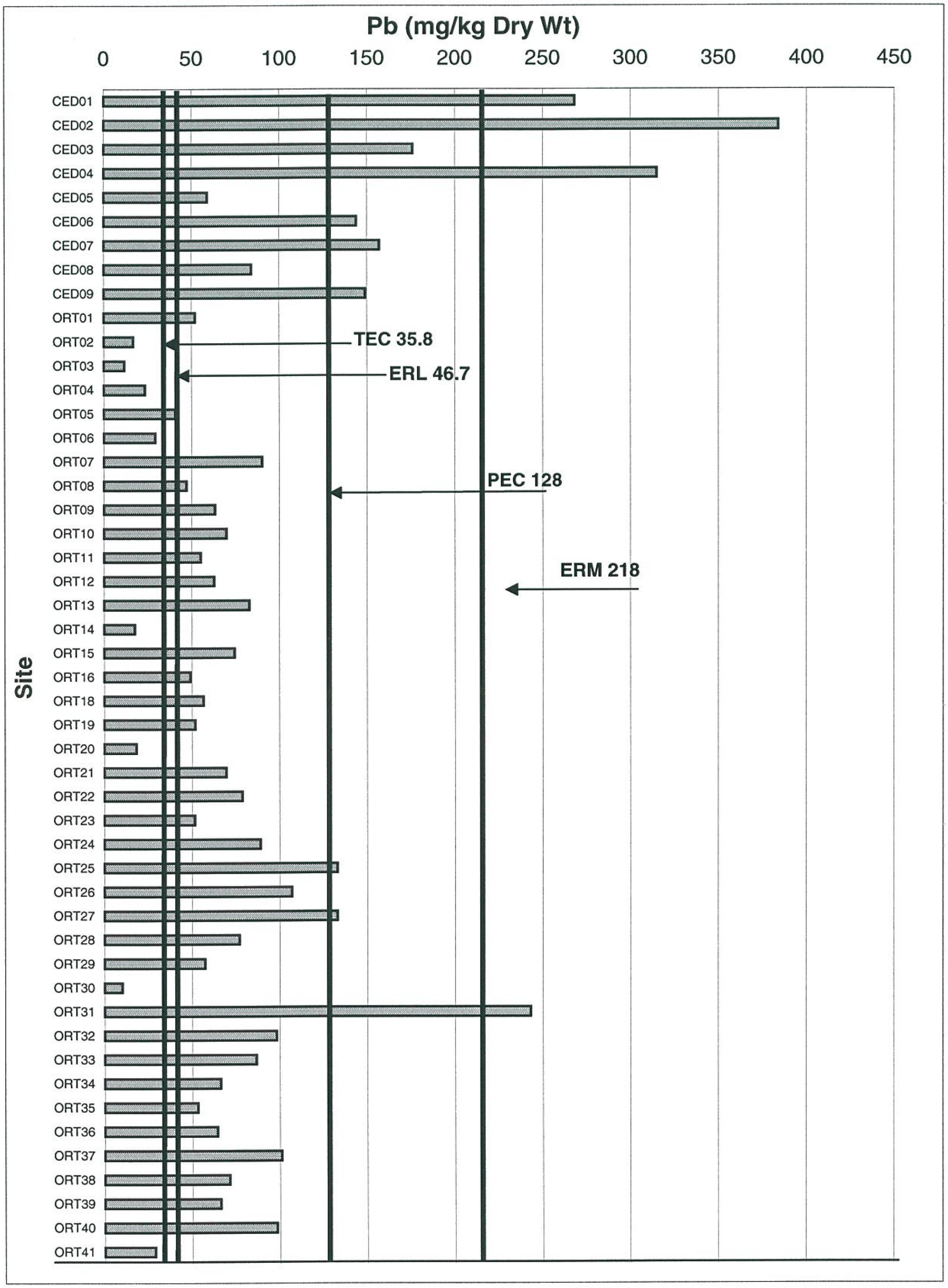


Figure 4-37. Surface Sediment Lead (Pb) Concentrations and SQG Values

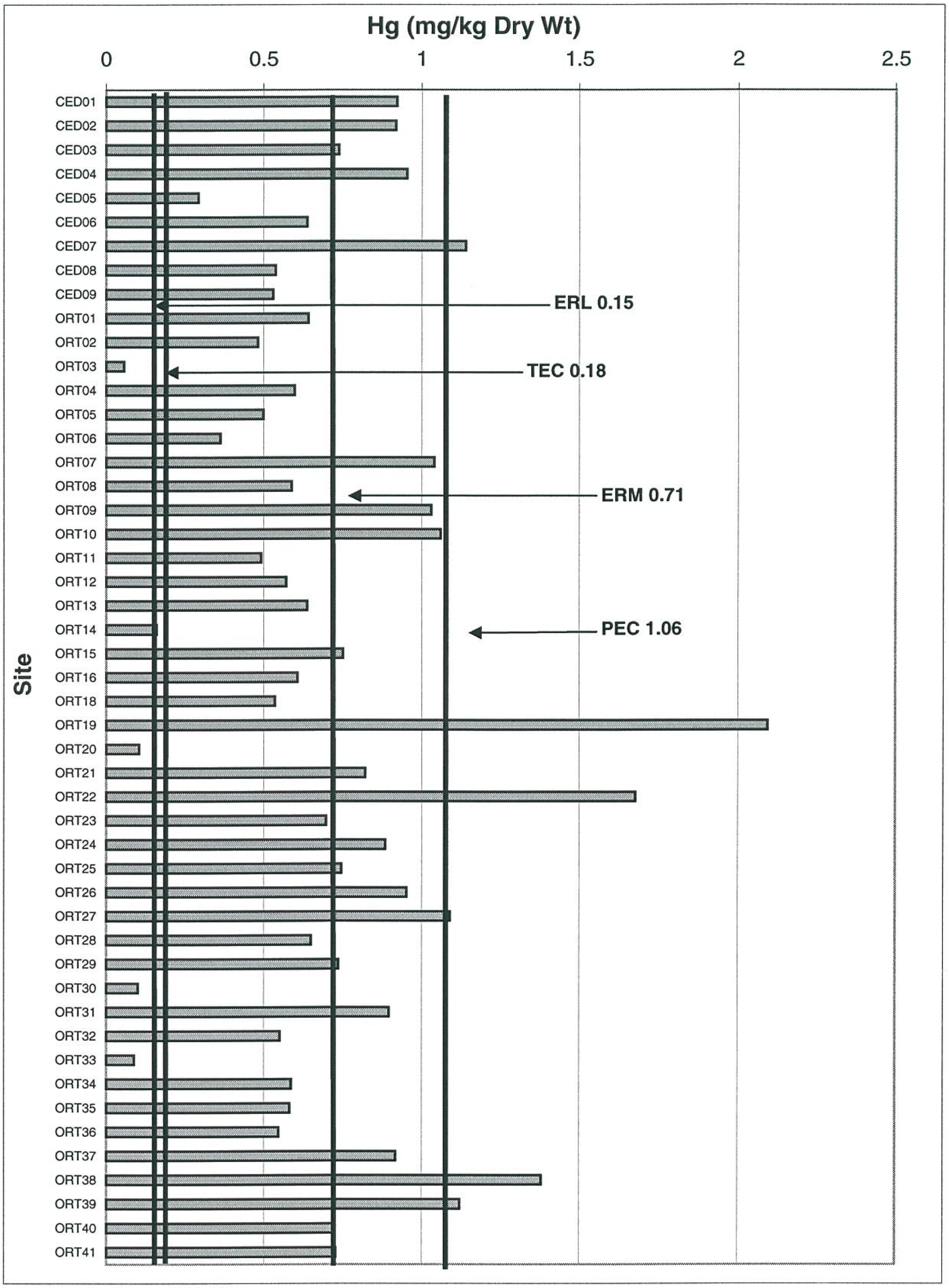


Figure 4-38. Surface Sediment Mercury (Hg) Concentrations and SQG Values

4.3 Preliminary Assessment of the Ecological Implications of the Measured Contamination

Surficial sediments of the Cedar-Ortega River system are contaminated with a wide variety of metal and organic contaminants, probably derived in large part from urban and industrial activities in the river drainage basin. For a chemical contaminant to be classified as a pollutant, it must be demonstrated to be causing adverse biological effects. Estimating or predicting the toxicity of chemicals in sediments is difficult. Many factors affect the bioavailability and toxicity of sediment-associated chemicals. For a chemical to be toxic to an aquatic organism, it must be in a form that is bioavailable. A chemical is said to be bioavailable if it is in a form that can move through or bind to the surface coating (e.g., skin, gill epithelium, gut lining, cell membrane) of an organism (Newman and Jagoe, 1994). The physical form and phase associations of the chemicals in the sediments control the bioavailability and, therefore, the toxicity of chemicals in sediments.

