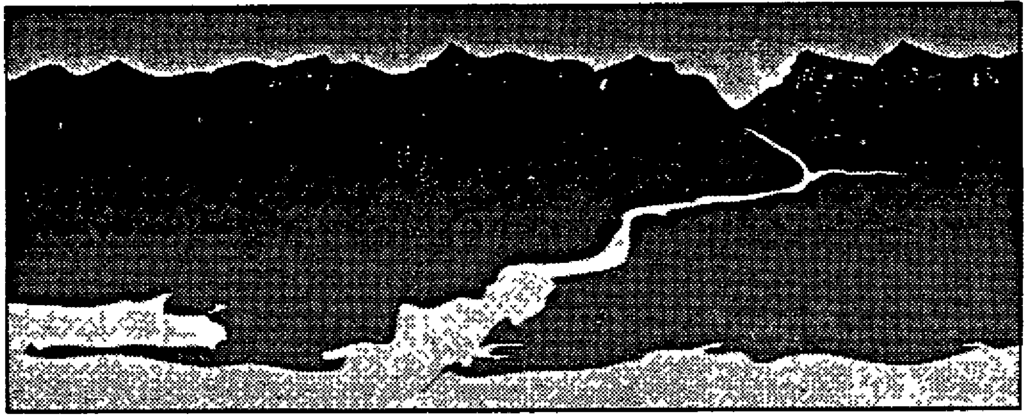
FINAL REPORT
TC 9497-06

LOWER COLUMBIA RIVER



BI-STATE PROGRAM

LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

VOLUME 1: RECONNAISSANCE REPORT

MAY 26, 1994

Prepared By:
TETRA TECH

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The Lower Columbia River
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- Aquatic Research, Inc. -- metals, nutrients
- Columbia Analytical Services, Inc -- bacteria
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EXECUTIVE SUMMARY

The Backwater Reconnaissance Survey was designed to complement and extend the 1991 Reconnaissance Survey of the lower Columbia River (Bonneville Dam to the Pacific). Both of these surveys were major steps toward accomplishing the major objectives of the Columbia River Bi-State Program's four-year plan These objectives include·

- characterize water quality in the lower Columbia River
- identify water quality problems
- determine whether beneficial uses of the river are impaired
- develop solutions to identified problems.

The 1991 survey found some concentrations of trace metals and organic compounds in exceedance of available reference levels Most of the sampling from this survey was done in deeper, more open parts of the river. Because there was concern that contaminant concentrations could be higher in backwater areas where fine sediments accumulate (fine sediments tend to attract and concentrate organic contaminants), a second survey was done to measure contaminants in water, sediment, and fish tissue from backwater areas.

The basic findings of the backwater survey are outlined below. An overall summary of findings is presented first, followed by results for each of the three media tested (water, sediments, and fish/crayfish tissue), a comparison to national data, and recommnedations for future research The phrase "reference level" is used generically for levels of contaminants that have been identified as having the potential to adversely affect wildlife or benthic organisms. These reference levels are in some cases standards or criteria promulgated by U.S. EPA or states (e.g., water quality criteria), but in many cases are simply guidelines that carry no regulatory weight. Where appropriate, references are also made to the results from the 1991 survey If a finding relates to one of the surveys only, it is labeled by year (1991 or 1993).

SUMMARY FINDINGS

As in the 1991 survey, several chemicals were found at concentrations in exceedance of available reference levels during the backwater survey At several sediment sites, eight different metals were found in concentrations up to seven times higher than available reference levels. With a few exceptions, organic contaminants were not detected at concentrations that have been associated with adverse effects to fish or wildlife.

There is a need for additional reference levels, particularly for contaminants in sediments and fish/crayfish tissue. The environmental implications of much of the data collected for these two surveys could not be evaluated due to a lack of suitable reference levels

Water

It is difficult to generalize about water quality from the collection of samples at a single point in time because of the dynamic nature of a large river system Also, levels of contaminants are often so dilute as to be difficult to detect (they are relatively more concentrated in sediments and tissues). In spite of these difficulties, analysis of water samples can yield important information about environmental conditions because most of the reference levels with regulatory authority (i e., standards and criteria) were written for water

Potential water quality problems were indicated by several results from the two surveys (Figure ES-1).

- ☐ **Temperature**—Washington standard (20° C) exceeded at 4 of 15 stations (1993). High temperature has historically been recognized as a problem in the lower Columbia
- ☐ **Nutrients**—phosphorus and nitrogen high enough to cause nuisance algae if other conditions (e.g., light and water residence time) are right (1993)
- ☐ **Chlorophyll *a***—(an indirect measure of algae) Oregon's action level exceeded at 5 of 15 stations (1993).

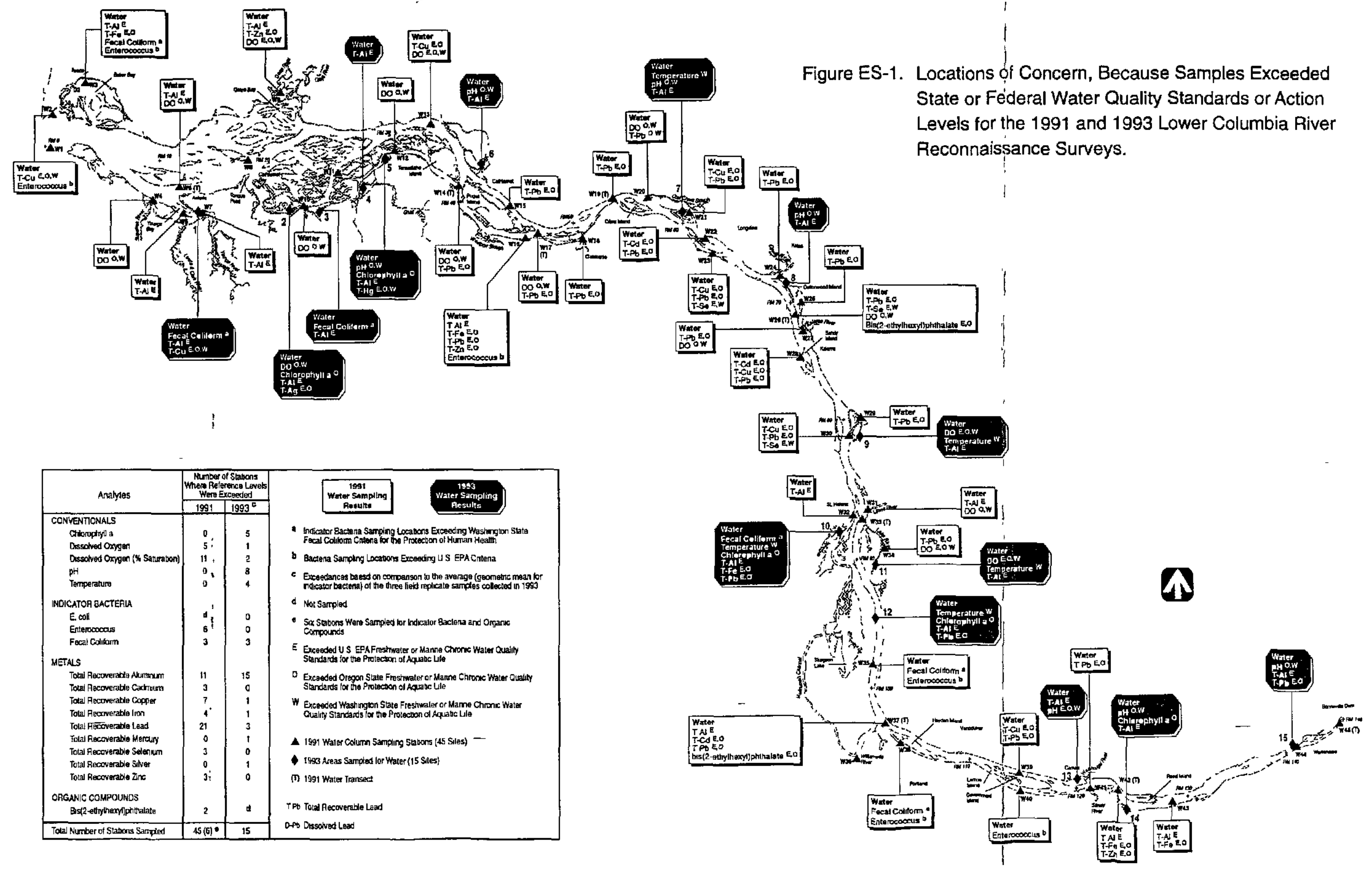


Figure ES-1. Locations of Concern, Because Samples Exceeded State or Federal Water Quality Standards or Action Levels for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.

Analytes	Number of Stations Where Reference Levels Were Exceeded	
	1991	1993 [c]
CONVENTIONALS		
Chlorophyll a	0	5
Dissolved Oxygen	5	1
Dissolved Oxygen (% Saturation)	11	2
pH	0	8
Temperature	0	4
INDICATOR BACTERIA		
E. coli	d	0
Enterococcus	6	0
Fecal Coliform	3	3
METALS		
Total Recoverable Aluminum	11	15
Total Recoverable Cadmium	3	0
Total Recoverable Copper	7	1
Total Recoverable Iron	4	1
Total Recoverable Lead	21	3
Total Recoverable Mercury	0	1
Total Recoverable Selenium	3	0
Total Recoverable Silver	0	1
Total Recoverable Zinc	3	0
ORGANIC COMPOUNDS		
Bis(2-ethylhexyl)phthalate	2	d
Total Number of Stations Sampled	45 (6) [e]	15

1991 Water Sampling Results

1993 Water Sampling Results

[a] Indicator Bacteria Sampling Locations Exceeding Washington State Fecal Coliform Criteria for the Protection of Human Health

[b] Bacteria Sampling Locations Exceeding U.S. EPA Criteria

[c] Exceedances based on comparison to the average (geometric mean for indicator bacteria) of the three field replicate samples collected in 1993

[d] Not Sampled

[e] Six Stations Were Sampled for Indicator Bacteria and Organic Compounds

[E] Exceeded U.S. EPA Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

[O] Exceeded Oregon State Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

[W] Exceeded Washington State Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

▲ 1991 Water Column Sampling Stations (45 Sites)

◆ 1993 Areas Sampled for Water (15 Sites)

(T) 1991 Water Transect

T-Pb Total Recoverable Lead

D-Pb Dissolved Lead

- **Dissolved oxygen**—reference levels exceeded at several stations from Portland/Vancouver to mouth of river

- **Trace Metals**—reference levels exceeded for copper and lead; aluminum and iron also high, but probably in a form not dangerous to aquatic life More testing needed for silver, selenium, and mercury due to difficulty in achieving very low detection limits

- **Bacteria**—standards for protecting human health (both for water sports and shellfish harvests) often exceeded, especially between Portland and Longview Better monitoring needed

Sediments

Sediments can be good indicators of water quality because they may accumulate contaminants over a period of time making them easier to detect. However, reference levels for the determination of the environmental significance of analytical data are still under development Only trace metal concentrations were higher in the finer-grained backwater sediments compared to the more open-water sediment stations sampled in 1991. The expected higher concentrations of organic pollutants in backwater sediments were not observed

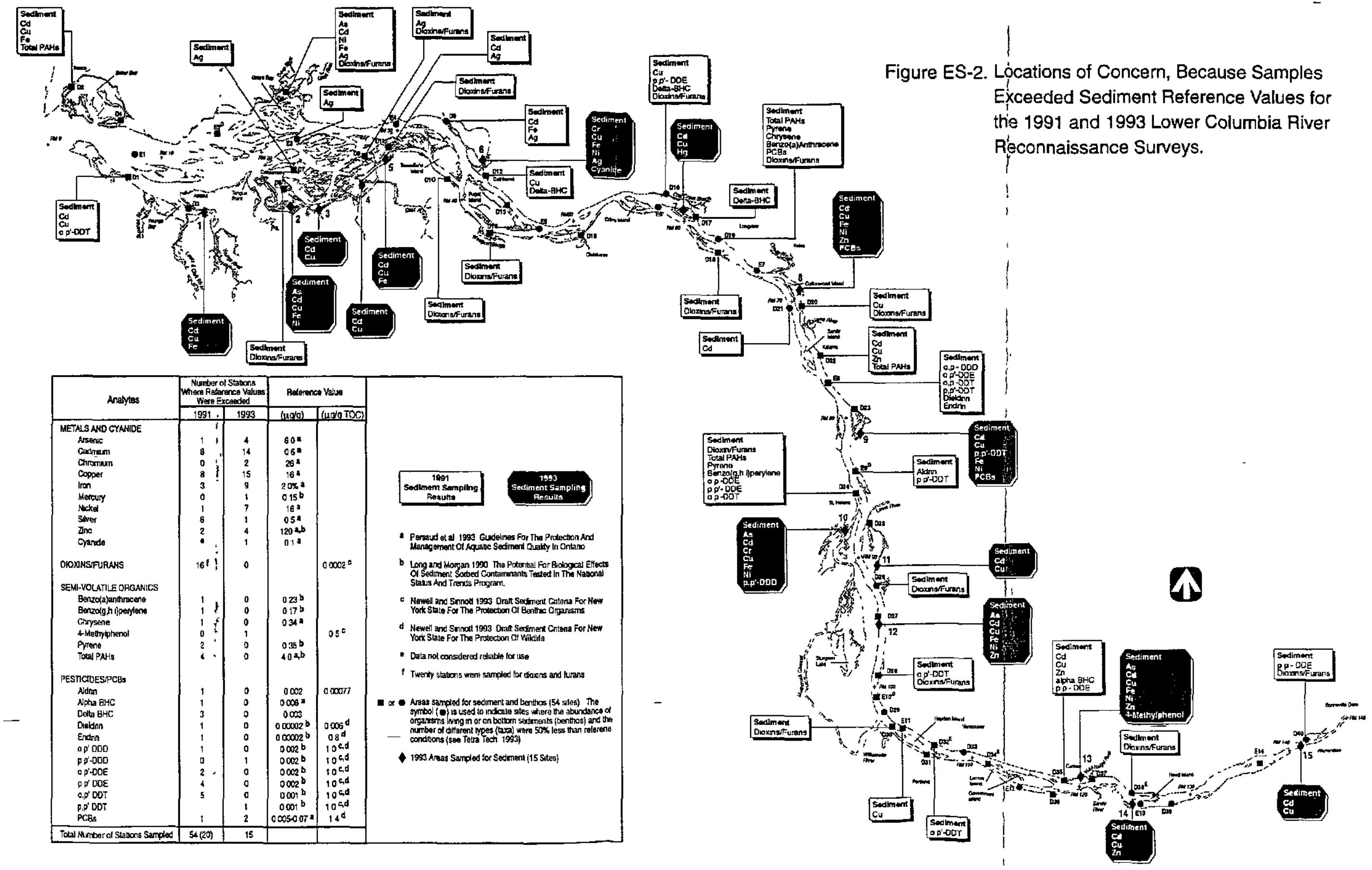
Potential sediment quality problems were indicated by several results from the two surveys (Figure ES-2).

- **Trace Metals and Cyanide**—reference levels exceeded in one or both surveys for arsenic, cadmium, chromium, copper, cyanide, iron, mercury, nickel, silver, and zinc

- **PAHs** (polynuclear aromatic compounds)—detected in both surveys; above standards at 1991 open water sites, not at 1993 backwater sites. Higher near urban and industrial areas.

- **Pesticides and PCBs**—overall, reference levels exceeded infrequently, but two stations exceeded standards for DDT and related compounds. Pesticides distributed all along the river; PCBs highest near urban and industrial areas.

Figure ES-2. Locations of Concern, Because Samples Exceeded Sediment Reference Values for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.



Analytes	Number of Stations Where Reference Values Were Exceeded		Reference Value	
	1991	1993	(µg/g)	(µg/g TOC)
METALS AND CYANIDE				
Arsenic	1	4	6.0 [a]	
Cadmium	8	14	0.6 [a]	
Chromium	0	2	26 [a]	
Copper	8	15	16 [a]	
Iron	3	9	2.0% [a]	
Mercury	0	1	0.15 [b]	
Nickel	1	7	16 [a]	
Silver	6	1	0.5 [a]	
Zinc	2	4	120 [a,b]	
Cyanide	e	1	0.1 [a]	
DIOXINS/FURANS	16 [f]	0		0.0002 [c]
SEMI-VOLATILE ORGANICS				
Benzo(a)anthracene	1	0	0.23 [b]	
Benzo(g,h,i)perylene	1	0	0.17 [b]	
Chrysene	1	0	0.34 [a]	
4-Methylphenol	0	1		0.5 [c]
Pyrene	2	0	0.35 [b]	
Total PAHs	4	0	4.0 [a,b]	
PESTICIDES/PCBs				
Aldrin	1	0	0.002	0.00077
Alpha BHC	1	0	0.006 [a]	
Delta BHC	3	0	0.003	
Dieldrin	1	0	0.00002 [b]	0.006 [d]
Endrin	1	0	0.00002 [b]	0.8 [d]
o,p' DDD	1	0	0.002 [b]	1.0 [c,d]
p,p'-DDD	0	1	0.002 [b]	1.0 [c,d]
o,p'-DDE	2	0	0.002 [b]	1.0 [c,d]
p,p' DDE	4	0	0.002 [b]	1.0 [c,d]
o,p' DDT	5	0	0.001 [b]	1.0 [c,d]
p,p' DDT		1	0.001 [b]	1.0 [c,d]
PCBs	1	2	0.005-0.07 [a]	1.4 [d]
Total Number of Stations Sampled	54 (20)	15		

1991 Sediment Sampling Results

1993 Sediment Sampling Results

[a] Persaud et al. 1993 Guidelines For The Protection And Management Of Aquatic Sediment Quality In Ontario

[b] Long and Morgan 1990 The Potential For Biological Effects Of Sediment Sorbed Contaminants Tested In The National Status And Trends Program.

[c] Newell and Sinnott 1993 Draft Sediment Criteria For New York State For The Protection Of Benthic Organisms

[d] Newell and Sinnott 1993 Draft Sediment Criteria For New York State For The Protection Of Wildlife

[e] Data not considered reliable for use

[f] Twenty stations were sampled for dioxins and furans

■ or ● Areas sampled for sediment and benthos (54 sites). The symbol (●) is used to indicate sites where the abundance of organisms living in or on bottom sediments (benthos) and the number of different types (taxa) were 50% less than reference conditions (see Tetra Tech 1993)

◆ 1993 Areas Sampled for Sediment (15 Sites)

- **Dioxins and Furans**—dioxin/furan reference level exceeded at most stations sampled in 1991, these compounds detected infrequently in 1993 Highest concentrations below pulp and paper mills, but also detected above these sources.

- **Butyltins**—detected frequently (1993), no reference levels exist. More study needed

- **Radionuclides**—cesium and plutonium detected frequently both years; no reference levels exist Concentrations not noticeably higher below Hanford than above

- **Sediment Toxicity**—sediments do not appear to be toxic except possibly at one station in the estuary (1993).

Fish/Crayfish

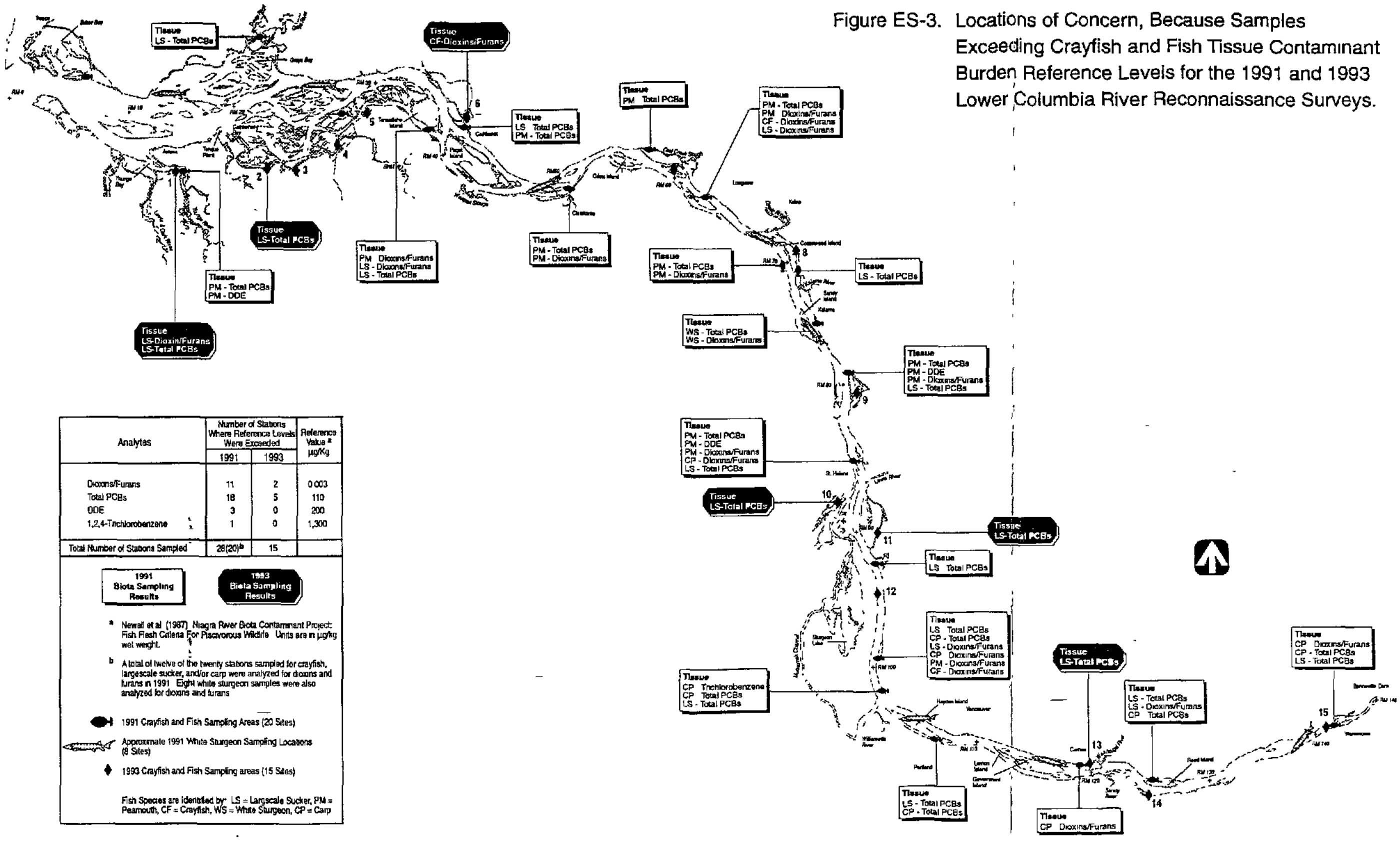
Contaminant levels in fish and shellfish may also be good indicators of environmental quality because only contaminants actually passed up the food chain are typically detected These chemicals can be cause for concern because of people and wildlife species who eat fish and shellfish. However, the environmental significance of chemical data in fish/shellfish tissue is difficult to evaluate because reference levels are almost complete lacking in this area

The chemicals for which concentrations exceeded available reference levels or were frequently detected are indicated below (Figure ES-3)

- **Trace Metals**—barium, cadmium, chromium, copper, lead, mercury, and zinc were frequently detected, with highest concentrations found in crayfish. The only available reference level (selenium) was not exceeded.

- **Pesticides & PCBs**—both DDT-related compounds and PCBs were detected in both surveys, mainly in fish. DDT compound concentrations were generally not above reference levels, but PCB levels exceeded reference levels at several sites in both years These levels are intended for the protection of fish-eating wildlife species.

Figure ES-3. Locations of Concern, Because Samples Exceeding Crayfish and Fish Tissue Contaminant Burden Reference Levels for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.



Analytes	Number of Stations Where Reference Levels Were Exceeded		Reference Value [a] µg/Kg
	1991	1993	
Dioxins/Furans	11	2	0.003
Total PCBs	18	5	110
DDE	3	0	200
1,2,4-Trichlorobenzene	1	0	1,300
Total Number of Stations Sampled	28(20)[b]	15	

1991 Biota Sampling Results

1993 Biota Sampling Results

[a] Newell et al. (1987). Niagra River Biota Contaminant Project: Fish Flesh Criteria For Piscivorous Wildlife. Units are in µg/kg wet weight.

[b] A total of twelve of the twenty stations sampled for crayfish, largescale sucker, and/or carp were analyzed for dioxins and furans in 1991. Eight white sturgeon samples were also analyzed for dioxins and furans.

1991 Crayfish and Fish Sampling Areas (20 Sites)

Approximate 1991 White Sturgeon Sampling Locations (8 Sites)

◆ 1993 Crayfish and Fish Sampling areas (15 Sites)

Fish Species are Identified by: LS = Largscale Sucker, PM = Peamouth, CF = Crayfish, WS = White Sturgeon, CP = Carp

- **Dioxins and Furans**—detected both years, but more frequently and at higher levels in 1991 open water sites, reference level for total dioxin/furan toxicity was frequently exceeded in 1991 survey Very frequently detected in fish, somewhat frequently in crayfish

- **Butyltins**—frequently detected in fish (1993), especially near the mouth of the river (butyltins were formerly used in marine paints) No reference levels exist

- **Radionuclides**—plutonium and cesium frequently detected in fish, but not in crayfish (1993) No reference levels exist

Comparison to National Data

Overall, levels of contaminants measured in the lower Columbia are similar to or slightly lower than average figures from national studies, with the exception of a few trace metal and organic compound concentrations in sediments

Recommendations for Further Study

The experience gathered form the two extensive reconnaissance surveys was useful for suggesting components of future sampling efforts

- Future studies should continue to sample both sediments and tissue, in addition to water The importance of this is shown by the fact that while PCBs are generally undetectable in water using standard laboratory methods, and were detected at only 3 of 69 stations sampled for sediment in the two surveys, they were detected in all fish samples in both surveys.

- While backwater areas should continue to be tested and monitored as part of an overall program of river monitoring, this study did not find justification for focusing special attention on these areas at the exclusion of other river habitats.

- Attention should be focused on areas near, and downstream of, known urban and industrial sources of pollutants

- Future water sampling of metals should focus on aluminum, iron, copper, and lead, and assess potentially toxic forms and concentrations of these metals Mercury and silver in the water may need to be assessed with more sensitive laboratory methods

- Assessment of algae levels in water should identify and count species

- Sediment variables such as grain size distribution and organic carbon content should continue to be measured for all future studies because these variables can give valuable insight on the distribution other types of contaminants.

- The sampling of tissue should include species at different levels in the food chain so that the variability in bioconcentration and biotransfer factors can be assessed.

1.0 INTRODUCTION

1.1 LOWER COLUMBIA RIVER BI-STATE PROGRAM

The Oregon and Washington state legislatures created the Lower Columbia River Bi-State Water Quality Program (Bi-State Program) in 1990. The Bi-State Program developed a four-year plan designed to characterize water quality in the lower Columbia River (below Bonneville Dam), identify water quality problems, determine whether beneficial uses of the river are impaired, and develop solutions to problems identified. The four-year plan proposed the following framework for conducting studies to evaluate water quality: 1) inventory of existing information; 2) reconnaissance surveys; 3) further evaluation of water quality (baseline studies); and 4) advanced studies. A number of studies have been completed, or are in progress, to help accomplish the Bi-State Program's legislative mandate. The 1993 backwater reconnaissance survey of the lower Columbia River was designed to collect data on contaminant levels in water, sediment, and fish tissue to augment the more extensive data set collected during the previous reconnaissance survey of the lower Columbia River during the fall of 1991 (Tetra Tech 1993a,b).

1.2 STUDY RATIONALE

The 1991 reconnaissance survey found levels of contaminants in water, sediment and fish and crayfish tissues at a number of locations in the lower Columbia that had the potential to cause adverse effects to aquatic organisms and wildlife. However, there was concern that not enough measurements were made in backwater areas where contaminant levels were expected to be higher due to their association with the finer sediments that accumulate in backwaters. Although several backwater sloughs were sampled in 1991 survey, sampling was generally confined to deeper waters near the river's mainstem that were accessible during the low-flow period selected for sampling (i.e., September and October 1991).

Backwater areas are by definition isolated from the main river channel and therefore tend to be lower energy environments with reduced current velocities These locations will tend to have a higher proportion of fine-grained sediments than other river locations where higher currents keep small particles in suspension. Concentrations of sediment contaminants are often inversely correlated with sediment grain size due to the greater surface area of smaller particles and the surface properties of clay minerals This trend was observed for contaminant levels in sediments collected in the 1991 survey: fine-grained sediments tended to have higher concentrations of metals and organic chemicals Since many aquatic and wildlife species utilize backwater areas as nursery and/or feeding areas, contamination of these locations is of concern.

1.3 OVERVIEW OF STUDY DESIGN AND OBJECTIVES

Although the 1993 backwater reconnaissance survey design was generally similar to the design of the 1991 survey, some aspects were altered, based on the results of the 1991 survey and the need for lower analytical detection limits and greater accuracy for several analytes in water, sediment, or fish and crayfish tissue The total number of sampling stations was lower for the backwater reconnaissance survey, but all stations were analyzed for each parameter, whereas in 1991, the more costly analyses (e.g , dioxins and furans) were conducted at a more limited number of stations Water column samples were not analyzed for organic compounds in the backwater survey, since these compounds were not detected, with few exceptions, in the 1991 survey However, water samples were analyzed for both total recoverable and filtered metals in 1993 (only total recoverable metals were measured in 1991) and field triplicate samples were analyzed for metals and nutrients to provide improved estimates of the ambient concentrations of these parameters.

The backwater survey also targeted a number of contaminants for more sensitive laboratory analytical methods to achieve lower detection limits and provide better estimates of actual sediment and tissue concentrations of these contaminants. These included several metals, polynuclear aromatic hydrocarbons (PAHs), pesticides, and polychlorinated biphenyl compounds (PCBs).

The backwater survey did not include sampling of benthic organisms. The 1991 survey indicated that, in general, benthic community variables were not significantly correlated with sediment contaminant levels The lack of association between benthic community variables and contaminant levels among the stations sampled in 1991 may have been due to the broad survey design and the consequent variety of physical habitats sampled, which could have masked the effects of variation in contaminant levels among the sampling sites. Instead, laboratory sediment toxicity testing was performed to assess the potential for adverse effects on benthic organisms of contaminant levels measured at each sampling location.

The backwater survey was conducted during June-August 1993, following the guidance and protocols outlined in the final Sampling and Quality Assurance/Quality Control (QA/QC) Plan (Tetra Tech 1993c). The primary objectives of the backwater reconnaissance survey were to.

- Extend the water quality data base of the 1991 survey to include additional freshwater and estuarine backwater areas with fine-grained sediments
- Expand the list of analytes to include additional contaminants of concern based on results of the 1991 reconnaissance survey (e.g , radionuclides and butyltin compounds in fish and crayfish tissues).
- Measure and evaluate the toxicity of Columbia River sediments using established bioassay protocols, as a tool for assessing/interpreting the results of sediment chemistry analyses.
- Confirm 1991 survey results for a limited number of fine-grained sediment/backwater locations
- Compare findings to existing reference levels (standards, criteria, and guidelines) for water, sediment, and tissue contaminants.

Three environmental media (water, sediment, and tissue) were surveyed to assess water quality in the lower Columbia River. Fifteen locations were sampled for water column characteristics, sediment chemistry, and tissue (fish and/or crayfish) bioaccumulation of contaminants. The sampling locations are shown in Figure 1-1 A list of analytes in each environmental medium is provided in Table 1-1.

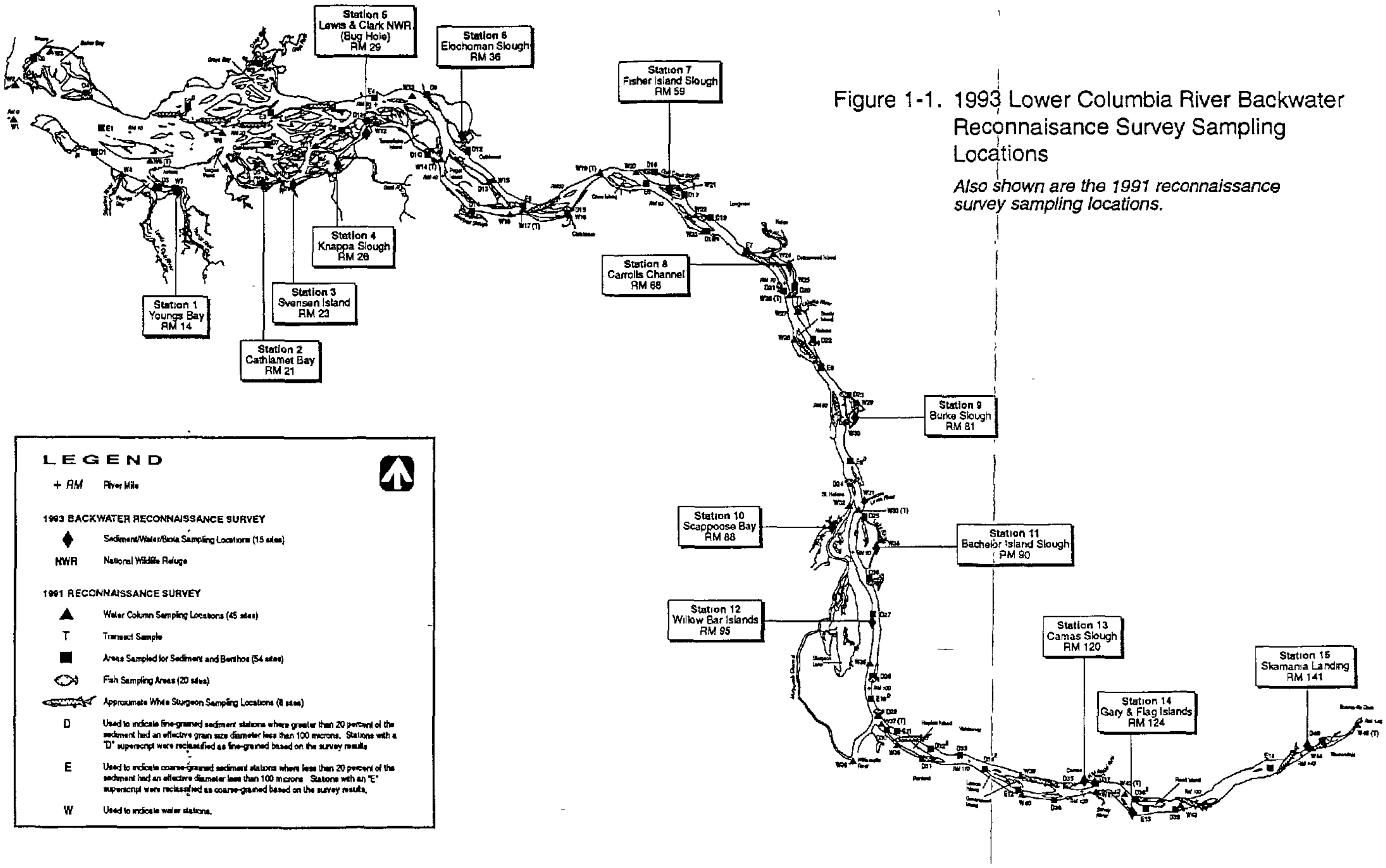


Figure 1-1. 1993 Lower Columbia River Backwater Reconnaisance Survey Sampling Locations

Also shown are the 1991 reconnaissance survey sampling locations.

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

(Page 1 of 6)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
METALS AND CYANIDE			
Aluminum	30	15	
Antimony[a]	30	15	29
Arsenic[a,b]	30	15	29
Barium	30	15	29
Beryllium[a]	30	15	
Cadmium[a,b]	30	15	29
Chromium[a]	30	15	29
Copper[a,b]	30	15	29
Iron	30	15	
Lead[a,b]	30	15	29
Mercury[a,b,c]	30	15	29
Nickel[a]	30	15	29
Selenium[a,b,c]	30	15	29
Silver[a]	30	15	29
Thallium[a]	30	15	
Zinc[a,b]	30	15	29
Cyanide[a]	15	15	
BUTYLTIN COMPOUNDS		15	29
SEMI-VOLATILE ORGANIC COMPOUNDS			
Phenolic Compounds			
Phenol[a]		15	29
2-Methylphenol		15	29
4-Methylphenol		15	29
2,4-Dimethylphenol[a]		15	29
Pentachlorophenol[a]		15	29
2-Chlorophenol[a]		15	29
2,4-Dichlorophenol[a]		15	29
2,4-Dinitrophenol[a]		15	29
2-Nitrophenol[a]		15	29

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

(Page 2 of 6)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
4-Nitrophenol[a]		15	29
2,4,6-Trichlorophenol[a]		15	29
Halogenated Ethers (Other than those listed elsewhere)			
bis(2-chloroethyl)ether[a]		15	29
bis(2-chloroethoxy)methane[a]		15	29
bis(2-chloroisopropyl)ether[a]		15	29
4-Bromophenylphenylether[a]		15	29
4-Chlorophenylphenylether[a]		15	29
Nitroaromatics			
2,4-Dinitrotoluene[a]		15	29
2,6-Dinitrotoluene[a]		15	29
Nitrobenzene[a]		15	29
Nitrosamines			
N-nitroso-di-n-propylamine[a]		15	29
N-nitrosodiphenylamine[a]		15	29
Chlorinated Naphthalene			
2-Chloronaphthalene[a]		15	29
Polynuclear Aromatic Hydrocarbons			
Acenaphthene[a]		15	29
Acenaphthylene[a]		15	29
Anthracene[a]		15	29
Benzo(a)anthracene[a]		15	29
Benzo(b,k)fluoranthene[a]		15	29
Benzo(a)pyrene[a]		15	29
Benzo(g,h,i)perylene[a]		15	29
Chrysene[a]		15	29
Dibenzo(a,h)anthracene[a]		15	29
Dibenzofuran		15	29
Fluoranthene[a]		15	29
Fluorene[a]		15	29

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

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Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Indeno(1,2,3-cd)pyrene[a]		15	29
2-Methylnaphthalene		15	29
Naphthalene[a]		15	29
Phenanthrene[a]		15	29
Pyrene[a]		15	29
Chlorinated Benzenes			
1,3-Dichlorobenzene[a]		15	29
1,2-Dichlorobenzene[a]		15	29
1,4-Dichlorobenzene[a]		15	29
1,2,4-Trichlorobenzene[a,c]		15	29
Hexachlorobenzene[a,c]		15	29
Hexachlorinated Organic Compounds			
Hexachlorobutadiene[a,c]		15	29
Hexachloroethane[a]		15	29
Hexachlorocyclopentadiene[a]		15	29
Benzidines			
3,3'-Dichlorobenzidine[a,d]		15	29
Phthalate Esters			
Dimethylphthalate[a]		15	29
Diethylphthalate[a]		15	29
Di-n-butylphthalate[a]		15	29
Butylbenzylphthalate[a]		15	29
bis-2-(ethylhexyl)phthalate[a,e]		15	29
Di-n-octylphthalate[a]		15	29
Miscellaneous Semi-volatile Compounds			
Carbazole		15	29
Benzyl alcohol		15	29
Benzoic acid		15	29
Isophorone[a]		15	29
4-Chloroaniline		15	29

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

(Page 4 of 6)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
PESTICIDES/PCBs			
Pesticides			
o,p'-DDE		15	29
o,p'-DDD		15	29
o,p'-DDT		15	29
p,p'-DDT[a,b,c,d,e]		15	29
p,p'-DDE[a,b,c,d,e]		15	29
p,p'-DDD[a,b,c,e]		15	29
Heptachlor[a,b,c,d,e]		15	29
Heptachlor epoxide[a,b,c,d,e]		15	29
Alpha-chlordane[a,b,c,d,e]		15	29
Gamma-chlordane[a,b,c,d,e]		15	29
Aldrin[a,b,d]		15	29
Dieldrin[a,b,c,d,e]		15	29
Dicofol		15	29
Methyl parathion		15	29
Toxaphene[a,b,e]		15	29
Endosulfan I[a]		15	29
Endosulfan II[a]		15	29
Endosulfan sulfate[a]		15	29
Endrin[a,b,c,e]		15	29
Endrin ketone		15	29
Endrin aldehyde[a]		15	29
Methoxychlor		15	29
alpha-BHC[a,b,c,d,e]		15	29
beta-BHC[a,d]		15	29
delta-BHC[a]		15	29
gamma-BHC (Lindane)[a,b,c,d,e]		15	29

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

(Page 5 of 6)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
PCBs			
Aroclor 1016/1042[a,d,e]		15	29
Aroclor 1221[a,d,e]		15	29
Aroclor 1232[a,d,e]		15	29
Aroclor 1248[a,b,d,e]		15	29
Aroclor 1254[a,b,d,e]		15	29
Aroclor 1260[a,b,d,e]		15	29
DIOXINS AND FURANS			
2,3,7,8-TCDD[a,c,d,e]		15	29
1,2,3,7,8-PeCDD[c,e]		15	29
1,2,3,4,7,8-HxCDD[c]		15	29
1,2,3,6,7,8-HxCDD[c,e]		15	29
1,2,3,7,8,9-HxCDD[c]		15	29
1,2,3,4,6,7 8-HpCDD[c,e]		15	29
Octachlorodibenzo-p-dioxin (OCDD)[c]		15	29
2,3,7,8-TCDF[c,e]		15	29
1,2,3,7,8-PeCDF[c,e]		15	29
2,3,4,7,8-PeCDF[c]		15	29
1,2,3,4,7,8-HxCDF[c]		15	29
1,2,3,7,8,9-HxCDF[c]		15	29
1,2,3,6,7,8-HxCDF[c]		15	29
2,3,4,6,7,8-HXCDF[c]		15	29
1,2,3,4,6,7,8-HpCDF[c]		15	29
1,2,3,4,7,8,9-HpCDF[c]		15	29
Octachlorodibenzofuran (OCDF)		15	29
RADIONUCLIDES			
Americium-241		15	29
Cesium 137		15	29
Cobalt-60		15	29
Europium-152		15	29

TABLE 1-1 CHEMICALS OF CONCERN ANALYZED IN VARIOUS MEDIA DURING THE 1993 LOWER COLUMBIA BACKWATER RECONNAISSANCE SURVEY

(Page 6 of 6)

Compound	Number of Samples (Excluding Duplicates)		
	Water	Sediments	Tissues
Europium-154		15	29
Europium-155		15	29
Plutonium-238		15	29
Plutonium-239/240		15	29
CONVENTIONALS, NUTRIENTS, AND CHLOROPHYLL[f]			
Nitrogen (TKN, NO_3+NO_2, NH_4)	15		
Phosphorus (TP, SRP)	15		
Chlorophyll/Phaeophytin *a*	15		
Total suspended solids (TSS)	15		
Hardness	15		
Total organic carbon (TOC)	15	15	
Particulate organic carbon (POC)	15		
Grain size		15	
Total solids		15	
Total sulfides		15	
Lipids			29
INDICATOR BACTERIA			
Fecal coliform	15		
Escherichia coli	15		
Enterococcus	15		

[a] U S EPA priority pollutants.

[b] Target compounds of U.S. Fish and Wildlife Service bioconcentration study (Schmitt and Brumbaugh 1990, Schmitt et al. 1990).

[c] Bioconcentrating compounds monitored in the National Bioaccumulation Study (U S EPA 1991a).

[d] Chemicals of highest concern listed by U.S. EPA (1991b).

[e] Currently monitored by Oregon Department of Environmental Quality.

[f] The following measurements were taken at each station in the field: pH, dissolved oxygen, conductivity, water temperature, and turbidity

1.4 DATA INTERPRETATION

Collecting chemical and biological data on contaminants is relatively straightforward, but determining the environmental significance of this data is difficult The complexity of environmental systems makes the development of reference levels a slow and painstaking process As part of this report, the currently available criteria, standards, and guidelines developed by appropriate state and federal resource agencies for contaminants in water, sediment, and fish/shellfish tissue have been compiled to provide reference levels for evaluating the potential environmental significance of survey findings Such evaluation in this report has been limited to potential effects on organisms living in the water column and in the sediments and on organisms that feed on these aquatic organisms, including wildlife and humans Reported contaminant levels in each medium were compared to available criteria or reference values, and problem chemicals and problem areas within the study area were identified.

There are relatively well-established criteria for a variety of contaminants in water However, the single water column samples collected for the reconnaissance survey are poor indicators of overall water quality in rivers due to the transitory nature of river water and the typically low concentrations of water column contaminants, which are often below the detection limits of conventional analysis. Due to the limited detection of contaminants in the water column, data collected during this study were of limited use in identifying problem chemicals and areas of concern. The water column data were also limited for identifying the relationship between water contamination and potential effects on aquatic and terrestrial biota or humans, due to both the low concentrations and the lack of an exposure assessment in the study design. Limited detection also made it impossible to make comparisons of findings among stations, except for conventional water quality variables, indicator bacteria, nutrients, and a few metals.

Sediments, especially those in depositional areas that collect the fine sediments associated with toxic contaminants, are generally considered good indicators of long-term water quality. Sediments record inputs of toxic substances from point and nonpoint sources to the river over a period of time. Since toxic substances become concentrated in the sediments, detection of many of the toxic constituents is possible with conventional laboratory techniques. However, sediment criteria or guidelines are not well developed and are often limited by the medium covered (marine vs freshwater) and in the number of chemicals covered. Several sediment standards are in the draft stage of development (e.g., state of Washington freshwater sediment standards, EPA sediment criteria). This made identification of potential effects to aquatic and terrestrial biota more difficult However, since many toxic constituents were detected, differences among stations could be evaluated This information, plus the limited sediment standards that were available, made it possible to identify both potential problem areas and problem contaminants.

Tissue burdens of chemicals in aquatic organisms are also good indicators of environmental quality since these directly measure contaminants as accumulated by aquatic organisms. If the sampled biota spend long periods in a single location in the river, the tissue contaminant levels should reflect long-term exposure to contaminants in a locally polluted area. However, because regulatory criteria or guidelines are poorly developed for tissue contaminant levels, it is difficult to assess the relative significance of the measured contaminant levels in tissues. Tissue contaminant levels are of direct concern for human consumption of commercial and game species and of direct concern to carnivorous wildlife, especially fish and birds, that live within and along the river Therefore, contaminant levels in commercially important fish (e.g , crayfish), fish that are important prey for piscivorous fish, birds, and mammals (e.g., largescale sucker), and fish with a high lipid (fat) content (e.g., largescale sucker and carp) were selected for sampling. Since many of the organic contaminants accumulate in the fat of organisms, animals with higher fat content are likely to accumulate higher contaminant levels. To identify potential problem areas and problem contaminants, tissue contaminant levels from this study were compared to tissue contaminant levels measured in national bioaccumulation studies, and available guidance values for tissue contaminant levels established for the protection of piscivorous (fish-eating) wildlife.

Data that did not meet the quality objectives of this study have been qualified appropriately or have been rejected and not used in this report. The qualification of data does not imply that the overall quality of the data is poor; on the contrary, careful data qualification is assurance that unqualified data is of high quality. It also alerts future investigators to the level of confidence in the data reported. The reader should realize that the measurement of trace amounts of environmental contaminants is not a simple exercise and that measurements may be complicated by concentrations of constituents that are at, or very near, the detection limits of conventional laboratory methods, or complicated by matrix interferences in the media studied. Therefore, results that are acceptable based on currently accepted protocols for sampling, analysis, and quality assurance may be questioned following further investigations and/or improvements in analytical technology.

1.5 REPORT ORGANIZATION

This report presents and interprets the results of the 1993 lower Columbia River backwater reconnaissance survey. It is organized in the form of a scientific report and includes sections covering the field and laboratory methods employed, the sampling results for each medium, a discussion of the results and their relationship to the 1991 reconnaissance survey data and relationships among the media sampled, and a final section that draws conclusions regarding the distribution and environmental significance of the contaminant levels measured.

The relevant environmental criteria and guidelines used as screening values to identify potential problem chemicals and problem areas are summarized in Section 2.0. Field sampling and laboratory methods are described in Section 3.0. The results of the 1993 backwater reconnaissance survey, including evaluation of the data based on the available reference levels, are summarized in Section 4.0 for each medium (i.e., water, sediment, and tissue sampling results). A comparison of these results to the results of the 1991 reconnaissance survey is provided in the discussion (Section 5.0). This section also a discusses the trends in chemical contamination from relatively coarse-grained sediment areas (generally located in the mainstem of the river) to fine-grained sediment areas in backwater areas of the river. Section 5.0 also discusses the relationships of chemical contaminant levels measured in the water column and in sediment to the contaminant levels measured in fish and crayfish tissue. Section 6.0 is a discussion of conclusions, based on the five primary objectives of the survey listed above. The 1993 backwater reconnaissance survey data validation report and data appendix are available under separate cover as Volumes 2 and 3, respectively (Tetra Tech 1993d,e).

2.0 SELECTION OF REFERENCE LEVELS FOR EVALUATION OF WATER, SEDIMENT AND FISH/SHELLFISH TISSUE DATA

Federal and state agencies have developed criteria[1], standards, and guidelines to identify pollutant levels in water, sediment, and fish/shellfish tissue that could adversely affect wildlife and human health They are used to estimate reasonable limits for the discharge of pollutants to state- and federally-protected waterways, and as legally defensible standards to protect designated beneficial uses of these waters Beneficial uses can include human consumption, recreation, and commerce, as well as all uses of the water body by aquatic and terrestrial biota

Specific beneficial uses of the lower Columbia River have been designated by Washington and Oregon Consumptive uses include domestic, agricultural, and industrial water supply. Other commercial uses include hydropower production, navigation, ports, and commercial fishering Recreational uses include swimming, boating, esthetic enjoyment, sport fishing, and hunting, Nonhuman uses include the support of all indigenous species, including anadromous fish.

Environmental criteria or standards based on water quality rather than available technology have become increasingly important in the management of the nation's water resources. Managing water quality by mean of technology-based regulations has not proved sufficient to support designated beneficial uses in many cases. Basing standards on water quality rather than technology has resulted in further improvements in wastewater treatment beyond "best available technology" and an increased focus on nonpoint source pollution.

The use of any single-value environmental standard (e.g., a concentration not to be exceeded or a maximum allowable change from reference conditions) is problematic Water bodies have tremendous chem-

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[1] The U.S. EPA generally defines *criteria* as those numerical or narrative standards recommended by the EPA, and *standards* as those criteria adopted by individual states and approved by EPA. *Guidelines* are not considered to be legally binding Guidelines are numerical or narrative indices used for screening purposes and resource management. The term *reference level* will be used to include all of these categories.

ical and physical variety and biotic diversity Aquatic environments range from salt lakes, to cold, high-mountain streams, to estuaries and coastal ocean environments Each of these environments contains unique organisms, which in turn pass through a spectrum of life stages and breeding and rearing periods Federal and state governments have responded to this by developing and adopting separate standards for fresh and saltwater environments. Other chemical factors (e.g , the mitigating effect of water hardness on metals toxicity) have been included in the formulations of some standards Only a particular chemical form of a contaminant may be toxic, resulting in standards or guidelines for that particular form Thus there are standards based on dissolved species, organo-metal species (e g., human health criteria for arsenic), or specific valence states (e.g., hexavalent and trivalent chromium).

Narrative standards that limit changes from background or natural conditions may be difficult to evaluate if the standard does not provide guidance on how background or natural conditions may be determined. In water bodies that have already suffered degradation, it may be very difficult to establish the pre-disturbance condition A narrative standard is also difficult to evaluate if the level of confidence and power of the statistical test required to differentiate natural and affected conditions is not specified.

Environmental criteria also do not generally address contaminant interactions, which can be additive, synergistic, or antagonistic in terms of final impact on the biota and human health.

Nonetheless, environmental standards and guidelines are useful for identifying potential water quality problems and guiding the allocation of resources for more specific investigations. Existing reference levels for contaminants in water, sediment, and fish/shellfish tissue are summarized below.

2.1 SELECTION OF WATER QUALITY REFERENCE LEVELS

Water quality reference levels have been developed to protect aquatic life and human health. However, the protection of wildlife has not generally been considered. There are water quality reference levels to protect aquatic life for dissolved oxygen, pH, and temperature; concentrations of metals and cyanide; and concentrations of organic compounds. Reference levels for protecting human health have been developed for metals, cyanide, organic compounds, and indicator bacteria.

The lower Columbia River has been designated by the state of Washington (WAC 173-201A, 1992) as a freshwater Class A waterbody from river mile (RM) 309 3 to the river's mouth Oregon has promulgated specific standards for the North Coast-Lower Columbia Basin in which freshwater, marine, and estuarine state criteria apply depending on the definition given in OAR 340-41-006 (1992). Here estuarine waters are defined as "all mixed fresh and oceanic waters in estuaries or bays from the point of oceanic water intrusion inland to a line connecting the outermost points of the headlands or protective jetties " For the purposes of this report, freshwater criteria will be applied to the data collected at all stations above (upstream) Station 1 in Youngs Bay (RM 14) Conductivity/salinity measurements made during the previous 1991 reconnaissance survey indicated the presence of significant saline water intrusion as far as RM 19 5 near Tongue Point Stations 2 through 5 (RM 21-29) are within the Tidal Fluvial Zone defined in the Columbia River Estuary Data Development Program (CREDDP), and are strongly influenced by freshwater river inputs (Simenstad et al 1990).

An estuary is a dynamic place where fresh and salt waters mix Due to fluctuations in tidal heights and changes in the flow of the river, the furthest point of intrusion of marine waters varies over a period of as short as a few hours. The available water quality criteria have been developed to protect either marine or freshwater organisms, due to the distinct physical and chemical characters of these environments and the adaptations of the organisms that live in them However, an estuary is a location where these two environments overlap, and where marine, freshwater, and estuarine organisms inhabit the same area, simultaneously or alternately

Due to the intermittent, mixed nature of an estuary, it is difficult to apply either marine or freshwater criteria to this environment Oregon considers part of the Columbia River to be an estuary To ensure that organisms inhabiting the estuarine portion of the Columbia River are protected, the more stringent criterion (freshwater or marine) will be applied to data from Station 1, which falls within the Estuarine Mixing Zone defined by CREDDP (Simenstad et al 1990). The only exception is for dissolved oxygen (DO), for which the state of Washington specifies that the marine water quality criterion shall apply when salinity is one part per thousand or greater (WAC 173-201A, 1992).

Water quality criteria are generally well established for concentrations of field-measured parameters such as DO, temperature, and pH; and for toxic constituents such as metals and organic compounds. The available federal water quality criteria and Oregon and Washington state standards are summarized separately below for 1) field-measured parameters, 2) conventional parameters, 3) nutrients and chlorophyll parameters, 4) toxic substances (metals and cyanide), and 5) indicator bacteria measured in the backwater reconnaissance survey. Water column sampling for the 1991 reconnaissance survey included analysis for organic compounds from five water-column sampling stations However, concentrations of these organic compounds were generally below the detection limits of the conventional laboratory methods that were employed. Therefore, water samples collected for the backwater survey were not analyzed for toxic organic substances and criteria for these organic substances are not summarized below

2.1.1 Reference Levels for Field Parameters, Conventional Parameters, and Nutrients and Chlorophyll

U.S. EPA has recommended criteria for the protection of aquatic organisms and their uses for a number of these parameters, and Oregon and Washington have generally adopted these criteria as standards.

2.1.1.1 Field-Measured Parameters. Field-measured parameters such as DO, temperature, pH, conductivity, salinity, and turbidity have a significant effect on biota in the river, especially coldwater anadromous fish. DO is an essential requirement for all animals· adequate levels are necessary for the protection of aquatic organisms. Anadromous coldwater fish are particularly sensitive to reductions in the DO content of marine and fresh water. Water temperature affects the metabolic rate of organisms. Colder temperatures are required for the maintenance of anadromous fish The pH may directly affect organisms, and pH affects the bioavailability of dissolved contaminants Conductivity and salinity determine what kinds of organisms may be able to survive. Elevated turbidity reduces the light available for photosynthetic organisms, thus reducing primary production, in turn affecting biota at higher trophic levels Sediment-induced turbidity may also affect bottom-dwelling organisms and the spawning of anadromous fish when excessive amounts of sediment are deposited on the river bottom.

Specific numerical criteria are available for DO, temperature, and pH (see Table 2-1). Both Oregon and Washington have numerical criteria for DO. The Oregon freshwater criterion for DO states that it shall not be less than 90% saturation (OAR 340-41-205, 1992). The Oregon marine/estuarine criterion states that DO shall not be less than 6 mg/L, except within zones of upwelled marine waters naturally deficient in DO. The class A freshwater criterion for Washington states that DO shall exceed 8.0 mg/L (WAC 173-201A, 1992). The Washington Class A marine criterion states that DO shall exceed 6.0 mg/L (WAC 173-201A, 1992) and should apply when salinity is greater than 1 ppt (WAC 173-201A, 1992)

Although Oregon has established temperature criteria, the criteria apply only to relative temperature changes above and below specific point and nonpoint source discharges (Table 2-1) Washington regulations provide both general temperature criteria for Class A waters as well as specific criteria for the lower Columbia River (Table 2-1) The Class A criteria require that the fresh water temperature not exceed 18° C and that the marine water temperature not exceed 16° C However, regulations promulgated specifically for the lower Columbia River establish a freshwater temperature criterion not to exceed 20° C

The pH standards for fresh and marine waters are the same for Oregon (OAR 1992) and Washington (WAC 1992) (Table 2-1) The freshwater standards state that water column pH should be between 6 5 and 8 5, the marine standard specifies 7 0-8 5

Although the U S EPA acknowledged the importance of conductivity and salinity and their effects on aquatic animals and plants, no criteria were recommended (U.S. EPA 1986a) Neither Oregon or Washington have adopted standards for these parameters (Table 2-1). However, it would be difficult to establish more than a narrative standard for these parameters since they vary by location and time in water bodies, especially in estuaries

Although water quality criteria have been established for turbidity, the criteria are narrative in form and generally apply only to the evaluation of the impacts caused by specific point or nonpoint source discharges (Table 2-1). Due to the broad-scale design of the backwater survey, it was not possible to assess turbidity during the survey period

***2.1.1.2 Conventional Parameters*.** The conventional variables generally have an indirect effect on aquatic organisms. Total suspended solids (TSS), like sediment-induced turbidity, may reduce the light available for photosynthetic organisms, reducing primary production, and in turn affecting biota at higher trophic levels Deposit of sediments on the river bottom may also affect bottom-dwelling organisms and the spawning of anadromous fish. Water hardness (the concentration of polyvalent metal ions, primarily calcium and magnesium) determines, in general, the types of organisms present at a particular location. Water hardness also mediates the toxicity of several metals. Organic carbon, in total, dissolved, and particulate forms (TOC, DOC, and POC), affects the types and abundances of organisms, and may also control the toxicity and bioaccumulation of trace elements and organic compounds.

TABLE 2-1. SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE FIELD-MEASURED PARAMETERS[a]

(Page 1 of 2)

	Freshwater[e]			Marine/Saltwater[f]		
	U S EPA[b]	Oregon[c]	Washington[d]	U S. EPA[b]	Oregon[c]	Washington[d]
FIELD MEASURED PARAMETERS						
Dissolved Oxygen (mg/L)	8 0 (5 0)[g] 9 5 (6 5)[h]	-	8	-	6	6
Dissolved Oxygen (percent saturation)	-	90	90	-	-	-
Temperature (°C)	[i]	[j]	20[k]	[d]	[j]	16[k]
pH	6 5-9 0[l]	6 5-8 5[l]	6.5-8 5[l]	6 5-8 5[l]	7 0-8 5[l]	7 0-8 5[l]
Conductivity	[m]	-	-	-	-	-
Salinity	[m]	-	-	-	-	-
Turbidity	[n]	[o]	[p]	-	[o]	[p]

[a] Freshwater and saltwater criteria that have been recommended or established for the protection of aquatic organisms, criteria are presented only for those substances measured in this survey Washington criteria are those established for waters designated Class A (excellent) by the state, which includes the lower Columbia River

[b] Criteria recommended by EPA for the protection of aquatic organisms (U S EPA 1986a)

[c] Criteria established by the state of Oregon for the protection of aquatic organisms (OAR 1992).

[d] Criteria established by the state of Washington for the protection of aquatic organisms (WAC 1992)

[e] EPA has defined fresh water as those waters in which the salinity is equal to or less than 1 part per thousand 95 percent or more of the time (Federal Register Vol 57 No 246), Oregon and Washington have not promulgated a definition of fresh water Oregon has allowed for the application of freshwater and saltwater criteria in the North Coast-Lower Columbia River Basin (OAR 1992), Washington has designated all of the waters of the Columbia River as fresh (WAC 1992).

[f] EPA has defined salt water as those waters in which the salinity is equal to or greater than 10 parts per thousand 95 percent or more of the time (Federal Register Vol 57 No 246) For salinity between 1 and 10 parts per thousand 95 percent or more of the time, the more stringent of the freshwater and saltwater criteria apply (Federal Register Vol 57 No 246) Oregon and Washington have not promulgated a chemical definition of salt water except for Washington's designation that marine dissolved oxygen criteria apply when salinity is 1 part per thousand or greater and that fecal coliform standards apply when salinity is 10 parts per thousand or greater

TABLE 2-1 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE FIELD-MEASURED PARAMETERS[a]

(Page 2 of 2)

[g] The 1-day minimum dissolved oxygen concentration to protect early life stages of coldwater anadromous fish, to maintain the spawning-gravel dissolved oxygen concentration shown in parentheses For warmwater fishes, the minimum criterion is 5 0 mg/L

[h] The 7-day mean dissolved oxygen concentration to protect early life stages of coldwater anadromous fish, to maintain the spawning-gravel dissolved oxygen concentration shown in parentheses The 7-day mean dissolved oxygen standard for protection of early life stages of warmwater fishes is 6 0 mg/L For warmwater fishes, the mean criterion is 6 0 mg/L

[i] EPA recommends a mixture of narrative criteria and quantitative species-specific models to determine temperature criteria for a specified location and season (U S EPA 1986a)

[j] Oregon's temperature criteria are established for upstream, and presumably unaffected, reference locations

[k] Washington's temperature criterion for waters designated Class A (including the lower Columbia) is 18° C for freshwater and 16° C for marine water However, a special condition has been established for the Columbia River from the mouth to river mile 309 3 which sets a temperature limit of 20 0° C due to human activities and a limit of an increase of 0 3° C due to a single source or 1 1° C due to all sources or activities combined when natural conditions cause the water temperature to exceed 20 0° C

[l] The acceptable lower and upper limits of pH measured in the water body

[m] EPA did not recommend criteria for the protection of aquatic life in the 1986 criteria document, although adverse effects of salinity changes on plants and animals were discussed (U S EPA 1986a) For the protection of public welfare, 250 mg/L of chlorides and sulfates in domestic water supplies (U S EPA 1986a)

[n] EPA recommended the following narrative criterion for solids (suspended, settleable) and turbidity to protect freshwater fish and other aquatic life "Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life" (U S EPA 1986a)

[o] Oregon turbidity standard allows no more than a 10 percent cumulative increase in natural stream turbidity due to turbidity causing activities

[p] Washington Class A standard does not allow more than a 5 NTU increase over background turbidity when background turbidity is 50 NTU or less, or more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU

Although water quality criteria have been recommended by U S EPA for TSS, the criteria are narrative in form (Table 2-2) Due to the broad-scale design of the backwater survey, it was not possible to assess whether TSS exceeded narrative criteria during the survey period

There are no water quality criteria established for water hardness, although the freshwater criteria for the metals cadmium, trivalent chromium, copper, lead, nickel, and zinc are dependent on water hardness There are no established or recommended standards for organic carbon, although water organic carbon levels appear to regulate the availability of hydrophobic toxic compounds to aquatic organisms

2.1.1.3 Nutrients and Chlorophyll Phosphorus and nitrogen compounds serve as essential nutrients for algae, and when present in sufficient amounts can result in noxious amounts of algal biomass Chlorophyll and phaeophytin *a* are surrogate measures of algae or phytoplankton biomass Moderate amounts of algae may provide a food supply for other organisms, but relatively high levels of algae can result in poor oxygen conditions and the death of fish and other organisms.

No criteria have been established for nutrients, with the exception of a 10 mg/L drinking water standard for nitrate, and a pH-dependent criterion for un-ionized ammonia (U.S. EPA 1986a) (Table 2-3) Un-ionized ammonia is toxic to aquatic life. The chronic criteria for un-ionized ammonia are dependent on pH and temperature. For fresh water with a pH of 8.5 and a temperature of 20° C (a conservative estimate for the conditions encountered during the survey), the criterion for un-ionized ammonia is equivalent to a total ammonia concentration (which was measured in this survey) of 0.32 mg/L The marine criterion at pH=8 5 and temperature=20° C is 2.2 mg/L

There are no standards for algal biomass or chlorophyll *a*, although Oregon has established an action level of 15 μg/L of chlorophyll *a* (a surrogate measure of phytoplankton biomass) to flag rivers and estuaries where recognized beneficial uses may be impaired (OAR 1992) (Table 2-3).

2.1.2 Reference Levels for Metals and Cyanide

Although the U.S. EPA has recommended, and the states adopted, both acute and chronic criteria to protect aquatic organisms from toxic substances, only the more restrictive chronic criteria will be summarized and used for screening purposes in this study. Criteria for protecting human health are also summarized below, but are not used in this study. Acute criteria are based on short-term exposure (e.g.,

TABLE 2-2 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE. CONVENTIONAL PARAMETERS[a]

(Page 1 of 2)

	Freshwater[e]			Marine/Saltwater[f]		
	U S EPA[b]	Oregon[c]	Washington[d]	U S EPA[b]	Oregon[c]	Washington[d]
CONVENTIONAL PARAMETERS						
Total Suspended Solids	g	-	-	-	-	-
Hardness[h]	-	-	-	-	-	-
Total Organic Carbon[i]	-	-	-	-	-	-
Particulate Organic Carbon[i]	-	-	-	-	-	-
Dissolved Organic Carbon[i]	-	-	-	-	-	-

[a] Freshwater and saltwater criteria that have been recommended or established for the protection of aquatic organisms, criteria are presented only for those substances measured in this survey Washington criteria are those established for waters designated Class A (excellent) by the state, which includes the lower Columbia River

[b] Criteria recommended by EPA for the protection of aquatic organisms (U S EPA 1986a)

[c] Criteria established by the state of Oregon for the protection of aquatic organisms (OAR 1992)

[d] Criteria established by the state of Washington for the protection of aquatic organisms (WAC 1992)

[e] EPA has defined fresh water as those waters in which the salinity is equal to or less than 1 part per thousand 95 percent or more of the time (Federal Register Vol 57 No 246); Oregon and Washington have not promulgated a definition of fresh water Oregon has allowed for the application of freshwater and saltwater criteria in the North Coast-Lower Columbia River Basin (OAR 1992), Washington has designated all of the waters of the Columbia River as fresh (WAC 1992).

[f] EPA has defined salt water as those waters in which the salinity is equal to or greater than 10 parts per thousand 95 percent or more of the time (Federal Register Vol 57 No 246). For salinity between 1 and 10 parts per thousand 95 percent or more of the time, the more stringent of the freshwater and saltwater criteria apply (Federal Register Vol 57 No 246) Oregon and Washington have not promulgated a chemical definition of salt water except for Washington's designation that marine dissolved oxygen criteria apply when salinity is 1 part per thousand or greater and that fecal coliform standards apply when salinity is 10 parts per thousand or greater

TABLE 2-2 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE CONVENTIONAL PARAMETERS[a]

(Page 2 of 2)

[g] EPA has recommended the following narrative criterion for solids (suspended, settleable) and turbidity for the protection of freshwater fish and other aquatic life: "Settleable and suspended solids should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life" (U S. EPA 1986a).

[h] Water hardness (a measure of the polyvalent metal ion content dissolved in water, primarily calcium and magnesium ions) can significantly affect the toxicity of several metals. Elevated hardness reduces the toxicity of metals due to the antagonistic effects of the principal cations contributing to hardness and/or to complexation/precipitation of toxic metals with metal hydroxides and carbonates. The U S EPA has not recommended water quality criteria for the protection of aquatic organisms for water hardness, but water hardness has been incorporated into calculations of freshwater quality criteria for metals where available data demonstrate the mitigating effect of water hardness on metals toxicity

[i] Organic carbon (total, particulate, and dissolved fractions) concentrations affect the partitioning of many toxic substances, especially nonpolar or hydrophobic organic compounds There are no recommended criteria for water concentrations of organic carbon

TABLE 2-3 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE[a] NUTRIENTS AND BIOMASS

(Page 1 of 2)

	Freshwater[e]			Marine/Saltwater[f]		
	U S EPA[b]	Oregon[c]	Washington[d]	U S EPA[b]	Oregon[c]	Washington[d]
NUTRIENTS[g]						
Total Phosphorus[h]	-	-	-	-	-	-
Soluble Reactive Phosphorus[h]	-	-	-	-	-	-
Ammonia-N (mg/L)[i]	[i]	[i]	[i]	[i]	[i]	[i]
Nitrate+Nitrite-N[j]	-	-	-	-	-	-
Total Kjeldahl Nitrogen[k]	-	-	-	-	-	-
BIOMASS						
Chlorophyll *a* (μg/L)[l]	-	15[m]	-	-	-	-
Phaeophytin *a*[n]	-	-	-	-	-	-

[a] Freshwater and saltwater criteria that have been recommended or established for the protection of aquatic organisms; criteria are presented only for those substances measured in this survey. Washington criteria are those established for waters designated Class A (excellent) by the state, which includes the lower Columbia River

[b] Criteria recommended by EPA for the protection of aquatic organisms (U S. EPA 1986a)

[c] Criteria established by the state of Oregon for the protection of aquatic organisms (OAR 1992)

[d] Criteria established by the state of Washington for the protection of aquatic organisms (WAC 1992)

[e] EPA has defined fresh water as those waters in which the salinity is equal to or less than 1 part per thousand 95 percent or more of the time (Federal Register Vol. 57 No 246), Oregon and Washington have not promulgated a definition of fresh water Oregon has allowed for the application of freshwater and saltwater criteria in the North Coast-Lower Columbia River Basin (OAR 1992), Washington has designated all of the waters of the Columbia River as fresh (WAC 1992)

TABLE 2-3 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE[a]
NUTRIENTS AND BIOMASS
(Page 2 of 2)

[f] EPA has defined salt water as those waters in which the salinity is equal to or greater than 10 parts per thousand 95 percent or more of the time (Federal Register Vol 57 No 246) For salinity between 1 and 10 parts per thousand 95 percent or more of the time, the more stringent of the freshwater and saltwater criteria apply (Federal Register Vol 57 No 246) Oregon and Washington have not promulgated a chemical definition of salt water except for Washington's designation that marine dissolved oxygen criteria apply when salinity is 1 part per thousand or greater and that fecal coliform standards apply when salinity is 10 parts per thousand or greater

[g] In general, cultural or anthropogenic eutrophication (the increase in the nutrient supply to a receiving water due to human activities) has been a significant concern for the management of fresh, estuarine, and marine waters, especially for freshwater lakes Increased concentrations of nutrients (when coupled with favorable conditions of light, temperature, low predation rates, and long water residence times) favor the formation of large standing crops of algae or phytoplankton. Nitrogen and phosphorus have most often been identified as problem nutrients, due in part to their relatively high concentrations in municipal and domestic wastewater. The nutrients identified are the principle forms of particulate and dissolved nitrogen and phosphorus.

[h] There are no recommended standards to protect aquatic life for phosphorus compounds, with the exception of a 0.10 µg/L standard for yellow (elemental) phosphorus for marine and estuarine waters.

[i] The standards for total ammonia nitrogen are based on the toxic effect of un-ionized ammonia at certain pH levels and water temperatures The state standards follow EPA recommended criteria (1986a).

[j] There are no recommended standards for the protection of aquatic life for nitrate plus nitrite nitrogen However, the EPA-recommended maximum-contaminant-level (MCL) for drinking water is 10,000 µg/L

[k] Total Kjeldahl nitrogen measures the sum of ammonia and organic nitrogen There are no recommended standards for the protection of aquatic life for total Kjeldahl nitrogen

[l] Chlorophyll *a* is a surrogate measure of algae or phytoplankton biomass. When light and nutrients permit, species of blue-green algae (cyanobacteria) may bloom at levels causing aesthetically displeasing scums on the water surface and unpleasant odors due to decay Decaying algae may reduce dissolved oxygen levels, in turn affecting other aquatic organisms.

[m] Oregon has established an action level of an average of 15 µg/L of chlorophyll *a* in reservoirs, rivers, estuaries, and natural lakes that do not thermally stratify. The average concentration is based on a minimum of 3 samples collected over any three consecutive months at a minimum of 1 representative location (e g , at point of mid-flow of a river) from samples integrated from the surface to a depth equal to twice the Secchi depth or to the bottom, whichever is less

[n] Phaeophytin *a* is a degradation product of chlorophyll *a* and is measured in the standard method for chlorophyll *a*. No standards have been recommended for this parameter

for one hour, no oftener than every three years on average) Chronic criteria address longer exposure to lower levels of toxic substances (e g , for four days no oftener than every three years on average) Human health criteria are water concentration criteria for protecting human health from the consumption of contaminated water, fish, and/or shellfish Although chronic criteria may be overly conservative for comparison to the single sample results of this survey, they will serve to identify potential water quality problems that may warrant further, more extensive studies

The U S EPA-recommended criteria for toxics have undergone several changes which have resulted in a variety of criteria for each toxic substance The U S EPA published the "gold book" of recommended criteria in 1986 (U S EPA 1986a) These recommended criteria have been updated in a number of Federal Register notices and documents published by U S EPA through 1988 (these are the criteria in the "U S. EPA 1986" column of Table 2-4) In 1991, U S EPA released a poster of updated water quality criteria with a reference to *Quality Criteria for Water 1992*, a "silver book" which has not yet been released to the public ("U S. EPA· 1991" column in Table 2-4). In December 1992, U S EPA published the "final toxics rule" which promulgated water quality criteria for 126 priority pollutants for states that did not have U S EPA-approved water quality criteria (U S EPA 1992a) ("U.S. EPA. 1992" column in Table 2-4) In July 1993, U.S EPA withdrew its promulgated criteria for arsenic and selenium for the state of Washington, since that state had adopted metals criteria in December 1992 that were subsequently approved by U.S EPA (U S. EPA 1993a).

Existing water quality criteria differ among U.S EPA, Oregon, and Washington for metals and cyanide These differences are summarized in Table 4-2, the following discussion addresses key differences Oregon adopted the 1986 U S EPA criteria (U S EPA 1986a) and has not incorporated more recent updates U S EPA promulgated specific saltwater toxics criteria for copper and cyanide for Washington, in 1992, Washington adopted the use of dissolved and total recoverable metal concentration limits for specific metals (WAC 173-201A 1992) (see Table 2-4) Freshwater chronic water quality criteria are available for cyanide and most of the metals measured in the backwater survey (see Table 2-4) No criteria have been recommended for antimony, barium, or thallium, though lowest observed effects levels have been summarized for antimony and thallium (see Table 2-4)

There are more significant differences among U.S EPA, Oregon, and Washington human health criteria U.S EPA has significantly changed or withdrawn human health criteria that were originally recom-

TABLE 2-4 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE AND HUMANS

METALS[a]

(Page 1 of 4)

	Freshwater Chronic[l]					Marine/Saltwater Chronic[m]					Consumption of Fish/Shellfish and Water[n]				
	U S EPA			Oregon	Washington	U S EPA			Oregon	Washington	U S EPA			Oregon	Washington
	1986[b]	1991[c]	1992[d]	1992[e]	1992[f]	1986[b]	1991[c]	1992[d]	1992[e]	1992[f]	1986[g]	1991[h]	1992[i]	1992[j]	1992[k]
CYANIDE AND METALS (Units in μg/L)															
Cyanide	5 2	5 2	5 2	5 2	5 2	1 0	-	1 0	1 0	o	200	700	700	200	o
Aluminum	87	p	q	-	-	-	-	q	-	-	-	-	q	-	-
Antimony	1600 LOEL[r]	/p/30[s]	-	1600 LOEL[r]	-	-	/p/500[s]	-	-	-	-	14	14	146	o
Arsenic			190					36		36/21[t,u]	0 0022	0 018	0 018	0 0022	o
-pentavalent	48 LOEL[r]	-	-	48 LOEL[r]	-	13 LOEL[r]	-	-	13 LOEL[r]	-	-	-	-	-	-
-trivalent	190	190	-	190	-	36	36	-	36	-	-	-	-	-	-
Barium	-	-	q	-	-	-	-	q	-	-	1000	-	q	1000	-
Beryllium	5 3 LOEL[r]	5 3 LOEL[r]	-	5 3 LOEL[r]	-	-	-	-	-	-	0 0068	0 0076	v	0 0068	o
Cadmium	0 7[w]	0 7[w]	0 7[w]	0 7[w]	0 6[w]	9 3	9 3	9 3	9 3	8 0[x]	10	10	v	10	o
Chromium															
-trivalent	117[y]	117[y]	117[y]	117[y]	117[y]	-	-	-	-	-	170000	33000	v	179000	o
-hexavalent	11	11	11	11	11	50	50	50	50	50	50	170	v	50	o
Copper	6 5[z]	6 5[z]	6 5[z]	6 5[z]	5 6[z]	2 9	-	2 9	2 9	o	-	1300	aa	-	-
Iron	1000	1000	q	1000	-	-	-	q	-	-	300	-	q	300	-
Lead	1 3[bb]	1 3[bb]	1 3[bb]	1 3[bb]	0 9[bb]	5 6	8 5	8 5	5 6	5 8[x]	50	-	v	50	o
Mercury	0 012	0 012	0 012	0 012	0 012	0 025	0 025	0 025	0 025	0 025	0 144	0 14	0 14	0 144	o
Nickel	88[cc]	88[cc]	88[cc]	88[cc]	83[cc]	8 3	8 3	8 3	8 3	7 9[x]	13 4	510	610	13 4	o
Selenium	5 0	5 0	5 0	35	5 0[t]	71	71	71	54	71 0[t]	10	104	v	10	o
Silver	0 12	0 12	-	0 12	-	-	/p/0 92[s]	-	-	-	50	91	aa	50	-
Thallium	40 LOEL[r]	40 LOEL[r]	-	40 LOEL[r]	-	-	-	-	-	-	13	1 7	1 7	13	o
Zinc	57[dd]	57[dd]	57[dd]	57[dd]	52[dd]	86	86	86	86	76 6[x]	-	-	-	-	-

TABLE 2-4 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE AND HUMANS METALS[a]

(Page 2 of 4)

[a] Criteria are presented only for those substances measured in this survey

[b] The chronic water quality criteria (4-day average concentration) for the protection of aquatic organisms and their uses recommended by EPA in *Quality Criteria for Water—1986* and relevant updates through 1988 (U S EPA 1986a)

[c] The chronic water quality criteria (4-day average concentration) for the protection of aquatic organisms and their uses provided in a summary table distributed by EPA dated May 1, 1991 The table references *Quality Criteria for Water—1992* which has not yet been made available to the public

[d] The chronic water quality criteria (criteria continuous concentration/4-day average concentration) for the protection of aquatic organisms and their uses established for several states by EPA to bring those states into compliance with the Clean Water Act section 303(c)(2)(B) (40 CFR Part 131, Federal Register Vol 57 No 246) This final rule is also known as "EPA's final toxics rule"

[e] The chronic water quality criteria for the protection of aquatic organisms and their uses established by the state of Oregon (OAR 1992, Chapter 340, Division 41)

[f] The chronic water quality criteria for the protection of aquatic organisms and their uses established by the state of Washington (WAC 1992, Chapter 173-201A)

[g] The water quality criteria for the protection of human health from the consumption of contaminated water, fish and shellfish recommended by EPA in *Quality Criteria for Water—1986* and relevant updates through 1988 (U S EPA 1986a)

[h] The water quality criteria for the protection of human health from the consumption of contaminated water, fish and shellfish provided in a summary table distributed by EPA dated May 1, 1991 The table references *Quality Criteria for Water—1992* which has not yet been made available to the public

[i] The water quality criteria (criteria continuous concentration/4-day average concentration) for the protection of human health from the consumption of contaminated water, fish and shellfish established for several states by EPA to bring those states into compliance with the Clean Water Act section 303(c)(2)(B) (40 CFR Part 131, Federal Register Vol 57 No 246)

[j] The water quality criteria for the protection of human health from the consumption of contaminated water, fish and shellfish established by Oregon (OAR 1992, Chapter 340, Division 41) Oregon has adopted the recommended EPA criteria for toxic and carcinogenic pollutants The human health criteria for Oregon have been set at the 10^{-6} risk level That means that the criteria concentrations would theoretically result in one additional cancer death per one million people due to the consumption of contaminated water, fish and shellfish

[k] The water quality criteria for the protection of human health from the consumption of contaminated water, fish and shellfish have been promulgated by EPA for the state of Washington to bring Washington into compliance with the Clean Water Act section 303(c)(2)(B) (40 CFR Part 131, Federal Register Vol 57 No 246) EPA has approved Washington's use of the 10^{-6} risk level for protection of human health from carcinogenic pollutants That means that the criteria concentrations (arsenic and beryllium in the table above) would theoretically result in one additional cancer death per one million people due to consumption of contaminated water, fish and shellfish

[l] EPA has defined fresh water as those waters in which the salinity is equal to or less than 1 part per thousand 95 percent or more of the time (Federal Register Vol 57 No 246) Oregon and Washington have not promulgated a chemical definition of fresh water Oregon does allow for the application of freshwater and saltwater criteria in the North Coast-Lower Columbia Basin (OAR 1992) The promulgation of water quality standards by EPA for the state of Washington includes the definition of fresh water given above (Federal Register Vol 57 No 246) Washington has designated all of the waters of the Columbia River as fresh water

[m] EPA has defined salt water as those waters in which the salinity is equal to or greater than 10 part per thousand 95 percent or more of the time (Federal Register Vol 57 No 246) For salinity between 1 and 10 parts per thousand 95 percent or more of the time, the more stringent of the freshwater and saltwater criteria apply (Federal Register Vol 57 No 246) Oregon and Washington have not promulgated a chemical definition of salt water The promulgation of water quality standards by EPA for Washington includes the definitions given above (Federal Register Vol 57 No 246)

TABLE 2-4 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE AND HUMANS
METALS[a]
(Page 3 of 4)

[n] The water quality criteria for the protection of human health from the consumption of contaminated water, fish and shellfish are based on concentrations of a toxic or carcinogenic substance that would be expected to result in the accumulation of those substances in aquatic organisms used for human consumption to levels that would be toxic to or would increase the risk of cancer in those persons consuming the contaminated organisms. The assumed exposure pathways for development of the criteria are the consumption of 2 liters of water per day at the criteria concentration and the consumption of 6.5 grams per day of fish and/or shellfish contaminated at a level equal to the criteria concentration multiplied by a bioconcentration factor (BCF) to estimate the contaminant level in edible portions of the contaminated organism. The criteria are also based on the assumption that the exposed individual is an average adult weighing 70 kilograms (i.e., a consumption rate of 0.093 grams per day of contaminated tissue per kilograms of human body weight). For non-carcinogenic substances (only arsenic and beryllium listed in the table above are considered carcinogens) the oral reference dose (RfD) is based on pollutant concentrations that cause threshold effects, that is the amount of contaminated water and fish/shellfish that could be consumed during a lifetime without appreciable risk of deleterious effects. Carcinogenic substances (arsenic and beryllium in the table above) are not considered to have a threshold for adverse health effects. Therefore, the criteria are based on the concentration of the carcinogenic substance that would cause an increased risk of cancer. The criteria in the table above are based on an increase of one cancer per year in a population of one million people. This is also referred to as the 10^{-6} risk level. This risk level has been adopted by both Oregon and Washington and is approved by EPA for application of criteria for carcinogenic pollutants in these states.

[o] Criteria for this substance were promulgated for the state of Washington by EPA. Therefore, the 1992 EPA criteria for this substance may be applied for legal purposes in the state of Washington (40 CFR Part 131, Federal Register Vol. 57 No. 246)

[p] The table indicates that the criteria for aluminum are pH dependent, but no further information is available. The document upon which the table is based, *Quality Criteria for Water—1992* has not been made publicly available as of November 1993

[q] This substance is not listed as a one of the 126 priority pollutants regulated by EPA, and therefore was not included in the promulgation of state standards by EPA (40 CFR Part 131, Federal Register Vol. 57 No. 246)

[r] Data are insufficient for the establishment of criteria. This is the lowest concentration that has been observed to have an effect on aquatic organisms (the lowest observed effect level or LOEL)

[s] The criterion has been presented as a proposed value only

[t] The Washington criteria for the protection of aquatic life and their uses has been approved by EPA (40 CFR Part 131, Federal Register Vol. 58, No. 127)

[u] Washington adopted the EPA saltwater criterion for arsenic, but nonlethal effects to diatoms common to Washington's marine and estuarine waters have been noted below the 36 µg/L level. Therefore, a chronic marine criterion of 21 µg/L has been established by Washington to be met wherever practical

[v] The human health criterion for this substance was withdrawn by EPA in their final rule to promulgate water quality criteria for states (40 CFR Part 131, Federal Register Vol. 58, No. 127) because it did not meet EPA requirements for establishment of human health criteria. However, EPA has recommended that the states should address this contaminant using the state's existing narrative criteria for toxics

[w] The criterion for cadmium is hardness dependent. The formula for calculating the criterion is $e^{(0.7852[\ln(\text{hardness})] - 3.490)}$. The result is multiplied by 0.865 for application of the Washington dissolved metals criterion. A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

[x] The state of Washington saltwater chronic criterion is based on the dissolved concentration of the metal

[y] The criterion for trivalent chromium is hardness dependent. The formula for calculating the criterion is $e^{(0.8190[\ln(\text{hardness})] + 1.561)}$. A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

[z] The criterion for copper is hardness dependent. The formula for calculating the criterion is $e^{(0.8545[\ln(\text{hardness})] - 1.465)}$. The result is multiplied by 0.862 for application of the Washington dissolved metals criterion. A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

TABLE 2-4 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF AQUATIC LIFE AND HUMANS METALS[a]

(Page 4 of 4)

[aa] The human health criterion for this substance was withdrawn by the U S EPA in their final rule to promulgate water quality criteria for states (40 CFR Part 131, Federal Register Vol 58, No 127) The originally recommended criterion did not meet the requirements for establishment of human health criteria used by EPA

[bb] The criterion for lead is hardness dependent The formula for calculating the criterion is $e^{(1\ 273[\ln(\text{hardness})]\ -\ 4\ 705)}$ The result is multiplied by 0 687 for application of the Washington dissolved metals criterion A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

[cc] The criterion for nickel is hardness dependent The formula for calculating the criterion is $e^{(0\ 8460[\ln(\text{hardness})]\ +\ 1\ 1645)}$ The result is multiplied by 0 950 for application of the Washington dissolved metals criterion A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

[dd] The criterion for zinc is hardness dependent The formula for calculating the criterion is $e^{(0\ 8473[\ln(\text{hardness})]\ +\ 0\ 7614)}$ The result is multiplied by 0 891 for application of the Washington dissolved metals criterion A water hardness of 50 mg/L, typical of the lower Columbia River (the mean of hardness concentrations from this survey), was used to calculate the criterion in the table

mended in 1986 Oregon's present standards do not reflect these changes (see Table 2-4) For example, the human health criterion for the consumption of fish/shellfish and water recommended by U S EPA (and promulgated for Washington) is much higher for cyanide, arsenic, and nickel and lower for thallium than the respective Oregon standard U S EPA has also withdrawn previously recommended human health criteria for beryllium, cadmium, trivalent chromium, hexavalent chromium, copper, lead, nickel, and silver (see Table 2-4) The currently recommended U S EPA chronic aquatic life criteria for lead and selenium also differ from the Oregon standards (see Table 2-4)

Freshwater criteria for cadmium, trivalent chromium, copper, lead, nickel, and zinc depend on the hardness of the water tested To assess possible exceedances of these hardness-based criteria in the non-estuarine portion of the river, a median hardness of 50 mg/L (based on the samples analyzed for the backwater survey) was used (see Table 2-4)

Historically, U.S. EPA has recommended measuring total recoverable or acid-soluble concentrations of metals for assessing ambient waters (U S. EPA 1986a). The use of the total recoverable method is still recommended for evaluating effluent quality (U.S. EPA 1992b). However, U.S EPA has recently re-evaluated the use of these methods for assessing ambient waters (U S EPA 1992b). In general, U S EPA has stated that although use of the total recoverable measurement provides greater safety than does the dissolved method, the total recoverable method may result in overestimation of metal toxicity U S EPA has further stated that while adjustment of the criteria to dissolved metal may be small for some metals (e g , copper), other metals may require larger adjustments to account for the much lower percentage of dissolved to particulate metal present during toxicity testing (e.g , aluminum) (U.S. EPA 1992b) Three approaches have been recommended by U S EPA for applying the metals criteria (U S. EPA 1992b).

- Continue to use the total recoverable method for water quality standard assessment

- Measure dissolved metal concentrations and compare these concentrations to criteria appropriate for dissolved metals

- Use a case-by-case assessment of the "water-effect ratio" in the receiving water to determine a site-specific value for the criteria.

While only the total recoverable method was used in the 1991 reconnaissance survey, in the 1993 backwater survey, dissolved metals analyses of filtered water samples were conducted for comparison with chronic dissolved metals criteria recently adopted by the state of Washington for cadmium, copper, lead, nickel, and zinc (WAC-201A, 1992) (see Table 2-4)

2.1.3 Reference Levels for Indicator Bacteria

Criteria and standards for indicator bacteria have been developed for fecal coliform bacteria, enterococcus, and *Escherichia coli* The standards for indicator bacteria differ from the other standards presented in that they are designed to protect human health while the majority of the standards presented above were established to protect the health of aquatic organisms (with the possible exceptions of the guideline for chlorophyll *a* and human health criteria for metals) These bacteria groups and species are surrogate measures of the presence of bacteria and viruses causing disease in humans, and indicate the potential contamination of recreational bathing waters or shellfish harvesting areas by human pathogens derived from human or animal waste.

Both Oregon and Washington have established fecal coliform criteria for marine, fresh, and shellfish-growing waters (WAC 1992; OAR 1992) (Table 2-5) The Oregon standards specify sampling frequency· a minimum of five samples collected over a 30-day period For the freshwater portion of the lower Columbia River, the geometric mean of the samples collected should not exceed 200 colonies per 100 mL, and no more than 10 percent of the samples collected should have more than 400 fecal coliform colonies per 100 mL. For marine and shellfish-growing waters, a maximum median concentration of 14 colonies per 100 mL is specified, and no more than 10 percent of the samples should exceed 43 colonies per 100 mL. For estuarine waters other than shellfish-growing waters, the Oregon standard is the same as that for freshwater. The Washington standards do not specify sampling frequency. For fresh water, the maximum geometric mean is 100 colonies per 100 mL, and no more than 10 percent of the samples collected should exceed 200 colonies per 100 mL For marine waters, the Washington standard is similar to that of Oregon for marine and shellfish-growing waters a maximum geometric mean of 14 colonies per 100 mL, with no more than 10% of the samples exceeding 43 colonies per 100 mL.

In general, Oregon and Washington have adopted U.S. EPA-recommended water quality criteria except for that addressing indicator bacteria. U S EPA has recommended that states no longer employ indicator bacteria standards based on measurement of fecal coliforms, using instead U.S. EPA criteria for either

TABLE 2-5 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF HUMAN HEALTH. INDICATOR BACTERIA[a]

(Page 1 of 2)

	Freshwater[e]			Marine/Saltwater[f]		
	U S EPA[b]	Oregon[c]	Washington[d]	U S EPA[b]	Oregon[c]	Washington[d]
INDICATOR BACTERIA[g]	---------------------- units in numbers of bacteria per 100 mL ----------					
Fecal coliform	h	200/400[i]	100/200[j]	15/43[k]	14/43 (200/400)[l]	14/43[m]
Escherichia coli	126[n]	-	-	-	-	-
Enterococcus	33[o]	-	-	35[p]	-	-

[a] Freshwater and saltwater criteria that have been recommended or established for the protection of human health, for organisms that were measured in this survey. The Washington criteria are those established for waters designated Class A (excellent) by the state, including the lower Columbia

[b] The water quality criteria recommended by EPA for bathing water quality and shellfish quality for the protection of human health (U S EPA 1986a)

[c] The water quality criteria established by Oregon for bathing water quality and shellfish quality for the protection of human health (OAR 1992)

[d] The water quality criteria established by Washington for bathing water quality and shellfish quality for the protection of human health (WAC 1992)

[e] EPA has defined fresh water as those waters in which the salinity is equal to or less than 1 part per thousand 95 percent or more of the time (Federal Register Vol. 57 No 246). Oregon and Washington have not promulgated a chemical definition of fresh water Oregon has allowed for the application of freshwater and saltwater criteria in the North Coast-Lower Columbia River Basin (OAR 1992). Washington has designated all of the waters of the Columbia River as fresh water (WAC 1992)

[f] EPA has defined saltwater as those waters in which the salinity is equal to or greater than 10 part per thousand 95 percent or more of the time (Federal Register Vol. 57 No 246). For salinity between 1 and 10 parts per thousand 95 percent or more of the time, the more stringent of the freshwater and saltwater criteria apply (Federal Register Vol 57 No 246). Oregon and Washington have not promulgated a chemical definition of saltwater, except to Washington's designation that marine dissolved oxygen criteria apply to waters when the salinity is 1 part per thousand or greater and that fecal coliform standards apply to waters when the salinity is 10 parts per thousand or greater.

[g] The indicator bacteria standard is established for the protection of human health from water contact recreation and the ingestion of shellfish.

[h] The U.S EPA does not recommend the use of a fecal coliform standard for water contact recreation, although the calculation of the EPA-recommended *Escherichia coli* and enterococcus standards are based on the previously-recommended fecal coliform standard of 200 fecal coliforms per 100 mL.

[i] The Oregon standard is a logarithmic mean concentration of 200 fecal coliforms per 100 mL based on a minimum of 5 samples collected over a 30-day period with no more than 10 percent of the samples in the 30-day period exceeding 400 fecal coliforms per 100 mL

TABLE 2-5 SUMMARY OF WATER QUALITY CRITERIA FOR THE PROTECTION OF HUMAN HEALTH INDICATOR BACTERIA[a]

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[j] The Washington Class A standard is a geometric mean concentration of 100 colonies per 100 mL with no more than 10 percent of all samples obtained for calculating the geometric mean exceeding 200 colonies per 100 mL.

[k] EPA has recommended an indicator bacteria criteria for shellfish harvesting waters of a median concentration of 15 fecal coliforms per 100 mL and a 90th-percentile standard of 43 fecal coliforms per 100 mL.

[l] The Oregon fecal coliform standard for marine and estuarine shellfish growing waters is a median concentration of 14 organisms per 100 mL, with no more than 10 percent of the samples exceeding 43 organisms per 100 mL The Oregon fecal coliform standard for estuarine waters other than shellfish growing waters (shown in parentheses in the table above) is a logarithmic mean of 200 fecal coliforms per 100 mL based on a minimum of 5 samples in a 30-day period, with no more than 10 percent of the samples in the 30-day period exceeding 400 fecal coliforms per 100 mL

[m] The Washington fecal coliform standard for marine waters is a geometric mean of 14 colonies per 100 mL, and no more than 10 percent of all samples obtained exceeding 43 colonies per 100 mL

[n] The EPA-recommended standard for freshwater bathing is 126 *E coli* per 100 mL, based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period). No single sample should exceed a one-sided confidence limit calculated for any of 4 different bathing frequency levels (U.S EPA 1986a)

[o] The EPA-recommended standard for freshwater bathing is 33 enterococcus per 100 mL, based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period) No single sample should exceed a one-sided confidence limit calculated for any of 4 different bathing frequency levels (U S EPA 1986a)

[p] The EPA-recommended standard for marine bathing is 35 enterococcus per 100 mL, based on a statistically sufficient number of samples (generally not less than 5 samples equally spaced over a 30-day period) No single sample should exceed a one-sided confidence limit calculated for any of 4 different bathing frequency levels (U S. EPA 1986a)

E coli or enterococcus for freshwater bathing areas, and enterococcus for marine bathing areas (U S. EPA 1986a) However, there are currently no state-promulgated standards for enterococcus or *E coli* bacterial densities for Oregon and Washington The U.S EPA (1986a) standard for *E coli* for freshwater bathing areas is 126 colonies per 100 mL (Table 2-5) The U S EPA standards for enterococcus bacteria in fresh and marine bathing waters are 33 and 35 colonies per 100 mL, respectively (Table 2-5) However, U S EPA continues to recommend the fecal coliform criteria adopted by Oregon and Washington (see above) for the protection of shellfish-harvesting waters (Table 2-5).

2.2 SELECTION OF SEDIMENT QUALITY REFERENCE LEVELS

There are fewer reference levels available for evaluating sediment quality than for evaluating water quality. A few resource agencies are developing, or have adopted, freshwater sediment criteria (e.g., New York State Department of Environmental Conservation (NYDEC), Ontario Ministry of the Environment) Oregon and Washington do not presently have draft or final freshwater sediment criteria, although the Washington Department of Ecology (WDOE) is in the process of developing freshwater sediment criteria for the protection of benthic organisms and human health. The National Oceanic and Atmospheric Administration (NOAA) has also developed screening concentrations to evaluate the potential adverse biological effects of sediment contaminant levels measured as part of their National Status and Trends (NS&T) Program (Long and Morgan 1990) Although the Long and Morgan screening concentrations were developed using contaminant and biological effects data primarily from marine and estuarine waters, data from freshwater environments were also included in their analysis. Therefore, these screening levels are considered suitable for use in this report to identify potential problem areas and problem chemicals, and to refine the focus of future studies of the river. In general, sediment quality criteria or guidelines have been developed by using four basic approaches:

- ☐ Estimation of background concentrations by analyzing sediments located in remote areas free of chemical contamination or by analyzing deeper sediments representative of pre-industrial influence

- ☐ Spiked-sediment bioassays to associate sediment chemical levels with adverse biological effects on benthic organisms

- Equilibrium partitioning analysis to predict bulk sediment criteria based on predictions of concentrations in sediment pore water equivalent to established water quality criteria

- Effects-based estimation methods using statistical methods to associate sediment contaminant levels with biological effects These methods include Screening Level Concentrations (SLC), Apparent Effects Threshold (AET), and Bioeffects/Contaminant Co-Occurrence (COA) approaches

There are advantages and limitations associated with each of these approaches. Although each is designed to address sediment toxicity to aquatic biota, the chemical (e.g , proportion of sediment organic carbon) and physical (e g , proportion of fine sediment) character of the sediment can strongly influence the potential effect of toxic substances on benthic organisms (e g , Luoma 1989, Landrum and Robbins 1990, Di Toro et al. 1991, Farrington 1991) The equilibrium partitioning approach is the only method that incorporates additional chemical influences (sediment organic carbon) into the derivation of sediment standards All of the approaches address single chemical constituents. However, sediments normally contain a mixture of contaminants with potential additive, synergistic, or antagonistic interactions which are not accounted for in these approaches However, exceeding guidelines developed using these approaches should indicate that adverse biological effects may occur

The screening levels adopted for this study rely on a combination of the approaches listed above Specific guidelines were taken from four sources

- Long and Morgan's (1990) Effects Range-Low (ER-L) and Effects Range-Medium (ER-M) concentrations

- Ontario Ministry of the Environment's Lowest Effect Levels (from the Provincial Sediment Quality Guidelines, Persaud et al. 1993)

- NYDEC's draft sediment criteria (Newell and Sinnott 1993)

- The five draft U.S. EPA freshwater sediment criteria (U.S. EPA 1993b,c,d,e,f).

Long and Morgan's 1990 reference concentrations were based on observed adverse effects to benthic organisms. They were developed as part of NOAA's National Status and Trends Program when the need arose to evaluate marine sediment data. Long and Morgan's screening levels were developed using a large database of marine, estuarine, and freshwater sediment chemistry and biological-effects data which resulted in calculations of Effects Range-Low (ER-L) concentrations (sediment concentrations at which effects are first observed), Effects Range-Medium (ER-M) concentrations (sediment concentrations above which biological effects were frequently or always observed), and an AET (an independently derived sediment concentration above which biological effects usually or always occur). Based on the available data for each chemical, the lowest 10th-percentile and 50th-percentile sediment concentrations associated with adverse biological effects were selected to represent the ER-L and ER-M concentrations respectively. The data base used to develop these screening levels included biological effects associated with order-of-magnitude ranges in measured contaminant levels.

The Ontario Ministry of the Environment compiled a set of numerical guidelines for the protection of freshwater biological resources (Persaud et al. 1993) using an effects-based SLC approach, which determined the lowest sediment metal concentration above which effects might be observed (Lowest Effect Level) and the sediment metal concentrations above which biological effects are almost always expected to be observed (Severe Effect Level) using the SLC method to associate the absence of benthic organisms with measured levels of metals in sediments. The Ontario guidelines are used to assess dredged material for disposal and possible benthic habitat restoration. Sediment quality guidelines have been developed three levels. No Effect, Lowest Effect, and Severe Effect. The guideline values (with a few exceptions) were developed by compiling contaminant- and species-specific data gathered at a minimum of 10 separate locations. The 90th-percentile chemical concentration provides a species screening level concentration (SSLC) for a single chemical and species. Screening Level Concentrations (SLCs) are then calculated. The lowest 5th-percentile of the SSLC chemical concentrations associated with a minimum of 20 species represents the Lowest Effect Level, and the 95th-percentile represents the Severe Effect Level. Interactive effects of organic carbon and non-polar organic compounds in the sediment were considered by normalizing the sediment chemical concentrations to the sediment organic carbon content prior to calculation of SSLCs and SLCs for these compounds.

NYDEC has developed criteria to identify areas of sediment contamination and to evaluate the potential risk it poses to benthic organisms, wildlife, and human health. NYDEC used equilibrium partitioning to develop sediment criteria for non-polar organic compounds based on available water quality standards and criteria (New York State standards, or U S EPA criteria when New York standards were not available) for the protection of aquatic life and human health for these substances New York has also adopted fish tissue quality criteria for the protection of piscivorous wildlife for several pesticides, PCBs, dioxins, and a few other organic compounds (see Section 2 3) This allowed for the calculation of sediment criteria for these substances for the protection of fish-eating wildlife The lowest of the ER-L (Long and Morgan 1990) and Lowest Effect Levels for metals (Persaud et al 1993) were selected by NYDEC as sediment metals screening levels

Draft criteria have been developed U S. EPA for the protection of freshwater benthic organisms from the pesticides dieldrin and endrin, and the polynuclear aromatic hydrocarbons (PAHs) acenaphthene, fluoranthene, and phenanthrene (U S EPA 1993b,c,d,e,f) These criteria have been developed using equilibrium partitioning.

2.2.1 Sediment Quality Reference Levels for Metals and Cyanide

Sediment quality reference levels are available for 11 of the 16 metals measured in sediments collected for the backwater survey (Table 2-6) from Long and Morgan (1990) and Persaud et al. (1993). Although these two approaches used differing approaches for deriving sediment metal screening levels and guidelines, the Ontario Lowest Effect Levels and the Long and Morgan's ER-Ls are comparable, as are Ontario's Severe Effect Levels and Long and Morgan's ER-Ms and AETs (see Table 2-6) Ontario's Lowest Effect Levels are slightly lower, with the exception of mercury, than Long and Morgan's ER-Ls, and Ontario's Severe Effects Levels are lower, with the exception of lead and mercury, than Long and Morgan's ER-Ms for metals that were evaluated by both programs (Table 2-6). This may be due to inherent differences in the two approaches, or because additional chemical or physical variables were not considered in evaluating the data from these two programs New York State has adopted the lowest metals effect-level concentrations provided by these two sources for use as sediment quality criteria for the protection of benthic organism (Newell and Sinnott 1993).

The toxicity and/or bioavailability of sediment metals may be affected by chemical processes (e g., pH, oxidation-reduction, sulfur reduction) or by the physical character of the sediment environment (e.g., sediment grain size). Several studies have demonstrated that acid-volatile sulfide (AVS) may be a significant factor in the control of bioavailability of sediment metals (e.g., Di Toro et al 1990; Ankley

TABLE 2-6 SUMMARY OF AVAILABLE SEDIMENT REFERENCE LEVELS FOR METALS AND CYANIDE FOR THE EVALUATION OF POTENTIAL ADVERSE EFFECTS TO BENTHIC ORGANISMS

	New York State (1993)		Ontario Ministry of the Environment (1993)			Long & Morgan (1990)		
	Units in mg/kg dry sediment							
	Lowest Effect Level	Moderate to Severe Effect Level	No Effect Level	Lowest Effect Level	Severe Effect Level	Effects Range-Low	Effects Range-Medium	Apparent Effects Threshold
Antimony	2.0	25.0	--	--	--	2	25	25
Arsenic	6.0	33.0	--	6	33	33	85	50
Cadmium	0.6	9.0	--	0.6	10	5	9	5
Chromium	26.0	110.0	--	26	110	80	145	--
Cobalt	--	--	--	50	--	--	--	--
Copper	16.0	110.0	--	16	110	70	390	300
Iron	20,000	40,000	--	20,000	40,000	--	--	--
Lead	31.0	110.0	--	31	250	35	110	300
Manganese	460.0	1100.0	--	460	1,100	--	--	--
Mercury	0.15	1.3	--	0.2	2	0.15	1.3	1
Nickel	16.0	50.0	--	16	75	30	50	--
Silver	1.0	2.2	--	0.5	--	1	2.2	1.7
Zinc	120.0	270	--	120	820	120	270	260
Cyanide	--	--	--	0.1	--	--	--	--

Sources: New York State draft sediment criteria for the protection of benthic organisms (Newell and Sinnott 1993)
Ontario Ministry of the Environment's Sediment Quality Guidelines for protection of benthic organisms (Persuad et al. 1993)
Long and Morgan's (1990) evaluation of benthic organism effects data for NOAA's National Status and Trends Program

et al 1991, Carlson et al 1991) However, no sediment metals criteria or guidelines have been developed using AVS

No criteria or guidance levels were available for the evaluation of the potential larger environmental significance of aluminum, barium, beryllium, selenium, and thallium in sediment. The reference levels given in Table 2-6 are for the evaluation of potential effects on benthic organisms only There are currently no reference levels available to evaluate potential adverse effects on aquatic organisms that live above sediments contaminated with these metals, or on wildlife that live and feed in the vicinity of such contaminated sediments.

2.2.2 Sediment Quality Reference Levels for Organic Compounds

Sediment quality reference levels for evaluating the potential adverse effects on benthic organisms and wildlife are available for several of the semi-volatile organic compounds, including 15 of the 17 polynuclear aromatic hydrocarbons (PAHs), 19 of the 26 pesticides, 4 of the 6 PCB Arochlor mixtures, total PCBs, and dioxin (Table 2-7) These reference levels were derived by all four of the sources cited above, using effects-based and equilibrium partitioning approaches to develop criteria, guidelines, and screening levels primarily for non-polar (neutral or nonionic) organic compounds. The development of standards and guidelines have focused on these types of compounds because their hydrophobic nature 1) results in their tendency to accumulate on suspended and deposited sediments, and 2) allows for the determination of the partitioning of these organic chemicals between sediment organic matter and interstitial water using equilibrium partitioning.

Equilibrium partitioning was used by NYDEC and U.S. EPA to develop criteria for the protection of benthic organisms, and NYDEC extended this approach to calculate sediment criteria for the protection of fish-eating wildlife and human health. U.S EPA has developed draft criteria for two pesticides (dieldrin and endrin) and three PAHs (acenaphthene, fluoranthene, and phenanthrene) for the protection of benthic organisms from adverse effects due to these chemicals (U.S. EPA 1993b,c,d,e,f) (Table 2-7). The U.S EPA criteria were based on the partitioning of these non-polar organic chemicals between the interstitial water and sediment organic matter and the freshwater chronic criteria for the protection of aquatic organisms (Di Toro et al. 1991).

TABLE 2-7 SUMMARY OF AVAILABLE SEDIMENT REFERENCE LEVELS FOR ORGANIC COMPOUNDS FOR THE EVALUATION OF POTENTIAL ADVERSE EFFECTS TO BENTHIC ORGANISMS, WILDLIFE, AND HUMANS

(Page 1 of 2)

	New York State (1993)				Ontario Ministry of the Environment (1993)			Long & Morgan (1990)			EPA (1991)
	µg/g OC				µg/kg dry wt		µg/g OC	µg/kg dry wt			µg/g OC
					Benthic organism effects concentrations and criteria						
	Benthic Aquatic Life Acute Toxicity	Benthic Aquatic Life Chronic Toxicity	Wildlife Bioaccumulation	Human Health Bioaccumulation	No Effect Level	Lowest Effect Level	Severe Effect Level	Effects Range Low	Effects Range Medium	Apparent Effects Threshold	draft sediment criteria
SEMI-VOLATILE ORGANIC COMPOUNDS											
Benzidine	--	--	--	0 003	--	--	--	--	--	--	--
Bis(2-ethylhexyl)phthalate	--	199 5	--	--	--	--	--	--	--	--	-
Dichlorobenzenes	120	12	--	--	--	--	--	--	--	--	--
Diphenylhydrazine	--	--	--	0 58	--	--	--	--	--	-	--
Hexachlorobenzene	9,081	5,570	12	1 12	--	--	--	--	--	--	-
Hexachlorobutadiene	55	5 5	4 0	--	--	--	--	--	-	--	-
Hexachlorocyclohexanes	12 6	0 06	1 5	--	--	--	--	--	--	-	--
Hexachlorocyclopentadiene	44	4 4	--	--	--	--	--	--	-	--	--
Pentachlorophenol	100	40	--	--	--	--	--	--	-	--	--
Phenols (total chlorinated)	--	0 6	--	--	--	--	--	--	-	--	--
Phenols(total unchlorinated)	--	0 5	--	--	--	--	--	--	--	--	--
Trichlorobenzenes	910	91	--	--	--	--	--	--	--	--	--
Triphenylphosphate	1556	156	--	--	--	--	--	--	--	--	--
Polynuclear Aromatic Hydrocarbons (PAHs)											
Acenaphthene	--	140	--	--	--	--	--	150	650	150	140
Anthracene	--	--	--	--	--	220	370	85	960	300	
Benzo[a]anthracene	--	--	--	1 3	--	320	1 480	230	1 600	550	--
Benzo[k]fluoranthene	--	--	--	1 3	--	240	1,340	--	--	--	--
Benzo[a]pyrene	--	--	--	1 3	--	370	1 440	400	2,500	700	--
Benzo[g h i]perylene	--	--	--	--	--	170	320	--	--	--	-
Chrysene	--	--	--	1 3	--	340	460	400	2 800	900	--
Dibenzo[a h]anthracene	--	--	--	--	--	60	130	60	260	100	--
Fluoranthene	--	1,020	--	--	--	750	1,020	600	3 600	1,000	1 020
Fluorene	--	--	--	--	--	190	160	35	640	350	--
Indeno[1 2,3-cd]pyrene	--	--	--	1 3	--	200	320	--	--	--	--
2-Methylnaphthalene	--	--	--	--	--	--	--	65	670	300	--
Naphthalene	--	--	--	--	--	--	--	340	2,100	500	--
Phenanthrene	--	120	--	--	--	560	950	225	1,380	260	120
Pyrene	--	--	--	--	--	490	850	350	2 200	1 000	--
PAHs (total)	--	--	--	--	--	4,000	10 000	4,000	35 000	22 000	--
VOLATILE ORGANIC COMPOUNDS											
Benzene	--	--	--	0 6	--	--	--	--	--	--	--
Carbon tetrachloride	--	--	--	1 96	--	--	--	--	--	--	--
Chlorobenzene	34 6	3 5	--	--	--	--	--	--	--	--	
1 2-Dichloroethane	--	--	--	3 0	--	--	-	--	--	--	-
1 1-Dichloroethylene	--	--	--	0 10	--	--	--	--	--	--	--
1 1 2 2-Tetrachloroethane	--	--	--	4 0	--	--	--	--	--	--	--
Tetrachloroethylene	--	--	--	0 8	--	--	--	--	--	--	--
1 1 2-Trichloroethane	--	--	--	6 2	--	--	--	--	--	--	-
Trichloroethy	--	--	--	2 0	--	--	--	--	--	--	-
Vinyl chlori	--	--	--	2 0	--	--	--	-	--	--	--

TABLE 2-7 SUMMARY OF AVAILABLE SEDIMENT REFERENCE LEVELS FOR ORGANIC COMPOUNDS FOR THE EVALUATION OF POTENTIAL ADVERSE EFFECTS TO BENTHIC ORGANISMS, WILDLIFE, AND HUMANS

(Page 2 of 2)

	New York State (1993)				Ontario Ministry of the Environment (1993)			Long & Morgan (1990)			EPA (1991)
	µg/g OC				µg/kg dry wt		µg/g OC	µg/kg dry wt			µg/g OC
					Benthic organism effects concentrations and criteria						
	Benthic Aquatic Life Acute Toxicity	Benthic Aquatic Life Chronic Toxicity	Wildlife Bioaccumulation	Human Health Bioaccumulation	No Effect Level	Lowest Effect Level	Severe Effect Level	Effects Range-Low	Effects Range Medium	Apparent Effects Threshold	draft sediment criteria
PESTICIDES											
Aldrin	--	--	0.77	0.1	--	2	8	--	--	--	--
Gamma BHC (Lindane)	--	--	--	--	0.2	3	1.0	--	--	--	--
Alpha-BHC	--	--	--	--	--	6	10	--	--	--	--
Azinphosmethyl	--	0.001	--	--	--	--	--	--	--	--	--
Carbofuran	1.82	0.2	--	--	--	--	--	--	--	--	--
Chlordane	--	--	0.006	0.001	5	7	6	0.5	6	2	--
Chloropyrifos	10.7	5.3	--	--	--	--	--	--	--	--	--
DDD	1100	1.0	1.0	0.59	--	8	6	2	20	--	--
DDE	1100	1.0	1.0	0.59	--	5	19	2	15	--	--
DDT	1100	1.0	1.0	0.59	--	8	71	1	7	6	--
DDT (total)	1100	1.0	1.0	0.59		7	12	3	350	--	--
Diazinon	--	0.007	--	--	--	--	--	--	--	--	--
Dieldrin	--	9.0	0.077	--	0.6	2	91	0.02	8	--	9.0
Endosulfan	0.78	0.03	--	--	--	--	--	--	--	--	--
Endrin	--	4.0	0.8	0.8	0.5	3	130	0.02	45	--	4.0
Heptachlor	--	--	0.03	--	0.3	--	--	--	--	--	--
Heptachlor epoxide	--	--	0.03	--	--	5	5.0	--	--	--	--
Isodecyldiphenyl phosphate	5526	427	--	--	--	--	--	--	--	--	--
Malathion	--	0.02	--	--	--	--	--	--	--	--	--
Methoxychlor	--	0.6	--	--	--	--	--	--	--	--	--
Mirex	--	0.7	3.7	--	--	7	130	--	--	--	--
Parathion	--	0.003	--	--	--	--	--	--	--	--	--
Toxaphene	3.2	0.01	--	--	--	--	--	--	--	--	--
POLYCHLORINATED BIPHENYL COMPOUNDS (PCBs)											
Aroclor-1016	--	--	--	--	--	7	53	--	--	--	--
Arclor-1248	--	--	--	--	--	30	150	--	--	--	--
Aroclor-1254	--	--	--	--	--	60	34	--	--	--	--
Aroclor-1260	--	--	--	--	--	5	150	--	--	--	--
PCBs (total)	--	--	1.4	0.0008	10	70	530	50	400	370	--
DIOXIN											
2,3,7,8-TCDD	--	--	0.0002	0.01	--	--	--	--	--	--	--

OC = Organic carbon

Sources New York State draft sediment quality criteria (Newell and Sinnott 1993)
Ontario Ministry of the Environment's sediment quality guidelines (Persuad et al. 1993)
Long and Morgan's (1990) evaluation of benthic organism effects data for the National Status and Trends Program
The U.S. Environmental Protection Agency's draft sediment criteria for acenaphthene, fluoranthene, phenanthrene, dieldrin, and endrin (U.S. EPA 1991c d,e,f,g)

The State of New York has adopted the U S EPA sediment criteria for 3 PAHs, and has calculated sediment criteria for the protection of benthic organisms for 11 other semi-volatile organic compounds and 16 pesticides using equilibrium partitioning and New York State water quality standards or U.S. EPA-recommended criteria when state standards were not available (Newell and Sinnott 1993) (Table 2-7) The NYDEC has also developed sediment criteria for the protection of fish-eating wildlife using state fish-flesh criteria (Newell et al 1987), accumulation factors for the calculation of a water quality criterion, and the sediment/water partitioning coefficient Sediment criteria for the protection of fish-eating wildlife were calculated for 3 semi-volatile compounds, 10 pesticides, and dioxin (Table 2-7) Sediment criteria for the protection of human health were also calculated using the equilibrium partitioning approach and state and federal water quality criteria to protect human health from the consumption of contaminated fish and/or shellfish (Table 2-7)

The Ontario Ministry of the Environment (Persaud et al 1993) and Long and Morgan (1990) determined sediment quality guidelines and screening levels using effects-based approaches to determine levels of PAHs, pesticides, and PCBs which adversely affect benthic organisms (Table 2-7) The Ontario Ministry of the Environment determined the Lowest Effect Level and the Severe Effect Level using the SLC method to associate the absence of benthic organisms with measured levels of organic contaminants in sediments. To determine effects levels for non-polar organic compounds, Ontario normalized the sediment contaminant data to organic carbon content prior to data analysis to incorporate the effect of sediment organic carbon on toxicity. Long and Morgan (1990) developed screening levels for organic contaminants using the same data base and methods described above (section 2.2) Although these two agencies (NOAA and the Ontario Ministry of the Environment) used differing approaches, the Ontario Lowest Effect Levels and the Long and Morgan (1990) ER-Ls are comparable for PAHs, although Ontario's Severe Effect Levels are generally lower than Long and Morgan's ER-Ms and AETs (see Table 2-7) However, Ontario's Lowest Effect Levels for pesticides are generally higher than Long and Morgan's (1990) ER-Ls (see Table 2-7).

2.3 SELECTION OF FISH TISSUE REFERENCE LEVELS

Reference levels (criteria, standards, guidelines) for evaluating contaminants in fish and shellfish tissue for potential adverse effects on other carnivorous or herbivorous aquatic organisms (especially fish-eating wildlife) are less developed than reference levels for water and sediments Reference levels to evaluate the potential adverse effects of contaminant burdens on the contaminated organisms themselves are even less developed. However, tissue contaminant criteria for organo-chlorine compounds for the protection of fish-eating wildlife have been developed by Newell et al. (1987) as part of the Niagara River Biota Contaminant Project. Aquatic biota tissue reference levels are also available for selenium, one of the metals measured in biota samples in this study Selenium guidelines for the protection of carnivorous fish and aquatic birds and for the protection of the health and reproductive success of freshwater and anadromous fish have been suggested by Lemly (1993) These criteria and guidelines are considered suitable for evaluating survey data to identify potential problem areas and problems relating to these few contaminants.

2.3.1 Fish and Shellfish Tissue Quality Reference Levels for Metals

A dietary selenium toxicity threshold for fish and wildlife of 3 mg/kg dry weight has been proposed by Lemly (1993) (Table 2-8). This is equivalent to the lowest food concentration shown to cause mortality of a carnivorous fish or wildlife species (rainbow trout, *Oncorhynchus mykiss*).

A selenium tissue concentration threshold for the health and reproductive success of freshwater and anadromous fish was proposed by Lemly (1993) on the basis of toxicity studies conducted on a variety of sensitive species, particularly *O. mykiss*. These were effects-based toxicity tests, with mortality, blood changes, reduced growth, and reproductive failure employed as endpoints. This effects-based whole-body tissue concentration (4.0 mg/kg dry weight) was slightly higher than the dietary toxicity threshold noted for the same fish species above.

The more conservative whole-body tissue concentration guideline for selenium of 3.0 mg/kg dry weight will be used for screening purposes in this study. This concentration needs to be converted from dry to wet weigh basis, as all tissue contaminant data in this study are reported on a wet weight basis. Assuming that the biota sampled in the reconnaissance survey contained approximately 75 percent moisture, the

TABLE 2-8. SUMMARY OF AVAILABLE FISH TISSUE REFERENCE LEVELS FOR THE EVALUATION OF LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY DATA

COMPOUND	REFERENCE VALUE
METALS (mg/kg dry wt)	
Selenium[a]	3.0 (0.75)[b]
SEMI-VOLATILE ORGANICS (μg/kg wet wt)[c]	
Hexachlorobutadiene	1,300
Hexachlorobenzene	330
Pentachlorophenol	2,000
1,2,4-Trichlorobenzene	1,300
PESTICIDES (μg/kg wet wt)[c]	
Alpha-BHC	100
Beta-BHC	100
Delta-BHC	100
Gamma-BHC (lindane)	100
Aldrin	120
Chlordane	500
Dieldrin	120
Endrin	25
Heptachlor	200
Heptachlor epoxide	200
DDD	200
DDE	200
DDT	200
PCBs (μg/kg wet wt)[c]	
Total PCBs	110
DIOXINS AND FURANS (ng/kg wet wt)[c]	
2,3,7,8-TCDD [Toxicity Equivalency Concentration (TEC)]	3.0

[a] Selenium reference level proposed by Lemly (1993) is for the dietary toxicity threshold for fish and wildlife.

[b] Value in parentheses indicates the wet weight reference value assuming a whole-body total moisture content of 75 percent.

[c] Wildlife reference value from the New York State guidelines for the protection of piscivorous wildlife (Newell et al. 1987).

wet weight selenium tissue concentration for the protection of carnivorous fish and wildlife would be 0 75 mg/kg (see Table 2-8)

2.3.2 Fish and Shellfish Tissue Quality Screening Levels for Organic Compounds

Criteria for tissue contaminant levels are available for 4 semi-volatile organic compounds, 17 pesticides, total PCBs, and dioxin (Table 2-8) The development of dietary intake criteria to protect fish-eating wildlife from organo-chlorine compounds relied on toxicity data from laboratory animal studies that were used to derive human health criteria The major advantage to using this approach is that much more extensive data is available for laboratory animals than for wildlife studied in the field. However, there are some limitations associated with this approach For example, stress associated with low availability of food or water, migration, or reproductive periods may make these organisms vulnerable to lower contaminant concentrations Therefore, the no observed effect level (NOEL) derived from this approach may be lower for wild animals than for those held in a laboratory Also, lipophilic contaminants accumulate in fatty tissues which may be metabolized during stressful periods. Neither of these effects, nor possible additive or synergistic interactions of contaminants, were accounted for in the derivation of these criteria However, these criteria will serve to indicate some areas where contaminants in fish and crayfish tissues are of particular concern.

3.0 FIELD SAMPLING AND LABORATORY METHODS

The field sampling and laboratory analytical methods used in the 1993 backwater reconnaissance survey are described in detail in the Sampling and QA/QC Plan (Tetra Tech 1993c) and the Data Validation Report (Tetra Tech 1993d) This is a brief summary of methods, including variations from the original Sampling and QA/QC Plan

3.1 FIELD SAMPLING

Three media (water, sediment, and aquatic biota) were sampled and analyzed. Water and sediments were sampled from a small craft in June and July of 1993, a period of relatively high water levels in the lower Columbia, to facilitate access to backwater areas. Fifteen backwater areas below Bonneville Dam were targeted for sampling In the field it was determined that one of the target locations (Goering Slough) was not connected to the river by water. An alternate station (Station 9; Burke Slough) was selected as a replacement (see Figure 1-1). Stations were located using USGS topographic maps, and exact sampling stations were selected based on test sediment grabs to locate areas with the finest sediments Station positions were then recorded using a Trimble Transpak II Global Positioning System (GPS) receiver. The GPS location was not corrected for the U.S. Department of Defense's Selective Availability (which degrades GPS accuracy for non-military uses); therefore, the GPS latitudes and longitudes provided are accurate to approximately ±100 m.

After water and sediments were sampled, crayfish and fish were collected for whole-body analysis of tissue chemical content. The fish and crayfish were all collected within approximately 1 km of the water and sediment sampling location as determined from the USGS topographic maps. Field sampling methods are described below

3.1.1 Water Column Sampling

Water column sampling was conducted in conjunction with sediment sampling between 24 June and 1 July 1993 at fifteen backwater locations Limited water column sampling (field-measured parameters only) was also performed during the crayfish sampling cruise (15-25 July) Table 3-1 lists sampling dates, times, and station position latitudes and longitudes Care was taken to avoid collecting water from areas where the shallow bottom had been disturbed by sediment sampling All water samples were collected from a depth of 0.5 m into appropriate sample containers using a variable-speed peristaltic pump equipped with Teflon tubing and a short piece of flexible Tygon tubing that passed through the pump-head. Some of the measurements of field parameters were taken slightly above or below 0.5 meters, depending on the overall depth of the water at that station at that time. Actual water depth and surface conditions were not recorded. Sample containers were rinsed with site water prior to filling the container with sample The parameters selected for water column sampling have been grouped as follows to facilitate the discussion of methods and results:

- Field-measured parameters - Water chemical properties measured in the field using water quality monitoring instruments: pH, dissolved oxygen (DO), temperature, conductivity, salinity, and turbidity

- Conventional parameters - Laboratory-measured parameters that are routinely monitored in water quality studies: total suspended solids (TSS), hardness, and total and particulate organic carbon (TOC and POC)

- Nutrients and phytoplankton biomass - The nutrient and phytoplankton biomass parameters measured in this study include total and soluble reactive phosphorus (TP and SRP); ammonium nitrogen; nitrate+nitrite; total Kjeldahl nitrogen (TKN); and chlorophyll and phaeophytin *a*, which were measured as surrogates to estimate phytoplankton biomass.

  - Metals and cyanide - 16 metals in both whole water samples (total recoverable) and filtered water samples (dissolved).

  - Indicator bacteria - Fecal coliform bacteria, enterococcus, and *Escherichia coli*.

TABLE 3-1 WATER COLUMN STATION LOCATIONS AND TIME OF SAMPLING FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 1 of 2)

Station	River Mile[a]	Latitude/Longitude	Sampling Date/Time[b]	Tide
1	14	46° 09' 56.3" N 123° 49' 39.3" W	6/28/93 1000 hrs	Ebb
Youngs Bay		46° 10' 06 5" N 123° 49' 37.3' W	7/23/93 0700 hrs	Ebb
2	21	46° 10' 36 7" N 123° 41' 59 4" W	6/27/93 1420 hrs 1640 hrs	Ebb Flood
Cathlamet Bay		46° 10' 33 6" N 123° 41' 43 7" W	7/23/93 0830 hrs	Ebb
3	23	46° 10' 29 4" N 123° 39' 53 5" W	6/27/93 0930 hrs	Ebb
Svensen Island		46° 10' 39 1" N 123° 40' 10 5" W	7/23/93 0830 hrs	Ebb
4	26	46° 12' 007 " N 123° 35' 11.3" W	6/26/93 0930 hrs	Ebb
Knappa Slough		46° 11' 55 9" N 123° 35' 04 4" N	7/23/93 1145 hrs	Ebb
5	29	46° 13' 25 6" N 123° 33' 07 0" N	6/26/93 1500 hrs	Ebb
Lewis & Clark NWR (Bug Hole)		46° 13' 15 1" N 123° 33' 19 6" W	7/23/93 1200 hrs	Ebb
6	36	NA	6/25/93 1610 hrs	Flood
Elochoman Slough		46° 13' 28 3" N 123° 24' 04 4" W	7/15/93 1500 hrs	Ebb
7	59	NA	6/25/93 0905 hrs 1310 hrs	Ebb Ebb
Fisher Island Slough		46° 10' 11.3" N 123° 04' 14.3" W	7/15/93 1300 hrs 1500 hrs	Flood Flood
8	68	46° 03' 28 1" N 122° 52' 05.8" W	6/24/93 1330 hrs	Ebb
Carrolls Channel		46° 03' 33 7" N 122° 52' 06.1" W	7/15/93 1030 hrs	Flood
9	81	45° 56' 14.2" N 122° 47' 12.1 W	6/29/93 1000 hrs	Flood
Burke Slough		45° 56' 27 1" N 122° 47' 09 6" N	7/16/93 1040 hrs	Ebb

TABLE 3-1 WATER COLUMN STATION LOCATIONS AND TIME OF SAMPLING FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

(Page 2 of 2)

Station	River Mile[a]	Latitude/Longitude	Sampling Date/Time[b]	Tide
10 Scappoose Bay	88	45° 49’ 35.8" N 122° 49’ 56.0" W	6/28/93 1700 hrs	Ebb
		45° 49’ 45.9" N 122° 49’ 58.6" W	7/20/93 1220 hrs	Ebb
11 Bachelor Island Slough	90	45° 49’ 29.6" N 122° 45’ 31.2" W	6/29/93 1710 hrs	Ebb
		45° 49’ 16.9" N 122° 45’ 29.5" W	7/18/93 1545 hrs	Flood
12 Willow Bar Islands	95	45° 44’ 25.6" N 122° 46’ 22.4" W	6/30/93 0930 hrs	Ebb
		45° 44’ 26.6" N 122° 46’ 22.0" W	7/20/93 0810 hrs	Ebb
13 Camas Slough	120	NA	7/1/93 1130 hrs	Ebb
		45° 34’ 42.4" N 122° 25’ 16.1" W	7/18/93 0900 hrs	Ebb
14 Gary & Flag Islands	124	45° 32’ 50.8" N 122° 20’ 21.6" W	7/1/93 0745 hrs	Ebb
		45° 32’ 26.9" N 122° 20’ 05.5" W	7/18/93 1045 hrs	Ebb
15 Skamania Landing	141	45° 36’ 57.4" N 122° 02’ 00.8" W	6/30/93 1615 hrs 1805 hrs	Flood Ebb
		45° 36’ 49.6" N 122° 02’ 05.4" W	7/18/93 1300 hrs	Ebb
		45° 36’ 53.2" N 122° 02’ 05.4" W	7/19/93 1100 hrs	Ebb

NWR = National Wildlife Refuge

NA = Not available. GPS receiver not functional.

[a] Approximate river mile (to the nearest mile) calculated from geographic coordinates.

[b] The time given is only the period of field-parameter sampling. Water samples for laboratory analyses were collected in conjunction with the first sampling trip to each station.

Table 1-1 contains a complete list of the water column parameters The field methods used to collect samples are described below

3.1.1.1 ***Field-Measured Parameters*** Field-measured parameters were measured directly in the water column using a Grant/Yellow Springs Instruments (Grant/YSI) model 3800 water quality monitoring instrument, which measures all six parameters listed above Measurements were taken in triplicate (three measurements recorded over the period of several minutes) at each of the 15 stations during both the water/sediment sampling and crayfish sampling cruises

3.1.1.2 ***Conventional Parameters*** Single samples were collected for the conventional parameters (TSS, hardness, TOC, and POC) except at the Burke Slough Station 9 (RM 81) where three field replicates were collected Samples were drawn from a depth of 0 5 m and placed directly into appropriate, labeled sample containers. The containers were placed on ice and shipped to the laboratory for analysis following standard chain-of-custody procedures. TOC samples were preserved in the field by acidifying with HCl to a pH of 2 or less. POC samples were collected in the field by pumping water directly into a 75 mL plastic syringe equipped with a 14 mm filter holder The filtering apparatus was first rinsed with sample water A pre-combusted glass fiber filter was placed in the filter holder, the syringe was filled with an appropriate aliquot of sample (generally 25 to 60 mL), and the water was pressed through the filter When relatively dry, the filters were removed and placed in pre-cleaned and combusted silver boats which were transported in the dark on ice, and then stored frozen prior to analysis by the laboratory

3.1.1.3 ***Nutrients and Phytoplankton Biomass.*** Sampling for phosphorous and nitrogen was done in triplicate at all stations Single field samples were collected for analysis of chlorophyll and phaeophytin *a*, except at the Burke Slough Station 9 (RM 81) where three field replicate samples were collected.

Samples collected for analysis of TP, TKN, and chlorophyll/phaeophytin *a* were drawn from 0.5 m and placed directly into appropriate, labeled sample containers which were placed on ice and shipped to the laboratory for analysis following standard chain-of-custody procedures. These samples were preserved in the field by acidifying with H_2SO_4 to a pH of 2 or less. Samples collected for SRP, ammonium nitrogen, and nitrate+nitrite nitrogen were prepared by equipping the peristaltic pump with a polycarbonate in-line filter holder and 0.45 μm Millipore^{TM} membrane filters. Water samples were pumped from 0.5 m through the filter and directly into the sample container All samples were placed on ice for transport to the laboratory Nutrient samples were shipped daily to the laboratory in order to meet the 48-hour holding time for SRP analysis

3.1.1.4 ***Metals and Cyanide*** Three field replicate samples were collected at all stations for the analysis of 16 metals, both total recoverable and filterable (operationally defined as dissolved) forms, and cyanide Water samples for total recoverable metal analysis were pumped from 0.5 m directly into appropriate sample containers Samples for analysis of metals that pass through a 0 45 μm filter (i e., dissolved metals) were collected using the filtering apparatus described above for SRP filtration, and both 0 45 μm Millipore^{TM} membrane and Nalgene^{TM} nylon filters. Although the filters that were used were not acid-rinsed prior to use as proposed in the Sampling and QA/QC Plan (Tetra Tech 1993c), equipment/filter blanks were prepared during the field effort using both filter types (membrane and nylon filters) to assess the potential for contribution of metals from the sampling and filtering apparatus. All samples collected for metals analysis were preserved in the field by acidifying with Ultrex-grade HNO_3 to a pH of 2 or less. Samples for cyanide analysis were pumped directly into appropriate, labeled sample containers and preserved in the field by alkalizing with NaOH to a pH of 12 or more. All samples were transported on ice to the laboratory following standard chain-of-custody procedures.

3.1.1.5 ***Indicator Bacteria***. Indicator bacteria (fecal coliforms, enterococcus, and *E. coli*) were sampled by pumping water from 0.5 m directly into appropriate sample containers Three field replicate samples were collected for analyses of indicator bacteria levels and transported to the laboratory on ice. Indicator bacteria samples were delivered almost daily to the laboratory (following chain-of-custody procedures) in order to meet the 30-hour holding time established for this survey.

3.1.2 Sediment Sampling

Sediment sampling was conducted, in conjunction with water sampling, between 24 June and 1 July 1993 at fifteen backwater locations. Table 3-2 lists sampling dates, times, and station position latitudes and longitudes. All sediment samples were collected using a modified 0 02-m^2 Petite-Ponar sediment grab sampler. Grabs were evaluated for acceptability according to the guidelines established in the Sampling and QA/QC Plan (Tetra Tech 1993c). Surface sediments were removed from accepted grab samples to a depth of 2 cm using a clean, dry stainless-steel spoon. Several grab samples were collected at each station to create a sediment composite sample which was homogenized using a dry, solvent-rinsed, stainless-steel bowl and spoon. Single field composite samples were collected from all stations, except

TABLE 3-2. SEDIMENT SAMPLING STATION LOCATIONS AND TIME OF SAMPLING FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

Station	River Mile[a]	Latitude/Longitude	Sampling Date/Time
1 Youngs Bay	14	46° 09' 56.3" N 123° 49' 39.3" W	6/28/93 1000 hrs
2 Cathlamet Bay	21	46o° 10' 36.7" N 123° 41' 59.4" W	6/27/93 1640 hrs
3 Svensen Island	23	46° 10' 29.4" N 123° 39' 53.5" W	6/27/93 0930 hrs
4 Knappa Slough	26	46° 12' 00.7" N 123° 35' 11.3" W	6/26/93 0930 hrs
5 Lewis & Clark-NWR (Bug Hole)	29	46° 13' 25.6" N 123° 33' 07.0" N	6/26/93 1500 hrs
6 Elochoman Slough	36	46° 13' 28.3" N 123° 24' 04.4" W	6/25/93 1610 hrs
7 Fisher Island Slough	59	46° 10' 11.3" N 123° 04' 14.3" W	6/25/93 0905 hrs
8 Carrolls Channel	68	46° 03' 28.1" N 122° 52' 05.8" W	6/24/93 1330 hrs
9 Burke Slough	81	45° 56' 14.2" N 122° 47' 12.1 W	6/29/93 1000 hrs
10 Scappoose Bay	88	45° 49' 35.8" N 122° 49' 56.0" W	6/28/93 1700 hrs
11 Bachelor Island Slough	90	45° 49' 29.6" N 122° 45' 31.2" W	6/29/93 1710 hrs
12 Willow Bar Islands	95	45° 44' 25.6" N 122° 46' 22.4" W	6/30/93 0930 hrs
13 Camas Slough	120	45° 34' 42.4" N 122° 25' 16.1" W	7/1/93 1130 hrs
14 Gary & Flag Islands	124	45° 32' 50.8" N 122° 20' 21.6" W	7/1/93 0745 hrs
15 Skamania Landing	141	45° 36' 57.4" N 122° 02' 00.8" W	6/30/93 1615 hrs

[a] Approximate river mile (to the nearest mile) calculated from geographic coordinates.

the Burke Slough Station 9 (RM 81) where three field-replicate composites were collected Sediment sampling parameters have been grouped as follows.

- ☐ Conventional parameters - Laboratory-measured parameters that are routinely monitored in sediment quality studies total solids, total volatile solids (TVS), total organic carbon (TOC), ammonia nitrogen, TKN, total sulfides, and sediment grain size
- ☐ Metals and cyanide - 16 total recoverable metals and cyanide.
- ☐ Semi-volatile organic compounds - 14 phenols, 5 halogenated ethers, 6 nitroaromatics, 18 PAHs and naphthalenes, 8 chlorinated benzenes, 1 benzidine compound, 6 phthalate esters, and 5 miscellaneous organic compounds.
- ☐ Pesticides and PCBs - 1 organophosphorus (methyl parathion) and 25 chlorinated pesticides, plus 6 PCB-Arochlor mixtures.
- ☐ Dioxins and Furans - 7 dioxin and 10 furan congeners.
- ☐ Butyltin compounds - Mono-, di-, and tributyltin (TBT) compounds.
- ☐ Radionuclides - 8 long-lived radionuclides.
- ☐ Sediment Toxicity Testing - Standard laboratory toxicity testing.

Table 1-1 is a complete list of sediment parameters analyzed in the 1993 backwater survey. The field methods used to collect samples are described below.

Composite sediment samples were collected and prepared as described above, and subsamples were placed in clean, dry, pre-labeled sample containers. The samples for total sulfide analysis were preserved in the field with 1 N zinc acetate. Samples were then transported to the laboratory on ice, following standard sample chain-of-custody procedure.

3.1.3 Crayfish and Fish Sampling

Crayfish, largescale suckers, and carp were collected during the survey for analysis of tissue chemical burdens Where suckers could not be collected in sufficient numbers (Youngs Bay/RM 14 and Skamania Landing/RM 141), carp were collected as an alternate species in accordance with the sampling procedures specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) Crayfish were collected at 13 sites, suckers at 14 sites, and carp at 2 sites (Table 3-3) Tables 3-4 and 3-5 detail sampling dates, species caught, number of individuals in the composite samples, and station latitudes and longitudes Crayfish were caught using traps baited with canned catfood. Several holes were made in each can, which allowed the scent of the food to escape but did not allow the crayfish to eat the food. The traps were deployed at each station and left overnight Captured crayfish were then removed from the traps and placed on ice prior to weighing. Crayfish were individually wrapped in foil and frozen live on dry ice for shipment to the laboratory. The laboratory composited samples and homogenized whole crayfish; Table 3-4 lists the number of individuals in each composite sample. Three field replicate composites of both crayfish and fish were collected from Camas Slough (RM 120)

Largescale sucker and carp were collected by electrofishing. Five individuals were collected from each station, weighed, measured (fork length), wrapped in aluminum foil, placed in a single plastic bag, and kept frozen on dry ice until delivery to the laboratory for compositing and homogenizing.

Crayfish and fish parameters have been grouped as follows to facilitate the discussion of laboratory methods and results

- <u>Conventional parameters</u> - Field-measured weight data for individual crayfish, weight and length data for individual fish, and lipid content for all species.
- <u>Metals</u> - 12 metals.
- <u>Semi-volatile organic compounds</u> - 14 phenolic compounds, 5 halogenated ethers, 6 nitroaromatics, 18 PAHs, 1 chlorinated naphthalene, 8 chlorinated benzenes, 1 benzidine, 6 phthalate esters, and 5 miscellaneous organic compounds.

TABLE 3-3. STATIONS SAMPLED FROM WHICH CAPTURED BIOTA WERE ANALYZED FOR CHEMICAL PARAMETERS

Station	Crayfish	Largescale Sucker	Carp
1			X
2	X	X	
3	X	X	
4	X	X	
5	X	X	
6	X	X	
7	X	X	
8	X	X	
9	X	X	
10	X	X	
11	X	X	
12	X	X	
13	X	X	
14	X	X	
15			X

TABLE 3-4. LOCATIONS AND DATES OF CRAYFISH SAMPLING FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY, 1993

(Page 1 of 1)

Station	River Mile	Latitude/Longitude	Date Trap Deployed	Date trap Retrieved	Number of Crayfish Retained for Analysis
1 Youngs Bay	14	46-09-56.3 N 123-10-36.7 W	7/21/93 - 7/22/93	7/22/93 - 7/23/93	0
2 Cathlamet Bay	21	46-10-36.7 N 123-41-59.4 W	7/21/93 - 7/22/93	7/22/93 - 7/23/93	15
3 Svensen Island	23	46-10-29.4 N 123-39-53.5 W	7/21/93	7/22/93	19
4 Knappa Slough	26	46-12-00.7 N 123-35-11.3 W	7/23/93	7/24/94	15
5 Lewis & Clark NWR	29	46-13-25.6 N 123-33-07.0 W	7/22/93	7/23/93	21
6 Elochoman Slough	36	46-13-28.3 N 123-24-04.4 W	7/15/93 - 7/16/93	7/16/93 - 7/17/93	13
7 Fisher I. Slough	59	46-10-11.3 N 123-04-14.3 W	7/15/93	7/16/93	15
8 Carrolls Channel	68	46-03-28.1 N 122-52-05.8 W	7/15/93 - 7/16/93	7/16/93 - 7/17/93	13
9 Burke Slough	81	45-56-14.2 N 122-47-12.1 W	7/15/93 - 7/16/93	7/16/93 - 7/17/93	15
10 Scappoose Bay	88	45-49-35.8 N 122-49-56.0 W	7/19/93 - 7/20/93	7/20/93 - 7/21/93	15
11 Bachelor I. Slough	90	45-49-29.6 N 122-45-31.2 W	7/17/93 - 7/19/93	7/18/93 - 7/20/93	15
12 Willow Bar Islands	95	45-44-25.6 N 122-46-22.4 W	7/19/93 - 7/24/93	7/20/93 - 7/25/93	12
13 Camas Slough	120	45-34-42.4 N 122-25-16.1 W	7/17/93	7/18/93	13
14 Gary & Flag Islands	124	45-32-50.8 N 122-20-21.6 W	7/17/93 - 7/18/93	7/18/93 - 7/19/93	8
15 Skamania Landing	141	45-36-57.4 N 122-02-00.8 W	7/17/93 - 7/18/93	7/18/93 - 7/19/93	0

TABLE 3-5. LOCATIONS AND DATES OF FISH SAMPLING FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY, 1993

(Page 1 of 1)

Station	River Mile	Latitude/Longitude	Fish Caught	Date Caught	Number of Fish Retained for Analysis
1 Youngs Bay	14	46-09-56.3 N 123-10-36.7 W	Largescale sucker Carp	8/6/93	2 4
2 Cathlamet Bay	21	46-10-36.7 N 123-41-59.4 W	Largescale sucker	8/6/93	5
3 Svensen Island	23	46-10-29.4 N 123-39-53.5 W	Largescale sucker	8/5/93	5
4 Knappa Slough	26	46-12-00.7 N 123-35-11.3 W	Largescale sucker	8/5/93	5
5 Lewis & Clark NWR	29	46-13-25.6 N 123-33-07.0 W	Largescale sucker	8/5/93	5
6 Elochoman Slough	36	46-13-28.3 N 123-24-04.4 W	Largescale sucker	8/5/93	5
7 Fisher Island Slough	59	46-10-11.3 N 123-04-14.3 W	Largescale sucker	8/5/93	5
8 Carrolls Channel	68	46-03-28.1 N 122-52-05.8 W	Largescale sucker	8/5/93	5
9 Burke Slough	81	45-56-14.2 N 122-47-12.1 W	Largescale sucker	8/5/93	5
10 Scappoose Bay	88	45-49-35.8 N 122-49-56 0 W	Largescale sucker	8/4/93	5
11 Bachelor I. Slough	90	45-49-29.6 N 122-45-31.2 W	Largescale sucker	8/4/93	5
12 Willow Bar Islands	95	45-44-25.6 N 122-46-22.4 W	Largescale sucker	8/4/93	5
13 Camas Slough	120	45-34-42.4 N 122-25-16.1 W	Largescale sucker	8/3/93	5
14 Gary & Flag Islands	124	45-32-50.8 N 122-20-21.6 W	Largescale sucker	8/3/93	5
15 Skamania Landing	141	45-36-57.4 N 122-02-00.8 W	Carp	8/3/93	5

- Pesticides and Polychlorinated biphenyls (PCBs) - 25 organochlorine pesticides, 1 organophosphorus pesticide, and 6 PCB (Arochlor) mixtures

- Dioxins and Furans - 7 dioxin and 10 furan congeners.

- Butyltin compounds - Mono-, di-, and tributyltin (TBT) compounds

- Radionuclides - 8 long-lived radionuclides

Table 1-1 provides a complete list of parameters analyzed in crayfish and fish samples.

3.2 LABORATORY METHODS

Laboratory analyses were conducted on whole and filtered water samples, whole surficial sediment composite samples, and whole-body composite samples of fish and crayfish tissues. Several laboratories were contracted to perform specific chemical analyses. Laboratory selection was based on analytical capabilities (i e , ability to achieve relatively low detection limits) and on logistical considerations for analytes with relatively short holding times (i.e , indicator bacteria). The separate data validation report (Tetra Tech 1993d) identifies the laboratories selected and the analyses they performed.

3.2.1 Water Column Analyses

Water samples were analyzed for the parameters identified in 3 1.1. The laboratory methods are summarized below Table 3-6 provides a complete list of the parameters analyzed and the methods used.

3.2.1.1 Conventional Parameters. Conventional parameters (TSS, hardness, TOC, and POC) were analyzed following standard methods provided by the American Public Health Association (APHA 1989; see Table 3-6). POC analysis followed the method of Hedges and Stern (1984) using a Carlo-Erba CHN analyzer.

3.2.1.2 Nutrients and Phytoplankton Biomass. Analyses for nutrients (TP, SRP, ammonium nitrogen, nitrate + nitrite nitrogen, and TKN) and phytoplankton biomass surrogate measures (chlorophyll *a* and its

TABLE 3-6 SUMMARY OF LABORATORY ANALYTES AND METHODS USED IN THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 1 of 4)

Analyte	Matrix	Method
CONVENTIONALS		
Total Suspended Solids (TSS)	Water	SM[a] 2540 D
Hardness	Water	SM 2340 C
Total Organic Carbon (TOC)	Water	SM 5310 C
	Sediment	SM 5310 B
Particulate Organic Carbon (POC)	Water	Hedges and Stern (1984) - CHN Analyzer
Total Solids	Sediment	PSEP Protocols[b]
Total Sulfides	Sediment	
Total Volatile Sulfides (TVS)	Sediment	
Grain Size	Sediment	
Percent Lipid	Fish/Crayfish Tissue	FDA gravimetric method
NUTRIENTS AND CHLOROPHYLL		
Total Phosphorus (TP)	Water	SM 4500-P F
Soluble Reactive Phosphorus (SRP)	Water	SM4500-P F
Ammonium Nitrogen	Water	SM 4500-NH_3 H
	Sediment	Plumb (1981)
Nitrate+Nitrite Nitrogen	Water	SM 4500-NO_3 F
Total Kjeldahl Nitrogen (TKN)	Water	SM 4500-ORG C
	Sediment	SM 4500-ORG C
Chlorophyll and Phaeophytin *a*	Water	SM 10200 H (spectrophotometric method)
METALS AND CYANIDE		
Aluminum	Water	EPA[c] 202.2 (GFAA)[d]
	Sediment	EPA 200.7 (ICP)[e]
Antimony	Water	EPA 204 2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	

TABLE 3-6 SUMMARY OF LABORATORY ANALYTES AND METHODS USED IN THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 2 of 4)

Analyte	Matrix	Method
Arsenic	Water	EPA 206.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Barium	Water	EPA 200.7 (ICP)
	Sediment	
	Fish/Crayfish Tissue	
Beryllium	Water	EPA 200.7 (ICP)
	Sediment	
	Fish/Crayfish Tissue	
Cadmium	Water	EPA 213.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Chromium	Water	EPA 218.2 (GFAA)
	Sediment	EPA 200.7 (ICP)
	Fish/Crayfish Tissue	EPA 218.2 (GFAA)
Copper	Water	EPA 220.2 (GFAA)
	Sediment	EPA 200.7 (ICP)
	Fish/Crayfish Tissue	
Iron	Water	EPA 200.7 (ICP)
	Sediment	
Lead	Water	EPA 239.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Mercury	Water	EPA 245.2 (CVAA)
	Sediment	
	Fish/Crayfish Tissue	

TABLE 3-6. SUMMARY OF LABORATORY ANALYTES AND METHODS USED IN THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 3 of 4)

Analyte	Matrix	Method
Nickel	Water	EPA 200.7 (ICP)
	Sediment	
	Fish/Crayfish Tissue	
Selenium	Water	EPA 270.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Silver	Water	EPA 272.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Thallium	Water	EPA 279.2 (GFAA)
	Sediment	
	Fish/Crayfish Tissue	
Zinc	Water	EPA 200.7 (ICP)
	Sediment	
	Fish/Crayfish Tissue	
Cyanide	Water	SM 4500-CN E (distillation for total cyanide)
	Sediment	
INDICATOR BACTERIA		
Enterococcus	Water	SM 9230 B (multiple-tube method)
Escherichia coli	Water	SM 9221 C (modified MPN[g] method)
Fecal Coliforms	Water	SM 9221 C (MPN[g] method)
ORGANIC COMPOUNDS		
Semi-volatile Organics	Sediment	EPA 8270 (GC/MS)[h] - SIM for PAHs[i]
	Fish/Crayfish Tissue	
Pesticides and PCBs	Sediment	EPA 8080 (GC/ECD)[j]
	Fish/Crayfish Tissue	

TABLE 3-6 SUMMARY OF LABORATORY ANALYTES AND METHODS USED IN THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

(Page 4 of 4)

Analyte	Matrix	Method
Dioxins and Furans	Sediment	EPA 1613 (high resolution method)
	Fish/Crayfish Tissue	
Butyltins (TBT)[k]	Sediment	Uhler et al. (1989)
	Fish/Crayfish Tissue	
Radionuclides	Sediment	EPA 907.0 for alpha emitters and EPA 901.1 for gamma emitters
	Fish/Crayfish Tissue	
Sediment Toxicity	Sediment	Microtox solid-phase (Microbics 1992) Amphipod 10-day acute test [Northwestern Aquatic Sciences 1992; SM E. 1383-90]

[a] SM = Standard Methods for the Examination of Water and Wastewater (APHA 1989).

[b] PSEP Protocols = Recommended Protocols for Measuring Selected Environmental Variables in Puget Sound (PSEP 1989).

[c] EPA = Methods for Chemical Analysis of Water and Wastes (U S EPA 1983), or Test Methods for the Evaluation of Solid Waste (U S. EPA 1986b), or Method 1613 Tetra- through Octa-chlorinated Dioxins and Furans by Isotope Dilution (U.S EPA 1992c)

[d] GFAA = Graphite furnace atomic absorption spectroscopy

[e] ICP = Inductively-coupled plasma emission spectroscopy

[f] CVAA = Cold vapor atomic absorption spectroscopy

[g] MPN = Multiple-tube fermentation method.

[h] GC/MS = Gas chromatography/Mass spectrometry method.

[i] Selective ion monitoring for analysis of polynuclear aromatic semi-volatile compounds

[j] GC/ECD = Gas chromatography/Electron capture detection method.

[k] TBT = Tributyltin.

degradation product, phaeophytin *a)*, followed standard APHA methods (1989, see Table 3-6) The spectrophotometric method (APHA 1989; 10200 H) was used for chlorophyll *a* analyses, and was corrected for phaeophytin *a*

3.2.1.3 Metals and Cyanide Water samples were analyzed for 16 metals using U S. EPA methods (U S. EPA 1983) and for cyanide using APHA methods (1989, see Table 3-6). All but 6 metals were analyzed by graphite furnace atomic absorption spectroscopy (GFAA); 5 metals were analyzed by inductively coupled plasma emission spectroscopy (ICP); mercury was analyzed by cold vapor atomic absorption spectroscopy (CVAA; see Table 3-6). Whole water samples for total recoverable metal analysis were digested using Ultrex^{TM} grade HNO_3 following U.S. EPA total recoverable metal digestion procedure (U.S. EPA 1983) Filtered metals samples for determining dissolved metal concentration were not digested prior to analysis Cyanide concentration was determined by the APHA Method 4500-CN-E, a distillation method followed by colorimetric determination of total cyanide (APHA 1989).

3.2.1.4 Indicator Bacteria. Water samples were analyzed to quantify the numbers of colonies of indicator bacteria (fecal coliforms, enterococcus, and *E. coli*). Fecal coliform bacteria were measured using the most-probable-number (MPN) method (APHA 1989, 9221 C) Enterococcus were determined by a multiple-tube fermentation procedure (APHA 1989, 9230 B). *E. coli* bacteria were quantified using a modification of the fecal coliform MPN procedure (APHA 1989; 9221 C), which used MUG media in a confirmation test.

3.2.2 Sediment Analyses

The laboratory methods used to analyze sediment parameters are summarized by category groups below Table 3-6 provides a complete list of parameters analyzed and methods used.

3.2.2.1 Conventional Parameters. All conventional parameters listed in 3 1.2 were analyzed. Analysis of total solids, TVS, and total sulfides followed protocols outlined for the Puget Sound Estuary Program (PSEP 1989) TOC was measured using the high-temperature combustion-infrared method in APHA 1989 (5310 B). Ammonia was determined using the method described by Plumb (1981) and TKN was determined by a modification of the semi-micro-Kjeldahl method (APHA 1989; 4500-N_{org} C). Sediment grain size distribution was determined using standard phi class sieves following PSEP protocols (1989).

3.2.2.2 Metals and Cyanide Sediment samples were analyzed for concentrations of 16 total recoverable metals and cyanide The methods used to determine metals concentrations were those provided by U S EPA (1983; see Table 3-6). All but 9 metals were analyzed by GFAA, 8 metals were analyzed by ICP; mercury was determined by CVAA The total recoverable metal digestion procedure outlined in the PSEP protocols (1989) was used, which extracts metals from the sediment with nitric and perchloric acids Cyanide concentration was measured by APHA Method 4500-CN- E, a distillation method followed by colorimetric determination of total cyanide (APHA 1989)

3.2.2.3 Semi-volatile Organic Compounds Sediment samples were analyzed to measure the concentrations of 63 semi-volatile organic compounds, including 17 PAHs, using U.S. EPA Method 8270, a gas chromatography/mass spectroscopy (GC/MS) method (U S. EPA 1986b, see Table 3-6). PAHs were measured using a modification of Method 8270 that incorporated a selective ion monitoring (SIM) system capable of detecting PAHs at concentrations (approximately 1 μg/kg, or 1 ppm) much lower than the laboratory detection limits achieved in the 1991 survey (Tetra Tech 1993a).

3.2.2.4 Pesticides and PCBs Sediment samples were analyzed to measure concentrations of 26 pesticides and 6 PCB Arochlor mixtures using U S. EPA Method 8080 (U.S. EPA 1986b; see Table 3-6) This is a GC method that incorporates the use of an electron capture detector (ECD) to improve detection of these chlorinated pesticides and PCBs. For both this survey and the 1991 survey, this method was modified by adding calibration standards and matrix spike analyses so as to detect pesticides not detectable by the original version of the method. These included the chlorinated pesticides o,p'-DDD, o,p'-DDE, o,p'-DDT, and dicofol, and the organophosphorus pesticide methyl parathion.

3.2.2.5 Dioxins and Furans. Sediment samples were analyzed to measure the concentrations of 7 dioxin and 10 furan congeners using EPA Method 1613 (U.S. EPA 1992c; see Table 3-6). This method was modified by including sample-specific Estimated Detection Limits (EDLs), which were calculated by the laboratory by estimating the signal-to-noise ratio of each selected ion current profile (SICP). This method detects relatively low concentrations (approximately 1 ng/kg, or 1 part per trillion) of dioxins and furans in sediments.

3.2.2.6 Butyltin Compounds. Sediment samples were analyzed to measure concentrations of 3 butyltin compounds (mono-, di-, and tributyltin) using a gas chromatography/flame photometric detector

(GC/FPD) method (Uhler et al 1989) This method converts the butyltin compounds to pentyl derivatives for quantitative analysis The 1991 survey utilized a slightly different method to analyze sediment butyltin concentrations. This method, GC/MS with selective ion monitoring, used ethyl derivatives of the butyltin compounds for quantitative analysis To make the different methods utilized by the two surveys more comparable, sediment butyltin concentrations are reported on a unit-tin basis (μg Sn/kg dry sediment)

3.2.2.7 Radionuclides Wet sediment samples were processed and analyzed by the laboratory for the alpha-emitting radionuclides americium 241, plutonium 238, and plutonium 239/240, and the gamma-emitting radionuclides cesium 137, cobalt 60, and europium 152, 154, and 155 The laboratory used U.S. EPA Method 907 0 for alpha spectroscopy and U.S. EPA Method 901.1 for gamma spectroscopy

3.2.2.8 Sediment Toxicity Testing Sediment toxicity was assessed using the solid-phase Microtox™ test (an indicator test of either chronic or acute toxicity in higher aquatic organisms; Microbics 1992) and the 10-day amphipod (*Hyalella azteca*) survival test (an acute toxicity test; Northwestern Aquatic Sciences 1992). Reference stations were selected *a priori* for sediment toxicity testing; relatively uncontaminated stations were sought to serve this reference function The Bachelor Island Slough Station 11 (RM 90) was selected as the freshwater reference, and the Lewis & Clark NWR Station 5 (RM 29) as the estuarine reference, in case sediment salinity became a relevant factor in evaluating toxicity testing results These stations were presumed to be relatively uncontaminated based on review of sediment contaminant levels measured at nearby stations in the 1991 survey (Tetra Tech 1993a).

In the Microtox™ test, the sediment is centrifuged to separate solids from pore water and solids are homogenized. Twelve serial dilutions are prepared, with suspensions of whole sediment ranging from 10% downwards to 0.005% (weight/volume). Both freshwater and estuarine sediments could be evaluated with this test because all sediments are diluted in a saline water solution for testing with a marine bacterium. The luminescence of the bacterium *Photobacterium phosphoreum* is measured after a 5-minute exposure to the sediment/water test solutions The luminescence for each dilution is compared to the luminescence of bacteria exposed to triplicate control solutions without sediment. Each of the control-normalized luminescence values is then plotted against the logarithm of the sediment concentration (ppm). The four points which bracket a 50% reduction in luminescence are then used to calculate a median effective concentration (EC_{50}) that would result in a 50% reduction in bacterial luminescence.

The acute toxicity test was performed with the amphipod *H azteca* using sediments from both freshwater and estuarine stations Although *H azteca* is relatively tolerant of brackish water, preliminary sediment toxicity tests were performed with both *H azteca* and the estuarine amphipod *Eohaustorius estuarius*, which tolerates a higher range of salinities than *H azteca*. These preliminary tests were designed to measure the salinity tolerance range of each species in case two species were needed to accommodate varying salinities The salinity tolerance test exposed triplicate chambers of 20 amphipods to six different salinities (0, 1, 3, 6, 9, and 12 ppt) These tests ran for 10 days following the standard protocol (Northwestern Aquatic Sciences 1992), results indicated that the mean percent survival between the two amphipods over the range of salinities tested was not significantly different (p=0 064, ANOVA on arcsin-square root-transformed data, Table 3-7) This finding is consistent with that of Nebeker and Miller (1988), who determined that *H. azteca* was suitable for toxicity testing of freshwater and estuarine sites with a water column salinity of 12 5 ppt or less

Based on the results of this test, *H azteca* was selected as the indicator species for all acute sediment toxicity testing because 1) *H azteca* would apparently tolerate the range of salinities involved, 2) use of a single species would facilitate comparison among the freshwater and estuarine stations, and 3) the laboratory had more experience working with *H. azteca*.

The laboratory performed the *H. azteca* acute toxicity test on sediments collected from all fifteen stations plus a control sediment, using five replicate test chambers per sample, each containing 20 amphipods.

3.2.3 Crayfish and Fish Analyses

Laboratory analyses were conducted for the parameters identified in Section 3 1.3. Methods for each category of analytes are summarized briefly below. Table 3-6 provides a complete list of parameters analyzed and methods used.

Prior to analysis, the laboratory composited and homogenized whole-body crayfish and fish by grinding frozen individuals in a blender and processing 3 times to ensure homogenization. Composite was then placed in a glass jar with a teflon-lined lid and stored at -20° C.

3.2.3.1 Conventional Parameters. Conventional parameters included weight and lipid content for crayfish, largescale suckers, and carp, plus length for suckers and carp. Weight and length were meas-

TABLE 3-7. PERCENT SURVIVAL OF *HYALELLA AZTECA* AND *EOHAUSTORIUS ESTUARIUS* IN SALINITY TOLERANCE TESTS LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

Salinity (ppt)	Laboratory Replicates			Mean Percent Survival[a]	Standard Deviation
Hyalella azteca	1	2	3		
0	100	95	100	98.3	2.9
1	95	90	95	93.3	2.9
3	95	90	90	91.7	2.9
6	100	90	100	96.7	5.8
9	100	90	90	93.3	5.8
12	80	80	90	83.3	5.8
Eohaustorius estuarius					
0	100	100	100	100	0
1	100	100	100	100	0
3	100	100	100	100	0
6	100	100	100	100	0
9	100	100	100	100	0
12	100	100	100	100	0

[a] ANOVA results yielded no significant differences ($p = 0.05$) between arcsin-square root-transformed mean survival rates for either *H. azteca* or *E. estuarius*

ured in the field, lipid content was analyzed in the laboratory, using the procedure outlined by the Food and Drug Administration (FDA 1990)

3.2.3.2 ***Metals.*** Tissue samples were analyzed to determine the concentrations of 12 metals. The laboratory followed U S EPA protocols to determine metal concentrations (U S EPA 1983; see Table 3-6) Seven metals were analyzed by GFAA, 4 by ICP, and mercury by CVAA Samples were digested using nitric acid and hydrogen peroxide as specified in PSEP protocols (1989)

3.2.3.3 ***Semi-volatile Organic Compounds.*** Tissue samples were analyzed to determine the concentrations of 63 semi-volatile organic compounds The laboratory used a GC/MS method (U S. EPA 8270) to analyze the samples. The PAHs were analyzed using a modification of Method 8270 that incorporated a SIM system capable of detecting PAHs at relatively low concentrations This method achieved substantially lower detection limits than those obtained in the 1991 survey.

3.2.3.4 ***Pesticides and PCBs.*** Tissue samples were analyzed to determine the concentrations of 25 organochlorine pesticides and 6 PCB Arochlor mixtures using a modification of U S. EPA Method 8080 (U S EPA 1986b) This is a GC method that incorporates the use of an ECD to improve detection. For both this survey and the 1991 survey, this method was modified by adding calibration standards and matrix spike analyses so as to detect pesticides not detectable by the original version of the method These included the chlorinated pesticides o,p'-DDD, o,p'-DDE, o,p'-DDT, and dicofol, and the organophosphorus pesticide methyl parathion.

3.2.3.5 ***Dioxins and Furans.*** Tissue samples were analyzed to determine the concentrations of 7 dioxin and 10 furan congeners using U.S. EPA Method 1613 (U S. EPA 1992c). This method was modified to include sample-specific EDLs, which were calculated by the laboratory by estimating the signal-to-noise ratio of each SICP. This method detects relatively low concentrations of dioxins and furans in aquatic biota.

3.2.3.6 ***Butyltin Compounds.*** Tissue samples were analyzed to determine the concentrations of 3 butyltin compounds (mono-, di-, and tributyltin). A GC/FPD was used to analyze the samples (Uhler et al. 1989). The data are reported on a unit-tin basis (μg Sn/kg wet weight).

3.2.3.7 ***Radionuclides.*** Tissue samples were analyzed to determine the concentrations of the alpha-emitting radionuclides americium 241, plutonium 238, and plutonium 239/240, and the gamma-emitting radionuclides cesium 137, cobalt 60, and europium 152, 154, and 155 The laboratory used U S EPA Method 907 0 for alpha spectroscopy and U S EPA Method 901.1 for gamma spectroscopy

3.3 DATA REPORTING

A detection limit was calculated for each compound and sample based on sample weight, extraction volume, and instrument response. Instrument response was quantified by analyzing replicates (five or more) of a low-level standard. The detection limit represents a concentration above which there is a 99% degree of confidence (approximately three standard deviations above the instrument response variability) that a reported concentration differs from zero

All analytical data reported as unqualified represent concentrations above the detection limit for that analyte in that sample. Concentrations below the detection limit are generally reported as "U". In some cases, concentrations just below the detection limit are not qualified as "U" because the analyst had a high degree of confidence that the observed chromatographic peak represented a concentration significantly different from zero These concentrations are characterized as "J".

4.0 RESULTS

This section presents the results of the analysis of water, sediment, and tissue samples collected in the 1993 backwater reconnaissance survey The data are presented in narrative form, accompanied by graphs and tables Findings are compared to the reference levels summarized in Section 2 to indicate possible adverse effects to aquatic organisms and fish-eating wildlife Findings are compared to those of the 1994 reconnaissance survey and discussed in Section 5 0 The complete survey data, with reference levels, are provided in a separate data appendix (Tetra Tech 1993e)

A Quality Assurance/Quality Control (QA/QC) evaluation of the analytical data was performed according to guidance provided by U.S. EPA (1991h; 1988a,b) This QA/QC data review included assessments of sample holding times, initial and continuing calibration, blank results, detection limits, accuracy (matrix spike, matrix spike duplicate, surrogate recoveries, and reference material analyses, when applicable), and precision (using laboratory and field replicate samples). Complete results of the QA/QC reviews are found in a separate data validation report (Tetra Tech 1993d).

The findings relating to each set of analytes opens with a summary statement, generally paired with a table which treats these analytes as a set. Each analyte is then discussed in turn, individual discussions generally refer to a graph or figure specific to that analyte. Tables and figures are interspersed with text, but kept on separate pages. When possible, a coefficient of variation (CV) is calculated, based on field triplicate samples collected at a specific sampling station Discussions of individual analytes are followed by a summary of data QA/QC.

Data relating to the condition of the river during the sampling period (flow and rainfall) were compiled at the conclusion of the survey (Hubbard et al 1994). These data are summarized in Section 4 4. Sampling stations will generally be referred to by name only; for station number, river mile, and exact location, refer to Table 3-1 or 3-2

4.1 WATER QUALITY

This section presents results of analyses of water samples collected in the backwater survey. Please note that single or triplicate field replicate samples are inadequate to characterize and evaluate overall water quality in a river system as dynamic as the lower Columbia However, frequent exceedances of reference values do indicate potentially serious water quality problems that warrant more intensive investigation

4.1.1 Field-Measured Parameters

Sampling for field-measured parameters (pH, DO, temperature, conductivity, salinity, and turbidity) was conducted during both the initial sampling cruise (24 June-1 July 1993) and the crayfish collecting cruise (15-25 July 1993) Table 4-1 presents a summary of these measurements, noting where standards were exceeded. Exceedances were noted for dissolved oxygen at one station (on both sampling visits), dissolved oxygen saturation at two stations, water temperature at four stations, and pH at eight stations.

4.1.1.1 Salinity and Conductivity. At the time the stations were sampled, the water overlying the sediments was essentially fresh at 14 of the 15 stations. Salinity of 1.8-2.9 ppt (and conductivity of 3 3-5.3 mMhos/cm) was measured at Youngs Bay, indicating a mixture of fresh and marine waters (Figures 4-1 and 4-2) Field-measured parameters were recorded on an ebb tide at this station (minimum ocean water intrusion); it is likely that higher salinities occur here, especially later in the summer when river flow is lowest.

Conductivity varied among freshwater stations (0.096-0.152 mMhos/cm), and also between the two sampling days at each station (e.g., 0.112 and 0.152 at Cathlamet Bay, see Figures 4-1 and 4-2). The lowest conductivity was measured at Scappoose Bay and the highest at Cathlamet Bay. The relatively low conductivity at Scappoose Bay may have been related to rainfall, which was heavy throughout the day; the relatively high conductivity at Cathlamet Bay may have been due to the influence of saline water. Relatively high conductivities were also measured at Willow Bar Islands on 30 June (0.144 mMhos/cm) and at Burke Slough on 16 July (0 149 mMhos/cm). These may indicate nearby pollution sources; the Burke Slough station was near a dike pumping station that moved water from a ditch into the river.

Although it is likely that variations of salinity and conductivity in the lower river, and especially the estuary, are due in part to human influences (e.g., seasonal flow control), there are no reference values

TABLE 4-1 SUMMARY OF WATER COLUMN FIELD-MEASURED PARAMETERS
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Number of Observations[a]	Range	Median	Frequency of Exceedances[b]	
				Freshwater	Saltwater
Dissolved Oxygen (mg/L) Jun-Jul 1993	15 (29)	5.0-12.3	10.1	1/14 (2/27)	0/10 (0/2)
Dissolved Oxygen (% saturation) Jun-Jul 1993	15 (29)	53-132	107	2/14 (3/27)	NA
Temperature (°C) Jun-Jul 1993	15 (30)	17.3-21.9	18.7	4/15 (5/30)[c]	
pH Jun-Jul 1993	15 (30)	7.1-9.0	8.3	8/14 (10/28)	0/1 (0/2)
Conductivity (mMhos/cm) Jun-Jul 1993	15 (30)	0.096-5.3	0.123	NA	NA
Salinity (ppt) Jun-Jul 1993	15 (30)	0.0-2.9	0.0	NA	NA
Turbidity (NTU) Jun-Jul 1993	15 (30)	5.7-30	13	NA	NA

NA = Not available

[a] The number presented is the number of sampling stations visited during each study. The number in parentheses indicates the total number of observations. Fifteen stations were sampled between 24 June-25 July 1993. In Jun-Jul 1993, the field-measured parameters were sampled on two separate occasions (n=30, with the exception of dissolved oxygen measurements). A single sample result was based on the average of triplicate field measurements of each parameter.

[b] The frequency of exceedance of the lowest freshwater and saltwater standard for any single sampling date at a particular station. The numbers in parentheses indicate the frequency of exceedance of the same standard for all the samples analyzed.

[c] The Washington temperature standard of 20° C is applied to the mouth of the Columbia River.

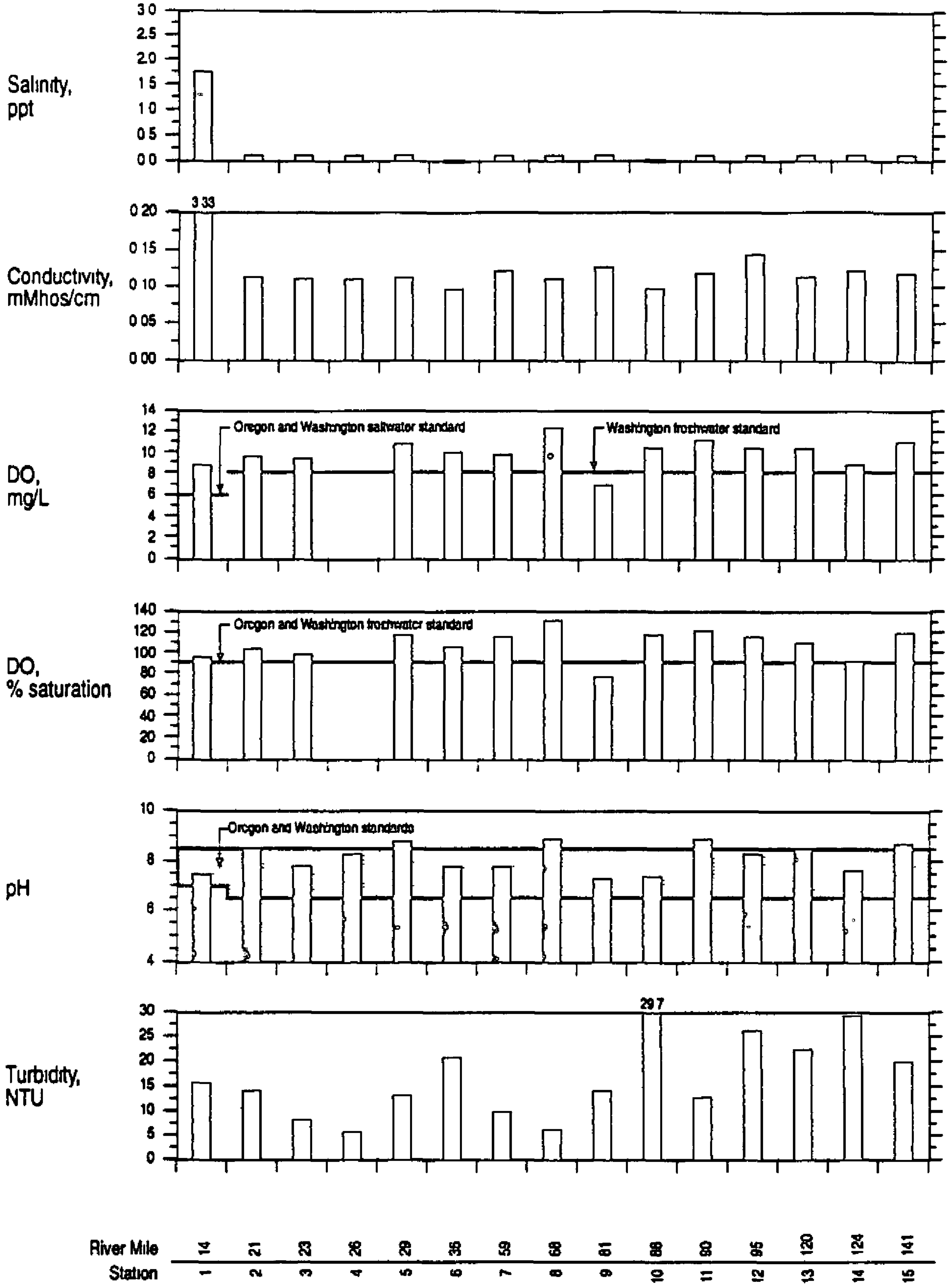


Figure 4-1. Water Column Field Measurement Results From the Lower Columbia River Backwater Reconnaissance Survey Water and Sediment Sampling Cruise (24 June - 1 July 1993).

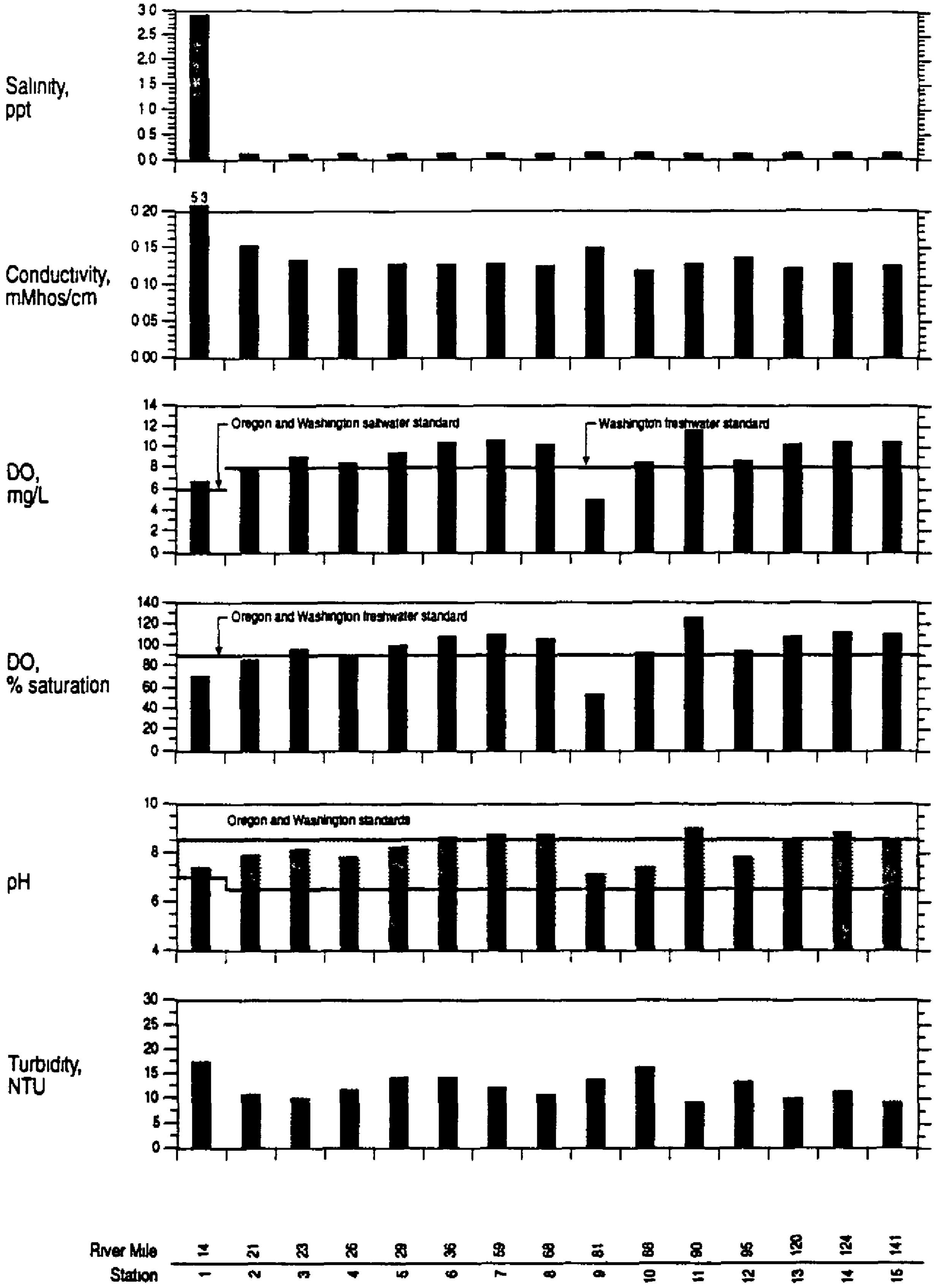


Figure 4-2. Water Column Field Measurement Results From the Lower Columbia River Backwater Reconnaissance Survey Crayfish Sampling Cruise (15-25 July 1993).

available to evaluate these data However, salinity data is valuable when applying standards and interpreting results.

4.1.1.2 Dissolved Oxygen DO concentrations were generally above 8 mg/L and 90% saturation at the freshwater stations, except for Burke Slough where concentrations were relatively low (4.9 and 6 9 mg/L, 53 and 77% saturation) The DO saturation was also below the freshwater 90% saturation standard at Cathlamet Bay (87%) on 27 June DO at Youngs Bay, the sole saltwater station, did not exceed the marine DO standard of 6 mg/L. Low DO at Burke Slough may also be related to the water being pumped from a ditch near the sampling area, noted above in relation to high conductivity.

Relatively high DO concentrations and saturation were measured at several of the stations sampled (Figures 4-1 and 4-2) Saturation greater than 110% was measured at 8 of the 15 stations. These concentrations likely indicate an excess of photosynthetic production over biological respiration. Aquatic plants, including *Potamogeton* and *Myriophyllum* species were present at several stations Photosynthetic production by aquatic plants, attached algae, and phytoplankton is probably responsible for high DO concentrations.

4.1.1.3 Temperature. Water temperature varied among the stations sampled, and between sampling dates at each station (Figure 4-3). In general, water temperature in the backwater areas ranged from 17 3 to 21.9° C, and was highest in the area from RM 59 (Fisher Island Slough) to RM 95 (Willow Bar Islands). Temperatures at 5 of the 6 stations along this stretch of the river exceeded the 20° C water temperature standard (see Figure 4-3); the exception was Carrolls Channel (RM 68).

These relatively high temperatures may be due, in part, to the generally more restricted flow in backwater areas. However, temperatures above 20° C have frequently been measured during the late summer in the mainstem of the lower Columbia, and may be partly due to human-induced changes (see Tetra Tech 1993a for a review of these data).

4.1.1.4 pH. pH varied among the stations sampled (7.1-9.0) and between sampling dates at each station (e.g., 7.8 and 8.2 at Svensen Island; see Figures 4-1 and 4-2). The lowest pH was consistently found at Burke Slough and may indicate the organic matter degradation assumed to be responsible for the low DO measured at this station. Relatively high pH was recorded at several stations; eight stations exceeded

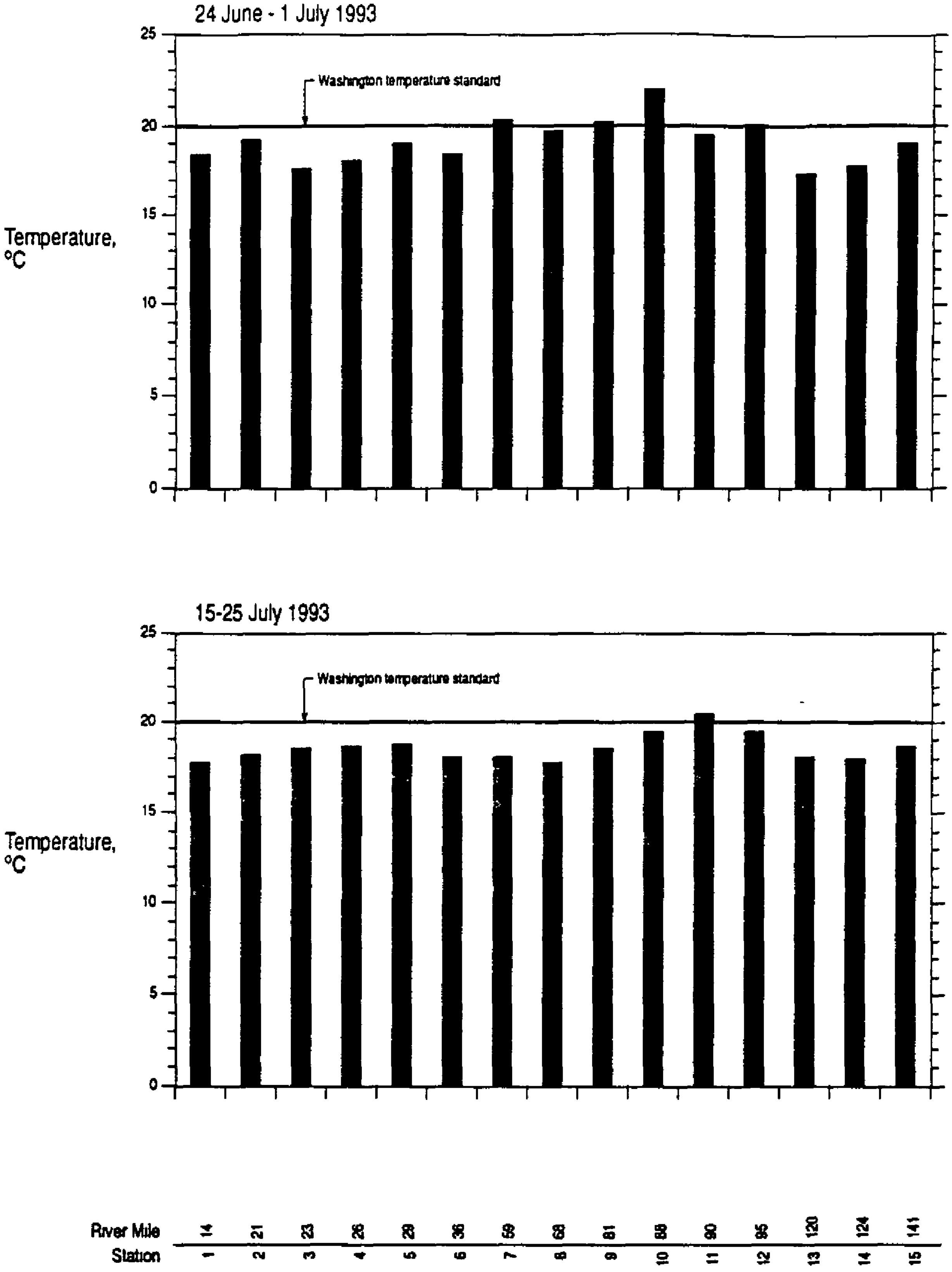


Figure 4-3. Water Temperature Measurement Results From the Lower Columbia River Backwater Reconnaissance Survey (24 June - 1 July and 15 July - 25 July 1993).

the 8.5 pH standard on at least one occasion. It is likely that this was due to photosynthetic carbon dioxide assimilation, which elevates pH, and not directly due to human activity. The shallow areas sampled were typically colonized by aquatic plants which could be responsible for high pH and DO (e.g., Frodge et al. 1991). However, it is possible that high pH could be the result of human-induced increases in the supply of nutrients to aquatic plants which has led to increased biomass and/or photosynthesis.

*4.1.1.5 **Turbidity.*** Turbidity varied among the stations sampled (5.7-29.7 NTU) and between sampling dates at each station (e.g., 19.8 and 9.2 at Skamania Landing, see Figures 4-1 and 4-2). The lowest turbidity was measured at Knappa Slough and the highest at Scappoose Bay, which coincided with the low conductivity measure, underlining the importance of rainfall runoff during sampling at this station.

It is likely that the patterns of variation of turbidity in the lower river have been altered by human influences (e.g., seasonal flow control), especially between historical high and low flows (e.g., Whetten et al. 1969). However, in backwater areas, local environmental factors (water depth, surface condition, etc.) are probably more important influences on turbidity. There are no reference values available to evaluate turbidity.

*4.1.1.6 **Quality Assurance/Quality Control.*** Instrument calibrations were performed following manufacturers recommendations, and calibrations were routinely checked to ensure that calibration drift was not significant (e.g., no greater than 0.1 pH unit from the calibration standard). The DO sensor was calibrated at ambient atmospheric pressure and temperature, which were also measured by the instrument. Additional water samples were collected and fixed in the field for independent determination of DO by the azide modification of the Winkler method (APHA 1989; 4500-O C). The regression line of instrument-measured DO vs. Winkler DO was not significantly different than a line with a slope of 1.1 (i.e., the 95 percent confidence interval of the regression-line slope encompassed a slope of 1), and the concentrations determined by the two methods were not significantly different ($P=0.8515$; one-way ANOVA) indicating acceptable accuracy of instrument-measured DO.

4.1.2 Conventional Parameters

Sampling for conventional parameters (TSS, Hardness, TOC, and POC) was conducted 24 June-1 July 1993. Table 4-2 presents a summary of findings. Although it is likely that these parameters in the lower

TABLE 4-2 SUMMARY OF WATER COLUMN CONVENTIONAL PARAMETERS
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Numbers of Observations[a]	Units in mg/L		Frequency of Exceedances
		Range	Median	
Total Suspended Solids				
Jun-Jul 1993	15	6 4-63	15	NA
Hardness				
Jun-Jul 1993	15	35 7-359	51 (50)[b]	NA
Total Organic Carbon				
Jun-Jul 1993	15	2 22-9 44	2 7	NA
Particulate Organic Carbon				
Jun-Jul 1993	15	0 46-4 60	0 7	NA
Dissolved Organic Carbon[c]				
Jun-Jul 1993	15	1.37-4 84	1 9	NA

NA = No criteria or screening levels are available for determination

[a] The number of observations is equivalent to the number of stations sampled. Fifteen stations were sampled between 24 June-1 July 1993

[b] The number in parentheses is the median hardness of the freshwater stations sampled This number is used to determine the hardness-based metals criteria used for comparison.

[c] Dissolved organic carbon determined by the difference between the measurements of total organic carbon and particulate organic carbon.

river have been altered to some degree by human influences [e.g., see Dahm et al. (1981) for a discussion of human influence on lower Columbia organic carbon concentrations], there are no reference values available to evaluate these data. These data do provide a general picture of the variation and range in conventional parameters at the stations sampled, which is of interest because these parameters are important in regulating the transport, toxicity, and bioaccumulation of contaminants.

4.1.2.1 Total Suspended Solids The TSS concentration was highly variable among the fifteen stations (Figure 4-4). The lowest concentration (6.4 mg/L) was measured at Elochoman Slough and the highest (63 mg/L) at Scappoose Bay, which coincides with the maximum turbidity measured at this station in June (Figure 4-1). The median TSS concentration was 15 mg/L.

The coefficient of variation (CV) of the field triplicate sample collected from Burke Slough was relatively low (4.9%) and the concentration of TSS ranged from 6.8 to 7.4 mg/L. The relatively large differences in measured TSS are likely due to inter-station rather than intra-station variability.

4.1.2.2 Hardness. Water hardness ranged from 35.7 to 359 mg/L (Figure 4-4). The minimum hardness was measured at Scappoose Bay (coinciding with the minimum conductivity; see Figure 4-1) and the maximum at Youngs Bay in the estuary. This maximum is due to the higher polyvalent ion content of seawater, which mixes with fresh water at this station. The next highest hardness concentration measured was at Willow Bar Islands (85.8 mg/L), which coincides with high conductivity measured at this station (see Figure 4-1).

The CV of the field triplicate sample collected from Burke Slough was relatively low (1.7%) and the water hardness ranged from 53.1 to 54.9 mg/L. Some of the differences in measured hardness are likely due to inter-station rather than intra-station variability.

4.1.2.3 Total Organic Carbon. TOC ranged from 2.21 to 9.44 mg/L (Figure 4-4). The lowest concentration was measured at Elochoman Slough and the highest at Scappoose Bay; median concentration was 2.7 mg/L.

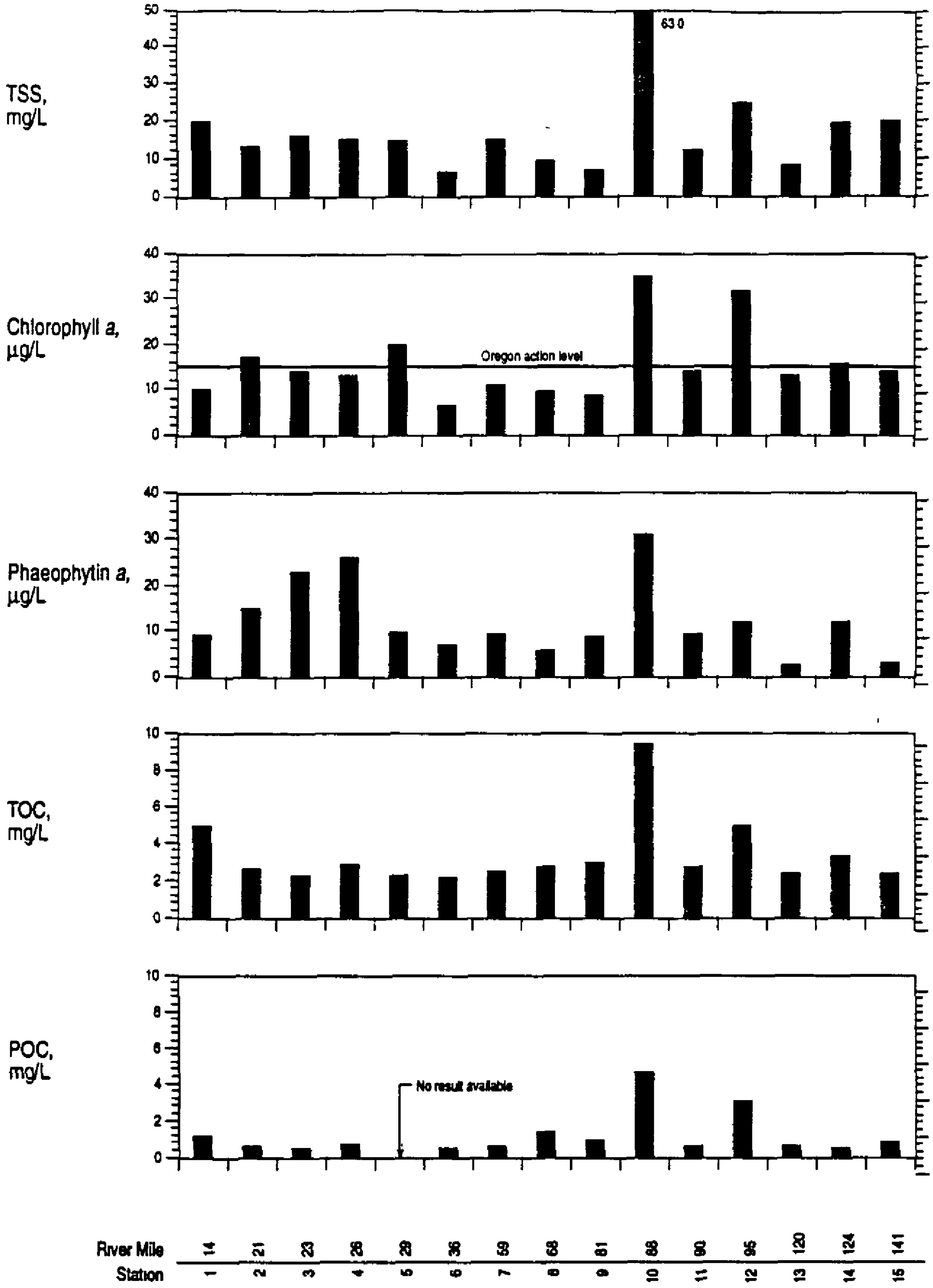


Figure 4-4. Water Concentrations of Total Suspended Solids, Chlorophyll, Phaeophytin, Total Organic Carbon, and Particulate Organic Carbon in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993.

The CV of the field triplicate sample collected from Burke Slough was relatively low (1.3%) and the TOC concentration ranged from 2.92 to 2.99 mg/L. Some of the differences in measured TOC are likely due to inter-station rather than intra-station variability.

4.1.2.4 Particulate Organic Carbon POC ranged from 0.46 to 4.60 mg/L (Figure 4-4). The lowest concentration was measured at Elochoman Slough and the highest at Scappoose Bay; median concentration was 0.7 mg/L.

The CV of the field triplicate sample collected from Burke Slough was relatively low (7.5%) and the POC concentration ranged from 0.73 to 1.12 mg/L. Some of the differences in measured POC are likely due to inter-station rather than intra-station variability.

4.1.2.5 Dissolved Organic Carbon DOC (defined as TOC minus POC) ranged from 1.37 to 4.84 mg/L (see Table 4-2). The lowest concentration was calculated for Carrolls Channel and the highest for Scappoose Bay, median concentration was 1.9 mg/L.

The CV of the differences between the field triplicate TOC and POC samples collected from Burke Slough was relatively low (9.2%) and the calculated DOC concentrations ranged from 1.87 to 2.19 mg/L. Some of the differences in measured DOC are likely due to inter-station rather than intra-station variability.

4.1.2.6 Summary of Quality Assurance/Quality Control. The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). For the conventional parameters, as defined above, no data qualifiers, other than "U" (not detected), were assigned. All conventional parameter data collected are suitable for use in this report.

4.1.3 Nutrients and Phytoplankton Biomass

Sampling for nutrients and phytoplankton biomass parameters was conducted 24 June-1 July 1993. Table 4-3 is a summary of findings. Although it is likely that these parameters have been altered to some degree by human influences [e.g., see Hileman et al. (1975) for a discussion of human influence on nutrient concentrations in the lower river], there are no reference values available to evaluate nutrient data. Exceedance of Oregon's action level for chlorophyll *a* is noted in 4.1.3.6 below.

TABLE 4-3 SUMMARY OF WATER COLUMN NUTRIENT AND CHLOROPHYLL DATA
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances
		Range	Median	
Total Phosphorus				
Jun-Jul 1993	15/15	26-172	59	NA
Soluble Reactive Phosphorus				
Jun-Jul 1993	15/15	2-15	10	NA
Ammonium Nitrogen				
Jun-Jul 1993	11/15	10U-22	11	NA
Nitrate and Nitrite Nitrogen				
Jun-Jul 1993	11/15	10U-181	32	NA
Total Kjeldahl Nitrogen				
Jun-Jul 1993	15/15	145-474	232	NA
Chlorophyll *a*				
Jun-Jul 1993	15/15	6.7-35.0	14.0	5/15
Phaeophytin *a*				
Jun-Jul 1993	15/15	2.6-31.0	9.3	NA

NA = No criteria or screening levels available for determination.

U = Not detected. Preceding value is the detection limit

[a] Frequency of detected occurrence at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993 In Jun-Jul 1993 a single sample consisted of triplicate field samples collected at each of fifteen stations (n=15) The averages of field triplicate samples were used for comparison.

[b] Frequency of exceedance of the lowest standard or reference level (e.g., Oregon's 15 µg/L action level for chlorophyll *a*)

4.1.3.1 Total Phosphorus. TP concentration (mean of three field replicates) ranged from 26 to 172 μg/L (Figure 4-5). The minimum average concentration was measured at Camas Slough and the maximum at Scappoose Bay. Median concentration was 59 μg/L.

The CV of the field triplicate samples ranged from 3.6 to 108.4%, indicating a large range of variation at each station. CV was less than 25% at 11 of 15 stations, and greater than 50% at two: 58.6% at Elochoman Slough and 108.4% at Carrolls Channel. The variation of laboratory replicate analyses was less than 20%, indicating that laboratory variability is not a likely source of the large variability observed in a few of the field replicate samples.

4.1.3.2 Soluble Reactive Phosphorus. Average SRP concentration ranged from 2 to 15 μg/L (Figure 4-5). The minimum average concentration was measured at Burke Slough and the maximum at Cathlamet Bay. The median concentration was 10 μg/L.

The CV of the field triplicate samples ranged from zero to 28.4%. The CV at 13 of 15 stations was less than 25% and the concentration of SRP was below laboratory detection limits at Burke Slough, precluding calculation of the CV there. The CV was greater than 25% at Cathlamet Bay. Analysis of the laboratory replicate for this station resulted in a CV of 10.1%, indicating that laboratory variability is not a likely source of this relatively large variability.

4.1.3.3 Ammonium Nitrogen. Average ammonium nitrogen concentration ranged from undetected (detection limit of 10 μg/L) to 22 μg/L (Figure 4-5). Concentrations below laboratory detection in all three field replicate samples were measured at four stations (Cathlamet Bay, Carrolls Channel, Bachelor Island Slough, and Gary & Flag Islands); the maximum average concentration was measured at Elochoman Slough. Median concentration was 11 μg/L.

The CV of the field triplicate samples ranged from 10.2 to 18.0%. Relatively large differences in concentration between stations are likely due to inter-station rather than intra-station variability.

4.1.3.4 Nitrate+Nitrite Nitrogen. Average nitrate+nitrite nitrogen concentration ranged from undetected (detection limit of 10 μg/L) to 181 μg/L (Figure 4-5). Concentrations below laboratory detection limits in all three field replicate samples were measured at four stations (Carrolls Channel, Burke Slough,

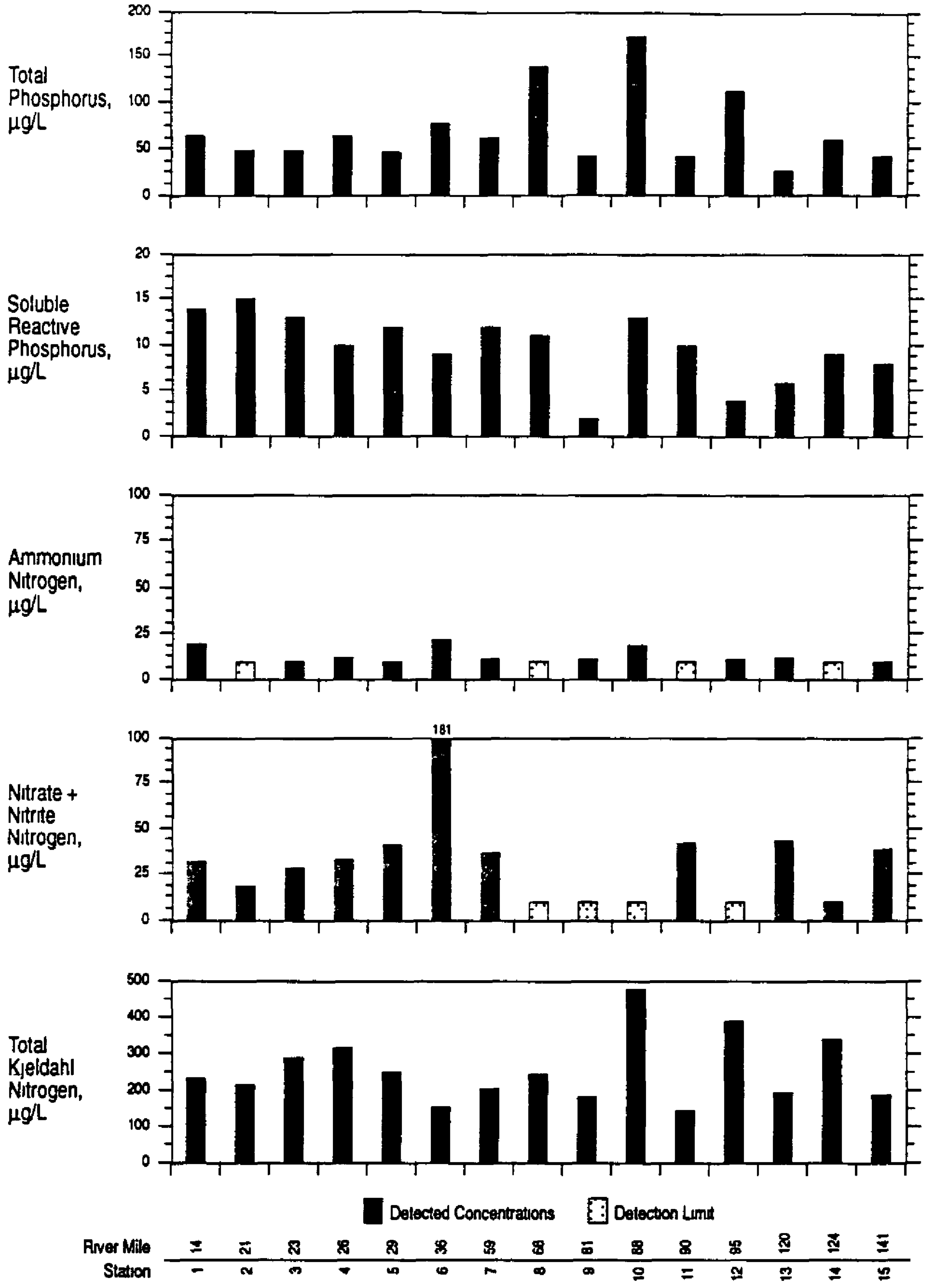


Figure 4-5. Nutrient Concentrations in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993). *Stippled bars indicate detection limit values.*

Scappoose Bay, and Willow Bar Islands), the maximum average concentration was measured at Elochoman Slough. Median concentration was 32 µg/L

The CV of the field triplicate samples ranged from 1.8 to 14.6%, relatively large differences in average sample concentrations between stations are likely due to inter-station rather than intra-station variability

4.1.3.5 Total Kjeldahl Nitrogen Average TKN concentration ranged from 145 to 474 µg/L (Figure 4-5) The minimum average concentration was measured at Bachelor Island Slough and the maximum at Scappoose Bay Median concentration was 232 µg/L

The CV of the field triplicate samples ranged from 1 9 to 22.4%; relatively large differences in average sample concentrations between stations are likely due to inter-station rather than intra-station variability

4.1.3.6 Chlorophyll and Phaeophytin a. Chlorophyll and phaeophytin *a* concentrations ranged from 6.7-35.0 and 2 6-31.0 µg/L, respectively (Figure 4-4) The minimum chlorophyll *a* concentration was measured at Elochoman Slough and the maximum at Scappoose Bay; median concentration was 14.0 µg/L. The minimum phaeophytin *a* concentration was measured at Camas Slough and the maximum again at Scappoose Bay, with a median of 9 3 µg/L. The relatively high proportion of phaeophytin *a* suggests the presence of a pool of senescent plant and algal detritus in these backwater areas.

The CVs of the field triplicate samples collected for chlorophyll analysis at Burke Slough were 19 0% and 20 6% for chlorophyll and phaeophytin analyses respectively. The relatively large differences in average sample concentrations between stations are likely due to inter-station rather than intra-station variability.

The chlorophyll *a* concentration exceeded Oregon's 15 µg/L action level at 5 of the 15 stations sampled. This indicates a potential impairment of beneficial uses of these backwater areas, possibly as a result of human-caused eutrophication. However, no measurements were made of algal species present at the time of sampling to indicate the relative abundance of nuisance algae (e.g., blue-green algae). Potential adverse effects on water quality of eutrophication and nuisance algae is discussed in more detail in Section 5.1.3.

4.1.3.7 Summary of Quality Assurance/Quality Control The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) For most of the nutrient parameters (TP, ammonium nitrogen, and nitrate+nitrite nitrogen), no data qualifiers, other than "U" (undetected), were assigned For SRP and TKN, one and two of the 45 samples, respectively, were qualified as estimated based on laboratory precision data Two of the 17 values for phaeophytin *a* were also qualified as estimated on the same basis In general, all of the nutrient and chlorophyll data are suitable for use in this report

4.1.4 Metals and Cyanide

Sampling for 16 total recoverable and filtered metals plus cyanide was conducted 24 June-1 July 1993 Table 4-4 presents a summary of total recoverable findings, including exceedances of standards Table 4-5 presents a summary for filtered metals data Exceedances of the standards for average total recoverable metal concentrations (mean of the three field-replicate samples) were noted for aluminum at 14 stations, lead at three stations, and copper, iron, mercury, and silver at one station each (see Table 4-4). Cyanide was not detected in any sample. The total recoverable metal standards, and the Washington dissolved metal standards where applicable, were not exceeded by the average filtered metals concentration at any station.

Note that for aluminum and iron especially the total recoverable data were very much higher than filtered data, indicating that these metals were mostly found in the samples in a particulate form that would not pass through a 0 45 μm screen No freshwater criteria or standards were available for barium, and no saltwater criteria or standards for aluminum, barium, beryllium, iron, or thallium. The detection limits achieved for mercury and silver in this study were not adequate to evaluate potential exceedances The exceedances of federal criteria and Oregon and/or Washington standards for aluminum, copper, iron, lead, mercury, and silver indicate potential adverse effects on aquatic organisms which will be discussed in more detail in Section 5 1.4.

4.1.4.1 ***Aluminum.*** Station average total recoverable aluminum concentrations ranged from 159 to 843 μg/L with a median concentration of 388 μg/L (Figure 4-6). The minimum average concentration was measured at Burke Slough and the maximum at Scappoose Bay The U.S. EPA-recommended water quality criterion for aluminum (87 μg/L) was exceeded at all 15 stations.

TABLE 4-4 SUMMARY OF WATER COLUMN TOTAL RECOVERABLE METALS AND CYANIDE DATA 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances[b]	
		Range	Median	Freshwater	Saltwater
Aluminum	15/15	159-843	388	14/14	1/1[c]
Antimony	1/15	3.0U-3.1	3.0U	0/14	0/1
Arsenic	2/15	3.0U-3.6	3.0U	0/14	0/1
Barium	15/15	11-24	18	NA	NA
Beryllium	0/15	--	2.0U	0/14	NA
Cadmium	0/15	0.10U-0.17U	0.10U	0/14	0/1
Chromium	1/15	1.0U-6.3	1.0U	0/14	0/1
Copper	13/15	1.0-4.6	2.3	0/14	1/1
Iron	15/15	188-2,523	421	1/14	0/1[c]
Lead	6/15	0.8U-2.0	0.8U	3/14	0/1
Mercury	1/15	0.11U-0.11	0.11U	1/14[d]	0/1[d]
Nickel	2/15	5.0U-6.0	5.0U	0/14	0/1
Selenium	0/15	--	3.0U	0/14	0/1
Silver	1/15	1.0U-4.6	1.0U	1/14[d]	0/1[d]
Thallium	5/15	1.0U-1.1	1.0U	0/14	NA
Zinc	10/15	3.0U-16.7	8.0	0/14	0/1
Cyanide	0/15	2.0U	2.0U	0/14	0/1[d]

NA = No criteria or screening levels available.
U = Not detected. Value preceding is the detection limit.

[a] Frequency of detected occurrence at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993. Each of the values reported represents the mean triplicate field samples.

[b] Frequency of exceedance of the lowest standard or reference level at the stations sampled. The numbers in parentheses indicate the frequency of exceedance of the same standard for all of the samples collected.

[c] No saltwater criteria or screening levels were available. The number of exceedances are based on the available freshwater criterion.

[d] Detection limits were higher than the chronic criteria. The number of exceedances are based on detected concentrations only

TABLE 4-5 SUMMARY OF WATER COLUMN FILTERED METALS DATA 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Frequency of Detection[a,c]	Units in µg/L		Frequency of Exceedances[b]	
		Range	Median	Freshwater	Saltwater
Aluminum	15/15	9-65	23	0/14	NA
Antimony	0/15	--	3.0U	0/14	0/1
Arsenic	0/15	--	3.0U	0/14	0/1
Barium	15/15	8-18	14	NA	NA
Beryllium	0/15	--	2.0U	0/14	NA
Cadmium	0/15	0.10U-0.18U	0.10U	0/14	0/1
Chromium	0/15	--	1.0U	0/14	0/1
Copper	0/15	--	1.0U	0/14	0/1
Iron	15/15	6-442	26	0/14	NA
Lead	3/15	0.8U-0.8	0.8U	0/14	0/1
Mercury	0/15	--	0.11U	0/14[d]	0/1[d]
Nickel	3/15	5.0U-5.7	5.0U	0/14	0/1
Selenium	1/15	3.0U-3.1	3.0U	0/14	0/1
Silver	0/15	--	1.0U	0/14[d]	0/1[d]
Thallium	6/15	1.0U-1.2	1.0U	0/14	NA
Zinc	5/15	3.0U-5.3	3.0U	0/14	0/1

NA = No criteria or screening levels available.

U = Not detected. Value preceding is the detection limit

[a] Frequency of detected occurrence at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993. Each of the values reported represents the mean of triplicate field samples.

[b] Frequency of exceedance of the lowest standard or reference level at the stations sampled. The numbers in parentheses indicate the frequency of exceedance of the same standard for all of the samples collected.

c Based on results of the 1993 Lower Columbia River Backwater Reconnaissance Survey.

[d] Detection limits were higher than the chronic criterion. The number of exceedances is based on detected concentrations only

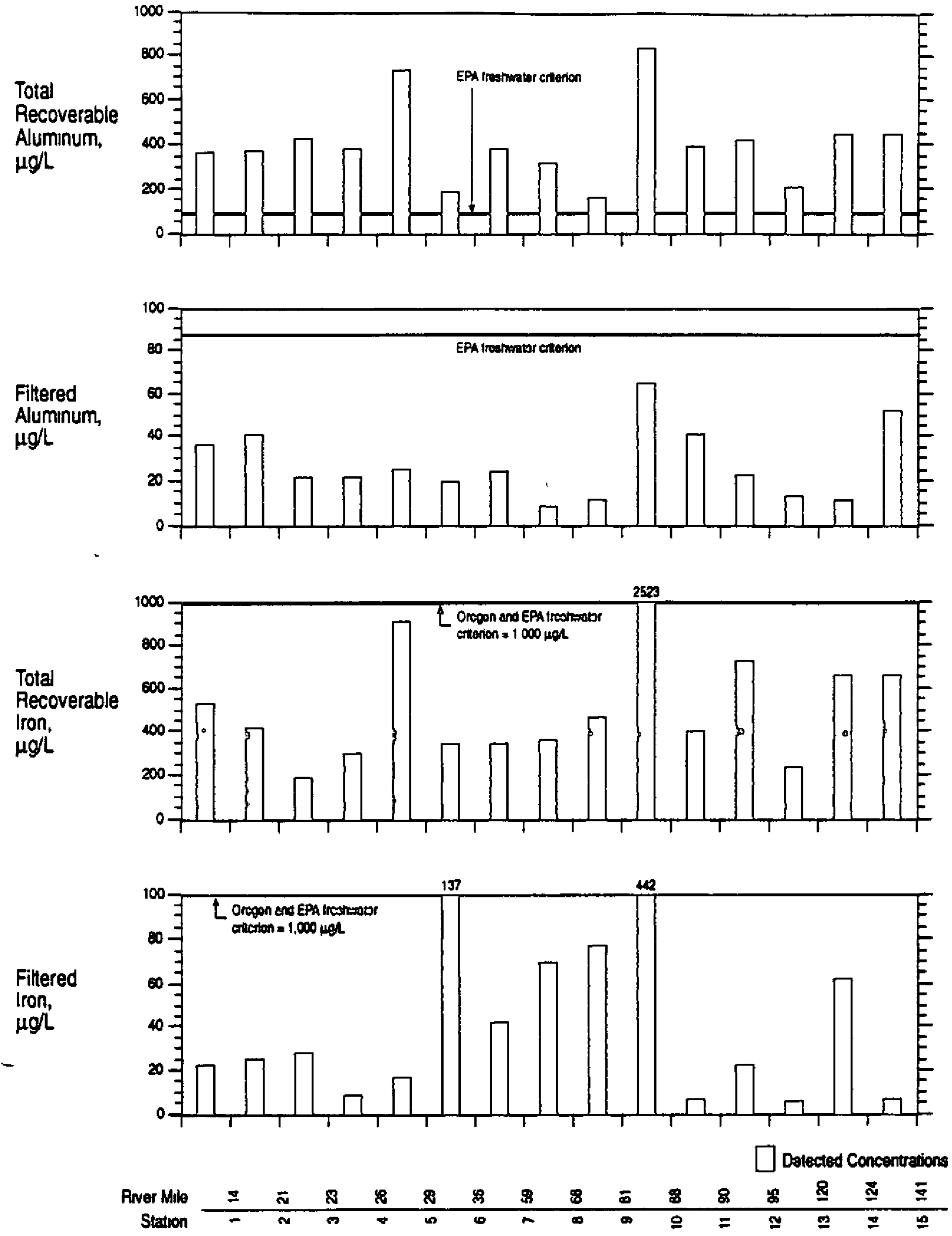


Figure 4-6. Water Column Concentrations of Total Recoverable and Filtered Aluminum and Iron in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

The CV of total recoverable aluminum samples ranged from 4 6 to 30 8% It was greater than 25% at Youngs Bay and Knappa Slough Laboratory precision was generally within QC limits, the relatively high variability at these stations may be due to field total recoverable aluminum variation. Relatively large differences in water column total recoverable aluminum concentrations between the stations sampled are likely due to inter-station rather than intra-station variability

Station average filtered aluminum concentrations ranged from 9 to 65 μg/L with a median concentration of 23 μg/L (Figure 4-6) The minimum average concentration was measured at Carrolls Channel and the maximum at Scappoose Bay There are no recommended criteria or standards for dissolved aluminum

The CV for filtered aluminum samples ranged from 0.9 to 53 3%. It was greater than 25% at Lewis & Clark NWR and Carrolls Channel. Laboratory precision was generally within QC limits, although laboratory replicate analysis of one of the triplicate field samples from Lewis & Clark NWR exceeded QC guidelines Therefore, the relatively high variability at these stations, particularly Lewis & Clark NWR, may be due to laboratory variation Relatively large differences in filtered aluminum concentrations among stations are likely due to inter-station rather than intra-station variability.

4.1.4.2 Antimony. In general, antimony was not detected above the laboratory detection limit of 3 0 μg/L in the total recoverable or filtered metals samples, except at Skamania Landing, where it was detected in two of the three field replicates (maximum average concentration = 3 0 μg/L; Figure 4-7). However, these concentrations are all less than the U.S. EPA-proposed freshwater criterion of 30 μg/L

Due to the infrequent detection of antimony, CV could not be determined.

4.1.4.3 Arsenic. Total recoverable arsenic was detected infrequently and filtered arsenic was not detected above the laboratory detection limit of 3 0 μg/L (Figure 4-7). Total recoverable arsenic was detected in at least one field replicate sample at Scappoose Bay and Willow Bar Islands. The highest average total recoverable concentration was measured at Willow Bar Islands (3.6 μg/L). However, these

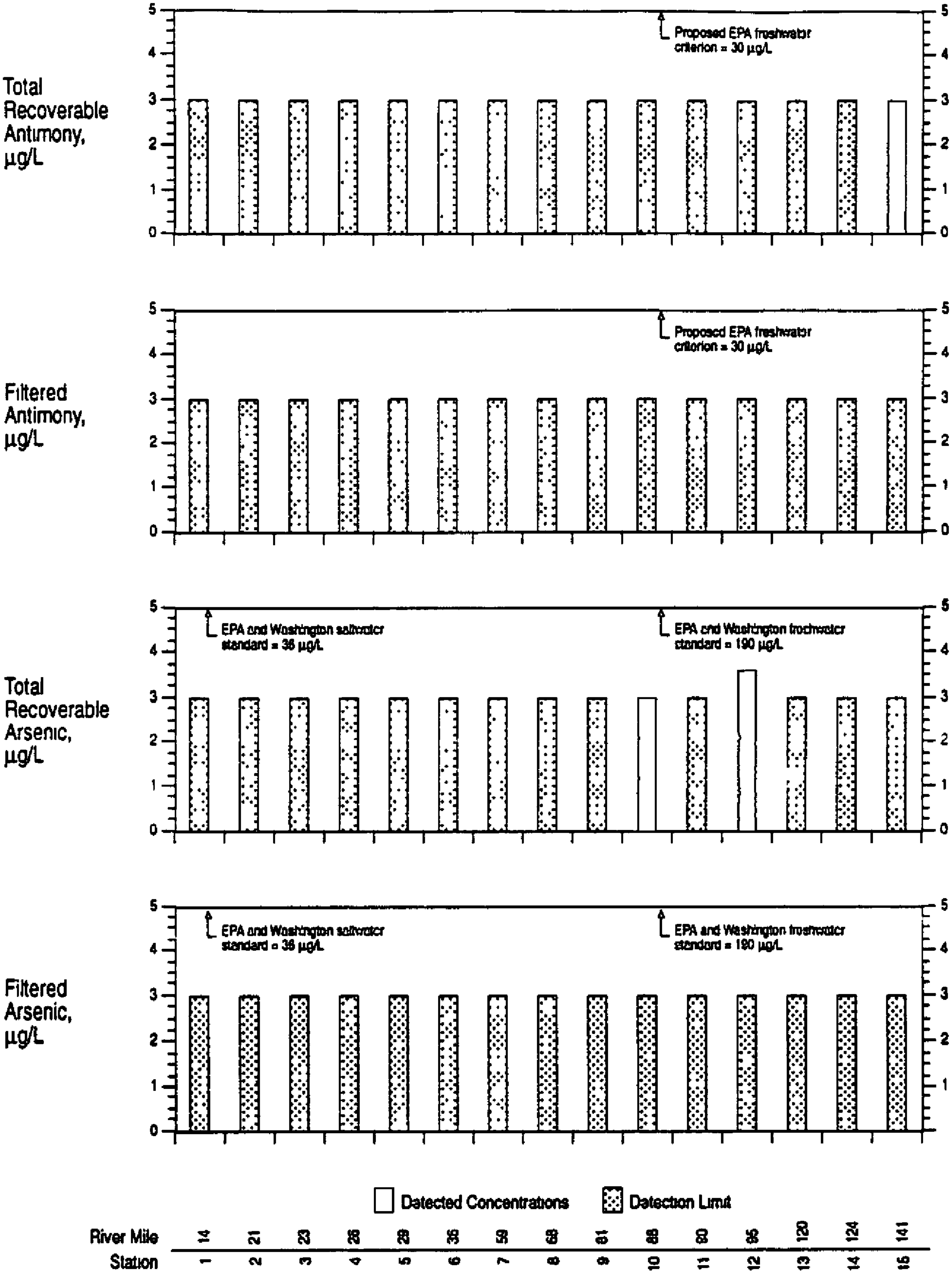


Figure 4-7. Water Column Concentrations of Total Recoverable and Filtered Antimony and Arsenic in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

concentrations are all lower than the U S EPA and Washington chronic freshwater and saltwater standards of 190 and 36 µg/L, respectively

Due to the infrequent detection of arsenic, CV could not be determined.

4.1.4.4 Barium Station average total recoverable barium concentrations ranged from 11 to 24 µg/L with a median concentration of 18 µg/L (Figure 4-8) The minimum average concentration was measured at Elochoman Slough and the maximum at Scappoose Bay Station average filtered barium concentrations ranged from 8 to 18 µg/L with a median concentration of 14 µg/L (Figure 4-8) Again, the minimum and maximum average concentrations were measured at Elochoman Slough and Scappoose Bay respectively (Figure 4-8) There are no recommended criteria or standards for total recoverable or dissolved barium, and therefore the environmental significance of these concentrations measured be assessed

The CV for total recoverable barium samples ranged from 2 8 to 17.6%, and for filtered barium from zero to 13 3% Relatively large differences in the average barium concentrations measured between stations are likely due to inter-station rather than intra-station variability

4.1.4.5 Beryllium Neither total recoverable nor filtered beryllium was detected above the laboratory detection limit of 2.0 µg/L in any sample (Figure 4-8) This detection limit is lower than the U S. EPA lowest observed effects level (LOEL) of 5.3 µg/L for freshwater aquatic organisms

Due to the infrequent detection of beryllium, CV could not be determined.

4.1.4.6 Cadmium. Neither total recoverable nor filtered cadmium was detected above the laboratory detection limit of 0 18 µg/L in any sample, detection limits were generally 0.10 µg/L (Figure 4-9). These detection limits are lower than both the lowest total recoverable standard (freshwater) of 0.7 µg/L and the Washington (freshwater) dissolved cadmium standard of 0.6 µg/L.

Due to the infrequent detection of cadmium, CV could not be determined.

4.1.4.7 Chromium Total recoverable chromium was detected infrequently and filtered chromium was not detected above the laboratory detection limit of 1 0 µg/L (Figure 4-9). Total recoverable chromium

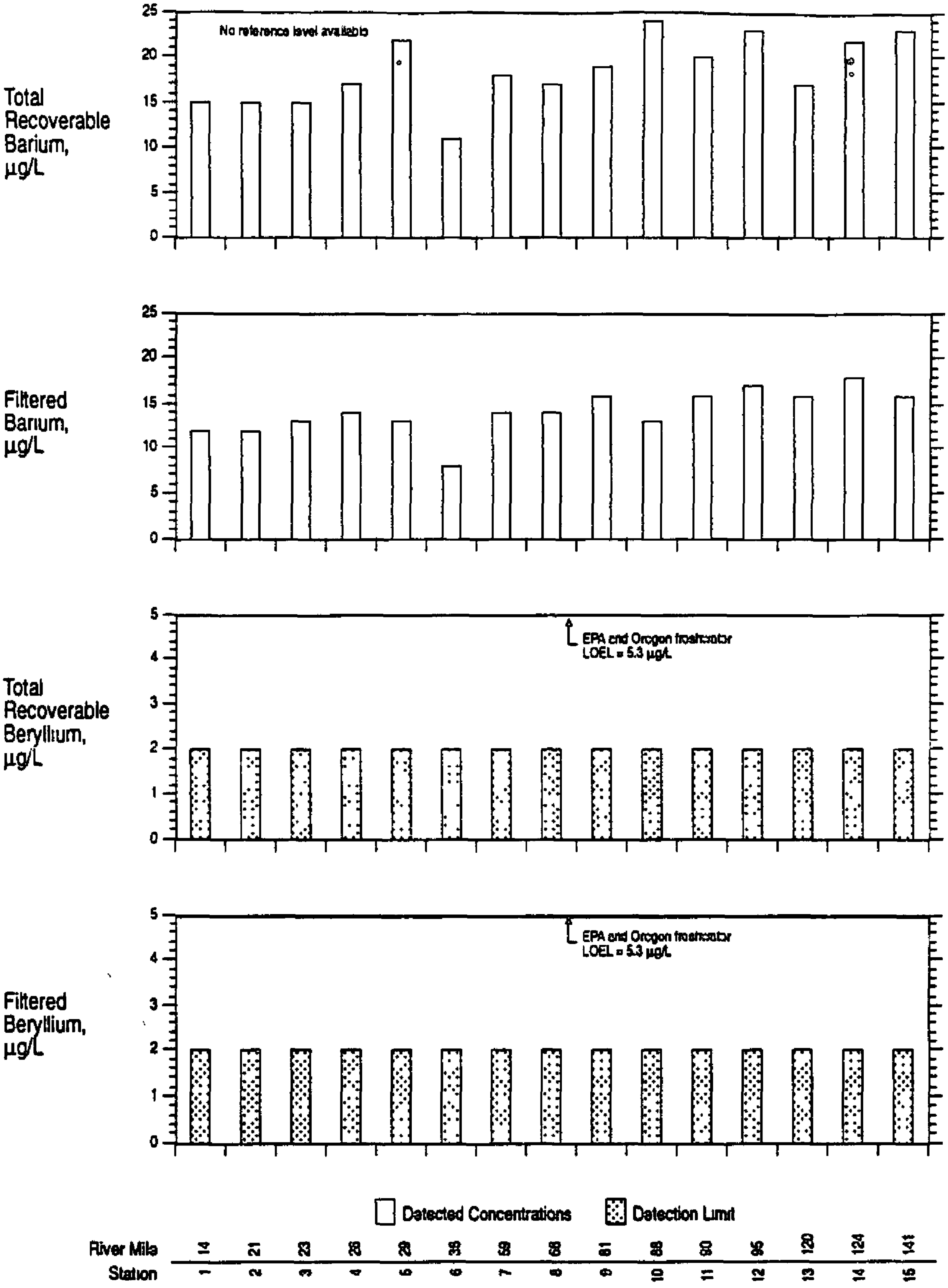


Figure 4-8. Water Column Concentrations of Total Recoverable and Filtered Barium and Beryllium in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

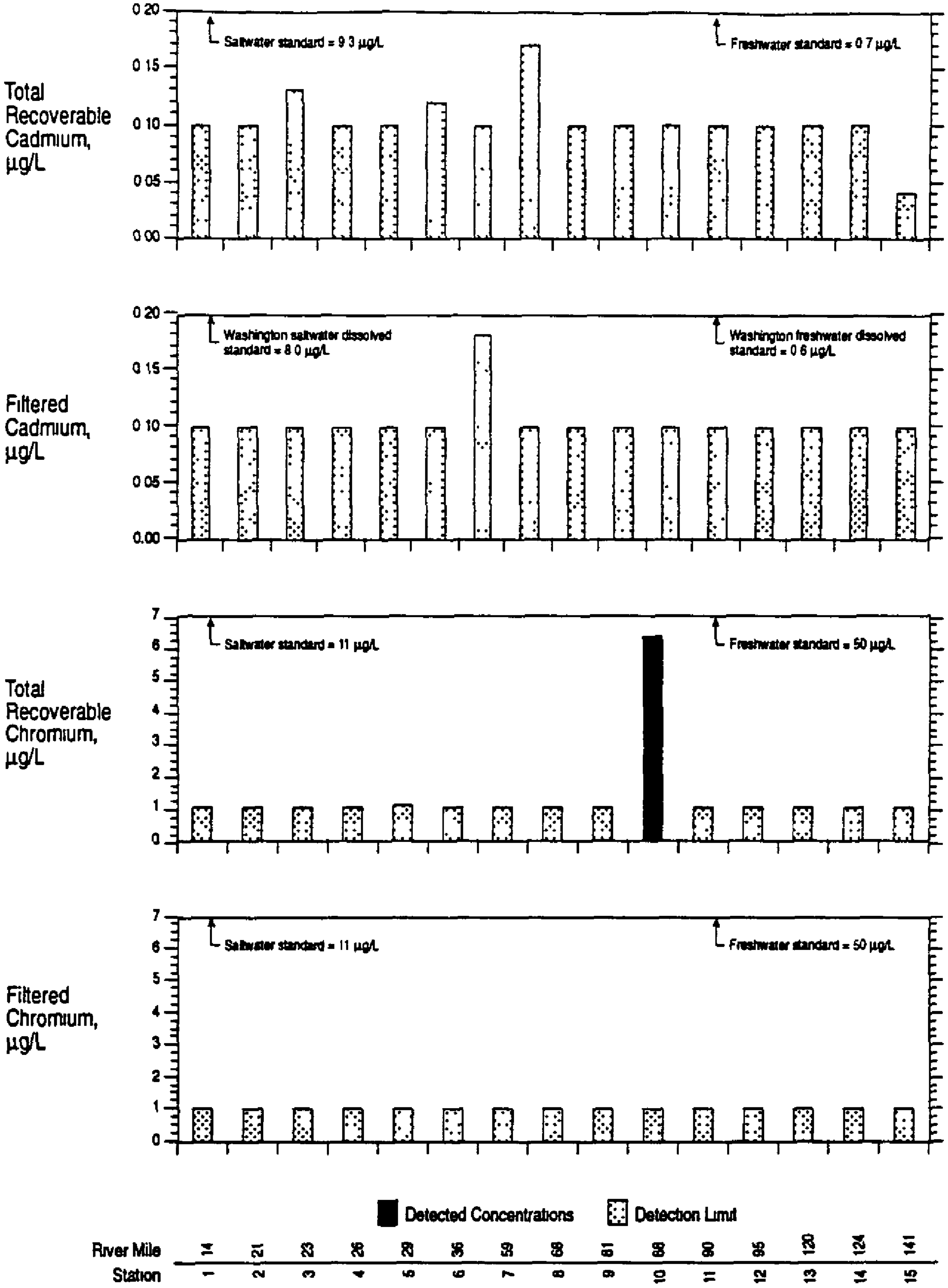


Figure 4-9. Water Column Concentrations of Total Recoverable and Filtered Cadmium and Chromium in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

was detected in all three field replicate samples at Scappoose Bay (average concentration 6 3 μg/L) These concentrations are all lower than the chronic freshwater and saltwater standards of 50 and 11 μg/L, respectively.

The CV of the three field replicate chromium samples of total recoverable chromium collected from Scappoose Bay was 96 4% All laboratory duplicate analyses were performed on samples with concentrations of chromium that were below the limit of detection Therefore, it is not possible to determine if the relatively high variability noted in this sample was due more to analytical or field variability Because the reported sample concentrations were near the laboratory detection limit, laboratory variability may have contributed to the variation noted in these field samples.

4.1.4.8 Copper. Station average total recoverable copper concentrations ranged from 1 0 to 4.6 μg/L with a median concentration of 2.3 μg/L (Figure 4-10). The minimum average concentration was measured at Elochoman Slough and the maximum at Youngs Bay The U.S EPA and Oregon freshwater standard for copper (6.5 μg/L) was not exceeded at any of the stations, but the saltwater standard (2.9 μg/L) was exceeded at Youngs Bay.

The CV of total recoverable copper samples ranged from 2 8 to 54 6%. It was greater than 25% at Svensen Island, Carrolls Channel, and Scappoose Bay Laboratory precision was within QC limits; therefore, the relatively high variability at these stations may be due to field variation in the total recoverable copper concentration. Relatively large differences in concentration between stations are likely due to inter-station rather than intra-station variability

Filtered copper concentrations were all below the laboratory detection limit of 1.0 μg/L and did not exceed the Washington freshwater dissolved standard of 5.6 μg/L (Figure 4-10).

4.1.4.9 Iron. Station average total recoverable iron concentrations ranged from 188 to 2,523 μg/L with a median concentration of 421 μg/L (Figure 4-6) The minimum average concentration was measured at Svensen Island and the maximum at Scappoose Bay. The U.S. EPA and Oregon water quality criterion for iron (1,000 μg/L) was exceeded only at Scappoose Bay.