The forms of metals that can readily partition between dissolved and particulate phases in sediment are the most bioavailable. Metals associated with iron and manganese oxyhydroxide coatings on clay particles or with carbonates seem to be the most bioavailable forms in oxidized freshwater sediment layers (Neff, 2001). When oxygen is depleted in sediments, the oxidation/reduction potential (redox potential) drops and iron and manganese oxides dissolve, releasing adsorbed metals. Most of the metals in hypoxic and anoxic (low redox potential) sediments precipitate as metal sulfides or complex with sediment organic matter (Fernandes, 1997; Mortimer and Rae, 2000). The sulfides and metal-organic matter complexes have a low bioavailability and toxicity.

The bioavailability of nonpolar (un-ionizable) organic chemicals, such as PAHs, PCBs, and chlorinated pesticides, to aquatic organisms also depends on the physical and chemical forms of the compounds. Organic chemicals in true solution in the water column or sediment pore water usually are much more bioavailable than organic chemicals that are present in complexed, adsorbed, or solid forms. Complexation of organic contaminants with natural dissolved organic matter in water and sediment pore water decreases their bioavailability to aquatic organisms (Landrum *et al.*, 1987). Organic matter in the water and sediments, primarily dissolved, colloidal, or solid humic substances (Gschwend and Schwarzenbach, 1992), tends to complex reversibly with dissolved nonpolar organic chemicals, such as PAHs, decreasing their bioavailability to aquatic organisms (Servos et al., 1989). Much of the PCBs in the porewater of contaminated harbor sediments is complexed to dissolved organic matter and is not in true solution (Brownawell and Farrington, 1986). These complexed PCBs have a low bioavailability. The tendency of nonpolar organic chemicals to form complexes with dissolved organic matter increases with molecular weight and hydrophobicity (the tendency for a chemical to escape the aqueous phase by adsorption or absorption, proportional to log octanol/water partition coefficient [K_{ow}]) and decreases with increasing ionic strength (salinity) of the water (McCarthy et al., 1985; Schlautman and Morgan, 1993). This concept forms the basis for derivation of sediment quality criteria for nonpolar organic contaminants in sediments based on equilibrium partitioning theory (Di Toro *et al.*, 1991).

PAHs have a complex geochemistry in sediments that affects their bioavailability and toxicity to aquatic organisms (Neff, 2001). PAHs may be present in the water and sediments of the Cedar-Ortega River in true solution, complexed with dissolved organic matter and colloids, as micelles, adsorbed on the surface of particles, occluded within particles (e.g., in soot, coal, or tar), associated with oil droplets, and in the tissues of aquatic organisms (Readman *et al.*, 1984a,b; Gschwend and Schwarzenbach, 1992). The hydrocarbons in the different phases are exchangeable but, at any given moment, only a fraction of the total hydrocarbons in the water is in bioavailable forms. The dissolved hydrocarbons are the most bioavailable, followed by those in tissues of aquatic organisms (if the organisms are eaten) or associated with liquid oil droplets. Particulate PAHs associated with soot and coal particles have a low bioavailability to aquatic organisms (Farrington, 1986; Baumard *et al.*, 1999).

Sediments of the Cedar-Ortega River contain high concentrations of total organic carbon (TOC). The median TOC concentration in surficial layers of tested sediments was 12.5 percent; the range of concentrations was from 2.3 percent to 21.6 percent (Table 3-13). Subsurface layers of the sediments contain slightly higher concentrations of TOC. The chemical structure and origins of the organic matter in the sediments is not known. There is not a relationship between the fraction of silt plus clay and TOC concentration in the sediments, indicating that at least part of the organic matter is coarse-grained. Dissolved/colloidal organic matter and organic matter sorbed to clay and iron/manganese oxide particles are responsible for most of the binding of nonpolar organic chemicals and some metals in sediments. Larger organic particles, such as plant debris and detritus, binds relatively little of the chemical contaminants in sediments. Because of the heterogeneity of the TOC in these sediments, there is no correlation between TOC concentration and any metal or organic contaminant concentration in the sediments. Therefore, it is not possible to estimate the dissolved (bioavailable) fraction of organic compounds in sediment pore water based on equilibrium partitioning theory (Di Toro *et al.*, 1991).

Fine-grained sediments with TOC concentrations greater than about 3 to 4 percent usually are hypoxic or anoxic (low redox potential). The oxygen concentration in Cedar-Ortega River sediments is not known, but probably is low. Thus, most of the metals in the sediments probably are associated with reduced phases, sulfides, and organic matter. Concentrations of the exchangeable, more bioavailable metals probably are low. The US EPA has proposed to develop sediment criteria for five metals based on concentrations of acid volatile sulfides (AVS) and simultaneously extractable metals (SEM) in sediments (Ankley *et al.*, 1996). The theoretical basis of this approach is that acid volatile sulfides in sediments control the fraction of the total metal in sediment that is in an exchangeable, bioavailable form. Any easily extractable metal in excess of that that could be bound to sulfide should be bioavailable. Thus the difference between the molar concentration of acid volatile sulfides and simultaneously extracted metals should represent the bioavailable, toxic fraction of the metal in sediments. If the concentration of sulfur is high in sediments, as it is in all marine sediments and many freshwater sediments, the concentration of acid volatile sulfide in anoxic sediment layers is likely to be in excess of the concentration of simultaneously extractable metals. Thus, if the river sediments are anoxic, the metals, even those that are present at high concentration, may have a limited bioavailability and toxicity to aquatic organisms.

However, the main effect of sediment hypoxia on river sediment communities is caused directly by the limited availability of oxygen. Organic enrichment of sediments causes a depletion of sediment oxygen concentrations (due to oxygen consumption by microbes that are degrading the organic matter) and results in a substantial reduction of the number and diversity of aquatic macroorganisms inhabiting the sediments (Pearson and Rosenberg, 1978; Spies *et al.*, 1988).

Because of the organic enrichment of Cedar-Ortega River sediments, it is not possible to accurately estimate the risk of sediment contaminants on plants and animals in the river system. A conservative (protective) estimate of sediment toxicity can be made by assuming that the bioavailability of metals and organic contaminants in the river sediments are similar to those in most other freshwater sediments. Sediment concentrations can be compared to sediment quality guidelines to identify sediments that contain sufficient concentrations of one or several contaminants to cause toxicity in aquatic organisms.

Contaminants and Areas of Concern

A hazard quotient (HQ) was estimated for 17 abundant contaminants or contaminant groups (e.g., total PAHs) in each of the 49 broadly characterized surficial sediment samples from the Cedar-Ortega River system. The HQs for all contaminants in each sediment were summed to develop a hazard index for total contaminants in each surficial sediment sample. For this exercise, we defined the HQ as the measured concentration of the contaminant in the sediment sample divided by the freshwater threshold effects concentration (TEC) or probable effects concentration (PEC) for chemicals in freshwater sediments (Table 4-3). HQs were determined using both the lower TEC and higher PEC values (Table 4-7a and b, respectively). Table 4-7 presents the data for the 4 primary organic contaminants and the 9 metal contaminants for which sediment quality guidelines are available. Additional HQ data are presented in Appendix R, including HQs calculated using ERL and ERM SQGs, in addition to TEC and PECs. Information on the approximate contribution of the different contaminants to the overall HI value for each site is also included in Appendix R.