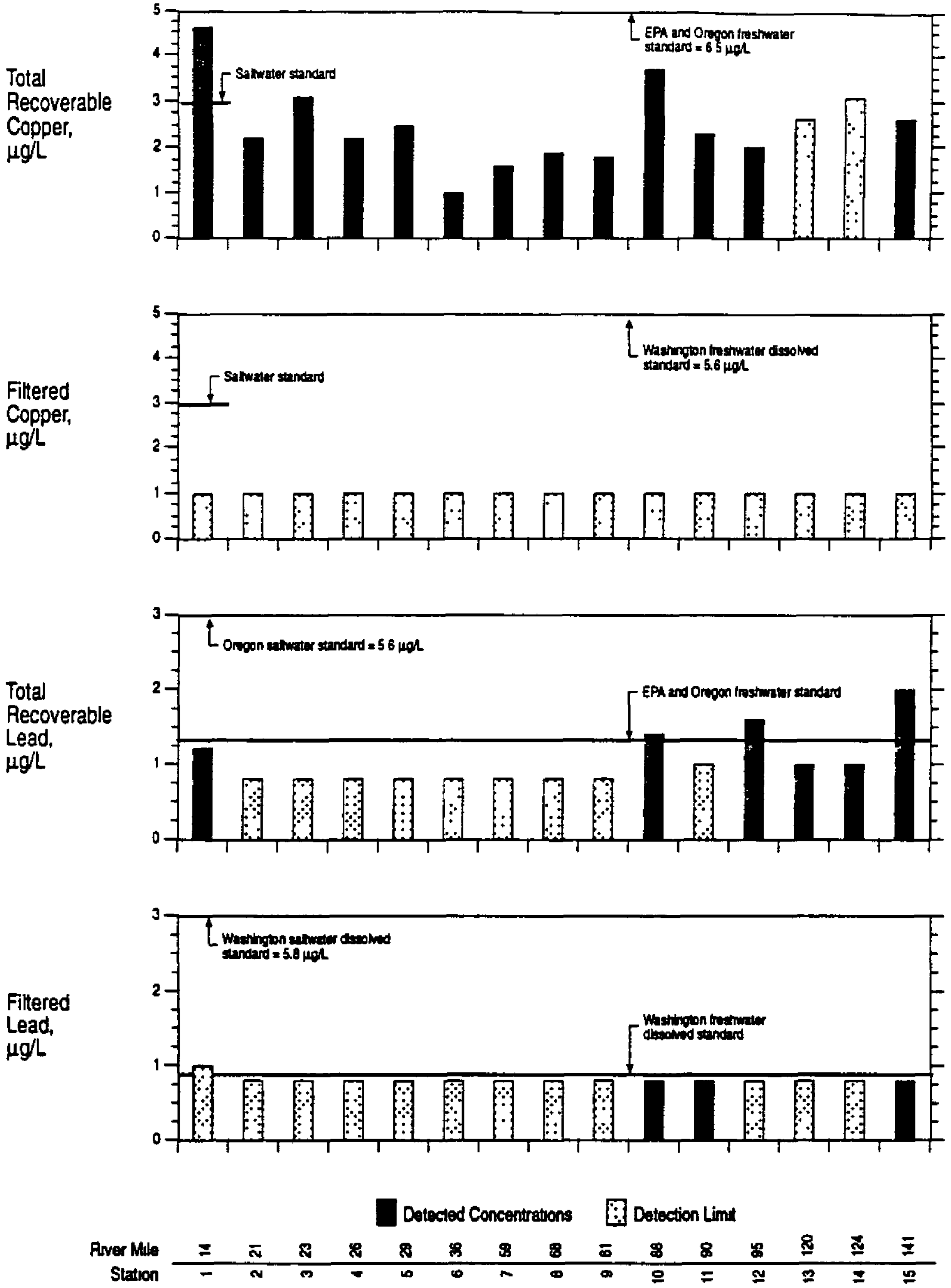


Figure 4-10. Water Column Concentrations of Total Recoverable and Filtered Copper and Lead in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

The CV of total recoverable iron samples ranged from 0.8 to 80.2%. It was greater than 25% at Knappa Slough, Scappoose Bay, Willow Bar Islands, and Skamania Landing. Laboratory precision was within QC limits; the relatively high variability at these stations may be due to field variation in the total recoverable iron concentration. Relatively large differences in concentration between stations are likely due to inter-station rather than intra-station variability.

Station average filtered iron concentrations ranged from 6 to 442 μg/L with a median concentration of 26 μg/L (Figure 4-6). The minimum average concentration was measured at Camas Slough and the maximum at Scappoose Bay. There are no recommended criteria or standards for dissolved iron.

The CV for filtered iron samples ranged from 4.1 to 33.6%. It was greater than 25% at Cathlamet Bay, Svensen Island, and Lewis & Clark NWR. Laboratory precision was within QC limits, the relatively high variability at these stations may be due to field variation in the filtered iron concentration. Relatively large differences in concentration among stations are likely due to inter-station rather than intra-station variability.

4.1.4.10 Lead. Station average total recoverable lead concentrations ranged from below laboratory detection (average detection limits of 0.8-1.0 μg/L) at nine stations to 2.0 μg/L, with a median concentration equivalent to the 0.8 μg/L detection limit (Figure 4-10). The maximum concentration was measured at Skamania Landing. The U.S. EPA and Oregon freshwater standard for lead (1.3 μg/L based on a water hardness of 50 mg/L) was exceeded at Scappoose Bay, Willow Bar Islands, and Skamania Landing.

The CV of the total recoverable lead detected in the three field replicate samples from Skamania Landing was 22.9%. The CV of one laboratory duplicate analysis was 15.7%. Therefore, the variability noted in the field samples from Skamania Landing may have been due more to analytical than field variability. Because the reported sample concentrations were near the laboratory detection limit, laboratory variability likely contributed to the variation noted in these field samples.

Filtered lead concentrations were generally below the laboratory detection limit of 0.8 μg/L, with the exception of lead detected in one of the three field replicate samples at each of three stations (Figure 4-10) These average concentrations were all below the Washington freshwater dissolved standard of 0 9 μg/L

4.1.4.11 ***Mercury***. In general, total recoverable and filtered mercury were not detected above the laboratory detection limit of 0 11 μg/L, except for one total recoverable mercury replicate sample collected from Lewis & Clark NWR in Bug Hole (Figure 4-11) Therefore, it is possible that the average total recoverable mercury concentration exceeded the freshwater standard of 0 012 μg/L at this station However, the detection limits were too high for an adequate evaluation of potential water quality problems It is not currently possible to measure mercury levels at concentrations below the water quality standards with the conventional laboratory methods used in this survey

Due to the infrequent detection of mercury, CV could not be determined.

4.1.4.12 ***Nickel.*** Station average total recoverable nickel concentrations ranged from below laboratory detection (detection limit range of 5 0-7 3 μg/L) at 13 stations to 6.0 μg/L, with a median concentration equivalent to the 5.0 μg/L detection limit (Figure 4-11). The maximum concentration was measured at Youngs Bay The U.S EPA and Oregon freshwater standard for nickel (88 μg/L) was not exceeded at any backwater station.

Filtered nickel concentrations were generally below the laboratory detection limit of 5.0 μg/L, with the exception of nickel detected in one of the three field replicate samples at each of three stations (Figure 4-11) The maximum average concentrations were below the Washington freshwater and saltwater dissolved standards of 83 and 7 9 μg/L, respectively

Due to the infrequent detection of total recoverable or filtered nickel in the field replicate samples, CV could not be determined.

4.1.4.13 ***Selenium***. In general, total recoverable and filtered selenium were not detected above the laboratory detection limit of 3.0 μg/L, except for one sample from Youngs Bay (Figure 4-12). The reported concentrations and detection limits were all lower than the U.S EPA and Washington freshwater and marine standards of 5.0 and 71 μg/L, respectively.

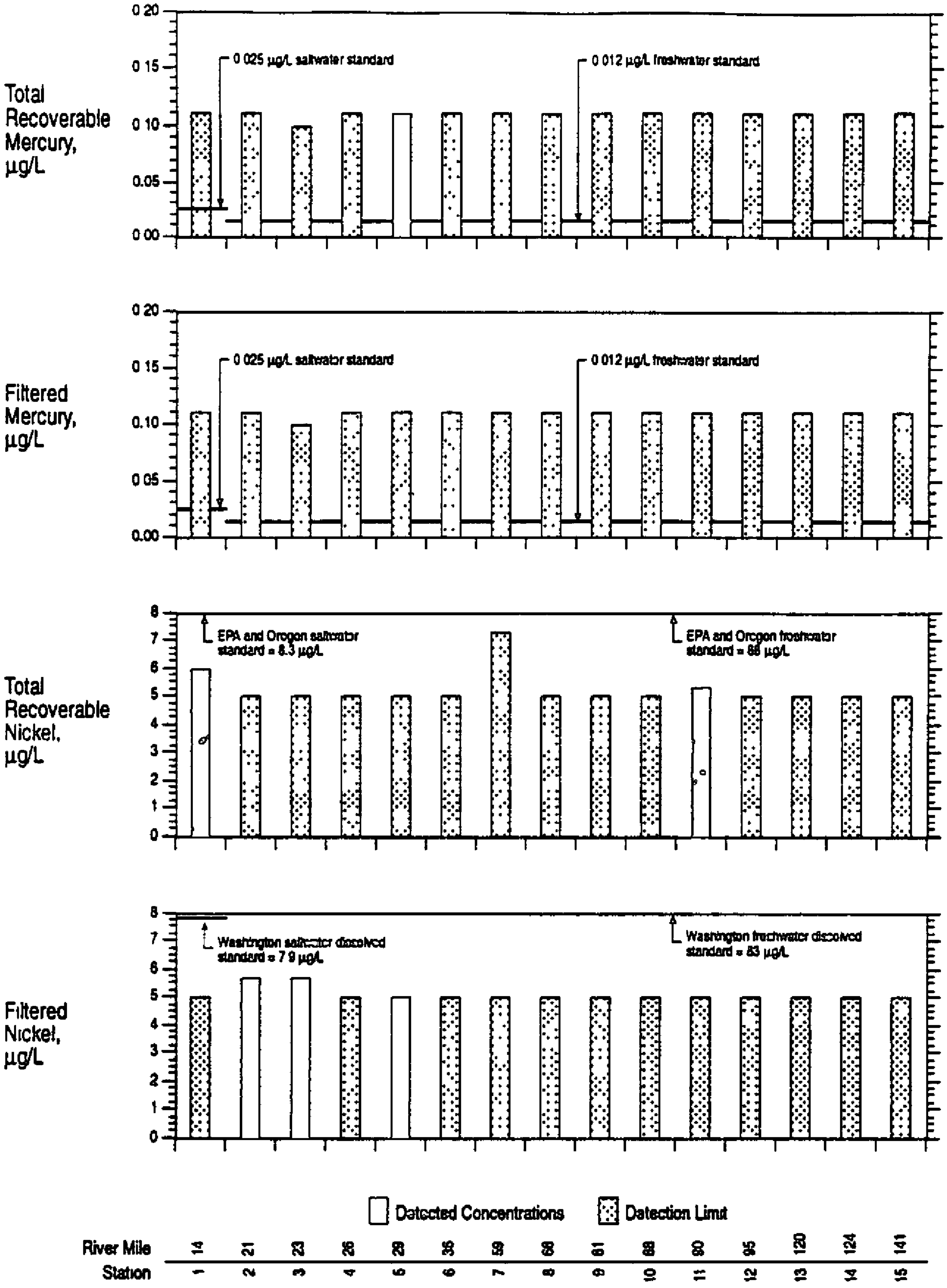


Figure 4-11. Water Column Concentrations of Total Recoverable and Filtered Mercury and Nickel in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

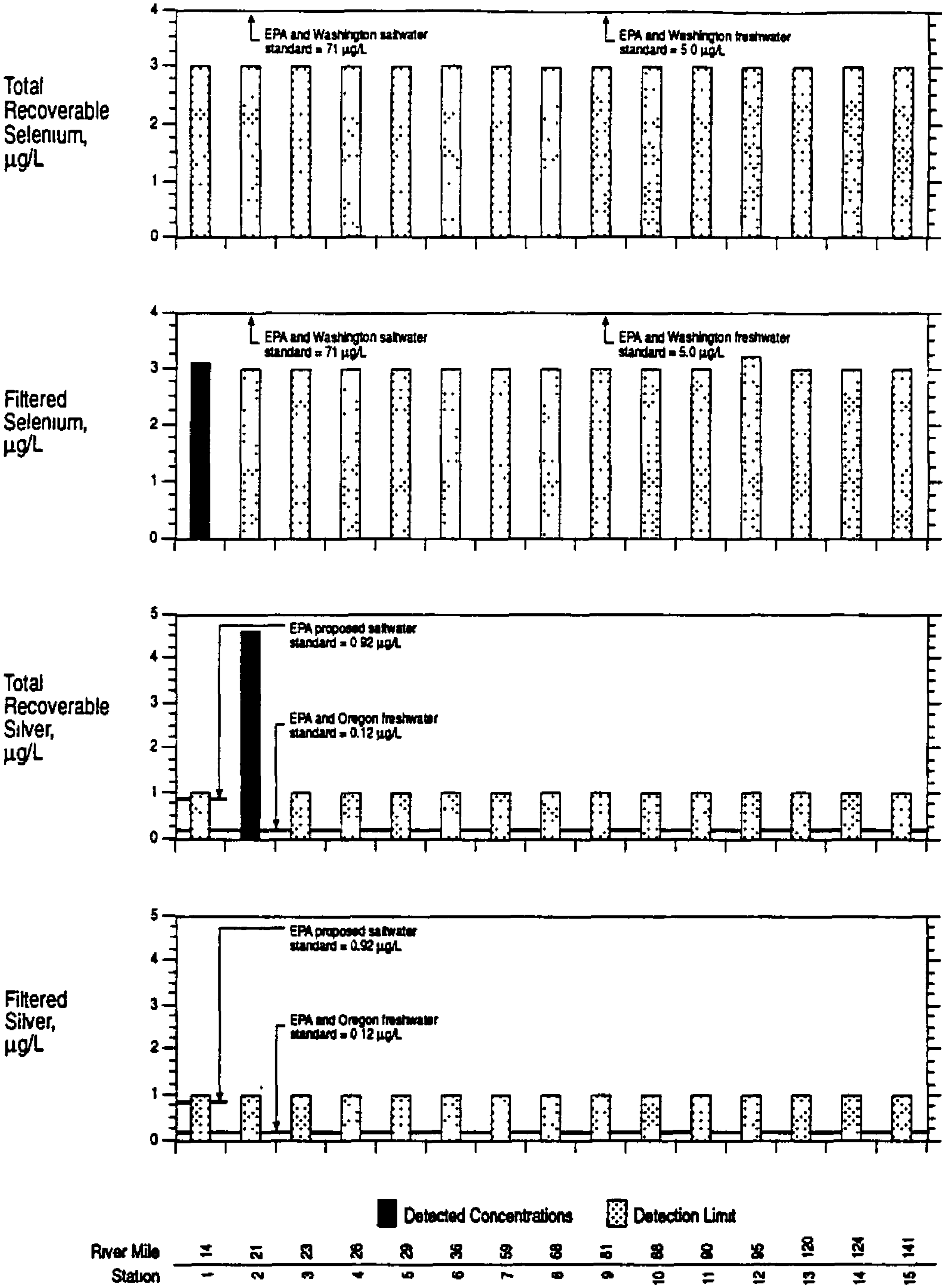


Figure 4-12. Water Column Concentrations of Total Recoverable and Filtered Selenium and Silver in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

Due to the infrequent detection of total recoverable or filtered selenium in the field replicate samples, CV could not be determined

4.1.4.14 Silver In general, total recoverable and filtered silver were not detected above the laboratory detection limit of 1 0 μg/L, except for one total recoverable sample from Cathlamet Bay (Figure 4-12). It is possible that the average total recoverable silver concentration exceeded the freshwater standard of 0 12 μg/L at this station However, the detection limits achieved were in general too high for an adequate evaluation of potential water quality problems. It is not currently possible to measure silver levels at concentrations below the water quality standards with the conventional laboratory methods used in this survey

Due to the infrequent detection of total recoverable or filtered silver in the field replicate samples, CV could not be determined

4.1.4.15 Thallium. Station average total recoverable thallium concentrations ranged from below laboratory detection (detection limit of 1 0 μg/L) at ten stations to 1.1 μg/L, with a median concentration equivalent to the 1.0 μg/L detection limit (Figure 4-13). The maximum concentrations were measured at Cathlamet Bay and Bachelor Island. The U S EPA and Oregon freshwater LOEL for thallium (40 μg/L) was not exceeded at any backwater station sampled.

Station average filtered thallium concentrations ranged from below laboratory detection (1.0 μg/L) at ten stations to 1.2 μg/L, with a median concentration equivalent to the 1 0 μg/L detection limit (Figure 4-13). The maximum concentration was measured at Lewis & Clark NWR in Bug Hole. The U S EPA and Oregon freshwater LOEL for thallium (40 μg/L) was not exceeded at any backwater station sampled.

Due to the infrequent detection of total recoverable or filtered thallium in the field replicate samples, CV could not be determined.

4.1.4.16 Zinc. Station average total recoverable zinc concentrations ranged from below laboratory detection limits (average 3.0-6 0 μg/L) at five stations to 16.7 μg/L, with a median concentration of 8 0 μg/L (Figure 4-13) The maximum average concentration was measured at Scappoose Bay The

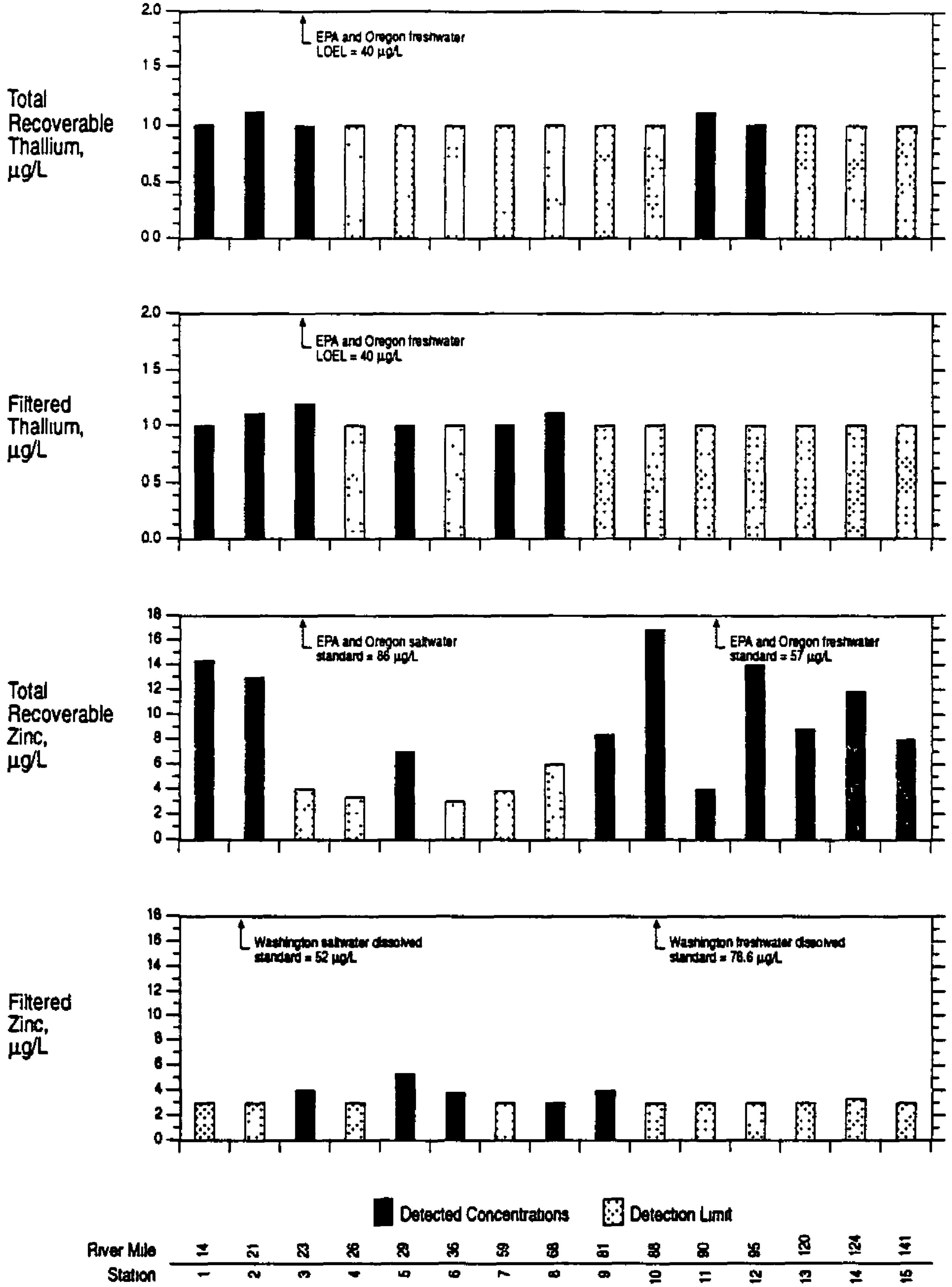


Figure 4-13. Water Column Concentrations of Total Recoverable and Filtered Thallium and Zinc in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

U.S. EPA and Oregon freshwater and saltwater standards for zinc (57 and 86 μg/L, respectively) were not exceeded at any backwater station sampled.

The CV of total recoverable zinc samples ranged from 19.8 to 66.4%. It was greater than 25% for five stations. Laboratory precision was generally outside of the QC limits for laboratory replicate results; the relatively high variability at these stations may be due to laboratory variation. Only very large differences in zinc concentrations between stations are likely due to inter-station rather than intra-station variability.

Filtered zinc concentrations were generally below the laboratory detection limit of 3.0 μg/L, except for zinc detected in one sample at each of five stations (Figure 4-13). The maximum average concentration of 5.3 μg/L measured at the Lewis & Clark NWR station was below the U.S. EPA and Oregon freshwater and marine standards for zinc (57 and 86 μg/L, respectively).

Due to the infrequent detection of filtered zinc in the field replicate samples, CV could not be determined.

4.1.4.17 Cyanide. Cyanide was not detected above the laboratory detection limit of 2 μg/L in any sample. The detection limit is lower than the 5.2 μg/L freshwater standard, but slightly higher than the saltwater standard of 1 μg/L. Therefore, it is possible that cyanide was present at potentially harmful levels at Youngs Bay in the estuary.

Because cyanide was not detected in the field replicate samples, CV could not be determined.

4.1.4.18 Summary of Quality Assurance/Quality Control Detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). The sample results for cyanide were all qualified as undetected, because sample concentrations were below the laboratory detection limit of 2 μg/L. Sample results for several metals were qualified as estimated based on evaluation of QA/QC data. Three positive values for cadmium and one for lead were qualified as estimates based on exceeding continuing calibration verification criteria. Because of metals detected in several laboratory blank samples, approximately 40 values for eight different metals (aluminum, cadmium, chromium, copper, lead, nickel, thallium, and zinc) were qualified as undetected due to blank contamination. Aluminum was detected in one equipment/filter blank sample at a concentration of

3 8 µg/L All dissolved aluminum concentrations associated with this equipment/filter blank that were less than five times the blank concentration have been qualified as undetected. Forty values for six different metals (aluminum, iron, lead, nickel, thallium, and zinc) were qualified as estimates based on exceeding QC guidelines for matrix spikes. Several values for aluminum, lead, and zinc were qualified as estimates based on exceeding QC guidelines for laboratory precision The qualification of many of the metals data is primarily due to ambient water and spike metals concentrations that are very near the laboratory-reported detection limits achieved for this study The detection limits themselves are generally lower than the typical method reporting limits recommended for the conventional analytical methods employed for this study

The qualification of data as undetected due to laboratory and field-equipment/filter blank contamination has ensured that the detected concentrations reported are not likely due to contamination, which has been a significant problem in previous studies that have attempted to measure trace amounts of metals in freshwater and marine systems (e.g., Windom et al 1991). Although a number of the metals data were qualified, the precision, accuracy, and completeness of the metals data were within project guidelines and the data, as qualified, are considered suitable for their intended use in this report.

4.1.5 Indicator Bacteria

Sampling for indicator bacteria (fecal coliforms, enterococcus, and *E. coli*) was conducted 24 June-1 July 1993. Table 4-6 presents summary statistics, including exceedances of standards Exceedances of the fecal coliform standards were noted at three stations. No exceedances the *E. coli* or enterococcus standards were noted. The significance of these findings is discussed in more detail in Section 5.1.5

4.1.5.1 Fecal Coliforms The geometric mean fecal coliform concentration ranged from 10 to 262 bacteria per 100 mL (Figure 4-14). The minimum geometric mean was measured at Lewis & Clark NWR and the maximum at Scappoose Bay The overall geometric mean concentration for all 15 stations was 40 bacteria per 100 mL. The Washington freshwater fecal coliform standard of 100 bacteria per 100 mL was exceeded at Svensen Island and Scappoose Bay The Washington and Oregon standard for marine and/or shellfish harvesting waters (14 bacteria per 100 mL) was exceeded at Youngs Bay in the estuary.

The CV of the field triplicate analyses ranged from 15 to 142%. The relatively high variation was generally due to the occurrence of much higher concentrations in one of the three field replicate samples.

TABLE 4-6. SUMMARY OF INDICATOR BACTERIA DATA
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Frequency of Detection[a]	Numbers of Bacteria per 100 mL		Frequency of Exceedance of Standard[d]
		Range[b]	Geometric Mean[c]	
Fecal Coliform				
Jun-Jul 1993	15/15	10-262	40	3/15 (20%)
Escherichia coli				
Jun-Jul 1993	15/15	8-85	26	0/15 (0%)
Enterococcus				
Jun-Jul 1993	12/15	2U-5	3	0/15 (0%)

NS = Not sampled.

[a] Frequency of detected occurrence at the stations sample Fifteen stations were sampled between [illegible] - June-1 July 1993 The numbers in parentheses indicate the frequency of detection of individual samples In Jun-Jul 1993 a single sample consisted of triplicate field samples collected at each of fifteen stations (n=15). The geometric mean of the triplicate samples was used for comparison with the standards

[b] Ranges given are for geometric means of three field replicate samples at each station.

[c] Overall geometric mean of individual station geometric means.

[d] Frequency of exceedance of the lowest standard (e g, 100 fecal coliforms per 100 mL) for the geometric mean concentration (n=3) at a particular station

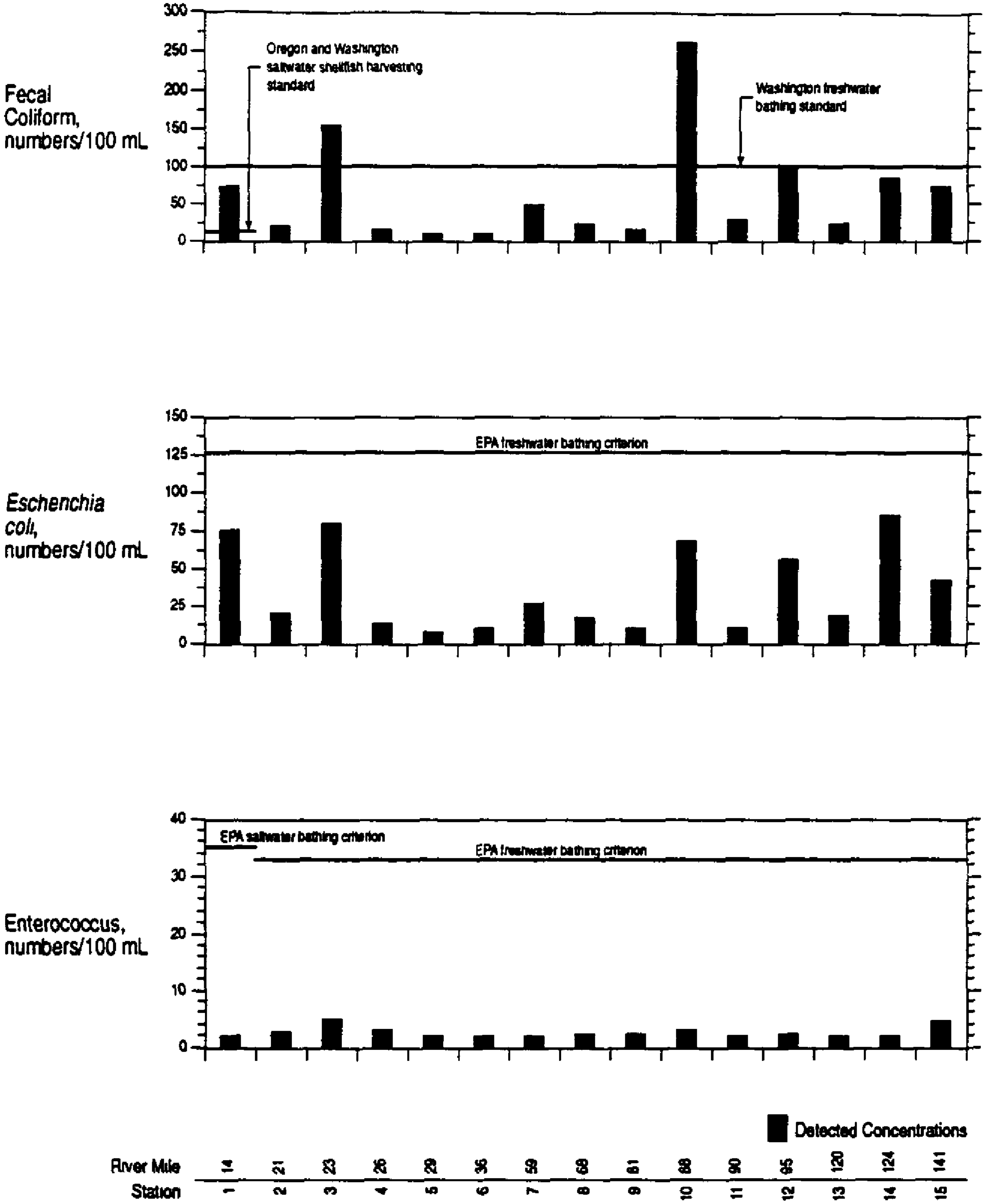


Figure 4-14. Indicator Bacteria Concentrations in Fifteen Backwater Areas of the Lower Columbia River (24 June - 1 July 1993).

Previous studies have attributed large variation in bacteria densities to the patchiness of these organisms and their association with particulate matter For example, the CV of co-located field triplicate samples ranged over 100% in a WDOE study of fecal coliforms in the lower Columbia (Hallock 1993). The variation in these samples was significantly greater than the variation in laboratory duplicate or sequential samples collected 15 minutes later from a single location (Hallock 1993). Very similar results have been obtained for *E coli* and enterococcus counts

4.1.5.2 Escherichia coli. The geometric mean *E. coli* concentration ranged from 8 to 85 bacteria per 100 mL (Figure 4-14). The minimum mean concentration was measured at Lewis & Clark NWR and the maximum at Gary & Flag Islands The overall geometric mean of the station mean values was 26 bacteria per 100 mL The U S EPA *E coli* criterion of 126 bacteria per 100 mL was not exceeded at any station.

The CV of the mean of the field triplicate analyses ranged from 17 to 144% See 4.1.5.1 above for a discussion of high variations in bacteria counts.

4.1.5.3 Enterococcus. The geometric mean enterococcus concentration ranged from undetected (reporting limit of 2 bacteria per 100 mL) to 5 bacteria per 100 mL (Figure 4-14) Enterococcus concentrations below the reporting limit in all three field replicate samples occurred at Elochoman Slough and Fisher Island Slough. The maximum geometric mean concentrations were measured at Svensen Island and Skamania Landing. The overall geometric mean of the station mean values was 3 bacteria per 100 mL. The U.S. EPA freshwater enterococcus criterion of 33 bacteria per 100 mL was not exceeded at any station, and the U.S EPA marine criterion of 35 bacteria per 100 mL was not exceeded at Youngs Bay

The CV of the mean of the field triplicate analyses ranged from 25 to 58% See 4.1.5.1 above for a discussion of high variations in bacteria counts.

4.1.5.4 Summary of Quality Assurance/Quality Control. The method reporting limit (MRL) specified by the laboratory (2 organisms per 100 mL), met the quantitation goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). Those samples that were not detected above the MRL were qualified as undetected. All samples were taken completely through a confirmation phase. No data qualifiers other than "U" (undetected) were assigned to any of the sample results and they are considered appropriate for use in this report

4.2 SEDIMENT QUALITY

This section presents results of analyses of sediment samples collected in the 1993 backwater reconnaissance survey Analytes are grouped and presented as for water samples, in narrative, tabular, and graphic formats Where calculable (from field triplicate samples), the coefficient of variation (CV) is presented within the discussion of each analyte, data QA/QC is summarized at the end of each group of analytes. Complete survey results are found in the separate data appendix (Tetra Tech 1993e), complete results of data QA/QC reviews are also presented separately (Tetra Tech 1993d).

Results are compared to existing reference levels (U.S EPA-recommended criteria and state standards; see Section 2) to provide a preliminary assessment of potential adverse effects to aquatic organisms. The single composite samples (of surficial sediments to the 2-cm sediment depth) collected for sediment analyses are more suitable than water column samples for characterizing and evaluating water quality in a river system, at least for persistent hydrophobic contaminants. Surficial sediments, especially fine-grained sediments in depositional areas, integrate the contaminants recently (on the order of months to years) discharged to the river system from both point and nonpoint sources. Therefore, exceedances of the reference values adopted for use in this study indicate potentially serious water quality problems that warrant more intensive investigation.

4.2.1 Conventional Parameters

Sediment samples were analyzed for the conventionally measured sediment parameters total organic carbon (TOC), grain size (percent fines), solids, total volatile solids (TVS), total sulfides, ammonia nitrogen, and total Kjeldahl nitrogen (TKN). Sediment sampling was conducted 24 June-1 July 1993. Table 4-7 presents summary statistics for these data. Although it is likely that these parameters have been altered to some degree by human influences (at least in localized areas of the river), there are no reference values available for this data. These parameters are important in regulating the transport, toxicity, and bioaccumulation of contaminants that enter the river, and provide useful information for evaluating chemical contaminant data.

TABLE 4-7 SUMMARY OF SEDIMENT CONVENTIONAL PARAMETERS 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

		Units in percent dry weight	
	Number of Observations[a]	Range	Median
Total Organic Carbon	15	0.7-3.7	1.8
Percent Fines (<63μm)	15	29-95	52
Total Solids	15	36.2-57.6	45.4
Total Volatile Solids	15	2.9-8.9	5.3
		Units in mg/kg dry weight	
Total Sulfides	15	1.8U-133.9	18.9
Ammonia Nitrogen	15	4.3-63.8	24.7
Total Kjeldahl Nitrogen	15	650-2,000	1,400

U = Not detected. The preceeding value is the laboratory detection limit.

[a] The number of observations is equivalent to the number of stations sampled. Fifteen stations were sampled between 24 June-1 July 1993. One of the observations represents a mean of three field replicate values.

4.2.1.1 Total Organic Carbon TOC concentrations ranged from 0.7 to 3 7% with a median of 1 8% (Table 4-7) The lowest sediment TOC concentration was measured at Bachelor Island Slough and the highest at Gary & Flag Islands.

The CV of sediment TOC at Burke Slough was 12%, with concentrations ranging from 3.0 to 3.8 mg/kg. Differences in sediment TOC content between stations are likely due to inter-station rather than intra-station variability

4.2.1.2 Percent Fines. Sediment percent fines (the silt and clay fraction less than 63 μm effective diameter) on a dry weight basis ranged from 29 to 95% with a median of 52% (Table 4-7). The lowest proportion was measured at Elochoman Slough and the highest Youngs Bay The remaining sediments at the backwater stations sampled were predominantly sand (4.4-70.4%) with very little gravel present (0 0-1.5%).

The CV of sediment percent fines at Burke Slough was 4.4% and the relative amount of fines in the three field replicate samples ranged from 42.7 to 46.2%. Differences in sediment percent fines content between stations are likely due to inter-station rather than intra-station variability.

4.2.1.3 Total Solids. Total solids ranged from 36.2 to 57 6% with a median concentration of 45 4% (Table 4-7) The lowest percent total solids was measured at Scappoose Bay and the highest at Bachelor Island.

The CV of sediment total solids at Burke Slough was 2.5% and the total solids in the three field replicate samples from this station ranged from 45 4 to 47.7%. Differences in total solids between stations are likely due to inter-station rather than intra-station variability.

4.2.1.4 Total Volatile Solids. TVS ranged from 2.9-8.9% with a median of 5.3% (Table 4-7). The lowest TVS was measured at Fisher Island Slough and the highest at Burke Slough.

The CV of sediment TVS at Burke Slough was 12.2%, TVS in the three field replicate samples from this station ranged from 7.0 to 8.9%. Differences in sediment TVS between stations are likely due to inter-station rather than intra-station variability.

4.2.1.5 Total Sulfides. Sediment total sulfide concentrations ranged from undetected (detection limit of 1.8 mg/kg), to 133.9 mg/kg (Table 4-7). Sulfide was not detected at Fisher Island Slough. The lowest detected total sulfide concentration (3.4 mg/kg) was measured at Carrolls Channel, and the highest (133.9 mg/kg) at Youngs Bay. The next highest concentration (64 mg/kg) was measured at Elochoman Slough.

The CV of sediment total sulfides at Burke Slough was 13.8%, with concentrations in the field triplicate samples ranging from 16.0 to 21.0 mg/kg. Differences in total sulfides between stations are likely due to inter-station rather than intra-station variability.

4.2.1.6 Ammonia Nitrogen. Sediment ammonia nitrogen concentrations ranged from 4.3 to 63.8 mg/kg. The lowest concentration was measured at Fisher Island Slough and the highest at Camas Slough.

The CV of sediment ammonia nitrogen at Burke Slough was 6.1%, with concentrations in the three field replicate samples ranging from 46.3 to 52.0 mg/kg. Differences in sediment ammonia nitrogen between stations are likely due to inter-station rather than intra-station variability.

4.2.1.7 Total Kjeldahl Nitrogen Sediment TKN concentrations ranged from 650 to 2,000 mg/kg. The lowest sediment TKN concentration was measured at Bachelor Island Slough and the highest at Scappoose Bay (Table 4-7).

The CV of sediment TKN at Burke Slough was zero percent and the TKN concentration in the three field replicate samples from this station was 1,200 mg/kg. Differences in sediment TKN between stations are likely due to inter-station rather than intra-station variability.

4.2.1.8 Summary of Quality Assurance/Quality Control. The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). For all parameters except grain size, no data qualifiers, other than "U" (undetected), were assigned. For grain size, one of the 17 samples was qualified as estimated based on laboratory precision data. All of the conventional parameter data are suitable for use in this report.

4.2.2 Metals and Cyanide

Sediment sampling for 16 total recoverable metals and cyanide was conducted 24 June-1 July 1993 Table 4-8 presents summary statistics, including exceedances of available reference levels for arsenic (4 stations), cadmium (14 stations), chromium (2 stations), copper (15 stations), iron (9 stations), nickel (7 stations), silver (1 station), zinc (4 stations), and cyanide (1 station) All of the detection limits achieved for these analytes were adequate to evaluate potential adverse effects on benthic organisms No reference levels were available for aluminum, barium, beryllium, selenium, or thallium.

These reference level exceedances indicate potential adverse effects on benthic aquatic organisms; this will be discussed in more detail in Section 5.2 4

4.2.2.1 Aluminum Sediment aluminum concentrations ranged from 14,200 to 33,300 mg/kg, with a median concentration of 18,033 mg/kg (Figure 4-15). The lowest concentration was measured at Fisher Island Slough, and the highest at Elochoman Slough. No reference values are available to evaluate the potential environmental significance of these data.

The CV of sediment aluminum samples from Burke Slough was 5.5%; concentrations in the three samples ranged from 16,900 to 18,700 mg/kg These differences in reported sediment aluminum content are likely due to inter-station rather than intra-station variability

4.2.2.2 Antimony. Antimony was not detected at any station (detection limits ranged from 0.23 to 0.41 mg/kg; Figure 4-15). Detection limits were all lower than the Ontario reference level for antimony (2 mg/kg).

4.2.2.3 Arsenic. Sediment arsenic concentrations ranged from 3.6 to 13.6 mg/kg with a median concentration of 4.5 mg/kg (Figure 4-15) The lowest concentration was measured at Bachelor Island Slough and the highest at Scappoose Bay. Concentrations exceeded the lowest reference concentration (Ontario's Lowest Effect Level of 6 mg/kg) at Cathlamet Bay, Scappoose Bay, Willow Bar Islands, and Camas Slough

TABLE 4-8 SUMMARY OF SEDIMENT METALS AND CYANIDE DATA
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Frequency of Detection[a]	Units in mg/kg dry sediment		Frequency of Exceedances[b]	
		Range	Median	Long and Morgan	Ontario
Aluminum	15/15	14,200-33,300	18,033	NA	NA
Antimony	0/15	0.23U-0.41U	0.30U	0/15	NA
Arsenic	15/15	3.6-13.6	4.5	0/15	4/15
Barium	15/15	59.9-186	144	NA	NA
Beryllium	15/15	0.42-1.2	0.76	NA	NA
Cadmium	15/15	0.49-1.9	1.0	0/15	14/15
Chromium	15/15	14.8-31.1	20.8	0/15	2/15
Copper	15/15	19.3-49.9	27.6	0/15	15/15
Iron	15/15	15,500-39,000	20,600	NA	9/15
Lead	12/15	9.5U-26.3	15.6	0/15	0/15
Mercury	15/15	0.06-0.18	0.08	1/15	0/15
Nickel	15/15	14.0-24.8	15.3	0/15	7/15
Selenium	0/15	0.91U-1.6U	1.2U	NA	NA
Silver	1/15	0.08U-3.1	0.11U	1/15	1/15
Thallium	0/15	0.30U-0.55U	0.40U	NA	NA
Zinc	15/15	68.3-155	97.3	4/15	4/15
Cyanide	1/15	0.100U-0.172	0.100U	NA	1/15

NA = No reference level available for determination.

U = Not detected. Value presented is the detection limit.

[a] Frequency of detection is equivalent to the number of stations sampled where the parameter was detected. Fifteen stations were sampled betweem 24 June-1 July 1993.

[b] Frequency of exceedance of the Long and Morgan (1990) Effects Range-Low or the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persaud et al. 1993) Lowest Effect Level for potential adverse effects on benthic organisms.

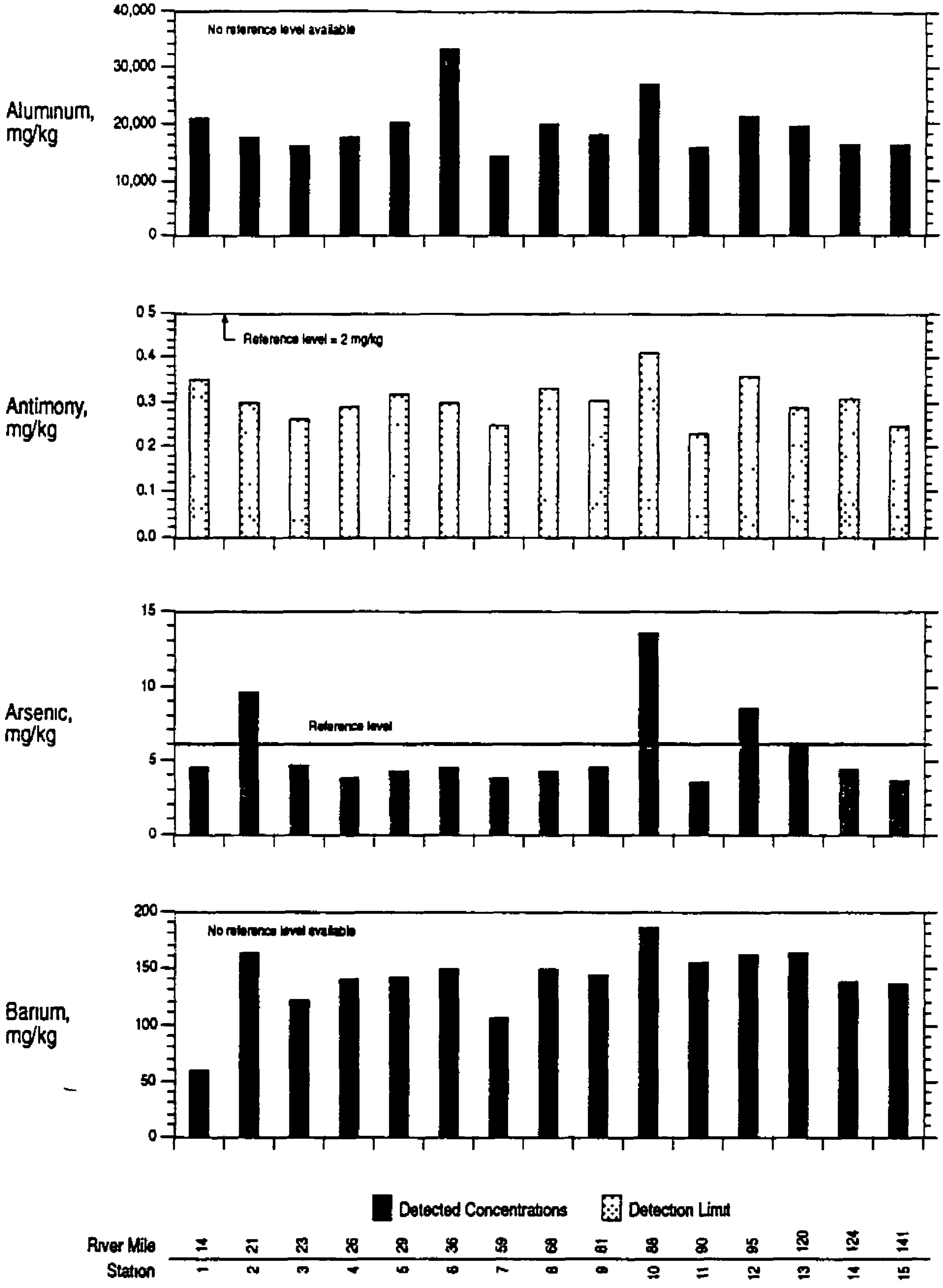


Figure 4-15. Sediment Concentrations of Antimony, Aluminum, Arsenic, and Barium (mg/kg dry wt).

The CV of sediment arsenic samples from Burke Slough was 9 3%, concentrations in the three samples ranged from 4 0 to 4 8 mg/kg These differences in sediment arsenic content are likely due to inter-station rather than intra-station variability

4.2.2.4 ***Barium***. Sediment barium concentrations ranged from 59.9 to 186 mg/kg, with a median concentration of 144 mg/kg (Figure 4-15) The lowest concentration was measured at Youngs Bay and the highest at Scappoose Bay No reference values are available to evaluate the potential environmental significance of these data.

The CV of sediment barium samples from Burke Slough was 9.2%, concentrations in the three samples ranged from 129 to 152 mg/kg These differences in sediment barium content are likely due to inter-station rather than intra-station variability

4.2.2.5 ***Beryllium***. Sediment beryllium concentrations ranged from 0 42 to 1.2 mg/kg, with a median concentration of 0.76 mg/kg (Figure 4-16) The lowest concentration was measured at Fisher Island Slough and the highest Elochoman Slough. No reference values are available to evaluate the potential environmental significance of these data.

The CV of sediment beryllium samples from Burke Slough was 14.2%, concentrations in the three samples ranged from 0.64 to 0 85 mg/kg. These differences in sediment beryllium content are likely due to inter-station rather than intra-station variability.

4.2.2.6 ***Cadmium*** Sediment cadmium concentrations ranged from 0 49 to 1.9 mg/kg, with a median concentration of 1.0 mg/kg (Figure 4-16). The lowest concentration was measured at Elochoman Slough and the highest at Willow Bar Islands. Sediment concentrations exceeded the lowest reference concentration (Ontario's Lowest Effect Level of 0.6 mg/kg) at all stations except Elochoman Slough.

The CV of sediment cadmium samples from Burke Slough was 21.9%, concentrations in the three samples ranged from 0.73 to 1.1 mg/kg. These relatively large differences in sediment cadmium content are likely due to inter-station rather than intra-station variability.

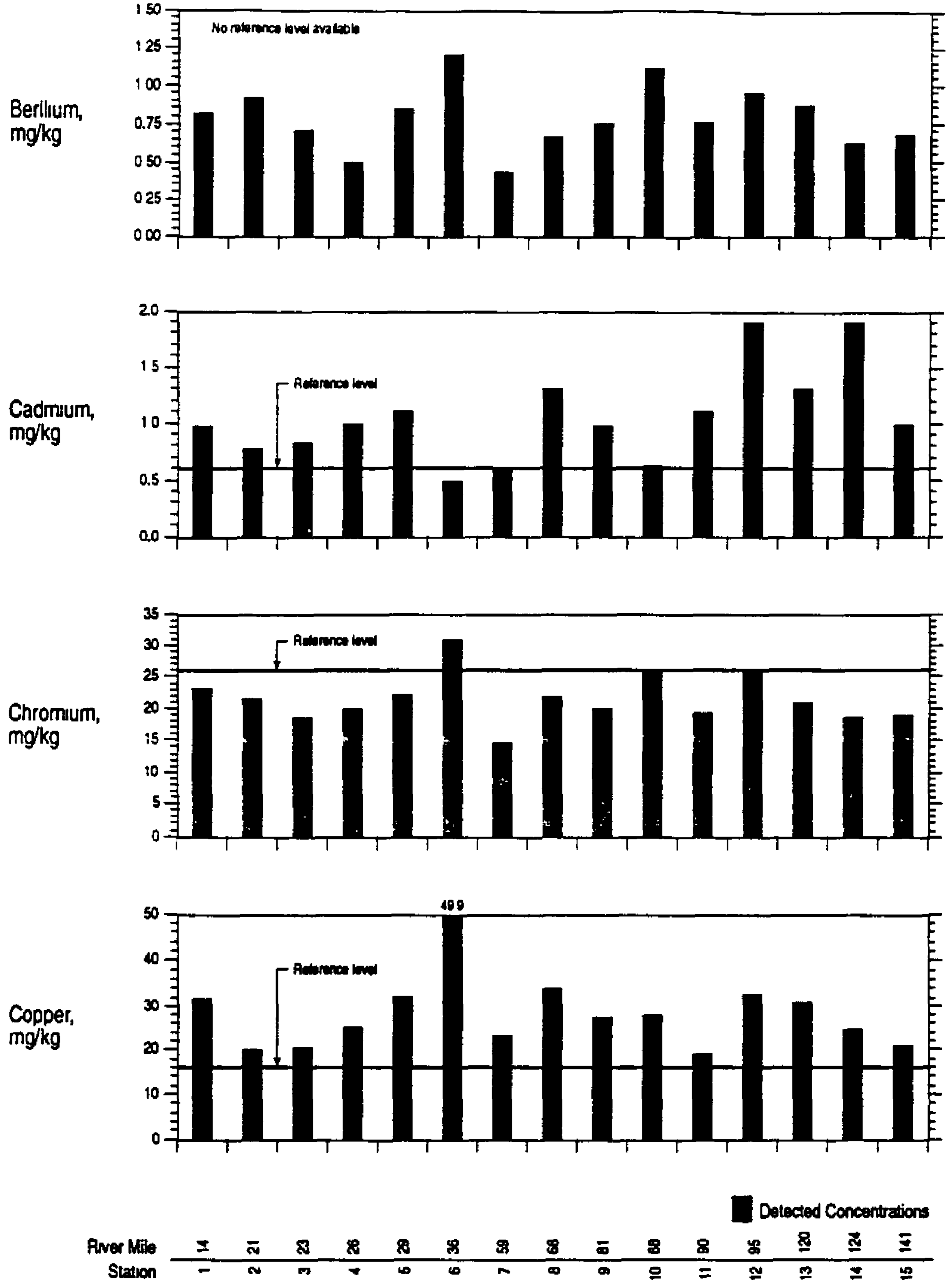


Figure 4-16. Sediment Concentrations of Berllium, Cadmium, Chromium, and Copper (mg/kg dry wt).

4.2.2.7 Chromium Sediment chromium concentrations ranged from 14.8 to 31.1 mg/kg, with a median concentration of 20.8 mg/kg (Figure 4-16). The lowest concentration was measured at Fisher Island Slough and the highest at Elochoman Slough. Sediment concentrations exceeded the lowest reference concentration (Ontario's Lowest Effect Level of 26 mg/kg) at Elochoman Slough and Scappoose Bay.

The CV of sediment chromium samples from Burke Slough was 0.5%, concentrations in the three samples ranged from 19.9 to 20.1 mg/kg. These differences in sediment chromium content are likely due to inter-station rather than intra-station variability.

4.2.2.8 Copper. Sediment copper concentrations ranged from 19.3 to 49.9 mg/kg, with a median concentration of 27.6 mg/kg (Figure 4-16). The lowest concentration was measured at Bachelor Island Slough and the highest at Elochoman Slough. Sediment concentrations exceeded the lowest reference concentration (Ontario's Lowest Effect Level of 16 mg/kg) at all stations sampled except Elochoman Slough.

The CV of sediment copper samples from Burke Slough was 6.9%; concentrations in the three samples ranged from 25.5 to 29.2 mg/kg. These differences in sediment copper content are likely due to inter-station rather than intra-station variability.

4.2.2.9 Iron. Sediment iron concentrations ranged from 15,500 to 39,000 mg/kg with a median concentration of 20,600 mg/kg (Figure 4-17). The lowest concentration was measured at Fisher Island Slough and the highest at Elochoman Slough. Sediment concentrations exceeded the reference concentration (Ontario's Lowest Effect Level of 20,000 mg/kg) at nine stations (see Figure 4-17).

The CV of sediment iron samples from Burke Slough was 5.8%; concentrations in the three samples ranged from 19,000 to 21,100 mg/kg. These differences in sediment iron content are likely due to inter-station rather than intra-station variability.

4.2.2.10 Lead. Sediment concentrations of lead ranged from below laboratory detection limits (9.5-18.1 mg/kg) to 26.3 mg/kg, with a median concentration of 15.6 mg/kg (Figure 4-17). The maximum concentration was measured at Willow Bar Islands. None of the measured sediment lead concentrations exceeded the reference levels (31-35 mg/kg) adopted for this survey.

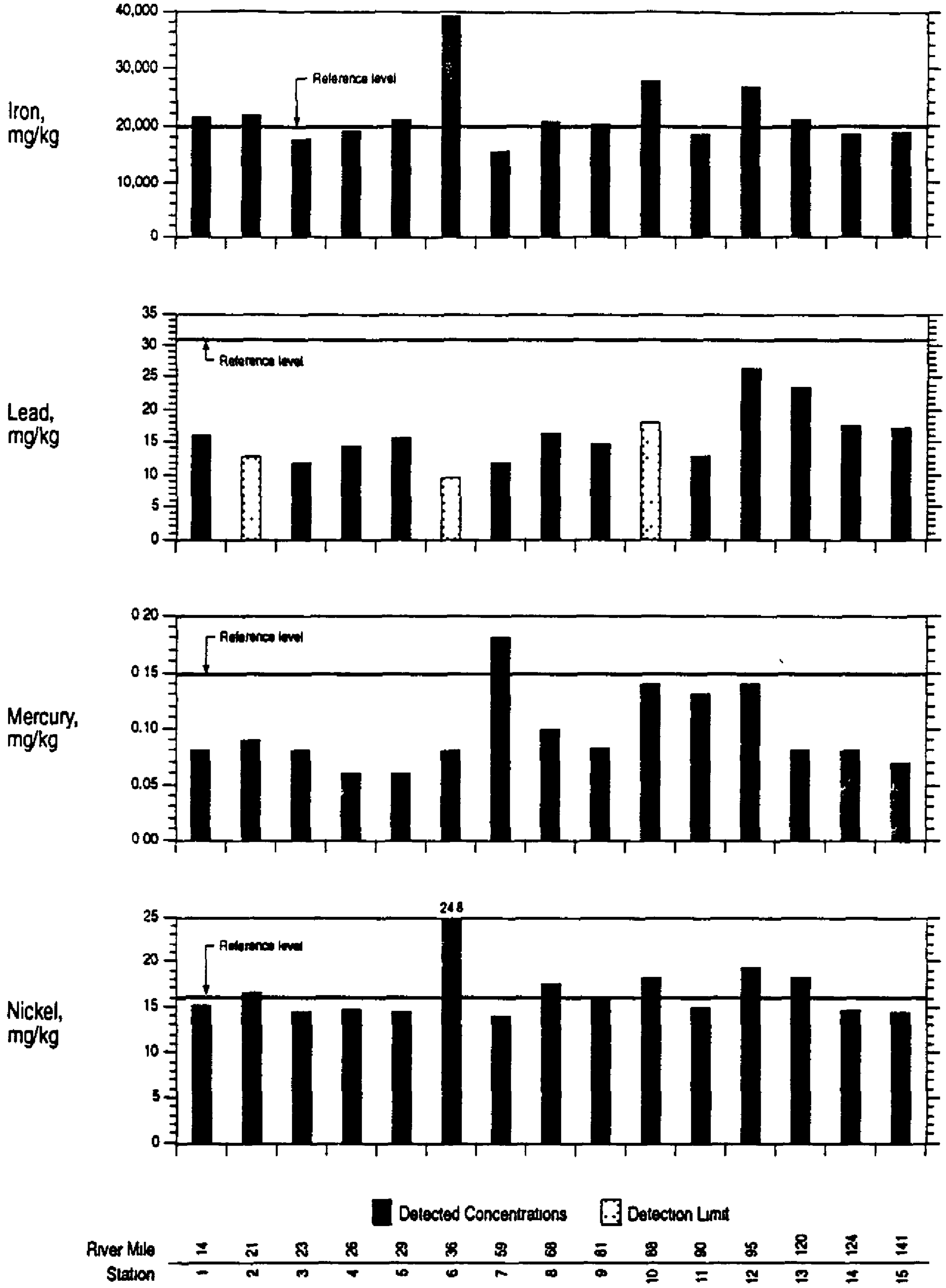


Figure 4-17. Sediment Concentrations of Iron, Lead, Mercury, and Nickel (mg/kg dry wt).

Because lead was detected in only two of the three samples collected from Burke Slough, CV could not be calculated

4.2.2.11 Mercury. Sediment mercury concentrations ranged from 0.06 to 0.18 mg/kg with a median concentration of 0 08 mg/kg (Figure 4-17) The lowest concentration was measured at both Knappa Slough and Lewis & Clark NWR, the highest at Fisher Island Slough. The lowest reference concentration (Long and Morgan's ER-L of 0 15 mg/kg) was exceeded at Fisher Island Slough.

The CV of sediment mercury samples from Burke Slough was 6.9%, concentrations in the three samples ranged from 0 08 to 0.09 mg/kg These differences in sediment mercury content are likely due to inter-station rather than intra-station variability.

4.2.2.12 Nickel. Sediment nickel concentrations ranged from 14 0 to 24 8 mg/kg with a median concentration of 15 3 mg/kg (Figure 4-17) The lowest concentration was measured at Fisher Island Slough and the highest at Elochoman Slough Sediment concentrations of nickel exceeded the lowest reference concentration (Ontario's Lowest Effect Level of 16 mg/kg) at seven stations: Cathlamet Bay, Elochoman Slough, Carrolls Channel, Burke Slough, Scappoose Bay, Willow Bar Islands, and Camas Slough

The CV of sediment nickel samples from Burke Slough was 4.5%, concentrations in the three samples ranged from 15 4 to 16 8 mg/kg. These differences in sediment nickel content are likely due to inter-station rather than intra-station variability

4.2.2.13 Selenium. Selenium was not detected at any station. Detection limits ranged from 0.91 to 1 6 mg/kg (Figure 4-18).

4.2.2.14 Silver. Silver was detected only at Elochoman Slough (3.1 mg/kg; Figure 4-18). Detection limits ranged from 0.08 to 0 49 mg/kg. The concentration of silver detected at this station exceeds both the Long and Morgan and Ontario reference levels of 1 and 0.5 mg/kg, respectively. Because silver was not detected in the field replicate samples, variation could not be assessed.

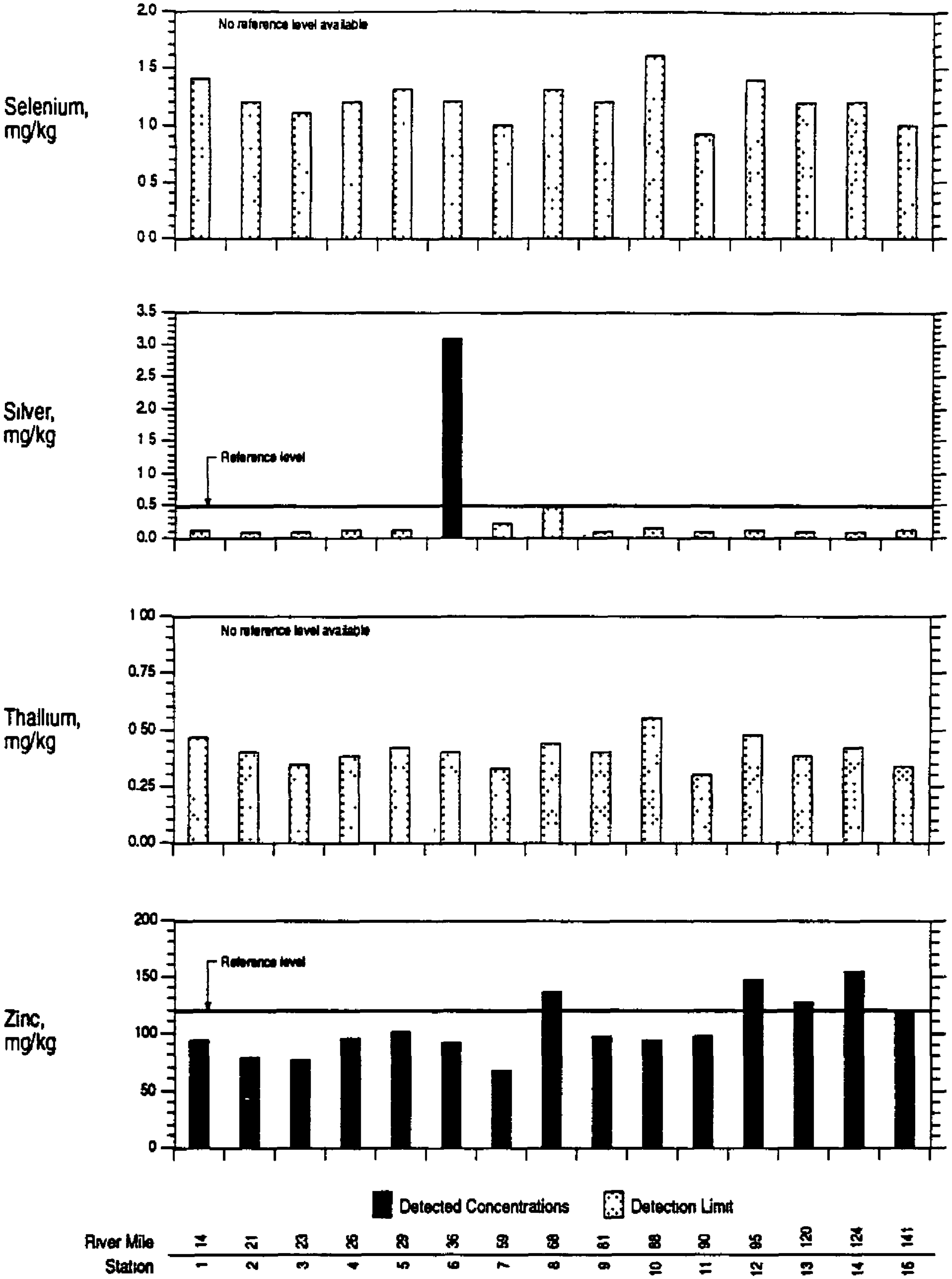


Figure 4-18. Sediment Concentrations of Selenium, Silver, Thallium, and Zinc (mg/kg dry wt).

4.2.2.15 Thallium Thallium was not detected at any station. Detection limits ranged from 0.30 to 0.55 mg/kg, Figure 4-18

4.2.2.16 Zinc. Sediment zinc concentrations ranged from 68.3 to 155 mg/kg with a median concentration of 97.3 mg/kg (Figure 4-18). The lowest concentration was measured at Fisher Island Slough and the highest at Gary & Flag Islands. Sediment concentrations of zinc exceeded the reference concentration of 120 mg/kg (Long and Morgan's ER-L and Ontario's Lowest Effect Level) at four stations: Carrolls Channel, Willow Bar Islands, Camas Slough, and Gary & Flag Islands.

The CV of sediment zinc samples from Burke Slough was 8.5%; concentrations in the three samples ranged from 89.4 to 106 mg/kg. These differences in sediment zinc content are likely due to inter-station rather than intra-station variability.

4.2.2.17 Cyanide. Cyanide was detected at one station: 0.172 mg/kg was measured at Elochoman Slough (detection limit of 0.1 mg/kg; Table 4-8). This concentration exceeded the reference level adopted for the reconnaissance survey (Ontario's Lowest Effect Level of 0.1 mg/kg). Because cyanide was not detected in the three field replicate samples, field variation could not be assessed.

4.2.2.18 Summary of Quality Assurance/Quality Control. Sample results for several metals were qualified as estimated based on evaluation of QA/QC data. Because of metals detected in various blank samples, four values each for lead and silver were qualified as undetected due to blank contamination. Because of high matrix spike recovery, all mercury values were qualified as estimates. Several values for arsenic, beryllium, and cadmium were qualified as estimates based on exceedances of QC guidelines for laboratory precision. Although a number of the metals data were qualified, the precision, accuracy, and completeness of the metals data were within project guidelines and the data are considered suitable for their intended use in this report.

4.2.3 Semi-volatile Organic Compounds

Sediment sampling for 63 semi-volatile organic compounds, including 17 PAHs, was conducted 24 June-1 July 1993. Except for the PAH compounds (analyzed using selective ion monitoring [SIM]), only three semi-volatile compounds were detected in the sediments sampled. The sediment concentration of 4-methylphenol measured at Camas Slough exceeded the New York State (NYS) sediment criterion for the protection of benthic organisms. The PAHs were detected frequently due to the relatively low laboratory detection limits achieved with the SIM methodology. None of the PAH concentrations exceeded the reference levels adopted for this study.

Reference levels are not available for of all the semi-volatile organic compounds analyzed. The detection limits achieved for these compounds are in some cases too high to evaluate exceedances of reference values that are available, because of the sensitivity of the SIM methodology, PAHs are an exception to this. The implications of the spatial distribution of the detected PAH concentrations are discussed in Section 5.2.3.

4.2.3.1 Polynuclear Aromatic Hydrocarbons. Sediment PAHs analyzed using SIM were detected frequently at all fifteen backwater stations sampled (Table 4-9). The concentrations detected did not exceed any of the reference values adopted for this study (Table 4-9 and Figures 4-19 to 4-23). No reference values were available to evaluate the detected concentrations of acenaphthalene, 2-methylnaphthalene, and dibenzofuran. The highest sediment PAH concentrations were typically measured at Carrolls Channel, Burke Slough, and Scappoose Bay. Relatively high concentrations were also frequently measured at Youngs Bay, Willow Bar Islands, and Gary & Flag Islands.

Fifteen PAHs were detected in all three field replicate samples collected from Burke Slough. The CV of the mean of these results ranged from 2.3 to 46.9%. It was greater than 25% for four compounds: anthracene (35.1%), benzo(a)anthracene (42.4%), chrysene (46.9%), and benzo(a)pyrene (28.5%).

4.2.3.2 Other Semi-volatile Compounds Only three semi-volatile compounds other than PAHs were detected in backwater sediments (Table 4-10). The compound 4-methylphenol was detected at Camas Slough at a concentration of 150 $\mu g/kg$. Its organic carbon-normalized concentration (10 $\mu g/g_{OC}$) exceeded the NYS draft sediment criterion of 0.5 $\mu g/g_{OC}$ for the protection of benthic aquatic organisms.

Bis(2-ethylhexyl)phthalate was detected at 13 stations. However, the organic carbon-normalized concentrations did not exceed the NYS draft sediment criterion of 199.5 $\mu g/g_{OC}$ for the protection of benthic organisms. The highest concentration (51 $\mu g/kg$) was measured at Scappoose Bay, and the highest organic carbon-normalized concentration (3.3 $\mu g/g_{OC}$) at Camas Slough.

TABLE 4-9 SUMMARY OF SEDIMENT SEMI-VOLATILE COMPOUNDS DETECTED 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

		Units in μg/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
4-Methylphenol	1/15	13-18	150	16U	150	1/15
Bis(2-ethylhexyl) phthalate	13/15	11-25	13-51	18U	24	0/15
Benzoic acid	14/15	160	20-68	160U	43	NA

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993.

[b] The frequency of exceedance of the lowest available reference level for potential adverse effects on benthic organisms or wildlife.

NA = No reference value available for comparison.

U = Not detected Value is the detection limit.

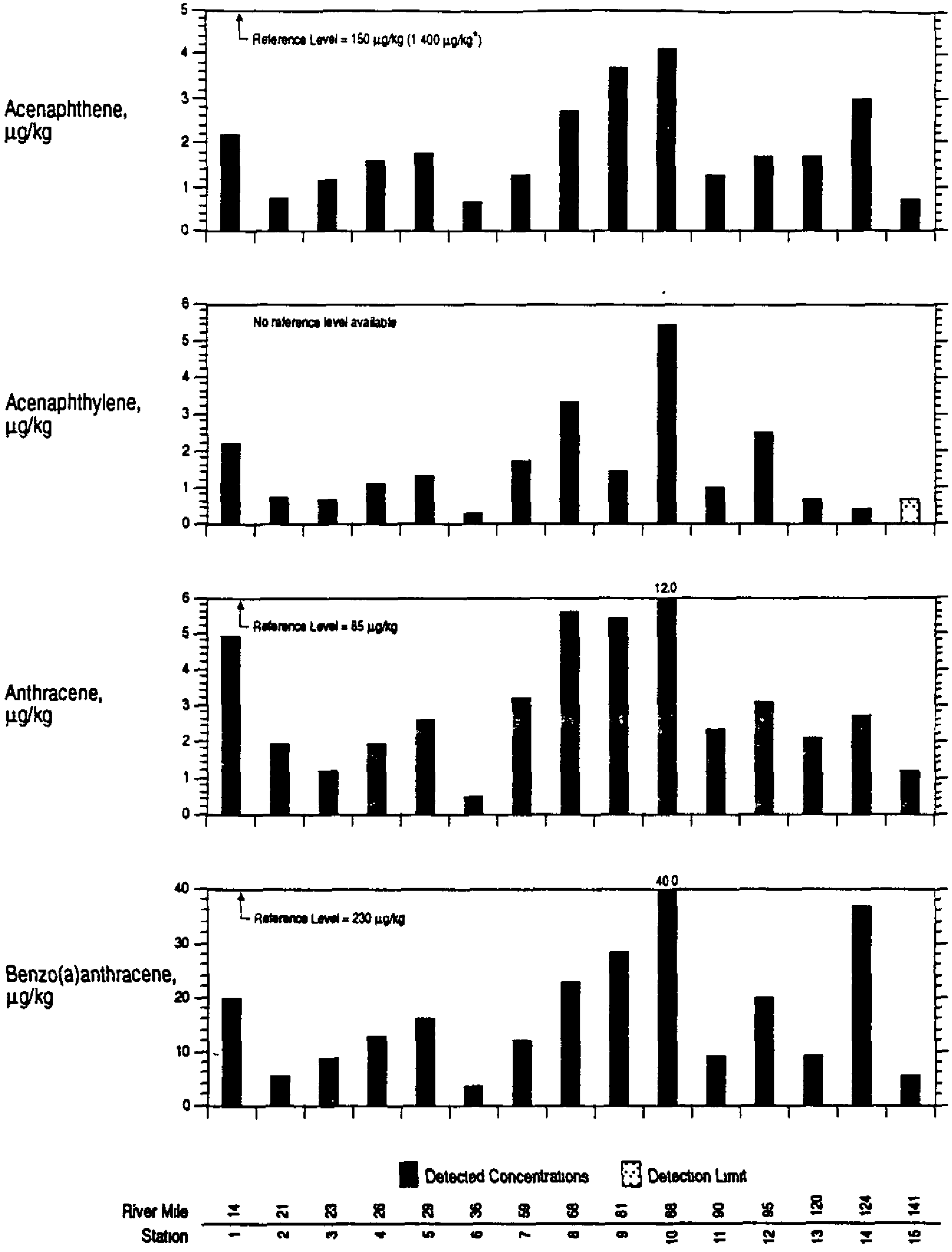


Figure 4-19. Sediment Concentrations of Polynuclear Aromatic Hydrocarbons; Acenaphthene, Acenaphthylene, Anthracene, and Benzo(a)anthracene (µg/kg dry wt). **Reference level concentration assuming a sediment TOC content of 1percent.*

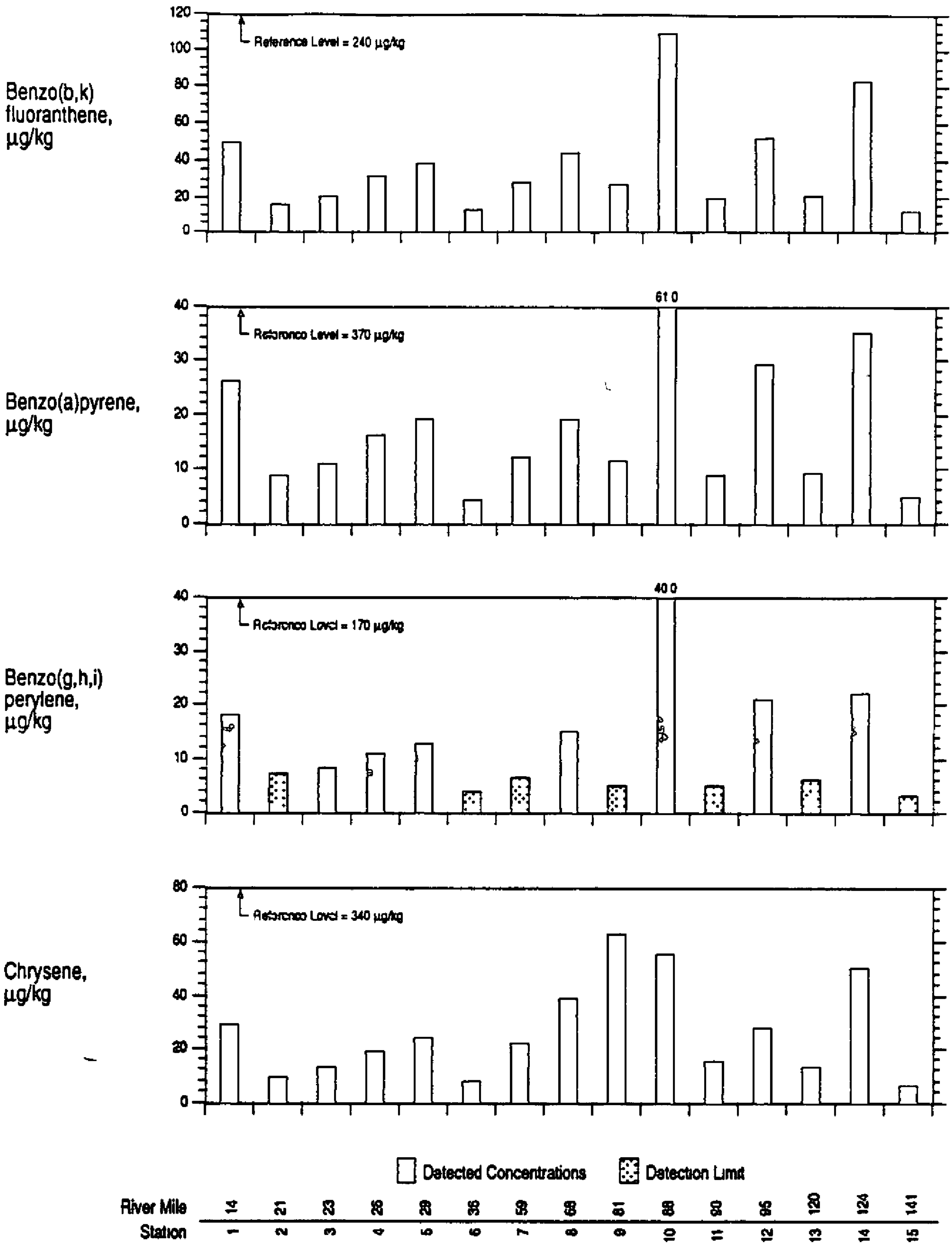


Figure 4-20. Sediment Concentrations of Polynuclear Aromatic Hydrocarbons; Benzo(b,k)fluoranthene, Benzo(a)pyrene, Benzo(g,h,i)perylene, Chrysene (µg/kg dry wt).

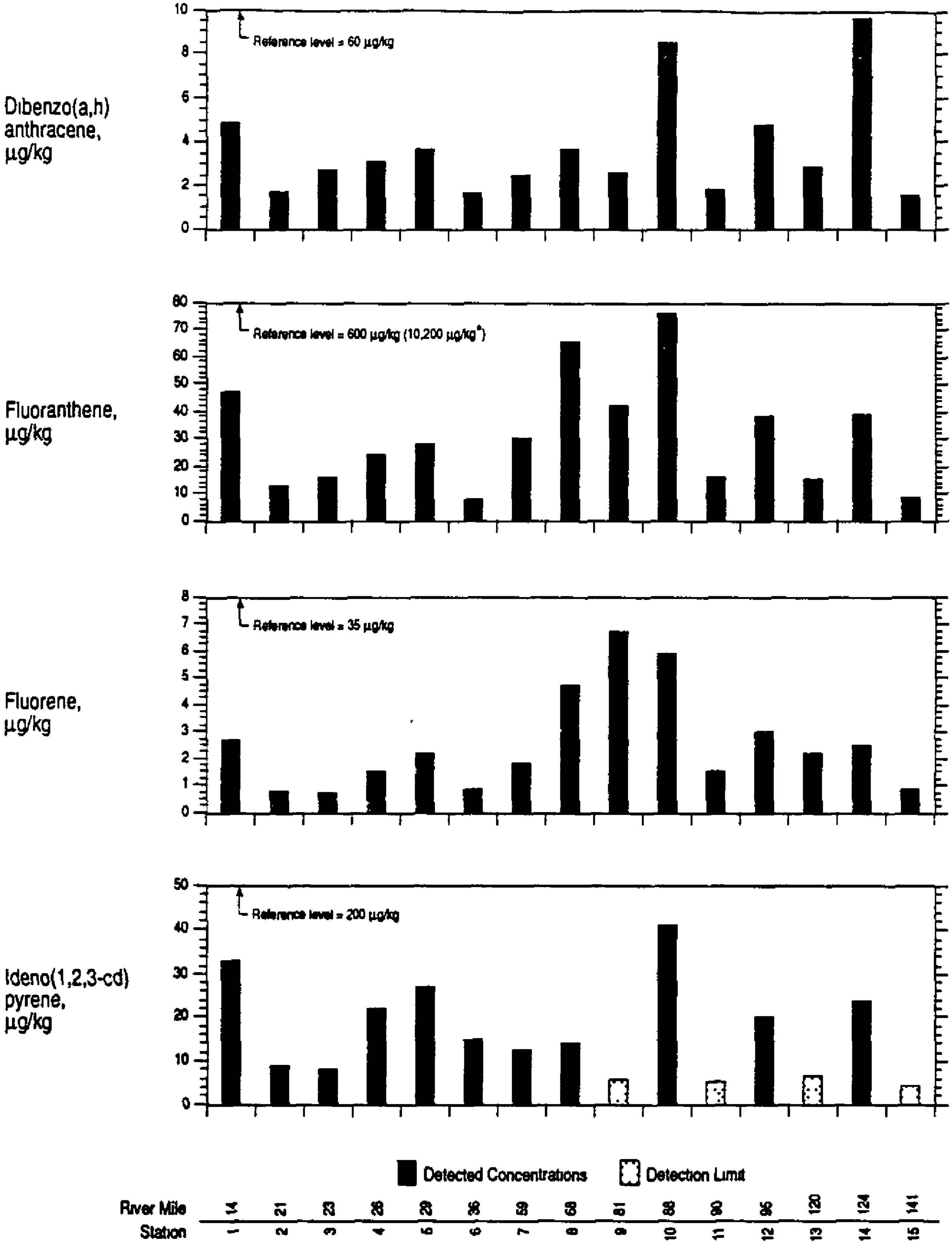


Figure 4-21. Sediment Concentrations of Polynuclear Aromatic Hydrocarbons; Dibenzo(a,h)anthracene, Fluoranthene, Fluorene, Ideno(1,2,3-cd)pyrene (µg/kg dry wt). **Reference level concentration assuming a sediment TOC content of 1 percent.*

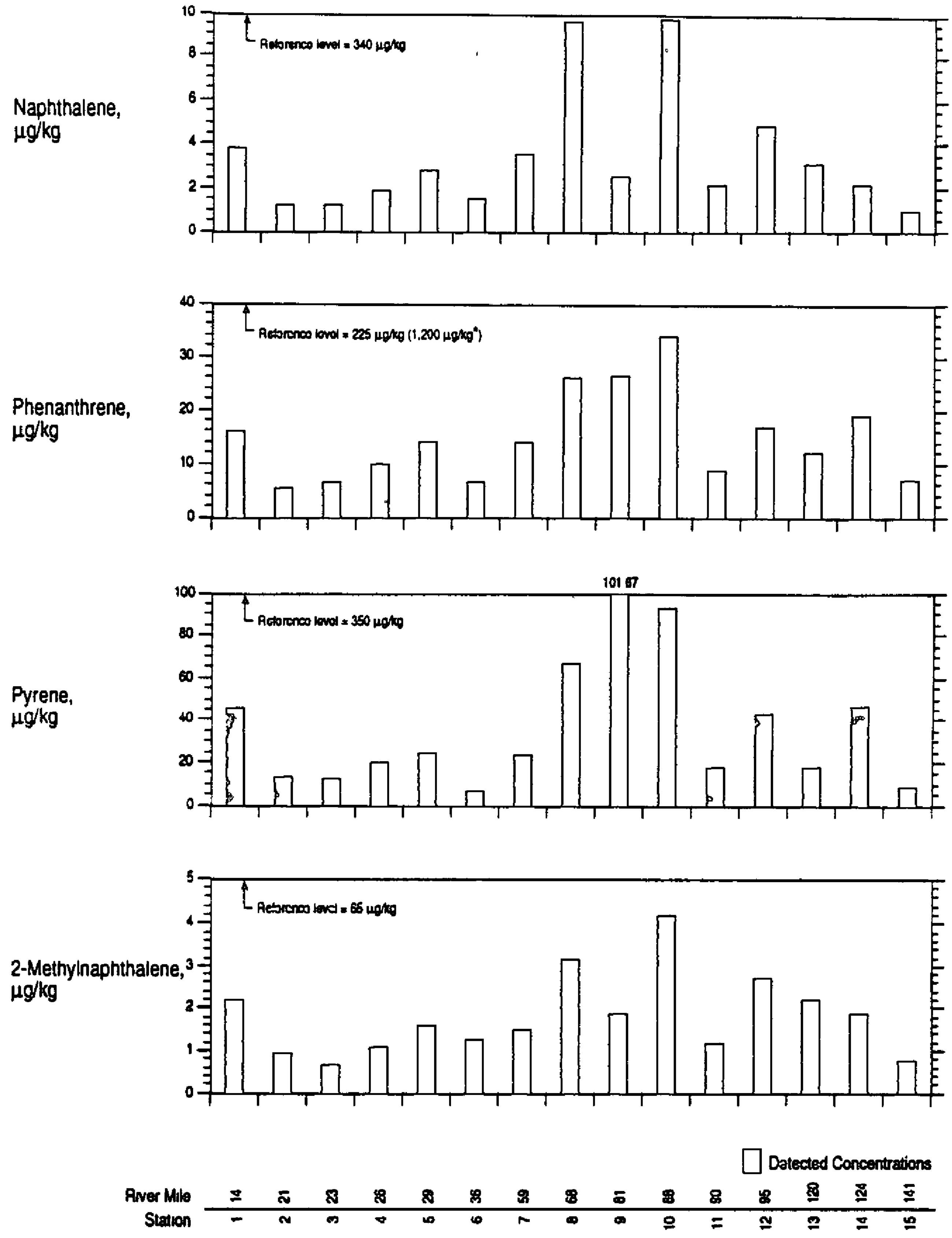


Figure 4-22. Sediment Concentrations of Polynuclear Aromatic Hydrocarbons; Naphthalene, Phenanthrene, Pyrene, 2-Methylnaphthalene (µg/kg dry wt). **Reference level concentration assuming a sediment TOC content of 1 percent.*

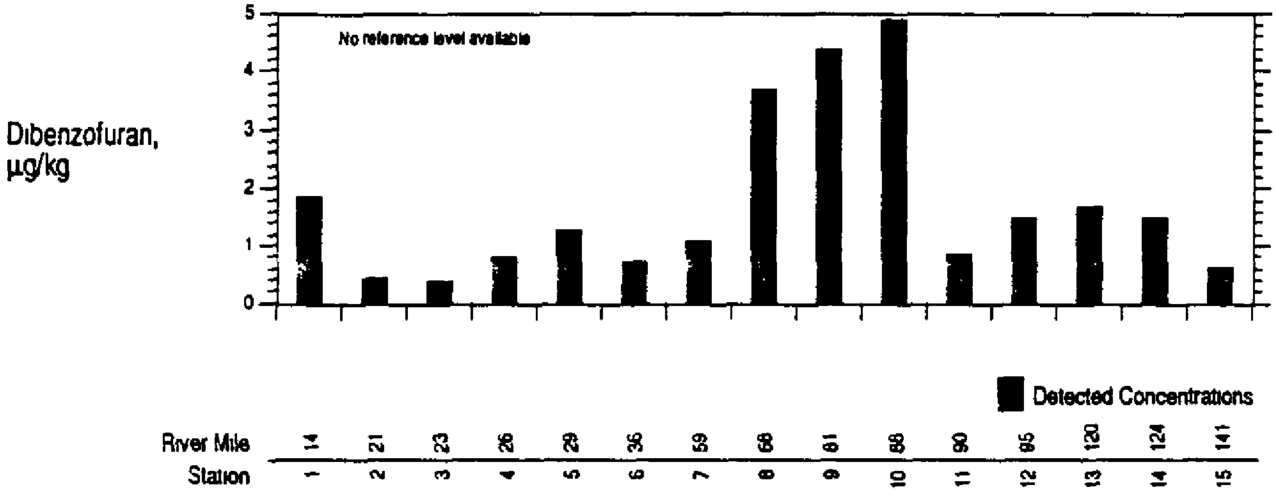


Figure 4-23. Sediment Concentrations of Polynuclear Aromatics Hydrocarbons; Dibenzofuran (µg/kg dry wt).

TABLE 4-10 SUMMARY OF SEDIMENT POLYNUCLEAR AROMATIC HYDROCARBON CONCENTRATIONS 1993 LOWER COLUMBIA RIVER RECONNAISSANCE BACKWATER SURVEY

		Units in µg/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedance[b]
Acenaphthene	15/15	--	0.67-4.1	--	1 7	0/15
Acenaphthylene	14/15	0 65	0 26-5 4	0 65U	1 2	NA
Anthracene	15/15	--	0 46-12	--	2 6	0/15
Benzo(a)anthracene	15/15	--	3 6-40	--	13	0/15
Benzo(b,k)fluoranthene	15/15	--	12-110	--	29	0/15
Benzo(a)pyrene	15/15	--	4 2-61	--	12	0/15
Benzo(g,h,i)perylene	8/15	3 3-7 4	8 4-40	5 0U	16.5	0/15
Chrysene	15/15	--	6.5-62	--	22	0/15
Dibenzo(a,h)anthracene	15/15	--	1.5-9.7	--	2.8	0/15
Fluoranthene	15/15	--	8 1-76	--	28	0/15
Fluorene	15/15	--	0 74-6 73	--	2.2	0/15
Indeno(1,2,3-cd)pyrene	11/15	4 5-6 8	8 1-41	5.6U	20	0/15
Naphthalene	15/15	--	1 0-9 8	--	2.5	0/15
Phenanthrene	15/15	--	5 6-34	--	14	0/15
Pyrene	15/15	--	7-102	--	24	0/15
2-Methylnaphthalene	15/15	--	0 70-4.2	--	1 6	NA
Dibenzofuran	15/15	--	0 39-4.9	--	1.3	NA

U = Not detected. Value presented is the detection limit.

NA = Reference levels not available.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993.

[b] Frequency of exceedances of the lowest available reference level for potential adverse effects on benthic organisms or wildlife.

Because bis(2-ethylhexyl)phthalate was detected in only one sample from Burke Slough, CV could not be calculated. The concentration of this compound was below the laboratory detection limit of 15 μg/kg in two of the three samples, and measured at a concentration of 49 μg/kg in the third sample The field variation in the concentration of this compound encompasses the range of concentrations measured at the other 14 stations, which suggests that these concentrations may be more variable within a sampling location than among other sampling locations

Benzoic acid was detected at 14 of the 15 stations No reference levels were available to evaluate the potential environmental significance of the concentrations measured The highest concentration (68 μg/kg) was measured at Scappoose Bay, and the highest organic carbon-normalized concentration (4.9 $\mu g/g_{OC}$) was measured at Bachelor Island Slough

Benzoic acid was detected in all three field replicate samples from Burke Slough The CV of the mean was 13 8% and the measured concentration ranged from 38 to 66 μg/kg in the samples Differences in the concentration of this compound between stations may be due to inter-station rather than intra-station variability

4.2.3.3 Summary of Quality Assurance/Quality Control The detection limits for PAHs measured by GC/MS with selective ion monitoring, and for other semi-volatile organic compounds measured by GC/MS, met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) Several sample results were qualified as undetected due to blank contamination. The compounds qualified in this manner included bis(2-ethylhexyl)phthalate (one sample), indeno(1,2,3-cd)pyrene (six samples), and benzo(g,h,i)-perylene (nine samples). These data are considered suitable for use in this report

4.2.4 Pesticides and PCBs

4.2.4.1 Summary of Results. Sediment sampling for pesticides (25 chlorinated and 1 organophosphorus) and 6 PCB Arochlor mixtures was conducted 24 June-1 July 1993. The two pesticides p,p'-DDD and p,p'-DDE were detected at stations from RM 68 to RM 141 (Tables 4-11 and 4-12). The pesticide p,p'-DDT was detected at Burke Slough, and the PCB Arochlor 1248 was detected at the Carrolls Channel and Burke Slough stations; no other pesticides or PCBs were detected. The reference levels for the detected DDD and DDT compounds were exceeded at two stations: p,p'-DDD (2.0 μg/kg) measured

TABLE 4-11 SUMMARY OF SEDIMENT PESTICIDE CONCENTRATIONS
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 1 of 2)

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
Aldrin	0/15	0.5	--	0.5U	--	NA	0/15
Dieldrin	0/15	1	--	1U	--	(DL>ref)[c]	0/15
Endrin	0/15	1	--	1U	--	(DL>ref)[c]	0/15
Endrin ketone	0/15	1	--	1U	--	NA	NA
Endrin aldehyde	0/15	1	--	1U	--	NA	NA
Alpha-BHC	0/15	0.5	--	0.5U	--	NA	0/15
Beta-BHC	0/15	0.5	--	0.5U	--	NA	0/15
Delta-BHC	0/15	0.5	--	0.5U	--	NA	0/15
Lindane (gamma-BHC)	0/15	0.5	--	0.5U	--	NA	0/15
Gamma-Chlordane	0/15	0.5	--	0.5U	--	0/15	0/15
Alpha-Chlordane	0/15	0.5	--	0.5U	--	0/15	0/15
Dicofol	0/15	11-15	--	14U	--	NA	NA
Endosulfan I	0/15	0.5	--	0.5U	--	NA	NA
Endosulfan II	0/15	1	--	1U	--	NA	NA
Endosulfan sulfate	0/15	1	--	1U	--	NA	NA
Heptachlor	0/15	0.5	--	0.5U	--	NA	NA
Heptachlor epoxide	0/15	0.5	--	0.5U	--	NA	NA
Methoxychlor	0/15	5	--	5U	--	NA	NA
Methyl parathion	0/15	11-15	--	14U	--	NA	NA
o,p'-DDE	0/15	0.16-0.20	--	0.20U	--	0/15	NA
o,p'-DDD	0/15	0.16-0.35	--	0.20U	--	0/15	NA
o,p'-DDT	0/15	0.16-0.24	--	0.20U	--	0/15	NA
p,p'-DDE	5/15	1	0.5-1.2	1U	0.8	0/15	0/15
p,p'-DDD	8/15	1	0.7-2.0	1U	0.85	1/15	0/1

TABLE 4-11 SUMMARY OF SEDIMENT PESTICIDE CONCENTRATIONS 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

(Page 2 of 2)

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
p,p'-DDT	1/15	1	1.1	1U	1.1	1/15	NA
Toxaphene	0/15	50	--	50U	--	NA	NA

NA = Reference value not available

U = Not detected. Value presented is the detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled between 24 June-1 July 1993.

[b] Frequency of exceedances of the Long and Morgan (1990) Effects Range-Low or the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persaud et al 1993) Lowest Effect Level. Detected pesticide concentrations did not exceed the available organic carbon-based reference values

[c] The detection limit was greater than the reference level

TABLE 4-12 SUMMARY OF SEDIMENT PCB DATA
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
Aroclor 1221	0/15	20	--	20U	--	0/15	0/15
Aroclor 1232	0/15	10	--	10U	--	0/15	0/15
Aroclor 1242/1016	0/15	10	--	10U	--	0/15	0/15
Aroclor 1248	2/15	10	7.3-11	10U	9.2	0/15	0/15
Aroclor 1254	0/15	10	--	10U	--	0/15	0/15
Aroclor 1260	0/15	10	--	10U	--	0/15	0/15

U = Not detected. Value presented is the detection limit

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled betweem 24 June-1 July 1993

[b] Frequency of exceedance of the Long and Morgan (1990) Effects Range-Low or the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persand et al 1993) Lowest Effect Level

at Scappoose Bay was equivalent to the Long and Morgan ER-L, and was therefore considered an exceedance, p,p'-DDT concentration (1 2 µg/kg) in one of the three samples from Burke Slough exceeded the Long and Morgan ER-L of 1 µg/kg None of the organic carbon-normalized concentrations exceeded the NYS draft carbon-normalized criteria for the protection of benthic organisms or fish-eating wildlife.

The CV of the mean of samples collected from Burke Slough could only be calculated for p,p'-DDD and p,p'-DDE, both were less than 10% Therefore, differences between stations in the concentrations of these compounds may be due to inter-station rather than intra-station variability

The detection limits achieved for some of these compounds were too high to evaluate possible exceedances of reference levels No reference values were available for several of these pesticides (see Table 4-11). The potential for adverse environmental effects of sediment pesticides and PCBs in the lower Columbia River is discussed in 5 2.4

4.2.4.2 Summary of Quality Assurance/Quality Control The detection limits reported by the laboratory were higher than the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) because of matrix interferences. None of the analytical data were qualified based on evaluation of the QA/QC data. The data are considered suitable for use in this report.

4.2.5 Dioxins and Furans

4.2.5.1 Summary of Results Sediment sampling for seven dioxin and ten furan congeners was conducted 24 June-1 July 1993. Dioxins and furans were not detected or were detected infrequently above the EDLs achieved in this study, except for octachlorodibenzo-*p*-dioxin (OCDD) which was detected at seven stations (Table 4-13 and Figures 4-24 through 4-28). The highest concentration of OCDD (52 5 ng/kg) was measured at Scappoose Bay, and the highest organic carbon-normalized concentration (3 7 ng/g_{OC}) at Skamania Landing (Figure 4-25). The only other compound that was detected was 1,2,3,4,6,7,8-heptachlorodibenzo-*p*-dioxin (1,2,3,4,6,7,8-HpCDD) which was detected at Scappoose Bay (see Figure 4-25)

Because dioxin and furan congeners were not detected in the field replicate sample from Burke Slough, variability could not be determined.

TABLE 4-13 SUMMARY OF SEDIMENT DIOXIN AND FURAN DATA
1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

		Units in ng/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
2,3,7,8-TCDD	0/15	0.3-1.4	--	0.4U	ND	0/15
1,2,3,7,8-PeCDD	0/15	0.4-1.1	--	0.8U	ND	NA
1,2,3,4,7,8-HxCDD	0/15	0.4-1.6	--	0.8U	ND	NA
1,2,3,6,7,8-HxCDD	0/15	0.7-2.2	--	1.1U	ND	NA
1,2,3,7,8,9-HxCDD	0/15	0.5-2.1	--	1.0U	ND	NA
1,2,3,4,6,7,8-HpCDD	1/15	0.9-6.9	5.0	3.3U	ND	NA
OCDD	7/15	4.5-46.9	10.4-52.5	8.0U	13.2	NA
2,3,7,8-TCDF	0/15	0.6-1.3	--	0.9U	ND	NA
1,2,3,7,8-PeCDF	0/15	0.3-1.1	--	0.7U	ND	NA
2,3,4,7,8-PeCDF	0/15	0.3-1.3	--	0.6U	ND	NA
1,2,3,4,7,8-HxCDF	0/15	0.8-2.1	--	1.1U	ND	NA
1,2,3,6,7,8-HxCDF	0/15	0.7-1.9	--	1.1U	ND	NA
1,2,3,7,8,9-HxCDF	0/15	1.0-2.7	--	1.6U	ND	NA
2,3,4,6,7,8-HxCDF	0/15	0.8-2.3	--	1.3U	ND	NA
1,2,3,4,6,7,8-HpCDF	0/15	0.5-7.1	--	1.3U	ND	NA
1,2,3,4,7,8,9-HpCDF	0/15	0.3-3.0	--	1.9U	ND	NA
OCDF	0/15	0.4-4.0	--	1.6U	ND	NA
TEC[c,d]	NA	NA	0.73-1.81	NA	1.17	0/15
TEC[c,e]	NA	NA	0-0.10	NA	0.0	0/15

NA = Not applicable.

ND = Not detected

U = Not detected. The number preceding the "U" is the detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993.

[b] Frequency of exceedance of the draft New York State reference level for protection of wildlife (Newell and Sinnott 1993)

[c] Toxicity Equivalency Concentration (TEC) calculated based on Barnes (1991).

[d] TEC based on the assumption that the concentrations for undetected compounds is equal to half the lower detection limit.

[e] TEC based on the assumption that the concentrations for undetected compounds is zero.

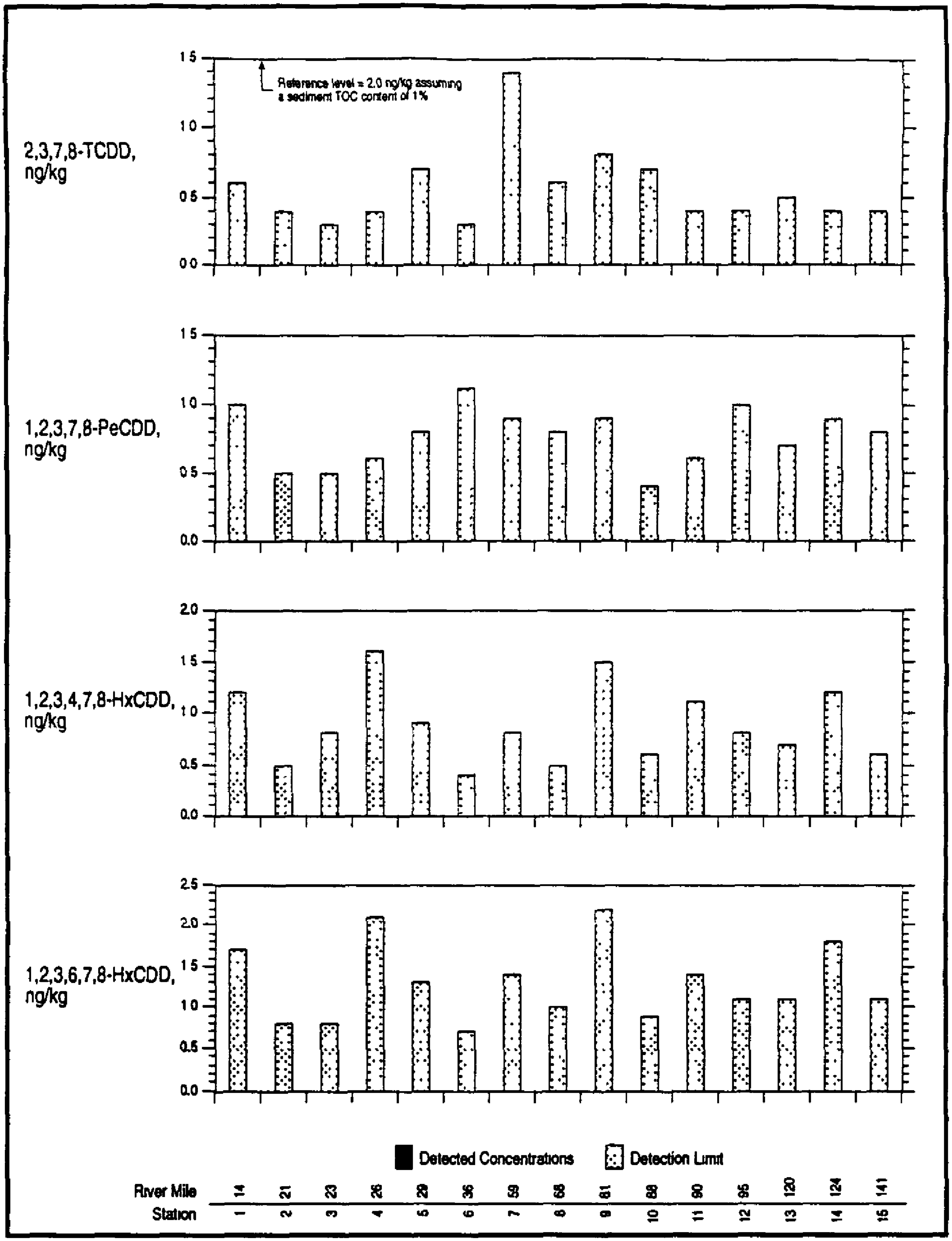


Figure 4-24. Sediment Concentrations of 2,3,7,8-TCDD; 1,2,3,7,8-PeCDD; 1,2,3,4,7,8-HxCDD; and 1,2,3,6,7,8-HxCDD (ng/kg dry wt).

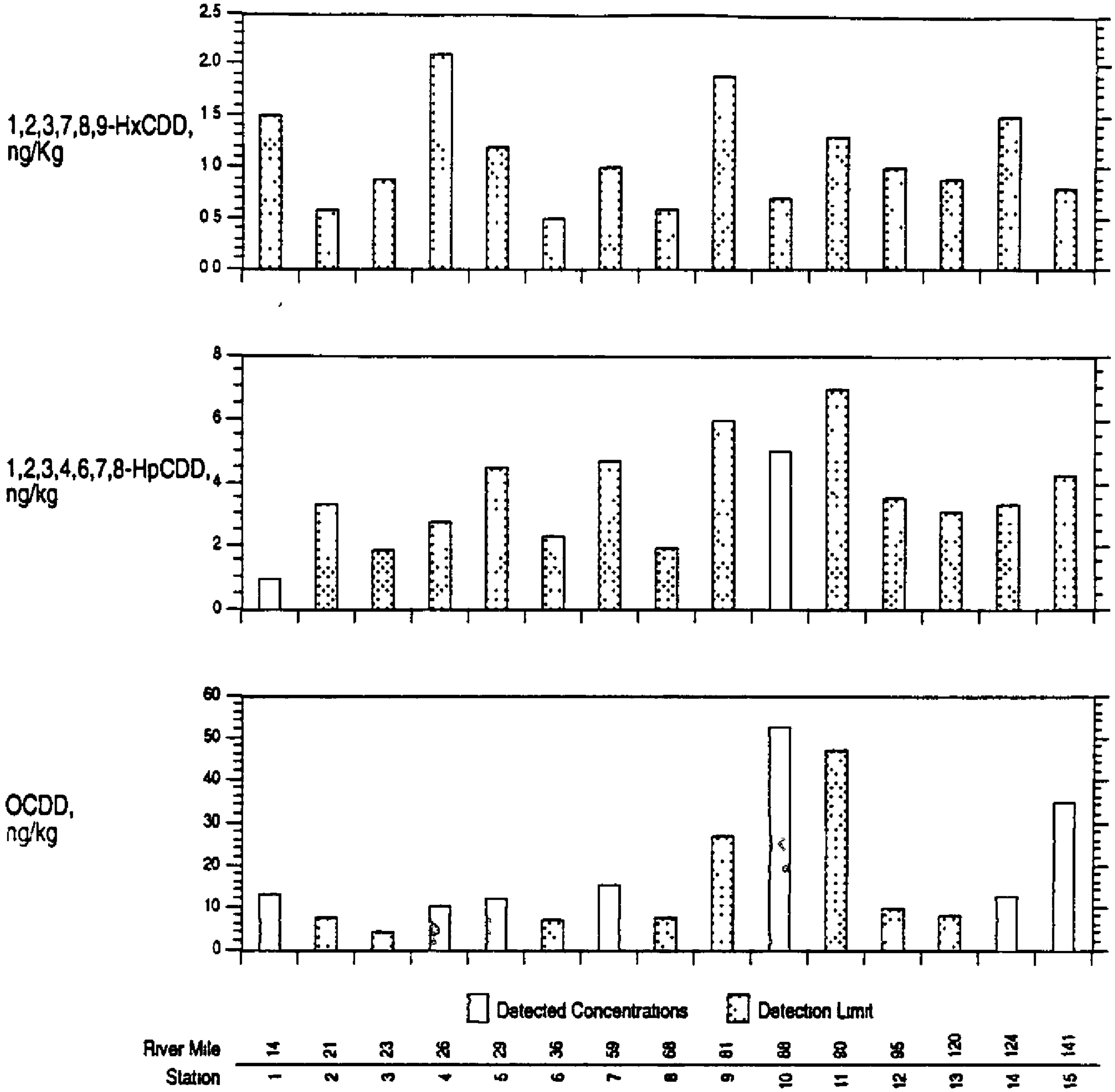


Figure 4-25. Sediment Concentrations of 1,2,3,7,8,9-HxCDD; 1,2,3,4,6,7,8-HpCDD; and OCDD (ng/kg dry wt).

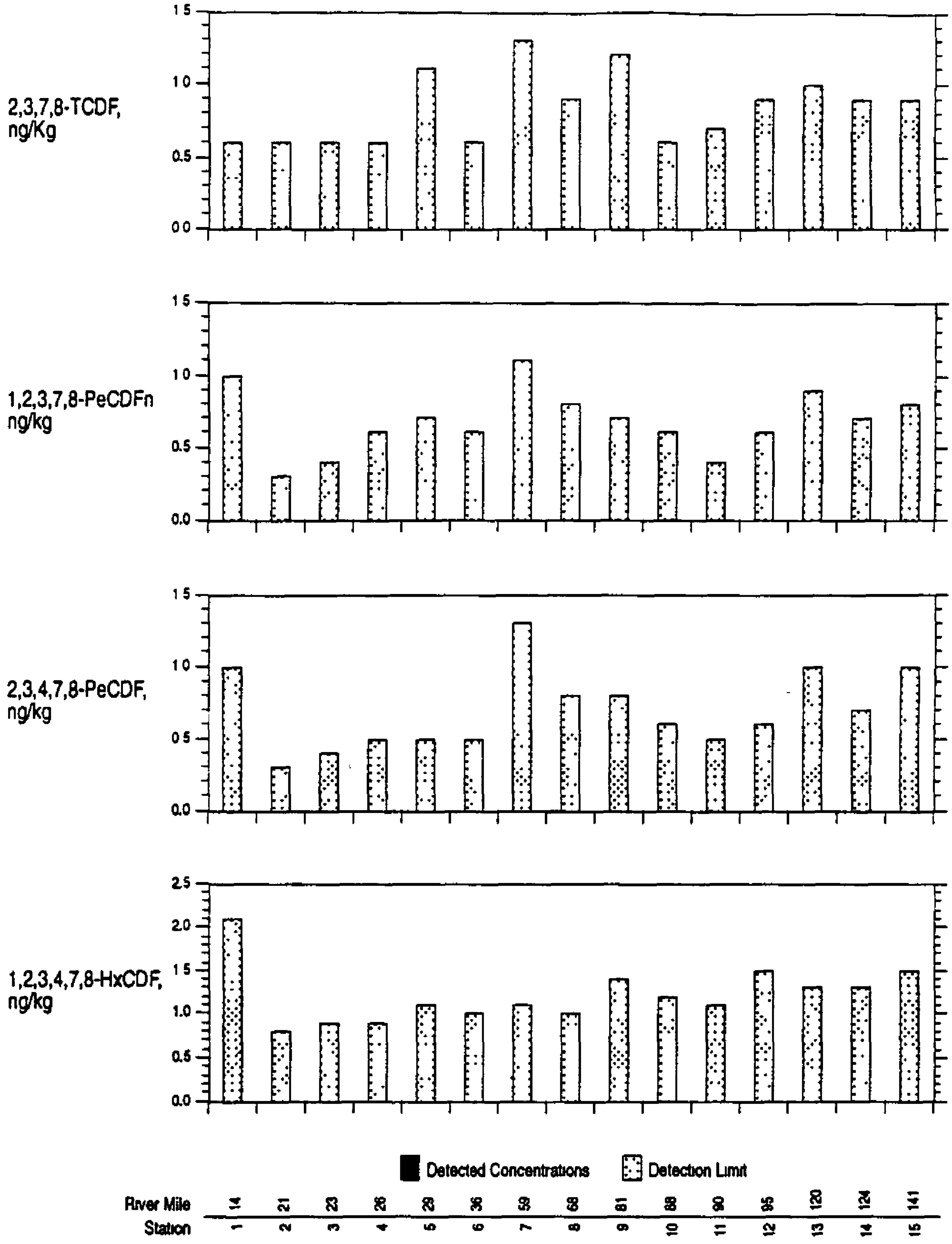


Figure 4-26. Sediment Concentrations of 2,3,7,8-TCDF; 1,2,3,7,8-PeCDF; 2,3,4,7,8-PeCDF; 1,2,3,4,7,8-HxCDF (ng/kg dry wt).

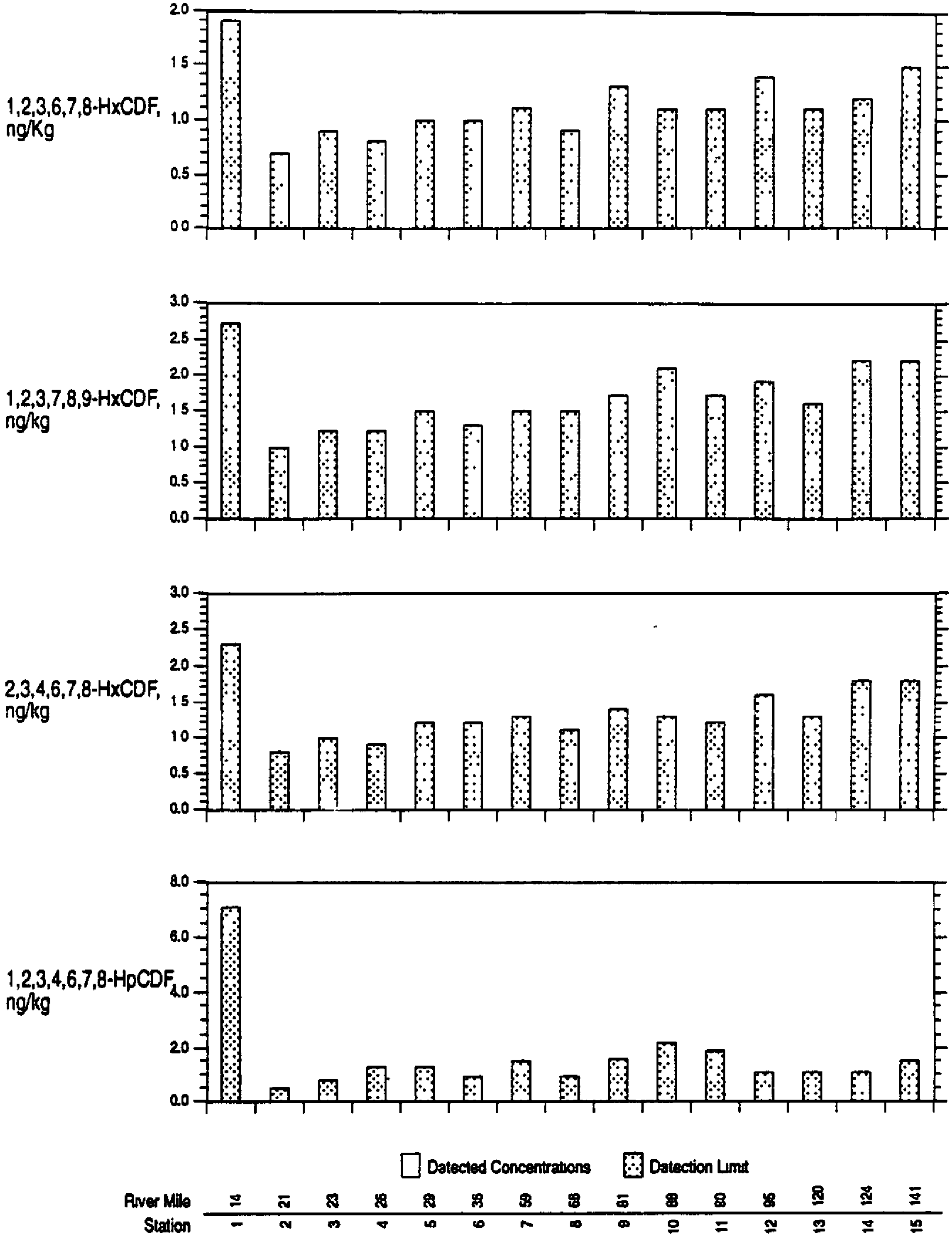


Figure 4-27. Sediment Concentrations of 1,2,3,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDF; 2,3,4,6,7,8-HxCDF; and 1,2,3,4,6,7,8-HpCDF (ng/kg dry wt).

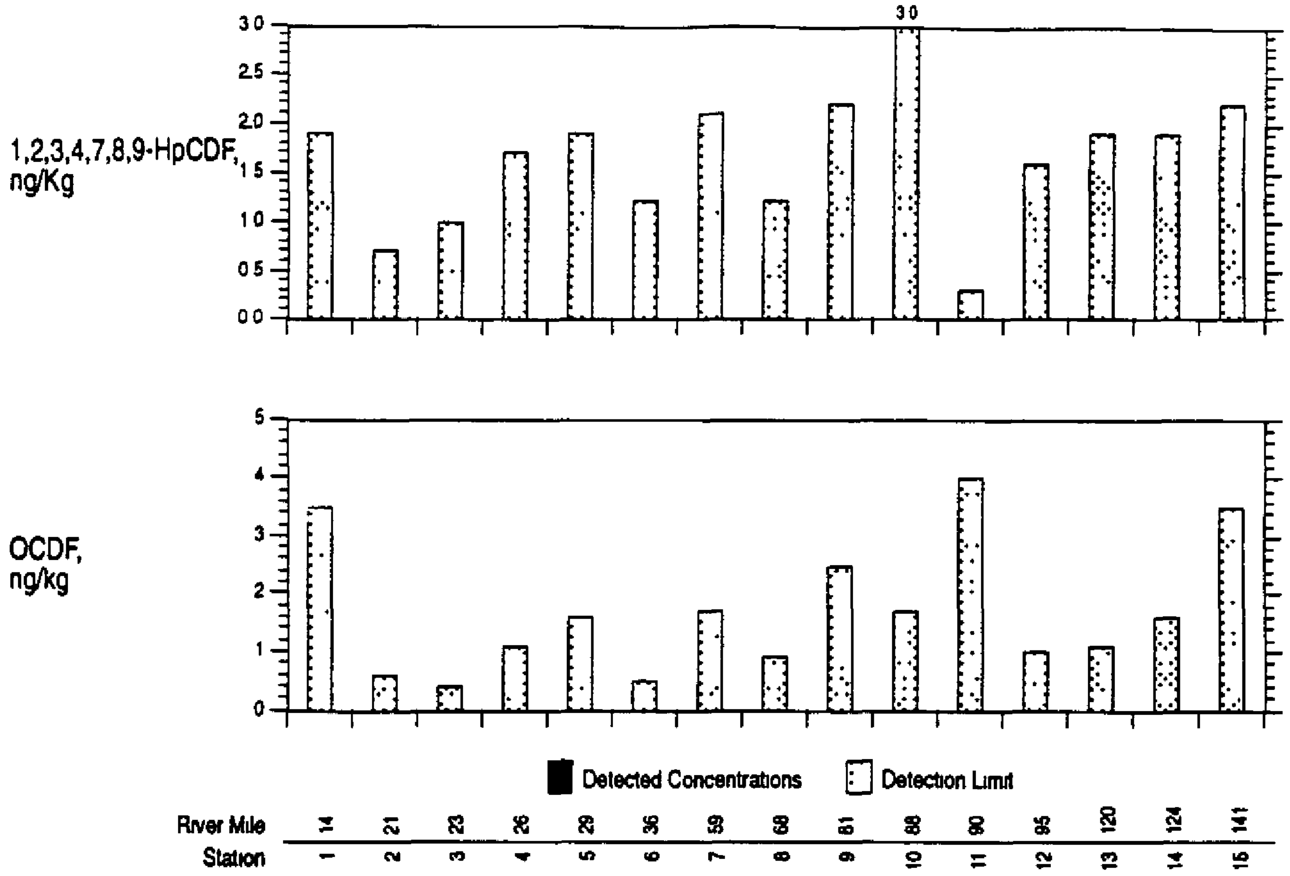


Figure 4-28. Sediment Concentrations of 1,2,3,4,7,8,9-HpCDF and OCDF (ng/kg dry wt).

The only sediment reference level adopted for use in this study for evaluating the potential environmental significance of dioxin and furan data is the NYS draft sediment criterion of 0 2 ng/g_{oc} for 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD). However, 2,3,7,8-TCDD was not detected in any of the sediment samples above detection limits that ranged from 0.3 to 1 4 ng/kg Normalized to sediment carbon, these detection limits are adequate for comparison with this reference level and indicate that concentrations of 2,3,7,8-TCDD in the areas sampled were below levels expected to have an adverse effect on fish-eating wildlife.

As a further evaluation of the data, sediment toxicity equivalency concentrations (TECs) were calculated for each station based on the toxicity equivalency factors (TEFs) for dioxin and dioxin-like congeners (using the TEFs in Barnes 1991). Two calculations were performed. 1) assuming that the concentration of undetected compounds was equivalent to half the reported detection limit, and 2) assuming a concentration of zero for non-detects. Neither organic carbon-normalized TEC exceeded the relevant NYS draft criterion at any station (see Tetra Tech 1993e-Table C-8 for the results of these calculations).

4.2.5.2 Summary of Quality Assurance/Quality Control. The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). Most of the sample results were qualified as undetected at the estimated detection limit (EDL) (qualifier code "U/E"). Three of the seventeen OCDD values were qualified as undetected due to blank contamination and two values were qualified as estimates based on laboratory precision data. The evaluation of the QA/QC data indicates that the reported data are suitable for use in this report

4.2.6 Butyltin Compounds

Sediment sampling for mono-, di-, and tributyltin compounds was conducted during 24 June-1 July 1993. Butyltin compounds were frequently detected (Table 4-14). However, there are no reference levels available to evaluate the potential environmental significance of these concentrations. The results for each butyltin compound are presented below

Because butyltin compounds were only detected in one of the three field replicate samples from Burke Slough, variability could not be determined.

TABLE 4-14 SUMMARY OF SEDIMENT BUTYLTIN DATA, 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

		Units in μg Sn/kg dry sediment			
		Range		Median	
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations
Monobutyltin	6/15	1.7-3.4	5.1-14.5	1.7	7.7
Dibutyltin	4/15	2.6	4.6-12.4	2.6	6.9
Tributyltin	12/15	3.2	2.4-34.4	3.2	5.6

[a] Frequency of detection of mono-, di-, and tributyltin at the stations sampled. Fifteen stations were sampled in 24 June-1 July 1993. No reference values are available for sediment levels of butyltins

4.2.6.1 Monobutyltin Monobutyltin (measured as n-butyltin trichloride) was detected at six backwater stations from RM 59 to RM 14 (Figure 4-29) The highest concentration (14 5 μg Sn/kg) was measured at Lewis & Clark NWR in Bug Hole (RM 29)

4.2.6.2 Dibutyltin Dibutyltin (measured as di-n-butyltin dichloride) was detected at four stations from RM 68 to RM 23 (see Figure 4-29). The highest concentration (12 4 μg Sn/kg) was measured at Lewis & Clark NWR in Bug Hole

4.2.6.3 Tributyltin (TBT) Tributyltin (measured as tri-n-butyltin chloride) was detected at 12 stations (see Figure 4-29). TBT was detected at stations throughout the study area from RM 141 to RM 21 However, the highest concentrations were detected at stations below RM 81 The highest concentration (34 4 μg Sn/kg) was measured at Lewis & Clark NWR in Bug Hole.

4.2.6.4 Summary of Quality Assurance/Quality Control The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). Two of the 17 values for monobutyltin were qualified as undetected due to blank contamination. All three butyltin compound concentrations were qualified as estimates at Scappoose Bay due to low surrogate recoveries. The evaluation of the QA/QC data indicates that the reported data are suitable for their intended use in this report

4.2.7 Radionuclides

4.2.7.1 Summary of Results. Composite sediment samples were analyzed for the alpha-emitting radionuclides americium 241 (Am-241), plutonium 238 (Pu-238), and plutonium 239/240 (Pu-239/340); and the gamma-emitting radionuclides cesium 137 (Cs-137), cobalt 60 (Co-60), and europium 152, 154, and 155 (Eu-152, Eu-154, Eu-155) in samples collected 24 June-1 July 1993. Pu-239/240 and Cs-137 were frequently detected above the lower limit of detection (LLD), and Co-60 and Am-241 were detected less frequently (Table 4-15). There are no reference levels available to evaluate the potential environmental significance of these concentrations.

Cs-137 was detected at all stations. Concentrations ranged from 0. 050 pCi/g at Fisher Island to 0.176 pCi/g at Willow Bar Islands. Pu-239/240 was detected at seven stations in concentrations ranging from 0 004 to 0.010 pCi/g. The highest Pu-239/240 concentration was measured at Willow Bar Islands.

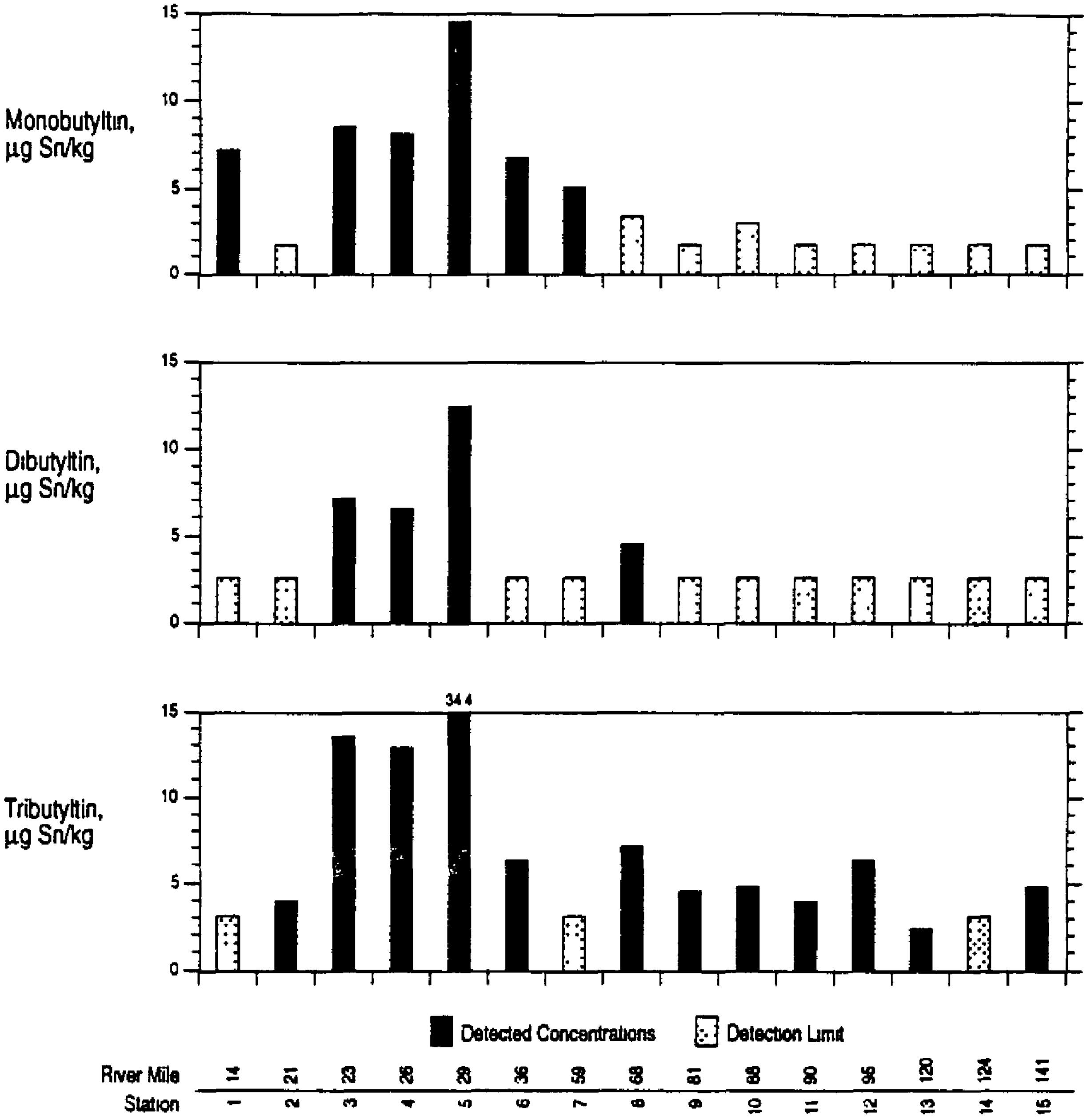


Figure 4-29. Sediment Concentrations of Organotin Compounds (µg Sn/kg dry wt).
No reference level available for sediment butyltin compounds.

TABLE 4-15 SUMMARY OF SEDIMENT RADIONUCLIDE DATA 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

			Units in pCi/g dry sediment			
			Range		Median	
	Radiologic Half-life (yr)	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations
Americium 241	458	1/15	0.011-0.026	0.040	0.016U	0.040
Cesium 137	30	15/15	--	0.050-0.176	–	0.083
Cobalt 60	5.3	3/15	0.02	0.012-0.022	0.02U	0.019
Europium 152	13	0/15	0.2	ND	0.2U	ND
Europium 154	16	0/15	0.02	ND	0.02U	ND
Europium 155	1.8	0/15	0.05	ND	0.05U	ND
Plutonium 238	86	0/15	0.007-0.014	ND	0.009U	ND
Plutonium 239/240	24,400/6,580	7/15	0.003-0.009	0.004-0.010	0.004U	0.007

ND = Not detected.

U = Not detected. Value is the reported detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled betweem 24 June-1 July 1993. No reference levels are available for the evaluation of these data

Co-60 was detected at three stations, with the highest concentration at Carrolls Channel Am-241 was detected in one of three separate analyses conducted on the sample collected from Skamania Landing at a concentration of 0 069 pCi/g However, Am-241 was not detected above the LLDs of 0.026 or 0.024 in the other two subsamples. Eu-152, Eu-154, Eu-155, and Pu-238 were not detected above the LLD at any station.

Because of infrequent detection of radionuclides at Burke Slough, CV could only be calculated for Cs-137 The CV of the mean concentration of the Burke Slough Cs-137 samples was 3 3% Differences in Cs-137 concentrations measured among the stations are likely due to inter-station rather than intra-station variability

4.2.7.2 Summary of Quality Assurance/Quality Control. The detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). For the radionuclides that were not detected, the data were reported as undetected at the sample-specific lower limit of detection (LLD). No data qualifiers were added to sample results based on evaluation of the QA/QC data. The evaluation of the QA/QC data indicates that the reported data are suitable for their intended use in this report

4.2.8 Sediment Toxicity Testing

Sediment sampling for toxicity testing was conducted 24 June-1 July 1993 The tests used were the solid-phase Microtox™ bioassay for chronic toxicity and the *Hyalella* 10-day acute toxicity test; results are summarized in Table 4-16. Comparison of toxicity data to reference guidelines for the Microtox™ ($EC_{50}=2\%$, Tung et al 1991) and the *Hyalella* (80% survival; U.S ACOE/U.S. EPA 1991) toxicity tests indicates that only sediments from Youngs Bay demonstrate relatively high toxicity

A comparison of the 95% confidence estimates of the EC_{50}s for the Microtox™ results between the designated reference station (Bachelor Island Slough) and the other stations indicated that the relative sediment toxicity was higher at five stations· Youngs Bay, Knappa Slough, Lewis & Clark NWR, Camas Slough, and Gary & Flag Islands. However, the results of a statistical test (Dunnett's Test) indicated that the mean survival at the reference station was not significantly different ($p \leq 0$ 05) than the mean survival at any other station. The contrasting results provided by these two bioassays may reflect the varying sensitivity of the two tests to the contaminants present in the samples. However, the relatively low

TABLE 4-16 SUMMARY OF SEDIMENT TOXICITY TESTING CONDUCTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY
(Page 1 of 2)

Station	Percent Sediment		Mean Percent Survival	
	Solid-Phase Microtox EC_{50}	95% Confidence Intervals	*Hyalella* 10-day acute toxicity	Standard Deviation (n=5)
1 Youngs Bay (RM 14)	0.36	0.32-0.40	85	12.7
2 Cathlamet Bay (RM 21)	7.9	4.7-13.3	85	11.2
3 Svensen Island (RM 23)	4.1	3.0-5.5	100	0
4 Knappa Slough (RM 26)	2.5	2.0-3.0	98	4.5
5 Lewis & Clark NWR (RM 29)	2.4	2.0-2.8	100	0
6 Elochoman Slough (RM 36)	11.3	1.7-76	96	4.2
7 Fisher Is. Slough (RM 59)	9.5	4.5-20	83	12.0
8 Carrolls Channel (RM 68)	15.3	0.09->100	88 (99[a])	24.1 (2.5[a])
9 Burke Slough (RM 81)	4.5	3.0-6.7	100	0
	3.8	3.3-4.3		
	4.1	3.5-4.8		
10 Scappoose Bay (RM 88)	3.5	2.9-4.3	99	2.2
11 Bachelor Is. Slough (RM 90)	10.6	3.8-29	94	6.5
12 Willow Bar Islands (RM 95)	5.7	4.0-8.1	95	3.5
13 Camas Slough (RM 120)	2.4	1.5-3.7	80 (95[a])	34.1 (7.1[a])

TABLE 4-16 SUMMARY OF SEDIMENT TOXICITY TESTING CONDUCTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

(Page 2 of 2)

Station	Percent Sediment		Mean Percent Survival	
	Solid-Phase Microtox EC_{50}	95% Confidence Intervals	*Hyalella* 10-day acute toxicity	Standard Deviation (n=5)
14 Gary & Flag Islands (RM 124)	2.7	2.4-3.0	81	8.2
15 Skamania Landing (RM 141)	5.1	3.2-8.2	91	4.2

[a] Summary statistics following removal of one outlier (i.e., n=4)

sediment toxicities evidenced by these two tests (i e., all but one station had an EC_{50} of >2%, and the average 10-day amphipod survival was greater than 80% at all stations) suggests that the significant differences noted from the reference station may be anomalous. Possible relationships between the sediment toxicity measured by the bioassays and the levels of contaminants measured in sediments from the same stations are explored in Section 5 2 8

4.2.8.1 Microtox™ The sediment EC_{50}s ranged from 0 36 to 15.3% sediment; lower EC_{50}s indicate greater toxicity (Figure 4-30) The lowest EC_{50} was measured at Youngs Bay and the highest at Carrolls Channel The reference station EC_{50} was 10 6%, which was higher than all the stations sampled except Carrolls Channel and Elochoman Slough. Tung et al (1991) have recommended that a sediment EC_{50} of 2% be used as a criterion for the selection of uncontaminated reference stations. Except for Youngs Bay, all of the stations sampled had a sediment EC_{50} >2% Therefore, the Youngs Bay station cannot be considered a reference station and may also be considered relatively toxic based on these results

Because single field samples were analyzed at all stations except for Burke Slough, it is not possible to evaluate the statistical significance of the observed differences from the EC_{50} measured at the reference station. However, comparing the reference station EC_{50} 95% confidence intervals to the confidence intervals for the other stations suggests that sediment toxicity is higher (approximately 90% confidence) than the reference station at Youngs Bay, Knappa Slough, Lewis & Clark NWR, Camas Slough, and Gary & Flag Islands (see Table 4-16).

4.2.8.2 10-day Amphipod Survival Test Mean amphipod survival (n=5) in these toxicity tests ranged from 80 to 100% (Figure 4-30). Removal of the lowest survival value (20%) measured in a single replicate sample from Camas Slough increases the mean survival at this station to 95%. The second lowest mean survival was 81%, measured at Gary & Flag Islands. Mean survival at the reference station was 94%, at 6 stations mean survival measure was lower than it was at the reference station. The U S Army Corps of Engineers (U.S. ACOE) and the U.S. EPA (U.S. ACOE/U S. EPA 1991) have suggested that in order for a sediment sample to be considered toxic, mean survival must be at least 20% lower than, and significantly less than, the mean survival of the reference sediment sample. Based on this guidance, the backwater sediment samples tested should not be considered toxic.

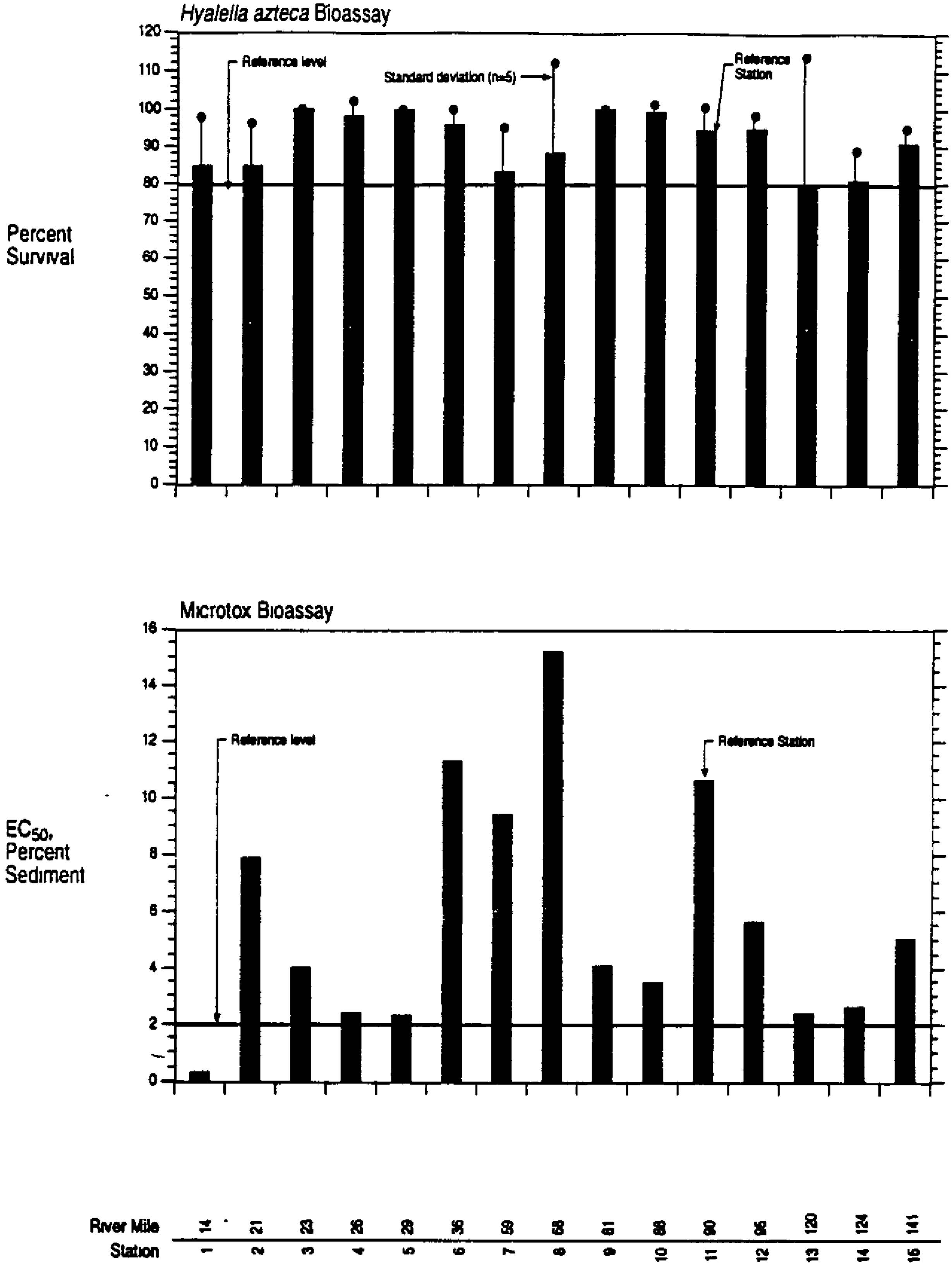


Figure 4-30. Sediment Toxicity Results Based for the Amphipod, *Hyalella azteca*, Acute Test and the Microtox Solid-Phase Bioassay. ***Note: Mean percent survival and standard deviation (n=5) are shown for the amphipod test.***

4.2.8.3 Summary of Quality Assurance/Quality Control The QA/QC results for the two toxicity tests are summarized separately below

Microtox™--The results of the control samples run with each sediment sample indicate acceptable laboratory precision However, the high relative percent differences (RPDs) between the laboratory duplicates indicates that the sediment sample may have been incompletely homogenized before subsamples were removed for testing The close agreement between the EC_{50}s calculated for the four reference toxicant tests indicates that the bacterial population used in these tests maintained a consistent dose-response relationship throughout the several-day period over which the tests were performed, so that test results from the four different test days may be compared to each other. No data qualifiers were assigned to any the sample results; results are acceptable for their intended use

10-day Amphipod Survival Test--Water quality parameters (temperature, salinity, DO, conductivity, alkalinity, and hardness) were monitored throughout the test period, and stayed within the ranges accepted for this test Results of the control sediment and reference toxicant tests indicate that the test organisms were healthy and not unusually sensitive to toxicants. The survival of amphipods in single replicate samples from each of two stations (Carrolls Channel and Camas Slough) was relatively low. In the case narrative that accompanied the final report, the laboratory could not explain the observed anomalies. Because water quality and test conditions (i.e., feeding, air supply) were all within normal parameters for these two replicates, these data were not rejected or qualified as estimates.

4.3 CRAYFISH AND FISH TISSUE QUALITY

This section presents results of analyses of fish and crayfish tissue samples collected in the 1993 backwater reconnaissance survey. Analytes are grouped and presented as for water and sediment samples. Findings relating to CV and data QA/QC are also presented as in the water and sediment sections. Complete survey results are found in the separate data appendix (Tetra Tech 1993e); complete results of data QA/QC reviews are also presented separately (Tetra Tech 1993d).

Results are compared to existing reference levels (see Section 2) to provide a preliminary assessment of potential adverse effects to aquatic organisms and fish-eating wildlife. The single whole-body composite samples collected for analysis are suitable for characterizing and evaluating water quality in a river system, at least for persistent lipophilic contaminants and metals that bioaccumulate. Aquatic organisms, especially fatty organisms that feed on benthic organisms and sediments, integrate contaminants discharged to the river system from both point and nonpoint sources. Therefore, exceedances of the reference values adopted for use in this study indicate potentially serious water quality problems that warrant more intensive investigation

4.3.1 Conventional Parameters

Conventional parameters for biota in this survey included wet weights and fork lengths (for fish only) of individuals included in the sample composite, and the lipid content of the sample composite. These variables were measured because animal weight and length provide an estimate of the age of the animals, and the size and/or age of the animal is often positively correlated with tissue contaminant concentrations (e.g., Griesbach et al. 1982; Evans et al. 1993) The lipid content of aquatic organisms is also important because it is generally believed that hydrophobic and/or lipophilic contaminant accumulation correlates positively with the fat/lipid content of the organism due to solubility considerations (e.g., Bannerjee and Baughman 1991), although the relationship becomes more complicated for very large organic compounds (Opperhuizen 1986, Barron 1990; Opperhuizen and Sijm 1990, Bannerjee and Baughman 1991).

4.3.1.1 Crayfish. Wet weights of individual crayfish (collected from 13 stations) ranged from 5.0 to 137 7 g (Figure 4-31) The mean weight of individuals included in each of the 15 composite samples analyzed (two samples collected from Camas Slough were field replicates) ranged from 32 3 to 92.1 g (Figure 4-31) The lipid content of samples ranged from 0.6 to 2.2% with a mean concentration of 1.4%

The CV of the mean average weights of individual crayfish in the three Camas Slough field replicate samples was 8 5% and the CV of the mean lipid content was 22%.

Data relating weight to age are not available for the crayfish *Pacifastacus leniusculus* in the lower Columbia River. However, crayfish age may be estimated using data collected for this species in the Sacramento-San Joaquin Delta in California (McGriff 1983). Table 4-17 shows the estimated age of different crayfish weight classes. The mean weights of individuals in each composite sample correspond to two age groups: 3-4 years (eight samples) and greater than 4 years (seven samples). Crayfish age-

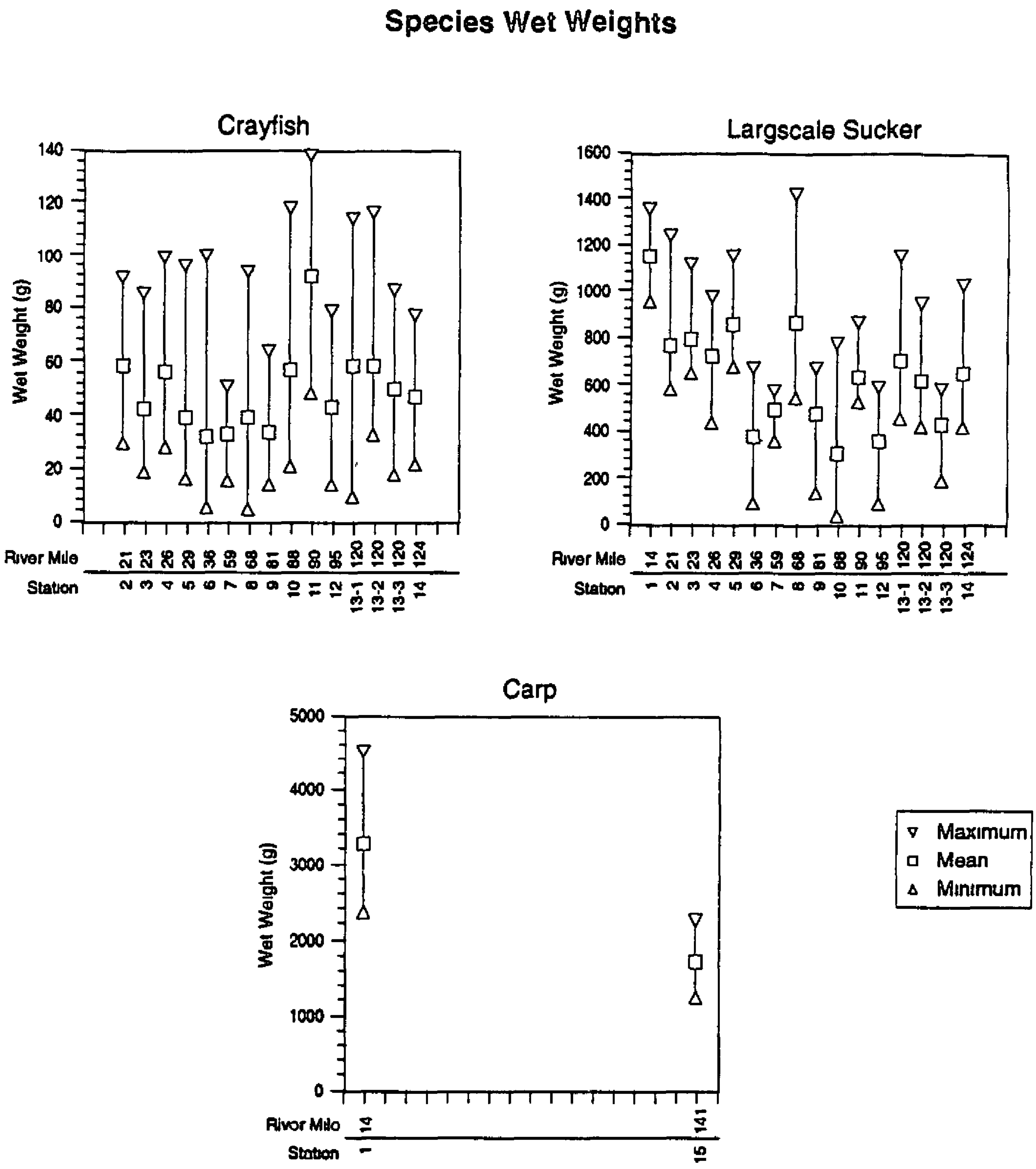


Figure 4-31. Minimum, Maximum, and Mean Wet Weights of Species Collected for the 1993 Backwater Reconnaissance Survey, July-August 1993.

TABLE 4-17 ESTIMATED RELATIONSHIP BETWEEN WHOLE-BODY WET WEIGHT AND AGE FOR THE CRAYFISH PACIFASTACUS LENIUSCULUS

Estimated Age (years)	Crayfish Weight (g)
<1	<8
1 - 2	8 - 15
2 - 3	15 - 31
3 - 4	31 - 48
>4	>48

Source McGriff (1983).

weight or age-length relationships vary with sex and environmental conditions (e g., McGriff 1983, Mitchell and Smock 1991). Therefore, the actual ages of crayfish collected in the lower Columbia River may differ from the estimates provided in Table 4-17.

4.3.1.2 ***Largescale Sucker.*** Sucker were collected at 14 stations, from Youngs Bay to Gary & Flag Islands. Wet weights of individual fish ranged from 40.0 to 1,351 0 g (Figure 4-31). The mean weight of individuals included in each sample ranged from 309.5 to 1,153.0 g Fork lengths of individual fish ranged from 15.5 to 48 0 cm, and the mean fork lengths of individuals in a sample ranged from 25.2 to 44.5 cm (Figure 4-32). The lipid content of the sucker samples was generally higher than that of the crayfish samples 0.6 to 8.4% with a mean concentration of 3 9%.

The CV of the mean of the average weight of suckers in the three samples collected from Camas Slough was 24% For fork length the CV was 9%, and for lipid content it was 59%.

Age estimates are not available for lower Columbia largescale sucker. Length-age relationships for this species in British Columbia suggest that the fish collected in this study could have ranged in age from 3 to over 10 years (see Table 4-18); mean fork lengths would indicate an age range from 6 to over 10 years

4.3.1.3 ***Carp.*** Carp were collected at two stations Youngs Bay and Skamania Landing. Wet weights of individuals ranged from 1,248 1 to 4,508 5 g (Figure 4-31) The mean weights of individuals in each composite sample were 1,738.8 and 3,275 2 g. Fork lengths of individual carp ranged from 39 5 to 58.5 cm. The mean fork length of individuals in the two samples were 44 5 and 53 1 cm (Figure 4-32) The lipid content of the two carp composite samples was similar to sucker lipid content (6.0 and 3.0%)

Age estimates are not available for lower Columbia carp. Length-age relationships for carp from other U.S locations are quite variable, and suggest that the fish collected in this survey could range in age from 2 to 4 years (Wydoski and Whitney 1979).

4.3.2 Metals

Crayfish, sucker, and carp whole-body composite samples were analyzed for 12 metals. All values reported are on a wet-weight basis. Table 4-19 summarizes frequency of detection, range of detected

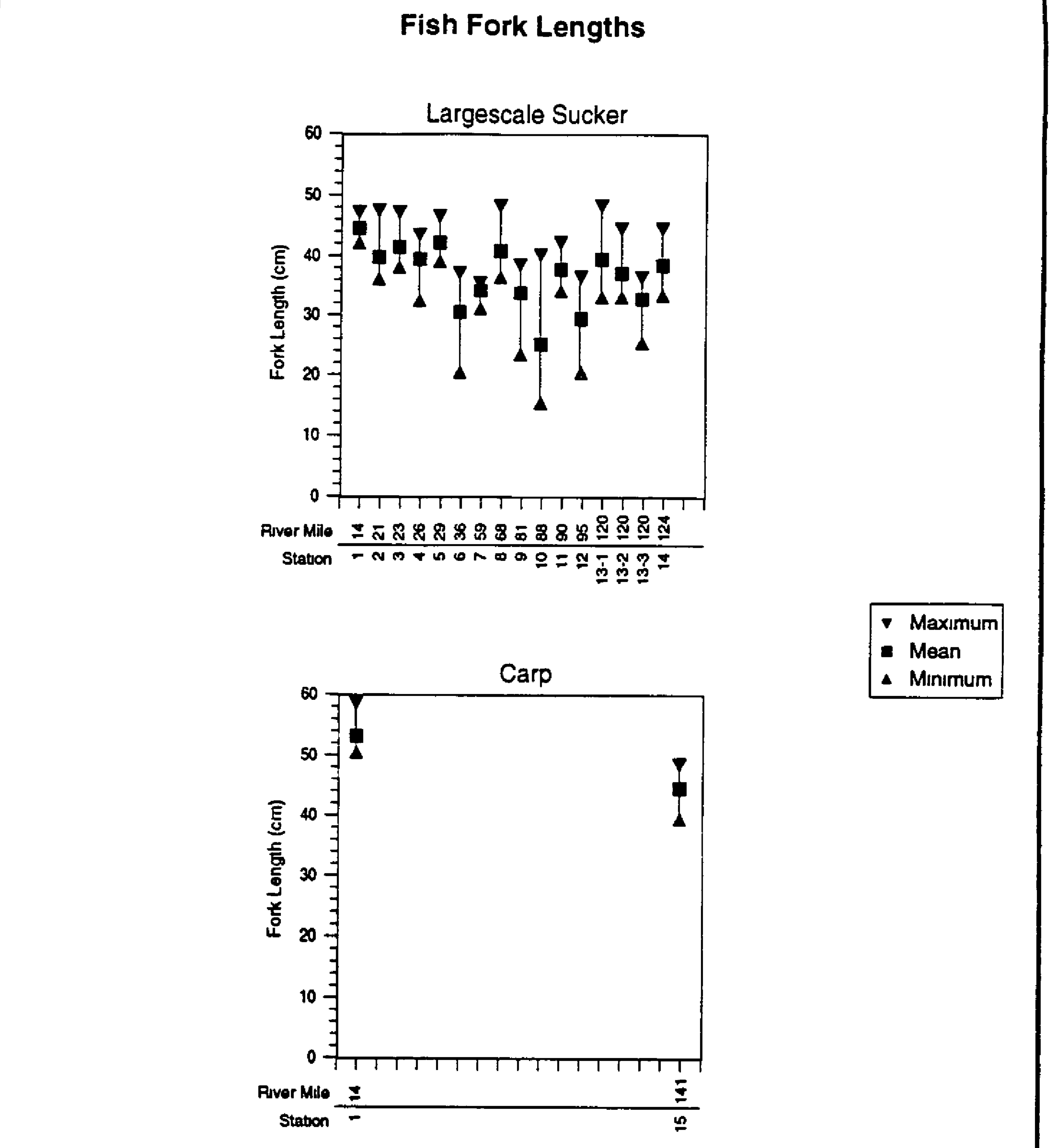


Figure 4-32. Minimum, Maximum, and Mean Fork Lengths of Fish Species Collected for the 1993 Backwater Reconnaissance Survey, July-August 1993.

TABLE 4-18 ESTIMATED RELATIONSHIP BETWEEN FORK LENGTH AND AGE FOR THE LARGESCALE SUCKER *CATOSTOMUS MACROCHEILUS*

Estimated Age (years)	Fork Length (cm)
1-2	4.6 - 7.6
2-3	7.6 - 12.2
3-4	12.2 - 16.8
4-5	16.8 - 18.8
5-6	18.8 - 22.6
6-7	22.6 - 27.9
7-8	27.9 - 30.2
8-9	30.2 - 33.8
9-10	33.8 - 35.3
> 10	> 35.3

Source: Wydoski and Whitney (1979)

TABLE 4-19 METALS ANALYZED IN THREE SPEC[illegible]COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
Antimony	mg/kg	0 012 - 0 018 (6 / 15)[d]	c	c	0 011 - 0 012
Arsenic	mg/kg	0 036 (1/ /15)	0 385 (1 / 16)	c	0 033 - 0 046
Barium	mg/kg	8 5 - 47 2 (15 / 15)	0 34 - 3 5 (16 / 16)	1 0 - 1 2 (2 / 2)	e
Cadmium	mg/kg	0 021 - 0 053 (14 / 15)	0 010 - 0 066 (16 / 16)	0 033 - 0 039 (2 / 2)	0 0004
Chromium	mg/kg	0 035 - 0 095 (15 / 15)	0 032 - 0 527 (16 / 16)	0 078 (1 / 2)	0 024
Copper	mg/kg	14 9 - 31 1 (15 / 15)	0 39 -1 23 (16 / 16)	0 76 - 1 26 (2 / 2)	e
Lead	mg/kg	0 096 0 444 (15 / 15)	0 106 - 0 507 (14 / 16)	0 116 - 0 173 (2 / 2)	0 009 - 0 010
Mercury	mg/kg	0 029 - 0 081 (15 / 15)	0 100 - 0 264 (16 / 16)	0 145 (1 / 2)	0 001
Nickel	mg/kg	0 24 - 1 33 (13 / 15)	0 13 - 0 88 (6 / 16)	0 78 (1 / 2)	0 09 - 0 10
Selenium	mg/kg	0 044 - 0 047 (3 / 15)	0 040 - 0 207 (6 / 16)	0 093 (1 / 2)	0 033 - 0 046
Silver	mg/kg	0 018 - 0 103 (14 / 15)	0 005 - 0 006 (2 / 16)	0 004 - 0 005 (2 / 2)	0 004
Zinc	mg/kg	24 6 - 83 3 (15 / 15)	12 3 - 23 7 (16 / 16)	29 6 - 92 1 (2 / 2)	e

[a] Reported results are on a wet weight basis.

[b] Detection limit range includes only those samples reported as undetected

[c] Compound was not detected in any sample.

[d] Values in parentheses indicate the frequency of detection among the entire sample set.

[e] Compound was detected in all samples

concentrations, and range of detection limits for the metals in these samples No reference levels were available for any of the metals except selenium None of the measured whole-body composite tissue burdens of selenium exceeded the reference concentration (adjusted for comparison on a wet weight basis) for potential effects on carnivorous fish and wildlife, or for the health and reproduction of freshwater and anadromous fish

In general, the highest concentrations of metals were measured in crayfish samples, including the highest concentrations of antimony, barium, copper, nickel, and silver Although the highest concentration of zinc was measured in the carp sample from Skamania Landing, the next four highest zinc concentrations were found in crayfish samples. Of the remaining metals, cadmium, chromium, mercury, and selenium typically occurred at higher concentrations in the sucker samples. The second highest concentration of selenium was also measured in a carp sample Arsenic was detected too infrequently to determine whether the highest concentrations tended to occur in crayfish or fish samples The highest concentrations of lead were measured in both crayfish and sucker samples.

The station with the most frequent occurrence of samples containing the highest metal concentrations was Svensen Island, where the highest concentrations of arsenic, lead, and selenium were detected in sucker samples, and the highest concentration of copper was measured in crayfish Samples collected from Gary & Flag Islands had the highest concentrations of antimony, cadmium, and chromium, ranking this as the station with the second greatest number of highest metal concentrations. The highest concentrations of barium and nickel were measured in crayfish from Fisher Island Slough The highest tissue concentrations of mercury and silver were measured in samples from Cathlamet Bay. The highest concentration of zinc was found in carp from Skamania Landing.

4.3.2.1 Antimony. Antimony was detected above laboratory detection limits in 6 crayfish samples collected from 4 stations (Figure 4-33). The maximum concentration measured was 0.018 mg/kg in one of three samples from Camas Slough. Antimony was not detected in any of the sucker or carp samples. Laboratory detection limits for the three species ranged from 0.011 to 0 012 mg/kg (see Table 4-19)

Antimony was detected in all three crayfish samples from Camas Slough; the CV of these concentrations was 18 2%. Concentrations at this station ranged from 0.013 to 0.018 mg/kg, nearly encompassing the range of concentrations in all other crayfish samples with measurable levels of antimony

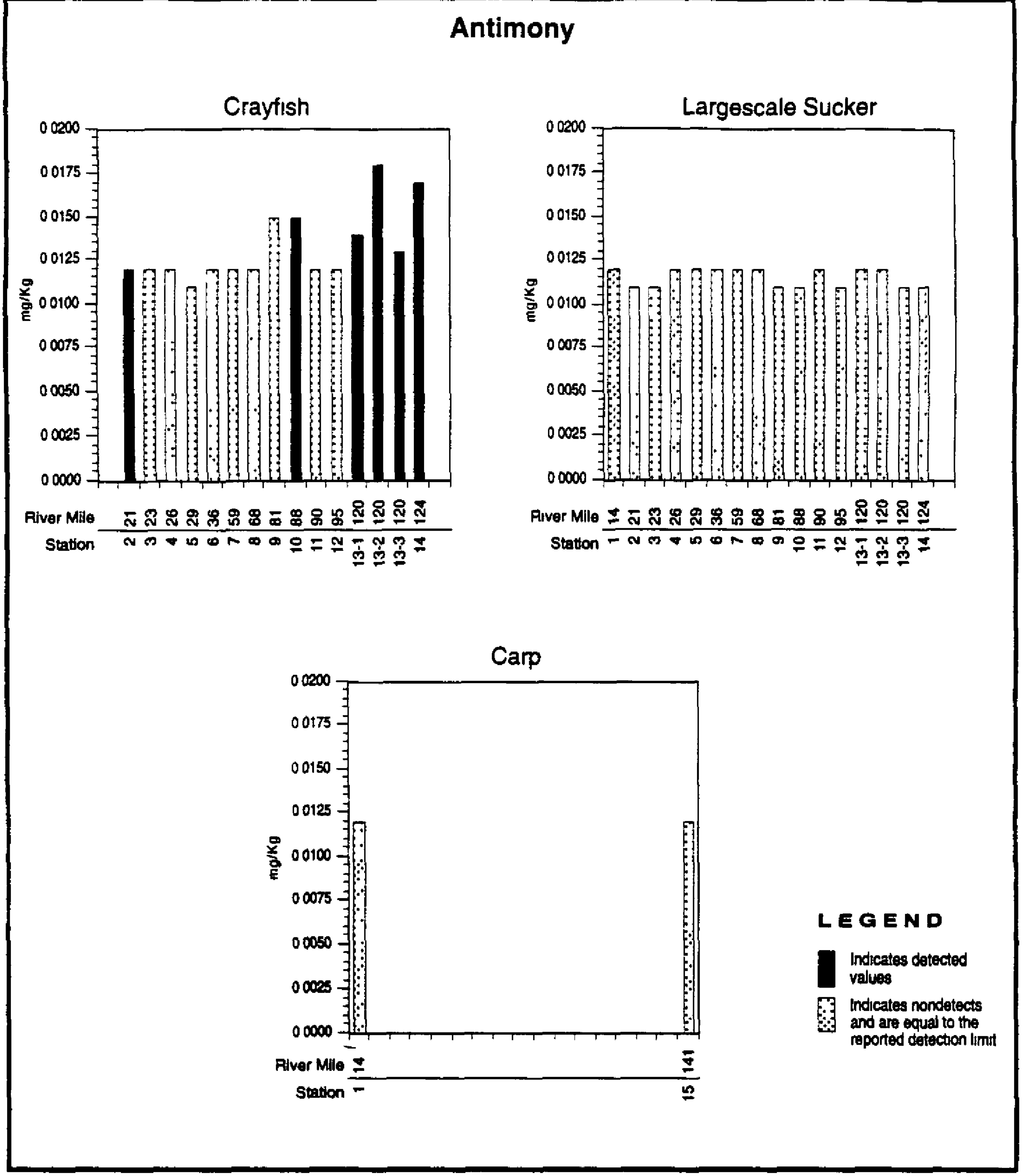


Figure 4-33. Antimony Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

Table 4-20 lists locations where antimony was detected in crayfish (the replicate results for Station 13 were averaged). Tissue concentrations ranged from 0 012 to 0 017 mg/kg and were measured in samples collected from Cathlamet Bay, Scappoose Bay, Camas Slough, and Gary & Flag Islands

4.3.2.2 Arsenic. Arsenic was detected in one crayfish and one sucker sample (Figure 4-34). The maximum detected concentration (0 385 mg/kg) was measured in the sucker sample

Because arsenic was not detected in either the crayfish or sucker samples from Camas Slough, field variation could not be determined.

Table 4-20 shows the locations of the two arsenic detections The concentrations measured were 0 385 and 0.036 mg/kg for the sucker and crayfish samples respectively The sucker sample was collected at Svensen Island and the crayfish sample at Scappoose Bay

4.3.2.3 Barium. Barium was detected in all tissue samples (Figure 4-35). The median concentrations for crayfish, sucker, and carp samples were 31.5, 1 4, and 1.1 mg/kg, respectively Crayfish tissue concentrations ranged from 8.5 to 47.2 mg/kg; the range in sucker and carp was from 0 34 to 3 5 mg/kg (see Table 4-19) The maximum concentration of 47.2 mg/kg was measured in a crayfish composite sample

The CV of mean barium content in crayfish and sucker samples from Camas Slough was relatively low (5 6 and 6 4%, respectively). Differences in barium content in these species are likely due to inter-station rather than intra-station variability

Table 4-20 lists the five highest barium concentrations, ranging from 33.5 to 47.2 mg/kg. All five were measured in crayfish samples. Four of these were collected between RM 59 and RM 95. The composite sample with the second highest concentration was collected from RM 26.

4.3.2.4 Cadmium. Cadmium was detected in all tissue samples except for one crayfish sample (Figure 4-36). Median concentrations were 0.033, 0.032, and 0.036 mg/kg for crayfish, sucker, and carp, respectively. The maximum concentration of 0.066 mg/kg was measured in a sucker sample.

TABLE 4-20. LOCATIONS OF MAXIMUM METAL CONCENTRATIONS MEASURED IN TISSUE SAMPLES [mg/kg (ppm) wet weight]

(Page 1 of 2)

Metal	Maximum Concentrations	Species	Station Designation	Location (River Mile)	Station Description
Antimony	0.017	Crayfish	14-CF	124	Gary & Flag Islands
	0.015	Crayfish	13-CF	120	Camas Slough
	0.015	Crayfish	10-CF	88	Scappoose Bay
	0.012	Crayfish	2-CF	21	Cathlamet Bay
	ND				
Arsenic	0.385	Largescale Sucker	3-LS	23	Svensen Island
	0.036	Crayfish	10-CF	88	Scappoose Bay
	ND				
	ND				
	ND				
Barium	47.2	Crayfish	7-CF	59	Fisher Island Slough
	38.5	Crayfish	4-CF	26	Knappa Slough
	36.9	Crayfish	10-CF	88	Scappoose Bay
	35.6	Crayfish	8-CF	68	Carrolls Channel
	33.5	Crayfish	12-CF	95	Willow Bar Island
Cadmium	0.062	Largescale Sucker	14-LS	124	Gary & Flag Islands
	0.059	Largescale Sucker	13-LS	120	Camas Slough
	0.057	Largescale Sucker	5-LS	29	Lewis & Clark NWR
	0.053	Crayfish	12-CF	95	Willow Bar Island
	0.051	Crayfish	14-CF	124	Gary & Flag Islands
Chromium	0.450	Largescale Sucker	14-LS	124	Gary & Flag Islands
	0.389	Largescale Sucker	13-LS	120	Camas Slough
	0.170	Largescale Sucker	12-LS	95	Willow Bar Island
	0.153	Largescale Sucker	7-LS	59	Fisher Island Slough
	0.139	Largescale Sucker	5-LS	29	Lewis & Clark NWR
Copper	31.1	Crayfish	3-CF	23	Svensen Island
	29.3	Crayfish	2-CF	21	Cathlamet Bay
	24.7	Crayfish	11-CF	90	Bachelor Island Slough
	24.2	Crayfish	7-CF	59	Fisher Island Slough
	22.3	Crayfish	6-CF	36	Elochoman Slough
Lead	0.507	Largescale Sucker	3-LS	23	Svensen Island
	0.444	Crayfish	14-CF	124	Gary & Flag Islands
	0.285	Largescale Sucker	13-LS	120	Camas Slough
	0.204	Largescale Sucker	12-LS	95	Willow Bar Island
	0.174	Crayfish	8-CF	68	Carrolls Channel
Mercury	0.264	Largescale Sucker	2-LS	21	Cathlamet Bay
	0.245	Largescale Sucker	1-LS	14	Youngs Bay
	0.222	Largescale Sucker	8-LS	68	Carrolls Channel
	0.213	Largescale Sucker	10-LS	88	Scappoose Bay
	0.196	Largescale Sucker	14-LS	124	Gary & Flag Islands
Nickel	1.33	Crayfish	7-CF	59	Fisher Island Slough
	1.23	Crayfish	11-CF	90	Bachelor Island Slough
	0.88	Crayfish	13-LS	120	Camas Slough
	0.83	Crayfish	3-CF	23	Svensen Island
	0.78	Carp	1-C	14	Youngs Bay

TABLE 4-20. LOCATIONS OF MAXIMUM METAL CONCENTRATIONS MEASURED IN TISSUE SAMPLES [mg/kg (ppm) wet weight]

(Page 2 of 2)

Metal	Maximum Concentrations	Species	Station designation	Location (River Mile)	Station Description
Selenium	0.207	Largescale Sucker	3-LS	23	Svenson Island
	0.093	Carp	1-C	14	Youngs Bay
	0.072	Largescale Sucker	12-LS	95	Willow Bar Island
	0.054	Largescale Sucker	7-LS	59	Fisher Island Slough
	0.047	Crayfish	10-CF	88	Scappoose Bay
Silver	0.103	Crayfish	2-CF	21	Cathlamet Bay
	0.091	Crayfish	12-CF	95	Willow Bar Island
	0.070	Crayfish	4-CF	26	Knappa Slough
	0.062	Crayfish	5-CF	29	Lewis & Clark NWR
	0.057	Crayfish	10-CF	88	Scappoose Bay
Zinc	92.1	Carp	15-C	141	Skamania Landing
	83.3	Crayfish	9-CF	81	Burke Slough
	55.7	Crayfish	14-CF	124	Gary & Flag Islands
	37.8	Crayfish	11-CF	90	Bachelor Island Slough
	35.5	Crayfish	6-CF	36	Elochoman Slough

ND = Not detected above the laboratory detection limit.

Whole-body tissue samples were analyzed

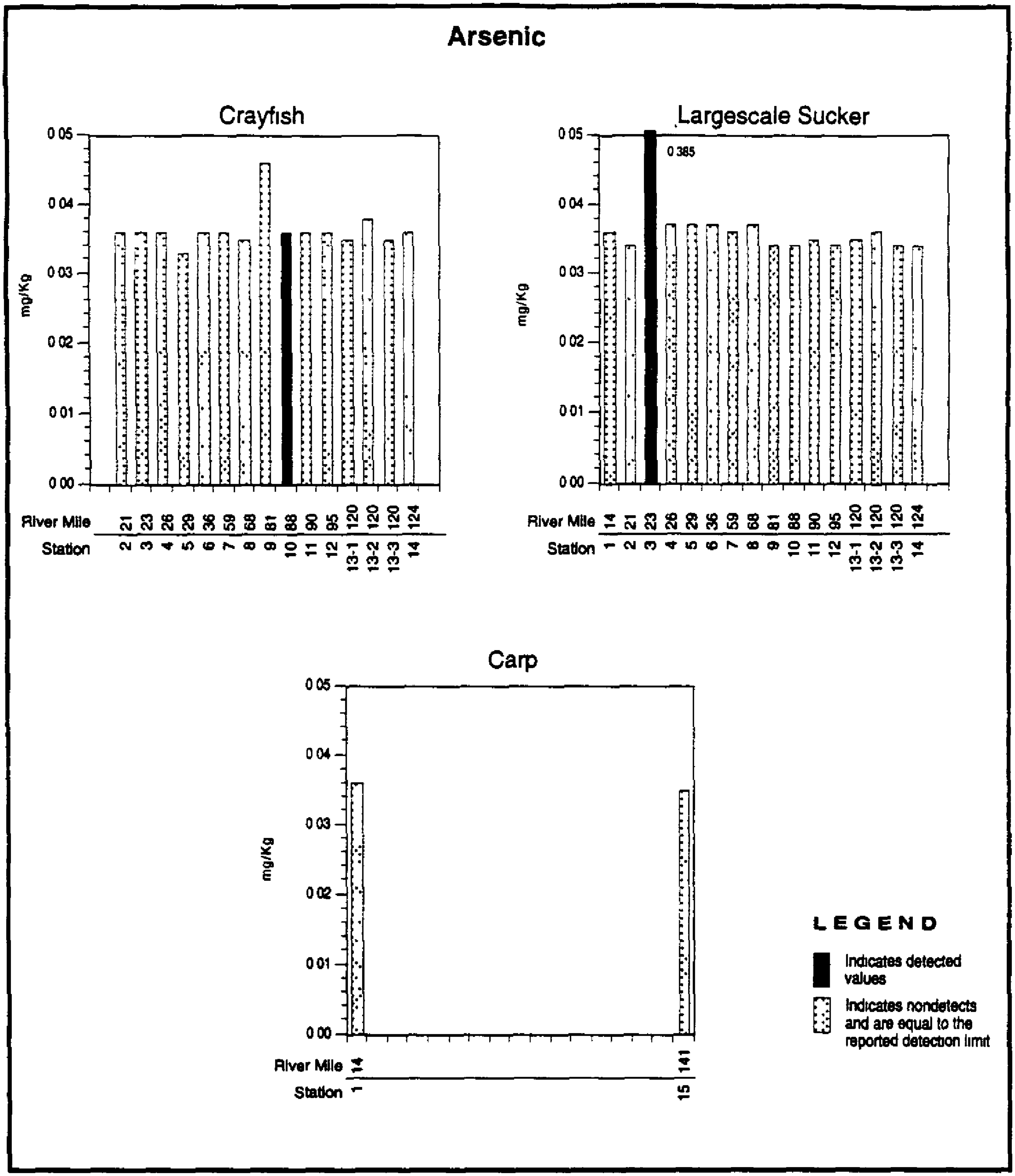


Figure 4-34. Arsenic Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

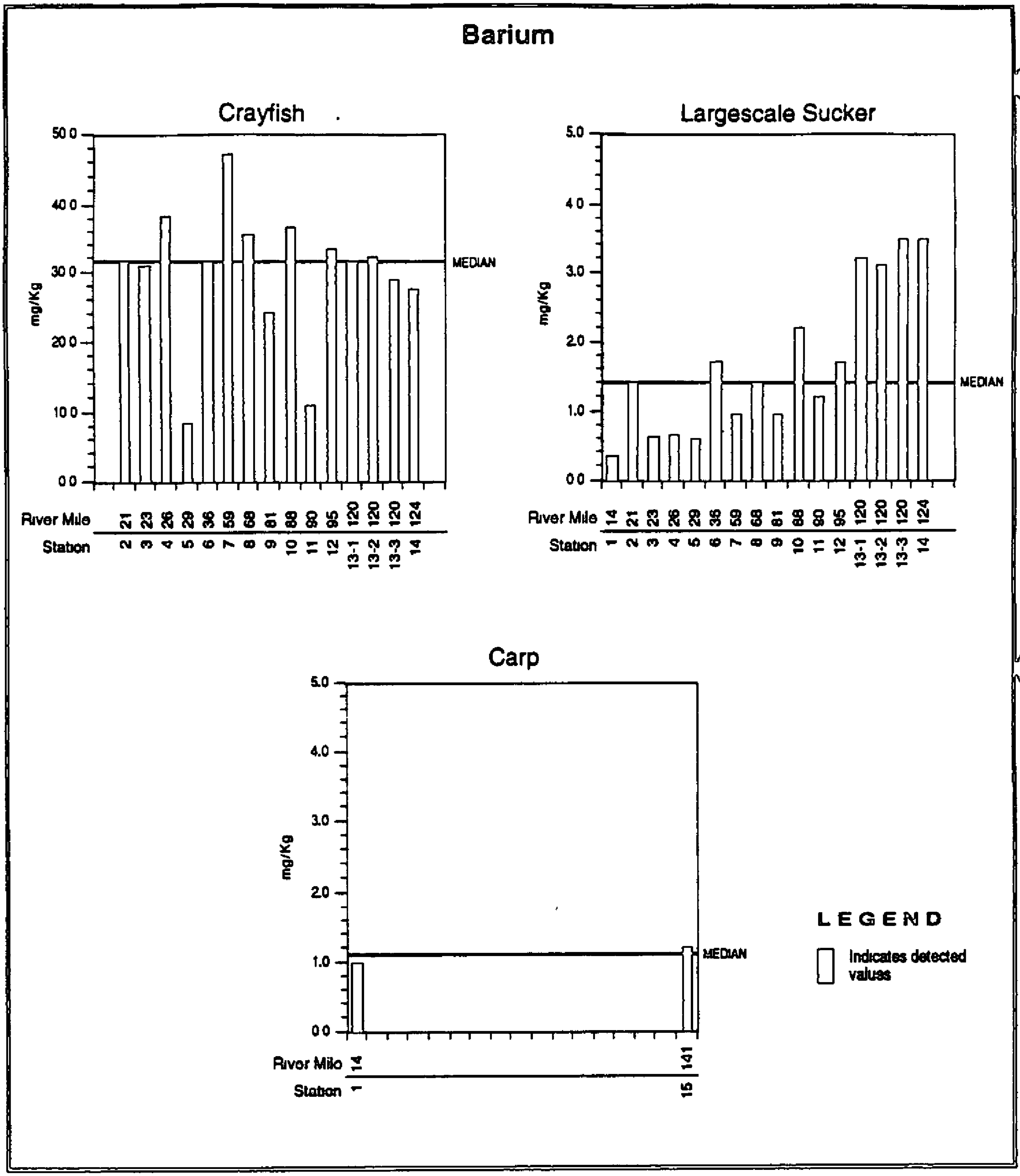


Figure 4-35. Barium Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight). (NOTE: axes not on same scale)

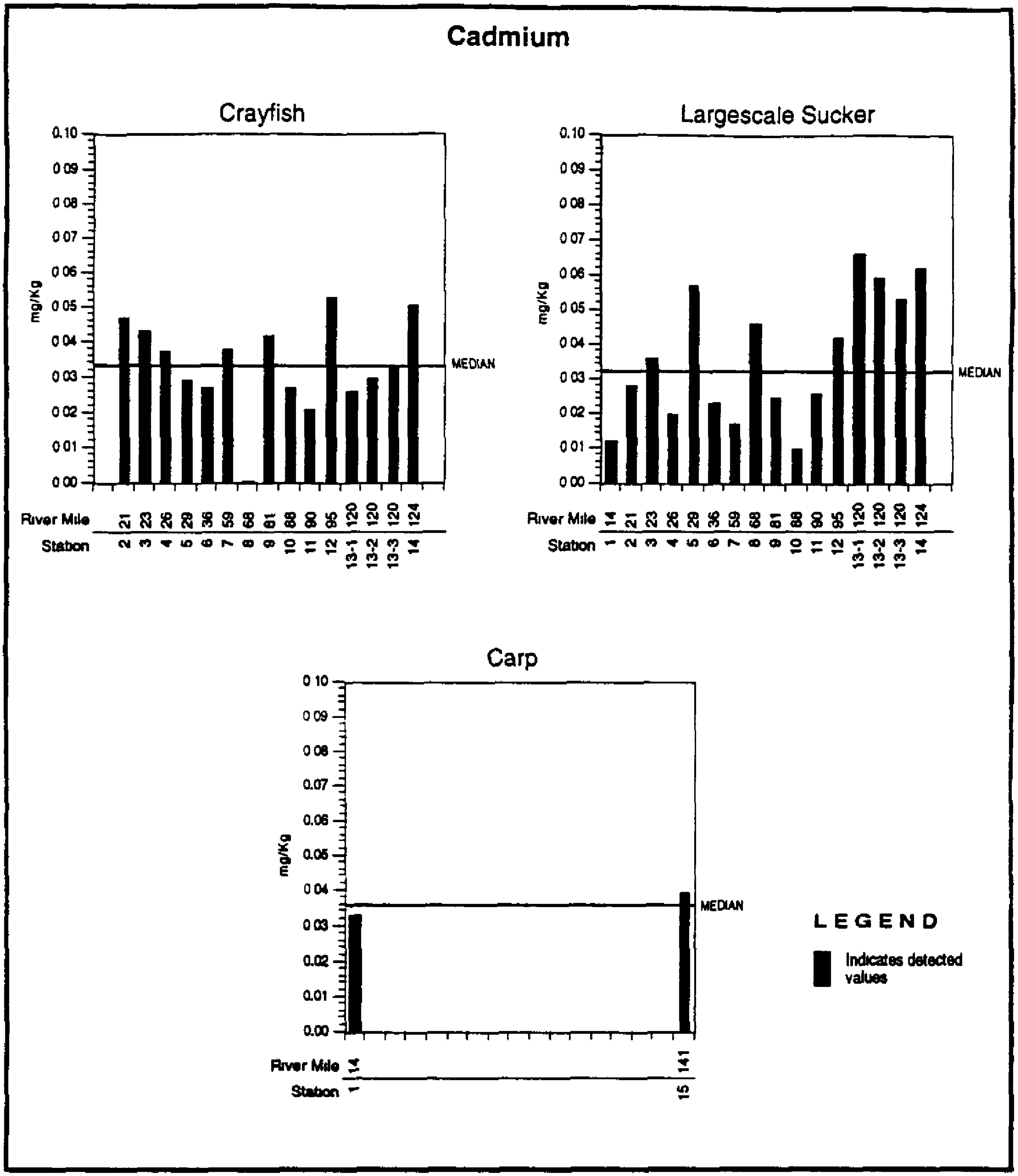


Figure 4-36. Cadmium Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

The CV of mean cadmium content in crayfish and sucker samples from Camas Slough was relatively low (5 6 and 6 4%, respectively) Differences in cadmium content in these species are likely due to inter-station rather than intra-station variability

Table 4-20 lists the five highest cadmium concentrations Three of these were detected in sucker samples and the remaining two in crayfish samples. Gary & Flag Islands had the two highest cadmium concentrations, in the sucker and crayfish samples Tissue concentrations ranged from 0 010 to 0 066 mg/kg (see Table 4-19).

4.3.2.5 Chromium Chromium was detected in all samples except for one carp sample (Figure 4-37) A maximum concentration of 0.527 mg/kg was measured in a sucker sample. Median concentrations were 0 077, 0.110, and 0 051 mg/kg for crayfish, sucker, and carp, respectively

The CV of mean chromium content in crayfish samples from Camas Slough was relatively low (9.0%). The CV of mean chromium content in sucker samples from this station was relatively high (30 9 percent). However, there were large differences in chromium content in sucker samples between stations; therefore the differences in chromium content in both crayfish and suckers between the stations are likely due to inter-station rather than intra-station variability.

Table 4-20 lists the five highest chromium concentrations; all five were detected in sucker samples These samples were from stations dispersed throughout the study area, from RM 29 to RM 124. Tissue concentrations ranged from 0 032 to 0.527 mg/kg with the highest value measured at Gary & Flag Islands (RM 124).

4.3.2.6 Copper. Copper was detected in all tissue samples. Median concentrations were 21 8, 0.735, and 1 01 mg/kg for crayfish, sucker, and carp, respectively (Figure 4-38) A maximum concentration of 31 1 mg/kg was detected in a crayfish sample.

The CVs of mean copper content in crayfish and sucker samples from Camas Slough were relatively low (5.8 and 3.0% respectively). Differences in copper content in these species are likely due to inter-station rather than intra-station variability.

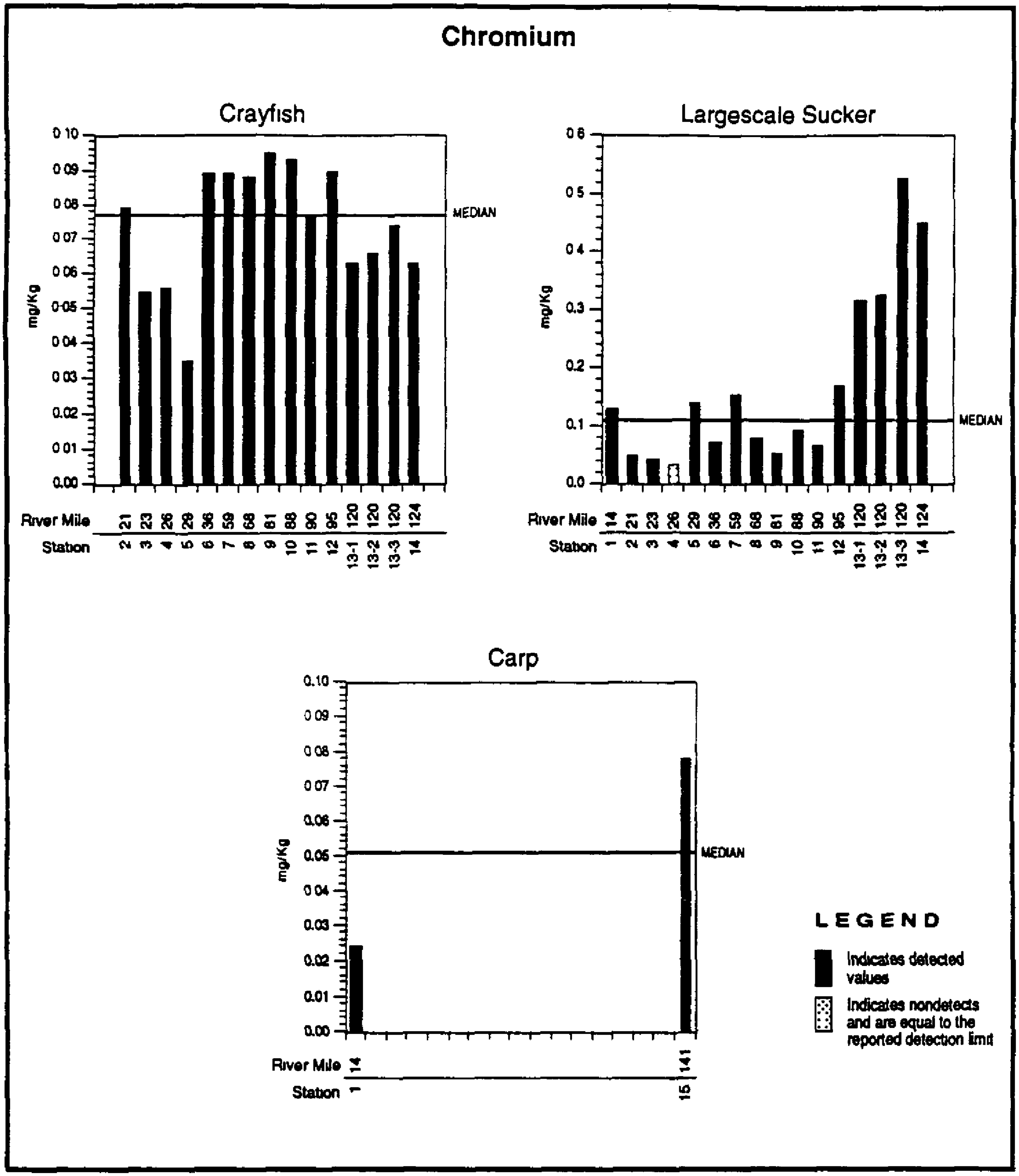


Figure 4-37. Chromium Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight). (NOTE: axes not on same scale)

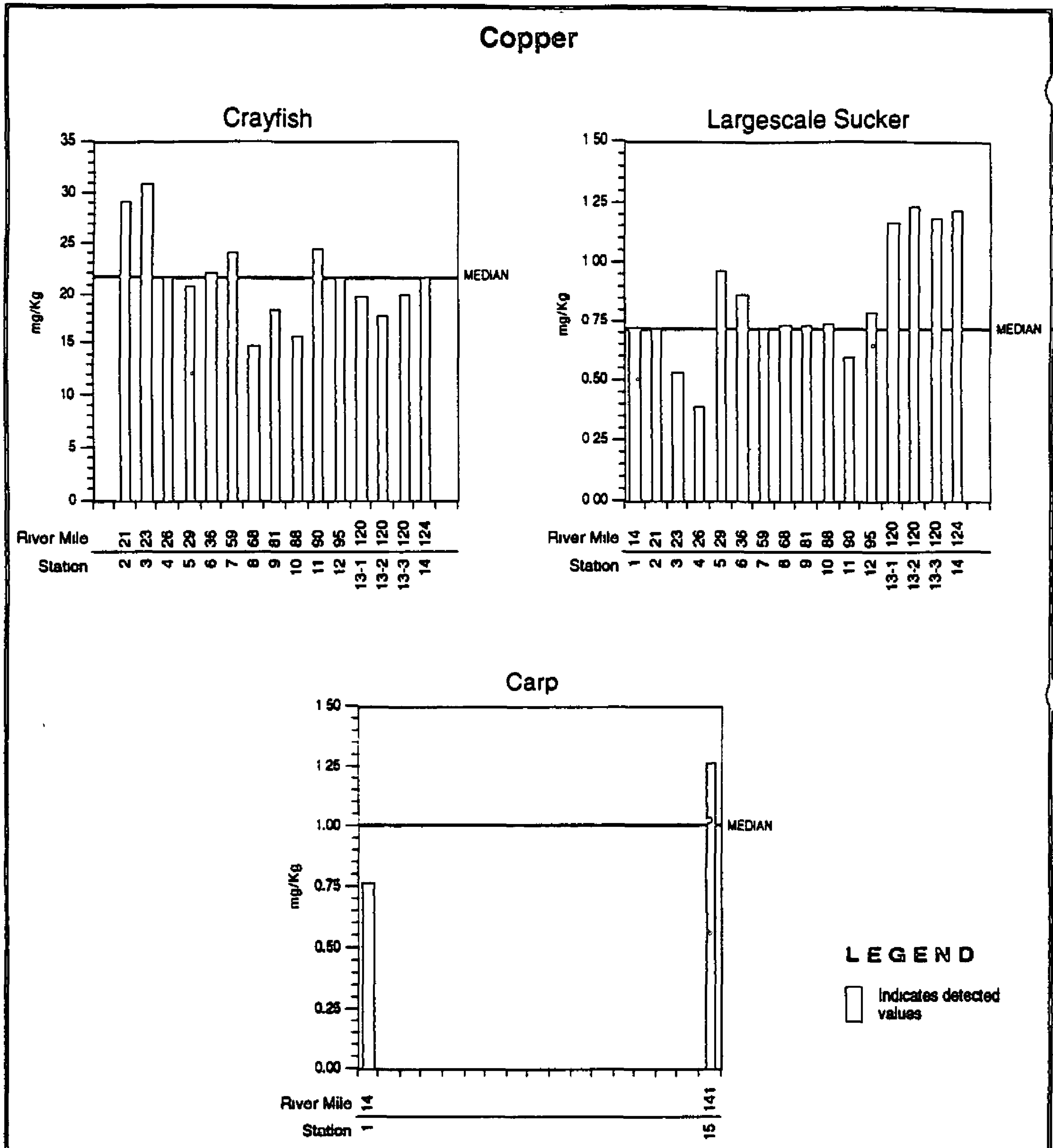


Figure 4-38. Copper Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight). (NOTE: axes not on same scale)

Table 4-20 lists the five highest copper concentrations, all five were detected in crayfish. Concentrations in crayfish ranged from 14.9 to 31.1 mg/kg. Concentrations in sucker and carp ranged from 0.39 to 1.26 mg/kg (see Table 4-19). Four of the five samples with the highest concentrations were collected between RM 21 and RM 59. The remaining high concentration was collected at RM 90.

4.3.2.7 Lead Lead was detected in all crayfish and carp samples, and 88% of sucker samples (Figure 4-39). A maximum concentration of 0.507 mg/kg was detected in a sucker sample. Median concentrations were 0.145, 0.095, and 0.144 mg/kg for crayfish, sucker, and carp, respectively.

The CV of mean lead content in crayfish samples from Camas Slough was relatively low (13.4%). However, the CV of mean lead content in sucker samples collected from this station was relatively high (34.0%). There were large differences in lead content in sucker samples between stations, therefore, the differences in lead content in both crayfish and suckers are likely due to inter-station rather than intra-station variability.

Table 4-20 lists the five highest lead concentrations detected. Three of these were detected in sucker samples and the other two in crayfish samples. Collection locations for these samples were dispersed throughout the study area, from RM 23 to RM 124. Concentrations ranged from 0.048 to 0.507 mg/kg (see Table 4-19). The sample with the highest concentration was collected at RM 23.

4.3.2.8 Mercury. Mercury was detected in almost all of the crayfish and sucker samples and one carp sample (Figure 4-40). A maximum concentration of 0.264 mg/kg was found in a sucker sample. Median concentrations were 0.045, 0.170, and 0.073 mg/kg for crayfish, sucker, and carp, respectively.

The CV of mean mercury content in crayfish samples from Camas Slough was relatively low (18.3%). Differences in mercury content in these species are likely due to inter-station rather than intra-station variability. The CV of mean mercury content in sucker samples from this station was relatively high (29.2%). Concentration ranged from 0.119 to 0.215 mg/kg, which encompassed a number of concentrations measured in sucker samples from other stations.

Table 4-20 lists the five highest mercury concentrations; all five were detected in sucker samples. The sample with the highest concentration was from Cathlamet Bay, followed by samples from Youngs Bay,

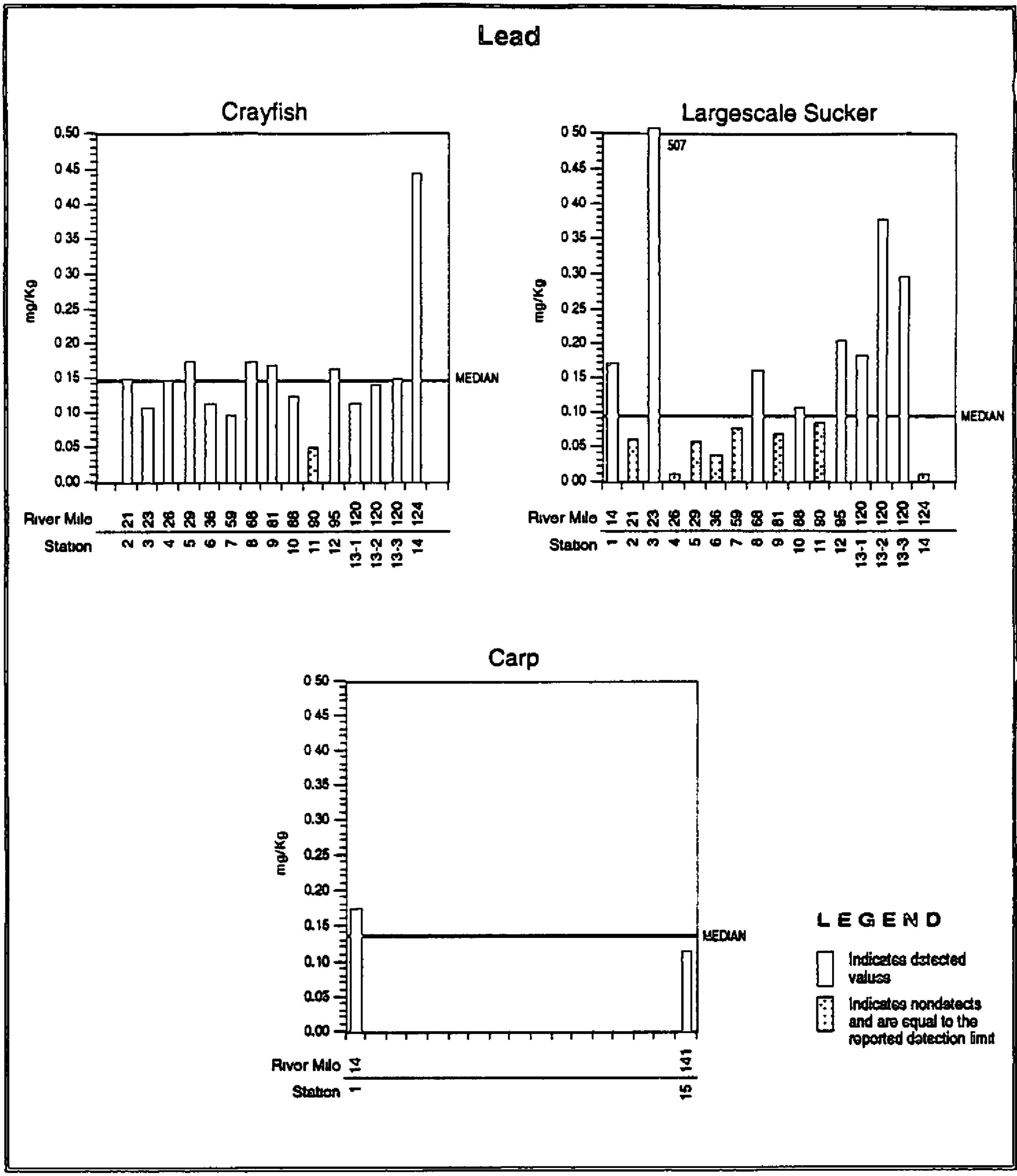


Figure 4-39. Lead Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

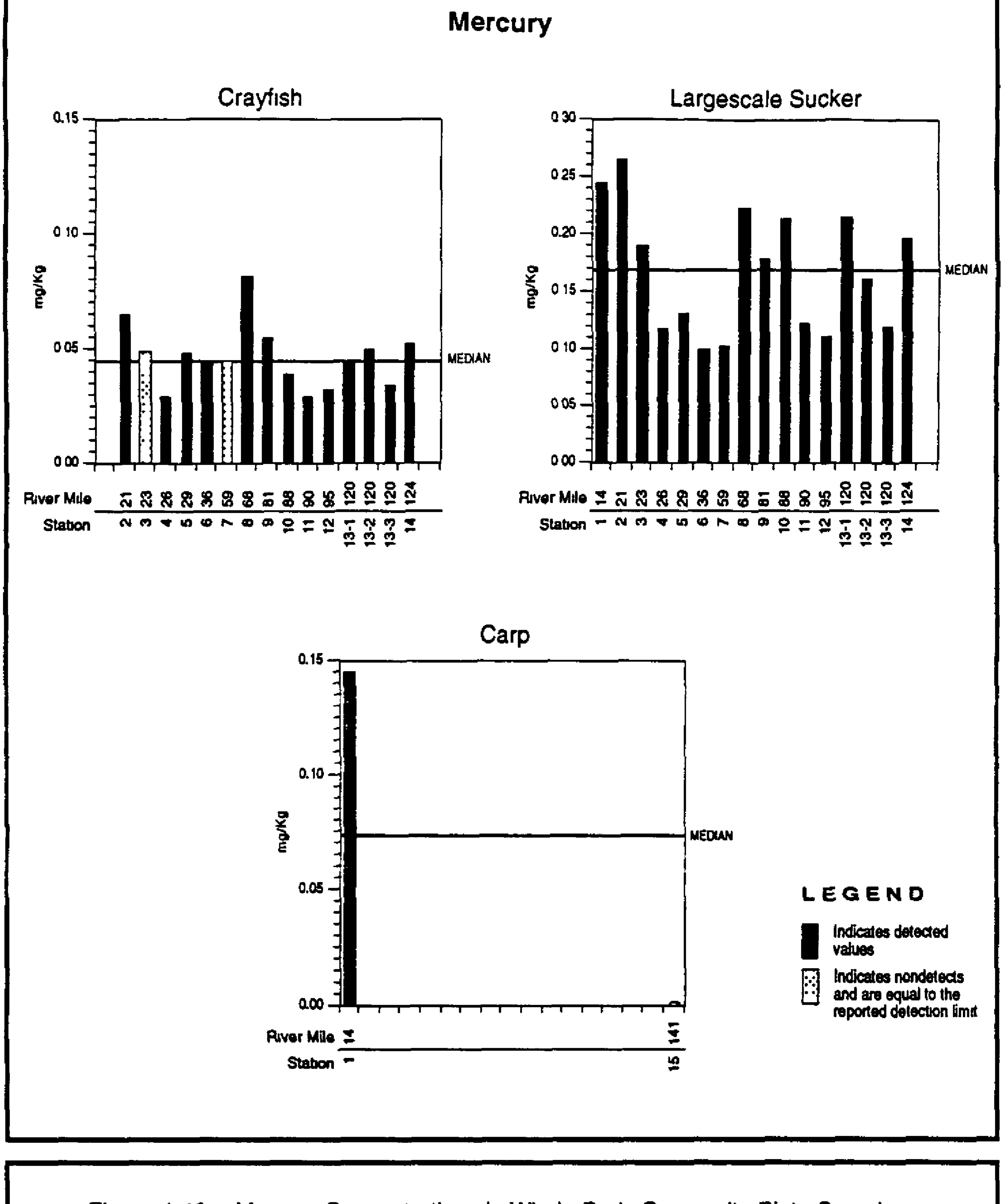


Figure 4-40. Mercury Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight)(Note: axes not on same scale).

Carrolls Channel, Scappoose Bay, and Gary & Flag Islands in order of decreasing concentration. Concentrations ranged from 0.029 to 0.264 mg/kg (see Table 4-19).

4.3.2.9 Nickel. Nickel was detected in 87% of the crayfish samples, 38% of the largescale sucker samples, and 50% of the carp samples (Figure 4-41). A maximum concentration of 2.26 mg/kg was detected in a sucker sample. The median concentration for crayfish was 0.53 mg/kg.

The CV of mean nickel content in crayfish samples from Camas Slough was relatively high (26.9%). However, there were relatively large differences in crayfish nickel content between stations; these differences are likely due to inter-station rather than intra-station variability. For sucker, the CV of mean nickel content was very high (136%), due primarily to the high value (2.26 mg/kg) in one of the three triplicate samples. The range of concentrations measured in the three subsamples (0.28 to 2.26 mg/kg) encompassed the range of concentrations measured in all but one of the other samples.

Table 4-20 lists the five highest nickel concentrations. The four highest values were detected in crayfish samples and the fifth in a carp sample. Collection locations for the crayfish samples with the highest measured nickel concentrations were dispersed throughout the study area from RM 23 to 120. The carp sample was collected from Youngs Bay (RM 14). Concentrations ranged from 0.13 to 2.26 mg/kg, laboratory detection limits ranged from 0.09 to 0.10 mg/kg (see Table 4-19).

4.3.2.10 Selenium. Selenium was detected in a relatively small proportion of the tissue samples: 20% of the crayfish samples, 38% of the sucker samples, and one of the two carp samples (Figure 4-42). A maximum concentration of 0.207 mg/kg was detected in a sucker sample. Crayfish sample concentrations ranged from 0.044 to 0.047 mg/kg; sucker concentrations from 0.040 to 0.207 mg/kg; the carp sample concentration was 0.093 mg/kg (see Table 4-19). The laboratory detection limits for selenium ranged from 0.033 to 0.046 mg/kg (see Table 4-19). Because selenium was not detected in any field replicate sample, variability could not be assessed.

Selenium is the only metal measured to have a tissue burden reference value. Selenium concentrations in all three species, as well as laboratory detection limits, were all below this reference level of 0.75 mg/kg wet weight. This indicates that adverse effects due to dietary intake of the target species by other fish or wildlife would be unlikely. The selenium concentrations measured are also lower than the

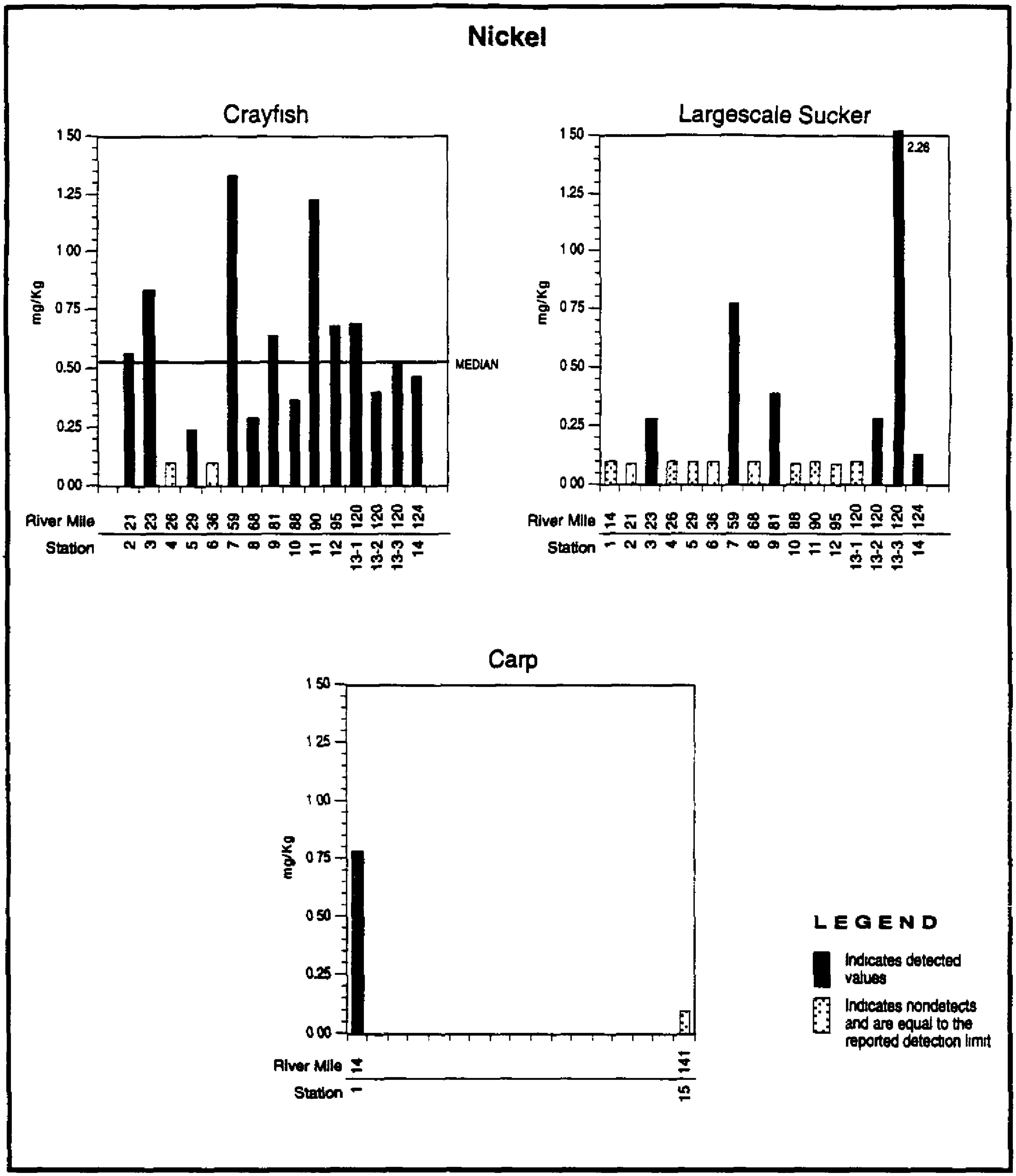


Figure 4-41. Nickel Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

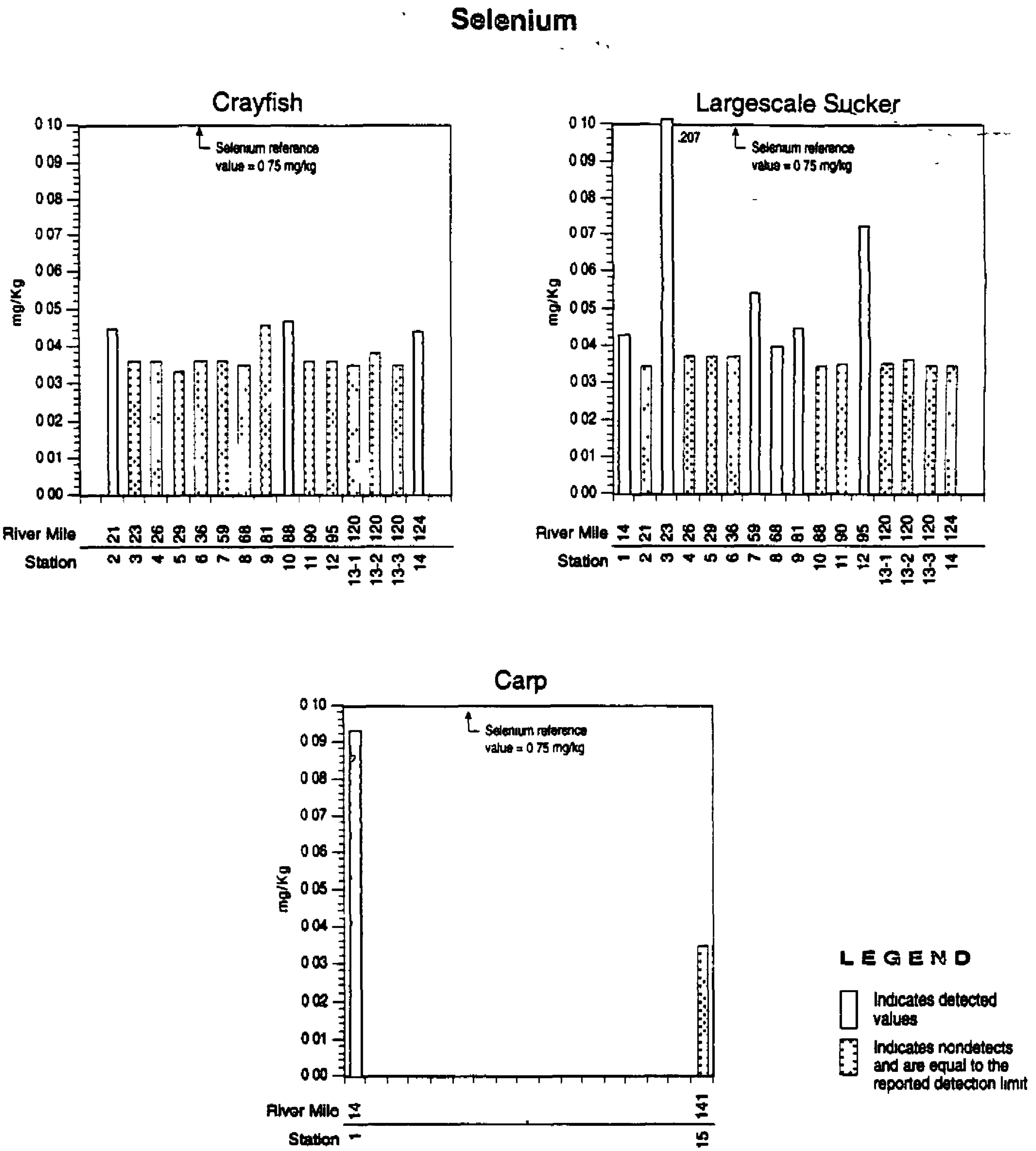


Figure 4-42. Selenium Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/Kg wet weight). *Selenium reference value is 0.75 mg/kg wet weight assuming a 75 percent body moisture content.*

concentration (1.0 mg/kg wet weight assuming 75% moisture content) considered by Lemly (1993) to be the threshold for potential adverse effects to the health and reproductive success of freshwater and anadromous fish.

Table 4-20 lists the five highest selenium concentrations. The highest concentration was in a sucker sample from Svensen Island and the second highest in a carp sample collected from Youngs Bay. The third and fourth highest concentrations were measured in sucker samples from Willow Bar Island and Fisher Island Slough, respectively. The fifth highest value was found in a crayfish sample collected from Scappoose Bay. Concentrations ranged from 0.040 to 0.207 mg/kg; laboratory detection limits ranged from 0.033 to 0.046 mg/kg (see Table 4-19).

4.3.2.11 Silver Silver was detected in 93% of crayfish samples, 12% of sucker samples, and both carp samples (Figure 4-43). The maximum concentration of 0.103 mg/kg was detected in a crayfish sample. Median concentrations were 0.053, 0.004, and 0.004 mg/kg for crayfish, sucker, and carp samples, respectively.

The CV of mean silver content in crayfish samples from Camas Slough was relatively high (26.1%). However, there were relatively large differences in crayfish silver content between stations, therefore, differences in silver content in this species are likely due to inter-station rather than intra-station variability. As silver was not detected in any of the field replicate samples, CV could not be assessed.

Table 4-20 lists the five highest silver concentrations. All five values were detected in crayfish samples and ranged from 0.057 to 0.103 mg/kg. The highest concentration was from Cathlamet Bay followed by samples from Willow Bar Island, Knappa Slough, Lewis and Clark NWR, and Scappoose Bay. Concentrations in sucker and carp samples ranged from 0.004 to 0.006 mg/kg (see Table 4-19).

4.3.2.12 Zinc. Zinc was detected in all tissue samples (Figure 4-44). The maximum concentration of 92.1 mg/kg was measured in a carp sample. Median concentrations were 32.3, 19.1, and 60.8 mg/kg for crayfish, sucker, and carp, respectively.

The CVs of mean zinc content in crayfish and sucker samples from Camas Slough were relatively high (13.3 and 24.3%, respectively). The range of zinc concentrations measured in these replicate samples

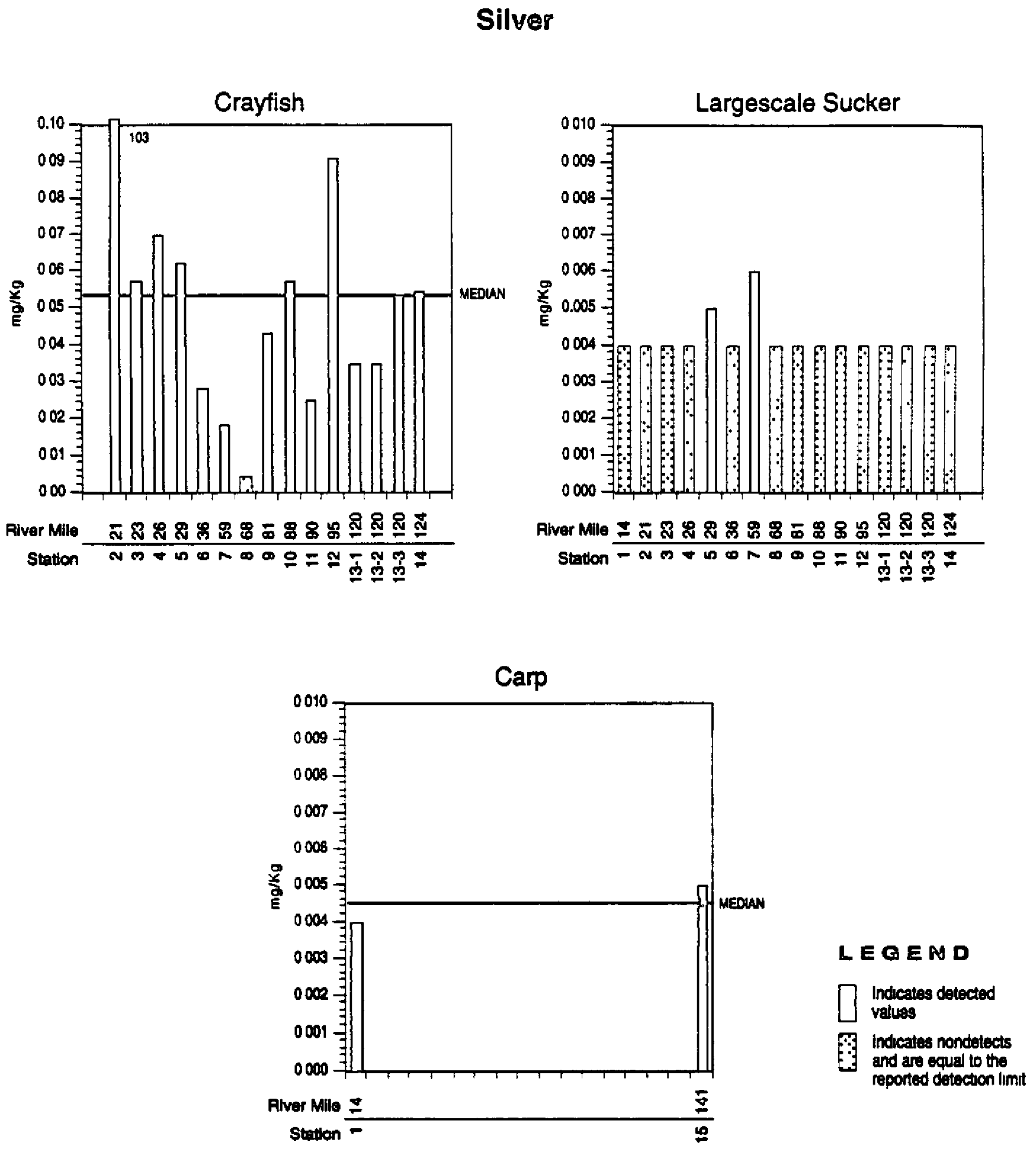


Figure 4-43. Silver Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

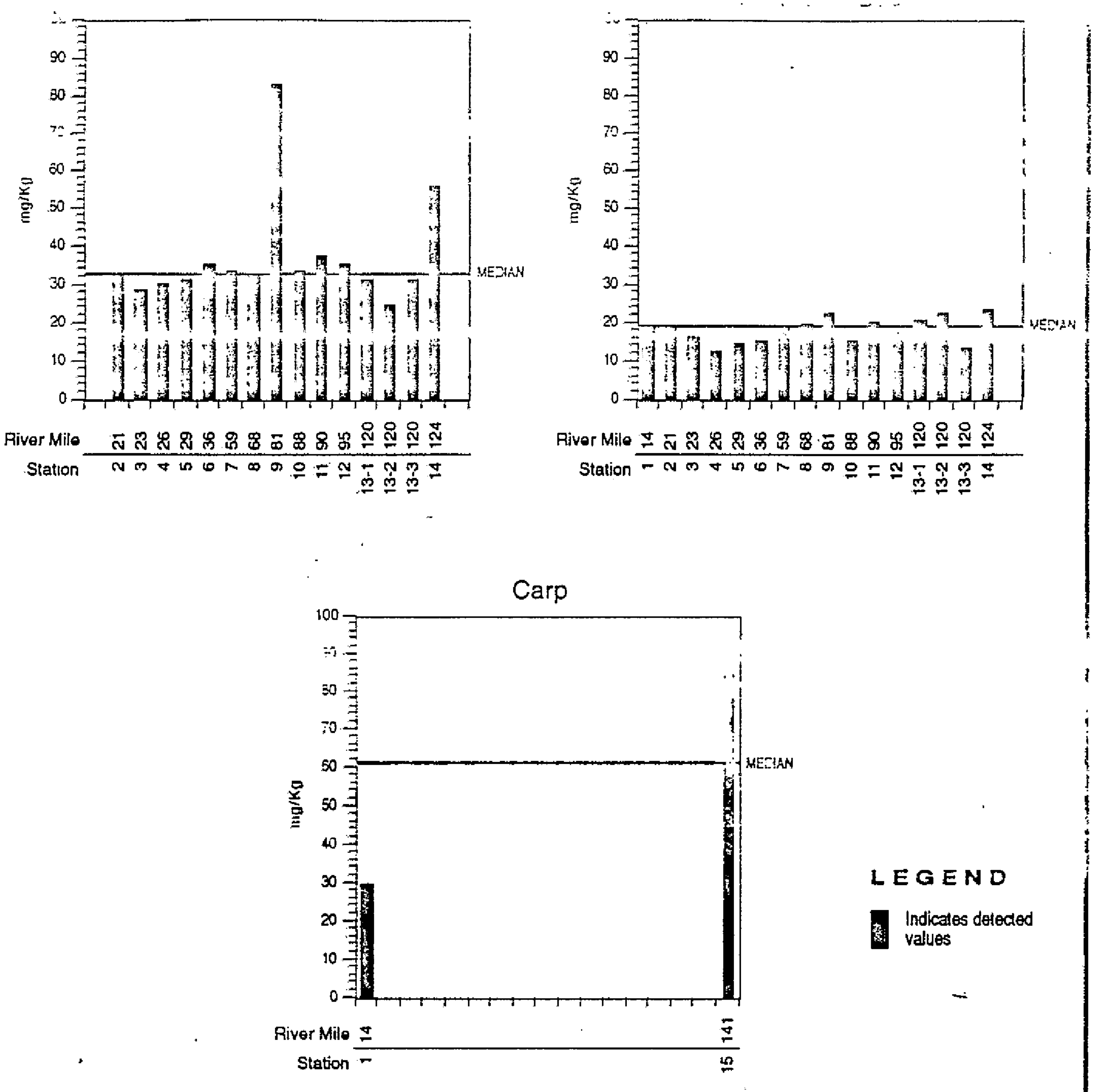


Figure 4-44. Zinc Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (mg/kg wet weight).

Station Variability

Table 4-20 lists the five highest zinc concentrations. The highest concentration was measured in a carp sample from Skamania Landing. The next four highest concentrations were measured in crayfish samples collected from Burke Slough, Gary & Flag Islands, Bachelor Island Slough, and Elochoman Slough. Concentrations detected in all three species ranged from 12.3 to 92.1 mg/kg (see Table 4-19).

4.3.2.13 Summary of Quality Assurance/Quality Control. A total of 33 tissue samples were analyzed for the 12 metals. Continuing calibration verification (CCV) analysis was conducted for each metal; results were within QC limits with the exception of 14 arsenic values, 1 cadmium value, 24 lead and selenium values, and 3 silver values. All positive values exceeding the CCV upper control limit, and all positive and undetected values below the lower control limit were qualified as estimated results. All zinc values were qualified as estimates based on exceeding ICP serial dilution QC guidelines. Chromium and lead were each detected in one method blank, mercury in 2 method blanks, and zinc in 4 method blanks. Sample concentrations detected at less than 5 times the blank detection amount were qualified as undetected due to blank contribution. As a result, 2 chromium samples, 7 lead samples, and 2 mercury samples were qualified as undetected. The detection limits reported for arsenic, lead, mercury, nickel, and selenium were approximately 3 times higher than those specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) due to matrix interference. The target detection limits were achieved for the remaining metals. The tissue metals data are considered acceptable for use in this report.

4.3.3 Semi-volatile Organic Compounds

Composite samples of all three species were analyzed for 63 semi-volatile organic compounds. All values are reported on a wet-weight basis. Table 4-21 lists compounds detected by species, range of measured concentrations, frequency of detection, and range of detection limits for those samples with concentrations below laboratory detection limits. Reference levels for potential adverse effects on fish-eating wildlife are available for the semi-volatile compounds pentachlorophenol, 1,2,4-trichlorobenzene, hexachlorobenzene, and hexachlorobutadiene. None of these compounds were detected. In general, the laboratory detection limits achieved for these compounds were adequate for comparison to available reference levels, with the exception of pentachlorophenol and hexachlorobenzene in sucker and carp samples.

TABLE 4-21. SEMI-VOLATILE COMPOUNDS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 1 of 5)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limit
PHENOLIC COMPOUNDS					
Phenol	µg/kg	100 - 690 (5 / 15)[d]	c	c	94 - 500
2-Methylphenol	µg/kg	c	c	c	93 - 500
4-Methylphenol	µg/kg	c	c	c	93 - 500
2,4-Dimethylphenol	µg/kg	c	c	c	93 - 500
Pentachlorophenol	µg/kg	c	c	c	460 - 12000
2-Chlorophenol	µg/kg	c	c	c	93 - 500
2,4-Dichlorophenol	µg/kg	c	c	c	280 - 1500
4-Chloro-3-methylphenol	µg/kg	c	c	c	190 - 1000
2,4-Dinitrophenol	µg/kg	c	c	c	460 - 5000
2-Nitrophenol	µg/kg	c	c	c	460 - 2500
4-Nitrophenol	µg/kg	c	c	c	460 - 2500
2,4,5-Trichlorophenol	µg/kg	c	c	c	460 - 2500
2,4,6-Trichlorophenol	µg/kg	c	c	c	460 - 2500
4,6-Dinitro-2-methylphenol	µg/kg	c	c	c	930 - 5000

TABLE 4-21. SEMI-VOLATILE COMPOUNDS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 2 of 5)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limi
HALOGENATED ETHERS					
Bis(2-chloroethyl)ether	µg/kg	c	c	c	93 - 500
Bis(2-chloroethoxy)methane	µg/kg	c	c	c	93 - 500
4-Bromophenyl-phenylether	µg/kg	c	c	c	93 - 500
4-Chlorophenyl-phenylether	µg/kg	c	c	c	93 - 500
2,2'-Oxybis[2-chloropropan	µg/kg	c	c	c	93 - 500
NITROAROMATICS					
2,4-Dinitrotoluene	µg/kg	c	c	c	460 - 2500
2,6-Dinitrotoluene	µg/kg	c	c	c	460 - 2500
Nitrobenzene	µg/kg	c	c	c	93 - 500
2-Nitroaniline	µg/kg	c	c	c	460 - 2500
3-Nitroaniline	µg/kg	c	c	c	460 - 2500
4-Nitroaniline	µg/kg	c	c	c	460 - 2500
POLYNUCLEAR AROMATIC HYDROCARBONS					
Acenaphthene	µg/kg	7.3 (1 / 15)	c	c	9.3 - 10
Acenaphthylene	µg/kg	c	c	c	9.3 - 10

TABLE 4-21 SEMI-VOLATILE COMPOUNDS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 3 of 5)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
POLYNUCLEAR AROMATIC HYDROCARBONS					
Anthracene	µg/kg	c	c	c	9.3 - 10
Benzo(a)anthracene	µg/kg	c	c	c	9.3 - 10
Benzo(b,k)fluoranthene	µg/kg	c	c	c	9.3 - 10
Benzo(a)pyrene	µg/kg	c	c	c	9.3 - 10
Benzo(g,h,i)perylene	µg/kg	c	c	c	9.3 - 10
Chrysene	µg/kg	c	c	c	9.3 - 10
Dibenzo(a,h)anthracene	µg/kg	c	c	c	9.3 - 10
Fluoranthene	µg/kg	c	c	c	9.3 - 10
Fluorene	µg/kg	5.3 (1 / 15)	c	c	9.3 - 10
Indeno(1,2,3-cd)pyrene	µg/kg	c	c	c	9.3 - 10
Naphthalene	µg/kg	9.5 - 57.0 (7 / 15)	6.6 - 13 (5 / 16)	c	4.4 - 10
Phenanthrene	µg/kg	7.7 (1 / 15)	c	c	7.7 - 10
Pyrene	µg/kg	c	c	c	9.3 - 10
2-Methylnaphthalene	µg/kg	7.7 - 20.0 (10 / 15)	8.8 - 23 (5 / 16)	c	5.3 - 10
Dibenzofuran	µg/kg	c	c	c	3.6 - 10

TABLE 4-21 SEMI-VOLATILE COMPOUNDS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]
(Page 4 of 5)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
CHLORINATED NAPHTHALENE					
2-Chloronaphthalene	µg/kg	c	c	c	93 - 500
CHLORINATED BENZENES					
1,3-Dichlorobenzene	µg/kg	c	c	c	93 - 500
1,2-Dichlorobenzene	µg/kg	c	c	c	93 - 500
1,4-Dichlorobenzene	µg/kg	c	c	c	93 - 500
1,2,4-Trichlorobenzene	µg/kg	c	c	c	93 - 500
Hexachlorobenzene	µg/kg	c	c	c	93 - 500
Hexachlorobutadiene	µg/kg	c	c	c	93 - 500
Hexachloroethane	µg/kg	c	c	c	93 - 500
Hexachlorocyclopentadiene	µg/kg	c	c	c	460 - 2500
BENZIDINES					
3,3'-Dichlorobenzidine	µg/kg	c	c	c	460 - 2500
PHTHALATE ESTERS					
Dimethyl phthalate	µg/kg	c	c	c	93 - 500
Diethyl phthalate	µg/kg	c	c	c	93 - 500
Di-n-butyl phthalate	µg/kg	240 (1 / 15)	430 (1 / 16)	c	96 - 3100

TABLE 4-21 SEMI-VOLATILE COMPOUNDS [illegible] THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BI-STATE [illegible] RECONNAISSANCE SURVEY[a]

([illegible] of [illegible])

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limit[b]
PHTHALATE ESTERS					
Benzyl butyl phthalate	µg/kg	[c]	[c]	[c]	[illegible]
Bis(2-ethylhexyl) phthalate	µg/kg	[c]	460 - 760 (2 / 16)[d]	[c]	[illegible]
Di-n-octyl phthalate	µg/kg	[c]	[c]	[c]	[illegible]
MISCELLANEOUS					
Carbazole	µg/kg	[c]	[c]	[c]	[illegible]
Benzyl alcohol	µg/kg	[c]	[c]	[c]	[illegible]
Benzoic acid	µg/kg	[c]	[c]	[c]	[illegible]
Isophorone	µg/kg		[c]	[c]	[illegible]
4-Chloroaniline	µg/kg		[c]	[c]	[illegible]

[a] Reported results are on a wet weight basis

[b] Detection limit range includes only those samples reported as not detected

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set

4.3.3.1 Phenolic Compounds. Samples were analyzed for fourteen phenolic compounds (Table 4-21). Phenol was the only compound detected, and only in 5 of 15 crayfish samples. The measured concentrations ranged from 100 to 690 µg/kg (Figure 4-45). Three of the five samples were collected between RM 29 and RM 59. The other two samples were collected from RM 81 and RM 88. Detection limits varied for the different compounds, but ranged from 93 to 12,000 µg/kg.

The only reference value available for these phenolic compounds is for pentachlorophenol: 2,000 µg/kg wet weight for the evaluation of adverse effects on fish-eating wildlife. This compound was not detected in any sample. Laboratory detection limits for crayfish analyses were all below this reference level; for sucker and carp they were above the reference level, making an assessment of the potential for adverse effects on fish-eating wildlife impossible.

4.3.3.2 Halogenated Ethers. Samples were analyzed for five halogenated ether compounds (Table 4-21). These compounds were not detected in any sample. Detection limits ranged from 93 to 500 µg/kg.

4.3.3.3 Nitroaromatic Compounds. Samples were analyzed for six nitroaromatic compounds (Table 4-21). These compounds were not detected in any sample. Detection limits ranged from 460 to 2,500 µg/kg with the exception of nitrobenzene, which ranged from 93 to 500 µg/kg.

4.3.3.4 Polynuclear Aromatic Hydrocarbons. Samples were analyzed for seventeen PAHs (Table 4-21). Detection limits ranged from 4.4 to 10 µg/kg (see Table 4-21). No PAHs were detected in the two carp samples.

Naphthalene and 2-methylnaphthalene were detected in 31% of the largescale sucker samples. These samples were collected from Youngs Bay, Elochoman Slough, Scappoose Bay, Bachelor Island Slough, and Camas Slough (Figures 4-46 and 4-47). The highest PAH concentration in the sucker samples (23 µg/kg) was for 2-methylnaphthalene (see Table 4-21).

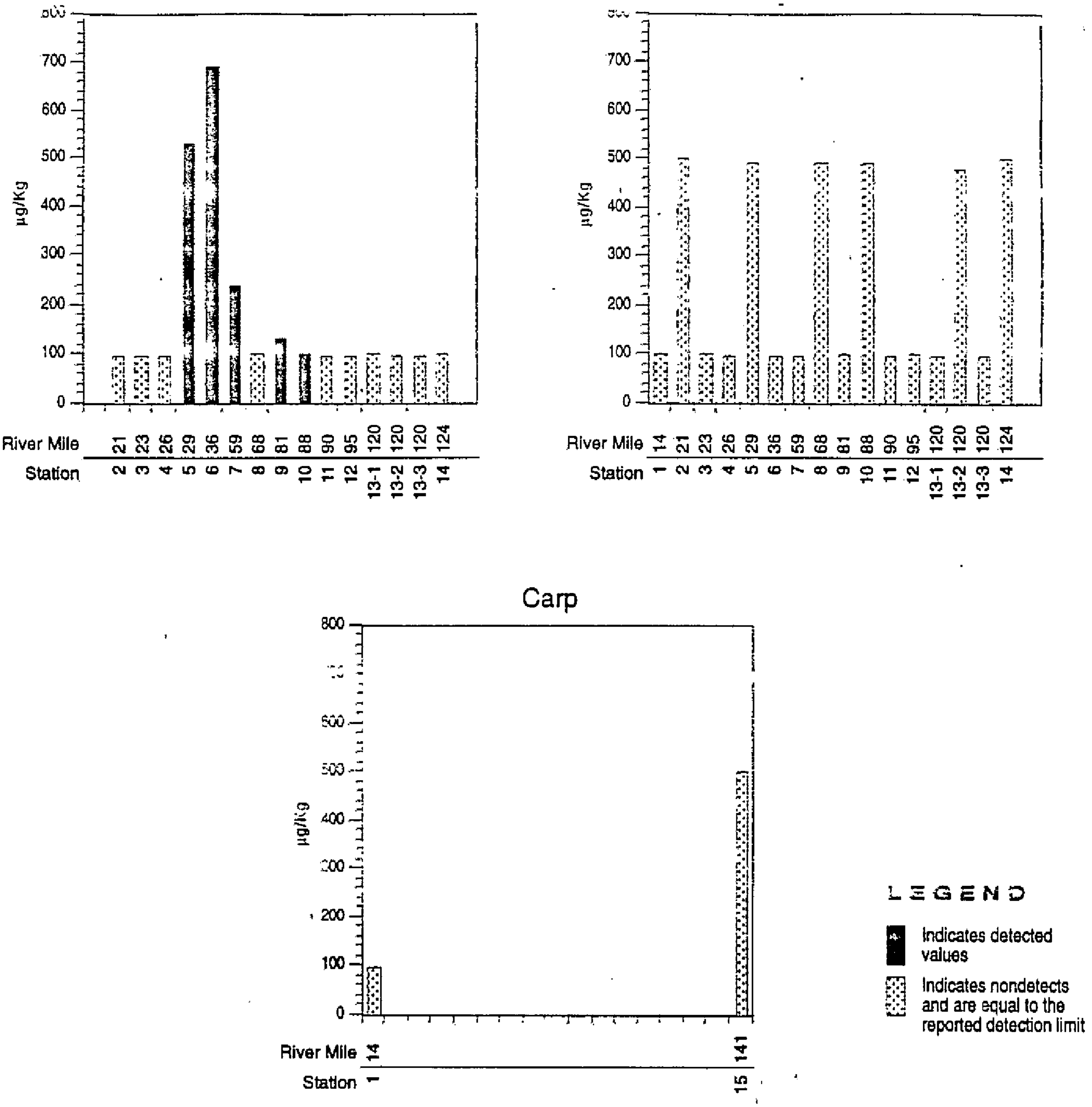


Figure 4-45. Phenol Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).