The TEC is a highly conservative guidance value, because the bioavailable fraction of contaminants in sediments probably was grossly overestimated by using the total measured concentration, as discussed above. Therefore, the PEC may give a more realistic estimate of the real risk for contaminants in these site sediments. However, the TEC can be used to perform a highly conservative general screening assessment, and combining both SQG evaluations provides a more complete understanding of the potential risk the sediments may pose. In the end, a review of the TEC and PEC-based HIs, along with such information using ERL and ERMs, provides a thorough assessment and yields an overall picture of the risk these sediments may potentially pose to the local ecology. In this approach, a hazard index (HI; sum of HQs) greater than about 1.5 to 2 using the PEC-based evaluation indicates that the sediment may be toxic to bottom living aquatic organisms (Lee *et al*., 2001), assuming that toxicity of contaminants is approximately additive. The sites in Table 4-7 are ranked in order of decreasing HI. The percent of sites with a HQ > 1.0 also is included in this table.

Most of the 49 surficial sediment samples from the Cedar-Ortega River system had PEC-based HI values greater than 2, indicating that most of the sediments could be toxic to sediment-dwelling freshwater organisms (Table 4-7b). The highest HI value was 31.1 (from Site CED02). Six sediment samples had HIs greater than 10, and 24 sites had HIs above five. The most toxic sediments were from the Cedar River. The only sediment that probably was not toxic was from around Site ORT30 near the confluence of the Ortega River with the St. Johns River.

Table 4-8 presents the average percent contribution of the different key contaminants to the calculated HI values. This table shows the *average* information for the Cedar-Ortega River Basin as a whole. However, the chemicals contributing the most to the toxicity of the sediments vary considerably for different sediments based on their location (Table 4-7 and Appendix R). The dominant toxicant in the three most toxic sediments (from Sites CED02, CED01, and CED04), and most of the Cedar-Ortega River Basin, is PCB (Table 4-7a and 4-7b). PCB contributed between 31% and 73% of the TEC- and PEC-based HI values for the three sites with the highest estimated toxicity. Four other sites (all from the Cedar River) had PEC-based HQs for PCBs greater than 1. The major contributor to the toxicity of the sediment from the Fishweir Creek area (sites ORT31 and ORT33) was chlordane; it contributed about half of the HI of the sediments in this area. PAH, in addition to chlordane and PCB, contributed greatly to the potential toxicity of the sediments at the mouth of Butcher Pen Creek (at site CED09).

PCB is the contaminant of greatest concern in the Cedar-Ortega River Basin sediments, contributing about 20 to 25% of the risk/impact to the Basin as a whole, and substantially more in the most contaminated sediments; more than 50% of the toxicity can be attributed to PCB at the most contaminated upstream Cedar River locations. However, there are several other contaminants that are a significant issue in the Basin. Chlordane, PAH, mercury, lead, and zinc also contribute substantially to the toxicity of many of the sediments (Tables 4-7 and 4-8). For instance, chlordane contributes between 40 and 55% of the TEC- and PEC-based toxicity estimates at the highly contaminated Fishweir Creek sites, and more than 80% of the sediments contain lead at a concentration resulting in a TEC-based HQ greater than 1.0 (20 percent had lead concentrations that exceeded the PEC). Cadmium, chromium, and copper also had a significant rate of TEC-based HQ values greater than 1, but were not present in any sediment at concentrations equivalent to a PEC-based HQ of above 1. Arsenic and silver were rarely detected at potentially toxic concentrations, except at some of the most upstream Cedar River sites.

Table 4-7a. Estimated Hazard Quotients (HQ) for Contaminants in the Cedar-Ortega River Basin Sediments (HQ:ratio of surface sediment concentration to TEC)

Site	PAH	PCB	DDT	Chlor	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn	Total HI[a]
CED02	7.73	192	5.91	6.24	1.54	3.68	2.16	3.29	10.7	5.10	1.05	4.04	11.8	262
CED01	3.42	167	16.6	2.23	2.50	3.87	2.21	2.63	7.49	5.12	1.00	5.39	16.9	236
CED04	9.92	50.8	3.82	6.40	0.88	3.06	1.87	2.79	8.80	5.29	1.00	1.37	6.58	105
CED09	18.5	13.7	6.83	24.2	0.51	1.44	1.19	1.66	4.16	2.94	0.66	0.68	4.32	83.4
CED03	6.46	38.7	3.54	5.37	0.64	2.09	1.21	2.07	4.92	4.10	0.73	1.06	5.02	77.4
ORT31	6.91	5.14	6.66	29.3	0.52	1.67	1.31	1.34	6.79	4.98	0.63	2.36	2.26	71.6
CED06	8.51	18.8	4.43	10.4	0.56	1.34	1.32	1.71	4.02	3.54	0.67	0.87	3.71	62.4
ORT33	9.47	2.99	9.74	23.2	0.18	0.58	0.39	0.69	2.42	0.49	0.22	0.25	1.79	59.8
CED07	5.16	21.3	2.30	5.02	0.53	1.67	1.53	1.80	4.39	6.33	0.73	1.11	3.50	56.8
ORT25	7.64	7.38	4.75	9.95	0.71	1.75	1.86	2.70	3.72	4.14	0.89	1.18	4.30	53.9
ORT27	5.20	8.77	3.26	4.27	0.63	1.76	1.65	2.26	3.72	6.06	0.82	1.39	4.85	46.3
ORT22	3.40	7.50	2.64	2.44	0.66	1.29	1.25	2.56	2.20	9.32	0.67	0.73	3.02	38.4
ORT32	3.92	4.29	5.19	8.74	0.67	1.22	1.47	1.34	2.74	3.06	0.69	1.24	1.55	38.2
ORT37	4.14	7.23	3.27	4.81	0.52	1.28	1.46	1.53	2.82	5.09	0.72	0.65	2.05	37.5
ORT26	4.24	5.60	4.09	3.94	0.55	1.59	1.63	1.86	2.99	5.29	0.79	0.95	2.07	37.1
ORT15	4.39	5.15	4.33	3.66	1.04	1.26	1.58	3.20	2.08	4.17	0.81	1.16	2.60	36.8
ORT07	3.28	2.28	8.67	2.45	0.75	1.65	1.73	1.74	2.52	5.78	0.92	1.08	1.89	36.0
ORT19	5.06	8.15	2.21	0.81	0.29	0.30	0.36	2.91	1.45	11.6	0.19	0.27	1.11	34.9
CED08	4.72	5.52	2.48	6.73	0.29	1.30	1.13	1.45	2.35	2.99	0.62	0.47	2.36	33.5
ORT24	3.58	3.10	5.11	3.17	0.68	1.02	1.53	1.59	2.49	4.92	0.74	0.85	1.93	32.6
ORT38	3.20	1.95	7.12	1.66	0.81	1.73	1.40	0.92	1.99	7.67	0.68	0.79	1.27	32.1
ORT28	3.12	2.92	3.78	3.89	0.77	1.18	1.34	1.63	2.15	3.61	0.68	0.71	2.70	31.6
ORT39	2.59	5.41	4.74	1.77	0.42	1.37	1.50	0.85	1.85	6.23	0.78	0.75	1.52	30.8
ORT23	2.47	5.39	2.80	1.92	0.47	0.59	1.30	0.83	1.44	3.88	0.60	0.47	1.56	27.0
ORT12	3.48	5.63	3.00	1.52	0.67	0.92	1.43	1.41	1.75	3.17	0.70	0.63	1.28	26.8
ORT40	3.02	3.19	1.41	2.45	0.49	1.47	1.31	1.32	2.75	4.03	0.71	0.71	2.28	26.7
ORT13	3.27	2.78	3.94	1.61	0.68	1.33	1.52	1.21	2.31	3.54	0.75	0.79	2.05	26.0
ORT09	2.44	1.98	2.99	1.14	0.65	1.72	1.35	0.90	1.77	5.72	0.61	0.91	1.93	25.6
ORT10	2.49	2.95	1.79	1.13	0.66	1.37	1.37	1.17	1.95	5.89	0.65	0.94	1.56	25.0
CED05	1.37	10.8	1.71	2.92	0.18	0.56	0.52	0.43	1.65	1.63	0.32	0.26	1.25	24.5
ORT21	2.42	3.06	2.58	1.34	0.47	0.86	1.31	0.96	1.94	4.57	0.61	0.70	1.13	23.2
ORT34	2.60	4.31	2.44	1.32	0.34	1.07	1.24	1.05	1.85	3.26	0.67	0.55	1.50	22.9
ORT36	2.49	1.92	3.63	2.31	0.52	1.03	1.32	1.02	1.79	3.04	0.65	0.55	1.22	22.7
ORT16	2.77	1.78	2.99	1.07	0.42	0.85	1.38	1.00	1.37	3.37	0.70	0.57	1.05	20.2
ORT11	1.82	3.25	2.08	0.83	0.69	1.05	1.45	0.82	1.54	2.73	0.70	0.65	1.81	20.1
ORT01	1.63	2.93	2.00	0.22	0.55	1.44	1.34	0.68	1.45	3.57	0.61	0.80	0.93	19.9
ORT08	1.35	3.29	2.11	0.64	0.56	1.09	1.51	0.79	1.31	3.27	0.74	0.90	1.42	19.5
ORT35	2.43	1.90	2.22	1.69	0.52	0.48	1.11	0.90	1.49	3.23	0.54	0.38	1.16	19.1
ORT18	3.01	1.91	1.53	1.27	0.38	0.92	1.16	0.92	1.58	2.98	0.62	0.50	1.16	18.8
ORT29	0.46	2.07	0.43	0.70	0.21	1.12	1.29	0.88	1.60	4.09	0.70	0.63	1.03	15.7
ORT41	1.26	1.28	1.85	0.46	0.31	0.65	0.92	0.61	0.80	4.04	0.57	0.33	0.66	14.5
ORT06	1.32	2.79	1.43	0.35	0.45	0.89	1.33	0.48	0.82	2.02	0.59	0.48	0.67	14.3
ORT05	2.01	1.48	1.85	0.00	0.45	0.77	1.24	0.60	1.14	2.77	0.60	0.46	0.89	14.3
ORT04	1.36	0.73	1.05	0.30	0.44	0.67	1.26	0.44	0.66	3.32	0.67	0.39	0.54	12.1
ORT02	0.60	0.50	0.35	0.01	0.39	0.51	1.26	0.33	0.47	2.68	0.63	0.37	0.43	8.6
ORT03	0.56	2.56	0.22	0.00	0.43	0.22	1.17	0.17	0.33	0.32	0.56	0.11	0.48	7.9
ORT14	1.17	0.55	0.86	0.06	0.33	0.42	1.19	0.34	0.49	0.89	0.60	0.29	0.39	7.9
ORT20	1.10	0.75	0.55	0.17	0.34	0.29	0.95	0.40	0.51	0.58	0.54	0.19	0.39	7.0
ORT30	0.35	0.15	0.18	0.00	0.14	0.14	0.43	0.15	0.28	0.56	0.19	0.11	0.62	3.6
%HQ>1	92	90	88	71	6	63	88	55	84	90	4	22	80	---

[a] The HI value includes the HQs of 4 additional pesticides for which TECs exist: Lindane, Dieldrin, Endrin, and Heptachlorepoxide. These were not included in the listing in Table 4-7 because they, on average, contributed 2% or less to the overall HI.

Table 4-7b. Estimated Hazard Quotients (HQ) for Contaminants in the Cedar-Ortega River Basin Sediments (HQ:ratio of surface sediment concentration to PEC)

Site	PAH	PCB	DDT	Chlor	As	Cd	Cr	Cu	Pb	Hg	Ni	Ag	Zn	Total HI[a]
CED02	0.55	16.99	0.05	1.15	0.46	0.73	0.85	0.70	3.00	0.87	0.49	1.09	3.12	31.1
CED01	0.24	14.76	0.15	0.41	0.74	0.77	0.86	0.56	2.09	0.87	0.47	1.46	4.47	27.8
CED04	0.70	4.49	0.04	1.18	0.26	0.61	0.73	0.59	2.46	0.90	0.47	0.37	1.73	14.6
ORT31	0.49	0.45	0.06	5.39	0.15	0.33	0.51	0.28	1.90	0.85	0.29	0.64	0.60	12.5
CED09	1.31	1.21	0.06	4.45	0.15	0.29	0.47	0.35	1.16	0.50	0.31	0.18	1.14	11.8
CED03	0.46	3.43	0.03	0.99	0.19	0.42	0.47	0.44	1.38	0.70	0.34	0.29	1.32	10.5
CED06	0.60	1.66	0.04	1.91	0.17	0.27	0.52	0.36	1.13	0.60	0.31	0.23	0.98	9.2
ORT25	0.54	0.65	0.04	1.83	0.21	0.35	0.73	0.57	1.04	0.70	0.41	0.32	1.13	9.1
CED07	0.36	1.88	0.02	0.92	0.16	0.33	0.60	0.38	1.23	1.08	0.34	0.30	0.92	8.9
ORT27	0.37	0.78	0.03	0.79	0.19	0.35	0.64	0.48	1.04	1.03	0.38	0.38	1.28	7.8
ORT33	0.67	0.26	0.09	4.27	0.05	0.11	0.15	0.15	0.68	0.08	0.10	0.07	0.47	7.5
ORT22	0.24	0.66	0.02	0.45	0.20	0.26	0.49	0.54	0.61	1.58	0.31	0.20	0.80	6.5
ORT32	0.28	0.38	0.05	1.61	0.20	0.24	0.58	0.28	0.77	0.52	0.32	0.34	0.41	6.4
ORT26	0.30	0.50	0.04	0.72	0.16	0.32	0.64	0.39	0.84	0.90	0.37	0.26	0.55	6.3
ORT37	0.29	0.64	0.03	0.89	0.16	0.26	0.57	0.32	0.79	0.87	0.34	0.18	0.54	6.2
ORT15	0.31	0.46	0.04	0.67	0.31	0.25	0.62	0.68	0.58	0.71	0.38	0.31	0.69	6.0
ORT28	0.22	0.26	0.03	0.72	0.23	0.23	0.52	0.34	0.60	0.61	0.32	0.19	0.71	5.6
ORT24	0.25	0.27	0.05	0.58	0.20	0.20	0.60	0.34	0.70	0.83	0.35	0.23	0.51	5.6
ORT07	0.23	0.20	0.08	0.45	0.22	0.33	0.67	0.37	0.70	0.98	0.43	0.29	0.50	5.5
CED08	0.33	0.49	0.02	1.24	0.09	0.26	0.44	0.31	0.66	0.51	0.29	0.13	0.62	5.4
ORT40	0.21	0.28	0.01	0.45	0.14	0.29	0.51	0.28	0.77	0.68	0.33	0.19	0.60	5.3
ORT23	0.17	0.48	0.03	0.35	0.14	0.12	0.51	0.18	0.40	0.66	0.28	0.13	0.41	5.2
ORT39	0.18	0.48	0.04	0.33	0.13	0.27	0.59	0.18	0.52	1.06	0.36	0.20	0.40	5.0
ORT19	0.36	0.72	0.02	0.15	0.09	0.06	0.14	0.62	0.41	1.98	0.09	0.07	0.29	5.0
ORT09	0.17	0.18	0.03	0.21	0.19	0.34	0.53	0.19	0.49	0.97	0.28	0.25	0.51	4.9
ORT38	0.23	0.17	0.07	0.31	0.24	0.34	0.55	0.20	0.56	1.30	0.32	0.21	0.34	4.8
ORT10	0.18	0.26	0.02	0.21	0.20	0.27	0.54	0.25	0.55	1.00	0.30	0.25	0.41	4.8
ORT13	0.23	0.25	0.04	0.30	0.20	0.27	0.60	0.26	0.65	0.60	0.35	0.21	0.54	4.5
ORT12	0.25	0.50	0.03	0.28	0.20	0.18	0.56	0.30	0.49	0.54	0.33	0.17	0.34	4.3
ORT21	0.17	0.27	0.02	0.25	0.14	0.17	0.51	0.20	0.54	0.78	0.29	0.19	0.30	4.1
ORT36	0.18	0.17	0.03	0.43	0.16	0.20	0.51	0.22	0.50	0.52	0.30	0.15	0.32	4.0
ORT01	0.12	0.26	0.02	0.04	0.16	0.29	0.52	0.14	0.41	0.61	0.28	0.22	0.24	4.0
ORT34	0.18	0.38	0.02	0.24	0.10	0.21	0.48	0.22	0.52	0.55	0.31	0.15	0.39	4.0
ORT11	0.13	0.29	0.02	0.15	0.21	0.21	0.57	0.17	0.43	0.46	0.33	0.17	0.48	3.7
CED05	0.10	0.95	0.02	0.54	0.05	0.11	0.20	0.09	0.46	0.28	0.15	0.07	0.33	3.6
ORT16	0.20	0.16	0.03	0.20	0.12	0.17	0.54	0.21	0.38	0.57	0.33	0.16	0.28	3.6
ORT08	0.10	0.29	0.02	0.12	0.17	0.22	0.59	0.17	0.37	0.55	0.34	0.24	0.37	3.6
ORT35	0.17	0.17	0.02	0.31	0.15	0.10	0.44	0.19	0.42	0.55	0.25	0.10	0.31	3.5
ORT18	0.21	0.17	0.01	0.23	0.11	0.18	0.45	0.19	0.44	0.51	0.29	0.14	0.31	3.5
ORT29	0.03	0.18	0.00	0.13	0.06	0.22	0.50	0.19	0.45	0.70	0.33	0.17	0.27	3.3
ORT06	0.09	0.25	0.01	0.07	0.13	0.18	0.52	0.10	0.23	0.34	0.28	0.13	0.18	2.8
ORT05	0.14	0.13	0.02	0.00	0.13	0.15	0.48	0.13	0.32	0.47	0.28	0.12	0.24	2.6
ORT41	0.09	0.11	0.02	0.09	0.09	0.13	0.36	0.13	0.22	0.69	0.27	0.09	0.17	2.6
ORT04	0.10	0.06	0.01	0.06	0.13	0.13	0.49	0.09	0.18	0.56	0.31	0.10	0.14	2.4
ORT02	0.04	0.04	0.00	0.00	0.12	0.10	0.49	0.07	0.13	0.45	0.30	0.10	0.11	2.0