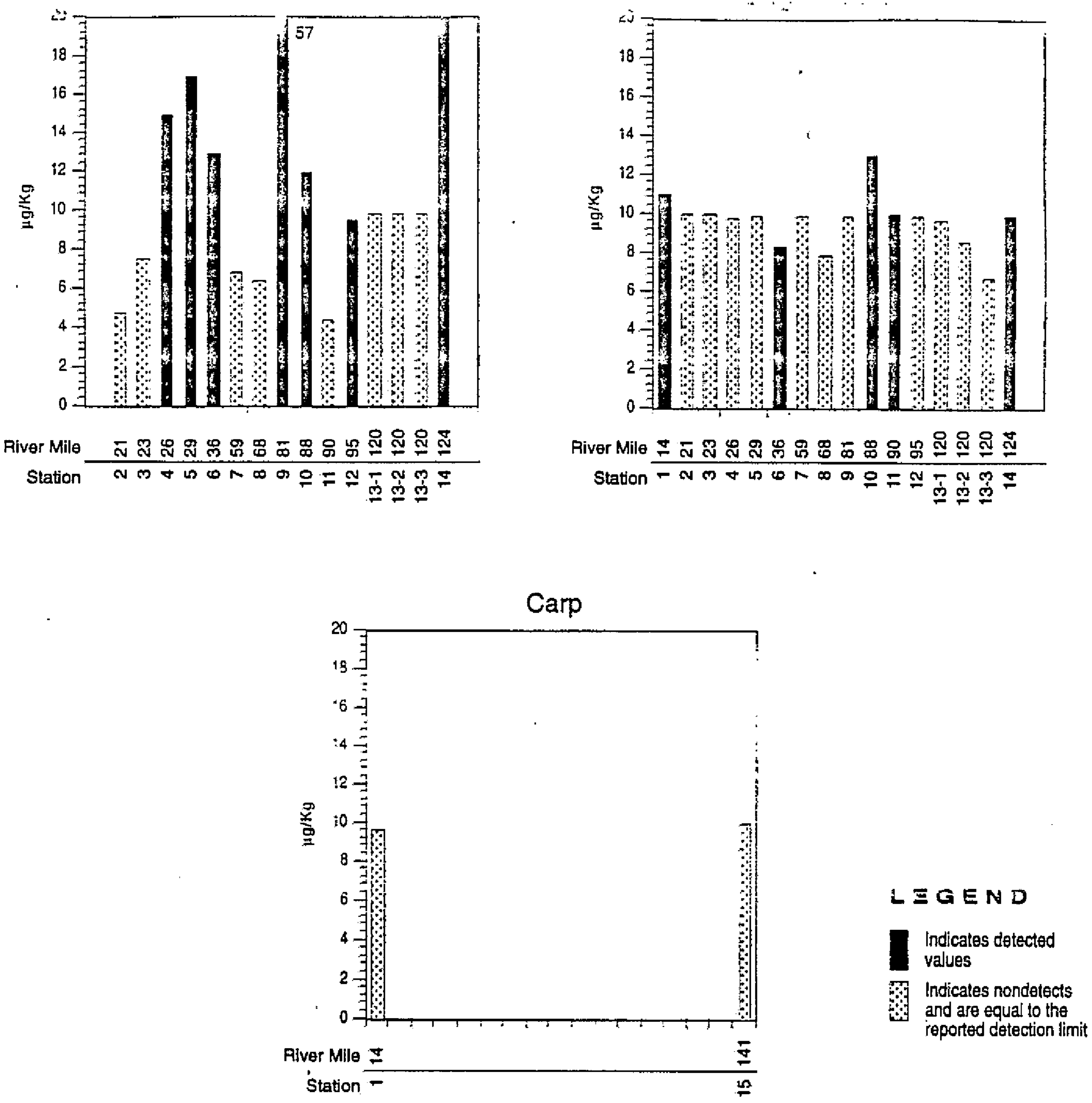


Figure 4-46. Naphthalene Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).

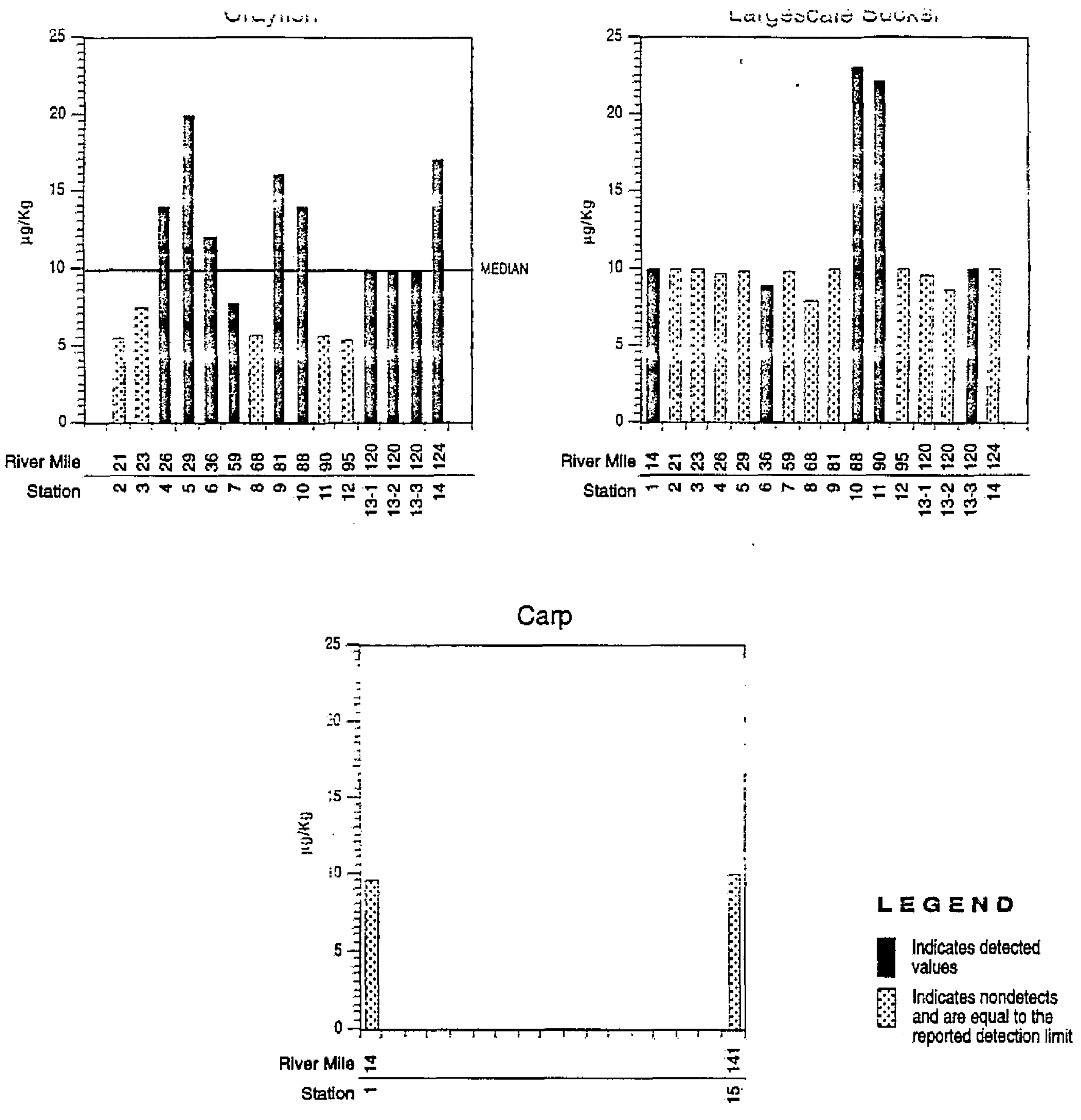


Figure 4-47. 2-Methylnaphthalene Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).

Burke Slough (Figure 4-46). Naphthalene was detected in 47% and 2-methylnaphthalene was detected in 62% of the crayfish samples. Acenaphthene, fluorene, and dibenzofuran were detected in one crayfish sample from Carrolls Channel (RM 68).

4.3.3.5 Chlorinated Naphthalene. The only chlorinated naphthalene compound measured was 2-chloronaphthalene (Table 4-21). This compound was not detected in any of the three species sampled. Detection limits ranged from 93 to 500 μg/kg.

4.3.3.6 Chlorinated Benzenes. Samples were analyzed for eight chlorinated benzene compounds (see Table 4-21). These compounds were not detected in any sample. Detection limits ranged from 93 to 500 μg/kg except for hexachlorocyclopentadiene, which ranged from 460 to 2,500 μg/kg.

Reference values were available for three of the chlorinated benzene compounds analyzed (1,2,4-trichlorobenzene, hexachlorobenzene, and hexachlorobutadiene). None of these compounds was detected. In general, the laboratory detection limits achieved for these compounds were adequate for comparison to the available reference levels, although 7 of the 16 sucker detection limits achieved for hexachlorobenzene were higher than the respective reference level.

4.3.3.7 Benzidines. Samples were analyzed for 3,3'-dichlorobenzidine (see Table 4-21). This compound was not detected in any sample. Detection limits ranged from 460 to 2,500 μg/kg.

4.3.3.8 Phthalate Esters. Samples were analyzed for six phthalate ester compounds (Table 4-21). None of these compounds was detected in the carp samples. The detection limits ranged from 93 to 7,400 μg/kg.

Di-n-butylphthalate was detected in one crayfish sample (240 μg/kg) collected from Lewis & Clark NWR and one largescale sucker sample (430 μg/kg) collected from Svensen Island (Figure 4-48). Bis(2-ethylhexyl)phthalate was detected in two sucker samples (Figure 4-49).

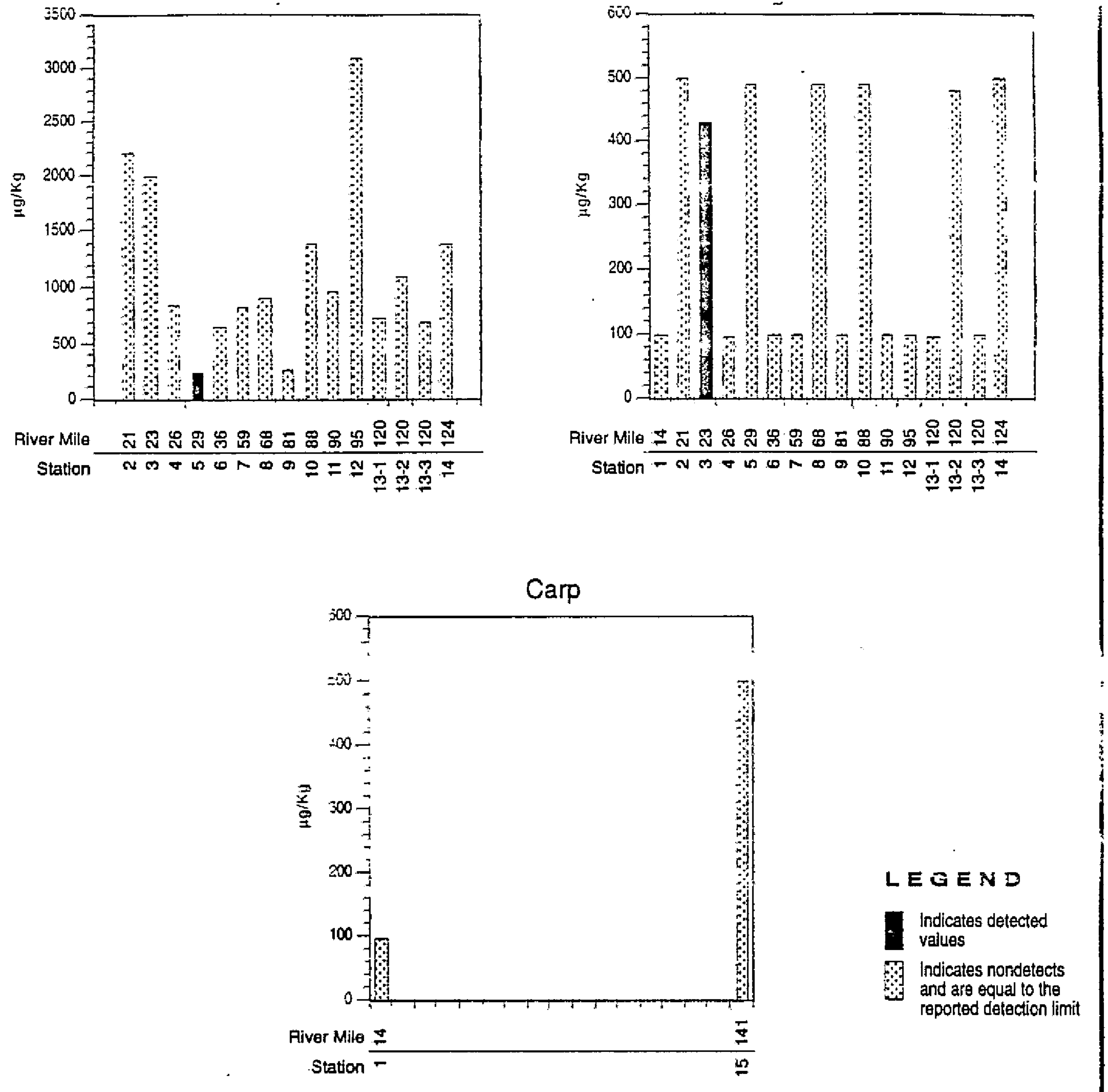


Figure 4-48. Di-n-butyl phthalate Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight)(Note: axes not on same scale).

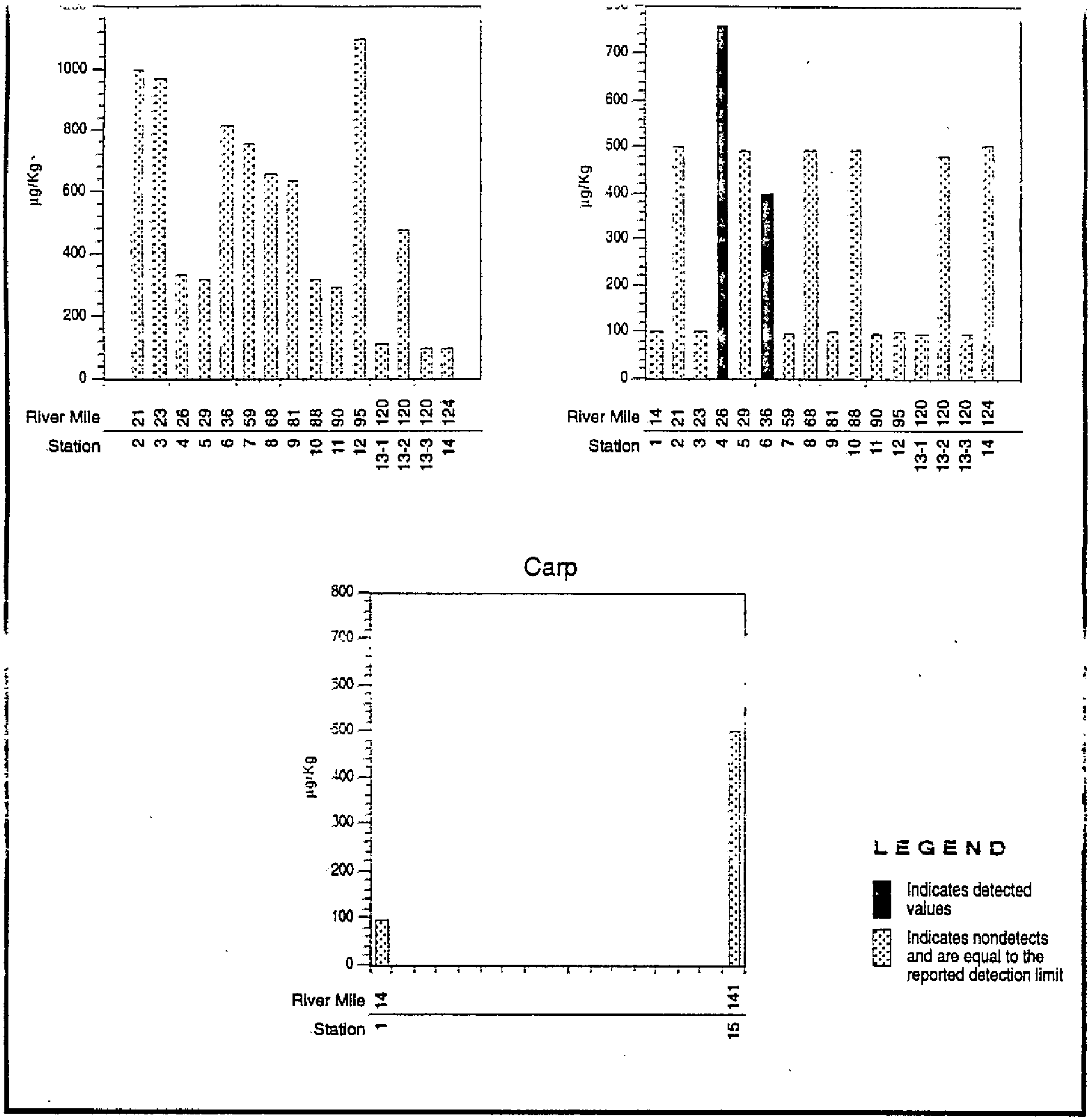


Figure 4-49. Bis(2-ethylhexyl)phthalate Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight). (NOTE: axes not on same scale)

detected Detection limits ranged from 93 to 500 μg/kg for the first four compounds listed above and 280 to 1,500 μg/kg for 4-chloroaniline (see Table 4-21)

4.3.3.10 Summary of Quality Assurance/Quality Control A total of 33 tissue samples were analyzed for semi-volatile organic compounds 15 crayfish, 16 sucker, and 2 carp samples Detection limits (excluding PAHs) were slightly higher than the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) due to matrix interference with the phthalate compounds detected in crayfish samples and the high lipid content of the fish samples Target detection limits for the analysis of PAHs were achieved using GC/MS in conjunction with selective ion monitoring Sample results qualified as undetected due to blank contribution included 8 naphthalene values for crayfish and 2 methylnaphthalene values for crayfish Several positive crayfish sample results were qualified as estimates due to the occurrence of internal standard recoveries outside of the advisory QC limits, including one detection each of acenaphthalene, dibenzofuran, and fluorene These data are considered suitable for use in this report

4.3.4 Pesticides and PCBs

Samples of all three species were analyzed for 26 pesticides and 6 Arochlor mixtures (PCBs) All values are reported on a wet-weight basis Tables 4-22 and 4-23 list compounds detected by species range of measured concentrations frequency of detection, and range of laboratory detection limits

4.3.4.1 Pesticides. Three of the 26 pesticides, (p p'-DDD, p,p'-DDE, and p,p'-DDT) were detected in tissue samples (see Table 4-22) DDT is an organochlorine pesticide that was banned from use in the United States in 1972 Prior to the ban, however, it was a widely used, low-cost agricultural insecticide Technical grade DDT was composed primarily of p,p'-DDT, but also contained up to 30% of the isomer o,p'-DDT Samples were analyzed for both isomers of DDT, o,p'-DDT was not detected, but p,p'-DDT was detected in all of the fish samples (Figure 4-50) DDT was not detected in the crayfish samples, which had a detection limit of 5 0 μg/kg The highest concentration of this pesticide (56 μg/kg) was measured in a sucker sample The five highest concentrations were collected found at Scappoose Bay, Camas Slough, Cathlamet Bay, Svensen Island, and Bachelor Island Slough Median concentrations were 10 5 and 3 8 μg/kg for sucker and carp samples, respectively

TABLE 4-22 PESTICIDES ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 1 of 2)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limit
Alpha-BHC	µg/kg	c	c	c	2 5
Beta-BHC	µg/kg	c	c	c	2 5 - 3 0
Delta-BHC	µg/kg	c	c	c	2 5 - 10
Lindane	µg/kg	c	c	c	2 5
Aldrin	µg/kg	c	c	c	2 5 - 38
Heptachlor	µg/kg	c	c	c	2 5
Heptachlor epoxide	µg/kg	c	c	c	2 5 - 22
Endosulfan I	µg/kg	c	c	c	2 5
Endosulfan II	µg/kg	c	c	c	5 0
Endosulfan sulfate	µg/kg	c	c	c	5 0
Dieldrin	µg/kg	c	c	c	5 0 - 65
Methoxychlor	µg/kg	c	c	c	25
p,p'-DDD	µg/kg	c	9 4 - 47 (16 / 16)[d]	20 - 21 (2 / 2)	5 0
p,p'-DDE	µg/kg	2 4 - 14 (14 / 15)	37 - 180 (16 / 16)	63 - 100 (2 / 2)	5 0
p,p'-DDT	µg/kg	c	4 0 - 56 (16 / 16)	3 7 - 3 9 (2 / 2)	5 0

TABLE 4-22 PESTICIDES ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 2 of 2)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limit
Endrin	µg/kg	c	c	c	5.0
Endrin ketone	µg/kg	c	c	c	5.0 - 200
Endrin aldehyde	µg/kg	c	c	c	5.0 - 6.0
Gamma-chlordane	µg/kg	c	c	c	2.5 - 44
Alpha-chlordane	µg/kg	c	c	c	2.5 - 6.0
Toxaphene	µg/kg	c	c	c	250
o,p'-DDE	µg/kg	c	c	c	5.0 - 130
o,p'-DDD	µg/kg	c	c	c	5.0 - 260
o,p'-DDT	µg/kg	c	c	c	5.0 - 210
Dicofol	µg/kg	c	c	c	26 - 62
Methyl parathion	µg/kg	c	c	c	26 - 62

---

[a] Reported results are on a wet weight basis

[b] Detection limit range includes only those samples reported as undetected

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set

TABLE 4-23 PCBs ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limi
Aroclor 1221	µg/kg	c	c	c	100 - 110
Aroclor 1232	µg/kg	c	c	30 (1 / 2)[d]	50 - 52
Aroclor 1242/1016	µg/kg	c	c	c	50 - 52
Aroclor 1248	µg/kg	c	c	c	50 - 52
Aroclor 1254	µg/kg	c	26 - 2700 (16 / 16)	36 - 65 (2 / 2)	50
Aroclor 1260	µg/kg	30 (1 / 15)	27 - 56 (8 / 16)	30 (1 / 2)	50 - 250
Total PCBs	µg/kg	30 (1 / 15)	26 - 2700 (16 / 16)	36 - 95 (2 / 2)	100

[a] Reported results are on a wet weight basis

[b] Detection limit range includes only those samples reported as undetected

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set

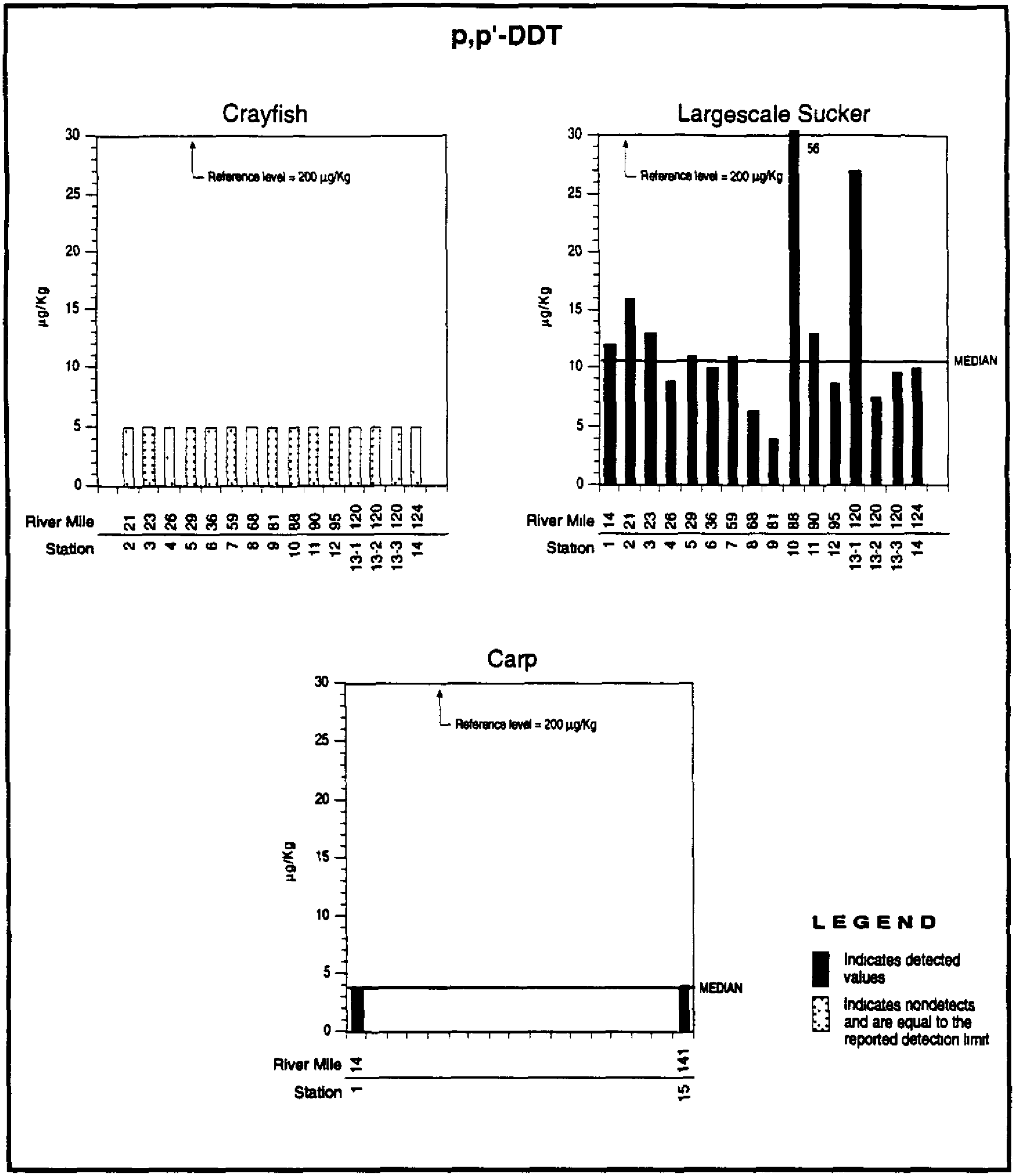


Figure 4-50. p,p'-DDT Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).

DDD is an organochlorine insecticide that was used less frequently than DDT, and also a degradation product of DDT. Biota samples were analyzed for two isomers of DDD: o,p'-DDD and p,p'-DDD (see Table 4-22), o,p'-DDD was not detected in any of the three species, but p,p'-DDD was detected in all of the fish samples (Figure 4-51). The highest concentration of this isomer (47 µg/kg) was measured in a sucker sample from Bachelor Island Slough (RM 90). Five of the seven highest concentrations were collected at stations between RM 88 and RM 124. DDD was not detected in any crayfish sample. Median concentrations of p,p'-DDD were 25.0 and 20.5 µg/kg for sucker and carp samples, respectively. Detection limits for the crayfish sample analyses were 5.0 µg/kg.

DDE is a degradation product of DDT not produced commercially. Biota samples were analyzed for two isomers of DDE: o,p'-DDE and p,p'-DDE (Table 4-22), o,p'-DDE was not detected, but p,p'-DDE was detected in all fish samples and 93% of the crayfish samples (Figure 4-52). The highest concentration (180 µg/kg) was measured in a sucker sample from Camas Slough. Fish samples with the 7 highest concentrations were collected from sampling locations dispersed throughout the study area. Four of the five highest concentrations measured in crayfish samples occurred between RM 90 and RM 124. Median concentrations were 5.0, 95.5, and 81.5 for crayfish, sucker, and carp samples respectively.

The CV of mean pesticide concentration in crayfish and sucker samples from Camas Slough could be determined for a limited number of compounds for each species. The CV of mean p,p'-DDE concentration in crayfish samples was 13.1%. The CV of mean p,p'-DDE concentration in sucker samples was 45.5%. The CVs of mean p,p'-DDT and p,p'-DDD concentration in sucker samples were 72.8 and 19.1% respectively. The relatively high CV for p,p'-DDT may have been due in part to analytical variability: the highest the three field replicate results was qualified for exceeding continuing calibration criteria.

Reference levels are available for 13 of the 26 pesticides analyzed (see Table 2-8). Laboratory detection limits achieved for the pesticide analyses were adequate for comparison to these reference levels except for o,p'-DDD and o,p'-DDT in one sucker sample analysis. Concentrations of individual DDT compounds did not exceed the 200 µg/kg reference level for potential adverse effects on fish-eating wildlife.

4.3.4.2 PCBs. Three PCB Arochlor mixtures were detected in biota samples: Arochlor 1232, Arochlor 1254, and Arochlor 1260 (see Table 4-23). Arochlor 1232 was detected in one carp sample (30 µg/kg)

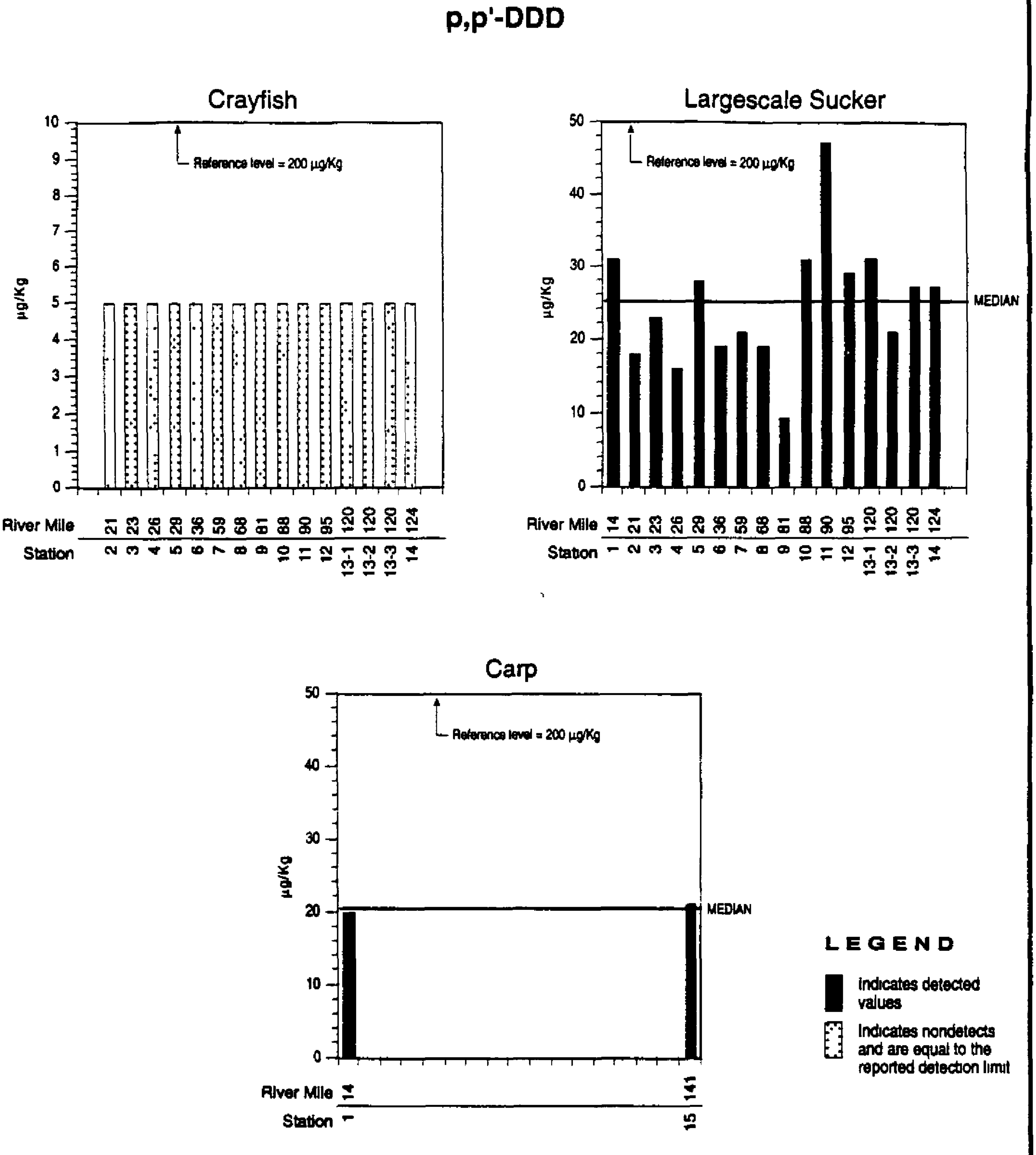


Figure 4-51. p,p'-DDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight)(Note: axes not on same scale).

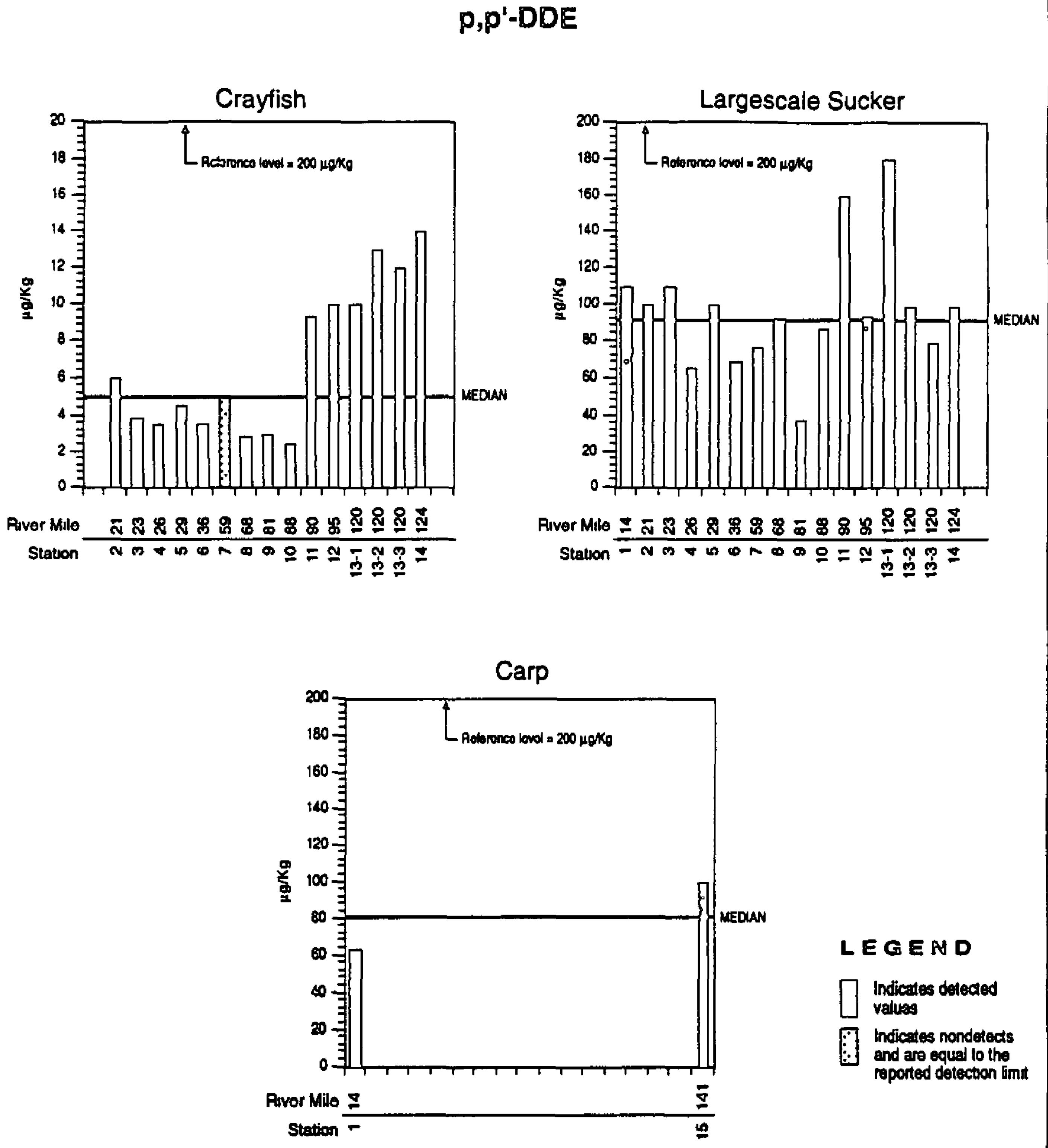


Figure 4-52. p,p'-DDE Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight)(Note: axes not on same scale).

but no crayfish or sucker samples The detection limit for Arochlor mixtures in all three species ranged from 50 to 250 μg/kg

Arochlor 1254 was detected in all of the fish samples, but no crayfish samples (Figure 4-53). Samples with the five highest concentrations were collected from Scappoose Bay, Camas Slough, Youngs Bay, Bachelor Island Slough, and Cathlamet Bay Concentrations ranged from 26 to 170 μg/kg except for one sucker sample which had a concentration of 2,700 μg/kg (see Table 4-23) The median concentrations for sucker and carp were 58 5 and 41 0 μg/kg respectively

Arochlor 1260 was detected in 56% of the sucker samples, one carp sample, and no crayfish samples (Figure 4-54) The five highest concentrations were collected from Camas Slough, Youngs Bay, Cathlamet Bay, Bachelor Island Slough, and Svensen Island; concentrations ranged from 30 to 56 μg/kg Median concentrations for sucker and carp samples were 52 and 41 μg/kg, respectively Arochlors 1260 and 1254 had four stations in common among their respective top five concentrations Youngs Bay, Cathlamet Bay, Bachelor Island Slough, and Camas Slough. These stations are distributed throughout the study area, from RM 14-120

Arochlor 1254 was the only PCB mixture detected in triplicate samples from Camas Slough. It was detected in the sucker samples, with a CV of 84 2% Concentrations ranged from 26 to 170 μg/kg, encompassing the range of PCB concentrations measured in all sucker samples except that from Scappoose Bay Inter-station variation in Arochlor 1254 concentration in sucker samples may not indicate any true difference between stations except for the Scappoose Bay sample.

A reference value for total PCBs (110 μg/kg) was available evaluate survey data to assess potential adverse effects to fish-eating wildlife Laboratory detection limits for individual PCB Arochlor mixtures were near to or higher than this reference value. Only concentrations greater than the laboratory detection limit were summed for comparison to the reference value Based on this analysis, the total PCB concentration exceeded the reference value at one station, Scappoose Bay, due to the high concentration of Arochlor 1254 (2,700 μg/kg) measured in the sucker sample.

4.3.4.3 Summary of Quality Assurance/Quality Control A total of 33 biota samples were analyzed for pesticides and PCBs· 15 crayfish samples, 16 sucker samples, and 2 carp samples. The detection limits

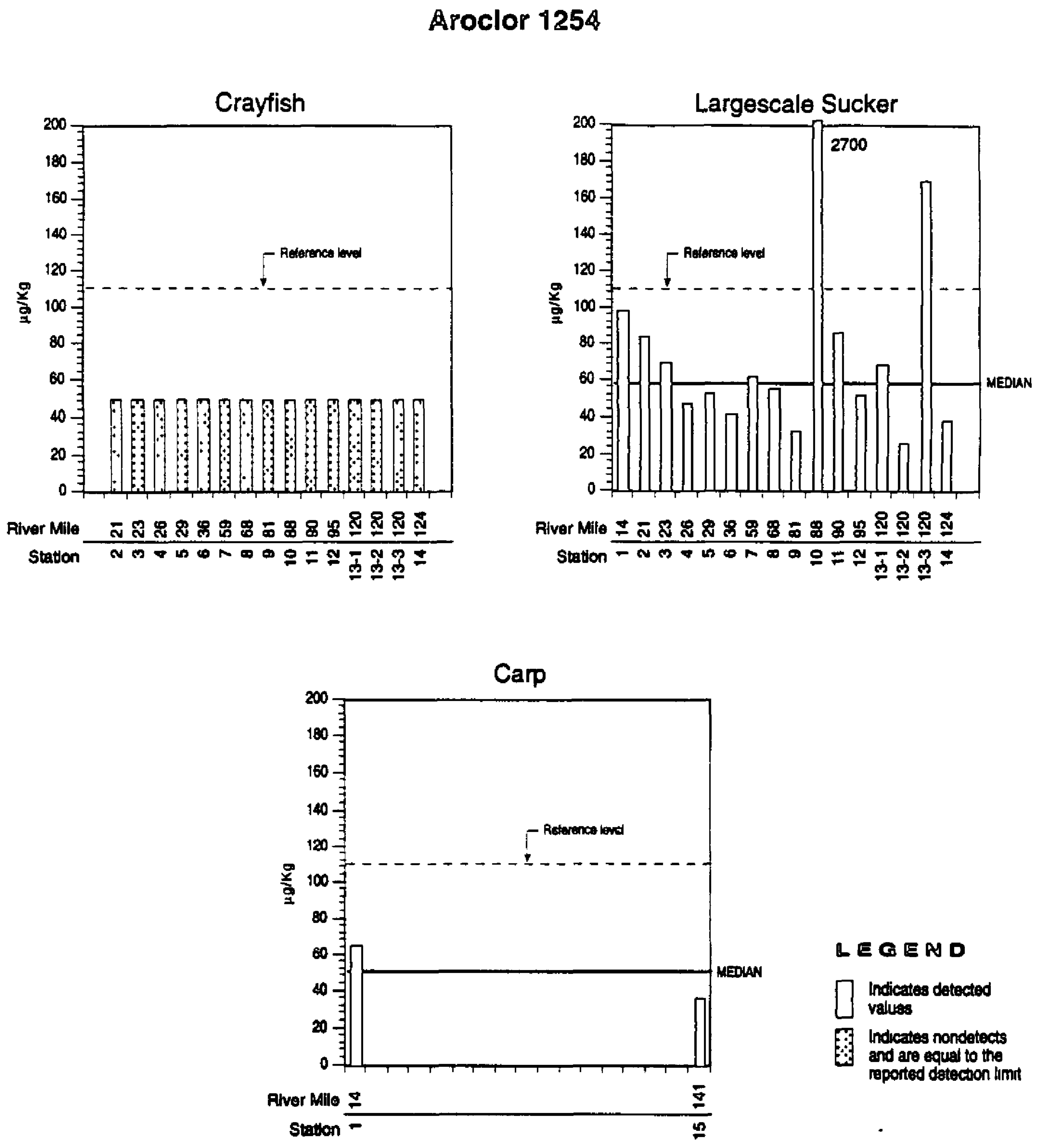
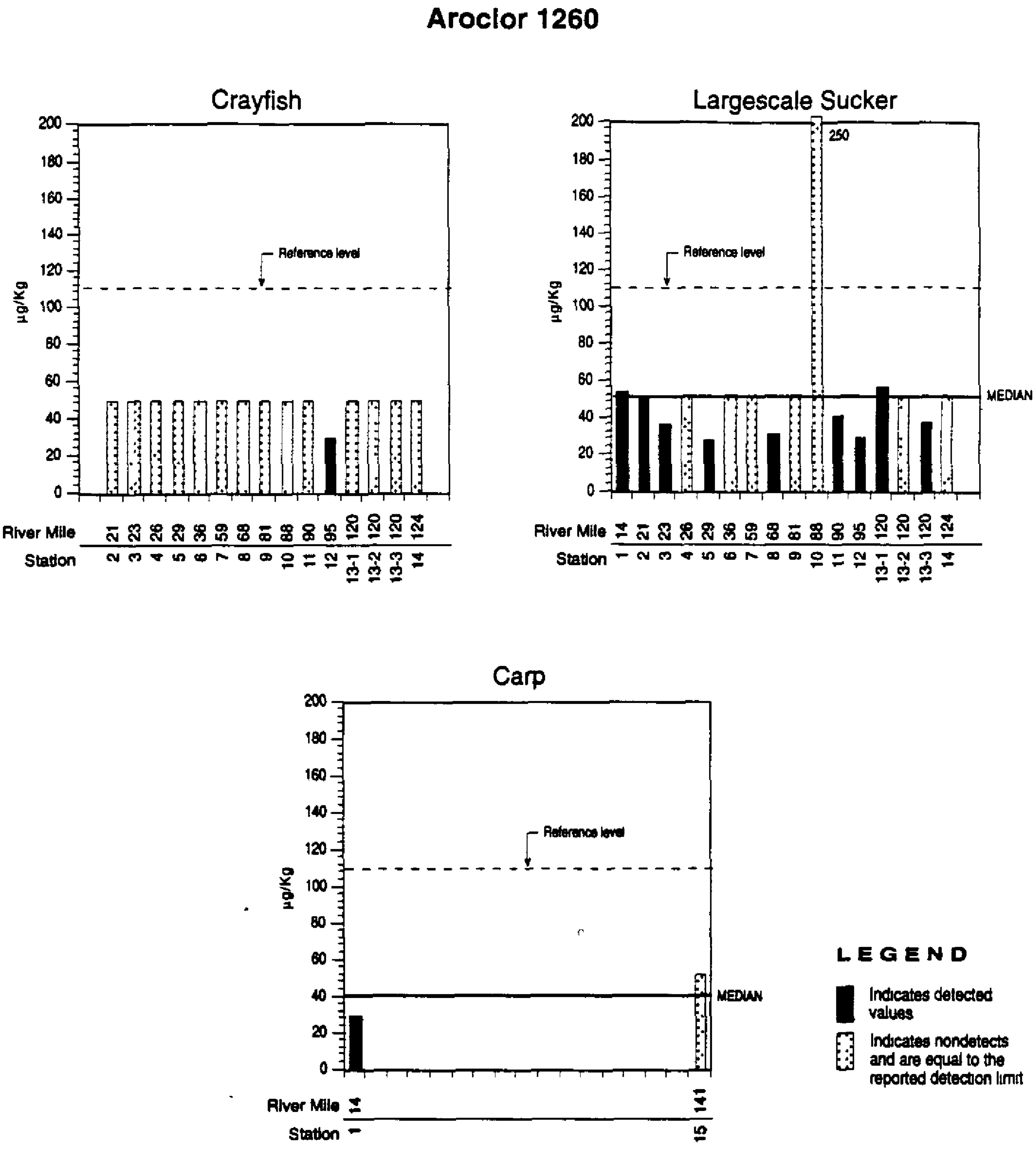


Figure 4-53. Aroclor 1254 Concentrations in Whole-Body Composite Biota Samples collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).


Aroclor 1260

Crayfish

Largescale Sucker

Carp

Figure 4-54. Aroclor 1260 Concentrations in Whole-Body Composite Biota Samples collected for the 1993 Backwater Reconnaissance Survey (µg/kg wet weight).

reported by the laboratory were slightly higher than those specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) due to matrix interference Several positive results for p,p'-DDT n the fish samples were qualified as estimates based upon exceedance of continuing calibration limits The data are considered suitable for use in this report.

4.3.5 Dioxin and Furans

Samples of all three species were analyzed for 7 dioxin and 10 furan congeners All values are reported on a wet weight basis Table 4-24 lists compounds detected by species, concentration range of detectable values, frequency of detection, and range of detection limits.

4.3.5.1 Dioxin Congeners. All dioxin congeners were detected in at least one of the species analyzed with the exception of 1,2,3,7,8,9-HxCDD, not detected in any sample. The most toxic member of this group of compounds, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD), was detected in 20% of the crayfish samples and 12% of the sucker samples (Figure 4-55) Concentrations ranged from 0 7 to 1.0 ng/kg, with the highest concentration measured in a crayfish sample from Elochoman Slough.

Five other dioxin congeners were detected in biota samples: 1,2,3,7,8-PeCDD; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDD; 1,2,3,4,6,7,8,-HpCDD; and OCDD (Figures 4-56 through 4-59). The congener 1,2,3,7,8-PeCDD was detected in one sucker sample (0.5 ng/kg) from Camas Slough; 1,2,3,4,7,8-HxCDD (Figure 4-56) and 1,2,3,6,7,8-HxCDD (Figure 4-57) were detected in three and two sucker samples respectively; both of these were also detected in one carp sample. All fish samples contained detectable levels of 1,2,3,4,6,7,8-HpCDD (Figure 4-58); concentrations ranged from 0 4 to 3.8 ng/kg with the highest found in a carp sample from Youngs Bay This congener was not detected in any crayfish sample OCDD was also detected in all fish samples and two crayfish samples (Figure 4-59) The concentrations ranged from 1.5 to 36 9 ng/kg with the highest detected in a sucker sample from Svensen Island.

4.3.5.2 Furan Congeners Eight furan congeners were detected in crayfish and fish samples. The most toxic congener, 2,3,7,8-PeCDF, was detected in two sucker samples (1.0 and 1.8 ng/kg) and one carp sample (0.2 ng/kg) (Figure 4-60). The congeners 1,2,3,7,8-PeCDF, 1,2,3,7,8,9-HxCDF; and 2,3,4,6,7,8-HxCDF were detected in the majority of the fish samples with concentrations ranging from 0.3 to 9 9 ng/kg, and median concentrations of 1.6, 1.65, and 0.55 ng/kg for largescale sucker, and 3.1,

TABLE 4-24 DIOXINS AND FURANS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 1 of 2)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
DIOXINS					
2,3,7,8-TCDD	ng/kg	0 7 - 1 0 (3 / 15)[d]	0 7 - 0 9 (2 / 16)	c	0 1 - 1 8
1,2,3,7,8-PeCDD	ng/kg	c	0 5 (1 / 16)	c	0 1 - 2 3
1,2,3,4,7,8-HxCDD	ng/kg	c	0 3 - 0 5 (3 / 16)	0 3 (1 / 2)	0 2 - 1 9
1,2,3,6,7,8-HxCDD	ng/kg	c	0 5 - 0 6 (2 / 16)	0 6 (1 / 2)	0 2 - 2 1
1,2,3,7,8,9-HxCDD	ng/kg	c	c	c	0 1 - 2 5
1,2,3,4,6,7,8-HpCDD	ng/kg	c	0 4 - 2 6 (16 / 16)	1 2 - 3 8 (2 / 2)	0 3 - 2 3
OCDD	ng/kg	6 7 - 23 7 (2 / 15)	1 5 - 36 9 (16 / 16)	3 9 - 7 5 (2 / 2)	0 5 - 2 8
FURANS					
2,3,7,8-TCDF	ng/kg	0 63 - 2 62 (15 / 15)	1 6 - 6 5 (15 / 16)	3 6 - 3 9 (2 / 2)	2 1
1,2,3,7,8-PeCDF	ng/kg	c	0 3 - 9 9 (12 / 16)	2 3 - 3 9 (2 / 2)	0 1 - 2 1
2,3,4,7,8-PeCDF	ng/kg	c	1 0 - 1 8 (2 / 16)	0 2 (1 / 2)	0 1 - 2 8
1,2,3,4,7,8-HxCDF	ng/kg	c	c	c	0 1 - 2 6
1,2,3,6,7,8-HxCDF	ng/kg	c	5 2 (1 / 16)	c	0 1 - 2 7

TABLE 4-24 DIOXINS AND FURANS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY[a]

(Page 2 of 2)

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
FURANS					
1,2,3,7,8,9-HxCDF	ng/kg	c	0 8 -4 5 (15 / 16)	2 3 - 2 5 (2 / 2)	0 2 - 1 9
2,3,4,6,7,8-HxCDF	ng/kg	c	0 3 - 5 2 (13 / 16)	0 7 - 1 0 (2 / 2)	0 1 - 1 1
1,2,3,4,6,7,8-HpCDF	ng/kg	5 2 (1 / 15)	0 4 - 5 5 (4 / 16)	c	0 2 - 5 6
1,2,3,4,7,8,9-HpCDF	ng/kg	c	c	c	0 2 - 3 1
OCDF	ng/kg	c	0 3 - 2 7 (6 / 16)	c	0 1 - 1 5
TEC[e]	ng/kg	0 34 - 1 55	0 92 - 3 14	1 41 - 2 07	NA

[a] Reported results are on a wet weight basis

[b] Detection limit range includes only those samples reported as undetected.

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set.

[e] TEC values were calculated using half the lower detection limit for undetected congeners

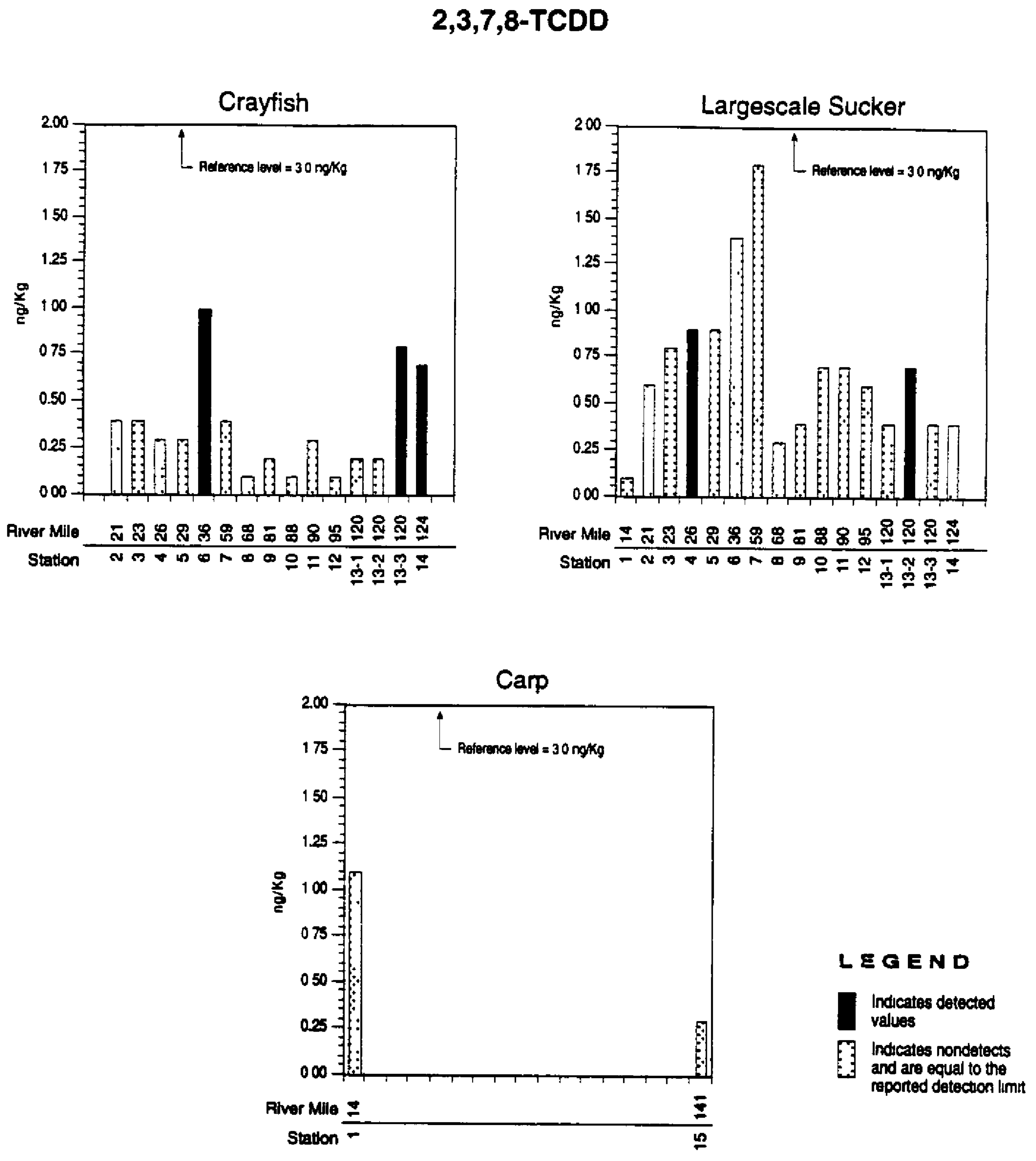


Figure 4-55. 2,3,7,8-TCDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

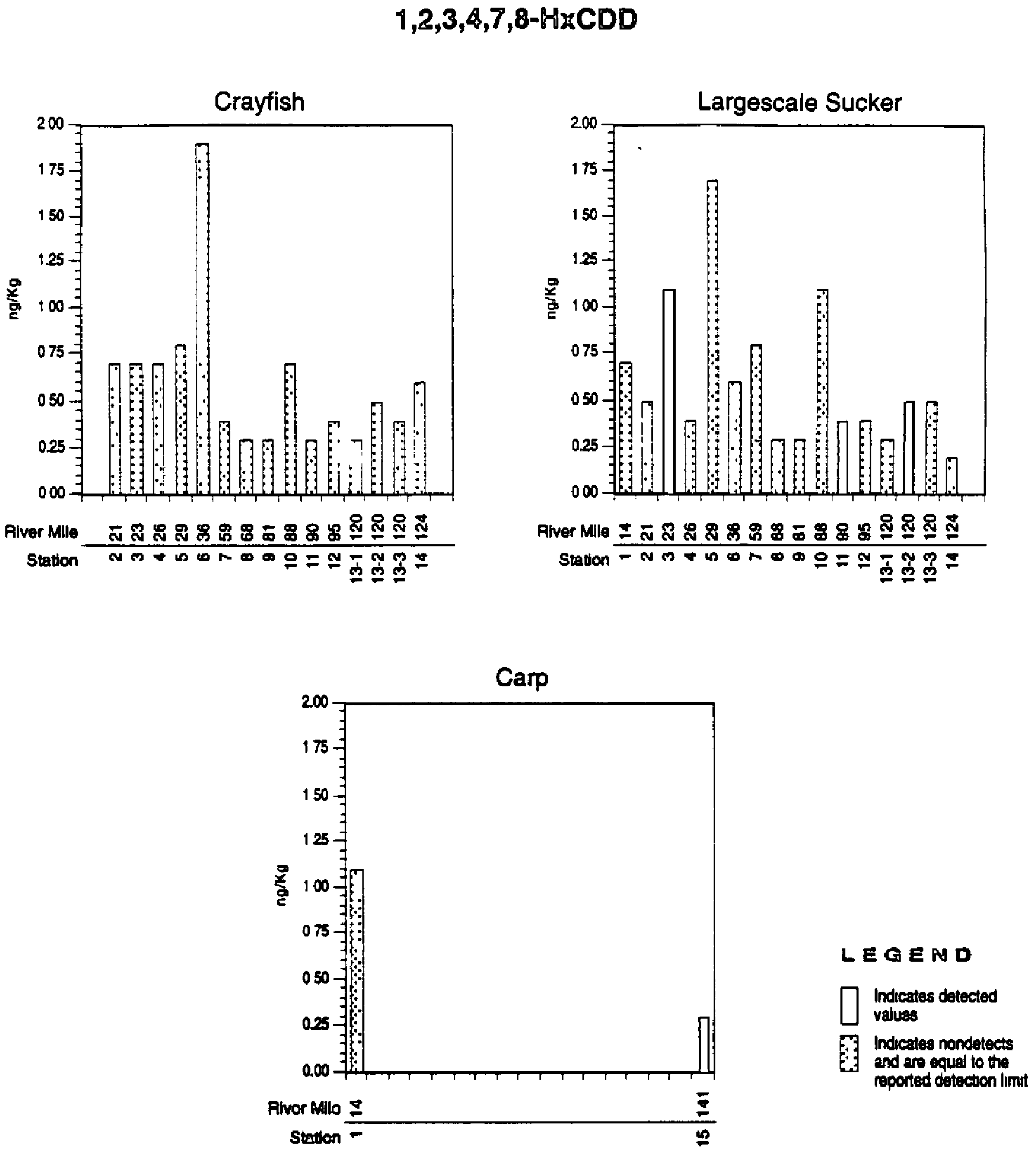


Figure 4-56. 1,2,3,4,7,8-HxCDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

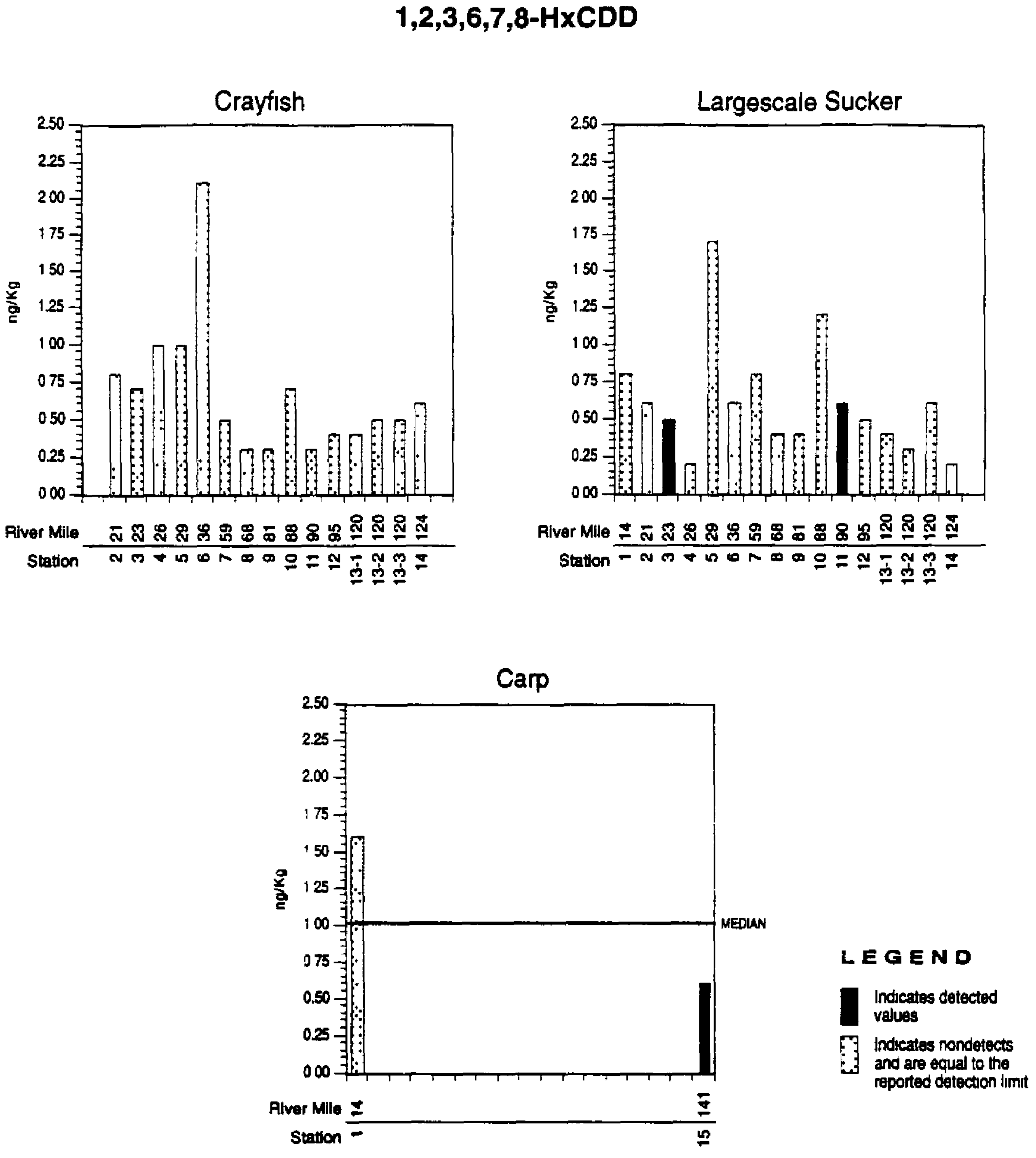


Figure 4-57. 1,2,3,6,7,8-HxCDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

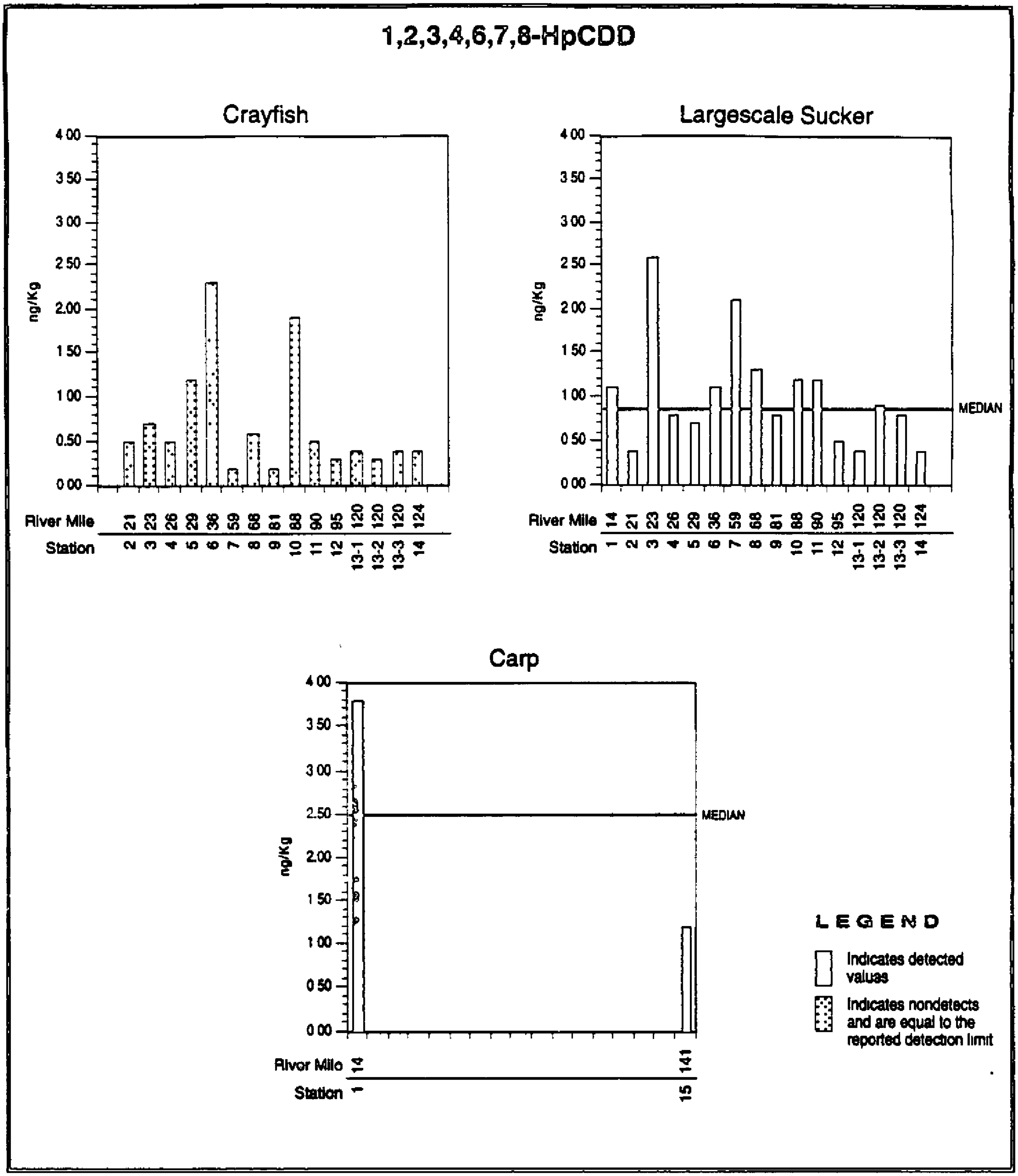


Figure 4-58. 1,2,3,4,6,7,8-HpCDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

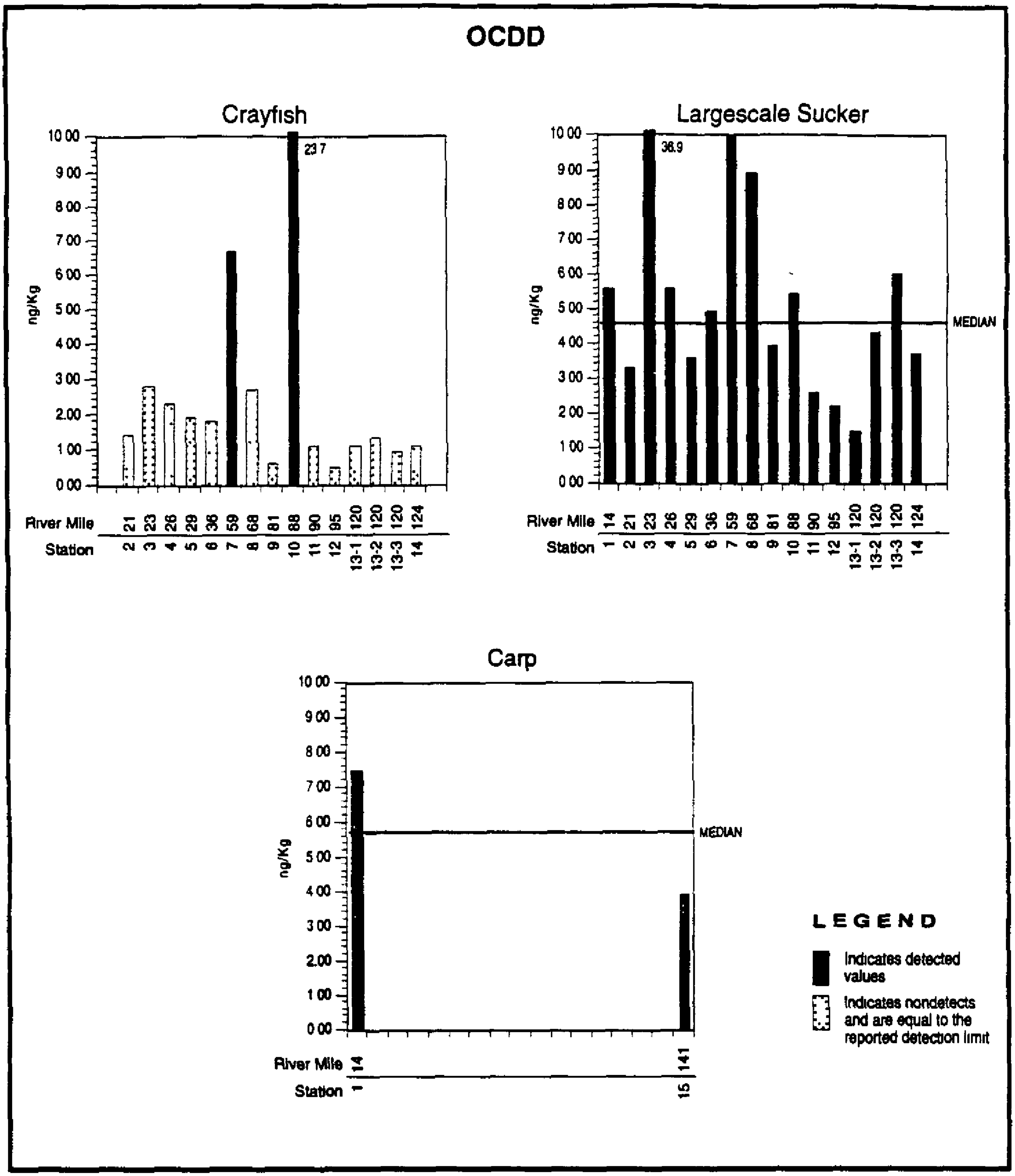


Figure 4-59. OCDD Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

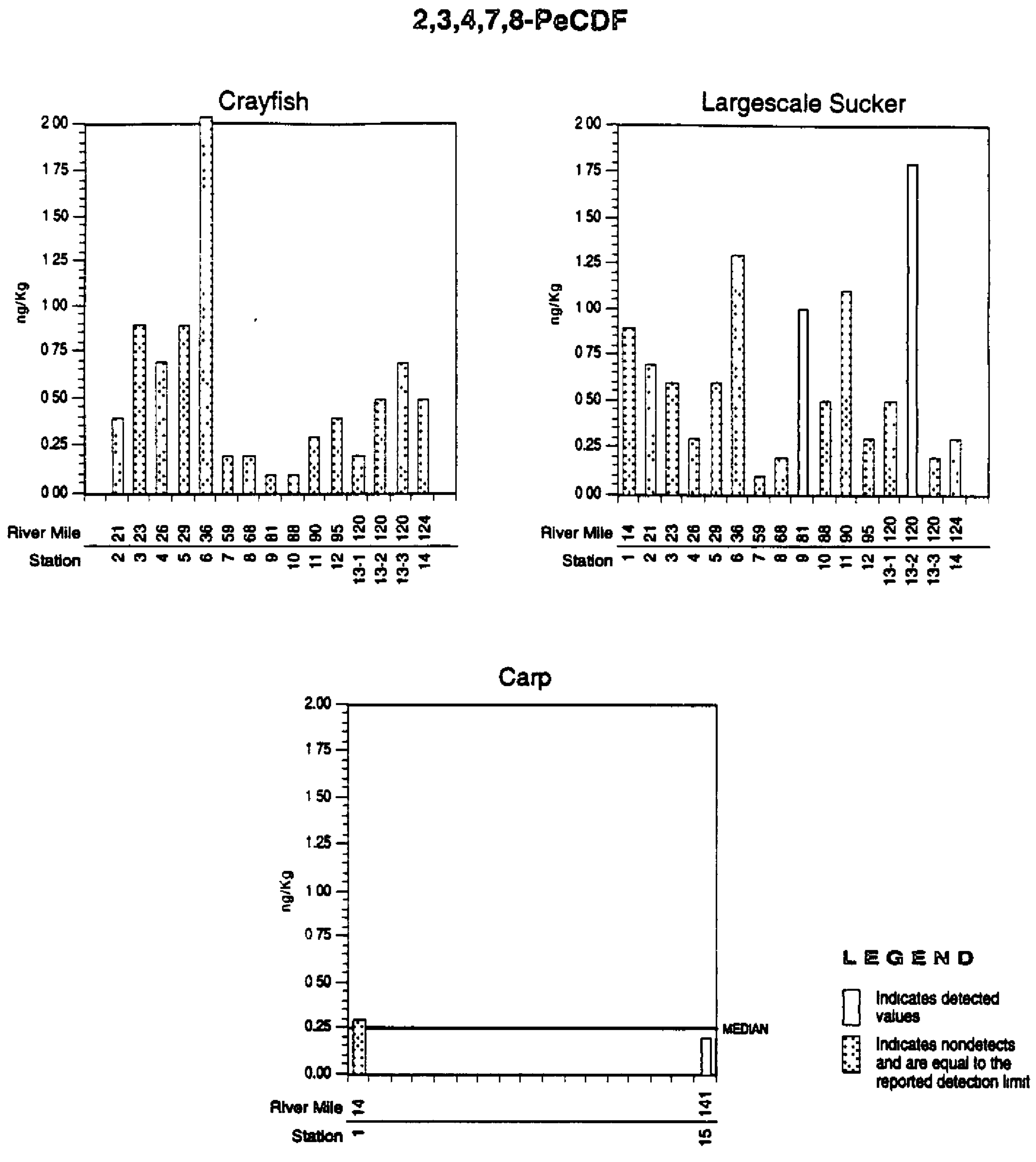


Figure 4-60. 2,3,4,7,8-PeCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

2 4, and 0 85 ng/kg for carp, respectively (Figures 4-61 through 4-63) The highest concentrations of 1,2,3,7,8-PeCDF and 2,3,4,6,7,8-HxCDF were found at Young's Bay The highest concentration of 1,2,3,7,8,9-HxCDF was in a sample from Cathlamet Bay The furan congeners OCDF (Figure 4-64) and 1,2,3,6,7,8-HxCDF (one detected value) were detected in sucker samples with concentrations ranging from 0 3 to 5 2 ng/kg The congener 1,2,3,4,6,7,8-HpCDF was detected in one crayfish sample (5 2 ng/kg) and four sucker samples (0 4 to 5 5 ng/kg) (Figure 4-65) The congener 2,3,7,8-TCDF was detected in all the biota samples except for one sucker sample (Figure 4-66); concentrations ranged from 0 63 to 6 5 ng/kg with median concentrations of 1 5, 3 95, and 3 75 ng/kg for crayfish, sucker, and carp respectively

The only dioxin or furan congener detected in the three crayfish samples from Camas Slough was 2,3,7,8-TCDF, the CV was 20 5% Five dioxin and furan congeners were detected in all three sucker samples collected from this station. The CVs of the mean concentrations of 1,2,3,4,6,7,8-HpCDD, OCDD, 2,3,7,8-TCDF, 1,2,3,7,8,9-HxCDF, and 2,3,4,6,7,8-HxCDF were 37 8, 57 8, 42 7, 41 8, and 20 4%, respectively The high variation of the field data indicate that only relatively large differences in these concentrations may be due to inter-station rather than intra-station variability

4.3.5.3 Toxicity Equivalency Concentrations Toxicity equivalency factors (TEFs) for dibenzo-*p*-dioxins and dibenzofurans have been developed as a method for estimating the hazard and dose-response of complex mixtures containing dioxin and furan congeners in addition to TCDD (Barnes 1991) Each congener is assigned a toxicity relative to TCDD (i e , their TEF) The concentration of each congener is then multiplied by its TEF and the sum of these products for all dioxin and furan congeners is the overall toxicity equivalency concentration (TEC)

TECs calculated for the three species collected for this survey are shown in Figure 4-67 For the calculation of TECs, non-detect values were assigned values equal to half the detection limit Sucker had the highest TECs, followed by carp and crayfish. Median concentrations were 0.82, 1 71, and 1 74 ng/kg for crayfish, largescale sucker, and carp, respectively. The median lipid-normalized TECs were 0 078, 0 047, and 0 041 ng/g lipid for crayfish, largescale sucker, and carp, respectively.

Table 4-25 gives the percentage of the total mean TEC for sediment, crayfish, and fish represented by each of the 17 dioxin and furan congeners. For each sample type, two calculation methods are compared

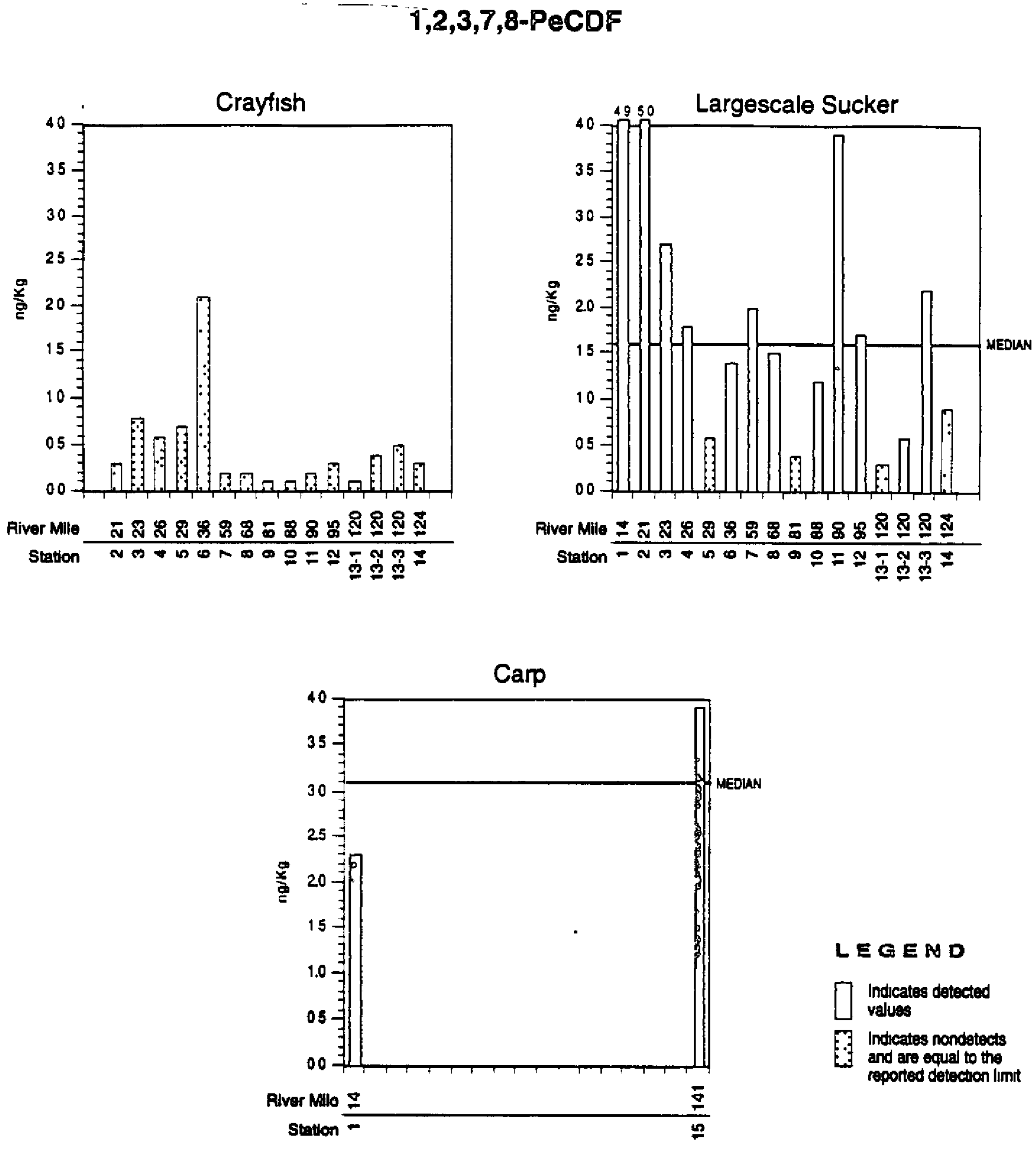


Figure 4-61. 1,2,3,7,8-PeCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

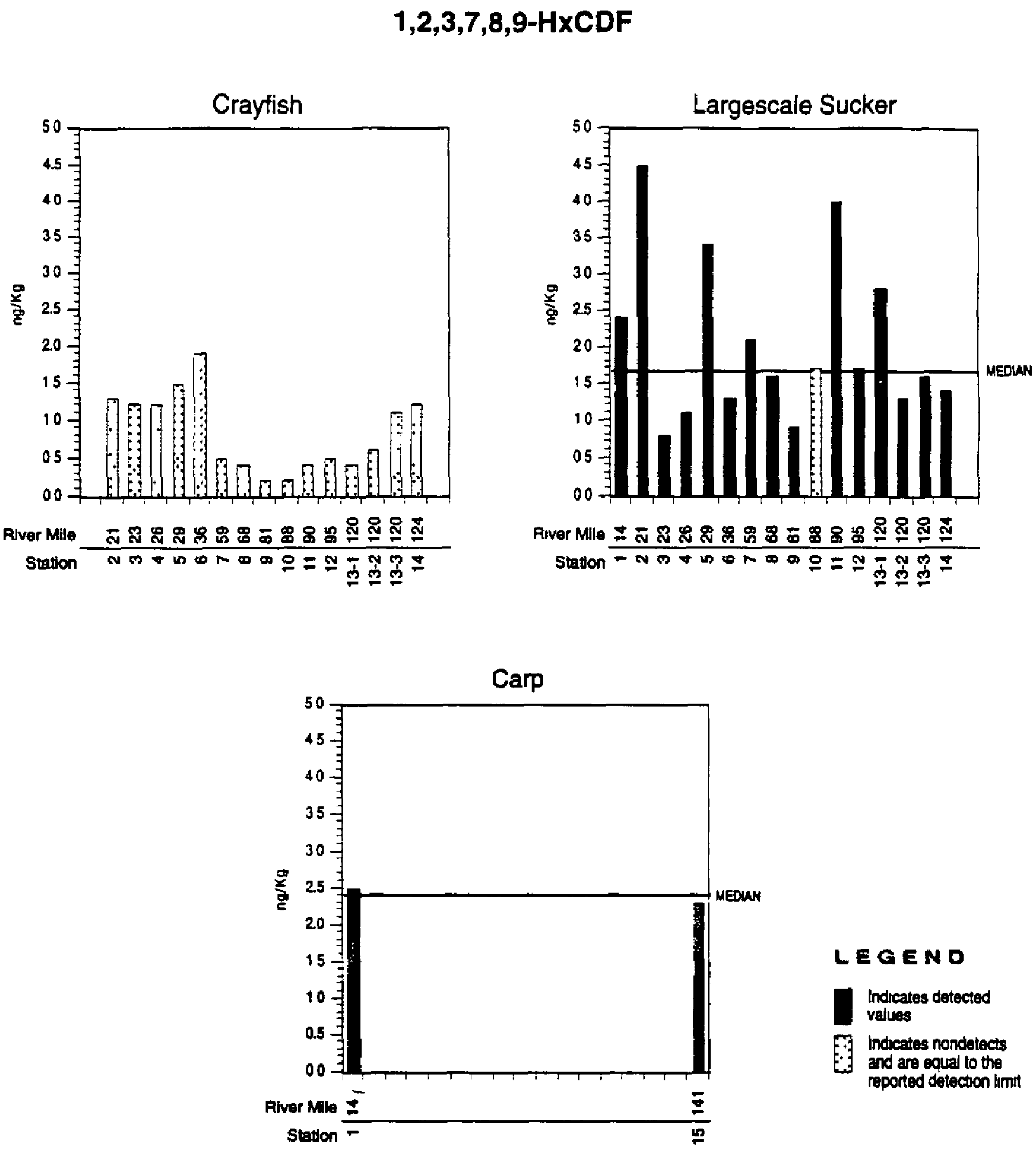


Figure 4-62. 1,2,3,7,8,9-HxCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

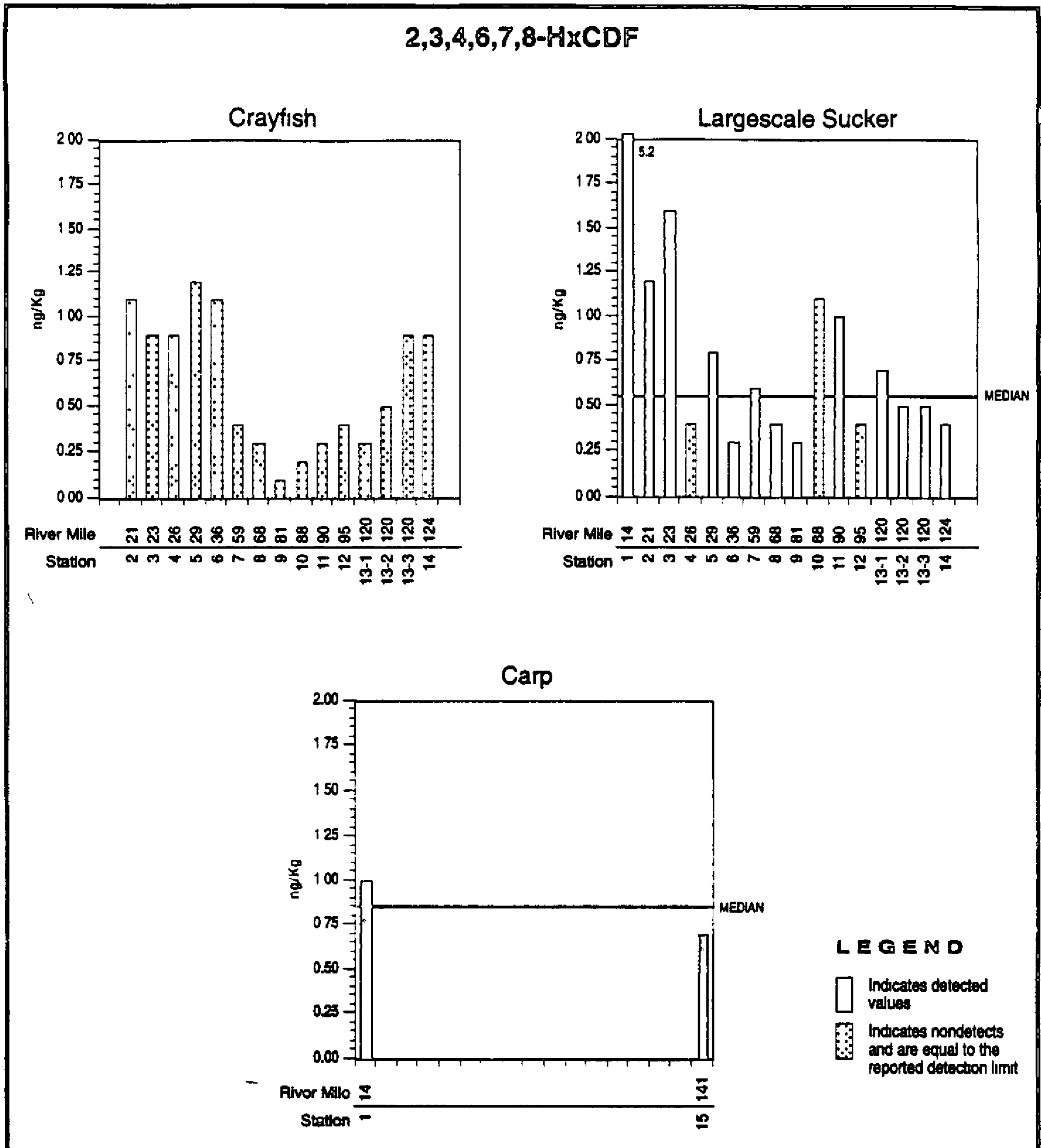


Figure 4-63. 2,3,4,6,7,8-HxCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

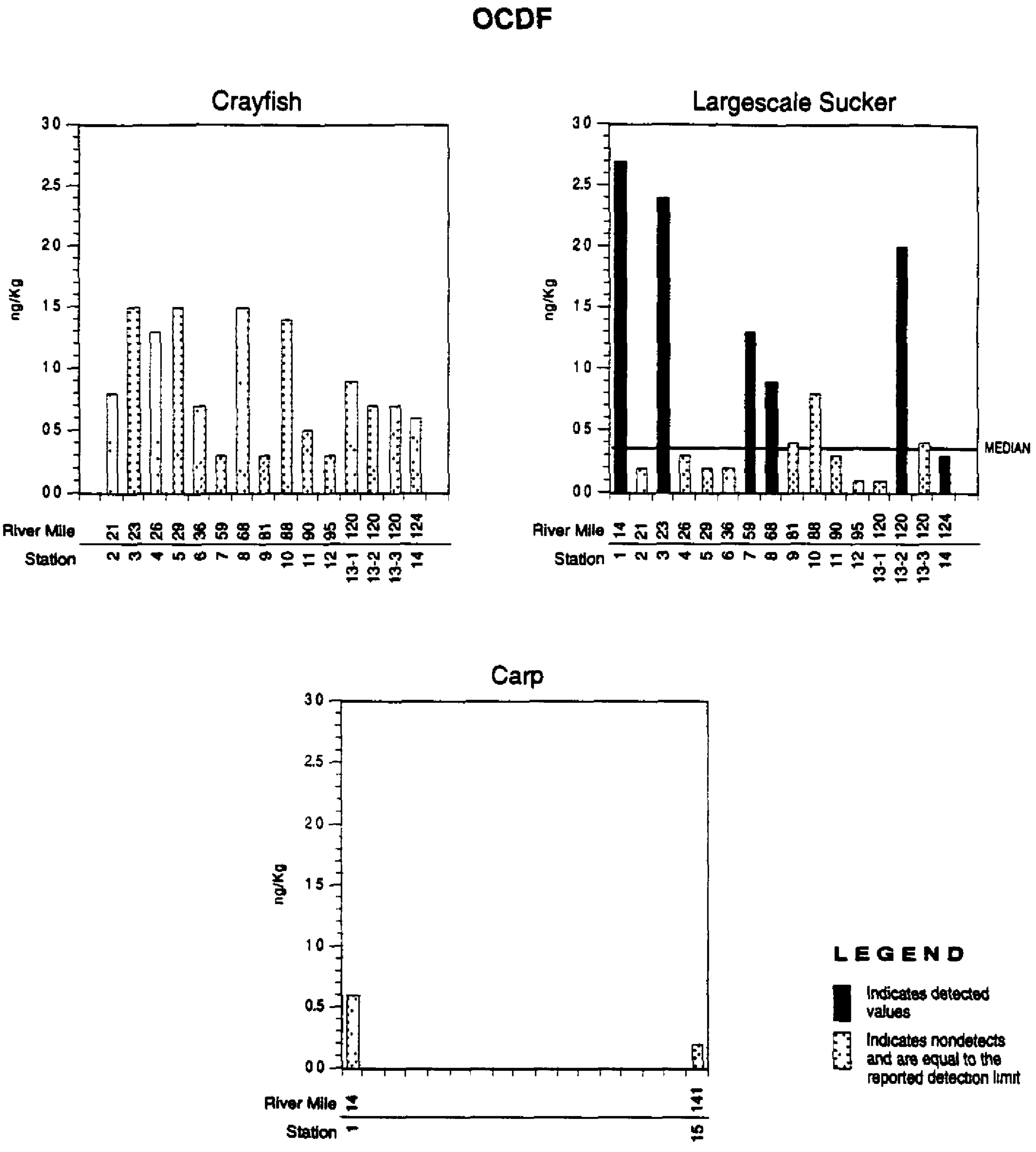


Figure 4-64. OCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

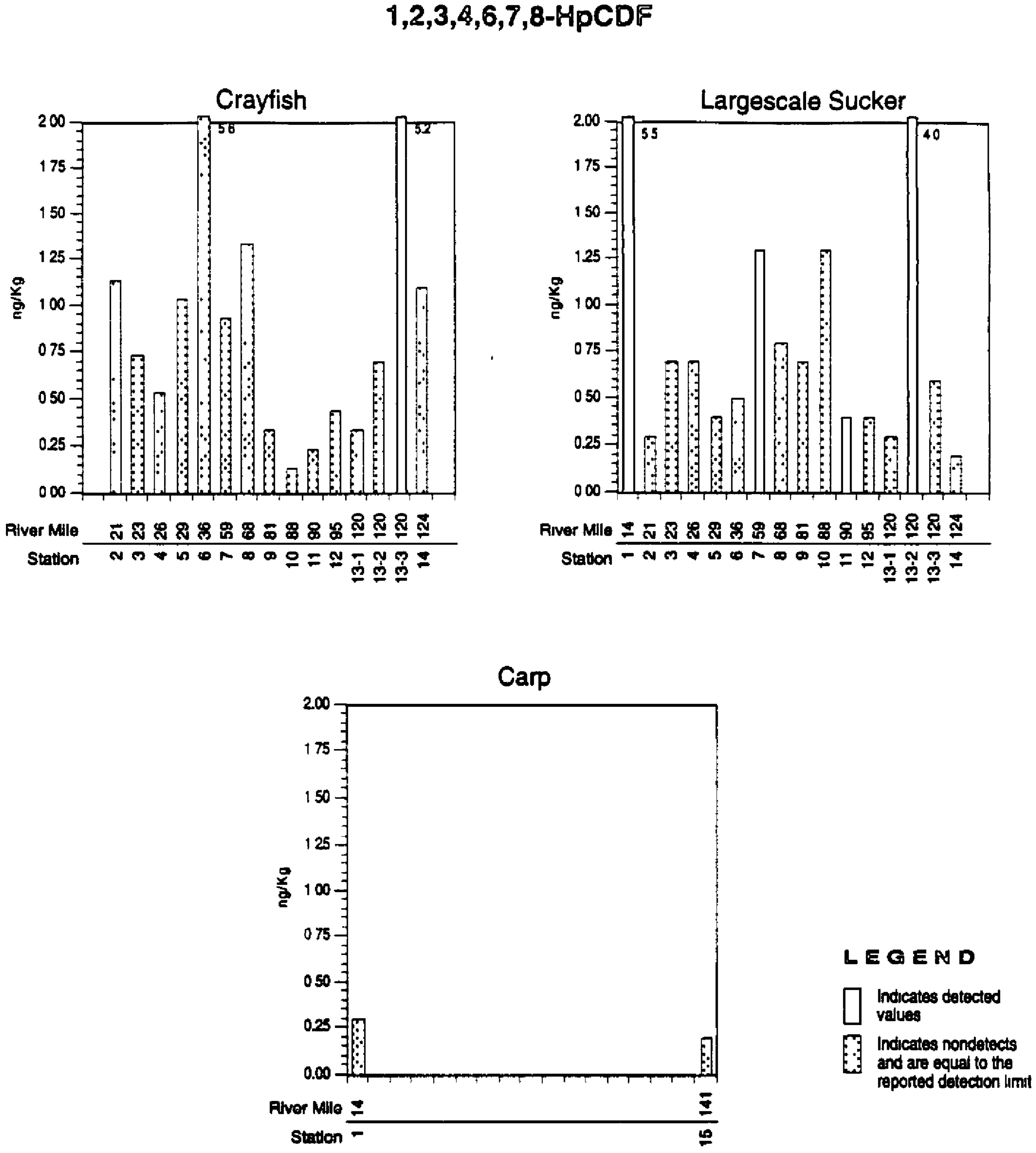


Figure 4-65. 1,2,3,4,6,7,8-HpCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

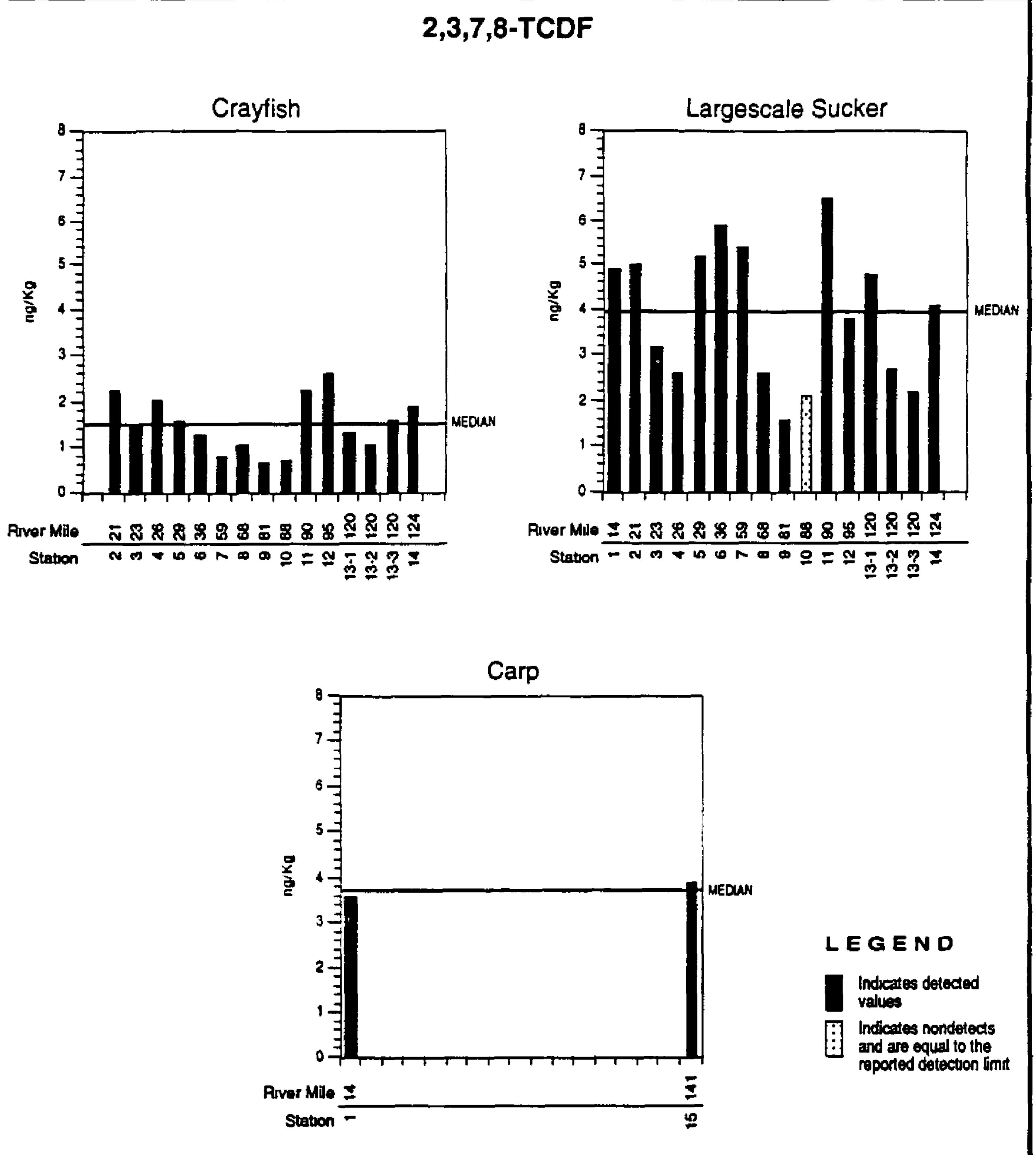


Figure 4-66. 2,3,7,8-TCDF Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (ng/kg wet weight).

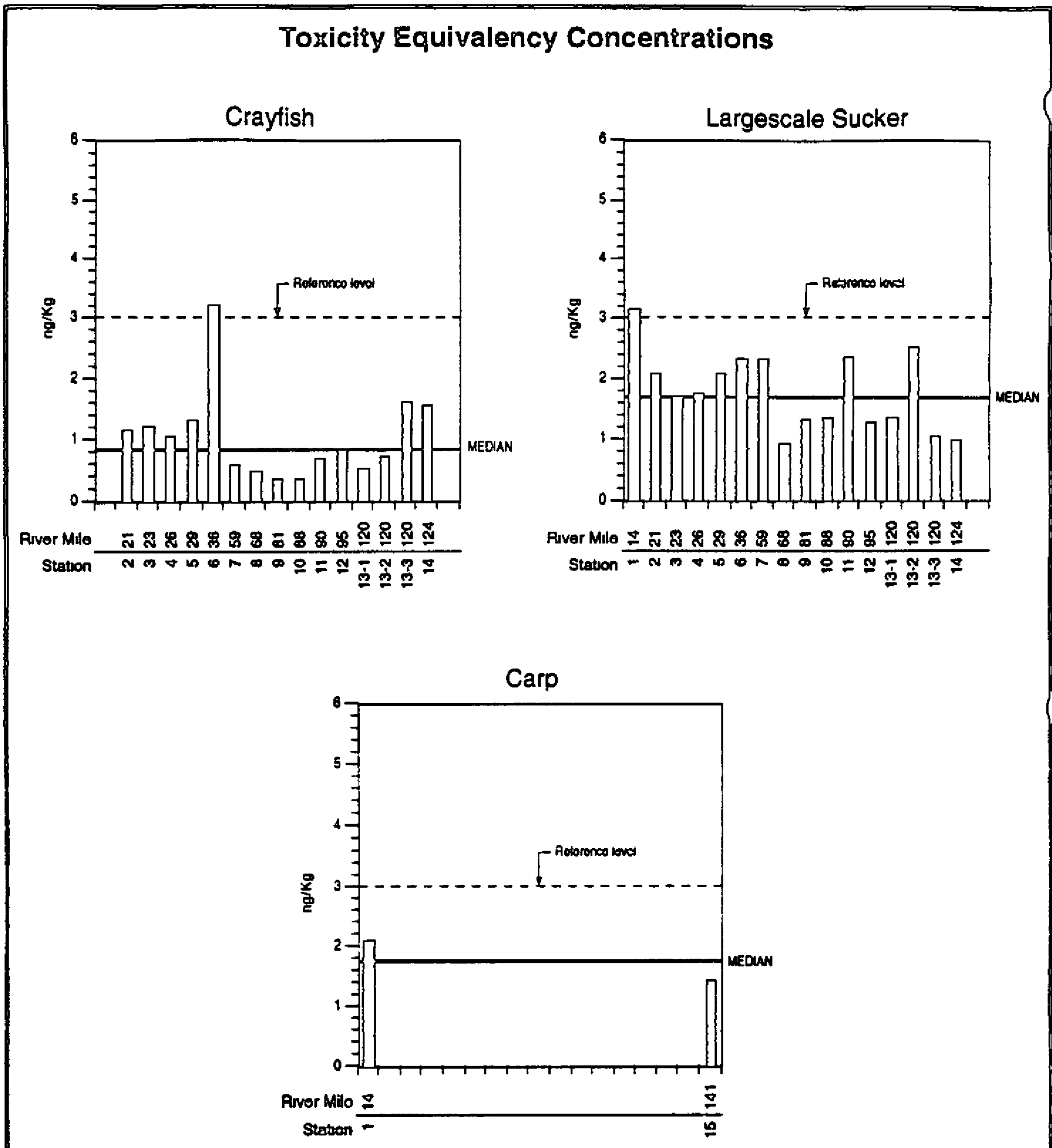


Figure 4-67. Toxicity Equivalency Concentrations (TECs) for Dioxins and Furans in Biota Samples (ng/kg wet weight). *New York State Guidelines for the Protection of Fish-Eating Wildlife are shown as a dashed line*

TABLE 4-25 PERCENT CONTRIBUTION OF EACH DIOXIN/FURAN CONGENER TO TEC CALCULATION 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY

	Sediment		Crayfish		Fish	
Congener	Percent of Mean TEC Calculated Using Only Detected Values	Percent of Mean TEC Calculated Using One-half Detection Limit for Non-detect Values	Percent of Mean TEC Calculated Using Only Detected Values	Percent of Mean TEC Calculated Using One-half Detection Limit for Non-detect Values	Percent of Mean TEC Calculated Using Only Detected Values	Percent of Mean TEC Calculated Using One-half Detection Limit for Non-detect Values
2378-TCDD	0.0	23.9	51.8	31.7	8.6	17.1
12378-PeCDD	0.0	16.0	0.0	15.2	1.3	7.1
123478-HxCDD	0.0	3.8	0.0	2.2	0.8	1.6
123678-HxCDD	0.0	5.7	0.0	2.5	0.9	1.7
123789-HxCDD	0.0	4.8	0.0	2.9	0.0	1.1
1234678-HpCDD	24.9	1.7	0.0	0.3	1.1	0.8
OCDD	75.1	1.2	0.6	0.3	0.6	0.5
2378-TCDF	0.0	3.5	46.5	21.9	36.6	27.1
12378-PeCDF	0.0	1.4	0.0	0.8	10.9	8.1
23478-PeCDF	0.0	14.6	0.0	10.9	8.1	9.8
123478-HxCDF	0.0	5.0	0.0	2.3	0.0	0.9
123678-HxCDF	0.0	4.7	0.0	2.2	2.8	2.9
123789-HxCDF	0.0	6.9	0.0	3.1	19.2	14.3
234678-HxCDF	0.0	5.5	0.0	2.3	8.2	6.2
1234678-HpCDF	0.0	0.7	1.1	0.9	0.6	0.5
1234789-HpCDF	0.0	0.7	0.0	0.5	0.0	0.1
OCDF	0.0	0.1	0.0	0.0	0.1	0.0

in adjacent columns the left column uses only detected values, and the right column assumes the value of half the detection limit for non-detects. For sediment and crayfish, which had relatively few detected values, the difference between the two approaches is substantial. Taking crayfish as an example, the two tetra congeners (2,3,7,8-TCDD and 2,3,7,8-TCDF) made up 98.3% of the total mean TEC when only detected values are used; when one half the detection limit values are used, the contribution of these two congeners falls to 53 6% For the fish samples, the two approaches yielded more similar results because of the greater number of detected values. In both approaches, the two tetra congeners represented less than 45% of the total mean TEC for fish

A TEC-based reference value for potential adverse effects on fish-eating organisms of dioxins and furans (3 0 ng/kg) was adopted to evaluate this data This reference concentration was exceeded in the largescale sucker sample from Youngs Bay and the crayfish sample from Elochoman Slough (see Figure 4-67).

4.3.5.4 Summary of Quality Assurance/Quality Control. A total of 33 biota samples were analyzed for dioxins and furans: 15 crayfish samples, 16 sucker samples, and 2 carp samples Detection limits reported by the laboratory met the goals specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). The majority of the sample results were qualified as undetected at an estimated detection limit (EDL) which was determined by examining instrument signal-to-noise ratios. For the fish samples, five results for 2,3,7,8-TCDF were qualified as estimated due to high matrix spike recoveries The dioxin and furan data are considered acceptable for use in this report

4.3.6 Butyltin Compounds

4.3.6.1 Summary of Butyltin Results. Samples of all three species were analyzed for the 3 butyltin compounds monobutyltin, dibutyltin, and tributyltin. All concentrations are reported on a unit tin (Sn) and a wet-weight basis. Table 4-26 lists compounds detected by species, range of detected concentrations, frequency of detection, and range of detection limits

None of the three butyltin compounds was detected in the crayfish samples; detection limits were 5.2 µg Sn/kg except for one sample which had a detection limit of 9.6 µg Sn/kg. Dibutyltin was detected in five sucker samples and one carp sample (Figure 4-68), with concentrations ranging from 1 3 to 2.6 µg Sn/kg.

TABLE 4-26 POLYBUTYLTIN COMPOUNDS ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY [a]

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits[b]
Monobutyltin	µg Sn/kg	c	c	c	3 4
Dibutyltin	µg Sn/kg	c	1 3 - 2 6 (5 - 16)[d]	1 3 (1 / 2)	5 2
Tributyltin	µg Sn/kg	c	6 4 - 54 3 (12 / 16)	28 8 (1 / 2)	1 3 - 9 6

[a] Reported results are on a wet weight basis.

[b] Detection limit range includes only those samples reported as undetected.

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set.

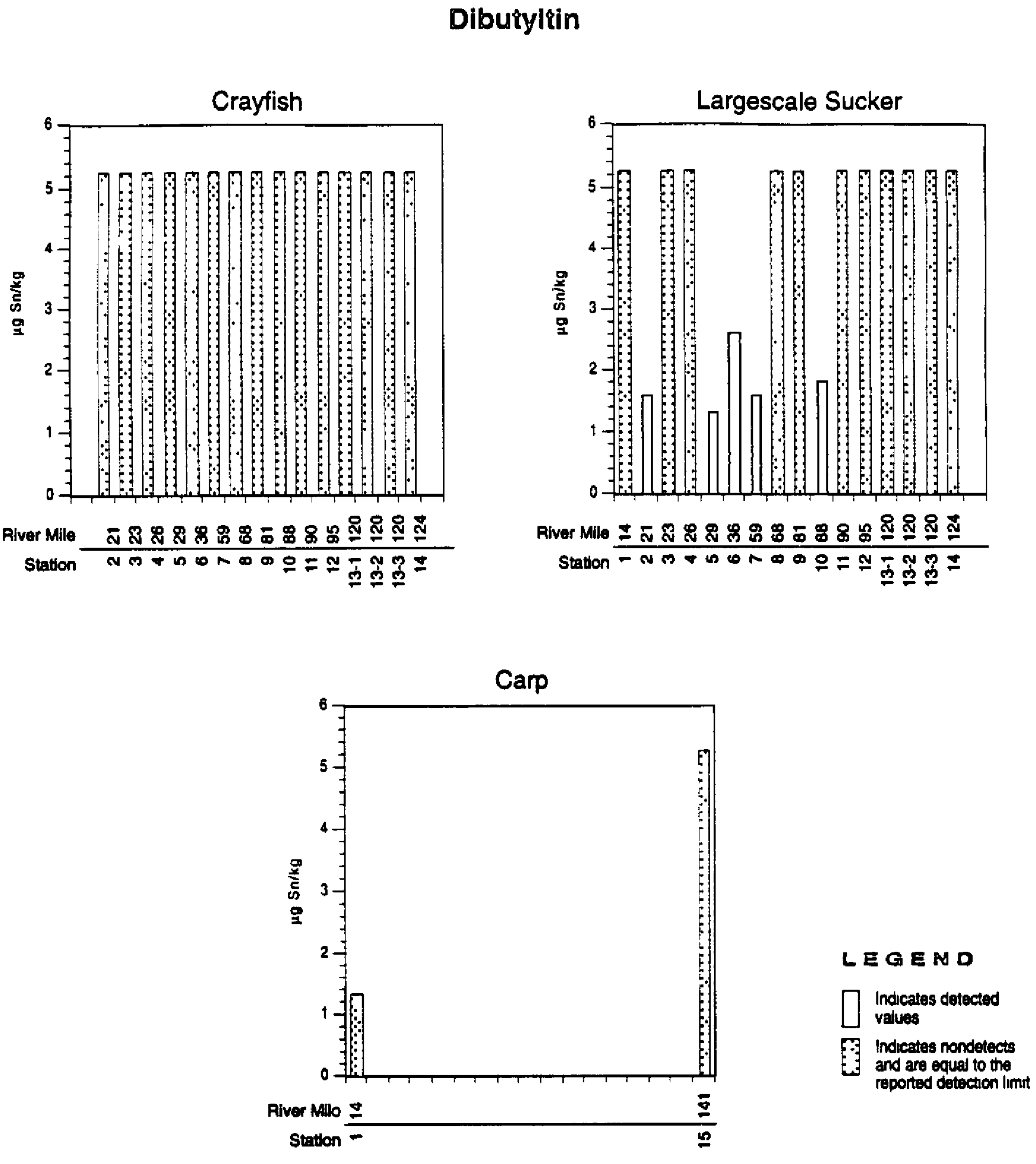


Figure 4-68. Dibutyltin Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg Sn/kg wet weight).

It should be noted that the concentrations were detected below the target detection limit for the above samples Tributyltin was detected in twelve sucker samples and one carp sample (Figure 4-69) Concentrations ranged from 6.4 to 54.3 μg Sn/kg, with the highest detected in a sucker sample. The five samples containing the highest concentrations were collected from Elochoman Slough, Cathlamet Bay, Youngs Bay, Lewis & Clark NWR, and Scappoose Bay

Because the butyltin compounds were not detected in all three replicate samples from Camas Slough, CV could not be assessed.

4.3.6.2 Summary of Quality Assurance/Quality Control A total of 33 biota samples, including 15 crayfish samples, 16 largescale sucker samples, and 2 carp samples were analyzed for three butyltin compounds Detection limits reported by the laboratory were slightly higher than those specified in the Sampling and QA/QC Plan (Tetra Tech 1993c) due to the necessity of performing gel permeation chromatography to remove lipids. Low-level blank contamination was noted in several instances. Due to blank contamination, one value for monobutyltin and six values for tributyltin were qualified as undetected For two samples, data for all three compounds were qualified as estimates due to low surrogate recoveries The butyltin data are considered acceptable for use in this report.

4.3.7 Radionuclides

4.3.7.1 Summary of Radionuclide Results Samples of all three species were analyzed for eight long-lived radionuclides. All values are reported on a wet-weight basis. Table 4-27 lists compounds detected by species, range of detected concentrations, frequency of detection, and range of detection limits.

None of the radionuclides was detected in the crayfish samples above the lower limit of detection. Plutonium 239/240 (Pu-239/240), plutonium 238 (Pu-238), and cesium 137 (Cs-137) were detected in fish samples. Pu-238 was detected in one sucker sample from Youngs Bay at a concentration of 0 011 pCi/g. Pu-239/240 was detected in 13 sucker samples and both carp samples; concentrations ranged from 0.001 to 0.003 pCi/g. Cs-137 was detected in two sucker samples: Burke Slough (0 016 pCi/g) and Camas Slough (0.020 pCi/g).

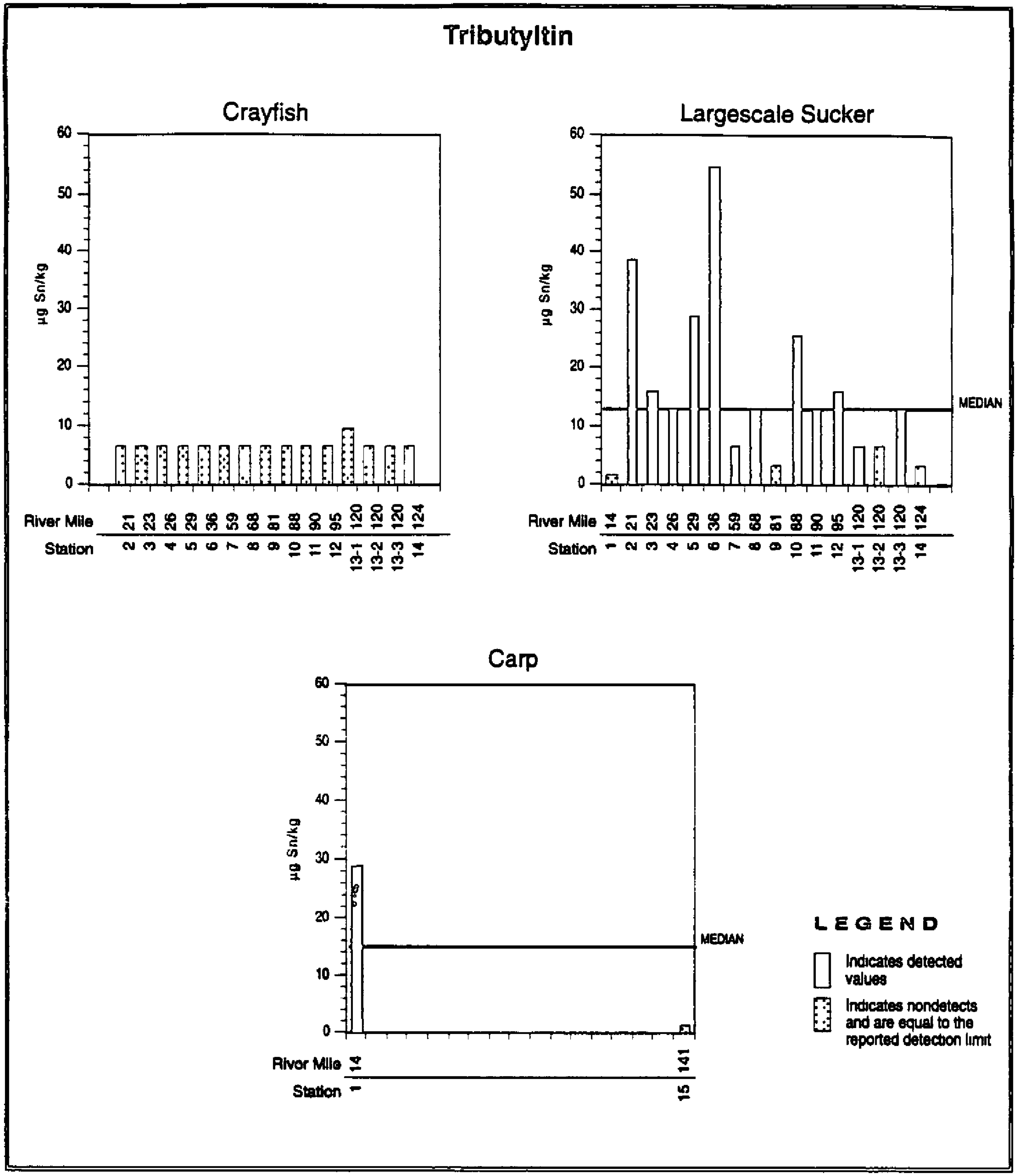


Figure 4-69. Tributyltin Concentrations in Whole-Body Composite Biota Samples Collected for the 1993 Backwater Reconnaissance Survey (µg Sn/kg wet weight).