ORT03	0.04	0.23	0.00	0.00	0.13	0.04	0.46	0.04	0.09	0.05	0.26	0.03	0.13	1.9
ORT14	0.08	0.05	0.01	0.01	0.10	0.08	0.46	0.07	0.14	0.15	0.28	0.08	0.10	1.7
ORT20	0.08	0.07	0.01	0.03	0.10	0.06	0.37	0.08	0.14	0.10	0.25	0.05	0.10	1.5
ORT30	0.02	0.01	0.00	0.00	0.04	0.03	0.17	0.03	0.08	0.10	0.09	0.03	0.16	0.8
%HQ>1	2	14	0	18	0	0	0	0	20	12	0	4	14	---

[a] The HI value includes the HQs of 4 additional pesticides for which PECs exist: Lindane, Dieldrin, Endrin, and Heptachlorepoxide. These were not included in the listing in Table 4-7 because they, on average, contributed 2% or less to the overall HI.

Table 4-8. Average Percent Contribution of Different Contaminants to the Hazard Index (HI) of Cedar-Ortega River Basin Sediments

Contaminant	Average % Contribution to HI[a]				
	Using TEC	Using PEC	Using ERL	Using ERM	Average Using All 4 Sediment Quality Measures[b]
PAH	11	4	2	2	5
PCB	18	10	26	29	21
DDT	10	1	17	5	8
Chlordane	9	10	24	22	16
Lindane	2	5			3
Dieldrin	2	<1			1
Endrin	<1	<1			<1
Heptachlor epoxide	<1	<1			<1
Arsenic	2	3	2	2	2
Cadmium	4	4	2	2	3
Chromium	6	12	2	3	6
Copper	4	5	2	2	3
Lead	7	11	3	5	7
Mercury	14	14	10	17	14
Nickel	3	7	2	6	5
Silver	3	4	2	3	3
Zinc	6	9	3	8	7

[a] HI: Hazard index. The sum of the HQ values (see Table 4-7 and Appendix R).
[b] The 4 sediment quality reference measures are threshold effects concentration (TEC), probable effects concentration (PEC), effects range low (ERL), and effects range median (ERM).

Based on an assessment of both the TEC- and PEC-based results, it appears that the predicted chemical toxicity in most of the surficial sediments from the Cedar-Ortega River system is caused primarily by PCB, chlordane, mercury, and lead, with notable contributions from PAH, DDT, chromium, or zinc in some of sediments. As discussed above, the estimated chemical toxicity could be overshadowed by effects of organic enrichment and resulting sediment anoxia. Sediment bioassays, coupled with benthic community structure analysis, and analytical chemistry (the sediment quality triad: Chapman *et al.*, 1997) could be performed to verify these predictions and identify the toxicants that contribute most to the toxicity of the sediments.

Most of the surficial sediment samples from the Cedar-Ortega River system have PEC-based HI values greater than 2, indicating that most of the sediments could be toxic to sediment-dwelling freshwater organisms. The most toxic sediments are from the Upper Cedar River; sites CED12, CED02, CED01, and CED04 are consistently the sites with the four highest HI values, using different reference values. Samples collected in parts of the lower Cedar River (e.g., sites CED09 and CED06 near Butcher Pen Creek) also had very high HI values, with contamination likely being contributed both by upstream Cedar River sources and local input. Samples from the Fishweir Creek area also have consistently high HIs (e.g., sites ORT31 and ORT33), and this location is less directly influenced by Cedar River sources and is therefore most likely more impacted by local sources than, for instance, the lower Cedar River.

Figure 4-39 presents a visualization of the overall ecological risk, as represented by the TEC-based HI value, using 3-dimensional visualization techniques and both the surface and subsurface sediment contaminant data. The elevated HI values in the surface and near-surface sediments indicate that there for some time has been, and continues to be, significant source(s) contaminating the Cedar-Ortega River Basin sediments. The Upper Cedar River is the area that is most impacted and of greatest ecological concern, and the sources of most of the contaminants measured in this area appear to lie upstream of the locations that were sampled. However, there are clearly significant contamination issues in the Fishweir Creek area and in parts of the lower Cedar River.

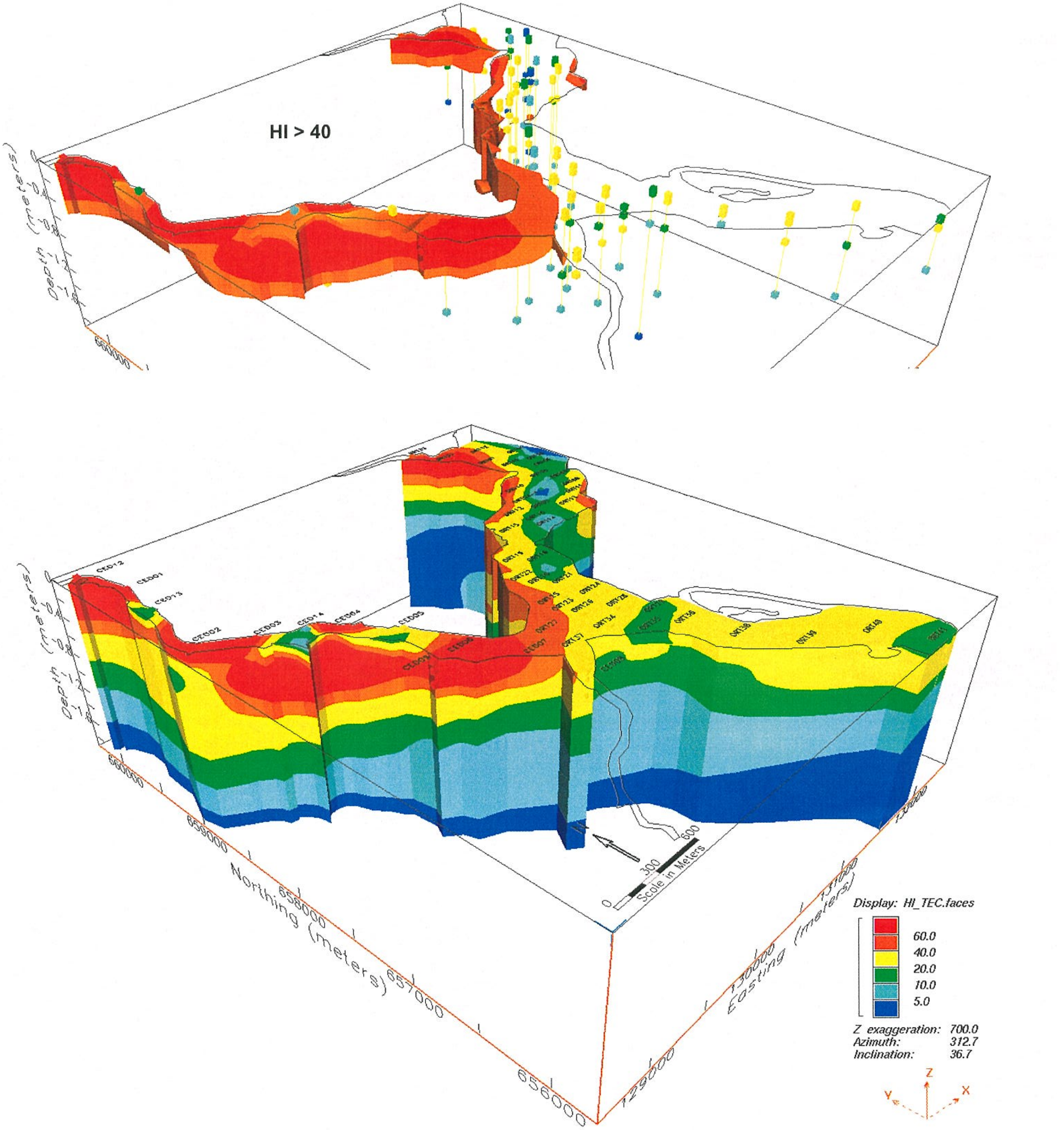


Figure 4-39. 3-D Visualization of the Ecological Risk of the Surface and Subsurface Sediment Contamination in the Cedar-Ortega River Basin. Hazard Index Based on TEC Sediment Quality Guidelines.

5. CONCLUSION

This study is the most complete sediment quality assessment of the Cedar-Ortega River Basin to date. This report describes surface sediment contaminant information previously reported (Battelle, 2004), but also includes information on the sub-surface sediment contamination, more detailed chemical characterization of key contaminants (e.g., PCBs), and presents a first-tier impression of the potential ecological relevance of the observed contamination.

A wealth of data were generated on the sediment contaminant characteristics of the Cedar-Ortega River Basin, and this provides a broad and solid foundation for future environmental management decisions. Newly generated information included uniquely detailed information on the contaminant characteristics of a large number of organic and metals contaminants, and the spatial coverage and resolution was much greater than in any previous sediment study in the area. The wealth of new data allow for 1) the identification of locations with potential contamination issues, 2) the identification of contaminants of potential concern, 3) the determination of the potential ecological implications of the contamination, and 4) the demonstration of locations and contaminants that do not appear to be of environmental concern.

Contaminant Status of the Cedar-Ortega River Basin

Cedar-Ortega River Basin sediments are of poor quality, from a chemical contaminant perspective, throughout the lower parts of the Cedar-Ortega River Basin and much of the Cedar River, and there appears to be a significant potential for adverse biological impact from the measured contaminants. However, the toxicity to aquatic organisms of the chemical contaminants in Cedar-Ortega River sediments is difficult to predict because of the high concentrations of TOC present in most sediments. The organic matter in the river sediments may cause an organic enrichment effect in the sediments, characterized by high microbial activity to degrade the organic matter, resulting in sediment hypoxia or anoxia and impaired benthic community structure and function.

Contaminants of Concern

Table 5-1 presents a summary of the contaminants of concern in the Cedar-Ortega River Basin sediments, and the relative significance of these contaminants. The data analysis resulted in three general groupings of contaminants-of-concern:

1. First Tier Contaminant: PCB, which appears to be contributing approximately 20-25 percent of the potential environmental risk/impact in the Cedar-Ortega River Basin, and a much greater percentage in the Cedar River.

2. Second Tier Contaminants: Chlordane, DDT, PAH, Lead, Zinc, and Mercury which each appear to be contributing approximately 5-15 percent of the potential environmental risk/impact in the Cedar-Ortega River Basin. These contaminants are all of significant concern, and it was difficult to rank their relative significance. Chlordane consistently ranked towards the top in relative significance, most often followed by mercury, but the contaminants appeared to have a relatively similar potential impact and there were mostly subtle differences in ranking order depending on the assessment method and reference measure.

3. Third Tier Contaminants: Chromium, Cadmium, Copper, Silver, which each appear to be contributing between 3 percent and 8 percent of the environmental risk/impact in the Cedar-Ortega River Basin. Chromium appears to be the most important of these metals.

Table 5-1. Summary of Relative Significance of Contaminants of Concern, their Primary Distribution in the Cedar-Ortega River Basin, and their Possible General Geographic Origin

Contaminant	Tier Ranking of Environmental Significance of Contaminant	Primary Distribution	Possible General Geographic Origin of Contaminants
PCB	1	Cedar River	Cedar River upstream
Chlordane	2	Fishweir Creek Area Lower Cedar River	Big Fishweir Creek; Little Fishweir Creek; Butcher Pen Creek
DDT	2	Cedar River; Fishweir Creek Area	Cedar River upstream; Big Fishweir Creek; Little Fishweir Creek
PAH	2	Lower Cedar River; Fishweir Creek Area; broadly distributed	Butcher Pen Creek; Big Fishweir Creek; Little Fishweir Creek; additional unidentified origin, possibly atmospheric deposition
Lead	2	Cedar River; Fishweir Creek Area	Cedar River upstream; Big Fishweir Creek; Little Fishweir Creek
Zinc	2	Cedar River	Cedar River upstream
Mercury	2	Broadly distributed	Unidentified origin, possibly atmospheric deposition
Chromium	3	Cedar River; broadly distributed	Cedar River upstream; unidentified origin
Cadmium	3	Cedar River; broadly distributed	Cedar River upstream; unidentified origin
Copper	3	Cedar River; middle Ortega River	Cedar River upstream; Roosevelt Boulevard Bridge area
Silver	3	Cedar River; Fishweir Creek Area	Cedar River upstream; Big Fishweir Creek; Little Fishweir Creek

PCB is clearly the contaminant of greatest concern in the Cedar-Ortega River Basin, but several other contaminants are a significant issue in the Cedar-Ortega River Basin. PCB is contributing about 20-25 percent of the risk/impact to the Basin as a whole, and the seven Tier I and Tier II contaminants together are contributing about 80-85 percent of the contamination issues. The six Tier II contaminants together appear to contribute about twice the potential risk of PCB alone. These values describe an approximate impact on the Basin as a whole; the relative impact of the contaminants varies from area-to-area, based on the distribution of the contamination. For instance, PCB appears to be contributing more than 50% of the risk in the sediments from the Upper Cedar River (upstream of site CED04), while chlordane, PAH, and PCB are contributing about equal amounts to the risk in parts of the lower Cedar River (near the mouth of Butcher Pen Creek), and chlordane is clearly the most significant contaminant in the Fishweir Creek area.