TABLE 4-27 RADIONUCLIDES ANALYZED IN THREE SPECIES COLLECTED FOR THE 1993 LOWER COLUMBIA RIVER BACKWATER RECONNAISSANCE SURVEY [a]

Compound	Units	Crayfish	Largescale Sucker	Carp	Detection Limits [b]
Plutonium 239/240	pCi/g	c	0.001 - 0.003 (13 / 16) [d]	0.001 - 0.002 (2 / 2)	0.000 - 0.011
Plutonium 238	pCi/g	c	0.011 (1 / 16)	c	0.004 - 0.018
Americium 241	pCi/g	c	c	c	0.006 - 0.026
Cobalt 60	pCi/g	c	c	c	0.02 - 0.15
Cesium 137	pCi/g	c	0.016 - 0.020 (2 / 16)	c	0.02 - 0.12
Europium 152	pCi/g	c	c	c	0.20 - 0.40
Europium 154	pCi/g	c	c	c	0.20 - 0.25
Europium 155	pCi/g	c	c	c	0.05 - 0.50

[a] Reported results are on a wet weight basis

[b] Detection limit range includes only those samples reported as undetected.

[c] Compound was not detected in any sample

[d] Values in parentheses indicate the frequency of detection among the entire sample set.

Because the selected long-lived radionuclides were not detected in all of the three samples from Camas Slough, CV could not be assessed

4.3.7.2 Summary of Quality Assurance/Quality Control A total of 33 biota samples—15 crayfish, 16 sucker, and 2 carp samples—were analyzed for the eight radionuclides The laboratory was able to achieve the detection limits specified in the Sampling and QA/QC Plan (Tetra Tech 1993c). No data qualifiers were assigned to sample results based upon evaluation of QC data.

4.4 RIVER FLOW AND RAINFALL CONDITIONS DURING THE SURVEY

River flow and rainfall conditions prevailing during the survey are important because they can affect the water quality parameters. However, short-term variation in flow and rainfall is expected to affect the levels of pollutants in the water column more than in sediments or tissue For example, when river flows are low, pollutants discharged from point sources may be present in higher concentrations because dilution by river water is reduced When rainfall is high, non-point input via runoff increases. High flows due to release of water stored in upstream reservoirs or from spring snowmelt can increase the dilution capacity of the river, but may also be associated with increased flow velocities which can resuspend bed sediment and transport suspended sediments downriver

Backwater sampling was performed under medium-flow conditions in the lower Columbia during June and July 1993, following a period of exceptionally high flows and river levels (see Figure 4-70) Figure 4-70 compares monthly average, maximum, and minimum discharge of the Columbia River at The Dalles, OR (RM 188.9) for 1993 with historical average, maximum, and minimum discharge. These data from the U.S. Geological Survey (Hubbard et al 1994) discharge monitoring station located above Bonneville Dam, do not reflect peak winter flows resulting from heavy rainfall typical of the lower river. Discharge at The Dalles may be fairly representative of conditions at Bonneville Dam, since no large tributaries discharge to the Columbia River between The Dalles and the dam. Based on this data, monthly average discharge was slightly below historical average, ranging from 232,926 cubic feet per second (cfs) in June to 124,400 cfs in August 1993 (see Figure 4-70). The maximum and minimum average flow for June through August were within historical ranges.

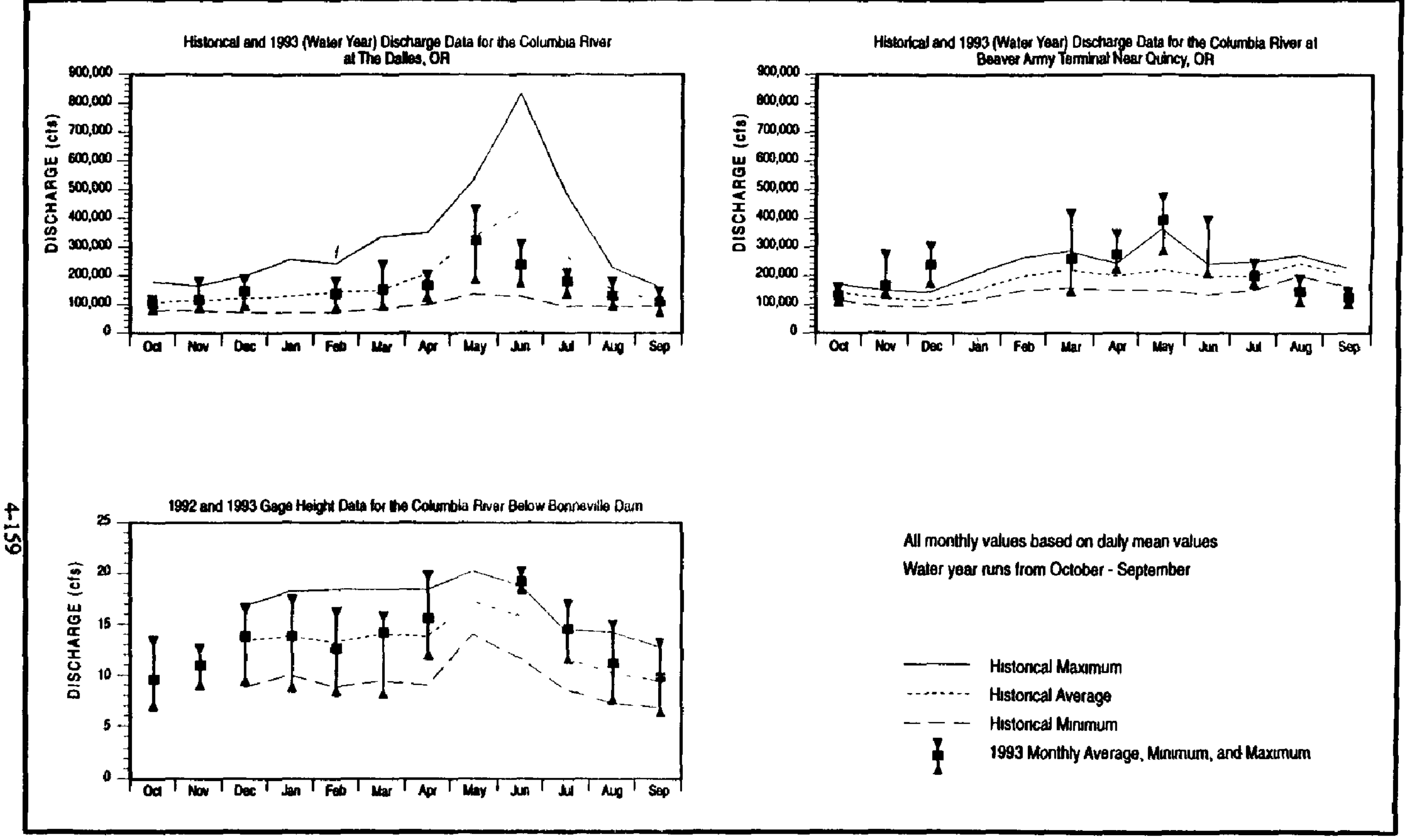


Figure 4-70. Summary of Columbia River Flow and Stage Data.

The discharge data from the USGS monitoring station at Beaver Army Terminal (RM 53.8) can be used to characterize the lower part of the river during this survey. Flow at Beaver Army Terminal is generally higher than flow measured at The Dalles or Bonneville Dam due to contributions from large tributaries, including, in descending order of flow contribution, the Willamette (RM 101.5), Cowlitz (RM 68), Lewis (RM 87), and Sandy (RM 120) (Tetra Tech 1992a). In June, the monthly average and maximum flow (387,000 cfs) at Beaver Army Terminal was much higher than it was in 1992 (see Figure 4-70). However, flow in July was average (198,100 cfs), although the minimum flow was somewhat higher than in 1992.

Gage height readings at a USGS monitoring station just below Bonneville Dam provide an indication of water level fluctuations in the lower river during the sampling period (Figure 4-70). Water levels below the dam are affected by both tidal height and discharge from the dam and tributaries. Monthly average, minimum, and maximum water levels at the gaging station in May 1993 were approximately 3 to 8 feet higher than in 1992 (see Figure 4-70). The levels remained somewhat higher than 1992 average values through July, but were similar to 1992 average levels in August.

Figure 4-71 compares 1993 USGS data on the monthly average, maximum, and minimum discharge of the Sandy, Willamette, Lewis, and Cowlitz Rivers with comparable historical data. Monthly average discharge of the Lewis and Sandy Rivers in June through August 1993 was generally similar to historical measurements, monthly average flow in the Cowlitz was generally below average during this period. The Willamette recorded flows much higher than historical averages from March-June 1993, but returned to normal flows by later in the summer (see Figure 4-71).

Water levels and flows during this survey can also be compared to those during the 1991 survey, which was conducted under low-flow conditions in September and October. Gage height below Bonneville Dam averaged 11.11 ft in September 1991 and ranged from 7.76 to 14.67 ft. The June 1993 gage height at the same station averaged 18.94 ft and ranged from 18.13 to 19.9 ft. Relatively higher water levels during the 1993 backwater survey facilitated water access to backwater areas along the river and ensured that fine sediments could be collected from these quiescent locations, removed from the mainstem of the river.

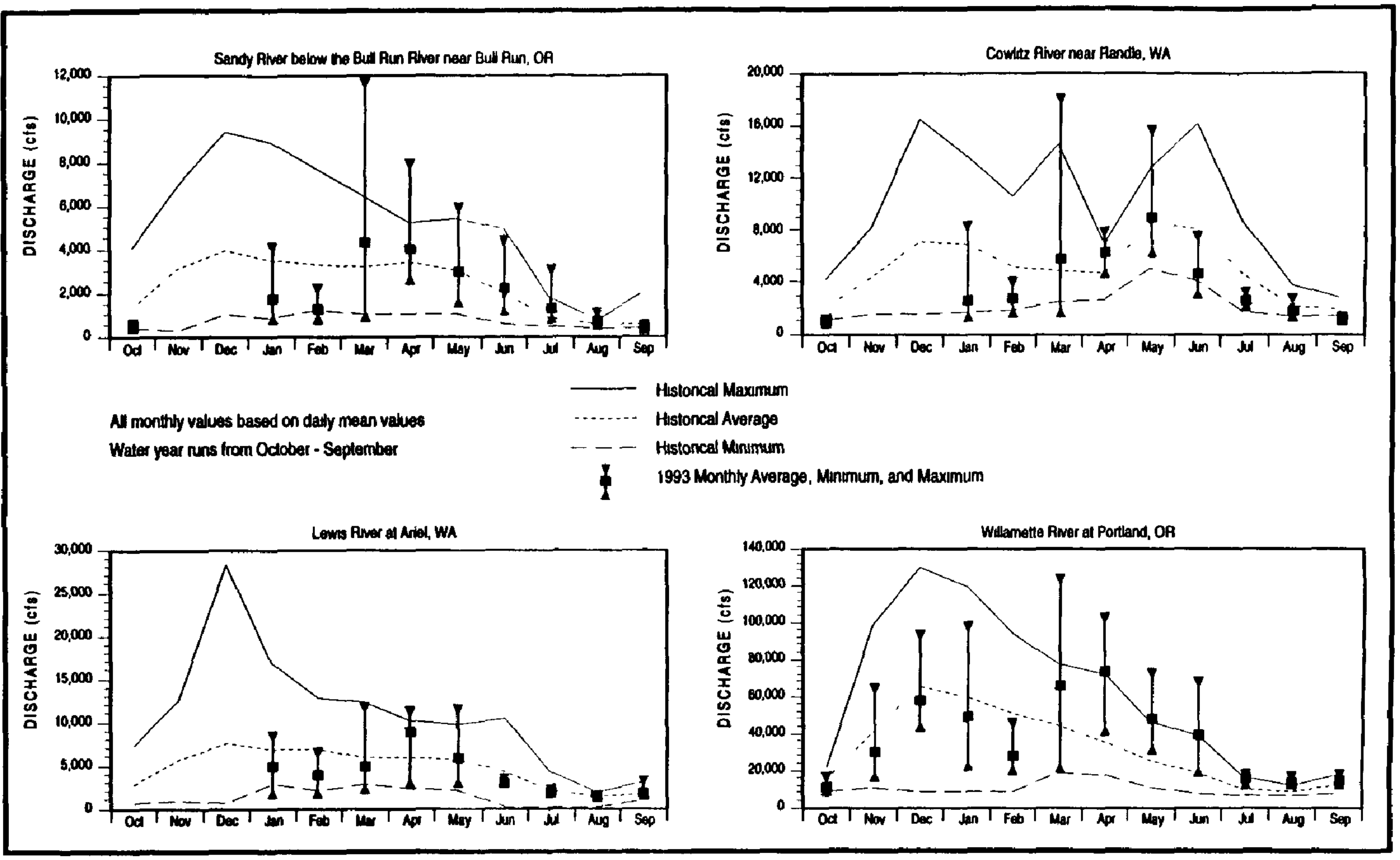
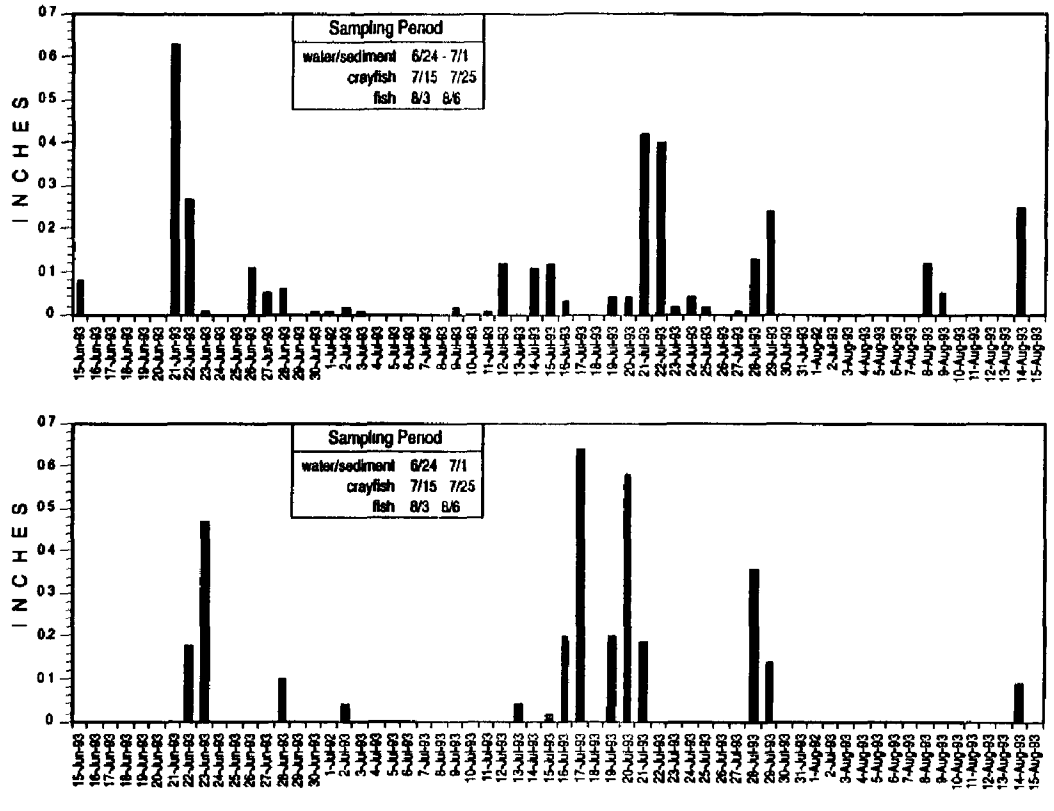


Figure 4-71. Historical and 1993 (Water Year) Discharge Data for the Sandy, Cowlitz, Lewis and Willamette Rivers.

Rainfall data for this period coincide with the flow and stage data presented above (Figure 4-72) Monthly rainfall at both Astoria and Portland was higher than historical averages for April-July 1993 Following a wet spring and early summer, the monthly rainfall in August 1993 was lower than the historical average   Figure 4-72 also shows the daily rainfall data for the sampling period. Little or no rain fell during the water/sediment (June 24-July 1) or fish sampling (August 3-6) efforts, but heavy rainfall occurred during the crayfish sampling (July 15-25)



ASTORIA

Monthly Data and Deviation From Historical Normal (inches)

April	9.01 (+4.41)
May	4.74 (+1.72)
June	3.70 (+1.30)
July	1.81 (+0.66)
August	0.57 (-0.76)

PORTLAND

Monthly Data and Deviation From Historical Normal (inches)

April	5.26 (+2.87)
May	4.36 (+2.30)
June	1.69 (+0.21)
July	2.41 (+1.78)
August	0.37 (-0.72)

Source NOAA, Climatological Data for Oregon, 1993

Figure 4-72. Daily and Monthly Rainfall and Comparison to Norms at Astoria and Portland During the Periods of Reconnaissance Survey Sampling.

5.0 DISCUSSION

The 1993 backwater reconnaissance survey of the lower Columbia River was designed to augment the more extensive reconnaissance survey of the lower Columbia River done in the fall of 1991 (Tetra Tech 1993a) Samples collected during the 1991 reconnaissance survey were obtained primarily in or along the main channel of the river during a period of very little rainfall and low river flow conditions In contrast, 1993 backwater samples were collected primarily in sloughs and back channels during a period of intermittent rainfall and moderate river flow conditions While the physical and seasonal differences between the two sample sets complicates data comparisons, taken together the two surveys should adequately characterize contaminant concentrations and other water quality parameters in the lower Columbia.

In the following sections, the backwater survey results are compared and contrasted with the 1991 survey results and, where appropriate, with other studies Each of the three media sampled—water, sediment, and tissue—are discussed in separate subsections. Potential relationships among contaminants in the different media are explored in Section 5 4

5.1 WATER QUALITY

The two surveys analyzed water samples for many of the same parameters, both field-measured and laboratory-analyzed. However, the 1991 survey analyzed single composite samples comprised of water collected from several depths at each site, while the backwater survey analyzed triplicate near-surface grab samples, i.e., field replicates, for most parameters. This change in sampling design was adopted to provide an estimate of the variance associated with water quality measurements and because the shallow water depths at collection sites precluded the need for compositing of water from several depths

Besides differences in sampling strategy, the shallow water depth and increased residence time of water in backwater locations suggests that these water samples may be influenced to a greater degree by bottom sediments, benthic communities, and local conditions than samples collected in the main river channel. These differences should be kept in mind when evaluating water quality data.

5.1.1 Field Measured Parameters

The water quality parameters that were measured in the field (as opposed to being analyzed in the laboratory) include salinity and conductivity, turbidity, dissolved oxygen (DO), temperature, and pH. Table 5-1 shows the range and median values for these parameters in the two surveys and summary statistics, including number of observations and frequency of exceedances of available standards for DO, temperature, and pH.

Median backwater conductivity and turbidity (0.123 mMhos/cm and 13 NTU, respectively) were relatively higher than mainstem conductivity and turbidity (0.089 mMhos/cm and 5.6 NTU). Although this may reflect genuinely higher ionic content and turbidity in backwater areas, some portion of these differences could be seasonal.

State standards for DO were exceeded in both surveys, although frequency of exceedances was generally higher in 1991. Again, this difference could be seasonal. Although the more restricted water exchange in backwater areas may allow for higher rates of production by phytoplankton, aquatic plants, and attached algae, relatively high DO concentrations (greater than 110% saturation) have also been measured in the lower river mainstem between April and August (Dahm et al. 1981). Relatively lower DO in late summer and fall may also reflect greater biological respiration over photosynthetic production during the low-flow period. The extent to which oxygen-demanding wastes contribute to relatively lower DO concentrations noted in the 1991 survey has not been assessed.

Exceedances of Washington's 20° C water temperature standard and the Oregon and Washington pH standard were noted in the 1993, but not the 1991 survey. High temperature standard has been a chronic problem in the lower river (Tetra Tech 1993a for a review of historical data). It is not clear to what extent this is due to human vs. natural causes, but relatively high temperature of the lower river in late summer can influence the success of cold- and warmwater fishes. The higher pH values measured in 1993 coincide with high DO concentrations measured at the same stations. These data indicate relatively

TABLE 5-1 SUMMARY OF WATER COLUMN FIELD-MEASURED PARAMETERS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Number of Observations[a]	Range	Median	Frequency of Exceedances[b]	
				Freshwater	Saltwater
Dissolved Oxygen (mg/L)					
Jun-Jul 1993	15 (29)	5.0-12.3	10.1	1/14 (2/27)	0/1 (0/2)
Oct-Nov 1991	45 (45)	5.8-12.2	8.8	3/37 (3/37)	2/8 (2/8)
Combined Data	60 (74)	5.0-12.3	9.0	4/51 (5/64)	2/9 (2/10)
Dissolved Oxygen (% saturation)					
Jun-Jul 1993	15 (29)	53-132	107	2/14 (3/27)	NA
Oct-Nov 1991	45 (45)	56-129	93	11/37 (11/37)	--
Combined Data	60 (74)	53-132	96	13/51 (14/64)	--
Temperature (^{o}C)					
Jun-Jul 1993	15 (30)	17.3-21.9	18.7	4/15 (5/30)[c]	
Oct-Nov 1991	45 (45)	10.6-19.2	18.0	0/45 (0/45)	
Combined Data	60 (75)	10.6-21.9	18.3	4/60 (5/75)	
pH					
Jun-Jul 1993	15 (30)	7.1-9.0	8.3	8/14 (10/28)	0/1 (0/2)
Oct-Nov 1991	45 (45)	7.2-8.4	7.7	0/37 (0/37)	0/8 (0/8)
Combined Data	60 (75)	7.1-9.0	7.8	8/51 (10/65)	0/9 (0/10)
Conductivity (mMhos/cm)					
Jun-Jul 1993	15 (30)	0.096-5.3	0.123	NA	NA
Oct-Nov 1991	45 (45)	0.013-32.0	0.089	--	--
Combined Data	60 (75)	0.013-32.0	0.110	--	--
Salinity (ppt)					
Jun-Jul 1993	15 (30)	0.0-2.9	0.0	NA	NA
Oct-Nov 1991	45 (45)	0.0-28.5	0.1	--	--
Combined Data	60 (75)	0.0-28.5	0.0	--	--
Turbidity (NTU)					
Jun-Jul 1993	15 (30)	5.7-30	13	NA	NA
Oct-Nov 1991	45 (45)	1.0-35	5.6	--	--
Combined Data	60 (75)	1.0-35	8.3	--	--

NA = Not available

[a] The first number is the number of sampling stations visited during each study, number in parentheses is the total number of observations. In Jun-Jul 1993, the field-measured parameters were sampled on two separate occasions (n=30, with the exception of dissolved oxygen measurements) A single sample was based on the average of triplicate field measurements of each parameter

[b] The frequency of exceedance of the lowest freshwater and saltwater standard for any single sampling date at a particular station. The numbers in parentheses indicate the frequency of exceedance of the same standard for all the samples analyzed

[c] The Washington temperature standard of 20° C is applied to the mouth of the Columbia River

higher productivity (by phytoplankton, aquatic plants, and/or attached algae) at the backwater stations The possibility that this difference may be seasonal cannot be ruled out

Some of the observed variability in pH and DO could have been caused by the necessity of sampling at different times of day, there is a natural daily cycle of photosynthetic respiration, which in turn affects the pH and DO of ambient waters Two ways to control for this effect are to sample each station over a 24 hour period, or to do all sampling at the same time of day. Neither of these was logistically feasible

5.1.2 Conventional Parameters

The conventional water quality parameters measured in both surveys include total suspended solids (TSS), hardness, total organic carbon (TOC), particulate organic carbon (POC), and dissolved organic carbon (DOC). Table 5-2 presents summary statistics for these parameters. Although no reference levels were available to evaluate these data, these parameters play important roles in the transport and bioaccumulation of pollutants in the river system. Analysis of POC was added to the 1993 backwater reconnaissance survey, so no comparisons are possible for POC or DOC (the calculated difference between TOC and POC)

The median TSS concentration was higher in 1993 samples than in 1991 samples However, the ranges of TSS were generally similar These results are consistent with turbidity ranges and medians (Table 5-1) Median freshwater hardness was lower in 1993 samples (50 mg/L) than in 1991 (57 mg/L). Some portion of these differences may be seasonal

Total suspended solids include inorganic and organic particles from within the river and from external sources that are carried suspended in the river system, which can absorb and transport contaminants. Physical and chemical processes (e.g., particle surface area, temperature, pH, oxidation-reduction potential, contaminant hydrophobicity, etc.) control the proportion of contaminant sorbed to suspended particles vs. dissolved in the water column. These processes also determine the amount of contaminants accumulating in organisms due to uptake through cell membranes (e g., the gills of fish) and the amount accumulated due to ingestion of particle. Water hardness is an important conventional variable because the polyvalent ion content of the water (primarily calcium and magnesium ions) appears to mitigate metal toxicity to aquatic organisms and may also affect bioaccumulation (Luoma 1989).

TABLE 5-2 SUMMARY OF WATER COLUMN CONVENTIONAL PARAMETERS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Numbers of Observations[a]	Units in mg/L		Frequency of Exceedances[a]
		Range	Median	
Total Suspended Solids				
Jun-Jul 1993	15	6 4-63	15	NA
Oct-Nov 1991	45	0 5-60	6 8	--
Combined Data	60	0 5-63	7 9	--
Hardness				
Jun-Jul 1993	15	35 7-359	51 (50)[b]	NA
Oct-Nov 1991	45	10-5,292	58 (57)[b]	--
Combined Data	60	10-5,292	57 (55)	--
Total Organic Carbon				
Jun-Jul 1993	15	2.2-9 4	2.7	NA
Oct-Nov 1991	5	0 7-2 4U	2 4U	--
Combined Data	20	0 7-9.4	2 7	--
Particulate Organic Carbon				
Jun-Jul 1993	15	0 5-4 6	0 7	NA
Oct-Nov 1991	NS	--	--	--
Combined Data	15	0 5	0 7	--
Dissolved Organic Carbon[c]				
Jun-Jul 1993	15	1 4-4 8	1 9	NA
Oct-Nov 1991	NS	--	--	--
Combined Data	15	1 4-4 8	1 9	--

NA = No criteria or screening levels are available for determination

NS = Not sampled.

U = Not detected. The value is the detection limit

[a] Number of observations is equivalent to the number of stations sampled.

[b] The number in parentheses is the median hardness of the freshwater stations sampled. This number is used to determine hardness-based metals criteria for samples from that period.

[c] Dissolved organic carbon is defined as of total organic carbon minus particulate organic carbon.

The concentration of total organic carbon in the water column and the proportion of TOC in dissolved and particulate forms (DOC and POC) also play an important role in contaminant transport and bioaccumulation in aquatic ecosystems. Comparison of the TOC concentrations measured in 1991 and 1993 is difficult due to the limited number of stations sampled, and the relatively high detection limits (2.4 mg/L) reported in 1991 (Table 5-2). However, TOC concentrations appeared to be somewhat higher in the backwater survey.

No clear seasonal pattern was evident in TOC concentrations measured in the mainstem of the lower river by Dahm et al. (1981), but lower concentrations generally occurred in late fall and winter. Although the maximum TOC concentration measured in the backwater survey (9.4 mg/L) is much higher than Dahm's reported maximum for the mainstem (approximately 3.3 mg/L), the median backwater concentration of 2.7 mg/L was relatively similar to the majority of Dahm's 1981 measurements (1.8-2.7 mg/L).

Water column concentrations of POC and DOC measured in 1993 ranged from 0.46 to 4.60 mg/L and 1.37 to 4.84 mg/L, respectively (Table 5-2). These concentrations are somewhat higher than the maximum POC and DOC concentrations of 0.9 mg/L and 2.4 mg/L, respectively, reported by Dahm et al. (1981) for June. Lower concentrations (to below detection for POC and 1.4 mg/L for DOC) typically occurred during late fall and winter. In general, DOC in the lower Columbia is greater than POC. The median percentage of DOC relative to TOC in the backwater survey was 76% with a range of 38—84%. High POC and DOC concentrations reported for the backwater survey were measured at Scappoose Bay during intermittent but heavy rainfall.

5.1.3 Nutrients and Phytoplankton Biomass

Human-caused eutrophication (the oversupply nutrients to a water body) has been a significant concern in water management (e.g., Beeton and Edmondson 1972; Paerl 1988). With adequate light, temperature, pH, nutrient supply, and relatively long water residence times, excess nutrients may result in increased production and/or biomass of phytoplankton. Any one of these factors may limit this growth and production, and predation by zooplankton can keep phytoplankton at relatively low levels even under ideal conditions. But when uncontrolled, species of blue-green algae (cyanobacteria) may bloom at levels causing aesthetically displeasing scums on the water surface and unpleasant odors due to rotting algae. Decaying algae may reduce DO, due to microbial degradation. Lowered DO levels may in turn adversely affect other aquatic organisms.

Table 5-3 presents summary statistics for nutrient and phytoplankton parameters, including total phosphorous (TP), soluble reactive phosphorous (SRP), ammonium nitrogen, nitrite+nitrate nitrogen, total Kjeldahl nitrogen (TKN), and chlorophyll and phaeophytin *a* from the 1993 backwater survey and from a WDOE study conducted on three dates at two stations (Bradwood, OR, RM 38 9; Warrendale, OR, RM 141-0) in the mainstem of the lower river during 1990 No reference levels were available evaluate nutrient data, an Oregon chlorophyll *a* action level (15 µg/L) is available to evaluate chlorophyll data. The study conducted by WDOE did not include analysis for total Kjeldahl nitrogen (TKN), chlorophyll *a*, or phaeophytin *a*, precluding comparisons for these parameters

5.1.3.1 Total Phosphorus. The backwater survey detected higher TP concentrations than the WDOE study (Table 5-3) The highest backwater concentration was more than twice the maximum average WDOE concentration. 172 µg/L vs 70 µg/L The median backwater concentration was 59 µg/L, vs 40 µg/L for the WDOE survey. Some portion of these differences may be seasonal

Generally, the concentration of TP associated with eutrophic conditions in lakes is 20 µg/L or greater (Welch 1980). The backwater and WDOE studies indicate that enough phosphorus is present to support nuisance algal growth if other conditions are adequate

5.1.3.2 Soluble Reactive Phosphorus. The backwater survey detected lower SRP concentrations than the WDOE study (Table 5-3) The highest concentration measured in the 1993 survey (15 µg/L) was less than half the maximum average SRP concentration measured by WDOE (40 µg/L) The median concentration in the backwater survey was also lower than in the WDOE survey 10 vs 30 µg/L Some portion of these differences may be seasonal

The lower SRP concentrations measured in the backwater survey suggest that soluble phosphorus was relatively depleted in the water column and that most of the phosphorus present was in particulate form, possibly incorporated into growing phytoplankton cells. This is consistent with previous studies (e.g., Park et al 1970; Dahm et al. 1981), which have shown that SRP is lower in the summer when phytoplankton are actively growing and assimilating soluble nutrients.

5.1.3.3 Ammonium Nitrogen. Findings of ammonium nitrogen (and nitrate+nitrite nitrogen; see below) in the two studies paralleled the SRP findings much lower in the backwater survey than in the WDOE

TABLE 5-3 SUMMARY OF WATER COLUMN NUTRIENT AND CHLOROPHYLL DATA, 1990 WDOE DATA AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances
		Range	Median	
Total Phosphorus				
Jun-Jul 1993	15/15 (15/15)	26-172	59	NA
Jan-Sep 1990	2/2 (6/6)	30-70	40	--
Combined data	17/17 (21/21)	26-172	48	--
Soluble Reactive Phosphorus				
Jun-Jul 1993	15/15 (15/15)	2-15	10	NA
Jan-Sep 1990	2/2 (5/6)	10U-40	30	--
Combined data	17 (21)	2-40	12	--
Ammonium Nitrogen				
Jun-Jul 1993	11/15 (11/15)	10U-22	11	NA
Jan-Sep 1990	2/2 (6/6)	10-50	20	--
Combined data	13/17 (17/21)	10U-50	11	--
Nitrate and Nitrite Nitrogen				
Jun-Jul 1993	11/15 (11/15)	10U-181	32	NA
Jan-Sep 1990	2/2 (6/6)	50-260	80	--
Combined data	13/17 (17/21)	10U-260	39	--
Total Kjeldahl Nitrogen				
Jun-Jul 1993	15/15 (15/15)	145-474	232	NA
Jan-Sep 1990	NS	--	--	--
Combined data	15/15 (15/15)	45-474	232	--
Chlorophyll *a*				
Jun-Jul 1993	15/15 (15/15)	6.7-35.0	14.0	5/15
Jan-Sep 1990	NS	--	--	--
Combined data	15/15 (15/15)	6.7-35.0	14.0	5/15
Phaeophytin *a*				
Jun-Jul 1993	15/15 (15/15)	2.6-31.0	9.3	NA
Jan-Sep 1990	NS	--	--	--
Combined data	15/15 (15/15)	2.6-31.0	9.3	--

NA = No criteria or screening levels available for determination.

NS = Not sampled.

U = Not detected. Value is the detection limit.

[a] Frequency of detected occurrence at the stations sampled. Fifteen stations were sampled in Jun-Jul 1993, two stations were sampled by the Washington Department of Ecology in Jan-Sep 1990. The numbers in parentheses indicate the frequency of detection of individual samples. In Jun-Jul 1993 a single sample consisted of triplicate field samples collected at each of fifteen stations (n=15), the Jan-Sep 1990 samples consisted of three or four transect samples collected at each station on three separate dates (n=6). The average of field triplicate or transect samples was used for comparison.

[b] Frequency of exceedance of the lowest standard or reference level (Oregon's 15 µg/L action level for chlorophyll *a*).

study (Table 5-3) The highest concentration measured in the backwater survey was 22 μg/L, vs a maximum average concentration of 50 μg/L measured by WDOE, median concentrations were 11 and 20 μg/L, respectively Concentrations in the backwater survey were often below the 10 μg/L laboratory detection limit Some portion of these differences may be seasonal

Low concentrations measured in the backwater survey suggest that soluble ammonium nitrogen was relatively depleted in the water column, possibly incorporated into growing phytoplankton cells

5.1.3.4 Nitrate+Nitrite Nitrogen. These findings parallel SRP and ammonium nitrogen findings much lower in the backwater survey than in the WDOE study (Table 5-3) The highest backwater nitrate+nitrite concentration was 181 μg/L, vs a maximum average concentration of 260 μg/L measured by WDOE Median measurements were 32 μg/L in the backwater survey and 80 μg/L in the WDOE survey Concentrations in the backwater survey were below the 10 μg/L laboratory detection limit in several samples Some portion of these differences may be seasonal

Low nitrate+nitrite concentrations measured in the backwater survey suggest that soluble ammonium nitrogen was relatively depleted in the water column, possibly incorporated into growing phytoplankton cells This is consistent with previous nutrient studies conducted on the lower river (e g , Park et al 1970, Dahm et al 1981) which have shown that nitrate concentrations are lower during the summer when phytoplankton are actively growing and assimilating soluble nutrients

Phytoplankton require nitrogen and phosphorous at a ratio of approximately 7 1 (Ryther and Dunstan 1971) The ratios of these nutrients in the water column can be used to determine which might limit plankton growth· a ratio greater than 7 would suggest phosphorous limitation, less than 7, nitrogen limitation. Other factors, including light and other essential nutrients, should be considered in determining which factor limits phytoplankton growth and any given time

The nitrogen to phosphorus ratios (calculated as SN [ammonium + nitrate+nitrite nitrogen) SP (SRP)] in the backwater survey ranged from 1.8 (Carrolls Channel) to 22 6 (Elochoman Slough) with a median ratio of 4 3 These ratios indicate that nitrogen may be the predominantly limiting nutrient in backwater areas of the lower river during the summer growing season. There were three stations with SN·SP ratios greater than 7· Carrolls Channel, Elochoman Slough, and Camas Slough Nitrogen limitation could also tend to favor the growth of nitrogen-fixing blue-green algae However, growth limitation by light or other essential nutrients not measured in this study cannot be ruled out.

5.1.3.5 Total Kjeldahl Nitrogen. The WDOE study did not analyze TKN, so no inter-study comparisons are possible TKN concentrations at backwater stations ranged from 145 to 474 μg/L

Ratios were calculated for total nitrogen to total phosphorus, to complement the soluble ratios noted above, using the TKN measurements in the backwater survey TN:TP ratios ranged from 1.8 (Carrolls Channel) to 9 1 (Camas Slough) with a median ratio of 4 5. These ratios also indicate that nitrogen may be the limiting nutrient in backwater areas of the lower river during the summer growing season; Camas Slough was the only station with a TN·TP ratio greater than 7 Nitrogen limitation could also tend to favor the growth of nitrogen-fixing blue-green algae However, limitation by light or other essential nutrients not measured in this study cannot be ruled out.

5.1.3.6 Chlorophyll and Phaeophytin a. The WDOE study did not include analysis for chlorophyll and phaeophytin *a*, so no inter-study comparisons are possible. The concentrations of chlorophyll *a* measured in the backwater survey was relatively high, ranging from 6.7 to 35 0 μg/L with a median concentration of 14 μg/L (Table 5-3) Phaeophytin *a* concentrations were also relatively high, ranging from 2 6 to 31 0 μg/L with a median concentration of 9 3 μg/L

The chlorophyll *a* concentration exceeded Oregon's 15 μg/L action level at 5 of 15 stations sampled These data are consistent with the chlorophyll *a* concentrations measured in the mainstem of the lower Columbia River by Haertl et al. (1969) which increased to concentrations greater than 15 μg/L during the summer. This level indicates a possible impairment of beneficial uses of backwater areas such as swimming and esthetic enjoyment. However, some nutrient enrichment could be considered beneficial to aquatic organisms and wildlife. No measurements were made of the species of algae present to determine the relative abundance of nuisance growth such as blue-green algae For example, the phytoplankton present in these backwater areas could be dominated by diatoms, which have been shown to be the dominant phytoplankton group in the lower Columbia mainstem throughout the year in a number of studies (e.g., Williams and Scott 1962; Haertl et al. 1969; Beak Consultants, Inc. 1978; Tetra Tech 1993a). Concentrations of blue-green algae (primarily *Oscillatoria* sp. and *Aphanizomenon* sp.), typically most abundant September-November when total phytoplankton abundance is lowest, have generally been low in the Columbia mainstem (e g , Beak Consultants, Inc 1978, Tetra Tech 1993a)

5.1.4 Metals and Cyanide

The difficulty of measuring relatively low concentrations of metals in ambient waters has been noted in a number of investigations (Shiller and Boyle 1987, Windom et al 1991), some of which have been conducted in the lower Columbia River (discussion by Velz 1984, pp 340-352) Although the U S Geological Survey (USGS) has conducted routine sampling of metals in the lower Columbia River as part of the National Stream Quality Accounting Network (NASQUAN), the USGS considers historical data reported for arsenic, boron, beryllium, cadmium, chromium, copper, lead, and zinc biased due to contamination of the samples by the metallic solenoid-activated, flow-weighting water sampler (Bortleson, G., 3 June 1992, personal communication) Current USGS metals sampling in the lower Columbia River is conducted at Warrendale (RM 141) and Beaver Army Terminal (RM 54) and is limited to reporting dissolved forms (0.45 μm pore-size filters) of aluminum, barium, cobalt, iron, lithium, magnesium, manganese, molybdenum, nickel, selenium, silver, strontium, and vanadium (Hubbard et al. 1993)

To obtain more accurate measurements, WDOE performed water sampling and analysis in 1990 designed to reduce contamination of samples and achieve lower detection limits (Johnson, A. and B Hopkins, 30 April 1991, personal communication to S Saunders, WDOE) While historical USGS data shows freshwater chronic criteria being exceeded for lead, copper, mercury, cadmium, and zinc, WDOE sampling showed total concentrations in whole water samples for copper, zinc, lead, cadmium, and mercury that were lower than freshwater chronic criteria. Dissolved concentrations of these same metals were also generally much lower in the WDOE study than in USGS monitoring data.

As part of the 1991 reconnaissance survey, composite water samples collected from 45 stations in the lower river were analyzed for sixteen metals, including the metals previously analyzed by WDOE. Findings were qualified as estimates ("E") because the contract laboratory provided only limited instrument calibration data. However, 1991 reconnaissance data indicated higher concentrations than the WDOE study, with chronic criteria being exceeded for aluminum, cadmium, copper, iron, lead, selenium, and zinc.

One of the primary objectives of collecting and analyzing water column metals data during the 1993 backwater survey was to confirm the results of the 1991 reconnaissance survey Confirmation of 1991 results was a high priority because of the uncertainty associated with the 1991 data and its variance from the results of the WDOE study As noted above, the 1991 data indicated potential water quality problems for a number of metals in the lower Columbia There are several possible explanations for the differences between the 1991 reconnaissance data and WDOE data 1) field or laboratory contamination, 2) seasonal differences in water quality, and 3) differences in station sampling locations and the possible influence of nearby pollution sources The data available from the 1991 survey were not adequate to identify the specific cause of the differences between the studies The 1993 backwater data were intended to assist in evaluating the potential causes of the study differences For the sake of simplicity, the three studies will be referred to by year· 1990 (WDOE), 1991 (reconnaissance survey), and 1993 (backwater reconnaissance survey)

In 1993, field and laboratory techniques were improved to reduce the potential for sample contamination. Based on the data validation review, some metals data were qualified as estimates due to exceedance of quality assurance criteria established for this project (Tetra Tech 1993d). The qualification of data as undetected due to laboratory and field-equipment/filter blank contamination has ensured that detected concentrations reported are not likely due to contamination Although a number of the metals data were qualified, overall precision, accuracy, and completeness of the metals data were within project guidelines and the data, as qualified, are considered suitable for their intended use

In 1993, samples were analyzed for 16 total recoverable and filtered (operationally defined as dissolved) metals and cyanide. Table 5-4 presents summary statistics for all three studies Statistics presented include range and median values for each analyte in each study, frequency of detection, and frequency of exceedances of available reference levels. Table 4-5 presented the dissolved metals data from the 1993 survey and includes information similar to Table 5-4

The uncertainty of the 1991 data was evaluated by sampling the same metals in 1993 and comparing those results to both 1991 and 1990 results. As can be seen from Table 5-4, there was generally good agreement between 1993 and 1990 data. This agreement tends to indicate that 1991 data may have been positively biased due to field or laboratory contamination. It is not possible from the data collected to rule out other causes of differences, but the data indicate that contamination may be the dominant factor.

TABLE 5-4 SUMMARY OF WATER TOTAL RECOVERABLE COLUMN METALS AND CYANIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS AND 1990 WASHINGTON DEPARTMENT OF ECOLOGY DATA

(Page 1 of 3)

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances[b]	
		Range	Median	Freshwater	Saltwater
Aluminum					
1993[c]	15/15	159-843	388	14/14	1/1[f]
1991[d]	11/45	120-1,300	250	7/39	4/8[f]
1990[e]	NS	--	--	--	--
Combined data	26/60	450-1,300	270U	21/53	5/9[f]
Antimony					
1993	1/15	3.0U-3.1	3.0U	0/14	0/1
1991	0/45	15U-150U	15U	0/37	0/8
1990	NS	--	--	--	--
Combined data	1/60	3.0U-3.1	15U	0/51	0/9
Arsenic					
1993	2/15	3.0U-3.6	3.0U	0/14	0/1
1991	0/45	--	5.0U	0/37	0/8
1990	NS	--	--	--	--
Combined data	2/60	3.0U-3.6	5.0U	0/51	0/9
Barium					
1993	15/15	11-24	18	NA	--
1991	44/45	10U-42	26	--	--
1990	NS	--	--	--	--
Combined data	59/60	10U-42	23	--	--
Beryllium					
1993	0/15	--	2.0U	0/14	--
1991	0/45	--	5.0U	0/37	--
1990	NS	--	--	--	--
Combined data	0/60	--	5.0U	0/51	--
Cadmium					
1993	0/15	0.10U-0.17U	0.10U	0/14	0/1
1991	3/45	0.5U-3.5	0.5U	3/37	0/8
1990	6/6	0.025-0.044	0.029	0/6	NS
Combined data	9/66	0.025-3.5	0.5U	3/57	0/9
Chromium					
1993	1/15	1.0U-6.3	1.0U	0/14	0/1
1991	3/45	5U-5.5	5U	0/37	0/8
1990	NS	--	--	--	--
Combined data	4/60	1.0U-6.3	5U	0/51	0/9
Copper					
1993	13/15	1.0-4.6	2.3	0/14	1/1
1991	10/45	5U-54	5.0U	6/37	1/8
1990	6/6	1.2-2.2	1.4	0/6	NS
Combined data	29/66	1.0-54	5.0U	6/57	2/9

TABLE 5-4 SUMMARY OF WATER TOTAL RECOVERABLE COLUMN METALS AND CYANIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS AND 1990 WASHINGTON DEPARTMENT OF ECOLOGY DATA

(Page 2 of 3)

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances[b]	
		Range	Median	Freshwater	Saltwater
Iron					
1993	15/15	188-2,523	421	1/14	0/1[f]
1991	43/45	100U-1,800	430	3/37	1/8[f]
1990	NS	--	--	--	--
Combined data	58/60	100U-2,523	425	4/51	1/9[f]
Lead					
1993	6/15	0.8U-2.0	0.8U	3/14	0/1
1991	25/45	1U-8	2.1	21/37	0/8
1990	6/6	0.18-0.50	0.34	0/6	NS
Combined data	37/66	0.18-8	1.0U	24/57	0/9
Mercury					
1993	1/15	0.11U-0.11	0.11U	1/14[g]	0/1[g]
1991	0/45	--	0.5U	0/37[g]	0/8[g]
1990	0/6	0.001U-0.002U	0.001U	0/6	NS
Combined data	1/66	0.001U-0.11	0.5U	1/57	0/9
Nickel					
1993	2/15	5.0U-6.0	5.0U	0/14	0/1
1991	0/45	--	40U	0/37	0/8
1990	NS	--	--	--	--
Combined data	2/60	5.0U-6.0	40U	0/51	0/9
Selenium					
1993	0/15	--	3.0U	0/14	0/1
1991	3/45	5U-22	5U	3/37	0/8
1990	NS	--	--	--	--
Combined data	3/60	3.0U-22	5U	3/51	0/9
Silver					
1993	1/15	1.0U-4.6	1.0U	1/14[g]	0/1[g]
1991	0/45	--	2U	0/37[g]	0/8[g]
1990	NS	--	--	--	--
Combined data	1/60	1.0U-4.6	2U	1/51	0/9
Thallium					
1993	5/15	1.0U-1.1	1.0U	0/14	--
1991	0/45	36U-360U	36U	0/37	--
1990	NS	--	--	--	--
Combined data	5/60	1.0U-1.1	36U	0/51	NA
Zinc					
1993	10/15	3.0U-16.7	8.0	0/14	0/1
1991	12/45	20U-84	20U	3/37	0/8
1990	5/6	0.33U-1.7	1.3	0/6	NS
Combined data	27/66	0.33U-84	20U	3/57	0/9

TABLE 5-4 SUMMARY OF WATER TOTAL RECOVERABLE COLUMN METALS AND CYANIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS AND 1990 WASHINGTON DEPARTMENT OF ECOLOGY DATA

(Page 3 of 3)

	Frequency of Detection[a]	Units in µg/L		Frequency of Exceedances[b]	
		Range	Median	Freshwater	Saltwater
Cyanide					
1993	0/15	2 0U	2 0U	0/14	0/1[g]
1991	0/45	2 0U	2 0U	0/37	0/8[g]
1990	NS	--	--	--	--
Combined data	0/60	2 0U	2 0U	0/51	0/9

NA = No criteria or screening levels available

NS = Not sampled.

U = Not detected Value is the detection limit

[a] Frequency of detected occurrence at the stations sampled Fifteen stations were sampled in 1993, forty-five stations were sampled in 1991, and two stations were sampled by the Washington Department of Ecology in 1990 In 1993, a single sample consisted of triplicate field samples, the 1991 samples were single analyses of a station composite sample, and the 1990 samples were replicate grab samples.

[b] Frequency of exceedance of the lowest standard or reference level at the stations sampled. The numbers in parentheses indicate the frequency of exceedance of the same standard for all of the samples collected

c Based on results of the 1993 Lower Columbia River Backwater Reconnaissance Survey

[d] Based on 1991 Lower Columbia River Reconnaissance Survey (Tetra Tech 1993a)

[e] Based on Washington Department of Ecology Study (Johnson, A and B Hopkins, personal communication, 30 April 1991).

f No saltwater criteria or screening levels were available The number of exceedances are based on the available freshwater criterion.

[g] Detection limits were higher than the chronic criteria The number of exceedances are based on detected concentrations only.

Thus, the 1993 and 1990 WDOE studies are given more weight in evaluating exceedances of reference levels

Analysis of the available data on metals and cyanide in the lower Columbia water column allows the definition of four groups or categories The first group includes analytes which appear to have little potential to cause chronic toxicity to aquatic organisms: antimony, arsenic, barium, beryllium, cadmium, chromium, mercury, nickel, thallium, and zinc, plus cyanide. The second group includes metals infrequently detected at concentrations greater than available chronic criteria, but which at present cannot be attributed wholly to sample contamination selenium and silver. The third group includes metals that frequently exceed available criteria, but are likely in forms that do not pose a chronic threat to aquatic organisms aluminum and iron The relatively high concentrations of these two metals is likely due to their presence in very fine particulate clays that are transported with the suspended sediments of the river (Conomos 1968, Whetten et al. 1969, Conomos and Gross 1972). Concentrations of these two metals showed significant regressions with TSS or turbidity (Table 5-5). The percentages of total aluminum and iron content that were dissolved rather than particulate (3-12% and 1-39%, respectively) are consistent with measurements made on two rivers in Japan which indicated dissolved percentages ranging from 1 to 45% and 1 to 19% for aluminum and iron, respectively (Tanizaki et al. 1992) The fourth group includes metals detected at concentrations that exceed chronic criteria, which have been analyzed in an independent study indicating comparable, albeit somewhat lower concentrations. These metals, which may warrant further study, are copper and lead

5.1.5 Indicator Bacteria

Indicator bacteria are used to assess the suitability of waters for water contact sports such as swimming, and for shellfish harvesting. Several studies of indicator bacteria have been conducted historically (e.g., Vasconcelos et al. 1975), and more recently, studies sampling for fecal coliform and enterococcus bacteria have been conducted for the Lower Columbia River Bi-State Water Quality Program (Tetra Tech 1993a, Hallock 1993; Ehinger 1993). Tetra Tech conducted shore-based sampling during a relatively rainy period in October and November of 1991 at six locations along the lower river, on five separate occasions over a 30-day period (Tetra Tech 1993a). WDOE conducted two separate indicator bacteria studies in 1992 (Hallock 1993 and Ehinger 1993) using the same six stations sampled by Tetra Tech (with minor modifications; Hallock 1993) plus six more. The WDOE sampling design was similar to that used

TABLE 5-5 REGRESSION COEFFICIENT OF DETERMINATION (r^2) BETWEEN WATER COLUMN METALS AND SUSPENDED SOLIDS AND TURBIDITY

	Total Suspened Solids		Turbidity		TR-Aluminum	TR-Iron
	1991	1993	1991	1993	1993	1993
TR[a]-Aluminum	0.0127	0.5920**	0.0061	0.0708		
D[b]-Aluminum	--	0.4969*	--	--	0.3761*	--
TR[a]-Iron	0.2072**	0.8696**	0.0068	0.3275*	--	--
D[b]-Iron	--	0.6605*	--	--	--	0.7619**
Total Suspended Solids	--	--	0.2608*	0.2876*	--	--

[a] TR = Total recoverable

[b] D = Filtered (0.45 μm membrane filter).

Statistically significant regressions noted by: * $P<0.05$, ** $P<0.001$

in the Tetra Tech study, five to six samples were collected and analyzed from each station over a 30-day period for analysis of fecal coliform and enterococcus bacteria

Sampling for indicator bacteria in the backwater survey differed in a number of respects from the previous studies, which complicates comparison of these data sets. The backwater survey involved the collection of three field-replicate samples from 15 backwater areas for analysis of fecal coliform, enterococcus, and *Escherichia coli* *E coli* analyses were added because this is an indicator bacteria species that is recommended by the U.S. EPA for use in evaluation of water quality which is also being considered by Oregon for incorporation into their water quality standards

Although these bacteria indicators are all commonly used to assess the quality of water with respect to water contact recreation, recent studies increasingly demonstrate that fecal coliform bacteria also occur in pristine environments; their presence does not always correlate with the occurrence of pathogens (Cabelli et al 1982, Cabelli 1983a,b, Cabelli et al. 1983, Dufour 1984; O'Shea and Field 1991, Fujioka et al. 1988; Ferley et al. 1989, Geldenhuys and Pretorius 1989) On the other hand, fecal enterococci, although suffering from some of the same limitations (Toranzos 1991; Cornax et al. 1991), are generally regarded as valuable indicators of the extent of fecal contamination in surface waters (Cabelli et al 1983, Cabelli 1983b, Dufour 1984, U S EPA 1986a, APHA 1989). *E. coli* is also considered to be an acceptable indicator of the risk of gastroenteritis in swimmers exposed to contaminated fresh water (Dufour 1984) Studies conducted for the U S EPA (Cabelli et al 1983; Dufour 1984) have led to the recommendation that enterococcus or *E. coli* measurements be used in place of fecal coliforms to assess the human health risk at freshwater bathing areas (U.S. EPA 1986a). However, for the protection of shellfish harvesting waters, the U S EPA still recommends the use of fecal coliform standards (U S. EPA 1986a).

Table 5-6 presents a summary and comparison of the results of the four indicator bacteria studies conducted for the Bi-State Water Quality Program. To facilitate comparisons between the four studies, frequency of detection and frequency of exceeding the appropriate criterion or standard are presented by station and for the total number of samples collected during each study The frequency of exceedance of a criterion or standard was determined by comparing the data for a single sampling event at each station (geometric mean of replicate samples) to a single standard (e.g., Washington's 100 coliforms/ 100 mL). Exceedances of state standards that address sampling over a period of time were not considered because sampling in 1993 was limited to a single sampling event.

TABLE 5-6 SUMMARY OF INDICATOR BACTERIA DATA COLLECTED FOR THE LOWER COLUMBIA RIVER BI-STATE COMMISSION

	Frequency of Detection[a]	Numbers of Bacteria per 100 mL		Frequency of Exceedance of Standard[b]
		Range	Geometric Mean	
Fecal Coliform				
Jun-Jul 1993	15/15 (15/15)	10-262	40	3/15 (20%) [3/15 (20%)]
Nov-Dec 1992	12/12 (71/71)	1-901	19	7/12 (58%) [20/71 (24%)]
Sep-Oct 1992	12/12 (60/60)	1-1,764	10	4/12 (33%) [7/60 (12%)]
Oct-Nov 1991	6/6 (27/30)	1-284	18	3/6 (50%) [5/30 (17%)]
Combined Data	27/27 (172/176)	1-1,764	16	11/27 (41%) [28/176 (16%)]
Escherichia coli				
Jun-Jul 1993	15/15 (15/15)	8-85	26	0/15 (0%) [0/15 (0%)]
Nov-Dec 1992	NS	--	--	--
Sep-Oct 1992	NS	--	--	--
Oct-Nov 1991	NS	--	--	--
Combined Data	15/15	8-85	26	0/15 (0%) [0/15 (0%)]
Enterococcus				
Jun-Jul 1993	12/15 (12/15)	2U-5	3	0/15 (0%) [0/15 (0%)]
Nov-Dec 1992	12/12 (66/66)	1-384	12	6/12 (50%) [14/66 (21%)]
Sep-Oct 1992	12/12 (57/60)	1-296	3	3/12 (25%) [3/60 (5%)]
Oct-Nov 1991	6/6 (30/30)	8-954	87	6/6 (100%) [20/30 (67%)]
Combined Data	27/27 (165/171)	1-954	10	9/27 (33%) [37/171 (20%)]

NS = Not sampled

[a] Frequency of detected occurrence at the stations sample Fifteen stations were sampled in Jun-Jul 1993, twelve stations were sampled in Sep-Dec 1992, and six stations were sampled in Oct-Nov 1991 The numbers in parentheses indicate the frequency of detection of individual samples In Jun-Jul 1993 a single sample consisted of triplicate field samples collected at each of fifteen stations (n=15), the Sep-Oct and Nov-Dec 1992 samples consisted of field duplicate samples collected on five or six separate days at twelve stations (n=60-61), and the Oct-Nov 1991 samples consisted of field duplicate samples collected on five separate days at six stations (n=30). The geometric mean of the duplicate or triplicate samples were used for comparison with the standards.

[b] Frequency of exceedance of the lowest standard (e.g, 100 fecal coliforms per 100 mL) for any single sampling date at a particular station The numbers in brackets indicate the frequency of exceedance of the same standard for all of the samples collected.

Although the maximum concentration of fecal coliforms was lower (262 bacteria/100 mL) in backwater samples compared to previous Bi-State studies, the geometric mean concentration was the highest (40 bacteria/100 mL, see Table 5-6) The number of stations that exceeded the 100 bacteria/100 mL standard was also relatively low (3 of 15 stations or 20%) compared to the previous studies which showed exceedances at as many as 7 of the 12 stations (58%) sampled (in November-December 1992).

Escherichia coli was not previously sampled in Bi-State studies, so comparison to previous data is limited to the observation that no exceedances of the U S EPA criterion for *E. coli* (126 bacteria/100 mL) were noted in the backwater sampling.

The maximum backwater concentration of enterococcus bacteria was low (5 bacteria/100 mL) compared to previous Bi-State studies The geometric mean concentration was also quite low (3 bacteria/100 mL, see Table 5-6) U.S. EPA enterococcus criteria were not exceeded at any backwater station

Some of the differences noted in indicator bacteria levels between backwater and mainstem sampling may be due to differences in the character of these areas; some of the differences may be seasonal. Varying rainfall runoff may also have contributed to variation in indicator bacteria densities. Although rainfall data have not yet been thoroughly evaluated, some generalizations can be made. Very few samples collected for the Bi-State Program bacteria studies have been collected during periods of dry weather. Such periods, especially during summer months, should be sampled because these are periods when water recreational activity is generally greatest, and the most people at risk (Ehinger 1993). According to climatological data published by NOAA, sampling conducted in October-November 1991 and October-November 1992 were performed during or between relatively heavy and intense rainfall typical of the early fall season. Sampling conducted in September-November 1992 was also conducted under intermittent rainfall, albeit of lower intensity. Although the backwater survey was conducted during the summer when rainfall is usually infrequent, it rained during or just before sampling at several stations, notably Scappoose Bay

There are ongoing debates about the correctness and utility of the recommended U.S. EPA criteria (e.g , Fleicher 1991) and the utility of the current indicator bacteria used in general (e.g., Toranzos 1991) However, data collected for the Bi-State Water Quality Study indicates that exceedances of state water quality standards and U S. EPA criteria are expected at a number of locations in the lower river, including Sauvie Island (RM 96) where indicator bacteria levels have exceeded standards for water contact recreation, and the Ilwaco Marina (RM 3) where indicator levels have exceeded the more restrictive standards for harvesting shellfish for human consumption (Hallock 1993, Ehinger 1993; Tetra Tech 1993a) High concentrations of indicator bacteria have also tended to occur in the reach of the lower river between RM 61 below Longview to RM 115 above the Portland/Vancouver area (Hallock 1993; Ehinger 1993) The sources of the indicator bacteria measured have not been identified, but likely include municipal and industrial point sources, and non-point sources associated with urban and agricultural runoff. Non-point sources of indicator bacteria may be more significant after the fall rains begin, because water column concentrations of indicator bacteria tend to be higher in late fall when rainfall intensity and duration is greater, and contact recreation less common (Ehinger 1993). Further studies of indicator bacteria in the lower Columbia should focus on the characterization of water quality during the relatively drier, peak recreational period. The most suitable indicators of the presence of human pathogens, the risks for contraction of various types of illness, and protocols for the regulatory application of these criteria should also be established.

Routine monitoring of indicator bacteria was initiated by the Oregon Department of Environmental Quality (ODEQ) at one station on the lower Columbia in February 1991 (RM 102.5), and the USGS routinely monitors the concentrations of fecal coliform and fecal streptococci at the Beaver Army Terminal (RM 54) and Warrendale (RM 141) stations The Washington State Department of Health (WSDH) has recommended that such bacterial sampling results be coupled with additional information (including sanitary surveys) and actions (including limiting bather densities to avoid contamination of the water by the bathers themselves) to ensure the health of public bathing areas (WSDH 1991). Direct sampling and analysis of shellfish tissue quality (of shellfish actually or potentially harvested for human consumption) would also provide more direct information on the suitability of these shellfish for human consumption. Further research, including epidemiological studies, evaluation of additional indicator organisms (e.g., Oregon is currently evaluating the use of *E. coli*), and evaluation of new methods for the direct detection of pathogens should be conducted to develop the criteria necessary to ensure the public health of recreational waters.

5.1.6 Water Quality Summary

Potential adverse effects on aquatic life were identified by comparing 1991 and 1993 survey data to relevant criteria and standards (Figure 5-1). Exceedances of water quality standards for the conventional

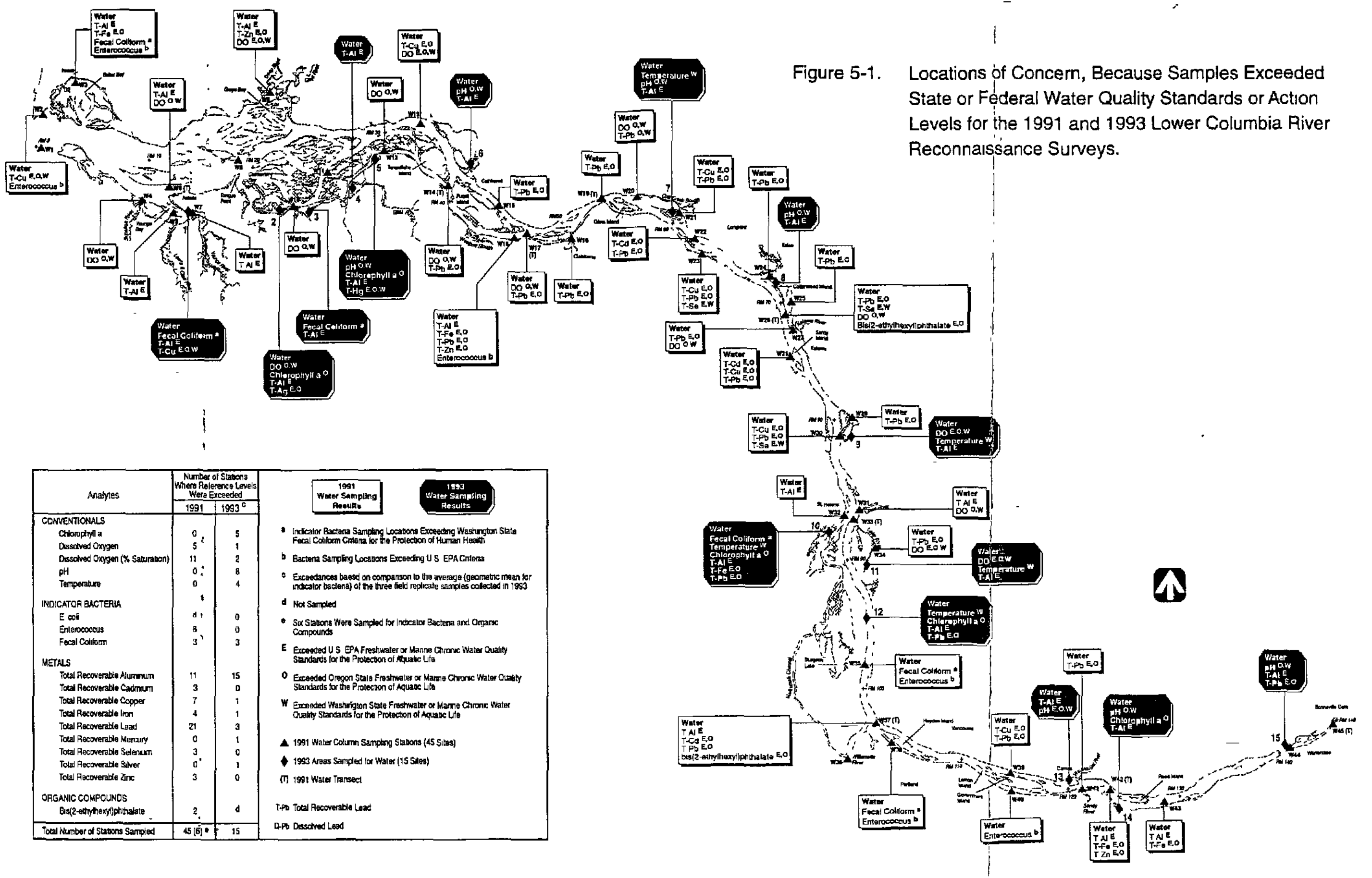


Figure 5-1. Locations of Concern, Because Samples Exceeded State or Federal Water Quality Standards or Action Levels for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.

Analytes	Number of Stations Where Reference Levels Were Exceeded	
	1991	1993 ^{c}
CONVENTIONALS		
Chlorophyll a	0	5
Dissolved Oxygen	5	1
Dissolved Oxygen (% Saturation)	11	2
pH	0	8
Temperature	0	4
INDICATOR BACTERIA		
E coli	d	0
Enterococcus	6	0
Fecal Coliform	3	3
METALS		
Total Recoverable Aluminum	11	15
Total Recoverable Cadmium	3	0
Total Recoverable Copper	7	1
Total Recoverable Iron	4	1
Total Recoverable Lead	21	3
Total Recoverable Mercury	0	1
Total Recoverable Selenium	3	0
Total Recoverable Silver	0	1
Total Recoverable Zinc	3	0
ORGANIC COMPOUNDS		
Bis(2-ethylhexyl)phthalate	2	d
Total Number of Stations Sampled	45 (6) ^{e}	15

1991 Water Sampling Results

1993 Water Sampling Results

[a] Indicator Bacteria Sampling Locations Exceeding Washington State Fecal Coliform Criteria for the Protection of Human Health

[b] Bacteria Sampling Locations Exceeding U S EPA Criteria

[c] Exceedances based on comparison to the average (geometric mean for indicator bacteria) of the three field replicate samples collected in 1993

[d] Not Sampled

[e] Six Stations Were Sampled for Indicator Bacteria and Organic Compounds

E Exceeded U S EPA Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

O Exceeded Oregon State Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

W Exceeded Washington State Freshwater or Marine Chronic Water Quality Standards for the Protection of Aquatic Life

▲ 1991 Water Column Sampling Stations (45 Sites)

◆ 1993 Areas Sampled for Water (15 Sites)

(T) 1991 Water Transect

T-Pb Total Recoverable Lead

D-Pb Dissolved Lead

variables dissolved oxygen, pH, and temperature were noted at several stations in either 1991 or 1993 Exceedances of dissolved oxygen standards occurred from the area below Portland/Vancouver out to the estuary Exceedances were more frequent for the 1991 survey which was conducted during the low-flow period of late summer and fall Water quality standards for pH and temperature were only exceeded at backwater stations sampled during the summer of 1993 This is probably due to the relatively warmer summer temperatures and higher primary productivity which results in elevated water temperatures and pH The more limited water exchange of backwater areas may be an additional factor Exceedance of Washington's 20° C water temperature standard has already been recognized as a chronic problem in the lower Columbia The degree to which these exceedances are due to pollutant discharges and/or human-induced changes in river flow has not been determined.

Although there are currently no reference levels to assess the environmental significance of the nutrient levels measured in the 1993 backwater reconnaissance survey, the concentrations of phosphorus and nitrogen approached levels that under proper conditions (e.g., light and water residence time) can cause nuisance algal blooms in lakes (Hileman et al 1975; Welch 1980) Such blooms could have an adverse effect on aquatic life (due to algal senescence and depletion of oxygen) and/or affect the aesthetic quality of the water for human uses. The chlorophyll *a* concentrations measured in backwater areas in 1993 also exceeded Oregon's action level of 15 μg/L at 5 of the 15 locations (Figure 5-1) It is possible that the relatively high concentrations of algae present are not nuisance blue-green forms, additional sampling (including algal species identification and enumeration) could be conducted to assess the potential beneficial use impairment of these backwater areas of the river. The degree to which nutrient levels have been elevated due to pollutant inputs has not been determined

Potential adverse effects on aquatic life due to water column metals concentrations were identified based on comparison to relevant chronic water quality criteria. The relatively infrequent exceedance of available standards and criteria for some metals that could not be attributed to sample contamination (silver and selenium) indicates relatively limited potential to cause chronic toxicity to aquatic organisms (Figure 5-1). The metals that frequently exceeded chronic water quality criteria or standards, and therefore present a potential for chronic toxicity to aquatic organisms include aluminum, iron, copper, and lead (Figure 5-1) However, most of the aluminum and iron are likely in mineral and particulate forms not readily available to aquatic biota This was evidenced by the relatively low dissolved concentrations of these metals, which were consistently below the available criteria and standards. The fact that the dissolved concentrations of copper and lead were also generally below detection limits, and below Washington's dissolved metals standards, further indicates that these metals may not pose a chronic problem for aquatic biota The degree to which metals levels have been elevated due to pollutant inputs has not been determined

Additional water column sampling of metals should focus on aluminum, iron, copper, and lead, and include an assessment of the potentially toxic forms and concentrations of these metals Further analyses of mercury and silver may also be warranted to assess whether these metals frequently occur above the relatively low standards established Less conventional, more costly techniques may be required to achieve the detection limits necessary to make these evaluations.

Potential adverse effects on human health due to water column indicator bacteria concentrations were identified by comparison to reference levels (Figure 5-1). Additional data collected for the Bi-State Program by WDOE have also indicated levels of fecal coliform and enterococcus that exceed water quality standards for the protection of recreational bathing waters (primarily in the area between Portland/Vancouver and Longview) and standards for the protection of shellfish harvesting waters (in Ilwaco). There are questions regarding the human health significance of indicator bacteria results and the utility of the current indicator bacteria used. Recommendations include routine monitoring at popular recreational and shellfish harvesting areas, ongoing studies and data review to identify the most relevant indicators, sanitary surveys, and controlling bather density.

5.2 SEDIMENT QUALITY

Sediment parameters analyzed for the 1993 backwater survey included conventional sediment variables, metals and cyanide, organic contaminants, and selected long-lived radionuclides. The sediment sampling design and the parameters sampled differed only slightly between the 1991 and 1993 surveys, facilitating comparison of these two data sets. The primary difference between the two surveys was that the backwater survey focused on the collection of predominantly fine-grained sediments from areas that were generally removed from the mainstem of the river, i.e., backwater sediments.

5.2.1 Conventional Parameters

Table 5-7 summarizes statistics for conventional parameters sampled in 1991 and 1993 No reference levels were available to evaluate these data, but these parameters play important roles in the transport and bioaccumulation of pollutants in the river system. Analyses for total solids, total volatile solids (TVS), total sulfide, TKN, and ammonia nitrogen were added for the backwater survey, so no comparisons are possible for these parameters

Sediments percent fines were defined for the 1991 survey as the weight percent of the sediment with grain sizes less than 100 μm (clay, silt, and fine sand) For the backwater survey, grain size was changed to less than 63 μm diameter (clay and silt only) This more restrictive definition was considered more useful for exploring the relationship between the contaminant concentrations and the proportion of fine sediment materials collected from each station Horowitz and Elrick (1987) found that the use of the <63 μm sediment fraction produced greater correlation coefficients with sediment metals concentrations than the use of finer (<2 and <16 μm), or coarser (<125 μm) grain size fractions for relatively fine sediments. Since a primary objective of the backwater survey was to determine if finer backwater sediments contained relatively higher amounts of contaminants, this was an important variable to define.

5.2.1.1 ***Total Organic Carbon.*** Sediment TOC is known to affect the bioavailability and toxicity of some substances and influence the composition and abundance of benthic communities (Landrum and Robbins 1990). The potential toxicity of non-polar, non-ionic organic compounds is related to the organic content of the sediments (e g , Di Toro et al 1991) Higher sediment organic content allows for the sorption of organic compounds and the reduction of the toxicity potential of a given sediment contaminant level. The relatively low TOC content of lower Columbia River sediments has been noted in other studies (e.g., Hedges et al. 1984; Fuhrer 1986, Johnson and Norton 1988).

The maximum TOC content of lower Columbia sediment samples reported in studies reviewed by Tetra Tech (1992b) did not exceed 2.0% In the backwater survey, sediment TOC concentrations exceeded 2 0% at 6 of the 15 stations, and 3.0% at 3 stations Elochoman Slough, Burke Slough, and Gary & Flag Islands. Median sediment TOC was higher for backwater samples (1 8%) than it was for samples in the 1991 survey (0.5%). The highest sediment TOC concentration (4.1%) was measured at Camas Slough in 1991 (Table 5-7). It was suggested that the relatively high TOC content of this sample was due to the presence of woody debris from nearby log storage areas and historical discharges from the

TABLE 5-7 SUMMARY OF SEDIMENT CONVENTIONAL PARAMETERS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Number of Observations[a]	Units in percent dry weight	
		Range	Median
Total Organic Carbon			
1993	15	0.7-3.7	1.8
1991	54	0.02-4.1	0.5
Combined Data	69	0.02-4.1	0.6
Percent Fines (<63μm)			
1993	15	29-95	52
1991	54	0.3-94	14
Combined Data	69	0.3-95	20
Total Solids			
1993	15	36.2-57.6	45.4
1991	NS	--	--
Combined Data	15	36.2-57.6	45.4
Total Volatile Solids			
1993	15	2.9-8.9	5.3
1991	NS	--	--
Combined Data	15	2.9-8.9	5.3
		Units in mg/kg dry weight	
Total Sulfides			
1993	15	1.8U-133.9	18.9
1991	NS	--	--
Combined Data	15	1.8-133.9	18.9
Ammonia Nitrogen			
1993	15	4.3-63.8	24.7
1991	NS	--	--
Combined Data	15	4.3-63.8	24.7
Total Kjeldahl Nitrogen			
1993	15	650-2,000	1,400
1991	NS	--	--
Combined Data	15	650-2,000	1,400

NS = Not sampled.

U = Not detected. Value is the detection limit.

[a] The number of observations is equivalent to the number of stations sampled.

former Crown-Zellerbach (Camas) pulp and paper mill (Tetra Tech 1993a) However, the TOC content of the Camas Slough sediments sampled in 1993 was 1 5% which was not an exceptional concentration in this survey. The degree to which woody debris and other coarse particulate organic matter contributed to the variation in sediment TOC cannot be ascertained. Hedges et al (1984) determined that the sediment organic matter of the Columbia River was generally dominated by non-woody angiosperm material, and to a lesser extent by woody gymnosperm material Furthermore, the variation in sediment TOC content varied by as much as 40% in the Columbia River reservoirs sampled (Hedges et al 1984) Analysis of the TOC content of various sediment grain size fractions collected from Cathlamet Bay led Fuhrer (1986) to conclude that most of the organic carbon in these sediments was in coarse particles. The quality and character of lower Columbia sediment carbon may require additional study to determine the effect of these variables on contaminant transport and toxicity (e.g , Socha and Carpenter 1987)

Although three sampling stations were common to the two surveys (Youngs Bay, Carrolls Channel, and Camas Slough), their sediments did not have similar TOC content from one sampling to another. Youngs Bay and Carrolls Channel sediments had higher TOC in 1993 than 1991 (2.1 vs. 0 60% and 2.1 vs. 0.85%, respectively) As mentioned above, the Camas Slough sediment had a much higher TOC content than the slough sediment collected in 1993 (4 06 vs 1 5%). A general positive relationship between sediment TOC and percentage of fine sediments has been noted in previous studies of the Columbia (e.g , Hedges et al 1984, Tetra Tech 1993a), higher TOC content was expected because finer sediments were sampled in 1993.

5.2.1.2 Sediment Grain Size. Sediment grain size distribution may be related to the bioavailability and toxicity of some substances (Luoma 1989, Landrum and Robbins 1990) and is related to the composition and abundance of benthic communities. The relatively sandy character of lower Columbia River sediments in the river's mainstem has been noted in previous studies (e.g., Whetten et al. 1969; Hubbel and Glenn 1973, Sherwood et al. 1984; Johnson and Norton 1988). A primary goal of the backwater survey was to locate and sample finer sediments in backwater areas. The backwater sampling effort succeeded in collecting sediments that were generally finer than the majority of sediments collected for the 1991 reconnaissance survey (Figure 5-2). Seven of the 1991 samples contained proportions of silt and clay (greater than 30% fines) that were within the range of the percent fines of 1993 backwater samples (Figure 5-2). The 1991 samples with relatively fine sediments tended to be backwater areas: stations D1

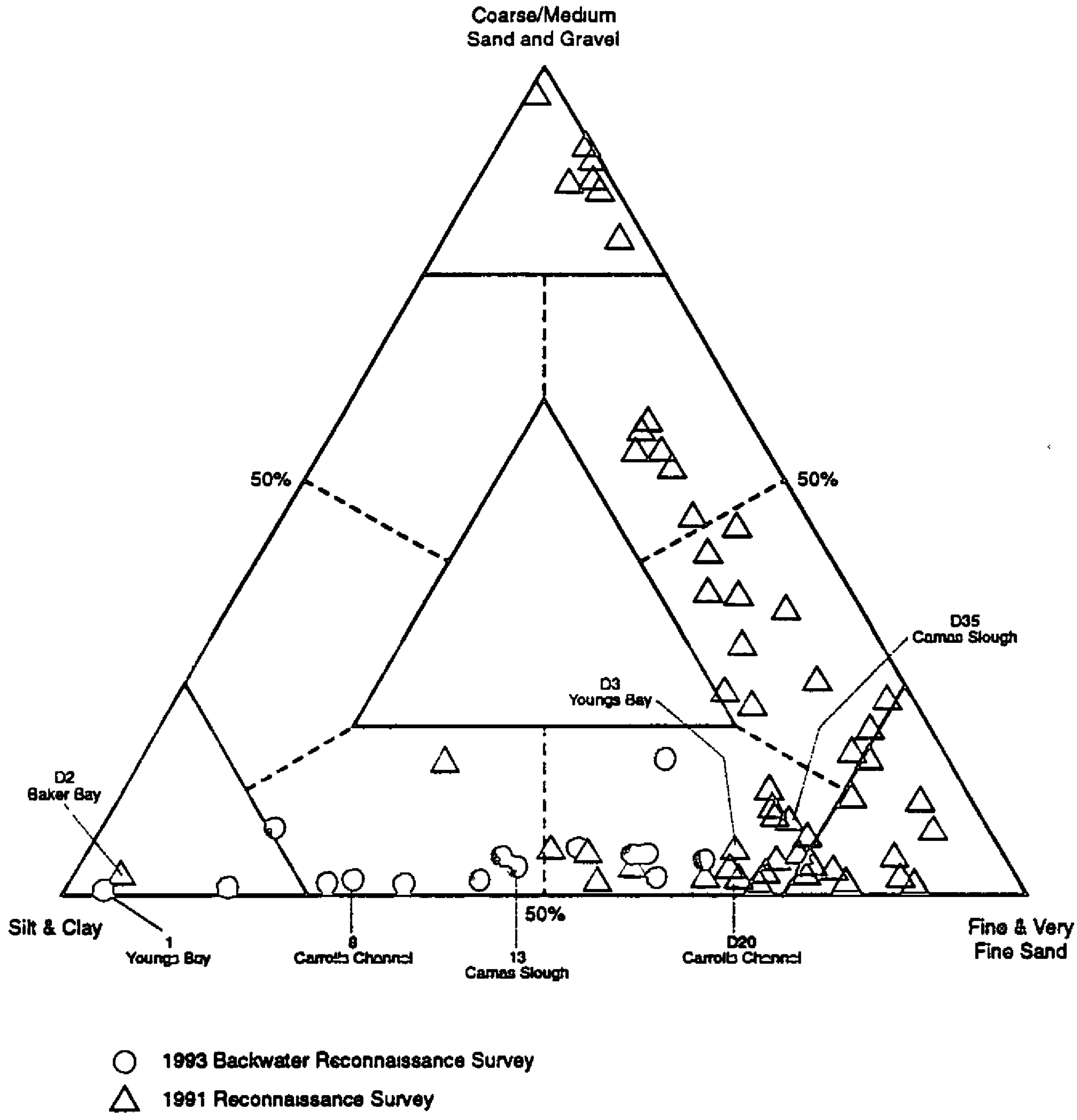


Figure 5-2. Ternary Diagram of Sediment Grain Size Distribution Between the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.

near Hammond OR, D2 and D4 in Baker Bay, D12 near Cathlamet, D16 in Coal Creek Slough, D22 in Kalama, and D23 in Martin Slough

Samples taken from the three stations sampled in both surveys (Youngs Bay, Carrolls Channel, and Camas Slough) tended to have finer sediments in 1993 (primarily silt) than in 1991 (primarily fine sand), which is consistent with the effort to collect finer sediments for chemical analyses in the backwater survey (Figure 5-2)

The sediment percent fines concentration exceeded 50% at 9 of the 15 backwater stations, exceeding 75% at 2 of these (Youngs Bay and Willow Bar Islands). The median percent fines concentration in backwater samples was 52%, compared to 14% in the 1991 survey (Table 5-7). The highest percent fines content were measured at stations located in the estuary Baker Bay, sampled in 1991 (94%) and Youngs Bay, sampled in 1993 (95%).

The sources of these sediments include natural geologic sources (land erosion, erosion and scouring of the river) and anthropogenic sources (land clearing, logging, agricultural activities, urban runoff, and point source discharges) Whetten et al. (1969) summarized the textural and mineral characteristics of mainstem Columbia River sediments and quantified sediment transport relationships in the river. They concluded that mainstem sediment is derived from two principal sources. upstream sediments (above the McNary Dam) from the metamorphic, plutonic, and sedimentary rocks of the upper river basin, and downstream sediments from andesitic volcanic rocks and sediments of the lower river basin. The upstream sediment is generally fine-grained and is transported by the river primarily in suspension. Volcanic sediments from the lower river basin are generally coarser and are transported as bedload [For example, the catastrophic input of mud and debris following the eruption of Mount St. Helens in May 1980 (Haeni 1983; Hubbell et al. 1983; Simenstad et al. 1984)]. Mainstem sediment particles have undergone relatively little chemical weathering and the amount of sediment transported in a single high-flow period may exceed the amount transported in an average year. Whetten et al. (1969) also concluded that the primary sources of suspended sediments to the river were the Snake and Willamette Rivers and that dam construction in the river basin had not affected the total annual discharge of sediment, but had altered the seasonal patterns of sediment transport and deposition.

The degree to which backwater sediments are representative of the fine-grained sediments transported in the mainstem vs deriving from local sources has not been determined This may be an important variable, affecting the relationship between fine sediment particles and their contaminant content which is presumably due primarily to upstream pollutant inputs from point and nonpoint sources, and the accumulation and settling of contaminated fine-grained sediments in backwaters Other potential sources of backwater contaminants include local point and nonpoint sources and atmospheric inputs.

5.2.1.3 Relationship Between Sediment TOC and Percent Fines. Sediment organic carbon tends to accumulate to greater concentrations in finer-grained sediments because finer-grained particles have greater surface area per mass and hence sorb relatively greater concentrations of organic carbon (Horowitz and Elrick 1987, Horowitz 1991) Finer-grained sediments also indicate areas where both coarse and fine organic materials tend to settle There also is a living biotic component of the sediment that includes micro- and macro-benthos and bacteria As a result, sediment TOC concentration tends to correlate positively with the percentage of finer-grained sediments (Figure 5-3). However, the relationship between percent fines and TOC was not significant in the backwater samples (Table 5-8). This lack of a significant relationship suggests the influence of localized sources of organic matter in the relatively confined backwater areas sampled (e g., litter fall from nearby trees, wood fibers from log-storage areas, and/or wetland and aquatic plant detritus) These stations may be identified as outliers from the 1991 regression relationship.

5.2.2 Metals and Cyanide

In general, the median concentrations of metals in 1993 backwater samples were higher than in 1991 samples. This was true for aluminum, arsenic, barium, cadmium, copper, iron, lead, nickel, silver, and zinc (Table 5-9). Frequency of exceedances of reference levels also increased for the metals that were identified in 1991 as potential problem contaminants: arsenic, cadmium, copper, iron, nickel, and zinc). The exception was silver, which was detected at only one backwater station (Elochoman Slough) at a concentration that exceeded both the Long and Morgan and Ontario reference levels (Table 5-9). Two additional metals were identified as potential problem contaminants due to higher concentrations in backwater samples Chromium exceeded the Ontario reference level of 26 mg/kg at 2 stations (Elochoman Slough and Scappoose Bay), and mercury exceeded the Long and Morgan reference level of 0.15 mg/kg at Fisher Island Slough (Table 5-9). Due to the relatively high detection limits for antimony and thallium, the differences between laboratory detection limits achieved for beryllium and selenium,

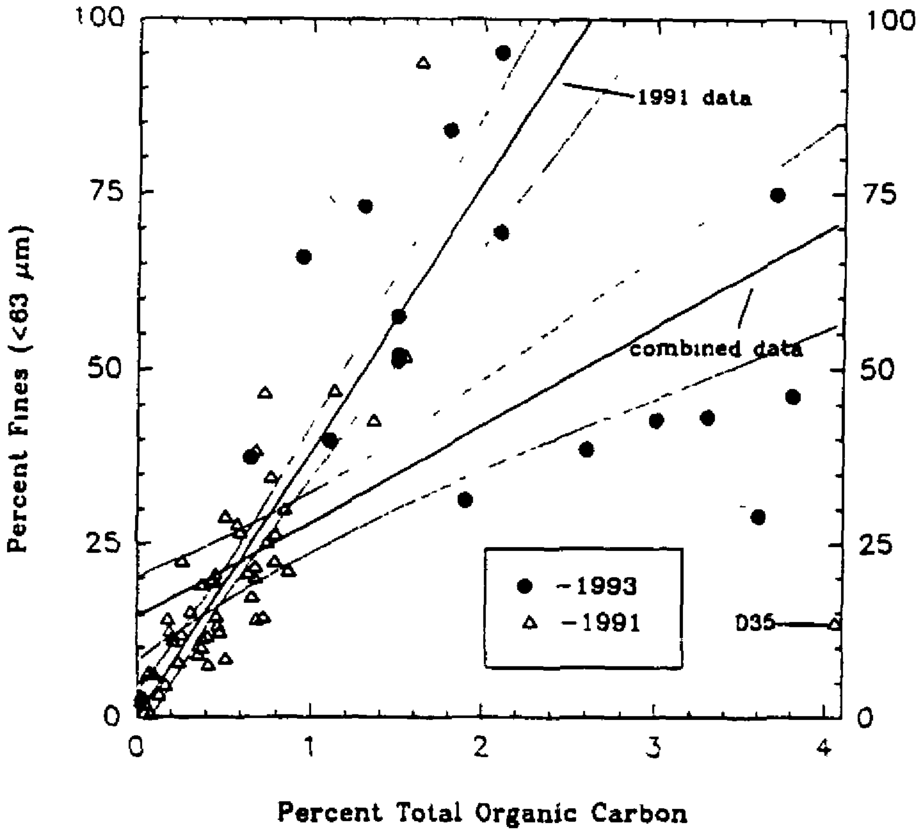


Figure 5-3. Scatterplots and Linear Regressions of Sediment TOC vs. Percent Fines Content in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals. Results for Station D35 (Camas Slough) were removed prior to regression.*

TABLE 5-8 REGRESSION COEFFICIENT OF DETERMINATION (r^2) BETWEEN SEDIMENT PERCENT FINES AND TOTAL ORGANIC CARBON

	Percent TOC[a]		
	1991	1993	Combined Data
Percent Fines[b]	0.7637**	0.0186	0.4665**

[a] Percent sediment total organic carbon. One outlier, TOC content at Station D35 - Camas Slough was removed prior to analysis.

[b] Percent fines defined as percent dry sediment less than 63 μm effective diameter

Statistically significant regressions noted by ** $P<0.001$.

TABLE 5-9 SUMMARY OF SEDIMENT METALS AND CYANIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS
(Page 1 of 2)

	Frequency of Detection[a]	Units in mg/kg dry sediment		Frequency of Exceedances[b]	
		Range	Median	Long and Morgan	Ontario
Aluminum					
1993	15/15	14,200-33,300	18,033	NA	NA
1991	54/54	2,794-15,060	6,752	--	--
Combined data	69/69	2,794-33,300	8,065	--	--
Antimony					
1993	0/15	0.23U-0.41U	0.30U	0/15	NA
1991	0/54	4.28U-11.1U	5.3U	0/54	--
Combined data	0/69	--	NC	0/69	--
Arsenic					
1993	15/15	3.6-13.6	4.5	0/15	4/15
1991	54/54	0.46-8.92	2.15	0/54	1/54
Combined data	69/69	0.46-13.6	2.5	0/69	5/69
Barium					
1993	15/15	59.9-186	144	NA	NA
1991	54/54	8.5-165	73.8	--	--
Combined data	69/69	8.5-186	83	--	--
Beryllium					
1993	15/15	0.42-1.2	0.76	NA	NA
1991	1/54	2.82U-7.99U	3.38U	--	--
Combined data	16/69	--	NC	--	--
Cadmium					
1993	15/15	0.49-1.9	1.0	0/15	14/15
1991	53/54	0.06U-2.66	0.38	0/54	8/54
Combined data	68/69	0.06U-2.66	0.43	0/69	22/69
Chromium					
1993	15/15	14.8-31.1	20.8	0/15	2/15
1991	52/54	2.3U-14.6	7.2	0/54	0/54
Combined data	67/69	2.3-31.1	7.9	0/69	2/69
Copper					
1993	15/15	19.3-49.9	27.6	0/15	15/15
1991	54/54	1.84-26.9	8.5	0/54	8/54
Combined data	69/69	1.84-49.9	10.7	0/69	23/69
Iron					
1993	15/15	15,500-39,000	20,600	NA	9/15
1991	54/54	3,906-24,408	11,635	--	3/54
Combined data	69/69	3,906-39,000	13,521	--	12/69
Lead					
1993	12/15	9.5U-26.3	15.6	0/15	0/15
1991	54/54	0.63-20.5	7.0	0/54	0/54
Combined data	66/69	0.63-26.3	8.0	0/69	0/69

TABLE 5-9 SUMMARY OF SEDIMENT METALS AND CYANIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 2 of 2)

	Frequency of Detection[a]	Units in mg/kg dry sediment		Frequency of Exceedances[b]	
		Range	Median	Long and Morgan	Ontario
Mercury					
1993	15/15	0.06-0.18	0.08	1/15	0/15
1991	10/54	0.057U-0.125	0.07U	0/54	0/54
Combined data	25/69	0.057U-0.18	NC	0/69	0/69
Nickel					
1993	15/15	14.0-24.8	15.3	0/15	7/15
1991	54/54	4.21-20.1	9.2	0/54	1/54
Combined data	69/69	4.21-24.8	10.4	0/69	8/54
Selenium					
1993	0/15	0.91U-1.6U	1.2U	NA	NA
1991	2/54	0.29U-0.75	NC	--	--
Combined data	2/69	0.29U-0.75	NC	--	--
Silver					
1993	1/15	0.08U-3.1	0.11U	1/15	1/15
1991	10/54	0.26U-1.49	0.32U	2/54	6/54
Combined data	11/69	0.08U-3.1	0.31U	3/69	7/69
Thallium					
1993	0/15	0.30U-0.55U	0.40U	NA	NA
1991	0/54	10.3U-26.8U	12.6U	--	--
Combined data	0/69	0.30U-26.8U	12.2U	--	--
Zinc					
1993	15/15	68.3-155	97.3	4/15	4/15
1991	54/54	16.4-161.3	63.8	2/54	2/54
Combined data	69/69	16.4-161.3	76.3	6/69	6/69
Cyanide					
1993	1/15	0.1U-0.172	0.1U	NA	1/15
1991	R	--	--	--	--
Combined data	1/15	0.1U-0.172	0.1U	--	1/15

NA = No reference level available for determination.

NC = Not calculated due to large number of detection limit values that were higher than detected concentrations measured in the 1991 Reconnaissance Survey.

U = Not detected. Value is the detection limit.

R = Samples analyzed, but data unusable due to exceedance of sample analysis holding times.

[a] Frequency of detection is equivalent to the number of stations sampled where the parameter was detected. Fifteen stations were sampled in 1993 and fifty-four stations were sampled in 1991.

[b] Frequency of exceedance of the Long and Morgan (1990) Effects Range-Low on the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persaud et al. 1993) Lowest Effect Level for potential adverse effects on benthic organisms.

and the lack of reference levels for these metals, their potential environmental significance and concentrations relative to 1991 data could not be determined

Cyanide was detected at 1 station at a concentration (0 172 mg/kg) that exceeded the Ontario reference level of 0 1 mg/kg

Table 5-10 compares results of sediment metals analyses conducted on samples collected from relatively similar locations for the 1991 and 1993 surveys Sediment metal concentrations were generally higher in the backwater survey, except for mercury concentrations which were similar between the 1991 and 1993 surveys The relatively higher metal concentrations are likely due to the relatively higher percent fines and TOC content of backwater sediments

5.2.2.1 ***Relationship Between Sediment Grain Size and Metals Concentrations.*** Metals, particularly aluminum and iron, are a component of river sediments due to their natural occurrence in rocks and soils. Metals are mobilized and concentrated in the environment by both natural processes and human activities, making, the assessment of anthropogenic contributions more difficult than it is for synthetic organic chemicals To clarify the geochemical variables that control natural concentrations of metals in sediment and to identify which concentrations are potentially elevated by human influence, statistical relationships between sediment metals concentrations and other sediment variables (percent fines and TOC content) are explored below

The correlation between finer sediments and increasing concentrations of metals has been demonstrated in a number of studies (e g , Horowitz and Elrick 1987; Horowitz et al 1989; Hanson et al 1993, Morse et al 1993, Rowan and Kalff 1993) The general association of metals with fine-grained sediments is due to covarying physical (e.g., particle surface area) and chemical (e g., cation exchange capacity) variables that enhance the adsorption of metal oxides and hydroxides (primarily of iron and manganese) and organic matter onto the surfaces of clay minerals (Horowitz et al. 1989; Horowitz 1991). Metal complexes, organic matter, and clay mineral surfaces all provide suitable binding sites for the concentration of trace metals. Relationships between sediment metals concentrations and both sediment percent fines and TOC content (for 1993 data and combined 1991 and 1993 data) are presented graphically for all of the metals that were detected frequently in sediments : aluminum, iron, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and zinc (Figures 5-4 through 5-15). Regression

TABLE 5-10 COMPARISON OF SEDIMENT METALS CONCENTRATIONS REPORTED FOR YOUNGS BAY, CARROLLS CHANNEL, AND CAMAS SLOUGH SAMPLED IN THE 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Youngs Bay (RM 14)		Carrolls Channel (RM 68)		Camas Slough (RM 120)	
	Station D3	Station 1	Station D20	Station 8	Station D35	Station 13
	1991	1993	1991	1993	1991	1993
Percent Fines	73.2	95.1	29.8	69.3	43.6	51.9
Percent TOC	0.6	2.1	0.85	2.1	4.06	1.5
	mg/kg dry sediment					
Aluminum	8,226	21,100	10,252	19,900	10,753	19,400
Antimony	5.36U	0.35U	5.91U	0.33U	6.72U	0.29U
Arsenic	2.43	4.6	3.59	4.3	3.99	6.2
Barium	39.3	59.9	102.5	149	125.4	164
Beryllium	3.47U	0.82	4.36U	0.66	4.64U	0.87
Cadmium	0.49	0.98	0.52	1.3	0.93	1.3
Chromium	9.66	23.1	8.28	21.8	9.41	20.8
Copper	8.94	31.7	16.17	34.0	17.03	31.0
Iron	13,591	21,500	14,196	20,600	16,129	21,100
Lead	12.78	16.1	9.41	16.4	11.7	23.6
Mercury	0.086	0.08	0.079U	0.10	0.09	0.08
Nickel	8.94	15.3	11.04	17.4	12.54	18.3
Selenium	0.36U	1.4U	0.39U	1.3U	0.45U	1.2U
Silver	0.32U	0.12U	0.35U	0.49U	0.4U	0.1U
Thallium	12.88U	0.47U	14.2U	0.44U	16.13U	0.39U
Zinc	78.7	93.2	90.7	136	161.3	128
Cyanide	NR	0.100U	NR	0.100U	NR	0.100U

NR = Not reported. Data were considered unusable.

U = Not detected. Value is the detection limit.

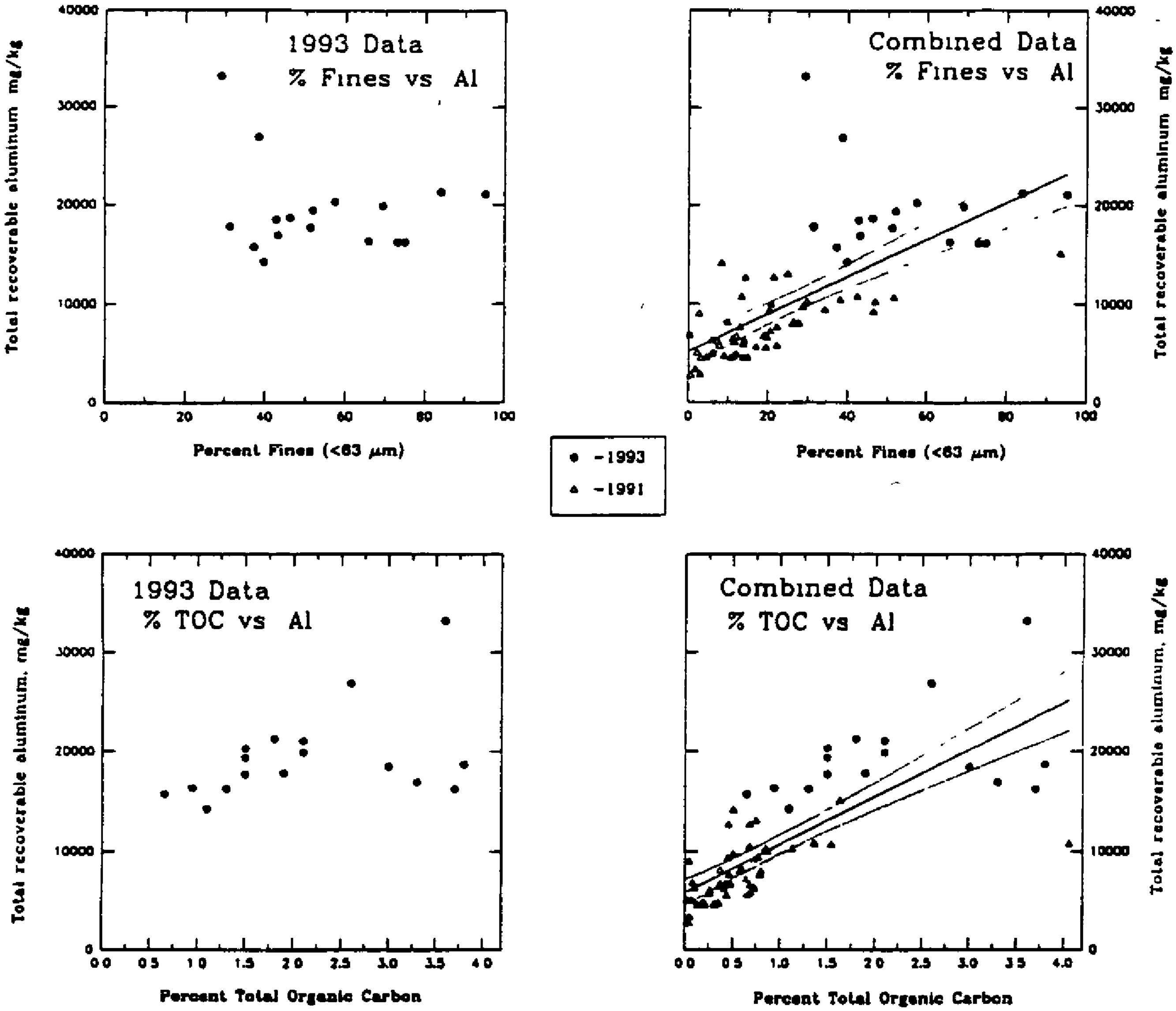


Figure 5-4. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Aluminum Content in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

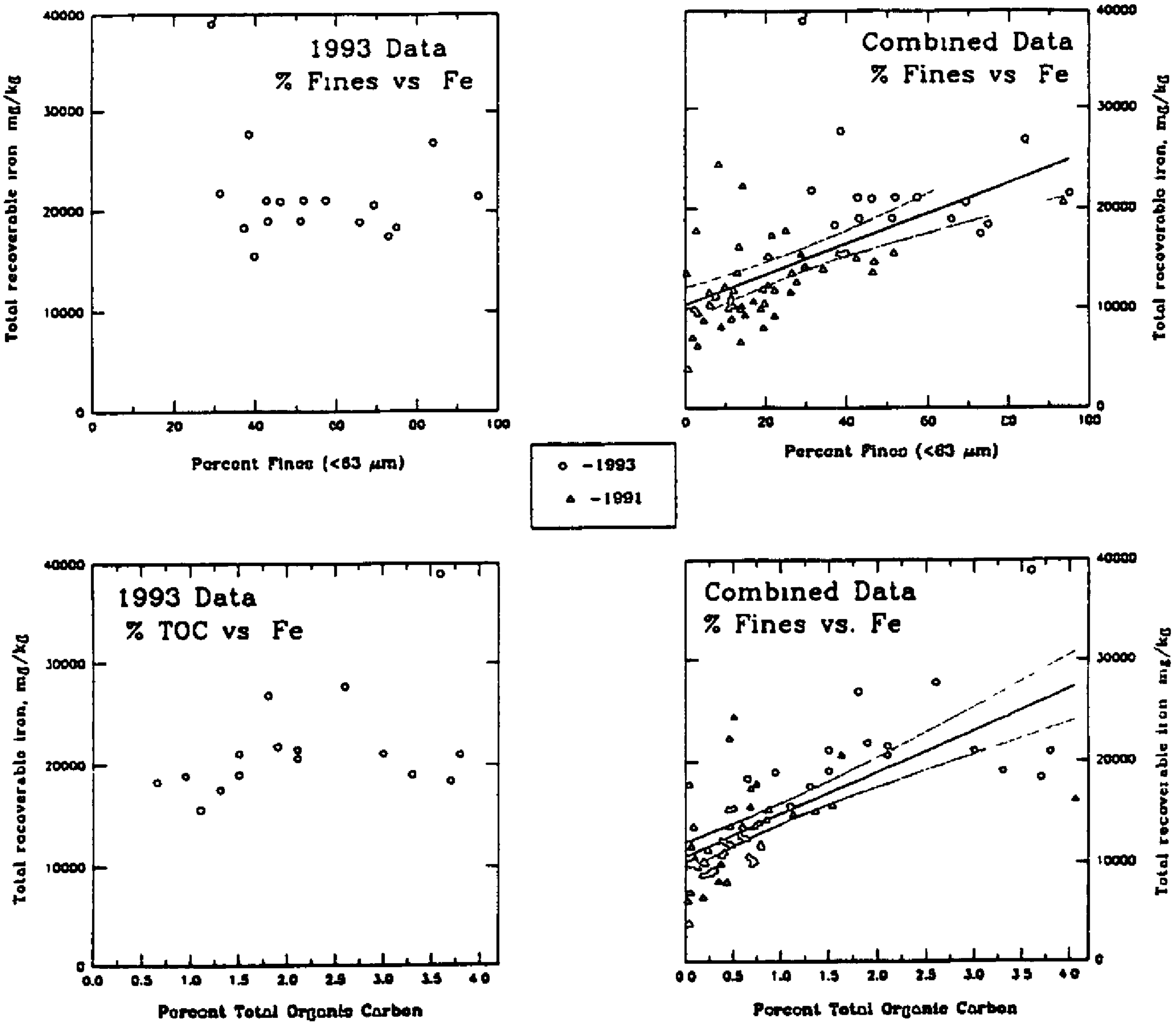


Figure 5-5. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Iron Content in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals*

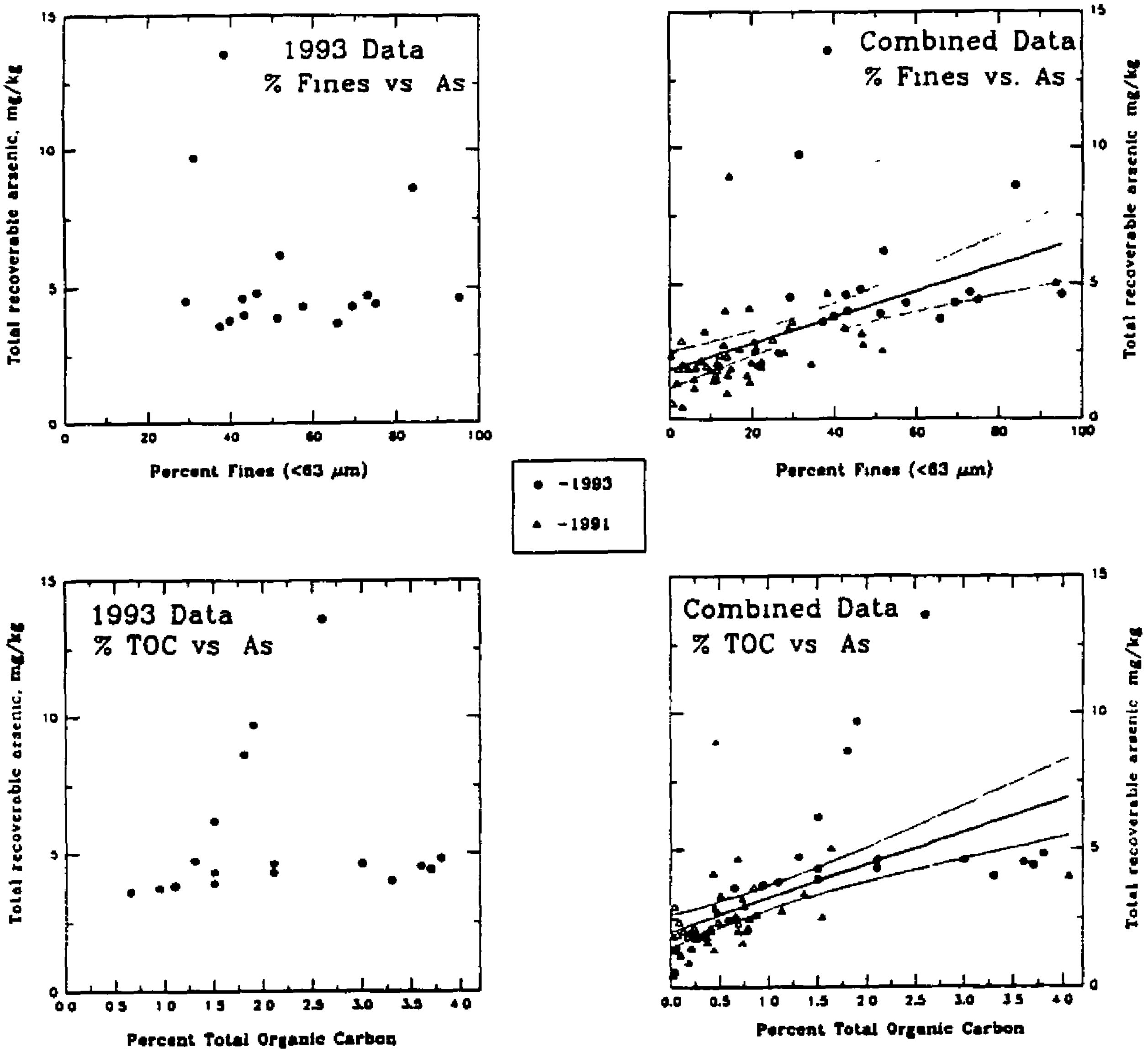


Figure 5-6. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Arsenic Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals*

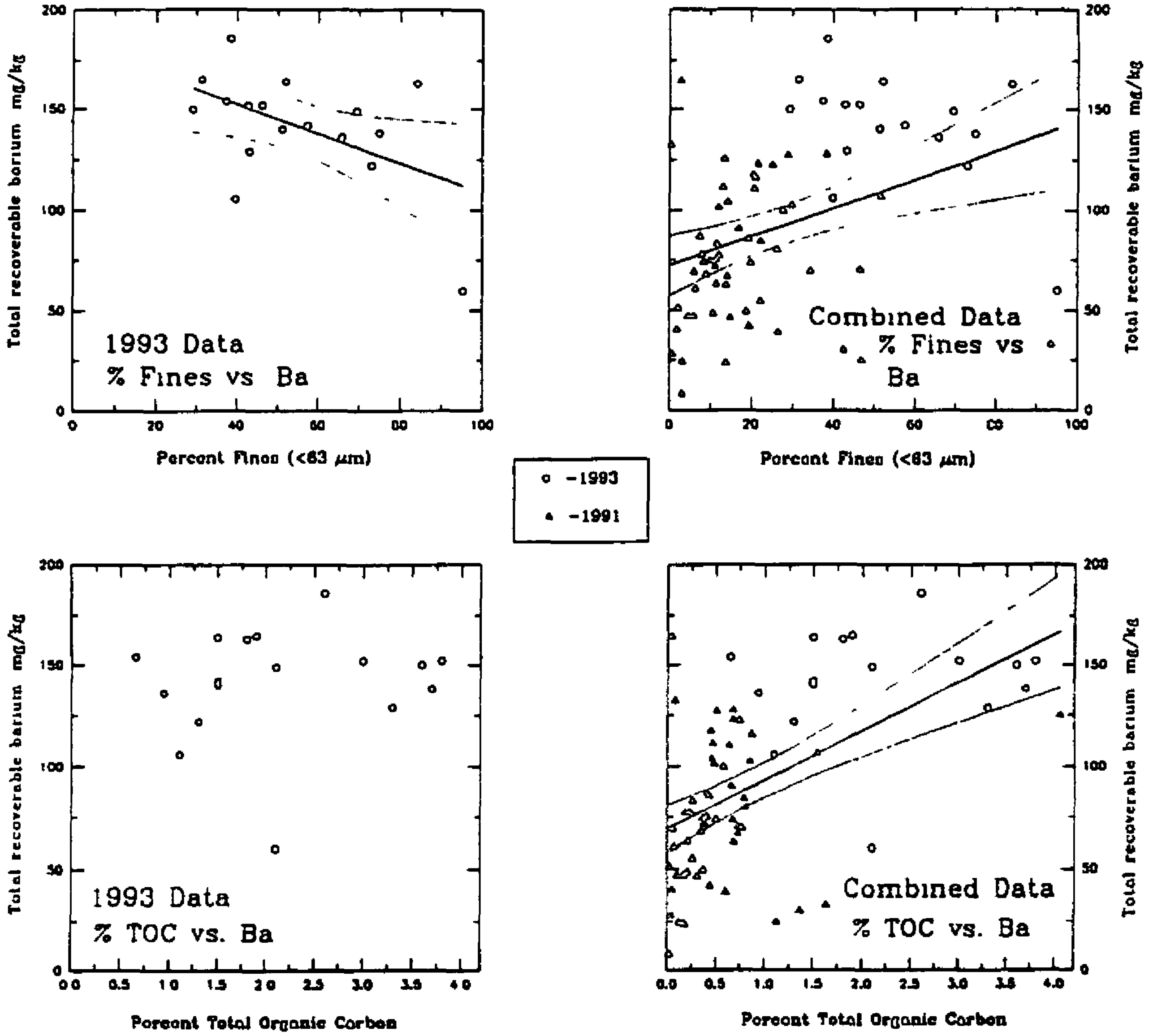


Figure 5-7. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Barium Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

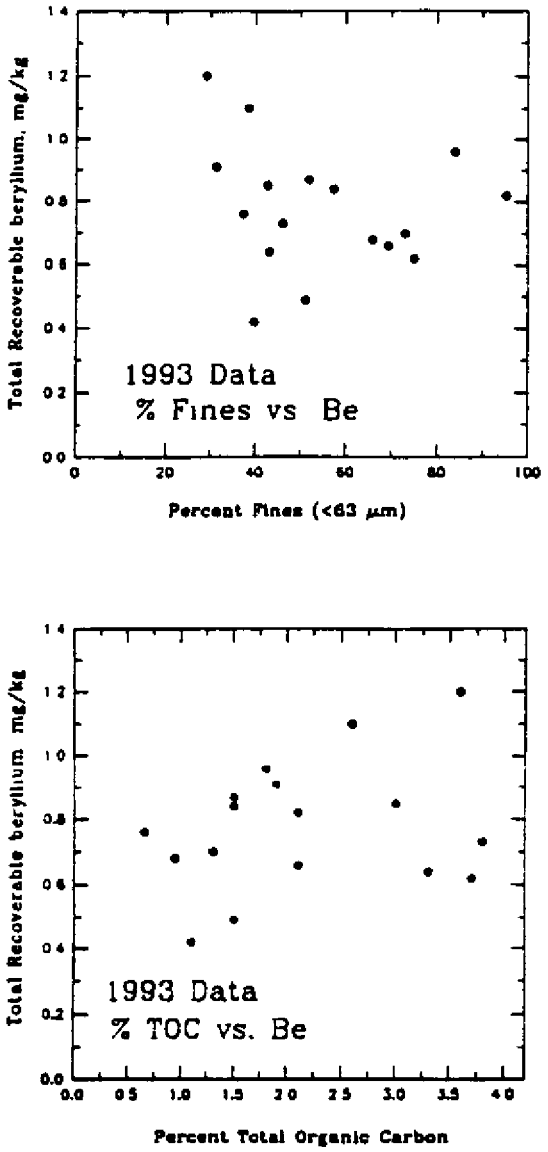


Figure 5-8. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Beryllium Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Beryllium was detected in only one sample in 1991 and therefore these data were not plotted. Dashed lines indicate 95% confidence intervals*