Areas of Concern

The Cedar-Ortega River Basin is widely contaminated with different organic and metals contaminants. However, there are still locations with clearly elevated concentrations within the Basin, compared to the rest of the Basin. Differences among the sources of these contaminants, including their proximity to the sampling locations, certainly accounts for some of the differences in the contaminant distribution patterns. 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.

Table 5-2 summarizes the relative significance of the contamination by geographical area. The investigated part of the Upper Cedar River is clearly the area most impacted and of greatest concern. The sources of most of the contaminants measured in this area most likely lie further upstream. There are also significant contamination issues in the Fishweir Creek area (with Big Fishweir Creek and Little Fishweir Creek likely being significant sources of input) and in parts of the lower Cedar River (with Butcher Pen Creek and the Cedar River both likely being significant sources). In fact, essentially all of the sediment in the Cedar-Ortega River Basin has contaminant concentrations that could be toxic to sediment-dwelling freshwater organisms.

Table 5-2. Summary of Relative Significance of Contamination by Geographical Area in the Cedar-Ortega River Basin, the Primary Contaminants of Concern, and their Possible General Geographic Origin

Geographical Area	Tier Ranking of Environmental Significance of Contamination	Primary Contaminants of Concern	Possible General Geographic Origin of Contaminants
Upper Cedar River (upstream of site CED04)	1	PCB, Lead, Zinc, DDT, Chromium, Cadmium, Copper, Silver	Cedar River upstream
Fishweir Creek Area (upstream of site ORT31)	2	Chlordane, Lead, DDT, PAH, Mercury, PCB, Silver	Big Fishweir Creek; Little Fishweir Creek
Lower Cedar River (site CED04 to CED07)	2	Chlordane, PAH, PCB, Lead, Zinc	Butcher Pen Creek; Cedar River
Middle Ortega River (site ORT16 to ORT37)	3	PCB, Mercury, PAH, Copper	Cedar River; Roosevelt Boulevard Bridge area
Lower Ortega River (site ORT01 to ORT16)	4	PCB, Mercury	Cedar River; Big Fishweir Creek; Little Fishweir Creek
Upper Ortega River (upstream of site ORT29)	4	PCB, Mercury, Lead	Ortega River; Cedar River

Some parts of the Basin clearly had elevated concentrations of contaminants and potential ecological risk when compared to the rest of the area, and contaminant profiles and considerations that may be of environmental quality interest include the following.

- The upper parts of the Cedar River had very high concentrations of PCB, and also significantly elevated concentrations of DDT and several metals (e.g., copper, lead, silver, and zinc). There was a sharp increase in the contaminant signals up the river, suggesting there is a significant source(s) of these contaminants upstream of site CED01.
- The lower part of the Cedar River, near the confluence with the Ortega River (as represented by site CED09 at the mouth of Butcher Pen Creek), had significantly elevated concentrations of PAH and selected pesticides (particularly chlordane) that appear to originate in this area.
- The small water body in which sites ORT33 and ORT31 were located, by the mouth of Big Fishweir Creek and Little Fishweir Creek and near the mouth of the Ortega River, had elevated concentrations of chlordane, PAH, DDT, and selected metals (e.g., lead, silver, zinc), indicating the presence of a local source(s).
- Elevated contaminant concentrations, although to a lesser degree than the other three locations, were also measured at site ORT19 (near the north shore of the Ortega River, just upstream of the Roosevelt Boulevard automobile and railroad bridge). The slightly elevated concentrations of PAH, mercury, and copper, in combination with the relatively site-specific composition of the PAH compounds, suggests there may be a small local source of contamination.
- Broadly and relatively uniformly distributed high concentrations of mercury and, to a lesser degree, chromium and cadmium, were observed. The mercury distribution suggests that the contamination may not be the result of direct point-source inputs to the Cedar-Ortega River Basin. However, the mercury concentrations are generally higher in the Cedar-Ortega River Basin sediments than they are in sediments from nearby lower St. Johns River locations (Battelle, 2004), suggesting that there may be non-point sources or significant levels of atmospheric deposition from nearby sources.

Summary
The quality of the sediments in the Cedar-Ortega River Basin were somewhat variable, but appear to be widely contaminated with a variety of organic and metal contaminants. The urbanized areas around the Cedar-Ortega River Basin are clearly exerting significant influence on the contaminant concentrations in the sediments. Although much of the contamination appears to be historic, the data clearly indicate that there are also significant current sources of contamination. The concentrations of PCB, PAH, some of the pesticides, and several metals are very high in this area, whether they are compared to the lower St. Johns River, other national monitoring programs, or widely used sediment quality guidelines. The PAH and PCB compound composition is also relatively unique in the Cedar-Ortega River Basin, suggesting there may be a fairly limited number of sources. The data suggest that this is an area that warrants environmental action.

High organic matter concentrations and low dissolved oxygen concentrations together limit the bioavailability and toxicity of the metal and organic contaminants in the sediments. However, if we assume that the contaminants in the Cedar-Ortega River sediments have a bioavailability similar to that of contaminants in other freshwater sediments, it is possible to estimate the relative toxicity of the sediments and identify the chemicals contributing most to that toxicity. This analysis revealed that all but one of the 52 surficial sediment samples could be toxic to aquatic organisms.

The toxicity of the most toxic sediments, all from the Cedar River, is caused primarily by PCBs. However, the toxicity of the sediments in the Basin varies from one sediment to another, with the most important contaminants being PCBs, chlordane, and mercury, but also PAH, DDT, and other metals (e.g., lead, zinc, cadmium, chromium, copper, silver), depending on the location. Concentrations of other pesticides and the metals are low enough in most sediments that they do not contribute much to the potential toxicity of the sediments. Sediment toxicity testing is needed to confirm these predictions of the magnitude and causes of toxicity of sediments from the Cedar-Ortega River system.

By controlling any current sources of the PCB, DDT, lead, and zinc inputs to the Cedar River, and mitigating existing sediment contamination, it may be possible to, ultimately, reduce the overall contaminant-based ecological risk from the Cedar-Ortega River Basin sediments by approximately 40 to 50 percent, based on the SQG assessment approach described in this report. The contaminant-based risk posed by the sediments would be reduced by a significantly greater amount in the Cedar River itself (likely well over 90 percent). Significant ecological risk would still be exerted by sediments in the Fishweir Creek and lower Cedar River areas due to local inputs and existing sediment concentrations of chlordane, PAH, DDT, lead, and zinc, and to the Basin as a whole by mercury. The toxicity due to contaminants in the Fishweir Creek sediments can likely be significantly reduced (possibly by approximately 60 to 80 percent) if local sources of chlordane, PAH, DDT, and lead are controlled, and the in-place sediments mitigated. This, in combination with control of the contamination from the Cedar River, should reduce the overall ecological risk due to contaminants in the sediments in the Fishweir Creek area by more than 90 percent. Similarly, there should be a significant ecological improvement if the chlordane and PAH inputs in the Butcher Pen Creek area were controlled. Following such source control measures, the mercury contamination of the sediments would likely be the primary cause of the remaining contaminant-based ecological risk. The identification and control of potential nearby non-point sources of mercury resulting in water-borne inputs, or nearby point sources releasing mercury to the atmosphere, may then significantly aid the eventual recovery of the Cedar-Ortega River Basin sediment. An investigation of potential sources of mercury may reveal that this contaminant can be relatively easily controlled, and such action may therefore be worthwhile to pursue concurrent with other contaminant source control and remediation efforts.