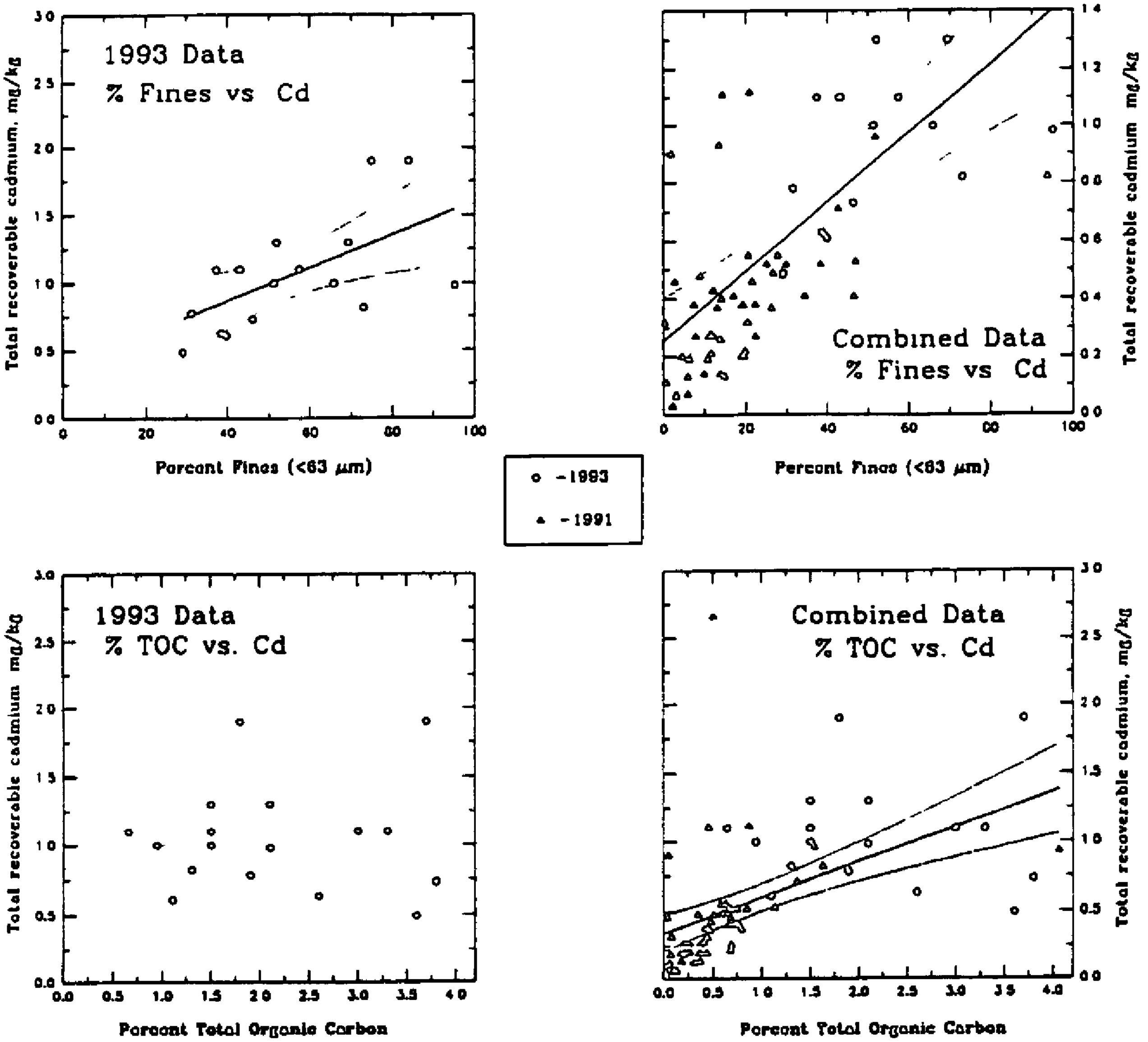


Figure 5-9. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Cadmium Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

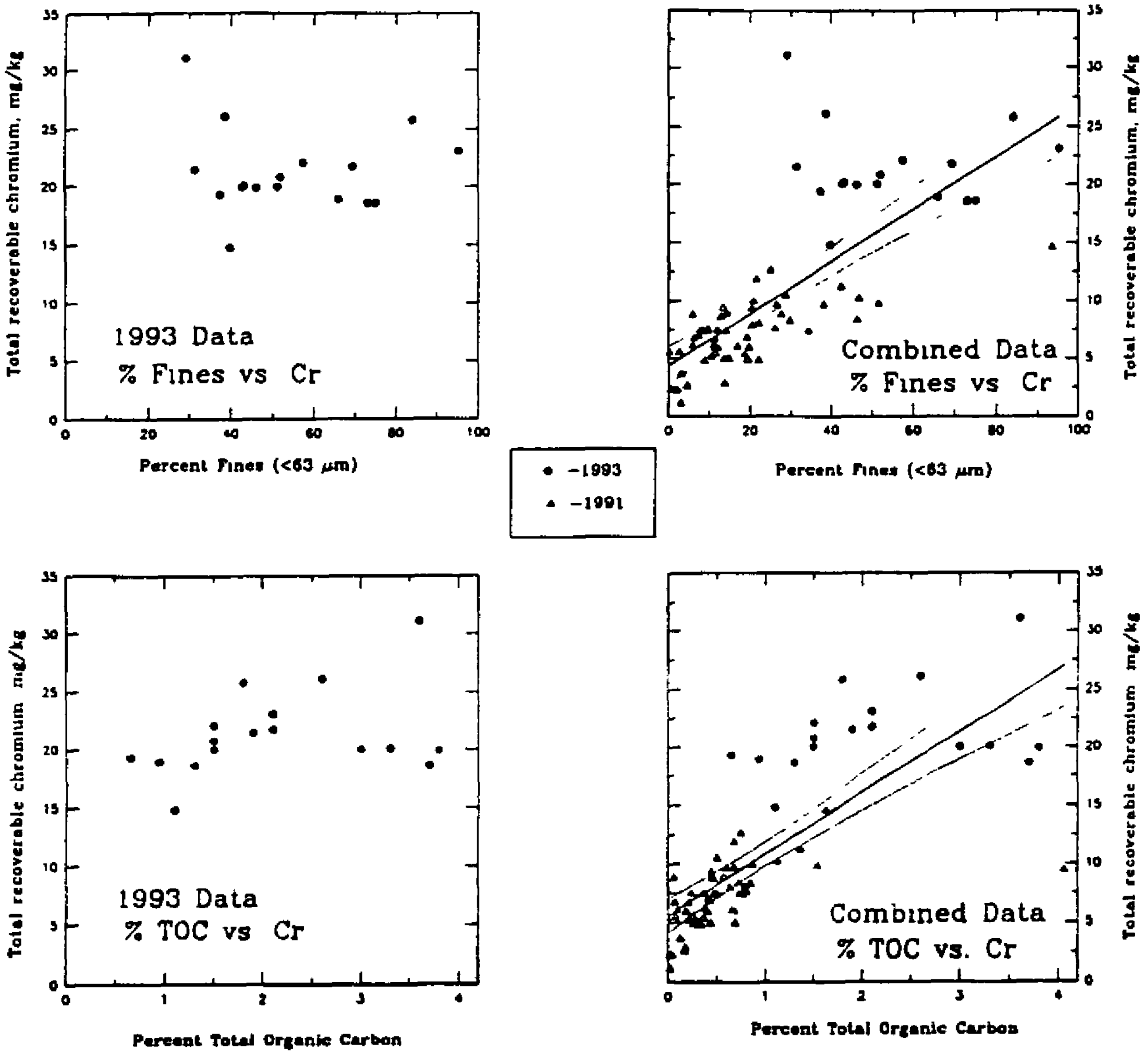


Figure 5-10. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Chromium Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

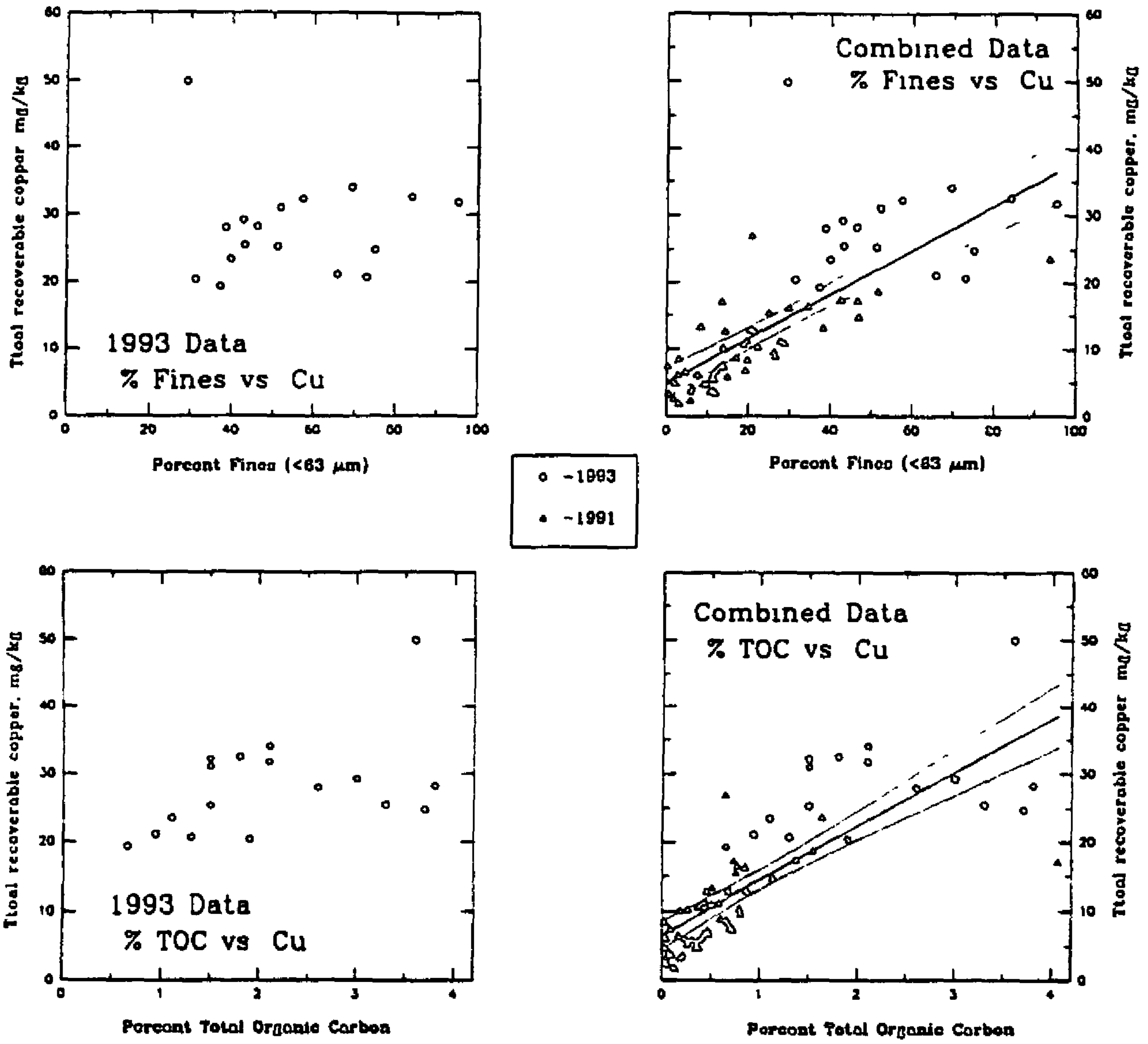


Figure 5-11. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Copper Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals*

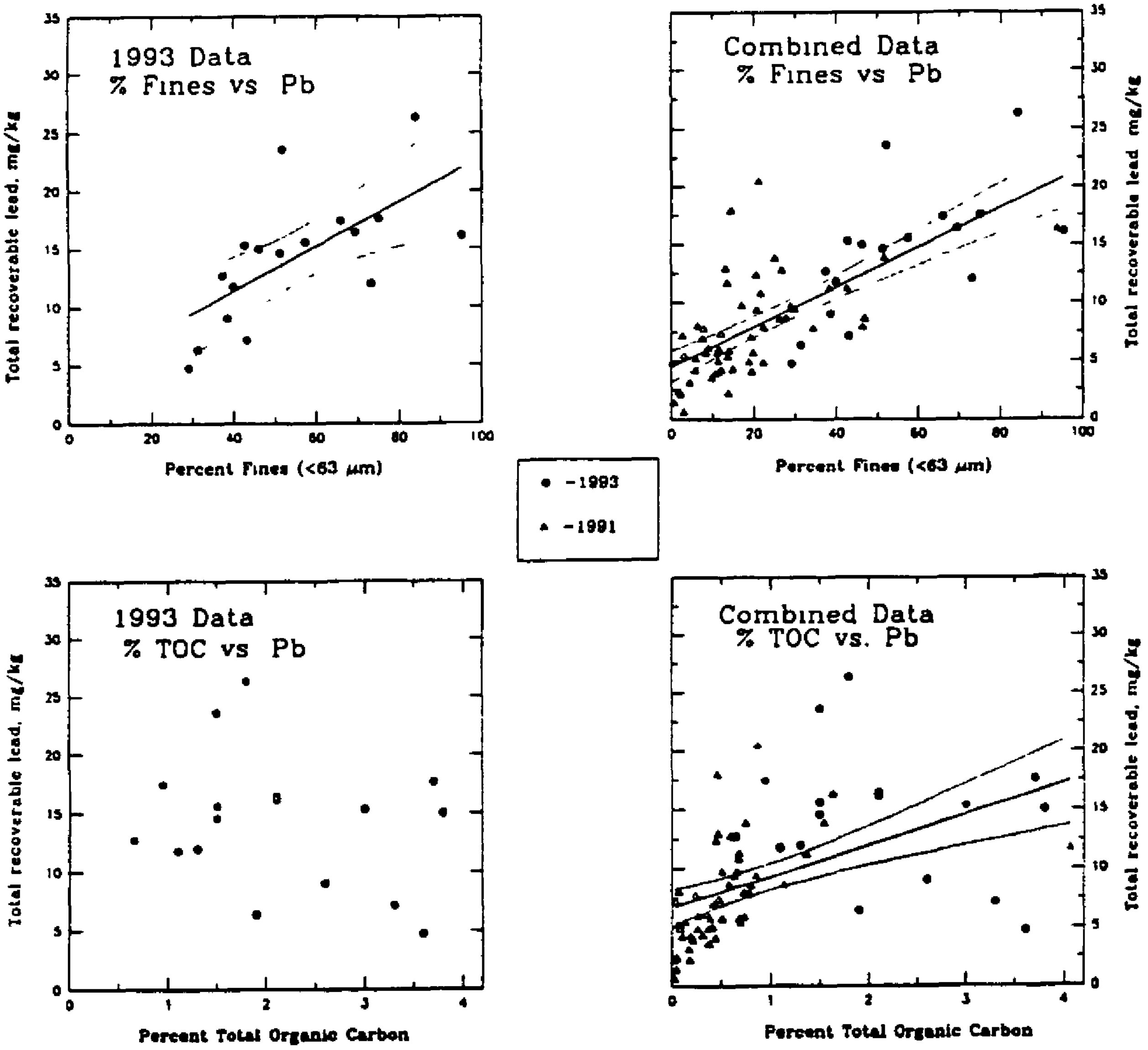


Figure 5-12. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Lead Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals*

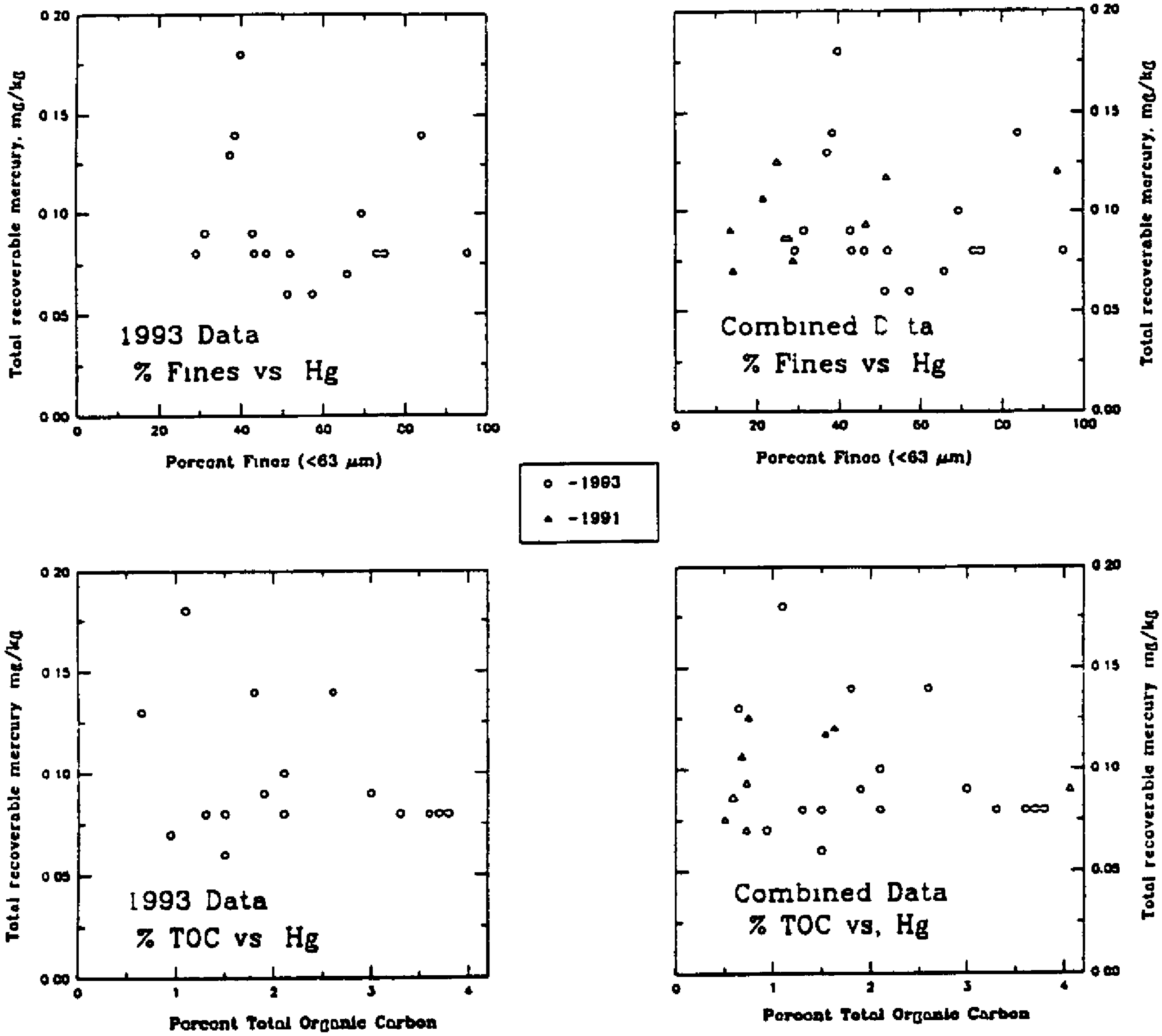


Figure 5-13. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Mercury Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *No significant linear regression relationships were found.*

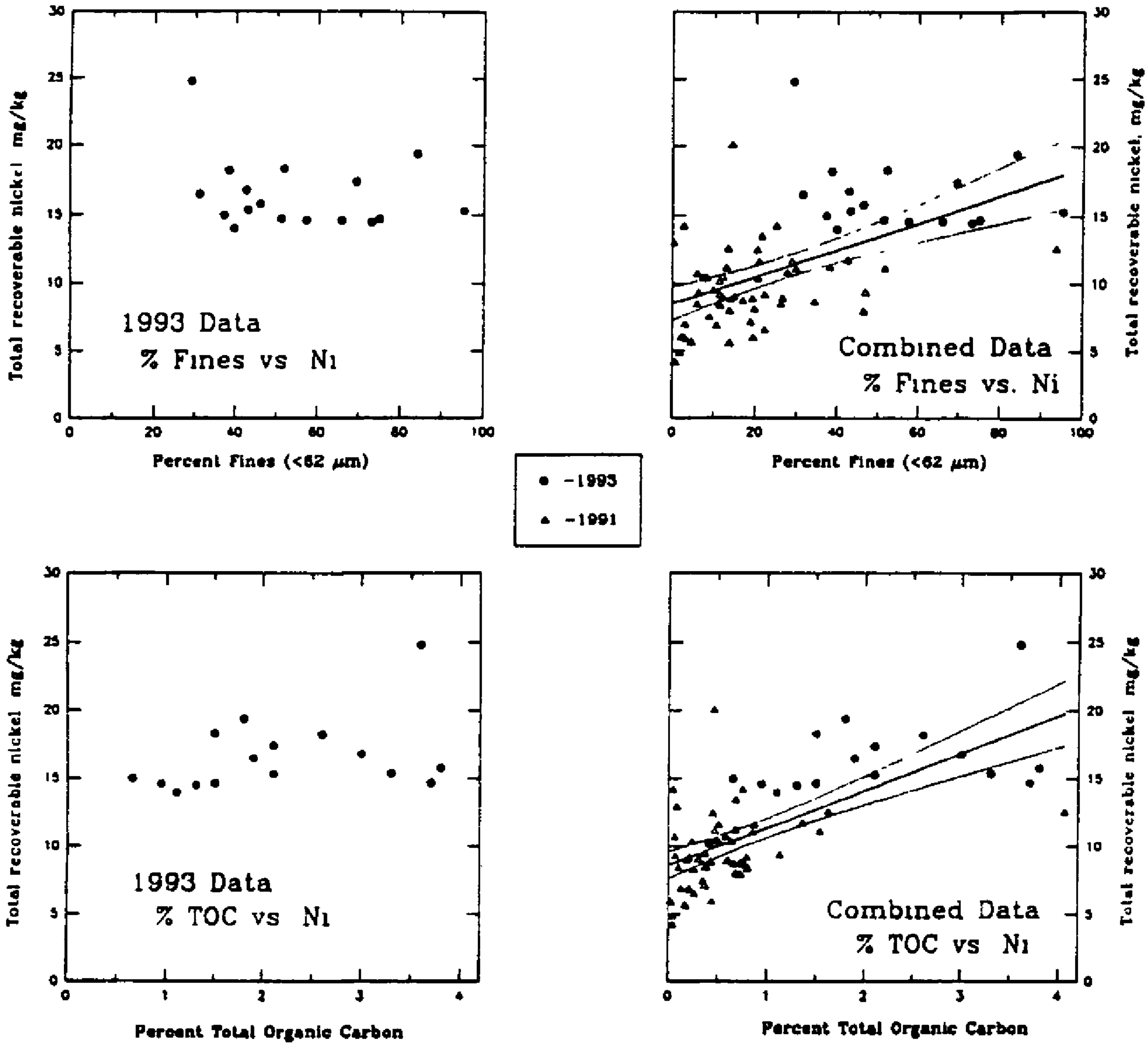


Figure 5-14. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Nickel Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

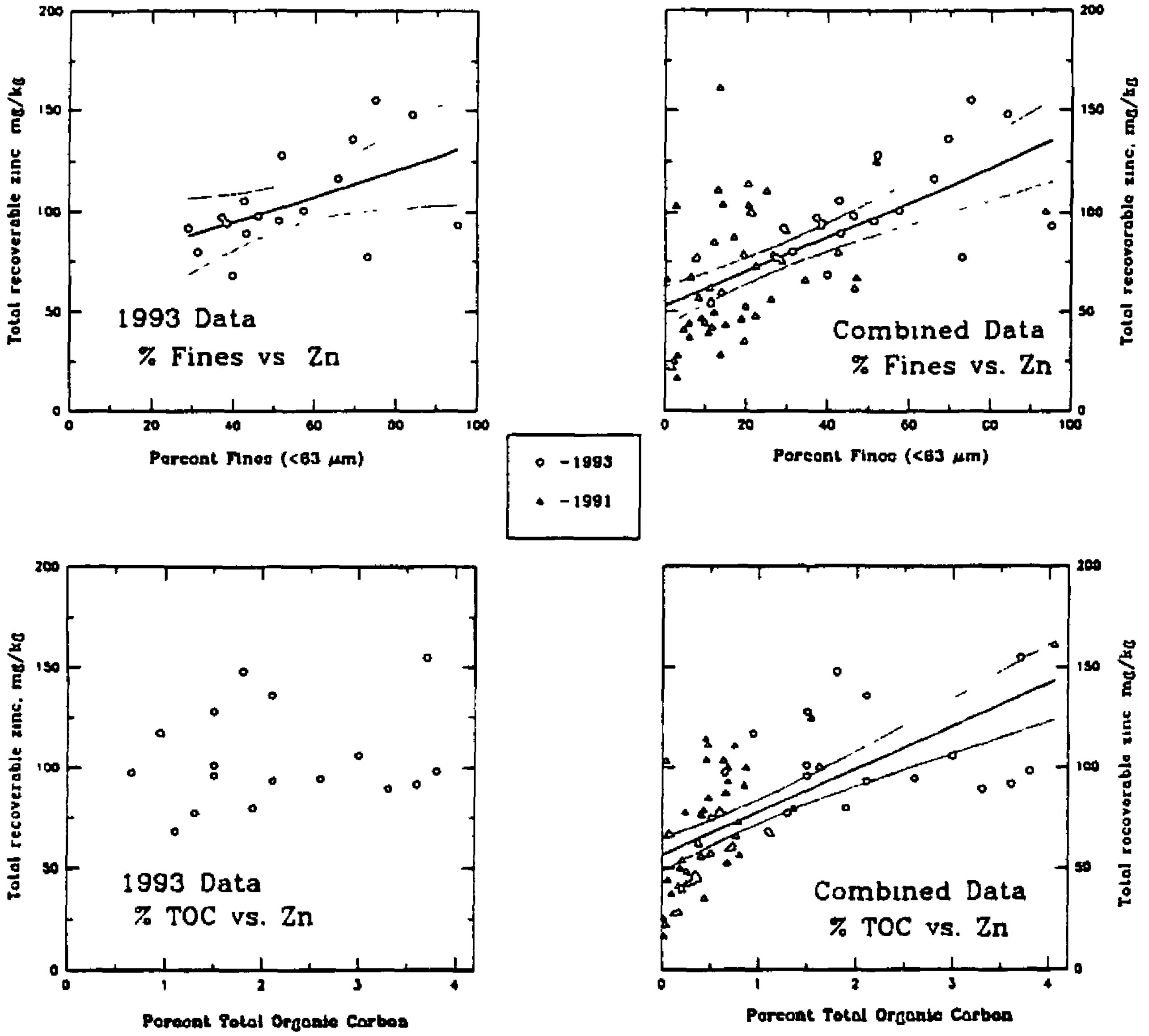


Figure 5-15. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Total Recoverable Zinc Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

coefficients of determination (r^2) for 1991, 1993, and combined data for percent fines and TOC vs metals concentrations are presented in Table 5-11 Fewer statistically significant linear relationships were noted for backwater survey data (none for TOC regressions, and only cadmium, lead, and zinc for percent fines regressions) compared to regression results for 1991 data (aluminum, iron, arsenic, cadmium, chromium, copper, lead, nickel, and zinc with TOC, and aluminum, iron, arsenic, chromium, copper, lead, and zinc with percent fines) This was probably due to the smaller number of samples collected in 1993 (Table 5-11) Combining the two data sets resulted in statistically significant relationships for all metals detected in 1991 and 1993 for both percent fines and TOC content, except for mercury which did not result in any significant regressions with either (Table 5-11) No significant regressions were obtained for beryllium and as this metal was detected in only one sample in 1991, no regressions were performed for 1991 or combined 1991 and 1993 data

In general, the variation in the 1991 metals data was better explained (higher r^2) by regression with percent fines than TOC (except for cadmium, nickel and zinc). However, except for cadmium and lead, variation in the combined data was better explained by regression with TOC. The differences noted between the 1991 and 1993 results may reflect differences in the character and sources of the sediments sampled, although the influence of sample size (fewer samples were collected in 1993) and laboratory precision and accuracy should also be considered

Other sediment metals investigations have found that sediment grain size generally provides a stronger relationship to sediment metals concentrations than sediment TOC content (e g., Windom et al 1989, Hanson et al 1993) Only cadmium, and possibly mercury, were considered to be strongly influenced by TOC in these studies Although TOC generally explains more of the metals variation in the lower Columbia surveys than does percent fines, this could be due to a closer association of sediment TOC content with the fine-grained trace metal-bearing phases.

In the analyses presented above, percent fines and TOC were used as surrogate measures of the trace metal-bearing fine sediment fraction Several studies have demonstrated that sediment aluminum content is a better surrogate than either of these for this fine sediment fraction (e.g., Windom et al 1989, Förstner 1990, Loring 1991; Horowitz 1991, Din 1992; Pardue et al. 1992; Hanson et al. 1993) Hanson et al. (1993) explained that the use of sediment aluminum concentration was consistent with a geochemical model with aluminosilicate clays and quartz (as well as feldspars, micas, pyroxenes, and amphiboles) as

TABLE 5-11 REGRESSION COEFFICIENT OF DETERMINATION (r^2) BETWEEN SEDIMENT METALS CONCENTRATIONS AND SEDIMENT PERCENT FINES AND TOTAL ORGANIC CARBON CONTENT

	Percent Fines[a]			Percent TOC[b]		
	1991	1993	Combined Data	1991	1993	Combined Data
Aluminum	0.4175°°	0.0355	0.4967°°	0.2976°°	0.0001	0.5943°°
Iron	0.2154°°	0.0527	0.3505°°	0.1783°	0.1804	0.4844°°
Arsenic	0.1783°	0.0234	0.2636°°	0.1490°	0.0070	0.3058°°
Barium	0.0001	(-)0.2534°[c]	0.1440°	0.0511	0.0162	0.3077°°
Beryllium	NC	0.0361	NC	NC	0.0807	NC
Cadmium	0.0555	0.3525°	0.3330°°	0.1375°	0.0004	0.2815°°
Chromium	0.4902°°	0.0040	0.5735°°	0.2878°°	0.1275	0.5868°°
Copper	0.5510°°	0.0040	0.5802°°	0.3674°°	0.2109	0.6218°°
Lead	0.3199°°	0.4287°	0.5357°°	0.2569°°	0.0677	0.2386°°
Mercury	0.2961	0.0281	0.0005	0.0144	0.0559	0.0187
Nickel	0.0666	0.0647	0.3191°°	0.1085°	0.1539	0.4546°°
Zinc	0.1666°	0.2591°	0.3640°°	0.4475°°	0.0286	0.4220°°

NC = Not calculated. Sediment concentrations were lower than laboratory detection limits.

[a] Percent fines defined as percent dry sediment less than 63 μm effective diameter.

[b] Percent sediment total organic carbon.

[c] The regression of 1993 percent fines vs barium was the only significant regression with a negative slope.

Statistically significantly regressions noted by: ° $P<0.05$; °° $P<0.001$

end members Aluminum functions as a surrogate measure of such aluminum-rich clay minerals as montmorillonite, kaolinite, illite, and chlorite Quartz and other silicate minerals are assumed to contain almost no trace metals Other variables that are not considered in this model include the influence of carbonates, organic matter, sea salts, and iron and manganese oxide and hydroxide coatings on coarse sediment grains (Windom et al 1989, Hanson et al 1993) Carbonates are not generally found in Columbia River sediments (Whetten et al 1969), and therefore would not be a significant influence in this study

Another assumption of the model is that aluminum has not been altered by contaminant inputs (constant aluminum associated sediment input over the study area is assumed) (Windom et al 1989, Hanson et al. 1993). Available data indicate that present direct point source discharges of aluminum to the lower river are relatively insignificant compared to tributary and upstream discharge loadings (Tetra Tech 1992a) Although it could be argued that local or regional variation in the aluminum content of geological sources of sediments preclude the use of aluminum to evaluate sediment trace metals levels, Rowan and Kalff (1993) found that geologic variables could only explain the variation in sediment cobalt, chromium, and nickel concentrations. Chromium and nickel were enriched in catchments containing ultramafic ophiolite minerals (Rowan and Kalff 1993)

The use of sediment aluminum concentrations to explain variation in sediment trace metal data on a regional scale has been recognized for estuarine and coastal environment, lake, and atmospheric metal concentrations (references in Hanson et al 1993) Models that have used geochemical variables (including aluminum) to explain variation in sediment trace metal concentrations have ranged from sophisticated multi-parameter models like principle component analysis (Horowitz et al. 1989) and multiple linear regression (Rowan and Kalff 1993) to simple linear regression models that included log-transformation prior to regression (Din 1992). Hanson et al (1993) concluded that linear regression without log-transformation of the data was more consistent with the geochemical model described above and that log-transformation of the data would generally assume a curvilinear relationship on a linear scale.

Sediment iron is another variable that may be suitable for evaluating sediment trace metal variation. Iron's abundance in sediments buffers it from anthropogenic changes. Available data indicate that present direct point source discharges of iron to the lower river are relatively insignificant when compared to tributary and upstream discharge loadings (Tetra Tech 1992a). Iron is also present in clay minerals, especially montmorillonite, an aluminum and iron-rich clay which is a significant fraction of the suspended sediment load of the lower river (Conomos 1968, Knebel et al. 1968, Whetten et al. 1969, Conomos and Gross 1972).

Although the use of total metals concentrations is more consistent with the geochemical model [total metal concentrations were used in the analyses conducted by Horowitz et al. (1989), Windom et al. (1989), Din (1992), Pardue et al (1992), and Hanson et al (1993)], only total recoverable metals concentrations were measured in this study However, relationships using sediment trace metal data based on recoverable or reactive metal concentrations have also been demonstrated (e.g , Rowan and Kalff 1993, Morse et al 1993) The relationships between total recoverable sediment metals and recoverable sediment aluminum and iron concentrations are explored below

Figures 5-16 through 5-26 show the relationships between sediment total recoverable metals concentrations and total recoverable aluminum and iron content (for 1993 data and combined 1991 and 1993 data) for all of the metals detected frequently in sediments: aluminum, iron, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and zinc Table 5-12 presents regression coefficients of determination (r^2) for these relationships. As suggested above, the strongest statistical relationship occurred between sediment aluminum and iron concentrations More of the variation in sediment trace metal concentrations was explained by regression with either aluminum or iron than with sediment percent fines or TOC (Table 5-11). Fewer statistically significant positive linear relationships were noted for backwater data for aluminum and iron (with beryllium, chromium, copper, and nickel) compared 1991 survey data (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, and zinc). This was probably due to the smaller number of samples collected in 1993 (Table 5-12).

Combining the two data sets resulted in statistically significant relationships with both aluminum and iron for all of the metals that were detected in 1991 and 1993, except for mercury (Table 5-12). With the possible exception of chromium, aluminum and iron concentrations explained a similar amount of the sediment trace metal variation, which ranged from greater than 30 to over 90% (Table 5-12). The amount of trace metal variation explained by aluminum decreased from Cr > Fe > Cu > Ni > As > Ba > Zn > Pb > Cd; the variation explained by iron decreased from Al > Ni > Cr > Cu > As > Ba > Zn > Cd > Pb.

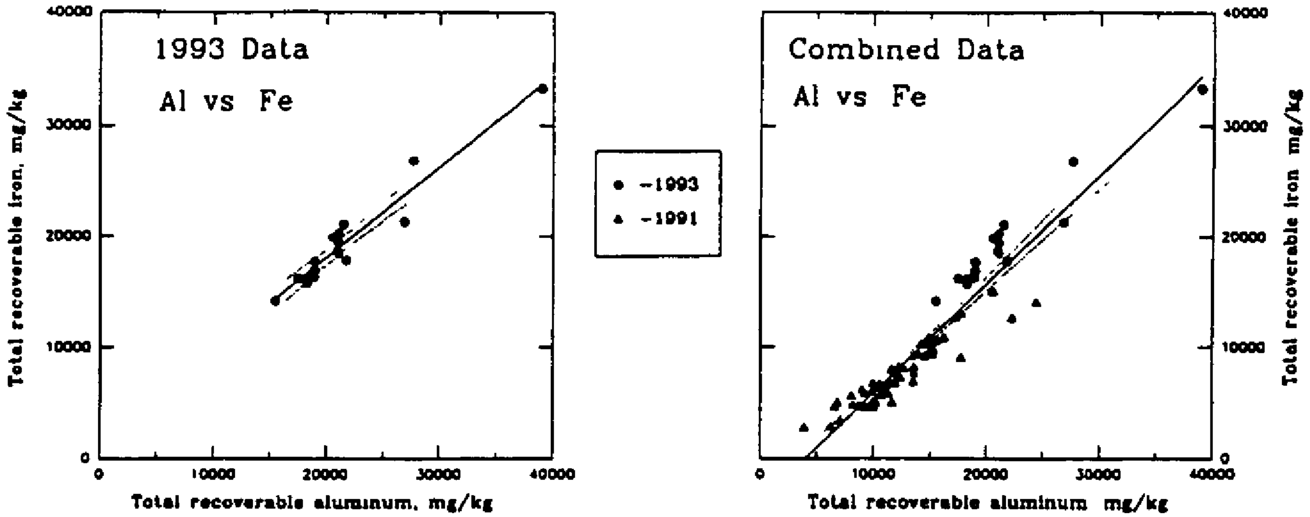


Figure 5-16. Scatterplots and Linear Regressions of Total Recoverable Aluminum vs. Iron in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

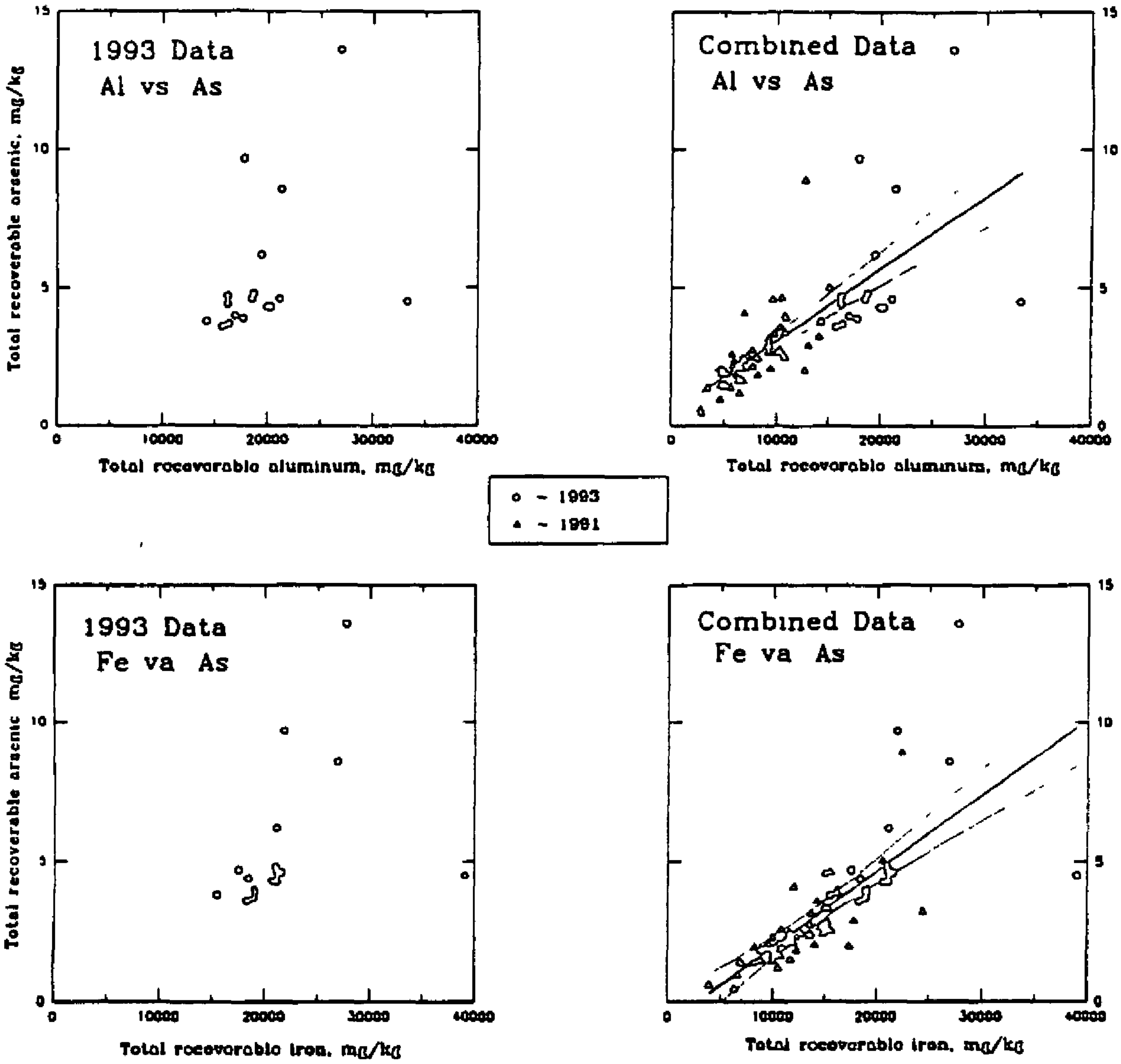


Figure 5-17. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Arsenic in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

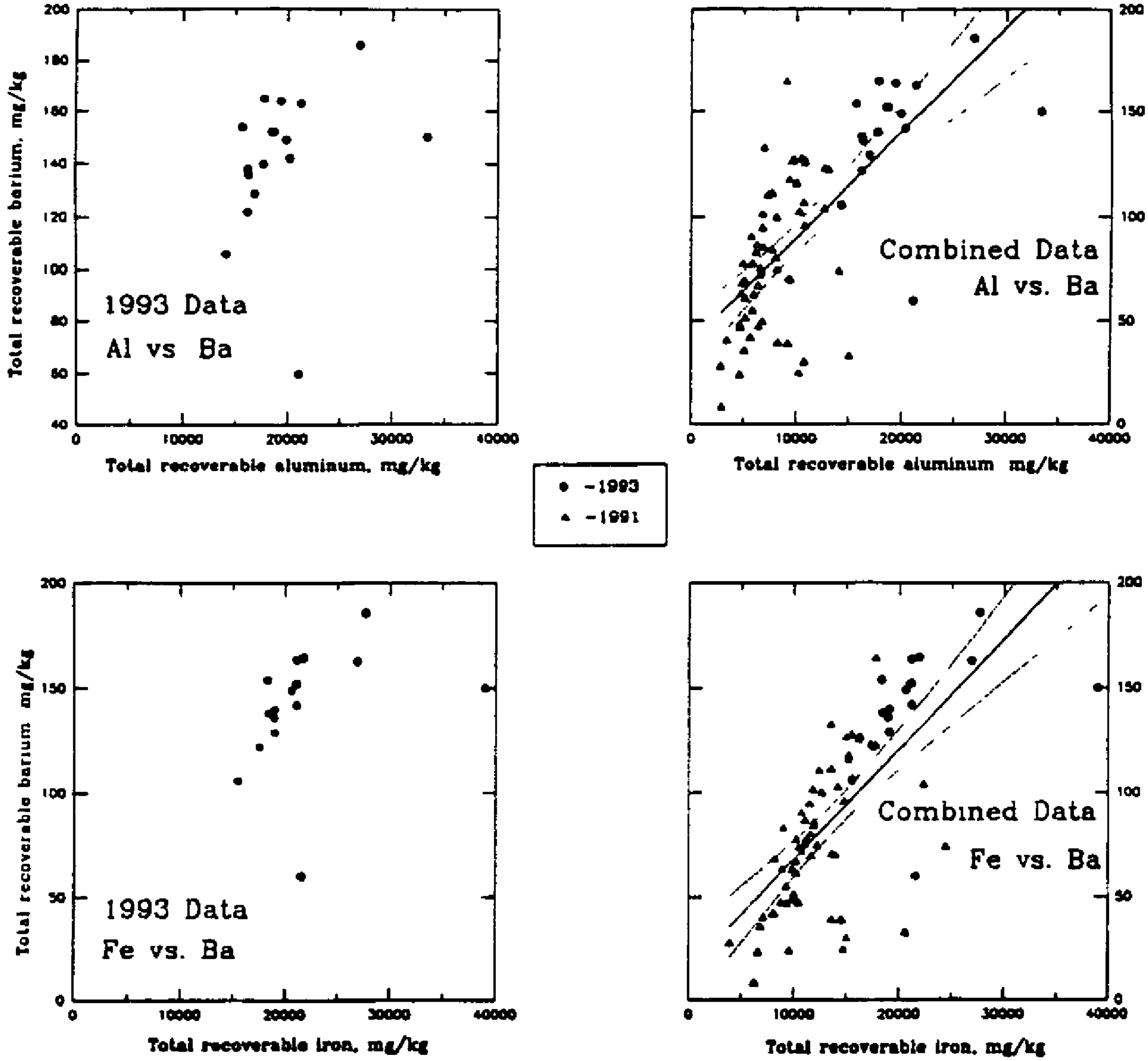


Figure 5-18. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Barium in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

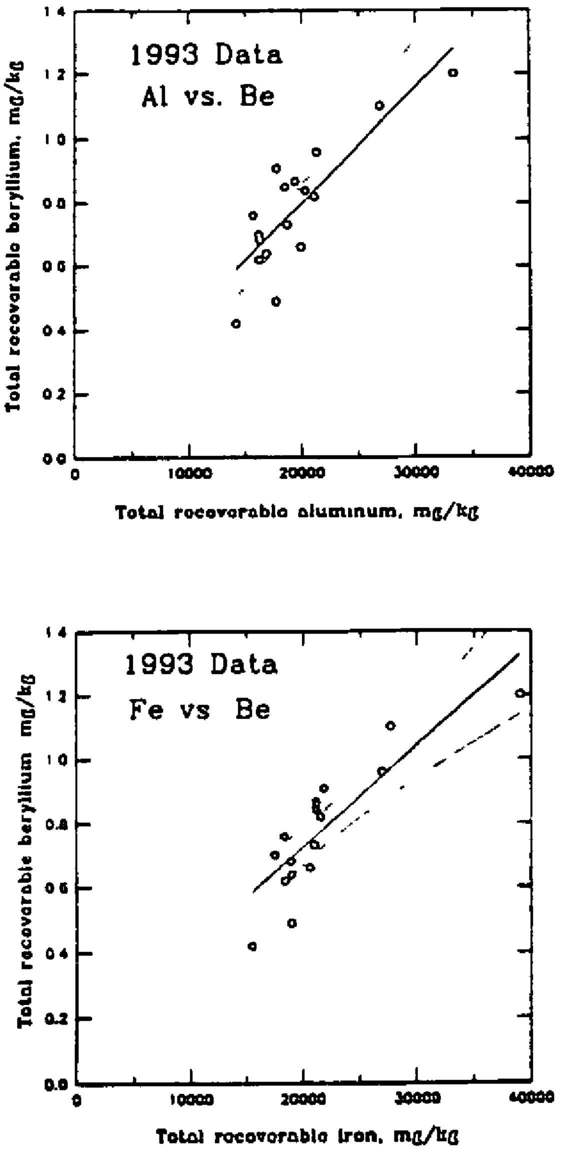


Figure 5-19. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Beryllium in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Beryllium was detected in only one sample in 1991 and therefore these data were not plotted. Dashed lines indicate 95% confidence intervals.*

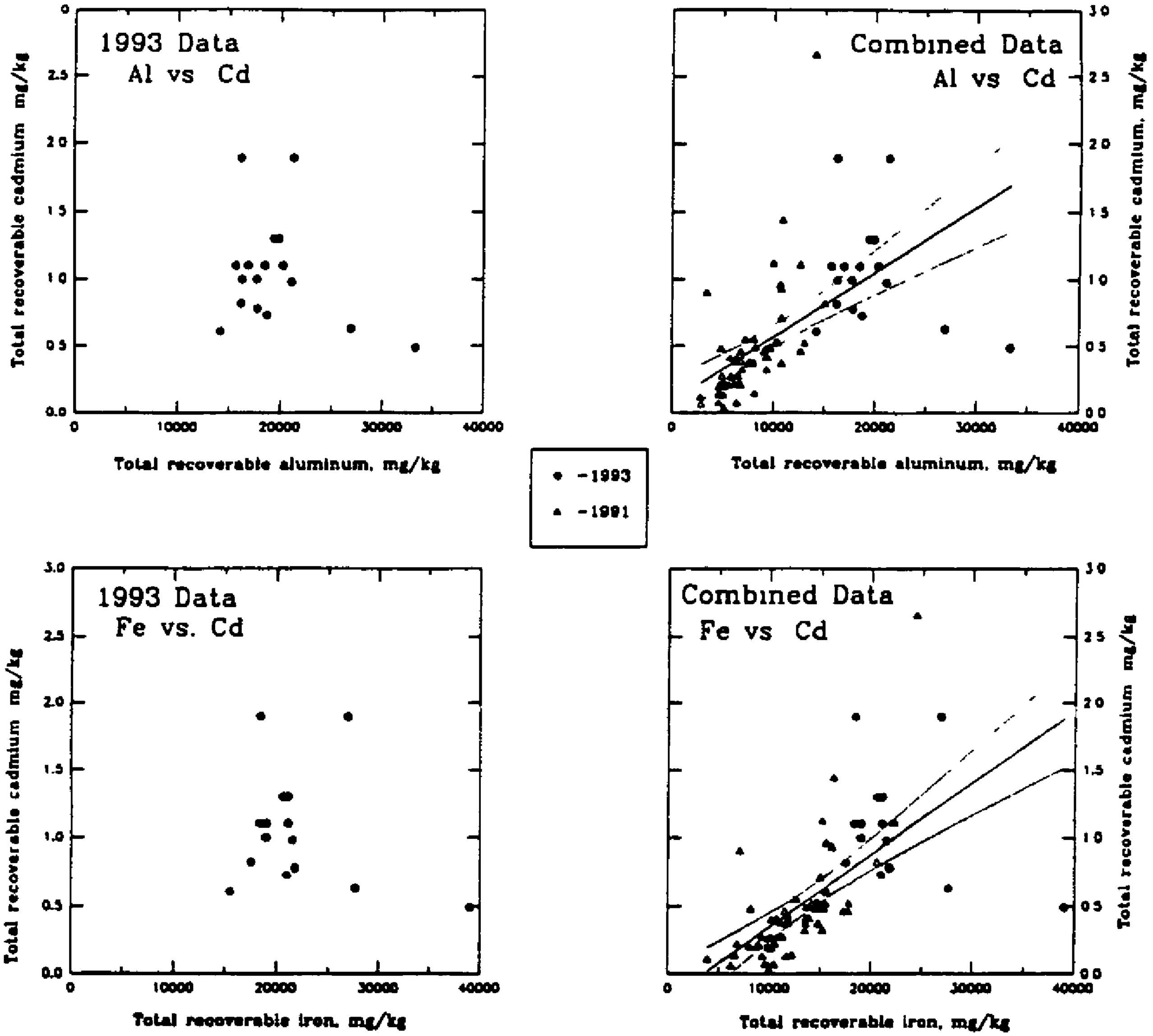


Figure 5-20. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Cadmium in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

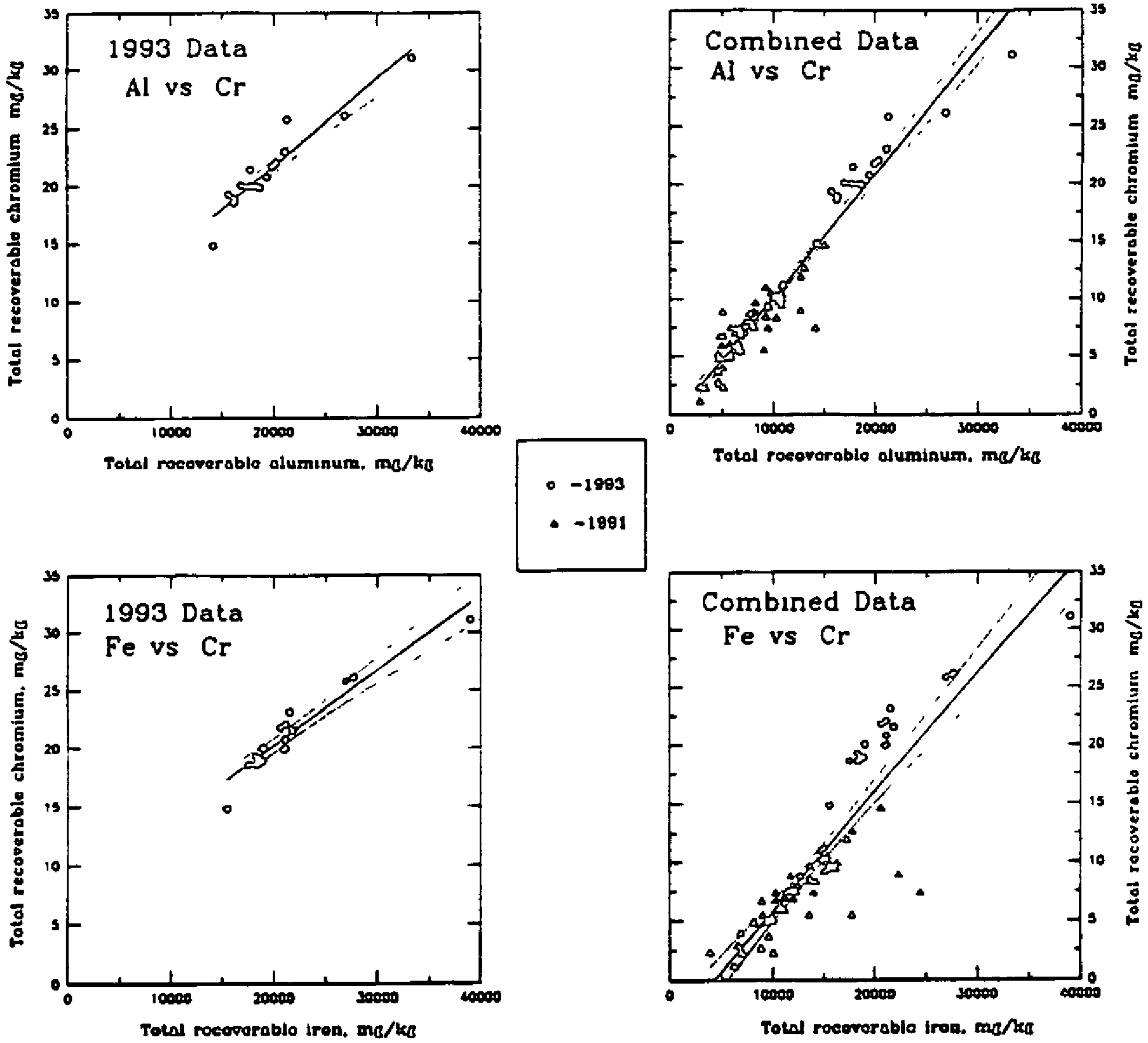


Figure 5-21. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Chromium in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

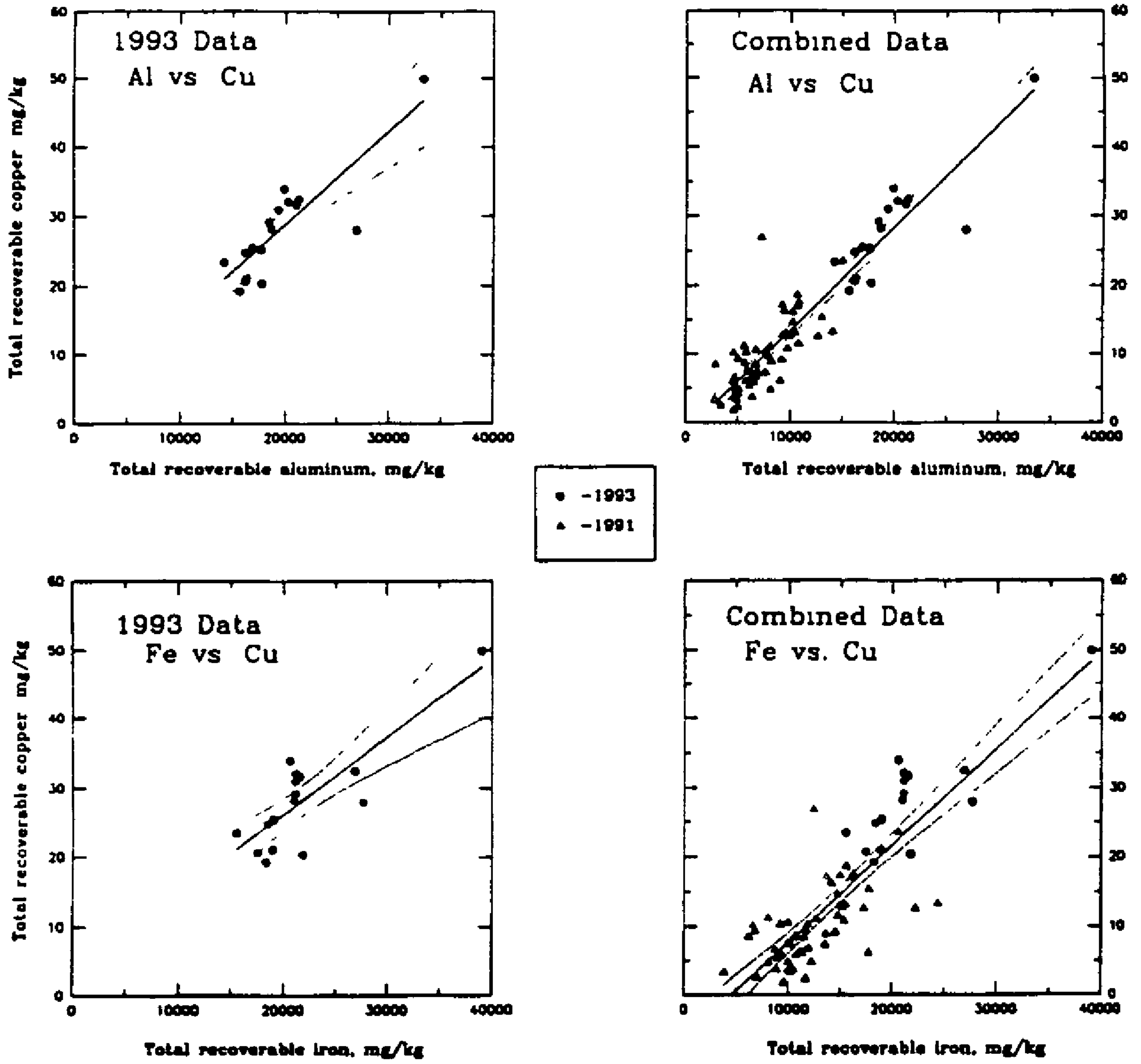


Figure 5-22. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Copper in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

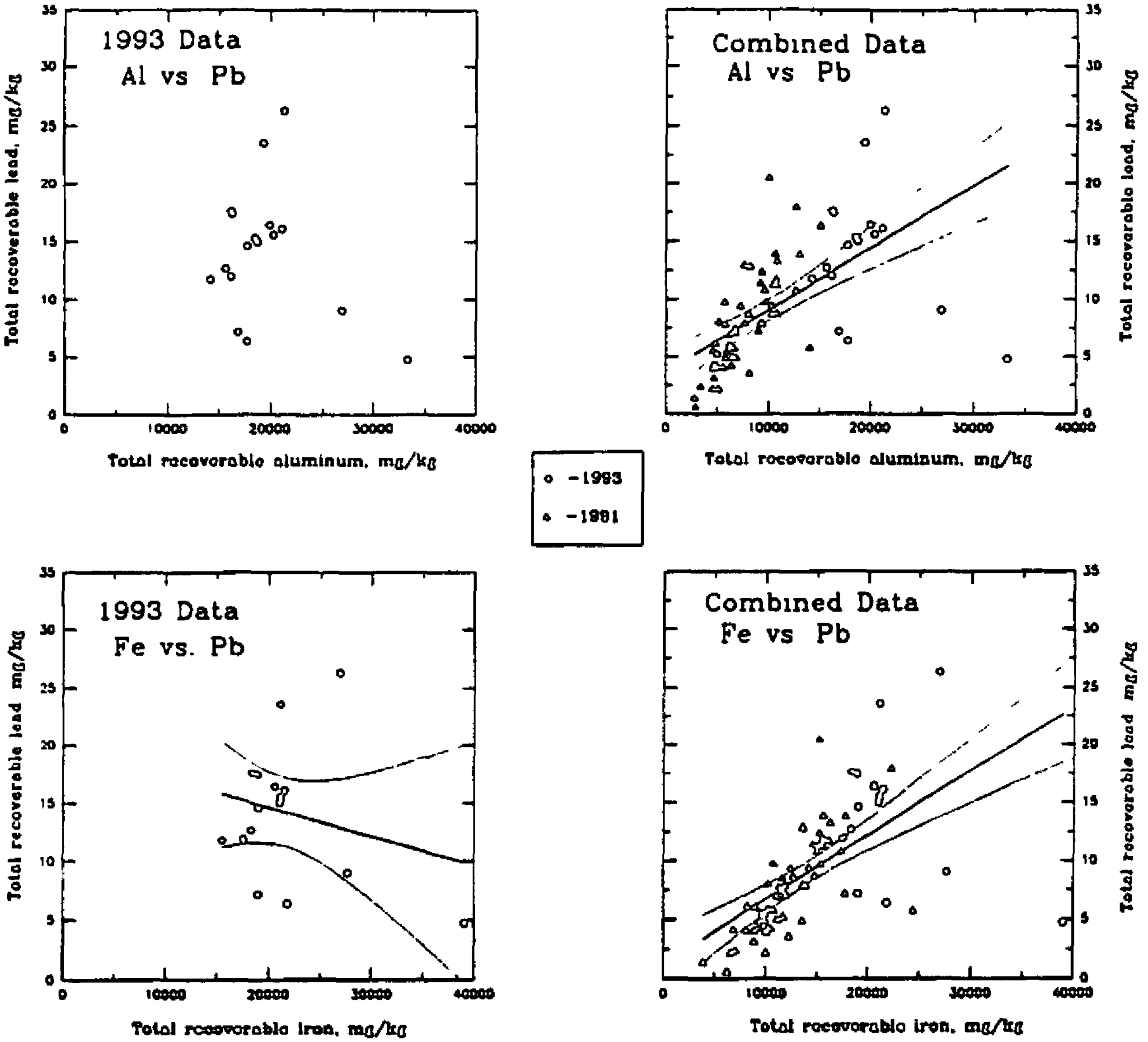


Figure 5-23. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Lead in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

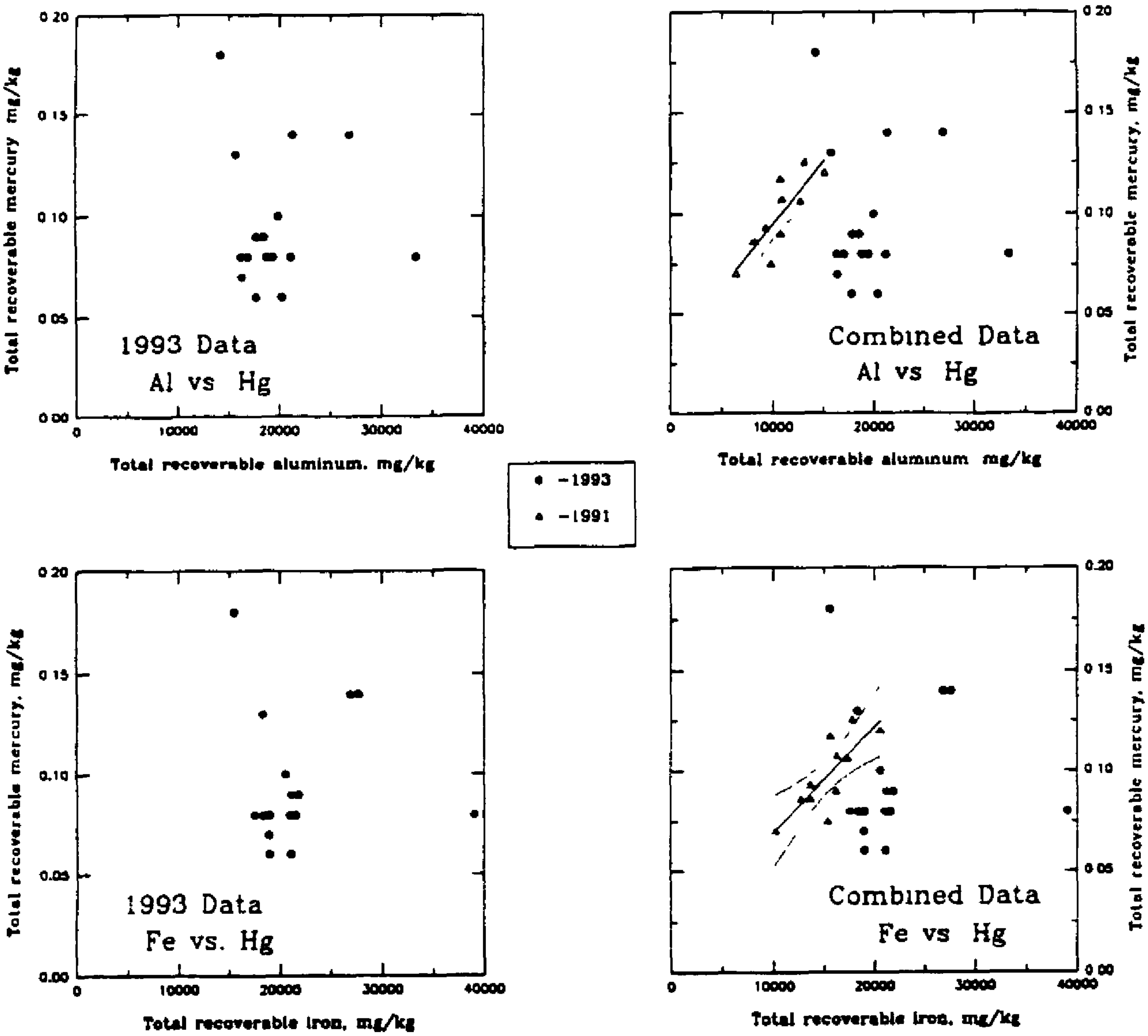


Figure 5-24. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Mercury in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Statistically significant regressions were found for 1991 mercury data only. Dashed lines indicate 95% confidence intervals.*

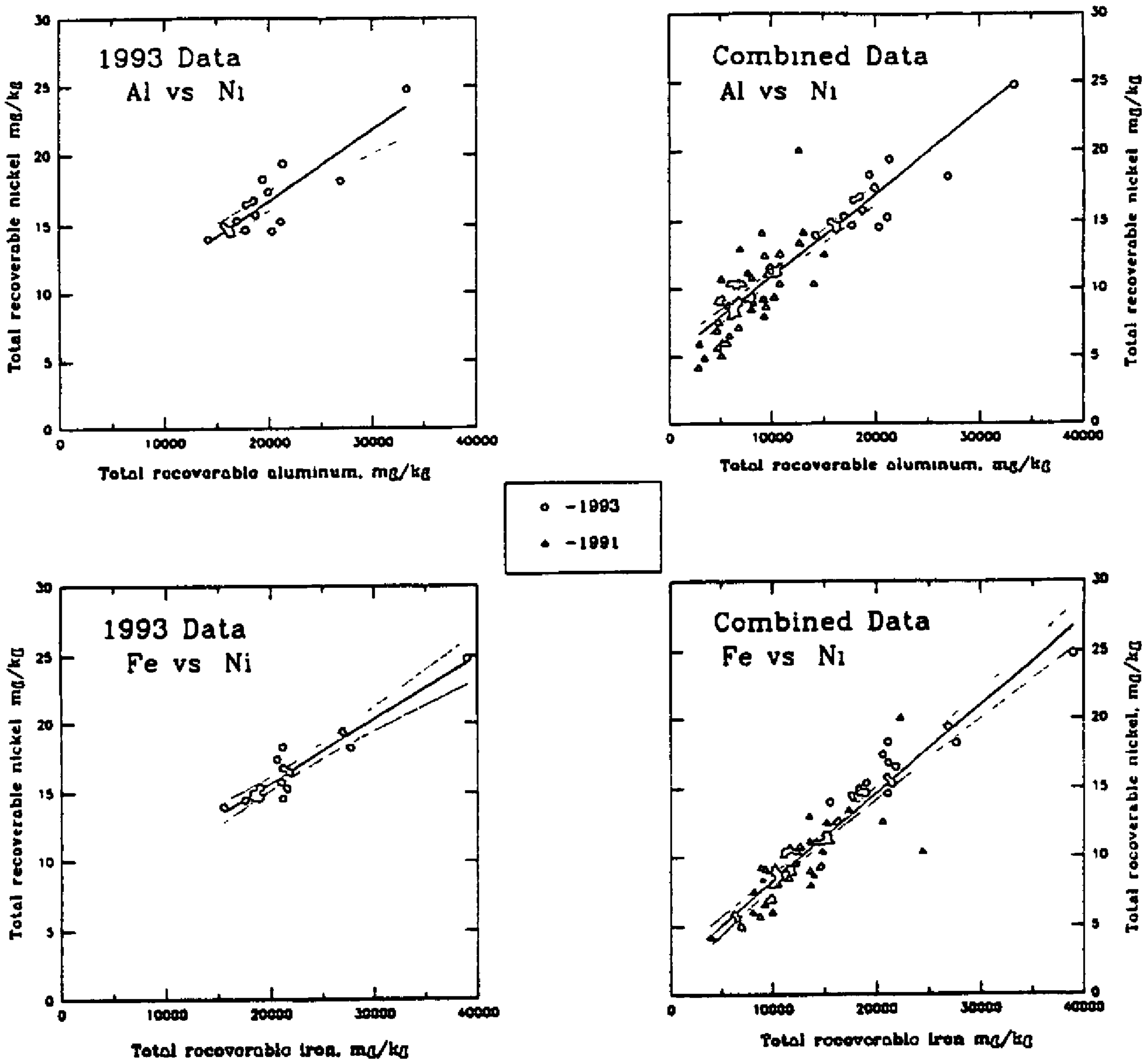


Figure 5-25. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Nickel in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals.*

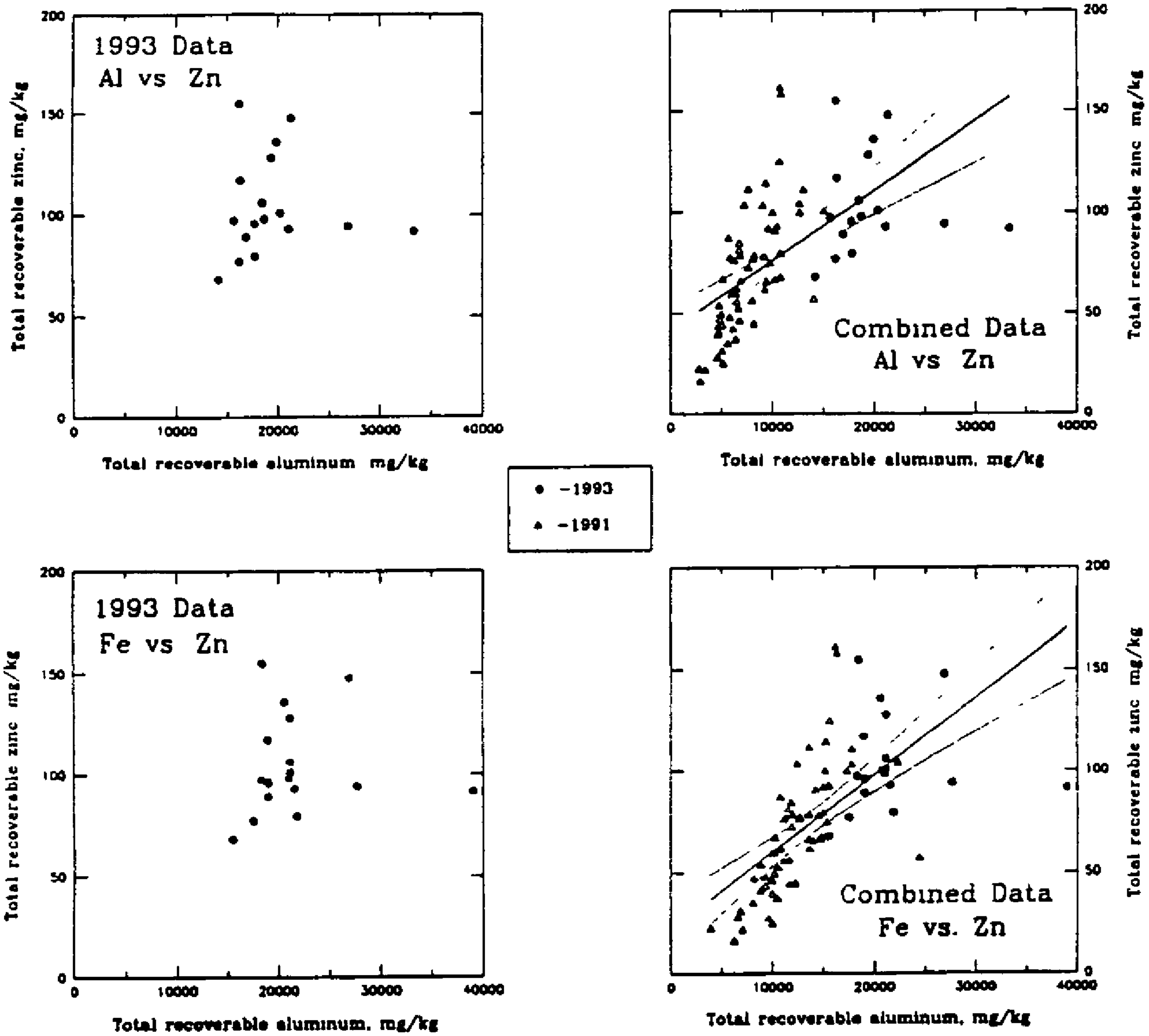


Figure 5-26. Scatterplots and Linear Regressions of Total Recoverable Aluminum and Iron vs. Zinc in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Dashed lines indicate 95% confidence intervals*

TABLE 5-12 REGRESSION COEFFICIENT OF DETERMINATION (r^2) BETWEEN SEDIMENT METALS AND SEDIMENT ALUMINUM AND IRON

	Aluminum			Iron		
	1991	1993	Combined Data	1991	1993	Combined Data
Aluminum	--	--	--	0.8783**	0.9265**	0.9008**
Iron	0.8783**	0.9265**	0.9008**	--	--	--
Arsenic	0.4857**	0.1547	0.5519**	0.5711**	0.1438	0.5569**
Barium	0.2255**	0.0753	0.4900**	0.2963**	0.1191	0.4976**
Beryllium	NC	0.6918**	NC	NC	0.7323**	NC
Cadmium	0.4172**	0.0832	0.3693**	0.5013**	0.0445	0.4125**
Chromium	0.7175**	0.8978**	0.9272**	0.5899**	0.9088**	0.7770**
Copper	0.5218**	0.7210**	0.8498**	0.3419**	0.6815**	0.7026**
Lead	0.5868**	0.0687	0.3726**	0.5403**	(-)0.0565[a]	0.3657**
Mercury	0.7024*	0.0024	0.0008	0.6260*	0.0002	0.0041
Nickel	0.5513**	0.7724**	0.8040**	0.6904**	0.8853**	0.8504**
Zinc	0.4876**	0.0001	0.3764**	0.4866**	0.0037	0.4257**

NC = Not calculated. Sediment concentrations were lower than laboratory detection limits.

Statistically significantly regressions noted by: * P<0.05; ** P<0.001.

[a] The regression of 1993 iron vs. lead was the only regression with a negative slope

Significant regressions were obtained for beryllium in 1993, but beryllium was detected in only one sample in 1991, so no regressions were performed for 1991, or combined 1991 and 1993 data The differences noted between the relationships between the 1991 and 1993 survey results may indicate some differences in the character and sources of sediments sampled, although the influence of sample size (fewer samples were collected in 1993) and laboratory precision and accuracy are also factors to consider

5.2.2.2 ***Identification of Stations with Elevated Sediment Metals Concentrations.*** Although linear regression (Fe vs. trace metal) and identification of station outliers (data above the upper 90% confidence limit) was used to identify 1991 sediment stations with potentially elevated sediment metals concentrations due to anthropogenic inputs (Tetra Tech 1993a), a somewhat different graphical approach was used in this study This approach is similar to that used by Rickert et al (1977) to evaluate sediment trace metal data and potential anthropogenic enrichment of trace metals in Willamette River sediments. Combined 1991 and 1003 sediment metals concentrations were separately normalized to sediment aluminum and iron content except for sediment mercury concentrations, which did not show any significant relationships with these variables. The data were then ranked, and cumulative data probabilities were calculated according to Velz (1984, pp 693-727); these data were plotted on normal-probability graphs. The normal-probability plots are presented in Figures 5-27 through 5-35 Changes in the trend of the slope of the plots suggests the presence of distinct groups of data; the higher concentration group is considered to be due to increased sediment trace metal input from either natural or anthropogenic sources (Rickert et al 1977) Distinct breaks in the normal-probability curves indicated anomalously high metals concentrations at several stations for arsenic, cadmium, and copper based on normalization to either aluminum or iron (Figures 5-27, 5-30, and 5-32) Possible, but less distinct breaks in the normal-probability curves were also noted for chromium, lead, nickel, and zinc (Figures 5-31, 5-33, 5-34, and 5-35). No distinct breaks were identified for aluminum- or iron-normalized barium or beryllium content (Figures 5-28 and 5-29) The data indicating potential anthropogenic enrichment of sediment concentrations of arsenic, cadmium, chromium, copper, lead, nickel, and zinc are summarized below

Arsenic--Potential anthropogenic elevation of sediment arsenic concentrations was identified for nine stations based on distinct breaks observed in both the aluminum- and iron-normalized normal-probability plots (Figure 5-27) Potentially elevated levels of arsenic were measured primarily in backwater areas in both surveys. Several of these stations are located in the estuary, and the remainder in backwater areas near more urban and industrial portion of the river between RM 80and 120 Although

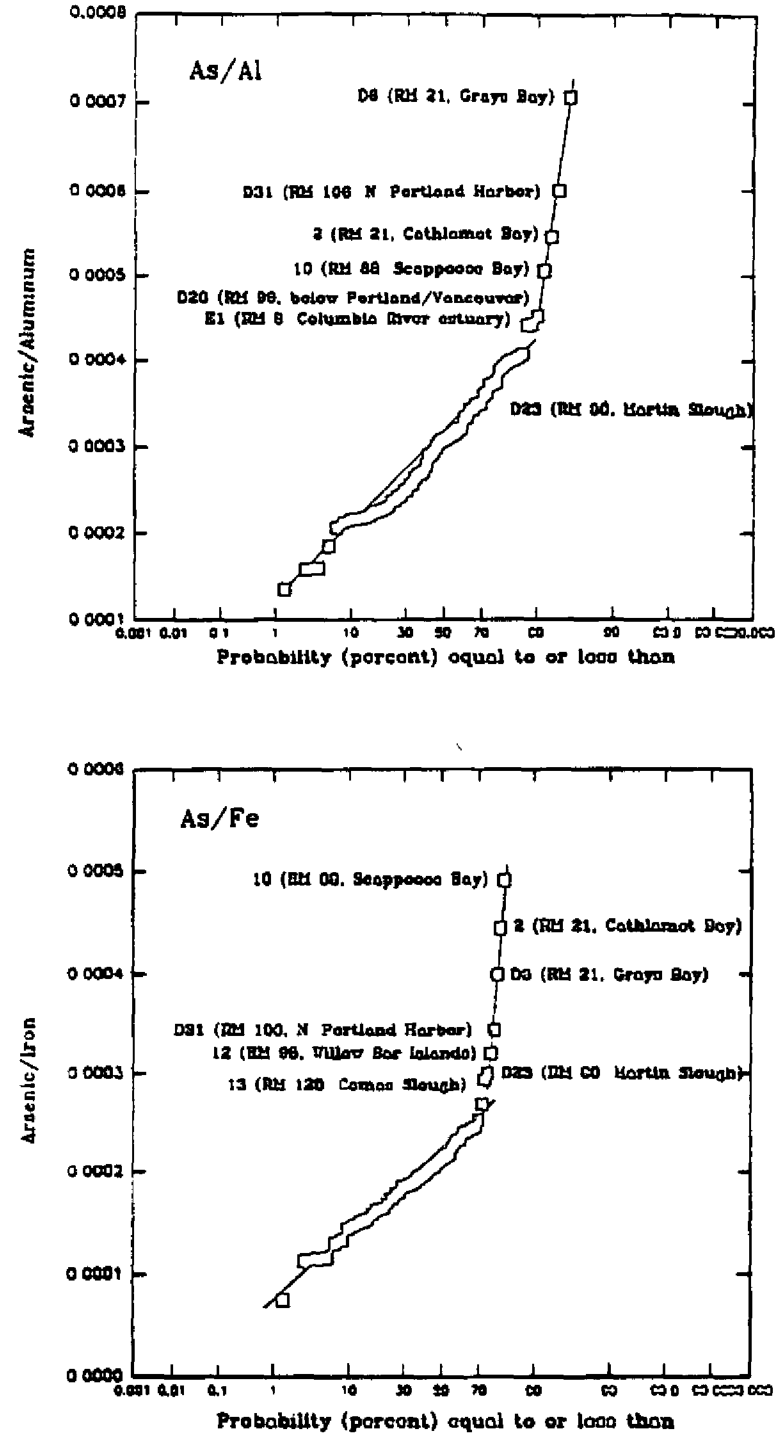


Figure 5-27. Normal-Probability Plots of Sediment Total Recoverable Arsenic Normalized to Aluminum (top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm).*

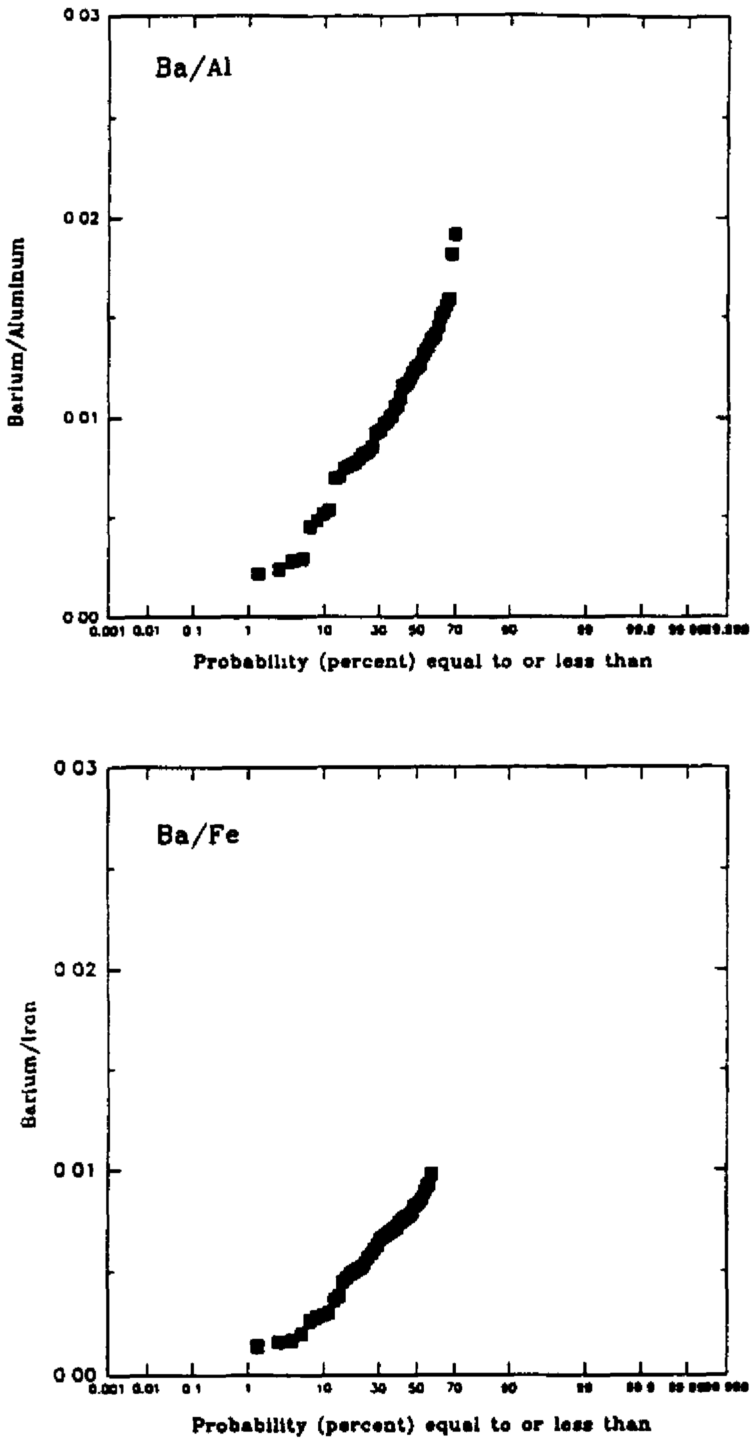


Figure 5-28. Normal-Probability Plots of Sediment Total Recoverable Barium Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *No distinct groups of data were identified.*

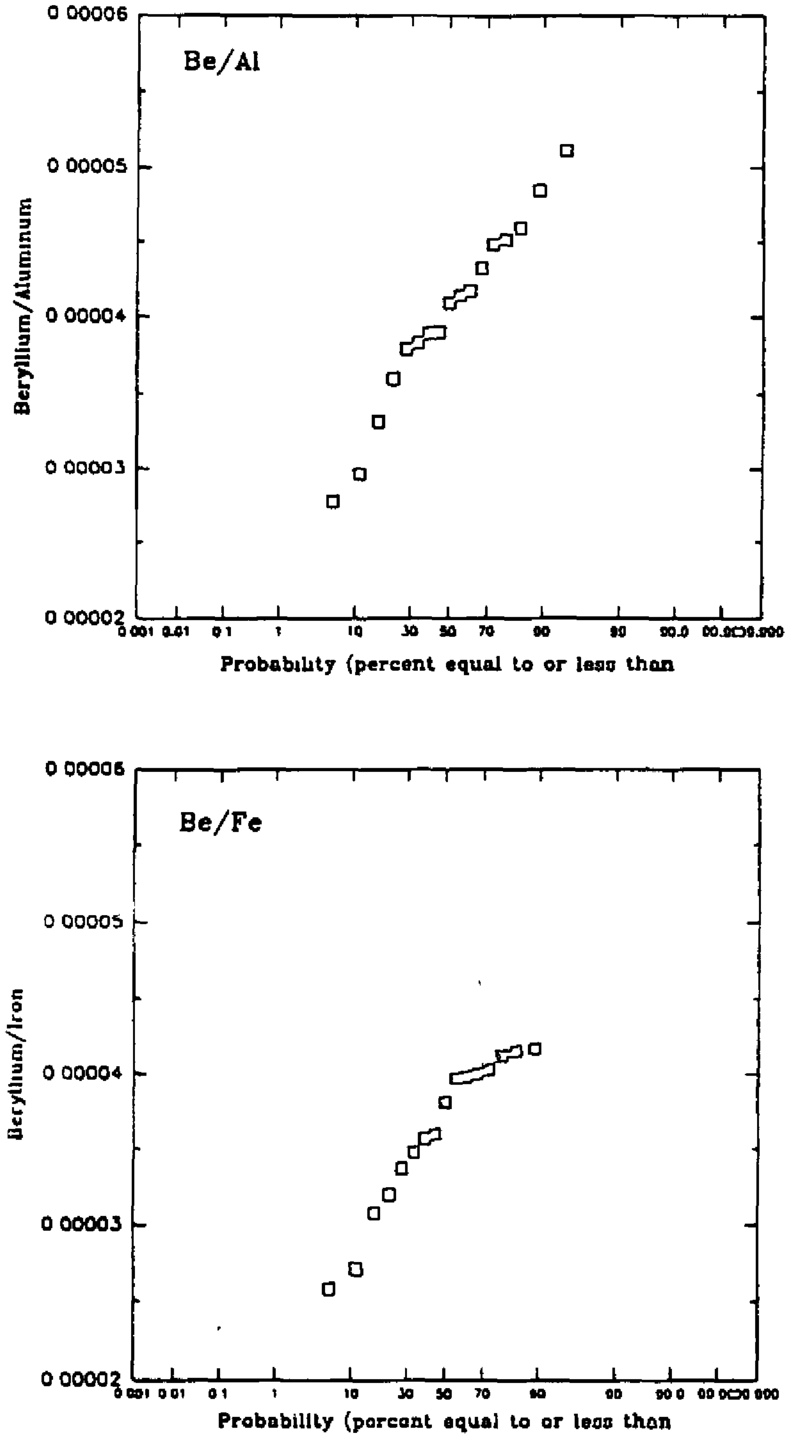


Figure 5-29. Normal-Probability Plots of Sediment Total Recoverable Beryllium Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1993 Reconnaissance Survey. *Beryllium was detected in only one sample in 1991 and therefore only the 1993 data were plotted. No distinct groups of data were identified.*

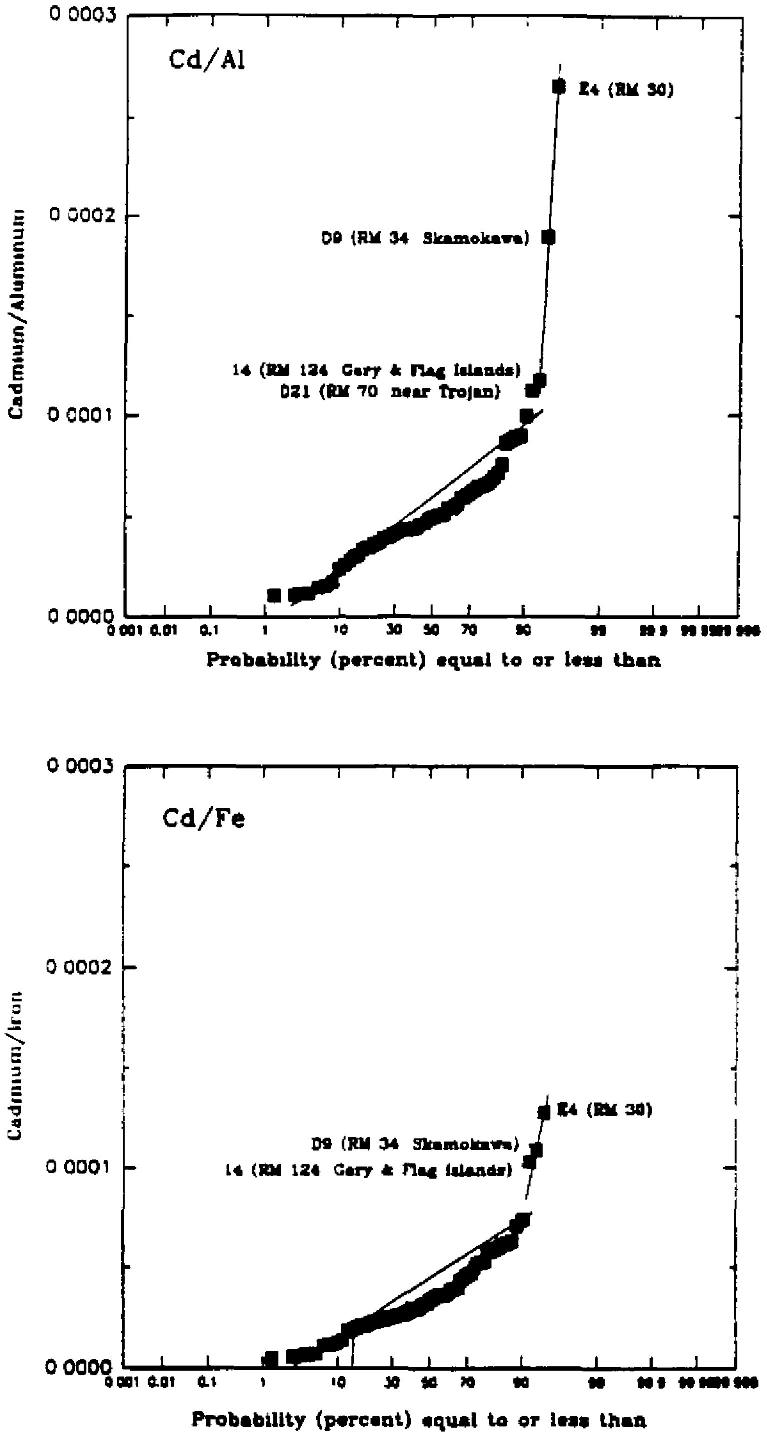


Figure 5-30. Normal-Probability Plots of Sediment Total Recoverable Cadmium Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Lines indicate two groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm).*

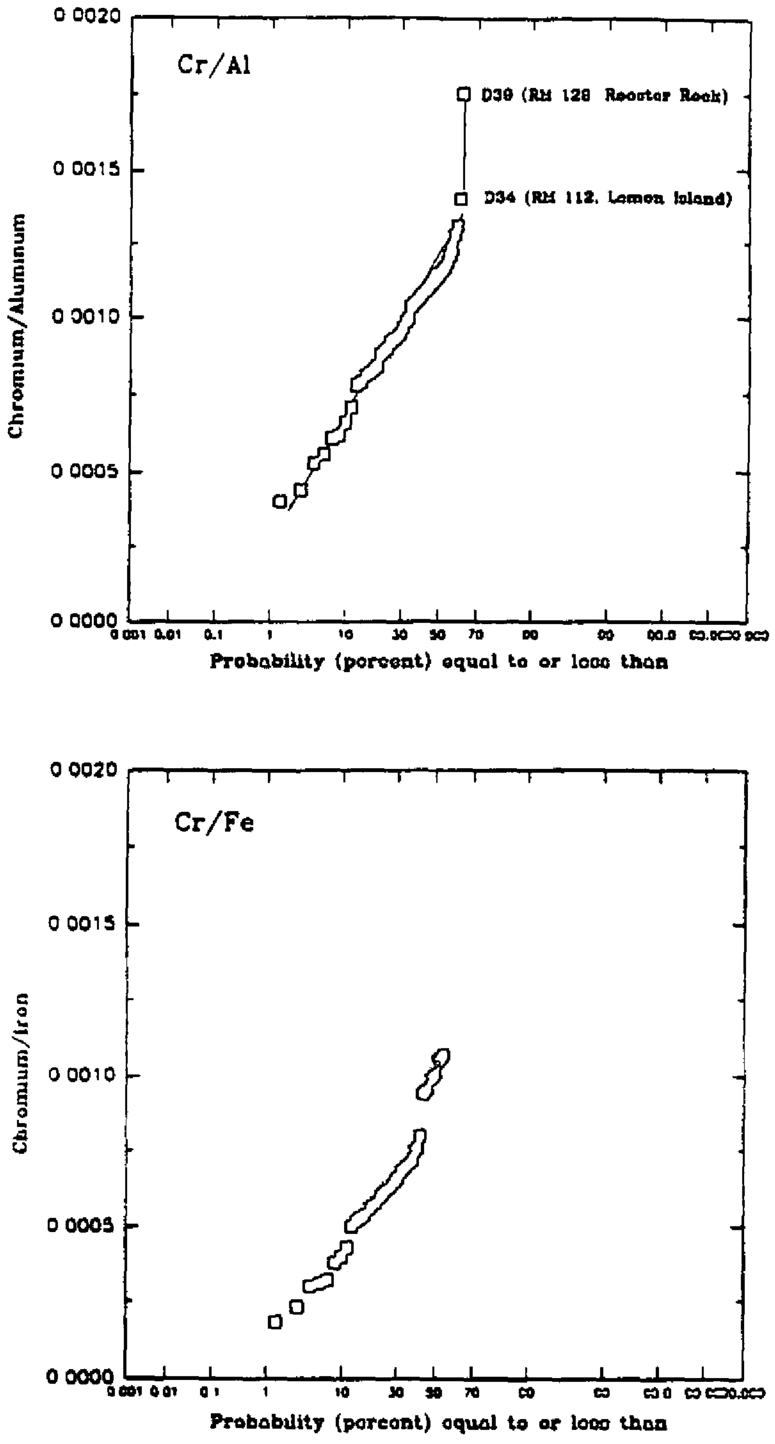


Figure 5-31. Normal-Probability Plots of Sediment Total Recoverable Chromium Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm)*

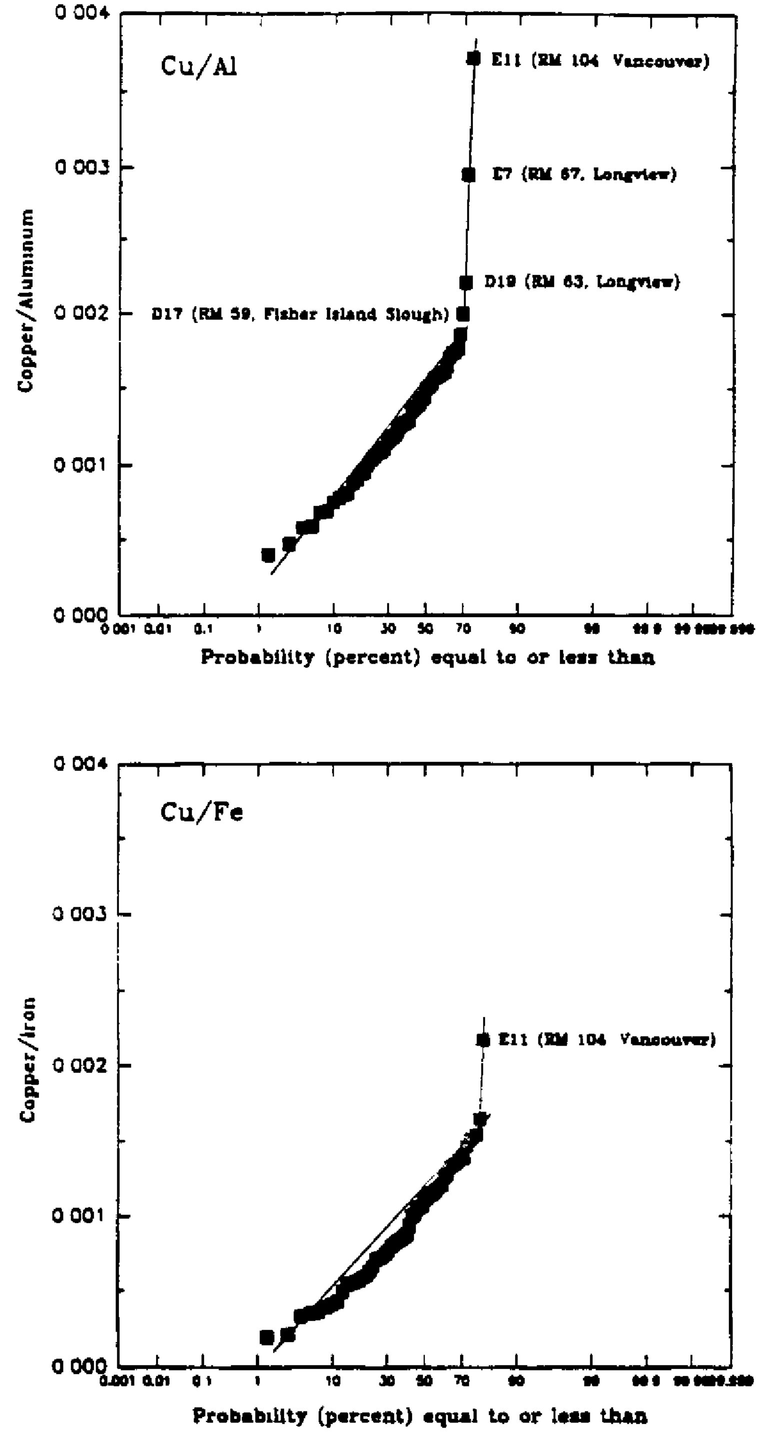


Figure 5-32. Normal-Probability Plots of Sediment Total Recoverable Copper Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm)*

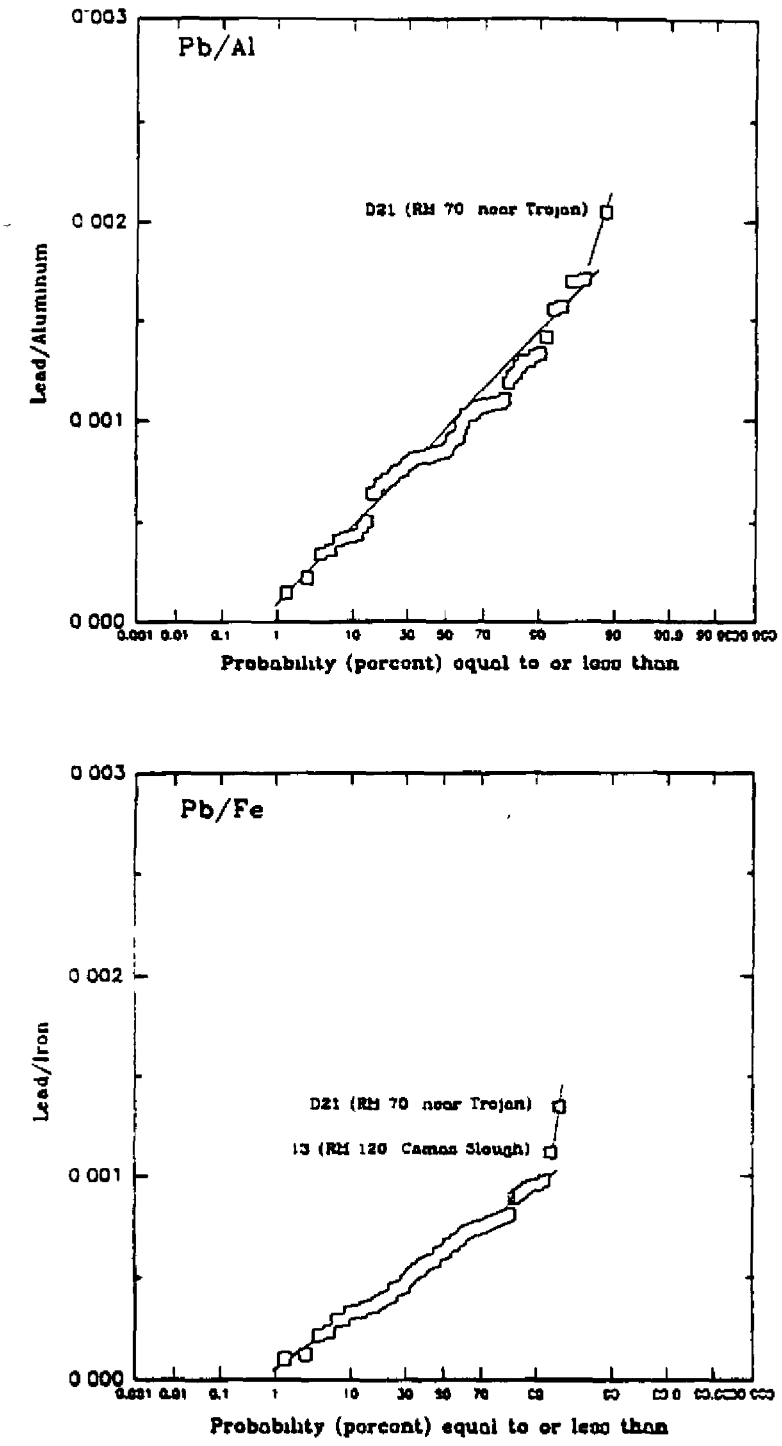


Figure 5-33. **Normal-Probability Plots of Sediment Total Recoverable Lead Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys.** *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm)*

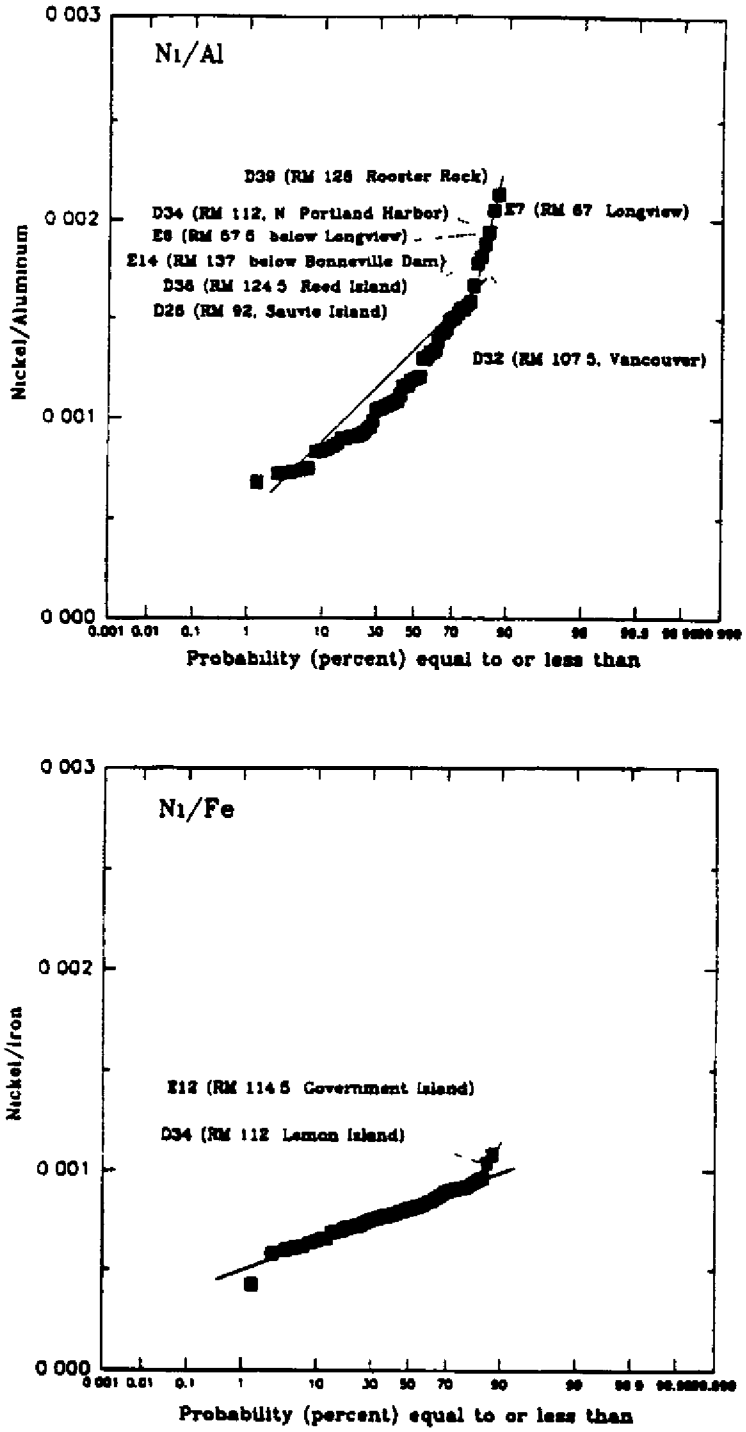


Figure 5-34. Normal-Probability Plots of Sediment Total Recoverable Nickel Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100µm) and E indicating coarse-grained (<20% < 100µm).*

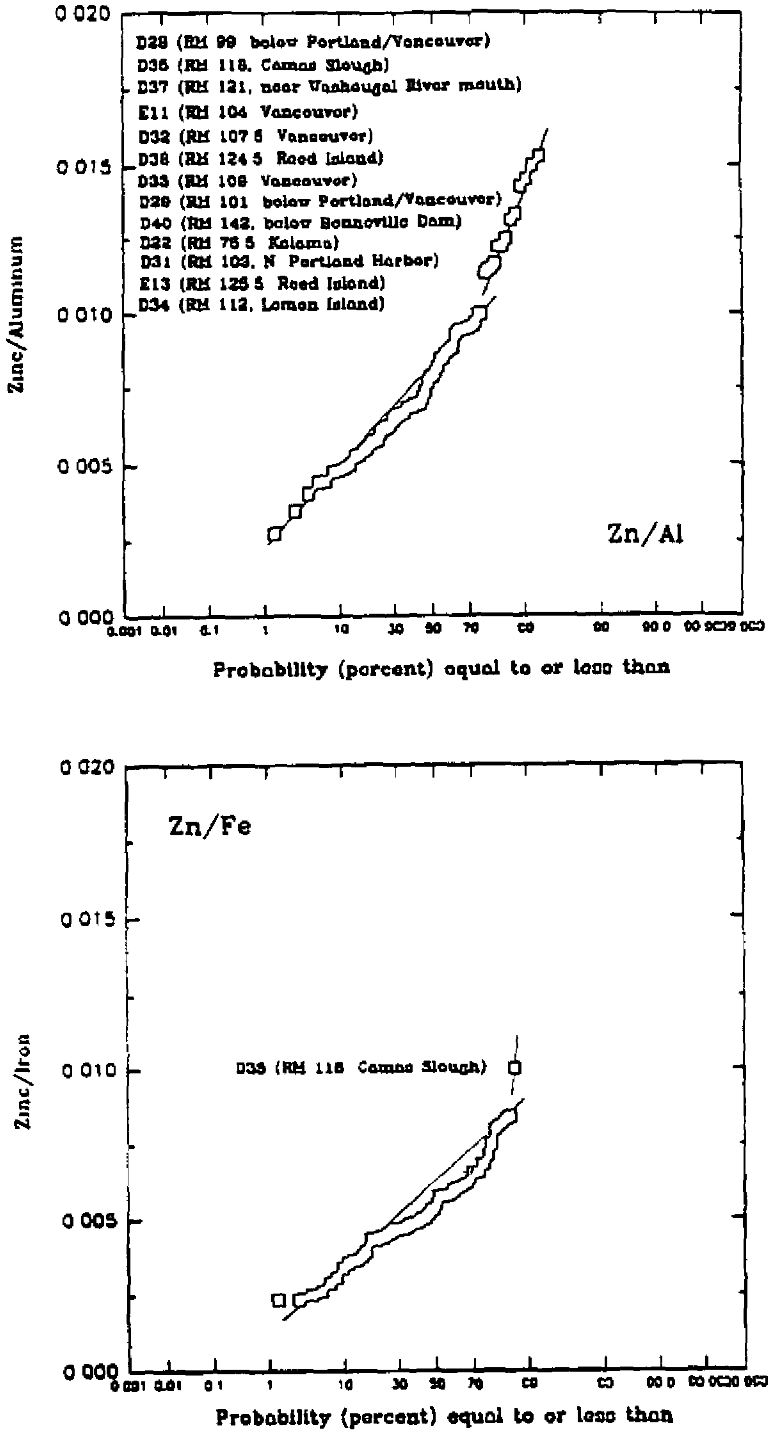


Figure 5-35. **Normal-Probability Plots of Sediment Total Recoverable Zinc Normalized to Aluminum (Top) and Iron (Bottom) Content of Sediments Collected for the 1991 and 1993 Reconnaissance Surveys.** *Lines indicate two possible groups of data. Numeric station designations are from 1993 survey; alphanumeric station designations are from 1991 survey with D indicating fine-grained (>20% > 100μm) and E indicating coarse-grained (<20% < 100μm).*

some of the potentially elevated sediment arsenic concentrations were identified based on only one normalization, all of the 5 stations where sediment arsenic levels exceeded Ontario's reference level of 6 mg/kg were identified by both normalizations.

Cadmium--Potential anthropogenic elevation of sediment cadmium concentrations was identified for 4 stations based on distinct breaks observed in the aluminum- and iron-normalized normal-probability plots (Figure 5-30) Potentially elevated cadmium levels were measured in both mainstem and backwater areas in both surveys These areas include near and below Skamokawa (RM 30-34), at Gary and Flag Islands (RM 124), and near the Trojan Nuclear Power Plant (RM 70) (Figure 5-30) The station near the Trojan Nuclear Power Plant was identified based on only the aluminum-normalized data. All four of these stations exceeded Ontario's reference level of 0 6 mg/kg, however, several other stations that exceeded the reference level (5 additional 1991 stations and 13 additional 1993 stations) were not identified as potentially elevated due to human contributions

Chromium--Potential anthropogenic elevation of sediment chromium concentrations was identified for two stations based on a fairly distinct break observed for the aluminum-normalized normal-probability plot, no distinct change was noted for iron-normalized sediment chromium data (Figure 5-31). These locations are in the upper river reach above the major urban and industrialized areas at RM 128 (near Rooster Rock) and RM 112 (Lemon Island). These two stations did not coincide with the two stations that exceeded Ontario's sediment chromium reference level of 26 mg/kg (Elochoman Slough and Scappoose Bay)

Copper--Potential anthropogenic elevation of sediment copper concentrations was identified at one station on the Washington side of the river below Vancouver, WA (RM 104), based on distinct breaks observed in both the aluminum- and iron-normalized normal-probability plots (Figure 5-32). This station was located just downstream of an area contaminated with copper from bulk ore loading at the Port of Vancouver (Century West Engineering Corporation 1989). Although a clean-up operation has been conducted at the facility, the target clean-up level of 1,300 mg/kg of copper, and post-dredging sample analyses (Century West Engineering Corporation 1989, 1990) indicate that elevated copper concentrations remain in the area, which could result in downstream sediments showing as anthropogenically elevated in copper concentration.

Potentially elevated concentrations of copper were also identified based on only the aluminum-normalized copper data (Figure 5-32) These areas, in the vicinity of Longview below the confluence with the Cowlitz River, were all sampled in 1991, and were primarily mainstem locations except for one backwater, Fisher Island Slough

The potentially elevated sediment copper concentration near Vancouver exceeded Ontario's sediment copper reference level of 16 mg/kg However, several other stations where copper concentrations exceeded the reference level (7 additional 1991 stations and all 1993 stations) were not identified as potentially elevated due to human contributions The three stations near Longview did not exceed the reference level.

Lead--Potential anthropogenic or elevation of sediment lead concentrations was identified for one station (Camas Slough) based on the distinct breaks in both normalizations for lead Potentially elevated concentrations of lead at Station D21 near the Trojan Nuclear Power Plant were identified based on only the iron normalization (Figure 5-33). This station was also identified as potentially enriched in cadmium No sediment lead concentrations exceeded Ontario's reference level of 31 mg/kg, and therefore lead concentrations at these two stations were also below the 31 mg/kg reference level.

Nickel--Potential anthropogenic elevation of sediment nickel concentrations was identified at Lemon Island, RM 112 based on somewhat distinct breaks observed in both normalizations. Potentially elevated concentrations of nickel were also identified at eight stations based on one normalization or the other (Figure 5-34) These were mainstem and backwater areas located between RM 92 and RM 128, plus two location near Longview (RM 67 and 57 5), all sampled in 1991

None of these stations exceeded Ontario's sediment nickel reference level of 16 mg/kg. Nickel concentrations exceeded the reference level at 1 station sampled in 1991 and 7 stations sampled in 1993 These concentrations were not identified as potentially elevated by human contributions

Zinc--Potential anthropogenic elevation of sediment zinc concentrations was identified at Camas Slough based on somewhat distinct breaks observed in both normalizations. Potentially elevated concentrations of zinc were also identified at twelve stations based on the aluminum normalization (Figure 5-35). These include mainstem and backwater areas located between RM 75.5 and RM 125 5.

Two of the stations where potentially elevated sediment zinc concentrations were identified (Kalama and Camas Slough) were also the two stations sampled in 1991 that exceeded Ontario's and Long and Morgan's sediment zinc reference level of 120 mg/kg However, four stations sampled in 1993 where zinc concentrations exceeded this reference level were not identified as potentially elevated due to anthropogenic contributions The other 11 stations identified as potentially enriched in zinc did not exceed the reference level

5.2.2.3 Comparisons Between Lower Columbia River Sediment Metals Concentrations and Other Relevant Data. To place the lower Columbia River sediment metals data into perspective, Table 5-13 compares range and median concentrations of sediment metals measured in both surveys to the reference levels adopted for this study and also to available data on metal content of presumed uncontaminated soils in the United States and shales (fine sedimentary rocks), which likely represent the uncontaminated metals content of fine sediments The aluminum and iron concentrations measured in lower river sediments are generally lower than those in soils and shales, which is to be expected since the total recoverable digestion does not completely recover these metals from mineral fragments. The maximum measured total recoverable concentrations of a few trace metals (antimony, barium, and chromium) in sediments are also generally lower than concentrations in soils or shales However, although the median sediment concentration is lower, the maximum measured concentrations of several metals exceed typical levels in soils or shales (arsenic, beryllium, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc) These comparisons suggest that some sediment areas may have relatively high concentrations of these elements due to localized enrichment from anthropogenic sources

Potential enrichment of arsenic, cadmium, copper, lead, nickel, and zinc were identified above based on the normal-probability plots of aluminum- and iron-normalized sediment trace metal concentrations. Lower Columbia sediment concentrations of cadmium, mercury, silver, and zinc (and antimony as well) have been ranked with the 20 highest sediment metals concentrations (normalized to the percent $<63\ \mu m$ sediment fraction) measured at 175 fine-grained sediment sampling sites located in coastal and estuarine areas of the United States (O'Connor and Ehler 1991, measured as part of NOAA's National Status and Trends Program at two locations in the lower Columbia River, including one sampling area in Youngs Bay) Higher concentrations of cadmium, copper, lead, and mercury in Columbia River sediments compared to lower Willamette River sediments have also been noted by Rickert et al. (1977).

TABLE 5-13. COMPARISON OF SEDIMENT METALS CONCENTRATIONS MEASURED IN THE 1991 AND 1992 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS TO REFERENCE LEVELS AND SOIL AND ROCK CONCENTRATIONS

	Lower Columbia River Reconnaissance Surveys		Units in mg/kg dry wt				
			Reference Values		Geometric Mean U.S. Soils[c]	Willamette Basin Soils[d]	Shales[e]
	Range	Median	L&M[a]	Ontario[b]			
Aluminum	2,794-33,300	8,065			47,000		92,000 (80,000)
Antimony	0.23-0.41	0.30	2		0.48		1.5 (1.5)
Arsenic	0.46-13.6	2.5	33	6	5.2		10 (13)
Barium	8.5-186	83			440		600 (580)
Beryllium	0.42-1.2	0.76			0.63		3 (3)
Cadmium	0.06U-2.66	0.43	5	0.6	--		0.3 (0.3)
Chromium	2.3-31.1	7.9	80	26	37	70	100 (90)
Copper	1.84-49.9	10.7	70	16	17	50	50 (45)
Iron	3,906-39,000	13,521		20,000	18,000		47,000 (47,200)
Lead	0.63-26.3	8.0	35	31	16	15	20 (20)
Mercury	0.057U-0.18	NC	0.15	0.2	0.058	0.2	0.3 (0.4)
Nickel	4.21-24.8	10.4	30	16	13		80 (68)
Selenium	0.29U-0.75	NC			0.26		0.6 (0.6)
Silver	0.08U-3.1	0.31U	1	0.5	--		0.1 (0.07)
Thallium	0.30U-26.8U	12.2U			--		1 (1.4)
Zinc	16.4-161.3	76.3	120	120	48	68	90 (95)

NC = Not calculated due to differences in detection limits between the 1991 and 1993 Reconnaissance Surveys.