Recommendations

Additional Characterization of Cedar-Ortega River Basin Contamination Issues

It is fairly well established that much of the contamination of the northern lower St. Johns River is from urban activities in Jacksonville. Given the significant contamination of the Cedar-Ortega River Basin, it is not unreasonable to question if some, and how much, of the elevated contamination in the northern part of the lower St. Johns River could be originating in the Cedar-Ortega River Basin. It would be valuable to gain a better understanding of the Cedar-Ortega River contaminant issues before more efforts are exerted on the lower St. Johns River near the confluence with the Ortega River.

Now that it is evident that the environmental quality of the Cedar-Ortega River Basin will likely warrant significant management action, additional, more comprehensive, contaminant assessment should be performed to enhance the understanding of the issues so that future management decisions can be made with a high degree of confidence. Key management decisions that need to be supported by reliable information may include (1) source identification and control, (2) contaminated sediment remediation, and (3) ecological restoration. Some of the additional work to consider would require additional sampling and laboratory analysis, while other would only require additional data analysis.

- Areas of potential and likely concern have been identified that may warrant additional site-focused investigations. The work should include a sound sampling and analysis plan that will ensure that the data can be confidently used for contaminant characterization, source location, and other interpretive analyses. The analysis can be focused to effectively address the issues by location.
  - The PCB contamination is significant, and detailed PCB congener characterization of the sediments up the Cedar River, further upstream of what was sampled in this study, could provide valuable information on the nature, fate, transport, and source of the contamination. The other major contaminants of this area (e.g., DDT and selected metals) should be co-investigated.
  - A detailed PAH characterization (with extensive PAH alkyl homologue measurements) of the sediments in the Basin, with particular focus on the identified "hot spot" areas, near Butcher Pen Creek and Fishweir Creek, can provide crucial information on the hydrocarbon material that is contaminating the Basin, including the nature, fate, transport, and source of this material. The other major contaminants in these areas (e.g., chlordane, DDT, and selected metals) should be co-investigated.
- Sediment contamination is generally associated with sediment deposition areas and knowledge of the hydrodynamic characteristics of the area, including locations of depositional areas and other sediment transport patterns, would be valuable for future contamination assessments and remediation activities. Typically, sediment transport models provide a cost effective method to determine patterns of sediments and contaminant movement and zones of deposition.
- It would be valuable to more thoroughly evaluate the contaminant distribution of the *sub*-surface sediments, to determine the sub-surface concentrations and identify contaminant gradients, for future management actions. This is a key exercise because the greatest volume of contaminated sediment is sub-surface sediment, and understanding both the surface and sub-surface characteristics will be critical for future management actions. Additional, more detailed, three-dimensional analysis, visualization, and presentation of the data using a contaminant interpolation and analysis tool (e.g., Earth Vision geo-statistical analysis, visualization, and modeling software package) could provide very valuable insight into the sub-surface sediment contamination. Such an evaluation could provide information on:
  - The overall amount of impacted sediment, and the distributions of those sediments. Using geo-statistical techniques (e.g., using Earth Vision), the volumes of sediment that are severely impacted by the contaminants of concern can be determined, along with the three-dimensional geographical distribution of the severely impacted sediment. The information can be generated and presented using different evaluation criteria, such as (1) general contaminant concentration distributions with common concentration cutoff values, (2) sediment that exceed a sediment criterion value and the geographical and depth distribution of the affected sediments, and (3) sediment that exceed contaminant concentration levels identified as typical from other monitoring programs (e.g., LSJR background levels). The critically contaminated sediment mass volume and distribution can also be calculated on a "rolled-up" level, integrating the contaminants that together are estimated to pose the bulk (e.g., >90%) of the risk. Contaminant "footprint" determinations of the surface sediment can also be determined, by mapping the surface sediment contour above the impacted sub-surface sediment zone (e.g., the area that would need to be dredged, if dredging becomes an approach to remediating the sediment).

  - The historical trends of the contaminant deposition characteristics. This will include a determination of which contaminants are increasing, decreasing, and staying the same in concentration loadings over time. This will aid in the determination of historic and current contaminant input, and for predicting future input trends.

- Although it is clear that the contaminant concentrations are elevated in the Cedar-Ortega River Basin, the true *ecological relevance* of this contamination needs to be better understood. An assessment should be performed to determine the potential effects of sediment bound contaminants to the biota and other components of the local ecology, since the existing comparisons to sediment quality guidelines have indicated the *potential* for organic and metal toxicity.

  The Cedar-Ortega River Basin sediments are quite unique (e.g., very high organic content) and it is important to better understand the availability of the contaminants in these particular sediments to be bioaccumulated and cause toxic effects. In addition, gaining a better understanding of the oxygen conditions of the sediments (discussed earlier) may be valuable for predicting what type of ecological recovery may be expected following sediment management actions. These investigations can be performed by analyzing surface and sub-surface sediment data using ecological and human health protective analyses specific to the Cedar-Ortega River Basin environment, by performing a limited amount of additional field and laboratory based work and then a screening-level ecological risk evaluation of the sediment contamination, and estimating the potential effects of toxic and bioaccumulatable contaminants to the local biological resources.

  - There is a need to better characterize the organic matter that is so abundant in most sediments. This organic matter may be causing sediment anoxia or hypoxia. The relationship between sediment redox potential and benthic community structure should be investigated to determine if organic enrichment effects are occurring. Several contaminants, particularly total PAHs, total PCBs, mercury, chlordane, lead, and zinc, are present at high enough concentrations in river sediments that they could make significant contributions to toxicity of the sediments to aquatic organisms.

  - The toxicity and bioaccumulation potential of the most heavily contaminated sediments should be tested with standard freshwater sediment toxicity and bioaccumulation tests. Standard test protocols are available for freshwater amphipods, insects, and oligochaete worms. Laboratory-based bioaccumulation are ideally complemented with field-based data, by collecting key aquatic species and/or by deploying caged animals (e.g., bivalves) in the Basin. Sediment toxicity and bioaccumulation testing should be coupled with benthic community analysis and analytical chemistry in a sediment quality triad approach to characterize the magnitude and causes of sediment toxicity.

  - An investigation of the contamination of the Cedar-Ortega River Basin should also include extensive records research, in addition to further field and laboratory-based work. Investigation of past and present industrial activities in the area, local drainage and discharge systems (including permitted and non-permitted discharges), and general commercial and recreational use of the area, should all be part of a thorough investigation of the contamination of the Cedar-Ortega River Basin.

This assessment could provide the District with a preliminary determination of the environmental risks associated with the Cedar-Ortega River Basin sediments, using established empirical assessment methods. The assessment could be a first-level empirical risk assessment review based on the existing field sample data, new sediment characterization field data (e.g., oxygen condition information), new laboratory-based toxicological and bioaccaumulation studies, and relevant associated physical and ecological information on the Basin. This screening level risk assessment review will be performed to obtain an impression of the risks the contaminants in the sediment are presenting to the local ecology and general environment, and the relative significance of the different contaminants.

Using the above listed information, it would be possible to estimate the environmental significance of the measure contamination and geographically delineate the most severely impacted sediments and contaminants of concern, and rank the zones and contaminants by degree of significance. This additional, more site-focused, analysis and interpretation of Cedar-Ortega River Basin data would support any proposed contaminant remediation plan, because it would provide a more specific spatial and temporal characterization of the contamination in this Basin and should provide information of the true relevance of the contamination.

Other Recommendations

- Follow-up assessment to determine the trends in the environmental contaminant loadings at selected sites may be very useful to support environmental management decisions and document their effectiveness. 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 and assessment 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., through Web-based mapping or other interactive Web-based data access and interface).

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