[a] Source: Long and Morgan (1990)

[b] Source: Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persaud et al. 1993).

[c] Source: Shacklette and Boerngen (1984). The geometric mean was based on the analysis of about 750 samples, except for antimony (n=223).

[d] Source: R. Mendes, U.S. Geological Survey, written communication (1975), as cited in Rickert et al. (1977). The modal concentrations of 50 soil samples analyzed for chromium, copper and lead, and the average concentration of three soil samples analyzed for zinc and mercury.

[e] Source: Krauskopf (1979). The source of the number in parentheses is Turekian and Wedepohl (1961)

Also of interest is the comparison of the reference values used in this study to typical soil and shale concentrations of the same metals For some metals, the reference levels (primarily the Ontario values) are lower than the concentrations that would be expected in uncontaminated soils and sediments (e.g , chromium and copper) These comparisons, and the analyses performed above, underline the difficulties in identifying elevated sediment metals concentrations due to human inputs, and identifying sediment metal concentrations that have a potentially harmful effect on biota The analyses presented above have provided some initial exploration of the available data, and emphasize the utility of sediment aluminum or iron concentrations to reduce the influence of variation in physical and chemical sediment properties, and to identify potentially elevated sediment metal concentrations The same or a similar approach may also be useful, when coupled with biological effects data, in identifying the potential for adverse biological effects and for the establishment of regional sediment guidelines or standards for sediment metals concentrations

5.2.3 Semi-volatile Organic Compounds

In general, few semi-volatile organic compounds other than PAHs were detected in sediments collected for either survey Due to lower detection limits achieved for these compounds analyses for the backwater survey, some of them were detected only in 1993 sediments, making comparisons impossible

The only semi-volatile compound detected in both surveys was bis(2-ethylhexyl)phthalate (Table 5-14). This compound was detected more frequently in the backwater survey, probably due to lower detection limits. The concentrations of bis(2-ethylhexyl)phthalate (normalized to sediment organic carbon content) do not exceed the New York State reference level for the protection of benthic organisms.

Two other semi-volatile compounds were detected in the 1993 survey 4-methylphenol (not detected in 1991) and benzoic acid (not measured in 1991; see Table 5-14) No reference value is available for benzoic acid, but the sediment concentration of 4-methylphenol (normalized to sediment organic carbon content) exceeded the New York State reference level for the protection of benthic organisms at one station, Camas Slough

PAHs were detected more frequently in 1993 sediment samples because of lower detection limits made possible by SIM methodology (Section 2) However, maximum and median sediment PAH concentrations were consistently higher for the PAHs that were detected in 1991 (Table 5-15).

TABLE 5-14 SUMMARY OF SEDIMENT SEMI-VOLATILE COMPOUNDS DETECTED IN EITHER THE 1991 OR 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

		Units in µg/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
4-Methylphenol						
1993	1/15	13-18	150	16U	150	1/15
1991	0/54	80-288	ND	176U	ND	(DL > ref)[c]
Combined data	1/69	13-288	150	176U	150	1/15
Bis(2-ethylhexyl) phthalate						
1993	13/15	11-25	13-51	18U	24	0/15
1991	18/54	40-310	47-790	92U	210	0/54
Combined data	31/69	11-310	13-790	88U	123	0/69
Benzoic acid						
1993	14/15	160	20-68	160U	43	NA
1991	NS	–	--	--	--	--
Combined data	14/69	160	20-68	160U	43	–

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993 and fifty-four stations were sampled in 1991

[b] The frequency of exceedance of the lowest available reference level for potential adverse effects on benthic organisms or wildlife.

[c] The detection limits were higher than the available reference level

NA = No reference value available for comparison.

ND = Not detected

NS = Not sampled.

U = Not detected. Value is the detection limit.

TABLE 5-15 SUMMARY OF SEDIMENT POLYNUCLEAR AROMATIC HYDROCARBON (PAH) CONCENTRATIONS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 1 of 2)

		Units in μg/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedance[b]
Acenaphthene						
1993	15/15	--	0.67-4.1	--	1.7	0/15
1991	0/54	40-144	--	88U	--	0/54
Combined data	15/69	40-144	0.67-4.1	88U	1.7	0/69
Acenaphthylene						
1993	14/15	0.65	0.26-5.4	0.65U	1.2	NA
1991	0/54	40-144	--	88U	--	--
Combined data	14/69	0.65-144	0.26-5.4	88U	1.2	--
Anthracene						
1993	15/15	--	0.46-12	--	2.6	0/15
1991	0/54	40-144	--	88U	--	(DL>ref)[c]
Combined data	15/69	40-144	0.46-12	88U	2.6	0/15
Benzo(a)anthracene						
1993	15/15	--	3.6-40	--	13	0/15
1991	3/54	40-144	65-260	88U	180	1/54
Combined data	18/69	40-144	3.6-260	88U	18	1/69
Benzo(b,k)fluoranthene						
1993	15/15	--	12-110	--	29	0/15
1991	3/54	80-288	63-400	176U	210	0/54
Combined data	18/69	80-288	12-400	176U	35	0/69
Benzo(a)pyrene						
1993	15/15	--	4.2-61	--	12	0/15
1991	3/54	80-288	100-260	176U	250	0/54
Combined data	18/69	80-288	4.2-260	176U	17.5	0/69
Benzo(g,h,i)perylene						
1993	8/15	3.3-7.4	8.4-40	5.0U	16.5	0/15
1991	2/54	80-288	78-200	176U	139	1/54
Combined data	10/69	3.3-288	8.4-200	100U	19.5	1/69
Chrysene						
1993	15/15	--	6.5-62	--	22	0/54
1991	4/54	40-144	48-630	88U	190	1/54
Combined data	19/69	40-144	6.5-630	88U	28	1/69
Dibenzo(a,h)anthracene						
1993	15/15	--	1.5-9.7	--	2.8	0/15
1991	0/54	80-288	--	176U	--	(DL>ref)[c]
Combined data	15/69	80-288	1.5-9.7	176U	2.8	0/15
Fluoranthene						
1993	15/15	--	8.1-76	--	28	0/15
1991	5/54	40-144	70-280	88U	88	0/54
Combined data	20/69	40-144	8.1-280	88U	38.5	0/69

TABLE 5-15 SUMMARY OF SEDIMENT POLYNUCLEAR AROMATIC HYDROCARBON (PAH) CONCENTRATIONS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 2 of 2)

		Units in µg/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedance[b]
Fluorene						
1993	15/15	--	0.74-6.73	--	2.2	0/15
1991	0/54	40-144	--	88U	--	(DL>ref)[c]
Combined data	15/69	40-144	0.74-6.73	88U	2.2	0/15
Indeno(1,2,3-cd)pyrene						
1993	11/15	4.5-6.8	8.1-41	5.6U	20	0/15
1991	3/54	80-288	62-170	176U	140	(DL>ref)[c]
Combined data	14/69	4.5-288	8.1-170	124U	23	0/15
Naphthalene						
1993	15/15	--	1.0-9.8	--	2.5	0/15
1991	0/54	40-144	--	88U	--	(DL>ref)[c]
Combined data	15/69	40-144	1.0-9.8	88U	2.5	0/15
Phenanthrene						
1993	15/15	--	5.6-34	--	14	0/15
1991	4/54	40-144	48-210	88U	95	0/54
Combined data	19/69	40-144	5.6-210	88U	16	0/69
Pyrene						
1993	15/15	--	7-102	--	24	0/15
1991	5/54	40-144	44-420	88U	130	2/54
Combined data	20/69	40-144	7-420	88U	43.5	2/69
2-Methylnaphthalene						
1993	15/15	--	0.70-4.2	--	1.6	NA
1991	0/54	40-144	--	88U	--	--
Combined data	15/69	40-144	0.70-4.2	88U	1.6	--
Dibenzofuran						
1993	15/15	--	0.39-4.9	--	1.3	NA
1991	NS	--	--	--	--	--
Combined data	15/15	--	0.39-4.9	--	1.3	--

NS = Not sampled.

U = Not detected. Value is the detection limit.

NA = Reference levels not available.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993 and 54 stations were sampled in 1991.

[b] Frequency of exceedances of the lowest available reference level for potential adverse effects on benthic organisms or wildlife.

[c] Detection limits greater than available reference levels

Table 5-16 compares results of sediment PAH analyses conducted on samples collected from three areas where sampling was done in both 1991 and 1993 Because of high detection limits, no PAHs were detected at these sites in 1991. Note that the concentrations detected in 1993 are all much lower than the corresponding 1991 detection limits.

PAH concentrations measured in 1993 appear to relate linearly to the percent fines and TOC content of the sediments, which may indicate regional background contaminant inputs from upriver and diffuse atmospheric sources. Stations D19 and D24 show elevated concentrations, readily apparent in Figures 5-36 and 5-37 These localized PAH concentrations may indicate PAH pollutant sources in the vicinity of Longview and St Helens. For example, Johnson and Norton (1988) measured sediment concentrations of PAHs below the Reynolds Aluminum facility (a source of PAHs) in Longview which exceeded the Long and Morgan (1990) Apparent Effects Threshold values for individual PAHs as well as Ontario's Severe Effect Level (Persaud et al 1993) and/or Long and Morgan's Effects Range-Medium values (Table 2-7) The total PAH concentration reported for this Longview location (19,000 μg/kg) also exceeded the Ontario Severe Effect Level of 10,000 μg/kg. These concentrations indicate the potential for adverse effects to benthic organisms in the vicinity of this aluminum smelter.

5.2.4 Pesticides and PCBs

In general, pesticides and PCBs were detected infrequently in samples collected for the 1991 and 1993 reconnaissance surveys An evaluation of the pesticide and PCB data is presented below

5.2.4.1 ***Pesticides.*** Pesticides were detected infrequently in both surveys (Table 5-17). Lower detection limits in 1993 plus infrequent detection of pesticides precludes most comparisons between the two surveys However, for the two pesticides detected in both surveys (p,p'-DDE and p,p'-DDT), higher concentrations were reported for 1991. Although few pesticide reference levels are available, and laboratory detection limits were near to or greater than the reference levels that were available, some exceedances for DDT compounds were noted in each survey (Table 5-17). These exceedances indicate the potential for adverse effects on benthic organisms

Although the low frequency of detection of pesticides precludes an adequate assessment of the distribution and potential sources of pesticides in the lower Columbia, pesticides were detected throughout the river at concentrations exceeding available reference levels. Relatively higher concentrations of some pesticides

TABLE 5-16 COMPARISON OF SEDIMENT PAH CONCENTRATIONS REPORTED FOR YOUNGS BAY, CARROLLS CHANNEL, AND CAMAS SLOUGH IN THE 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Youngs Bay (RM 14)		Carrolls Channel (RM 68)		Camas Slough (RM 120)	
	Station D3	Station 1	Station D20	Station 8	Station D35	Station 13
	1991	1993	1991	1993	1991	1993
Percent Fines	73.2	95.1	29.8	69.3	43.6	51.9
Percent TOC	0.6	2.1	0.85	2.1	4.06	1.5
	µg/kg dry sediment					
Acenaphthene	98U	2.2	110U	2.7	62U	1.7
Acenaphthylene	98U	2.2	110U	3.3	62U	0.67
Anthracene	98U	4.9	110U	5.6	62U	2.1
Benzo(a)anthracene	98U	20	110U	23.0	62U	9
Benzo(b)fluoranthene	196U	NR	220U	NR	124U	NR
Benzo(k)fluoranthene	196U	NR	220U	NR	124U	NR
Benzo(b,k)fluoranthene	NR	50	NR	44.0	NR	21
Benzo(a)pyrene	196U	26	220U	19.0	124U	9.3
Benzo(g,h,i)perylene	196U	18	220U	15.0	124U	6U
Chrysene	98U	29	110U	39.0	62U	13
Dibenzo(a,h)anthracene	196U	4.9	220U	3.7	124U	2.8
Fluoranthene	98U	47	110U	66.0	62U	15
Fluorene	98U	2.7	110U	4.7	62U	2.2
Indeno(1,2,3-cd)pyrene	196U	33	220U	14.0	124U	6.8U
Naphthalene	98U	3.9	110U	9.7	62U	3.1
Phenanthrene	98U	16	110U	26.0	62U	12
Pyrene	98U	46	110U	67.0	62U	18
2-Methylnaphthalene	98U	2.2	110U	3.2	62U	2.2
Dibenzofuran	NR	1.9	NR	3.7	NR	1.7

NR = Not reported.

U = Not detected. Value is the detection limit.

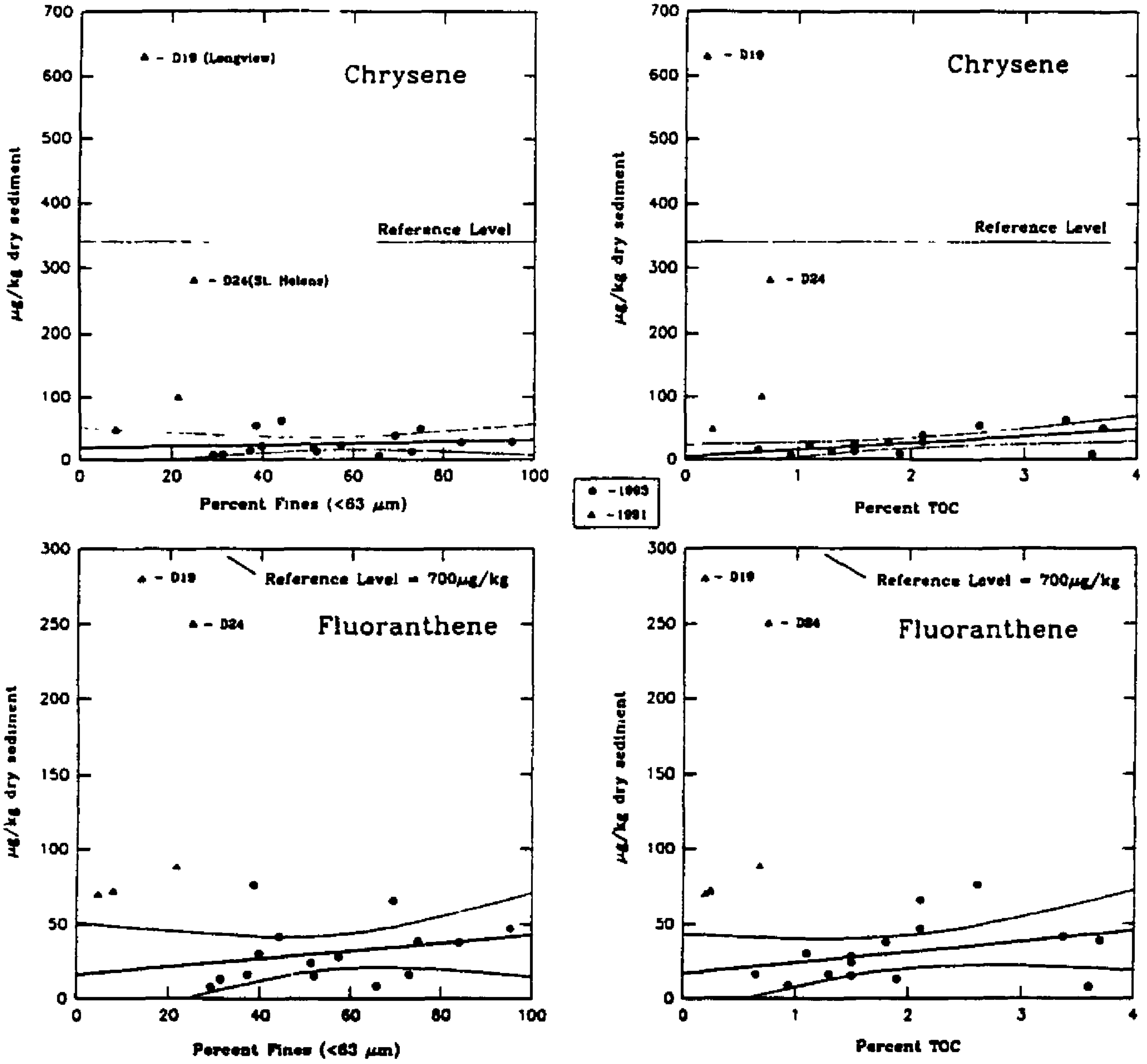


Figure 5-36. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Chrysene and Fluoranthene Concentrations in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Regressions shown are for the 1993 data only. Dashed lines indicate 95% confidence intervals. Reference levels also shown.*

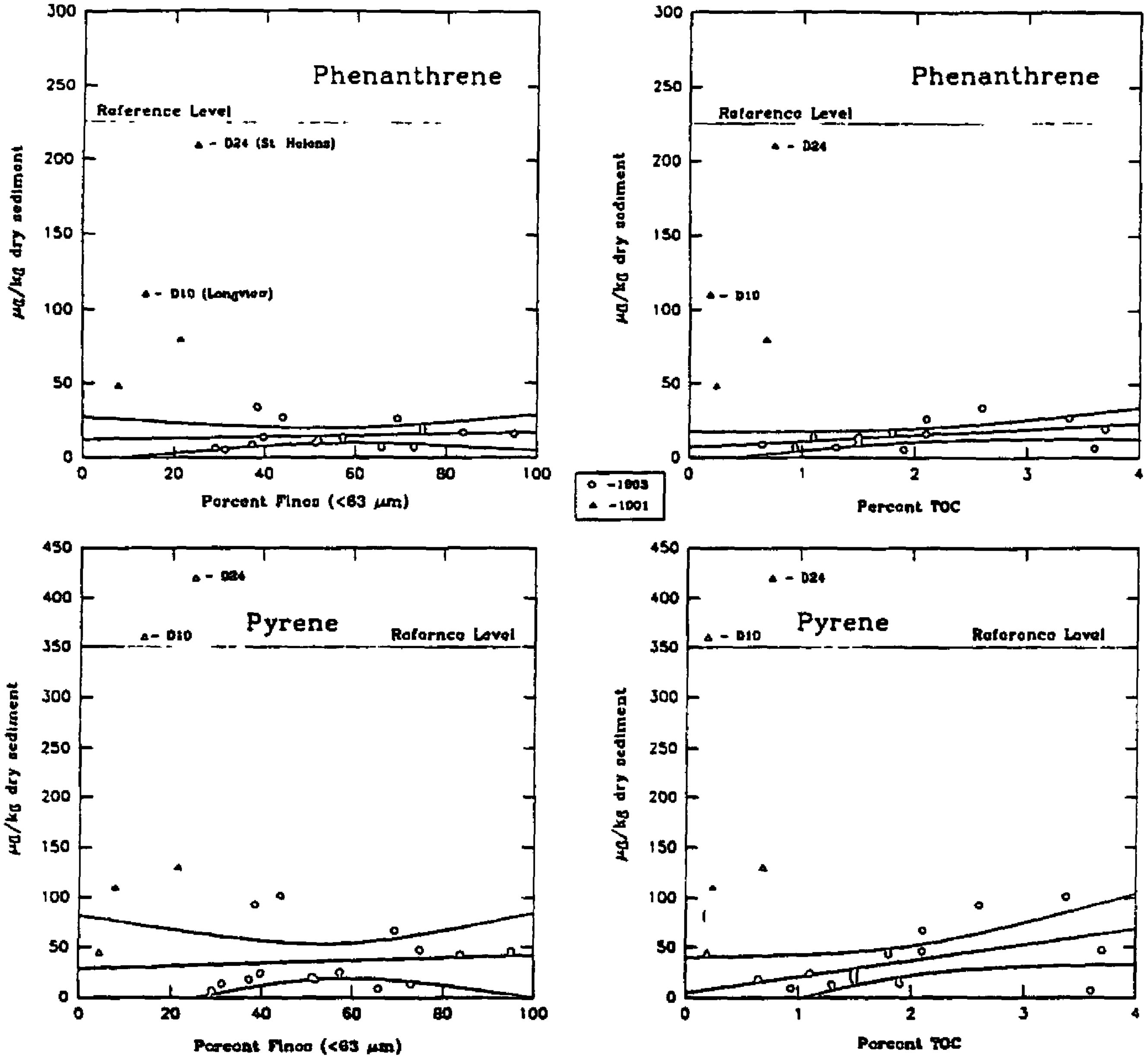


Figure 5-37. Scatterplots and Linear Regressions of Sediment Percent Fines and TOC Content vs. Phenanthrene and Pyrene Concentrations in Sediments Collected for the 1991 and 1993 Reconnaissance Surveys. *Regressions shown are for the 1993 data only. Dashed lines indicate 95% confidence intervals. Reference levels also shown.*

TABLE 5-17 SUMMARY OF SEDIMENT PESTICIDE CONCENTRATIONS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 1 of 3)

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
Aldrin							
1993	0/15	0.5	--	0.5U	--	NA	0/15
1991	1/54	2-20	3.1	2U	3.1	--	1/54
Combined Data	1/69	0.5-20	3.1	2U	3.1	--	1/69
Dieldrin							
1993	0/15	1	--	1U	--	(DL > ref)[c]	0/15
1991	1/54	2-20	3.3	2U	3.3	(DL > ref)[c]	1/54
Combined Data	1/69	1-20	3.3	2U	3.3	--	1/69
Endrin							
1993	0/15	1	--	1U	--	(DL > ref)[c]	0/15
1991	1/54	2-20	4.5	2U	4.5	(DL > ref)[c]	1/54
Combined Data	1/69	1-20	4.5	2U	4.5	--	1/69
Endrin ketone							
1993	0/15	1	--	1U	--	NA	NA
1991	NS	--	--	--	--	--	--
Combined Data	0/15	1	--	1U	--	--	--
Endrin aldehyde							
1993	0/15	1	--	1U	--	NA	NA
1991	0/54	2-20	--	2U	--	--	--
Combined Data	0/69	1-20	--	2U	--	--	--
Alpha-BHC							
1993	0/15	0.5	--	0.5U	--	NA	0/15
1991	3/54	2-20	2.6-4.0	2U	2.9	--	1/54
Combined Data	3/69	0.5-20	2.6-4.0	2U	2.9	--	1/69
Beta-BHC							
1993	0/15	0.5	--	0.5U	--	NA	0/15
1991	0/54	2-24	--	2U	--	--	0/54
Combined Data	0/69	0.5-24	--	2U	--	--	0/69
Delta-BHC							
1993	0/15	0.5	--	0.5U	--	NA	0/15
1991	3/54	2-20	4.2-7.9	2U	5.5	--	3/54
Combined Data	3/69	0.5-20	4.2-7.9	2U	--	--	3/69
Lindane (gamma-BHC)							
1993	0/15	0.5	--	0.5U	-	NA	0/15
1991	1/54	2-20	2.2	2U	2.2	--	0/54
Combined Data	1/69	0.5-20	2.2	2U	2.2	--	0/69
Gamma-Chlordane							
1993	0/15	0.5	--	0.5U	--	0/15	0/15
1991	0/54	2-20	--	2U	--	(DL > ref)[c]	0/54
Combined Data	0/69	0.5-20	--	2U	--	0/15	0/69

TABLE 5-17 SUMMARY OF SEDIMENT PESTICIDE CONCENTRATIONS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 2 of 3)

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
Alpha-Chlordane							
1993	0/15	0.5	--	0.5U	--	0/15	0/15
1991	0/54	2-20	--	2U	--	(DL>ref)[c]	0/54
Combined Data	0/69	0.5-20	--	2U	--	0/15	0/69
Dicofol							
1993	0/15	11-15	--	14U	--	NA	NA
1991	0/54	20-200	--	20U	--	--	--
Combined Data	0/69	11-200	--	20U	--	--	--
Endosulfan I							
1993	0/15	0.5	--	0.5U	--	NA	NA
1991	0/54	2-20	--	2U	--	--	--
Combined Data	0/69	0.5-20	--	2U	--	--	--
Endosulfan II							
1993	0/15	1	--	1U	--	NA	NA
1991	0/54	2-20	--	2U	--	--	--
Combined Data	0/69	1-20	--	2U	--	--	
Endosulfan sulfate							
1993	0/15	1	--	1U	--	NA	NA
1991	0/54	2-20	--	2U	--	--	--
Combined Data	0/69	1-20	--	2U	--	--	--
Heptachlor							
1993	0/15	0.5	--	0.5U	--	NA	NA
1991	3/54	2-20	2.1-6.1	2U	2.5	--	--
Combined Data	3/69	0.5-20	2.1-6.1	2U	2.5	--	--
Heptachlor epoxide							
1993	0/15	0.5	--	0.5U	--	NA	NA
1991	0/54	2-20	--	2U	--	--	--
Combined Data	0/69	0.5-20	--	2U	--	--	--
Methoxychlor							
1993	0/15	5	--	5U	--	NA	NA
1991	0/54	20-200	--	20U	--	--	--
Combined Data	0/69	5-200	--	20U	--	--	--
Methyl parathion							
1993	0/15	11-15	--	14U	--	NA	NA
1991	13/54	2-20	2.3-68	2U	4.9	--	--
Combined Data	13/69	2-20	2.3-68	2U	4.9	--	--
o,p'-DDE							
1993	0/15	0.16-0.20	--	0.20U	--	0/15	N
1991	2/54	2-20	3.2-3.6	2U	3.4	2/54	--
Combined Data	2/69	0.16-20	3.2-3.6	2U	3.4	2/69	--

TABLE 5-17 SUMMARY OF SEDIMENT PESTICIDE CONCENTRATIONS, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

(Page 3 of 3)

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
o,p'-DDD							
1993	0/15	0 16-0 35	--	0 20U	--	0/15	NA
1991	1/54	2-20	6 6	2U	6 6	1/54	--
Combined Data	1/69	0.16-0 35	6 6	2U	6.6	1/69	--
o,p'-DDT							
1993	0/15	0.16-0 24	--	0 20U	--	0/15	NA
1991	4/54	2-20	2 7-9 4	2U	7 0	5/54	--
Combined Data	4/69	0.16-20	2.7-9 4	2U	7.0	5/69	--
p,p'-DDE							
1993	5/15	1	0 5-1 2	1U	0.8	0/15	0/15
1991	4/54	2-20	2.1-5 6	2U	2.9	4/54	1/54
Combined Data	9/69	1-20	0.5-5 6	2U	1.2	4/69	1/69
p,p'-DDD							
1993	8/15	1	0 7-2.0	1U	0 85	1/15	0/15
1991	0/54	2-20	--	2U	--	0/54	0/54
Combined Data	8/69	1-20	0 7-2.0	--	0.85	1/69	0/69
p,p'-DDT							
1993	1/15	1	1 1	1U	1 1	1/15	NA
1991	2/54	2-20	3.3-100	2U	51 7	2/54	--
Combined Data	3/59	1-20	1.1-100	2U	3 3	3/69	--
Toxaphene							
1993	0/15	50	--	50U	--	NA	NA
1991	0/54	100-1,000	--	100U	--	--	--
Combined Data	0/69	50-1,000	--	100U	--	--	--

NA = Reference value not available.

NS = Not sampled.

U = Not detected. Value is the detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993 and fifty-four stations were sampled in 1991

[b] Frequency of exceedances of the Long and Morgan (1990) Effects Range-Low or the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persaud et al. 1993) Lowest Effect Level. Detected pesticide concentrations did not exceed the available organic carbon-based reference values.

[c] The detection limit was greater than the reference level.

were measured near the mainstem below St Helens, specific sources of these pesticides cannot be identified The low concentrations measured may indicate diffuse sources derived from historical and/or current applications of pesticides to agricultural and residential lands.

Pesticide concentrations measured in 1993 sediments from Carrolls Channel and Camas Slough were close to, but lower than sediment detection limits reported for these areas in 1991 (Table 5-18)

5.2.4.2 PCBs. PCBs (measured as Arochlor mixtures of PCB congeners) were infrequently detected for both reconnaissance surveys, although lower detection limits were achieved for the 1993 backwater survey (Table 5-19) Arochlor 1248 was detected at Carrolls Channel and Burke Slough in 1993, and Arochlor 1254 was detected in Longview in 1991. Only the concentration measured in Longview exceeded reference levels

Comparisons of sediment PCB levels measured at the three locations sampled in both surveys are difficult due to differing detection limits. The 1993 concentration of Arochlor 1248 from Carrolls Channel was only somewhat lower than the detection limit reported for analysis of sediment collected from this area in 1991 (11 vs 25 μg/kg; see Table 5-18)

5.2.5 Dioxins and Furans

Dioxins and furans were detected less frequently in 1993 sediment samples primarily because of relatively higher detection limits (Table 5-20). For two compounds detected in both 1991 and 1993 [1,2,3,4,6,7,8-HpCDD (heptachlorodibenzo-*p*-dioxin) and OCDD (octachlorodibenzo-*p*-dioxin)], 1991 sediment concentrations were generally much higher (Table 5-20). Relatively high concentrations were typically measured in sediments collected at or near Camas Slough, St. Helens, Longview, and Wauna, OR (Tetra Tech 1993a). These stations are located below chlorinated-bleach kraft pulp mills that are known sources of dioxins and furans (e.g., Amendola et al. 1989; Clement et al. 1989; Campin et al. 1991). However, dioxin and furan congeners occur in sediments above the pulp mills, suggesting additional sources of these contaminants. Possible sources include the atmosphere (Koester and Hites 1992, Macdonald et al 1992), and wood treatment facilities (Campin et al 1991). The effect of chemical and biological transformations of these compounds that would alter the ultimate sediment dioxin and furan content has not been evaluated (e.g., Koester and Hites 1992).

TABLE 5-18 COMPARISON OF SEDIMENT PESTICIDE AND PCB CONCENTRATIONS REPORTED FOR YOUNGS BAY, CARROLLS CHANNEL, AND CAMAS SLOUGH IN THE 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Youngs Bay (RM 14)		Carrolls Channel (RM 68)		Camas Slough (RM 120)	
	Station D3	Station 1	Station D20	Station 8	Station D35	Station 13
	1991	1993	1991	1993	1991	1993
Percent Fines	73.2	95.1	29.8	69.3	43.6	51.9
Percent TOC	0.6	2.1	0.85	2.1	4.06	1.5
	µg/kg dry sediment					
Aldrin	2U	0.5U	2.0U	0.5U	2U	0.5U
Dieldrin	2U	1U	2.0U	1.0U	2U	1U
Endrin	2U	1U	2.0U	1.0U	2U	1U
Endrin ketone	NR	1U	NR	1.0U	NR	1U
Endrin aldehyde	2U	1U	2.0U	1.0U	2U	1U
Alpha-BHC	2U	0.5U	2.0U	0.5U	2U	0.5U
Beta-BHC	12U	0.5U	2.0U	0.5U	6U	0.5U
Delta-BHC	3U	0.5U	2.0U	0.5U	5U	0.5U
Lindane	2U	0.5U	4.0U	0.5U	3U	0.5U
Chlordane	2U	NR	2.0U	NR	2U	NR
Gamma-Chlordane	NR	0.5U	NR	0.5U	NR	0.5U
Alpha-Chlordane	NR	0.5U	NR	0.5U	NR	0.5U
Dicofol	20U	15U	20U	14U	20U	14U
Endosulfan I	2U	0.5U	2.0U	0.5U	2U	0.5U
Endosulfan II	2U	1U	2.0U	1.0U	2U	1U
Endosulfan sulfate	2U	1U	2.0U	1.0U	2U	1U
Heptachlor	2U	0.5U	2.0U	0.5U	2U	0.5U
Heptachlor epoxide	2U	0.5U	2.0U	0.5U	2U	0.5U
Methoxychlor	20U	5U	20U	5.0U	20U	5U
Methyl parathion	6U	15U	2.0U	14U	2U	14U
o,p'-DDE	2U	0.22U	2.0U	0.2U	2U	0.2U
o,p'-DDD	2U	0.3U	2.0U	0.5U	2U	0.3U
o,p'-DDT	2U	0.22U	2.0U	0.2U	2U	0.2U
p,p'-DDD	2U	1U	2.0U	**1.2**	2U	**0.8**
p,p'-DDE	2U	1U	2.0U	**1.6**	2U	**0.8**
p,p'-DDT	2U	1U	2.0U	1.0U	6U	1U
Toxaphene	100U	50U	100U	50U	100U	50U
Malathion	2U	NR	2.0U	NR	2U	NR
Parathion	2U	NR	2.0U	NR	2U	NR
Dacthal	2U	NR	2.0U	NR	2U	NR
Mirex	2U	NR	2.0U	NR	**5.2**	NR
Aroclor 1016	25U	NR	25U	NR	25U	NR
Aroclor 1242/1016	NR	10U	NR	10U	NR	10U
Aroclor 1221	25U	20U	25U	20U	25U	20U
Aroclor 1232	25U	10U	25U	10U	25U	10U
Aroclor 1242	25U	NR	25U	NR	25U	NR
Aroclor 1248	25U	10U	25U	**11**	25U	10U
Aroclor 1254	25U	10U	25U	10U	25U	10U
Aroclor 1260	25U	10U	25U	10U	25U	10U

NR = Not reported
U = Not detected Value is the detection limit

TABLE 5-19 SUMMARY OF SEDIMENT PCB DATA, 1991 AND 1993
LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

		Units in µg/kg dry sediment				Frequency of Exceedances[b]	
		Range		Median			
	Frequency of Detection	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Long and Morgan	Ontario
Aroclor 1221							
1993	0/15	20	--	20U	--	0/15	0/15
1991	0/54	25-250	--	25U	--	0/54	0/54
Combined Data	0/69	20-250	--	25U	--	0/69	0/69
Aroclor 1232							
1993	0/15	10	--	10U	--	0/15	0/15
1991	0/54	25-250	--	25U	--	0/54	0/54
Combined Data	0/69	10-250	--	25U	--	0/69	0/69
Aroclor 1242/1016							
1993	0/15	10	--	10U	--	0/15	0/15
1991	0/54	25-250	--	25U	--	0/54	0/54
Combined Data	--	10-250	--	25U	--	0/69	0/69
Aroclor 1248							
1993	2/15	10	7.3-11	10U	9.2	0/15	0/15
1991	0/54	25-250	--	25U	--	0/54	0/54
Combined Data	2/69	10-250	7.3-11	25U	9.2	0/69	0/69
Aroclor 1254							
1993	0/15	10	--	10U	--	0/15	0/15
1991	1/54	25-250	85	25U	85	1/54	1/54
Combined Data	1/69	10-250	85	25U	85	1/69	1/69
Aroclor 1260							
1993	0/15	10	--	10U	--	0/15	0/15
1991	0/54	25-250	--	25U	--	0/54	0/54
Combined Data	0/69	10-250	--	25U	--	0/6	0/69

U = Not detected. Value is the detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993 and fifty-four stations were sampled in 1991

[b] Frequency of exceedance of the Long and Morgan (1990) Effects Range-Low or the Ontario Ministry of the Environment's Provincial Sediment Quality Guidelines (Persand et al. 1993) Lowest Effect Level.

TABLE 5-20 SUMMARY OF SEDIMENT DIOXIN AND FURAN DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS
(Page 1 of 3)

		Units in ng/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
2,3,7,8-TCDD						
1993	0/15	0.3-1.4	--	0.4U	ND	0/15
1991	18/20	0.09	0.07-0.35	0.1U	0.2	0/20
Combined data	18/35	0.09-1.4	0.07-0.35	0.4U	0.2	0/20
1,2,3,7,8-PeCDD						
1993	0/15	0.4-1.1	--	0.8U	ND	NA
1991	16/20	0.08	0.09-3.38	0.11U	0.18	--
Combined data	16/35	0.08-1.1	0.09-3.38	0.7U	0.18	--
1,2,3,4,7,8-HxCDD						
1993	0/15	0.4-1.6	--	0.8U	ND	NA
1991	19/20	0.17	0.10-1.92	0.17U	0.31	--
Combined data	19/35	0.17-1.6	0.10-1.92	0.8U	0.31	--
1,2,3,6,7,8-HxCDD						
1993	0/15	0.7-2.2	--	1.1U	ND	NA
1991	20/20	--	0.14-5.95	--	1.18	--
Combined data	20/35	0.7-2.2	0.14-5.95	1.1U	1.18	--
1,2,3,7,8,9-HxCDD						
1993	0/15	0.5-2.1	--	1.0U	ND	NA
1991	20/20	--	0.1-5.04	--	0.87	--
Combined data	20/35	0.5-2.1	0.1-5.04	1.0U	0.87	--
1,2,3,4,6,7,8-HpCDD						
1993	1/15	0.9-6.9	5.0	3.3U	5.0	NA
1991	20/20	--	0.9-188	--	18.25	--
Combined data	21/35	0.9-6.9	0.9-188	3.3U	16.5	--
OCDD						
1993	7/15	4.5-46.9	10.4-52.5	8.0U	13.2	NA
1991	20/20	--	6.8-1,480	--	176	--
Combined data	27/35	4.5-46.9	6.8-1,480	7.9U	105	--
2,3,7,8-TCDF						
1993	0/15	0.6-1.3	--	0.9U	ND	NA
1991	20/20	--	0.06-3.23	--	1.39	--
Combined data	20/35	0.6-1.3	0.06-3.23	0.9U	1.39	--
1,2,3,7,8-PeCDF						
1993	0/15	0.3-1.1	--	0.7U	ND	NA
1991	19/20	0.07	0.17-1.37	0.07U	0.30	--
Combined data	19/35	0.07-1.1	0.17-1.37	0.7U	0.30	--

TABLE 5-20 SUMMARY OF SEDIMENT DIOXIN AND FURAN DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

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		Units in ng/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
2,3,4,7,8-PeCDF						
1993	0/15	0.3-1.3	--	0.6U	ND	NA
1991	19/20	0.07	0.16-1.46	0.07U	0.28	--
Combined data	19/35	0.07-1.3	0.16-1.46	0.6U	0.28	--
1,2,3,4,7,8-HxCDF						
1993	0/15	0.8-2.1	-	1.1U	ND	NA
1991	20/20	--	0.31-7.47	0.07U	0.69	--
Combined data	20/35	0.8-2.1	0.31-7.47	1.1U	0.69	--
1,2,3,6,7,8-HxCDF						
1993	0/15	0.7-1.9	--	1.1U	ND	NA
1991	20/20	--	0.11-2.22	--	0.27	--
Combined data	20/35	0.7-1.9	0.11-2.22	1.1U	0.27	--
1,2,3,7,8,9-HxCDF						
1993	0/15	1.0-2.7	--	1.6U	ND	NA
1991	16/20	0.10-0.24	0.07-7.21	0.20U	0.15	--
Combined data	16/35	0.10-2.7	0.07-7.21	1.5U	0.15	--
2,3,4,6,7,8-HxCDF						
1993	0/15	0.8-2.3	--	1.3U	ND	NA
1991	20/20	--	0.16-6.21	--	0.46	--
Combined data	20/35	0.8-2.3	0.16-6.21	1.3U	0.46	--
1,2,3,4,6,7,8-HpCDF						
1993	0/15	0.5-7.1	--	1.3U	ND	NA
1991	20/20	--	0.51-27.8	--	3.27	--
Combined data	20/35	0.5-7.1	0.51-27.8	1.3U	3.27	--
1,2,3,4,7,8,9-HpCDF						
1993	0/15	0.3-3.0	--	1.9U	ND	NA
1991	19/20	0.42	0.12-15.5	0.42U	0.37	--
Combined data	19/35	0.3-3.0	0.12-15.5	1.8U	0.37	--
OCDF						
1993	0/15	0.4-4.0	--	1.6U	ND	NA
1991	20/20	--	1.19-128	--	9.03	--
Combined data	20/35	0.4-4.0	--	1.6U	9.03	--
TEC[c,d]						
1993	NA	NA	0.73-1.81	NA	1.17	0/15
1991	--	--	0.22-7.58	--	1.58	16/20
Combined data	--	--	0.22-7.58	--	1.21	16/35

TABLE 5-20 SUMMARY OF SEDIMENT DIOXIN AND FURAN DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS
(Page 3 of 3)

		Units in ng/kg dry sediment				
		Range		Median		
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations	Frequency of Exceedances[b]
TEC[c,e]						
1993	NA	NA	0-0 10	NA	0 0	0/15
1991	--	--	0 12-7 58	--	1 58	16/20
Combined data	--	--	0-7 58	--	0 76	16/35

NA = Not applicable.

ND = Not detected

U = Not detected. Value is the detection limit.

[a] Frequency of detection at the stations sampled Fifteen stations were sampled in 1993 and twenty stations were sampled in 1991

[b] Frequency of exceedance of the draft New York State reference level for protection of wildlife (Newell and Sinnott 1993)

[c] Toxicity Equivalency Concentration (TEC) calculated based on Barnes (1991)

TEC based on the assumption that the concentrations for undetected compounds is equal to half the lower detection limit.

[e] TEC based on the assumption that the concentrations for undetected compounds is zero

The New York State sediment dioxin criterion for the protection of fish-eating wildlife, 0 2 ng/g OC, was not available to evaluate 1991 data Comparison of toxicity equivalency concentrations (TECs) calculated for both surveys to this criterion indicated exceedances at 16 of the 20 stations sampled in 1991 but no exceedances at the backwater areas sampled in 1993 (Table 5-20) These data indicate some potential for adverse effects on fish-eating wildlife from the levels of dioxins and furans measured in lower Columbia sediments

The concentrations of dioxins and furans detected in sediments collected from Carrolls Channel and Camas Slough in 1991 were similar to or somewhat lower than 1993 detection limits for these areas (Table 5-21) However, the concentrations of a few congeners, most notably 1,2,3,4,6,7,8-HpCDD; OCDD, 1,2,3,4,6,7,8-HpCDF (heptachlorodibenzofuran); and OCDF (octachlorodibenzofuran) were consistently higher in the 1991 sediment samples than 1993 quantification limits Although the differences noted between the 1991 and 1993 studies may reflect relatively lower sediment dioxin and furan concentrations in backwater areas farther removed from the mainstem of the river (consistent with the results of sediment PAH analyses), differences due to laboratory analytical bias cannot be ruled out.

5.2.6 Butyltin Compounds

Butyltin compounds were detected at similar frequencies and at relatively similar concentrations in 1991 and 1993 (Table 5-22). Although marinas and port facilities were targeted for sampling in 1991, the highest concentrations of dibutyltin (12 4 μg Sn/kg) and tributyltin (34 4 μg Sn/kg) were measured at the 1993 backwater station Lewis & Clark NWR (Table 5-22) The highest concentration of monobutyltin was measured in 1991 in Longview (50 3 μg Sn/kg)

Although reference levels are not available to evaluate the potential environmental significance of the butyltin data, the concentrations reported are within the range of sediment butyltin concentrations classified as lightly (3-20 μg Sn/kg) to moderately (20-100 μg Sn/kg) contaminated based on sampling of sediments in two estuaries in Great Britain. In this study, concentrations as high as 3,935 μg Sn/kg for TBT, 2,964 μg Sn/kg for DBT, and 174 μg Sn/kg for MBT were measured in sediments collected from marinas (Dowson et al 1992). Although the use of organotins in anti-fouling paints was controlled by legislation enacted in 1988 in the U.S. and decreasing trends in water concentrations have been demonstrated in some areas (Huggett et al 1992), sediments in the lower Columbia River appear to harbor

TABLE 5-21 COMPARISON OF SEDIMENT DIOXIN CONCENTRATIONS REPORTED FOR YOUNGS BAY, CARROLLS CHANNEL, AND CAMAS SLOUGH SAMPLED IN THE 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Youngs Bay (RM 14)		Carrolls Channel (RM 68)		Camas Slough (RM 120)	
	Station D3	Station 1	Station D20	Station 8	Station D35	Station 13
	1991	1993	1991	1993	1991	1993
Percent Fines	73.2	95.1	29.8	69.3	43.6	51.9
Percent TOC	0.6	2.1	0.85	2.1	4.06	1.5
	ng/kg dry sediment					
2,3,7,8-TCDD	NR	0.6U	0.24	0.6U	0.28	0.5U
1,2,3,7,8-PeCDD	NR	1.0U	0.12	0.8U	0.13U	0.7U
1,2,3,4,7,8-HxCDD	NR	1.2U	0.31	0.5U	0.4	0.7U
1,2,3,6,7,8-HxCDD	NR	1.7U	1.48	1.0U	1.39	1.1U
1,2,3,7,8,9-HxCDD	NR	1.5U	0.89	0.6U	1.0	0.9U
1,2,3,4,6,7,8-HpCDD	NR	0.9U	54.3	1.9U	20	3.1U
OCDD	NR	13.2	566	7.4U	193	8U
2,3,7,8-TCDF	NR	0.6U	2.07	0.9U	2.94	1U
1,2,3,7,8-PeCDF	NR	1U	0.17	0.8U	1.14	0.9U
2,3,4,7,8-PeCDF	NR	1U	0.28	0.8U	0.18	1U
1,2,3,4,7,8-HxCDF	NR	2.1U	0.61	1.0U	2.99	1.3U
1,2,3,6,7,8-HxCDF	NR	1.9U	0.25	0.9U	0.94	1.1U
1,2,3,7,8,9-HxCDF	NR	2.7U	0.55	1.5U	1.02	1.6U
2,3,4,6,7,8-HxCDF	NR	2.3U	0.16	1.1U	0.22	1.3U
1,2,3,4,6,7,8-HpCDF	NR	7.1U	3.42	0.9U	6.46	1.1U
1,2,3,4,7,8,9-HpCDF	NR	1.9U	0.37	1.2U	1.76	1.9U
OCDF	NR	3.5U	12.5	0.9U	16.9	1.1U

NR = Not reported.

U = Not detected. Value is the detection limit.

TABLE 5-22 SUMMARY OF SEDIMENT BUTYLTIN DATA,
1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

		Units in µg Sn/kg dry sediment			
		Range		Median	
	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations
Monobutyltin					
1993	6/15	1.7-3.4	5.1-14.5	1.7	7.7
1991	7/10	3.3-5.0	1.3-50.3	3.4	2.7
Combined data	13/25	1.7-5.0	2.9-50.3	1.7	5.1
Dibutyltin					
1993	4/15	2.6	4.6-12.4	2.6	6.9
1991	6/10	4.9-7.5	4.1-8.8	5.1	5.6
Combined data	10/25	2.6-7.5	4.1-12.4	2.6	6.7
Tributyltin					
1993	12/15	3.2	2.4-34.4	3.2	5.6
1991	5/10	5.8-8.9	5.8-22.7	6.1	17.0
Combined data	17/25	3.2-8.9	2.4-34.4	5.8	6.4

[a] Frequency of detection of mono-, di-, and tri-butyltin at the stations sampled. Fifteen stations were sampled in 1993 and ten stations were sampled in 1991

No reference values are available for the evaluation of these data.

butyltin compounds and may serve as a reservoir of these contaminants for continued release to the water column and accumulation by aquatic organisms

5.2.7 Radionuclides

Radionuclides were generally detected at similar frequencies and concentrations in 1991 and 1993 (Table 5-23) An exception was americium 241 (Am-241) detected at Skamania Landing in 1993, it was detected in only one of three subsamples analyzed The radionuclides detected in both surveys were cesium 137 (Cs-137) and plutonium 239/240 (Pu-239/240) These show similar ranges and median concentrations (Table 5-23) Differences in the frequency of detection of cobalt 60 (Co-60) and europium 152 (Eu-152) are due to the differences in the detection limits achieved for the two surveys

The concentration of radionuclides in 1991 sediments from Carrolls Channel and Camas Slough were similar to or somewhat lower than 1993 detection limits for these areas (Table 5-24). The greatest difference was noted for the sediment concentrations of Cs-137 in Camas Slough· 0.25 pCi/g in 1991 0.082 pCi/g in 1993

Although no reference levels are available to evaluate the potential environmental significance of radionuclide data, the levels measured are similar to concentrations measured in sediments above Hanford, WA, the largest potential direct source of these radionuclides (Tetra Tech 1993a) The concentrations measured in areas removed from direct radionuclide inputs are primarily the result of the accumulation of fallout from historical above-ground nuclear weapons testing For example, Beasley et al. (1981) estimated that only about 4% of the Pu-239/240 in Youngs Bay sediment (which was considered to be minimally influenced by sediment input from the Youngs and Lewis and Clark rivers) was derived from Hanford operations Beasley and Jennings (1984) estimated that about 20-25% of the Pu-239/240 and 50% of the Cs-137 in sediments behind McNary Dam (directly below Hanford) was derived from Hanford operations, and the remainder of these radionuclides, plus others such as Am-241 came from atmospheric sources. The presence of Co-60 was attributed to operations at Hanford (Beasley and Jennings 1984) Following the termination of significant radionuclide input from the old once-through plutonium production reactors in 1971, sediment radionuclide concentrations have steadily declined due to radioactive decay, dispersion, transport, and burial of radionuclides by relatively uncontaminated sediments (Robertson and Fix 1977).

TABLE 5-23 SUMMARY OF SEDIMENT RADIONUCLIDE DATA, 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

			Units in pCi/g dry sediment			
			Range		Median	
	Radiologic Half-life (yr)	Frequency of Detection[a]	Detection Limits	Detected Concentrations	Detection Limits	Detected Concentrations
Americium 241						
1993	458	1/15	0.011-0.026	0.040	0.016U	0.040
1991		0/6	0.003-0.006	ND	0.003U	ND
Combined data		1/21	0.003-0.026	0.040	0.014U	0.040
Cesium 137						
1993	30	15/15	--	0.050-0.176	--	0.083
1991		6/6	--	0.07-0.29	--	0.15
Combined data		21/21	--	0.050-0.29	--	0.094
Cobalt 60						
1993	5.3	3/15	0.02	0.012-0.022	0.02U	0.019
1991		0/6	0.03-0.05	ND	0.04U	ND
Combined data		3/21	0.02-0.05	0.012-0.022	0.02U	0.019
Europium 152						
1993	13	0/15	0.2	ND	0.2U	ND
1991		2/6	0.08-0.10	0.11-0.14	0.09U	0.125
Combined data		2/21	0.08-0.2	0.11-0.14	0.2U	0.125
Europium 154						
1993	16	0/15	0.02	ND	0.02U	ND
1991		NS	--	--	--	--
Combined data		0/15	0.02	ND	0.02U	ND
Europium 155						
1993	1.8	0/15	0.05	ND	0.05U	ND
1991		0/6	0.07-0.10	ND	0.09U	ND
Combined data		0/21	0.05-0.10	ND	0.05U	ND
Plutonium 238						
1993	86	0/15	0.007-0.014	ND	0.009U	ND
1991		0/6	0.002-0.006	ND	0.002U	ND
Combined data		0/21	0.002-0.014	ND	0.008U	ND
Plutonium 239/240						
1993	24,400/6,580	7/15	0.003-0.009	0.004-0.010	0.004U	0.007
1991		3/6	0.001-0.002	0.002-005	0.001U	0.003
Combined data		10/21	0.001-0.009	0.002-0.010	0.004U	0.005

ND = Not detected.

NS = Not Sampled

U = Not detected. Value is the detection limit.

[a] Frequency of detection at the stations sampled. Fifteen stations were sampled in 1993 and six stations were sampled in 1991

No reference levels are available for the evaluation of these data

TABLE 5-24 COMPARISON OF SEDIMENT RADIONUCLIDE CONCENTRATIONS REPORTED FOR YOUNGS BAY, CARROLLS CHANNEL, AND CAMAS SLOUGH 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Youngs Bay (RM 14)		Carrolls Channel (RM 68)		Camas Slough (RM 120)	
	Station D3	Station 1	Station D20	Station 8	Station D35	Station 13
	1991	1993	1991	1993	1991	1993
Percent Fines	73.2	95.1	29.8	69.3	43.6	51.9
Percent TOC	0.6	2.1	0.85	2.1	4.06	1.5
	pCi/g dry sediment					
Americium 241	NS	0.012U	0.006U	0.016U	0.003U	0.021U
Cobalt 60	NS	0.02U	0.03U	0.022	0.05U	0.20U
Cesium 137	NS	0.071	0.07	0.155	0.25	0.082
Europium 152	NS	0.20U	0.09U	0.20U	0.11	0.20U
Europium 154	NS	0.20U	NR	0.20U	NR	0.20U
Europium 155	NS	0.05U	0.09U	0.05U	0.07	0.05U
Plutonium 239/240	NS	0.007	0.003	0.007	0.002U	0.004U
Plutonium 238	NS	0.014U	0.002U	0.011U	0.006U	0.008U

NR = Not reported.

NS = Not sampled for radionuclides in 1991.

U = Not detected. Value is the detection limit.

5.2.8 Sediment Toxicity

Sediment toxicity testing was implemented as part of the 1993 backwater survey to evaluate the toxicity of Columbia River sediments using established bioassay protocols, as a tool for interpreting the results of sediment chemistry analyses. The toxicity tests employed were the solid-phase Microtox– test and the 10-day amphipod (*Hyalella azteca*) survival test The results of these tests, presented in Section 4.2.8, are briefly summarized below

Comparison of the toxicity data to reference guidelines for the two toxicity tests indicates that only sediments collected from Youngs Bay demonstrated relatively high toxicity (based on the results of the Microtox– test). A comparison of the 95% confidence estimates of the EC_{50}s for the Microtox– results of the designated reference station (Bachelor Island Slough) with results from the other 14 sampling stations indicated that the relative sediment toxicity was significantly higher at five stations (Youngs Bay, Knappa Slough, Lewis & Clark NWR, Camas Slough, and Gary & Flag Islands) The results of a statistical test (Dunnett's Test) indicated that the mean *Hyalella* survival at the reference station was not significantly different ($p \leq 0.05$) than at any other station. The contrasting results provided by these two bioassays may reflect the varying sensitivities of the two tests to the contaminants present However, the relatively low sediment toxicities shown by these two tests (all but one station with a sediment EC_{50} of 2% and average 10-day amphipod survival greater than 80% at all 15 stations) suggests that the significant differences noted from the reference station may be anomalous

Such equivocal results are typical when sediment toxicity is relatively low For example, WDOE conducted acute bioassays on sediments collected from 10 locations, including 5 industrial and/or port facilities (Camas, Vancouver, Kalama, Longview, and Ilwaco) and a reference location near Reed Island, upstream of lower river urban and industrial areas (Johnson and Norton 1988) Two test organisms and exposure times were used (a 4-day *Hyalella* test and a 48-hour *Daphnia* test). Although at least one of these areas was shown to have potentially toxic levels of PAHs (the sampling station below Reynolds Aluminum in Longview, see Section 5.2.3.2 above), none of the sediments tested showed higher toxicity than the reference station (Johnson and Norton 1988) The percent mortality of *Daphnia* was actually greatest (25 and 30%) in the Reed Island reference sediment (Johnson and Norton 1988)

5.2.8.1 Relationship of Sediment Toxicity to Sediment Contaminant Levels. In order to determine the extent to which the variation in toxicity measured by the Microtox– and *Hyalella* bioassays could be explained by the variation in the sediment parameters, linear regression analyses were performed using sediment physical or chemical parameters as the independent variable The parameters chosen for analysis were the conventional sediment variables (percent fines, TOC, total solids, TVS, ammonia nitrogen, TKN, and total sulfides), and the metals detected frequently at all 15 stations (Al, As, Ba, Be, Cd, Cr, Cu, Fe, Pb, Hg, Ni, and Zn) Organic contaminants (including butyltin compounds) and radionuclides were detected too infrequently to be used in this analysis, and the detected sediment PAH concentrations were well below concentrations expected to cause acute toxic effects

There were no significant (alpha=0 05) linear relationships between *Hyalella* percent survival and any of the variables tested (Table 5-25). Normalization of the metals data to sediment aluminum content resulted in an increase in the strength and number of negative correlations with percent survival, but none of these relationships was statistically significant (Table 5-25)

There were no significant (alpha=0 05) linear relationships between Microtox- EC_{50} and any of the variables tested (Table 5-25) A negative correlation between TVS and sediment EC_{50} was found [correlation coefficient (r) of -0 3367] and a coefficient of regression (r^2) for TVS vs sediment EC_{50} indicated that 11% of the variance in percent survival was explained by the regression (Table 5-25) However, the regression relationship was not significantly different from zero (P=0 2198). A negative correlation with percent fines was also noted, also not statistically significant. The highest correlation of sediment EC_{50}s with metals was for lead (r=-0 3359), again not statistically significant. Normalization of the metals data to sediment aluminum content resulted in little change in the strength and number of negative correlations with sediment EC_{50} (Table 5-25).

Although the variation in measured sediment toxicity could not be attributed to variation in the amounts of individual contaminants or other physical and chemical sediment variables, sediment concentrations of several contaminants were measured at levels that exceeded reference values. For example, the highest sediment concentration of total sulfide (133.9 mg/kg) was measured at Youngs Bay which had the lowest Microtox- EC_{50} Concentrations of copper and cadmium measured in Youngs Bay sediments also exceeded reference values. The other stations (Knappa Slough, Lewis & Clark NWR, Camas Slough, and Gary & Flag Islands) where the Microtox- EC_{50} was significantly different from that of the reference sediments also contained concentrations of copper and cadmium that exceeded reference values The highest sediment butyltin concentrations were generally measured at the Lewis & Clark NWR station.

TABLE 5-25 CORRELATIONS AND LINEAR REGRESSION RELATIONSHIPS BETWEEN SEDIMENT TOXICITY AND MEASURED SEDIMENT PHYSICAL AND CHEMICAL VARIABLES

Note Regressions were performed only for relationships showing a negative correlation coefficient greater than 0 30

None of the correlations shown below are statistically significant (p ≥ 0 05)

A. Sediment variables vs. Hyalella percent survival

	correlation coefficient	r-square	P-value		correlation coefficient	r-square	P-value
% TOC	0 0160	--	--				
% Fines	-0 1624	--	--				
total solids	-0 2260	--	--				
TVS	0 4009	--	--				
Ammonia-N	-0 0235	--	--				
Sulfides	-0 0978	--	--				
TKN	0 0354	--	--				
Al	0 2972	--	--	Al/Fe	0 05219	--	--
As	0 0934	--	--	As/Al	-0 09841	--	--
Ba	0 2513	--	--	Ba/Al	-0 06331	--	--
Be	0 2554	--	--	Be/Al	0 00645	--	--
Cd	-0 2747	--	--	Cd/Al	-0 3565	0 1271	0 1921
Cr	0 3231	--	--	Cr/Al	-0 09531	--	--
Cu	0 1132	--	--	Cu/Al	-0 31101	0 0967	0 2592
Fe	0 2743	--	--	Fe/Al	-0 04764	--	--
Pb	-0 2306	--	--	Pb/Al	-0 3223	0 1039	0 2414
Hg	-0 1418	--	--	Hg/Al	-0 29054	--	--
Ni	0 1105	--	--	Ni/Al	-0 44896	0 2016	0 0932
Zn	-0 2800	--	--	Zn/Al	-0 42315	0 1791	0 116

B. Sediment variables vs. Microtox EC-50

	correlation coefficient	r-square	P-value		correlation coefficient	r-square	P-value
% TOC	-0 0474	--	--				
% Fines	-0 3813	0 1454	0 1608				
total solids	0 2818	--	--				
TVS	-0 3367	0 1134	0 2198				
Ammonia-N	-0 3543	0 1255	0 1951				
Sulfides	-0 3132	0 0981	0 2556				
TKN	-0 3557	0 1265	0 1932				
Al	0 1295	--	--	Al/Fe	-0 25223	--	--
As	-0 1338	--	--	As/Al	-0 13851	--	--
Ba	0 2364	--	--	Ba/Al	0 16765	--	--
Be	0 0249	--	--	Be/Al	-0 10598	--	--
Cd	-0 1808	--	--	Cd/Al	-0 16584	--	--
Cr	0 1078	--	--	Cr/Al	-0 05567	--	--
Cu	0 2067	--	--	Cu/Al	0 13027	--	--
Fe	0 2014	--	--	Fe/Al	0 24893	--	--
Pb	-0 3359	0 1128	0 2209	Pb/Al	-0 29381	--	--
Hg	0 3860	--	--	Hg/Al	0 35785	--	--
Ni	0 3482	--	--	Ni/Al	0 30438	--	--
Zn	-0 0400	--	--	Zn/Al	-0 07905	--	--

The highest sediment concentration of ammonia nitrogen was measured at Camas Slough, as were the highest concentrations of 4-methylphenol and bis(2-ethylhexyl)phthalate. Furthermore, the sediment concentrations of 4-methylphenol, arsenic, iron, lead, nickel, and zinc at this station also exceeded reference values. Gary & Flag Islands had the highest sediment concentration of TKN, a concentration of zinc above the reference level, and a cadmium concentration determined to be potentially elevated due to human inputs

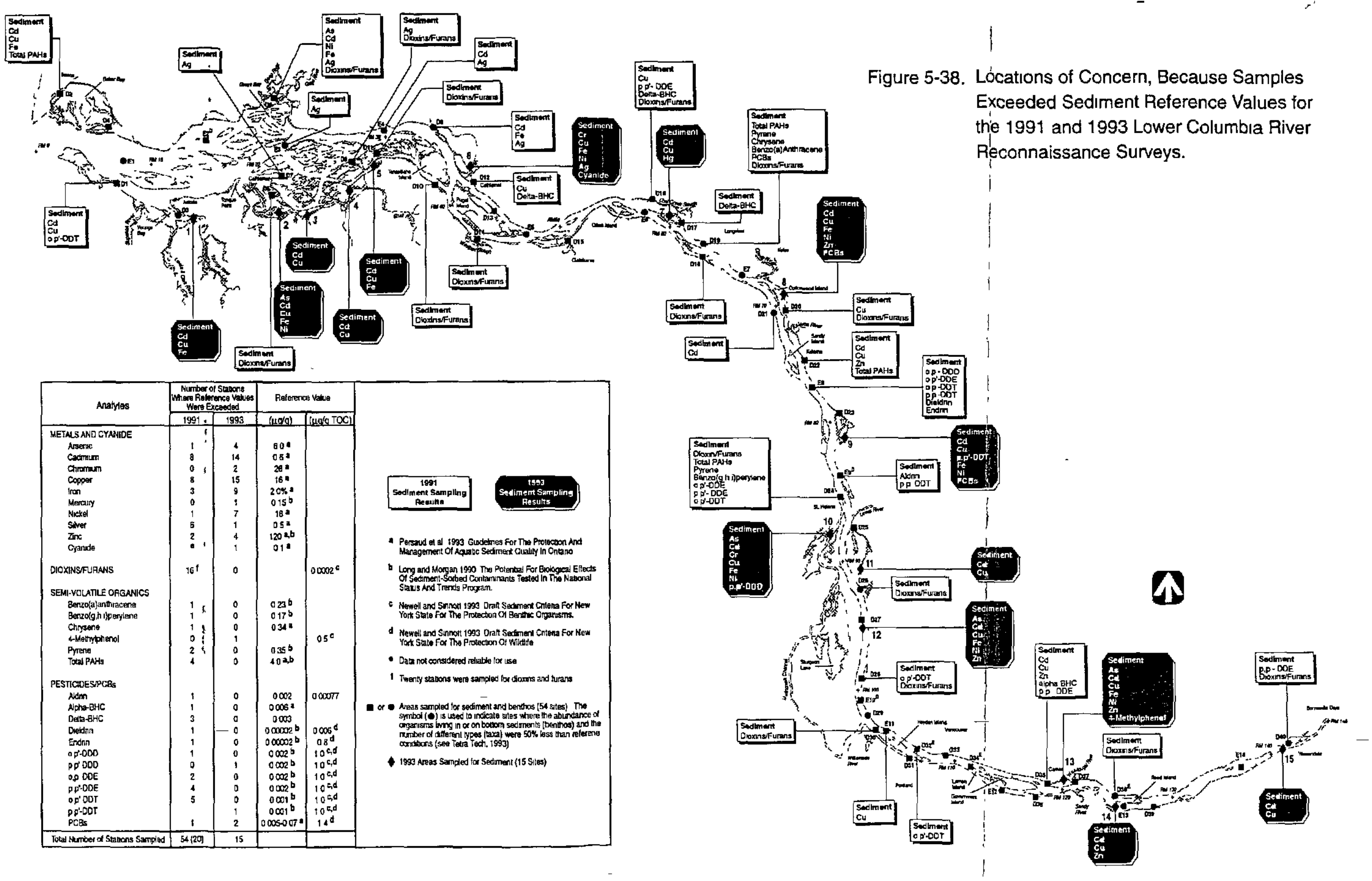
The frequent detection of contaminants in lower river sediments which exceed reference levels for protecting benthic organisms suggests that sub-lethal effects may occur. Such effects are difficult to detect using established toxicity testing methods Sediments from locations closer to contaminant sources may be more toxic, although this was not observed in Johnson and Norton's 1988 study for WDOE

5.2.9 Sediment Quality Summary

Potential adverse effects on aquatic life or wildlife were identified by comparing 1991 and 1993 survey data to reference levels adopted for this study (Figure 5-38). A number of metals exceeded reference levels in one or both surveys, including As, Cd, Cr, Cu, Fe, Hg, Ni, Ag, and Zn. Sediment cyanide exceeded the reference concentration at one station in 1993. Dioxin exceeded the reference level for protecting fish-eating wildlife at all stations sampled for dioxins and furans in 1991, but not at the 1993 stations. Potentially harmful levels of PAHs were measured at four locations in 1991, but PAH levels were consistently lower (below reference values) at all 1993 stations Considering the number of stations sampled, pesticide levels exceeded reference levels relatively infrequently in both surveys. Most exceedances of pesticide reference levels were for DDT compounds and metabolites, especially p,p'-DDE.

In general, the sediment sampling objectives of the 1993 backwater survey were satisfied. The initial 1991 sediment quality data base was extended to additional fine-grained backwater areas along the lower river The sampling results for the 1991 reconnaissance survey at three sampling locations also sampled in 1993 generally confirmed the original analytical results with the possible exception of a few dioxin and furan congeners. The toxicity of the sediments sampled was also evaluated, and an attempt was made to relate the variation in sediment toxicity to the variation in measured sediment contaminant levels. However, the sediments did not appear to be acutely toxic (based on comparison to reference levels), although significant differences between reference station toxicity and toxicity measured at other stations

Figure 5-38. Locations of Concern, Because Samples Exceeded Sediment Reference Values for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.



Analytes	Number of Stations Where Reference Values Were Exceeded		Reference Value	
	1991	1993	(µg/g)	(µg/g TOC)
METALS AND CYANIDE				
Arsenic	1	4	6.0 a	
Cadmium	8	14	0.6 a	
Chromium	0	2	26 a	
Copper	8	15	16 a	
Iron	3	9	2.0% a	
Mercury	0	1	0.15 b	
Nickel	1	7	16 a	
Silver	6	1	0.5 a	
Zinc	2	4	120 a,b	
Cyanide	e	1	0.1 a	
DIOXINS/FURANS	16 f	0		0.0002 c
SEMI-VOLATILE ORGANICS				
Benzo(a)anthracene	1	0	0.23 b	
Benzo(g,h,i)perylene	1	0	0.17 b	
Chrysene	1	0	0.34 a	
4-Methylphenol	0	1		0.5 c
Pyrene	2	0	0.35 b	
Total PAHs	4	0	4.0 a,b	
PESTICIDES/PCBs				
Aldrin	1	0	0.002	0.00077
Alpha-BHC	1	0	0.006 a	
Delta-BHC	3	0	0.003	
Dieldrin	1	0	0.00002 b	0.006 d
Endrin	1	0	0.00002 b	0.8 d
o,p'-DDD	1	0	0.002 b	1.0 c,d
p,p'-DDD	0	1	0.002 b	1.0 c,d
o,p'-DDE	2	0	0.002 b	1.0 c,d
p,p'-DDE	4	0	0.002 b	1.0 c,d
o,p'-DDT	5	0	0.001 b	1.0 c,d
p,p'-DDT		1	0.001 b	1.0 c,d
PCBs	1	2	0.005-0.07 a	1.4 d
Total Number of Stations Sampled	54 (20)	15		

1991 Sediment Sampling Results

1993 Sediment Sampling Results

[a] Persaud et al. 1993. Guidelines For The Protection And Management Of Aquatic Sediment Quality In Ontario

[b] Long and Morgan 1990. The Potential For Biological Effects Of Sediment-Sorbed Contaminants Tested In The National Status And Trends Program.

[c] Newell and Sinnott 1993. Draft Sediment Criteria For New York State For The Protection Of Benthic Organisms.

[d] Newell and Sinnott 1993. Draft Sediment Criteria For New York State For The Protection Of Wildlife

[e] Data not considered reliable for use

[f] Twenty stations were sampled for dioxins and furans

■ or ● Areas sampled for sediment and benthos (54 sites). The symbol (●) is used to indicate sites where the abundance of organisms living in or on bottom sediments (benthos) and the number of different types (taxa) were 50% less than reference conditions (see Tetra Tech, 1993)

◆ 1993 Areas Sampled for Sediment (15 Sites) were noted The variation in toxicity could not be explained by variation in individual contaminant levels or other sediment variables

With the exception of sediment metals, the concentrations of contaminants detected in lower Columbia River sediments did not appear to be consistently elevated in the relatively finer-grained backwater sediments. The use of metal normalization techniques to account for the general association of trace metals with fine sediment revealed potential anthropogenic elevation of several metals in both fine backwater sediments (e g , arsenic) and in relatively coarse-grained mainstem sediments (e.g , copper) Although sediment organic carbon content was found to be related to at least a few semi-volatile PAH compounds, the highest PAH concentrations did not occur in backwater areas with relatively higher TOC, but in the vicinity of urban and industrial sources of these compounds Pesticides were detected infrequently throughout the study area in both surveys at relatively low concentrations, probably due to diffuse inputs from agricultural sources located in upper and lower river tributary basins as well as local nearshore sources. PCBs were also detected infrequently, the highest sediment PCB concentration was measured near urban and industrial sources of these compounds near Longview.

A more limited number of locations have been sampled for dioxins and furans, butyltin compounds, and selected long-lived radionuclides. Dioxin and furan concentrations measured in backwater areas in 1993 were lower than those reported in 1991 In general, the highest concentrations of dioxins and furans occurred below bleach kraft pulp and paper mills that are known sources of these compounds Although butyltin compounds were detected relatively frequently in 1991 and 1993, the potential environmental significance of these concentrations cannot be determined and may warrant further study The selected long-lived radionuclides analyzed in the 1991 and 1993 surveys were generally detected infrequently Although the potential environmental significance of the levels detected cannot be assessed, the maximum concentrations measured are generally lower than or similar to concentrations measured above Hanford—the largest potential direct source of these radionuclides in the river basin.

5.3 CRAYFISH AND FISH TISSUE QUALITY

Human-introduced contaminants in the aquatic environment are of concern because of possible human health risks from consuming contaminated fish and shellfish, and possible risks to wildlife from consuming contaminated prey There is also concern that aquatic species themselves may be impaired by the accumulation of toxic chemicals in tissue For example, Lemly (1993) determined that accumulations of selenium in freshwater and anadromous fish could cause adverse health and reproductive effects

There is some evidence that fish-eating wildlife in the lower Columbia River have experienced adverse effects due to the consumption of contaminated prey species. For example, Henny et al. (1981) found elevated levels of PCBs and organophosphorus pesticides in mink (*Mustela vison*) and otters (*Lutra canadensis*) collected along the lower Columbia River and suggested that population declines of these species might be attributed to reproductive failure from consuming PCB-contaminated fish Impaired reproductive success of predatory birds from accumulated organochlorine pesticides has been documented in many areas of the United States Anthony et al (1993) have suggested that the relatively low breeding success of bald eagles in the Columbia River estuary is due to the accumulation of DDT, PCB, and dioxin and furan compounds from contaminated prey species These prey species may be smaller migratory birds (exposed to current uses of DDT in Central and South America) or fish species such as largescale sucker, American shad, common carp, and peamouth.

Whole-body composite samples of crayfish (*Pacifastacus leniusculus*), largescale sucker (*Catostomus macrocheilus*), and common carp (*Cyprinus carpio*) were collected for the 1991 and 1993 reconnaissance surveys Whole-body composite samples of peamouth (Mylocheilus caurinus) and filet samples of white sturgeon (*Acipenser transmontanus*) were also collected for the 1991 reconnaissance survey For comparative purposes, however, only those species collected for both surveys will be discussed

Due to the limited number of reference values available to assess potential adverse effects on aquatic organisms and wildlife, comparisons of reconnaissance survey data with contaminant levels measured in national studies as well as additional data for the lower and middle reaches of the Columbia River and major lower river tributaries (available from U.S EPA's STORET database) are provided.

The national studies used for comparisons include the following, listed by the reference format used in this report:

Measurements of metals and pesticides in freshwater fish reported by

- May and McKinney 1981
- Schmitt et al 1981
- Lowe et al 1985
- Schmitt et al. 1985
- Schmitt et al 1990
- USFWS-NCBP· the National Contaminant Biomonitoring Program of the U.S. Fish and Wildlife Service; previously known as the National Pesticide Monitoring Program (Schmitt and Brumbaugh 1990)

Measurements of metals and organic contaminants in freshwater fish (and a limited number of shellfish and marine fish species) conducted by:

- EPA-NSCRF: the National Study of Chemical Residues in Fish of the U.S. Environmental Protection Agency (U S. EPA 1992d); previously known as the National Bioaccumulation Study (U.S. EPA 1991a)

5.3.1 Conventional Parameters

The conventional parameters measured in the 1991 and 1993 reconnaissance surveys are considered important variables that are related to contaminant accumulation in aquatic biota. Fish age and/or size (e.g., length or weight) has been used to explain variation in levels of trace metals (Evans et al. 1993) and DDT (Griesbach et al. 1982) in aquatic organisms Percent lipid content has been used to explain variation in contaminant levels in aquatic organisms (Pereira et al. 1988, Lake et al. 1990); it is an important component of equilibrium partitioning models of contaminant accumulation in benthic organisms and bottom-feeding fish (Thomann 1981; Thomann et al. 1992; Gobas 1993). However, some studies have not found a consistent relationship between contaminants and the lipid content of some organisms (Bierman 1990; Opperhuizen and Sijm 1990; Borgmann and Whittle 1992). Factors which may complicate this relationship include translocation and storage of contaminants in specific tissues, non-equilibrium conditions, variation in prey contaminant concentration or feeding habits, age and/or body size variation, excretion and/or biotransformation of contaminants, and inhibition of contaminant uptake due to solubility factors (e.g., steric hindrance).

The 1991 and 1993 survey data for wet weight, length, and tissue lipid content are examined to answer the following questions 1) did these variables differ between 1991 and 1993 in the two species sampled frequently (crayfish and largescale sucker), 2) were length or weight variables related to lipid content, and 3) did lipid content differ significantly among species sampled

5.3.1.1 Differences in Conventional Parameters Between the 1991 and 1993 Reconnaissance Surveys.

Crayfish--The average weights of the crayfish in composite samples for the surveys ranged from 27.7 to 92.1 g and lipid concentrations ranged from 0.6 to 2.2%. The difference between the average crayfish weights and the average lipid concentrations for the composite samples collected in 1991 and 1993 varied only slightly and were not significantly different (Student's t-test; $P=0.3735$ and $P=0.3735$, respectively). Therefore, it is assumed when comparing pollutant data from the two surveys that the crayfish analyzed were roughly the same ages

Largescale Sucker--The average weights and lengths of the largescale suckers in composite samples collected for the two surveys ranged from 309.5 to 1,153 g and 25.2 to 53.1 cm, respectively. Lipid concentrations ranged from 0.6 to 8.4%. The difference between the average largescale sucker weights, lengths, and lipid content for the composite samples collected in 1991 and 1993 did not substantially vary and were not significantly different (Student's t-test, $P=0.1926$, $P=0.1919$, and $P=0.0546$, respectively) Therefore, based upon length-age data presented in Table 4-18, it is assumed that largescale suckers collected for the two surveys were similar ages.

Common Carp--The average weights and lengths of the carp composite samples collected for the two surveys ranged from 378 to 3,275.2 g and 31.2 to 53.1 cm, respectively. The lipid content ranged from 2.3 to 6.5% The difference between the average weights, lengths, and lipid content for the carp composite samples collected in 1991 and 1993 were not significantly different (Student's t-test; $P=0.1834$, $P=0.0774$, and $P=0.7828$, respectively). As weight and length did not substantially vary between samples collected for the two surveys, it is assumed that carp were similar ages.

5.3.1.2 Relationships Among Weight, Length, and Percent Lipid. Average individual weights and lengths in composite samples, and composite percent lipid content from the two surveys were combined for each of the three species sampled. Linear regression analysis was used to determine if there were simple relationships between the averages of length and weight, lipid and length, and lipid and weight for each species sampled Statistically significant relationships were found for length vs. weight (log-normalized) for both fish species (largescale sucker, $r^2=0.8635$, $P<0.001$, carp, $r^2=0.9119$, $P<0.001$) However, no statistically significant linear relationships were found between lipid and weight or lipid and length for any species

5.3.1.3 Differences in Percent Lipid Among the Species Sampled for the Two Reconnaissance Surveys. Statistically significant differences in mean lipid content of the three species collected for the 1991 and 1993 surveys were found (ANOVA, $P<0.001$) To determine statistically significant differences in whole-body lipid content among the pairs of species sampled, a Student-Newman-Keuls (SNK) test was performed The lipid content of carp and largescale sucker was significantly higher than that of crayfish, but the lipid content of carp and largescale sucker was not significantly different.

5.3.2 Metals

The following discussion will focus on 1) differences in metal concentrations measured among the three species, 2) comparison of these metal concentrations to metal concentrations measured in national studies, and to additional STORET data, and 3) possible relationships between conventional variables and the tissue concentrations of metal

5.3.2.1 Comparison of 1991 and 1993 Reconnaissance Survey Results, Comparison with Historical Data, and Comparison with Criteria. All metals were detected in biota samples analyzed for both surveys except antimony and selenium, which were not detected in any of the 1991 samples (Table 5-26). Antimony and selenium were detected in 1993 samples due to the lower detection limits achieved by the laboratory for these metals in this survey Sample analysis for chromium was added in 1993 backwater survey, so no comparisons can be made for this metal. All concentrations are reported on a wet weight basis.

Antimony--Antimony was detected in six crayfish samples in the 1993 survey at concentrations ranging from 0 012 to 0 018 mg/kg (Table 5-26) Antimony was not detected in any other biota samples collected for either survey, which suggests that this metal occurs at relatively higher concentrations in crayfish than the other species sampled. The concentrations measured in 1993 samples were below the lower limit of detection reported by the laboratory in 1991 (0.20 to 4.05 mg/kg), indicating that detection

TABLE 5-26 METALS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

(Page 1 of 2)

Metal	Units	Crayfish		Largescale Sucker		Carp		Peamouth [b]	White Sturgeon [b]
		1991	1993	1991	1993	1991	1993	1991	1991
		N=20	N=15	N=18	N=16	N=8	N=2	N=10	N=17
Antimony									
Concentration range	mg/kg	c	0.012 - 0.018	c	c	c	c	c	c
Concentration range (1991-1993)	mg/kg	NA		NA		NA		NA	NA
Frequency of detection		(6 / 35)		(0 / 34)		(0 / 10)		(0 / 10)	(0 / 17)
Arsenic									
Concentration range	mg/kg	c	0.036	c	0.385	c	c	c	0.27 - 1.86
Concentration range (1991-1993)	mg/kg	NA		NA		NA		NA	NA
Frequency of detection		(1 / 35)		(1 / 34)		(0 / 10)		(0 / 10)	(7 /17)
Barium									
Concentration range	mg/kg	0.60 - 3.5	8.5 - 47.2	1.1 - 5.4	0.34 - 3.5	1.3 - 3.4	1.0 - 1.2	1.9 - 4.2	c
Concentration range (1991-1993)	mg/kg	0.60 - 47.2		0.34 - 5.4		1.0 - 3.4		NA	NA
Frequency of detection		(35 / 35)		(34 / 34)		(10 / 10)		(10 / 10)	(0 / 17)
Cadmium									
Concentration range	mg/kg	0.02 - 0.13	0.021 - 0.053	0.02 - 0.06	0.010 -0.066	0.03 - 0.35	0.033 - 0.039	0.02 - 0.08	0.02 - 0.04
Concentration range (1991-1993)	mg/kg	(0.02 - 0.13)		(0.010 - 0.066)		(0.03 - 0.35)		NA	NA
Frequency of detection		(34 / 35)		(34 / 34)		(10 / 10)		(10 / 10)	(2 / 17)
Chromium									
Concentration range	mg/kg	d	0.035 - 0.095	d	0.043 - 0.527	d	0.078	d	d
Concentration range (1991-1993)	mg/kg	NA		NA		NA			
Frequency of detection		(15 / 15)		(16 / 16)		(1 /2)			
Copper									
Concentration range	mg/kg	17.94 - 46.40	14.9 - 31.1	0.70 - 1.23	0.39 - 1.23	1.20 - 1.82	0.76 - 1.26	0.90 - 27.81	0.45 - 0.50
Concentration range (1991-1993)	mg/kg	(14.9 - 46.40)		(0.39 - 1.23)		(0.76 - 1.82)		NA	NA
Frequency of detection		(35 / 35)		(34 / 34)		(10 / 10)		(10 / 10)	(2 / 17)
Lead									
Concentration range	mg/kg	0.01 - 0.05	0.096 - 0.444	0.04 - 0.86	0.106 - 0.507	0.02 - 0.23	0.116 - 0.173	0.05 - 1.35	0.01 - 1.12
Concentration range (1991-1993)	mg/kg	(0.01 - 0.444)		(0.04 - 0.86)		(0.02 - 0.23)		NA	NA
Frequency of detection		(30 / 35)		(28 / 34)		(10 / 10)		(10 / 10)	(16 / 17)

TABLE 5-26 METALS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

(Page 2 of 2)

		Crayfish		Largescale Sucker		Carp		Peamouth	White Sturgeon
		1991	1993	1991	1993	1991	1993	1991	1991
Metal	**Units**	N=20	N=15	N=18	N=16	N=8	N=2	N=10	N=17
Mercury									
Concentration range	mg/kg	0 014 - 0 078	0 029 - 0 081	0 022 - 0 137	0 100 - 0 264	0 056 - 0 166	0 145	0 054 - 0 230	0 021 - 0 521
Concentration range (1991-1993)	mg/kg	(0 014 - 0 081)		(0 022 - 0 264)		(0 056 - 0 166)		NA	NA
Frequency of detection f		(32 / 35)		(34 / 34)		(9 / 10)		(10 / 10)	(14 / 17)
Nickel									
Concentration range	mg/kg	1 01 - 1 23	0 24 - 1 33	0 96 - 1 36	0 13 - 2 26	1 17 - 17 29	0 78	1 97 - 3 42	0 59
Concentration range (1991-1993)	mg/kg	(0 24 - 1 33)		(0 13 - 2 26)		(0 78 - 17 29)		NA	NA
Frequency of detection		(16 / 35)		(9 / 34)		(4 / 10)		(2 / 10)	(1 / 17)
Selenium									
Concentration range	mg/kg	c	0 044 - 0 047	c	0 040 - 0 207	c	0 093	c	c
Concentration range (1991-1993)	mg/kg	NA		NA		NA		NA	NA
Frequency of detection		(3 / 35)		(6 / 34)		(1 / 10)		(0 / 10)	(0 / 17)
Silver									
Concentration range	mg/kg	0 34 - 1 54	0 018 - 0 103	c	0 005 - 0 006	c	0 004 - 0 005	c	0 23
Concentration range (1991-1993)	mg/kg	(0 018 - 1 54)		NA		NA		NA	NA
Frequency of detection		(30 / 35)		(2 / 34)		(2 / 10)		(0 / 10)	(1 / 17)
Zinc									
Concentration range	mg/kg	20 2 - 38 8	24 6 - 83 3	17 3 - 98 0	12 3 - 23 76	78 5 - 133 7	29 6 - 92 1	22 7 - 44 2	2 3 - 16 0
Concentration range (1991-1993)	mg/kg	(20 2 - 83 3)		(12 3 - 98 0)		(29 6 - 92 1)		NA	NA
Frequency of detection		(35 / 35)		(34 / 34)		(10 / 10)		(10 / 10)	(15 / 17)

a Concentrations are reported on a wet weight basis
b Samples were not collected for 1993 study
c Compound was not detected in any sample
d Compound was not analyzed
NA Not Applicable

of this metal in 1993 was due to the lower detection limits achieved Antimony was not detected at the stations in both surveys except in one 1993 crayfish sample from Camas Slough (Table 5-27)

Antimony was not measured in USFWS-NCBP or EPA-NSCRF, so no comparison of antimony concentrations with national studies is possible However, limited data were available in STORET for biota sampled in the lower Columbia and the four major lower river tributaries. The geometric mean based on half the reported laboratory detection limit for values reported below detection is the most appropriate statistic for comparison of these data These geometric mean concentrations of antimony were 0.091, 0 110, and 0.054 mg/kg in the reconnaissance surveys, lower Columbia STORET data, and Willamette River STORET data, respectively (Table 5-28) Antimony was not detected in the single samples collected from the Cowlitz, Kalama, and Lewis rivers reported in STORET No reference levels are currently available for comparison with reconnaissance survey data

Arsenic--Arsenic was detected infrequently in tissue samples for the 1991 and 1993 surveys (Table 5-26). The highest concentrations were measured in white sturgeon sampled in 1991 (0.26 to 1.86 mg/kg), although relatively lower concentrations were also measured in one crayfish and one sucker sample analyzed in 1993 (0 036 and 0.385 mg/kg measured in samples collected from Scappoose Bay and Svensen Island, respectively) These measurements suggest that arsenic may occur at higher concentrations in sucker (0 385 mg/kg) than in crayfish (0 036 mg/kg) The detection of arsenic in fish for the 1993 study was likely due to the lower detection limits (0 033 to 0 046 mg/kg) compared to 1991 (0 24 to 0 64 mg/kg). Arsenic was not detected in any sample from the stations sampled in both years (Table 5-27)

Arsenic was measured in USFWS-NCBP in 1984; the geometric mean arsenic concentration in aquatic biota collected nationwide was 0.14 mg/kg (Table 5-28). Arsenic was detected in only nine percent of reconnaissance survey tissue samples, with a geometric mean concentration of 0.108 mg/kg, similar to that obtained in USFWS-NCBP Data on the arsenic content of biota in the lower and middle Columbia River and lower river tributaries were also available in STORET. The geometric mean concentrations of arsenic were 0.064, 0.380, and 0 078 mg/kg in the lower Columbia, middle Columbia, and Willamette rivers, respectively (Table 5-28). Arsenic was not detected in the single samples collected from the Cowlitz, Kalama, and Lewis rivers reported in STORET Overall, the concentrations of arsenic detected in biota collected for the reconnaissance surveys do not exceed typical background

TABLE 5-27 COMPARISON OF TISSUE METAL CONCENTRATIONS REPORTED FOR CARROLLS CHANNEL AND CAMAS SLOUGH 1991 AND 1993 LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS

	Carrolls Channel				Camas Slough			
	Crayfish		Largescale Sucker		Crayfish		Largescale Sucker	
	Station D20	Station 8	Station D20	Station 8	Station D35	Station 13	Station D35	Station 13
Metal	1991	1993	1991	1993	1991	1993	1991	1993
Antimony	4.05U	0.012U	0.32U	0.012U	1.78U	0.015	0.25U	0.012U
Arsenic	0.54U	0.035U	0.42U	0.037U	0.24U	0.036U	0.33U	0.035U
Barium	3.5	35.6	2.5	1.40	1.0	30.9	1.4	3.27
Cadmium	0.08	0.0004U	0.04	0.046	0.02	0.030	0.03	0.059
Chromium	NA	0.088	NA	0.080	NA	0.068	NA	0.389
Copper	27.0	14.9	1.04	0.73	26.17	19.4	0.91	1.19
Lead	0.03U	0.174	0.20	0.161	0.01	0.134	0.02U	0.285
Mercury	0.022	0.081	0.072	0.222	0.056	0.129	0.070	0.165
Nickel	0.95U	0.29	0.74U	0.10U	1.02	0.54	0.96	0.88
Selenium	0.54U	0.035U	0.42U	0.040	0.24U	0.036U	0.33U	0.035U
Silver	1.54	0.004U	0.19U	0.004U	0.61	0.041	0.15U	0.004U
Zinc	29.7	31.9	23.4	20.0	27.4	29.1	19.9	18.9

Values presented are mg/kg wet weight.

U = Not detected Value is the detection limit.
NA = Not analyzed.

TABLE 5-28 COMPARISON OF LOWER COLUMBIA RIVER RECONNAISSANCE SURVEY BIOTA CONTAMINANT LEVELS WITH THOSE MEASURED NATIONWIDE AND IN THE COLUMBIA RIVER AND TRIBUTARIES

Compound	Lower Columbia River[a] Reconnaissance Survey (1991 & 1993)			Lower Columbia River[a,b]			Middle Columbia River[a,b]			Columbia River Tributaries[a,b]												National Study of Chemical Residues in Fish[c] 1987-1989		National Contaminant Biomonitoring Program[d] 1984
										Cowlitz River			Kalama River			Lewis River			Willamette River					
	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Geometric Mean	Frequency of Detection	Median	Frequency of Detection	Geometric Mean
Metals [mg/kg (ppm) wet weight]																								
Antimony	(0.322)*	(0.061)*	6/105	0.115	0.110	2/2	–	–	–	(0.050)*	(0.025)*	0/1	(0.050)*	(0.025)*	0/1	(0.05)*	(0.025)*	0/1	0.070	0.054	4/6	–	–	–
Arsenic	(0.392)*	(0.108)*	9/103	0.100	0.064	3/6	0.250	0.380	14/15	(0.060)*	(0.030)*	0/1	(0.060)*	(0.030)*	0/1	(0.060)*	(0.030)*	0/1	0.150	0.078	31/52	–	–	0.14
Barium	1.91	1.62	89/105	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cadmium	0.039	0.034	81/105	0.040	0.034	13/17	0.030	0.024	14/15	0.080	0.086	3/3	0.030	0.030	1/1	0.03	0.03	1/1	(0.030)*	(0.016)*	24/64	–	–	0.03
Chromium	0.079	0.087	32/33	0.140	0.112	4/6	(0.030)*	(0.015)*	0/2	0.300	0.471	3/3	0.200	0.200	1/1	0.20	0.20	1/1	0.165	0.143	25/38	–	–	–
Copper	1.23	2.64	93/105	0.85	0.97	16/16	0.96	1.00	13/13	1.15	1.08	3/3	0.70	0.70	1/1	0.20	0.20	1/1	0.77	0.90	51/51	–	–	0.65
Lead	0.073	0.064	94/105	(0.100)*	(0.049)*	3/16	0.100	0.068	13/13	1.770	0.947	3/3	0.300	0.300	1/1	0.20	0.20	1/1	(0.100)*	(0.068)*	26/60	–	–	0.11
Mercury	0.071	0.067	99/105	0.120	0.109	23/24	0.080	0.077	19/19	0.030	0.024	2/3	0.010	0.010	1/1	0.36	0.36	1/1	0.120	0.127	63/68	0.170	345/374	0.10
Nickel	(0.74)*	(0.37)*	33/105	0.20	0.20	11/12	–	–	–	0.20	0.20	1/1	0.30	0.30	1/1	0.30	0.30	1/1	0.50	0.41	7/7	–	–	–
Selenium	(0.370)*	(0.107)*	10/103	0.185	0.178	11/12	0.270	0.437	11/11	(0.060)*	(0.030)*	0/1	0.060	(0.030)*	0/1	(0.060)*	(0.03)*	0/1	0.130	0.164	16/19	–	–	0.42
Silver	(0.191)*	(0.064)*	35/105	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Zinc	23.6	21.7	104/105	17.6	15.8	12/12	17.4	17.3	13/13	17.2	13.1	3/3	8.0	8.0	1/1	4.0	4.0	1/1	17.6	19.2	19/19	–	–	21.7
Semi-Volatile Organics [mg/kg (ppm) wet weight]																								
Bis(2-ethylhexyl)phthalate	0.260	0.191	56/106	–	–	–	–	–	–	0.200	0.200	1/1	0.200	0.200	1/1	0.100	0.100	1/1	0.130	0.389	7/9	–	–	–
Di-n-butylphthalate	(0.100)*	0.085	10/106	–	–	–	–	–	–	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(0.010)*	(0.014)*	0/9	–	–	–
Isophorone	(0.100)*	0.062	7/105	(0.020)*	0.031	6/15	–	–	–	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(0.030)*	(0.020)*	0/10	–	–	–
2-Methylnaphthalene	(0.100)*	(0.029)*	20/106	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Naphthalene	(0.100)*	(0.027)*	13/106	(0.020)*	(0.012)*	1/15	–	–	–	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(0.030)*	(0.014)*	0/51	–	–	–
Phenol	(0.100)*	0.063	6/106	–	–	–	–	–	–	(5.0)*	(2.5)*	0/1	(5.0)*	(2.5)*	0/1	(5.0)*	(2.5)*	0/1	(0.009)*	(0.024)*	0/8	–	–	–
1,2,4-Trichlorobenzene	(0.200)*	(0.092)*	1/106	(0.002)*	(0.001)*	0/15	(0.002)*	–	0/3	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(2.0)*	(1.0)*	0/1	(0.007)*	(0.006)*	1/13	0.00014	193/362	–
Pesticides and Herbicides [mg/kg (ppm) wet weight]																								
Aldrin	(0.003)*	(0.002)*	7/105	(0.010)*	(0.002)*	0/23	(0.002)*	(0.001)*	3/15	(0.001)*	(0.0005)*	0/5	(0.001)*	(0.0005)*	0/1	(0.001)*	(0.0005)*	0/1	(0.002)*	(0.001)*	19/106	–	–	–
Alpha-BHC	(0.003)*	(0.002)*	2/105	(0.010)*	(0.003)*	4/29	0.010	0.006	23/34	0.002	0.002	4/5	(0.001)*	(0.0005)*	0/1	(0.001)*	(0.0005)*	0/1	(0.002)*	–	32/138	0.00072	199/362	ND
Gamma-BHC (Lindane)	(0.003)*	(0.002)*	5/105	(0.010)*	(0.002)*	0/29	0.010	0.004	16/26	0.030	0.008	4/5	0.008	0.008	1/1	(0.001)*	(0.0005)*	0/1	(0.002)*	(0.002)*	28/132	ND	153/362	ND
Chlordane	(0.003)*	(0.002)*	0/105	(0.002)*	(0.001)*	0/8	(0.025)*	(0.013)*	0/9	0.004	0.005	5/5	(0.001)*	(0.0005)*	0/1	0.060	0.060	1/1	(0.010)*	(0.007)*	3/97	0.0037[e]	232/362	0.03[e]
o,p'-DDD	(0.004)*	(0.003)*	10/105	0.060	0.044	15/17	(0.001)*	(0.0005)*	0/2	–	–	–	–	–	–	–	–	–	(0.001)*	(0.004)*	21/47	–	–	–
o,p'-DDE	(0.005)*	(0.003)*	14/105	(0.010)*	(0.007)*	3/17	0.025	0.005	1/2	(0.0001)*	(0.00007)*	0/4	–	–	–	–	–	–	(0.007)*	(0.002)*	15/47	–	–	–
p,p'-DDD	0.007	0.006	47/105	0.080	0.083	23/23	0.135	0.074	10/10	0.001	0.002	4/5	(0.001)*	(0.0005)*	0/1	0.009	0.009	1/1	0.010	0.009	65/110	–	–	0.06
p,p'-DDE	0.023	0.018	77/105	0.110	0.085	25/29	0.625	0.320	13/14	0.030	0.009	4/5	(0.001)*	(0.0005)*	0/1	0.020	0.020	1/1	0.030	0.025	95/117	0.058	357/362	0.19
p,p'-DDT	0.005	0.004	45/105	0.030	0.022	16/23	0.010	0.008	7/11	0.004	0.005	5/5	(0.001)*	(0.0005)*	0/1	0.060	0.060	1/1	(0.010)*	(0.006)*	47/112	–	–	0.03
Dieldrin	(0.003)*	(0.002)*	8/105	0.010	0.005	16/29	0.010	0.006	36/48	(0.001)*	(0.0002)*	2/5	(0.001)*	(0.0005)*	0/1	0.001	0.001	1/1	(0.003)*	–	62/154	0.0042	218/362	0.04
Dicofol	(0.030)*	(0.019)*	0/106	(0.003)*	(0.002)*	0/6	(0.003)*	(0.002)*	0/3	–	–	–	–	–	–	–	–	–	(0.003)*	(0.002)*	1/5	ND	56/362	–
Endosulfan I	(0.003)*	(0.002)*	5/105	(0.010)*	(0.003)*	0/21	0.023	0.011	7/9	(0.001)*	(0.0005)*	0/1	(0.001)*	(0.0005)*	0/1	(0.001)*	(0.0005)*	0/1	(0.002)*	(0.002)*	7/80	–	–	–
Endrin	(0.003)*	(0.002)*	5/105	(0.010)*	(0.002)*	1/29	0.010	0.008	40/45	(0.0001)*	(0.00008)*	0/5	(0.001)*	(0.0005)*	0/1	(0.001)*	(0.0005)*	0/1	(0.003)*	–	46/151	ND	38/362	ND
Methoxychlor	(0.030)*	(0.018)*	6/105	(0.020)*	(0.008)*	0/21	(8.000)*	(0.557)*	0/12	(0.0008)*	(0.0002)*	0/4	–	–	–	–	–	–	(0.150)*	(0.075)*	8/67	ND	26/362	–
Methyl parathion	(0.010)*	(0.005)*	6/106	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Mirex	(0.003)*	(0.002)*	1/73	(0.010)*	(0.003)*	0/21	0.010	0.005	8/11	–	–	–	–	–	–	–	–	–	(0.010)*	(0.005)*	9/29	ND	137/362	ND
PCBs [mg/kg (ppm) wet weight]																								
Aroclor 1254	0.025	0.044	54/106	0.350	0.103	15/23	(0.025)*	(0.012)*	0/9	0.062	0.062	1/1	(0.010)*	(0.005)*	0/1	1.52	1.52	1/1	(0.025)*	(0.021)*	18/87	–	–	0.21
Aroclor 1260	0.025	0.036	16/106	0.025	0.058	11/23	(0.025)*	(0.016)*	0/11	(0.010)*	(0.005)*	0/1	(0.010)*	(0.005)*	0/1	(0.010)*	(0.005)*	0/1	0.050	0.047	47/92	–	–	0.15
Total PCB's	0.130	0.123	70/106	0.510	0.456	23/23	0.100	0.103	6/6	0.155	0.127	4/4	–	–	–	–	–	–	0.240	0.360	46/57	0.208	331/362	0.39
Dioxins and Furans [ng/kg (ppt) wet weight]																								
2,3,7,8-TCDD	0.70	0.49	42/77	1.75	1.63	12/14	0.50	1.24	5/9	–	–	–	–	–	–	–	–	–	2.25	0.50	9/9	1.38	273/388	–
1,2,3,7,8-PeCDD	0.66	0.39	26/77	0.93	0.58	7/14	(0.23)*	(0.03)*	3/9	–	–	–	–	–	–	–	–	–	1.56	0.36	6/9	0.93	206/385	–
1,2,3,4,7,8-HxCDD	0.37	0.23	31/77	(2.46)*	(1.19)*	0/14	(2.44)*	(0.05)*	0/9	–	–	–	–	–	–	–	–	–	(2.46)*	(0.25)*	3/9	1.24	121/375	–
1,2,3,6,7,8-HxCDD	0.50	0.34	32/77	0.85	0.72	8/14	(0.37)*	(0.04)*	2/9	–	–	–	–	–	–	–	–	–	1.84	0.61	6/9	1.32	258/375	–
1,2,3,7,8,9-HxCDD	0.38	0.22	25/77	(1.37)*	(0.54)*	2/14	(1.36)*	(0.004)*	0/9	–	–	–	–	–	–	–	–	–	(1.35)*	(0.22)*	4/9	0.69	142/375	–
1,2,3,4,6,7,8-HpCDD	1.04	0.86	55/77	1.78	1.54	10/14	0.33	0.54	5/9	–	–	–	–	–	–	–	–	–	2.47	0.90	7/9	2.83	315/354	–
OCDD	3.91	3.48	63/77	–	–	–	(0.005)*	(0.005)*	1/4	–	–	–	–	–	–	–	–	–	(0.005)*	(0.002)*	0/2	–	–	–
2,3,7,8-TCDF	4.31	4.80	76/77	18.94	16.88	14/14	41.78	31.87	5/5	–	–	–	–	–	–	–	–	–	3.35	4.71	7/7	2.97	347/388	–
1,2,3,7,8-PeCDF	0.38	0.36	47/77	(0.77)*	(0.39)*	6/14	(0.64)*	(0.04)*	2/9	–	–	–	–	–	–	–	–	–	(0.82)*	(0.24)*	4/9	0.45	183/387	–
2,3,4,7,8-PeCDF	0.49	0.35	40/77	0.63	0.42	8/14	0.85	0.96	4/5	–	–	–	–	–	–	–	–	–	2.19	1.62	6/7	0.75	249/387	–
1,2,3,4,7,8-HxCDF	0.30	0.22	26/77	(2.83)*	(1.33)*	1/14	(2.83)*	(1.66)*	1/5	–	–	–	–	–	–	–	–	–	2.83	1.99	6/7	1.42	159/379	–
1,2,3,7,8,9-HxCDF	0.40	0.26	30/77	(2.77)*	(1.38)*	0/14	(2.75)*	(0.06)*	0/9	–	–	–	–	–	–	–	–	–	(2.72)*	(0.33)*	1/9	1.38	5/379	–
1,2,3,6,7,8-HxCDF	0.50	0.20	27/77	(2.84)*	(1.42)*	0/14	(2.34)*	(1.42)*	0/5	–	–	–	–	–	–	–	–	–	(2.84)*	2.01	3/7	1.42	79/379	–
2,3,4,6,7,8-HxCDF	1.20	0.75	50/77	(1.96)*	(1.38)*	0/14	(1.96)*	(0.98)*	0/5	–	–	–	–	–	–	–	–	–	0.87	0.75	6/7	0.98	120/379	–
1,2,3,4,6,7,8-HpCDF	0.47	0.34	35/77	(1.44)*	(0.62)*	4/14	(1.44)*	(0.72)*	0/5	–	–	–	–	–	–	–	–	–	2.66	1.63	6/7	0.72	190/353	–
1,2,3,4,7,8,9-HpCDF	0.30	0.18	18/77	(2.61)*	(1.31)*	0/14	(2.61)*	(1.30)*	0/5	–	–	–	–	–	–	–	–	–	(2.61)*	(1.36)*	1/7	1.3	14/353	–
OCDF	0.60	0.42	33/77	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

[a] Geometric means were calculated using one-half the detection limit for samples where the analyte was not detected. Medians were calculated using the detection limit for samples where the analyte was not detected.

[b] Data derived from STORET database

[c] Source: U.S. EPA 1992d

[d] Source: Schmitt and Brumbaugh 1990, Schmitt et al. 1990

[e] Value indicated is for cis-Chlordane

* Indicates value at (for median) and below (for geometric mean) the laboratory detection limit.

ND = Median below the laboratory detection limit.

concentrations found nationwide No reference levels are currently available for comparison with reconnaissance survey data

Barium--Barium was detected in all species sampled for the two reconnaissance surveys, except white sturgeon (Table 5-26) This is likely due to the natural occurrence of barium in bone and connective tissue which comprised a significant portion of the whole body samples of crayfish, sucker, carp, and peamouth, but was excluded in the white sturgeon filet samples Barium concentrations in the fish samples were relatively similar and ranged from 0 34 to 4 2 mg/kg, except crayfish in the 1993 survey, which had a higher barium content, ranging from 8 5 to 47 2 mg/kg (Table 5-26)

The mean barium content of sucker was significantly lower (ANOVA, $P<0.05$) in 1993 than 1991, barium concentrations in crayfish were significantly higher (ANOVA, $P<0\ 001$) in 1993 than 1991 (Table 5-29) Combining the data for 1991 and 1993 resulted in significantly higher concentrations of barium in crayfish than other species sampled (Table 5-29) The difference in the mean barium concentration of crayfish analyzed for both surveys was quite different (29 8 vs 1 4 mg/kg). Possible reasons for such large differences include seasonal or temporal variation, and differences in sampling locations (backwater vs. mainstem). As the size and lipid content of the crayfish was similar between 1991 and 1993, these factors do not explain the differences observed

Barium concentrations in crayfish samples were more than 10 times higher in 1993 for the two stations sampled in both years For sucker samples, the relationship between 1991 and 1993 was not consistent at these stations (Table 5-27)

Barium was not measured in USFWS-NCBP or EPA-NSCRF, so no comparison of the barium concentrations with national studies is possible. Furthermore, no data on barium concentrations were available in STORET No reference levels are currently available for comparison with reconnaissance survey data.

Cadmium--Cadmium was detected in almost all of the tissue samples collected in both surveys. Although the concentrations of cadmium measured in the various species were generally similar (0.01 to 0 13 mg/kg)' the highest concentration was measured in a 1991 crayfish sample from RM 50 5 near Clatskanie (Table 5-26).

TABLE 5-29 ANALYSIS OF VARIANCE OF METALS CONCENTRATIONS IN CRAYFISH AND LARGESCALE SUCKER SAMPLED IN THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

	Number of Samples	mg/kg wet weight													
		Barium		Cadmium		Chromium		Copper		Lead		Mercury		Zinc	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1993-Crayfish	13	29.8	10.5	0.034	0.014	0.075	0.018	22.0	4.6	0.157	0.093	0.047	0.015	38.3	15.2
1993-Sucker	13	1.55	0.94	0.035	0.017	0.14	0.13	0.78	0.23	0.128	0.138	0.162	0.053	18.1	3.3
1991-Crayfish	18	1.43	0.72	0.072	0.025	n/m	-	30.1	7.8	0.021	0.012	0.034	0.021	26.8	4.5
1991-Sucker	18	2.73	1.04	0.038	0.013	n/m	-	0.99	0.17	0.179	0.201	0.081	0.033	29.8	24.9
1993+1991-Crayfish	31	13.3	15.7	0.056	0.028	-	-	26.7	7.7	0.078	0.091	0.039	0.020	31.6	11.7
1993+1991-Sucker	31	2.23	1.14	0.037	0.015	-	-	0.90	0.22	0.158	0.177	0.115	0.058	24.9	19.7
ANOVA Results (P-values)[a]															
1993-Crayfish vs Sucker		**9.20E-10**		0.93		0.11		**1.22E-14**		0.54		**7.62E-08**		**8.80E-05**	
1991-Crayfish vs Sucker		**1.16E-04**		**1.00E-05**		-		**2.96E-17**		**2.20E-03**		**1.40E-05**		0.61	
1993+1991-Crayfish vs Sucker		**2.28E-04**		**1.10E-03**		-		**1.23E-26**		**0.03**		**4.87E-09**		0.11	
1991 vs 1993-Crayfish		**2.40E-12**		**3.00E-05**		-		**0.0024**		**1.40E-06**		0.0711		**0.0046**	
1991 vs 1993-Largescale Sucker		**0.0030**		0.54		-		**0.0080**		0.4170		**1.04E-05**		0.1030	

SD = Standard deviation

n/m = Chromium was not measured in the aquatic biota samples collected in 1991

[a] Reported ANOVA results are the probability value that the null hypothesis (means are equal between two populations) is true
For P-values less than 0.05, the means are considered to be significantly different The significant P-values are shown in bold type

The cadmium content of 1993 crayfish samples was significantly lower (ANOVA, $P < 0.001$) than it was in 1991 (Table 5-29) There was no significant difference in cadmium concentrations in sucker samples between 1991 and 1993 (Table 5-29) The combined crayfish data for both years was significantly higher in cadmium (ANOVA, $P < 0.001$) than the combined sucker data (Table 5-29).

Cadmium concentrations in crayfish and sucker remained similar at the two stations sampled in both years, except for crayfish samples from Carrolls Channel (Table 5-27). In 1991, this concentration was 0 08 mg/kg in 1991, but in 1993 the concentration of cadmium was below the detection limit of 0 0004 mg/kg.

Cadmium was measured in biota samples collected for USFWS-NCBP The geometric mean cadmium concentration of these samples was 0 03 mg/kg Cadmium was detected in 77% of the samples collected for the reconnaissance surveys at a geometric mean concentration of 0.034 mg/kg. Cadmium was also detected frequently in STORET (Table 5-28). The geometric mean cadmium concentrations of samples collected in the lower and middle Columbia and reported in STORET were 0 034 mg/kg and 0 024 mg/kg respectively Geometric mean cadmium concentrations measured in lower river tributary biota samples were 0.016 and 0.200 mg/kg for the Willamette and Lewis Rivers, respectively Overall, cadmium concentrations detected in the reconnaissance surveys are similar to those measured in other reaches of the Columbia River and to concentrations measured nationwide No reference levels are currently available for comparison with reconnaissance survey data

Chromium--Chromium was not measured in 1991 tissue samples, so comparisons are limited to the three species collected in 1993 Chromium was detected in all samples except one carp sample (Table 5-26). Concentrations ranged from 0.032 to 0.527 mg/kg and the highest concentration was measured in a sucker sample from Camas Slough. The concentration of chromium in crayfish and sucker samples was not significantly different (ANOVA, $P > 0.05$) (Table 5-29).

Chromium was not measured in either USFWS-NCBP or EPA-NSCRF, so no comparison with national studies is possible. However, comparisons were made between STORET and the reconnaissance survey data. The geometric mean chromium concentration of STORET samples collected in the lower Columbia River was 0.112 mg/kg. For the Lewis this figure was 0.030 mg/kg, and for the Cowlitz it was 0.471 mg/kg. Chromium was not detected in the two samples collected in the middle Columbia River above a detection limit of 0.030 mg/kg. The geometric mean concentration of the reconnaissance survey data, 0.087 mg/kg, is within the geometric mean concentrations measured in other reaches of the Columbia (Table 5-28). No reference levels are currently available for comparison with reconnaissance survey data.

__Copper__--Copper was detected in all crayfish and fish samples except white sturgeon samples, for which it was detected in only 12% of the samples. Concentrations ranged from 0.70 to 46.40 mg/kg in 1991 and from 0.39 to 31.1 mg/kg in 1993. The concentrations measured in crayfish were much higher (14.90 to 46.40 mg/kg) than those measured in other species (Table 5-26). Crayfish contain naturally higher concentrations of copper due to the presence of the respiratory pigment hemocyanin, a large copper-containing protein that is used in the transport of oxygen in species of decapods and other crustaceans (Eckert and Randall 1978, Rainbow 1988; Van Hattum et al. 1991).

The copper concentration in crayfish was significantly lower (ANOVA, $P<0.05$) in 1993 than in 1991 (Table 5-29). The copper concentration in sucker was also significantly lower (ANOVA, $P<0.05$) in 1993 vs. 1991 (Table 5-29).

The copper content of crayfish was significantly higher (ANOVA, $P<0.001$) than that of sucker in 1991, 1993, and for combined 1991 and 1993 data (Table 5-29). The mean concentration of copper in crayfish sampled in 1991 and 1993 was 26.7 mg/kg and the mean concentration in largescale sucker was 0.90 mg/kg. As stated above, this difference is due to the presence of hemocyanin in crayfish.

The copper concentration in crayfish was slightly higher in 1991 at the two stations sampled in both years. For sucker the relationship was not consistent (Table 5-27).

Copper was measured in USFWS-NCBP, with a geometric mean concentration of 0.65 mg/kg. Copper was detected in 89% of the samples collected for the reconnaissance surveys at a geometric mean concentration of 2.64 mg/kg. Copper was also frequently reported in STORET (Table 5-28); geometric mean copper concentrations of 0.97 mg/kg and 1.00 mg/kg were reported for the lower and middle Columbia respectively. For the Lewis the figure was 0.002 mg/kg and for the Cowlitz, 1.075 mg/kg. The relatively high geometric mean copper concentration calculated for the reconnaissance survey data is likely due to the inclusion of crayfish, which have been shown to have elevated copper concentrations. No reference levels are currently available for comparison with reconnaissance survey data.

Lead--Lead was detected in 89% of the samples collected for the two reconnaissance surveys (Table 5-26). Concentrations ranged from 0.01 to 0.86 mg/kg in 1991 and from 0.048 to 0.376 mg/kg in 1993. Considerable variation in the measured lead concentrations can be seen both among the species sampled and for the same species sampled between 1991 and 1993.

The mean lead concentration measured in crayfish was significantly higher (ANOVA, $P<0.001$) in 1993 than in 1991 (Table 5-29). 0.157 mg/kg and 0.024 mg/kg respectively. The lead concentrations measured in sucker were not significantly different (ANOVA, $P>0.05$) between 1991 and 1993.

The concentrations of lead measured in crayfish vs. sucker were not significantly different in 1993, but were in 1991 (ANOVA, $P<0.001$) and for the combined data (ANOVA, $P<0.05$); the lead concentration of sucker was significantly higher than that of crayfish in these two data sets. The mean concentrations of lead in crayfish and sucker averaged 0.08 and 0.16 mg/kg, respectively, for the combined data.

Lead concentrations in 1993 crayfish and largescale sucker samples were generally higher than 1991 measurements at the two locations sampled both years (Table 5-27).

Lead was reported in USFWS-NCBP, with a geometric mean concentration of 0.11 mg/kg. Lead was also frequently reported in STORET (Table 5-28). The geometric mean lead concentration for the lower Columbia was 0.049 mg/kg and for the middle Columbia was 0.068 mg/kg. For the Willamette the figure was 0.068 mg/kg, and for the Cowlitz, 0.947 mg/kg. The geometric mean concentration for the reconnaissance surveys was 0.064 mg/kg, which is lower than the national figure and similar to that measured in other reaches of the Columbia. No reference levels are currently available for comparison with reconnaissance survey data.

Mercury--Mercury was detected frequently in all species sampled (Table 5-26). Detected concentrations ranged from 0.014 to 0.264 mg/kg. The concentration of mercury in crayfish was not significantly different (ANOVA, $P>0.05$) between 1991 and 1993 (Table 5-29). However, the mercury content of sucker was significantly higher (ANOVA, $P<0.001$) in 1993 than 1991 (Table 5-29). Mean mercury concentrations in sucker samples were 0.162 in 1993 and 0.081 mg/kg in 1991.

The mercury concentration of sucker samples was also significantly higher (ANOVA, $P < 0.001$) than that of crayfish samples in both years and for the combined data (Table 5-29). The combined average concentration of mercury in crayfish was 0 04 mg/kg and in sucker, 0 11 mg/kg

The mercury concentration in suckers was slightly higher in 1993 at the two stations sampled in both years For crayfish the relationship was not consistent (Table 5-27).

Mercury was reported in both USFWS-NCBP and EPA-NSCRF. The geometric mean concentration of mercury in USFWS-NCBP was 0.10 mg/kg, somewhat higher than the geometric mean of the reconnaissance survey, 0.067 mg/kg. The median mercury concentration reported in EPA-NSCRF was 0.170 mg/kg, also somewhat higher than the reconnaissance survey median of 0.071 mg/kg. Mercury was also frequently reported in STORET (Table 5-28) Geometric mean mercury concentrations were 0.109 mg/kg in the lower Columbia and 0.077 mg/kg in the middle Columbia. The geometric mean for the Kalama was 0.010 mg/kg, and for the Lewis 4 00 mg/kg.

Mercury criteria have not been promulgated for the protection of fish-eating wildlife. A reference value of 5.0 mg/kg has been proposed for the maximum concentration of mercury in fish tissue [brook trout (*Salvelinus fontinalis*)] (Eisler 1987). The derivation of this value was not provided and cannot be evaluated, so it will not be considered further.

Nickel--Nickel was detected more frequently in 1993 than in 1991. The difference may be attributed to the much lower detection limits achieved by the laboratory in 1993: 0.09 mg/kg as opposed to 0.43 mg/kg for 1991. Concentrations ranged from 0 13 to 17 29 mg/kg; the majority of the samples analyzed had concentrations below 2.0 mg/kg.

No consistent relationship was noted for nickel concentrations in crayfish and sucker samples at the two stations sampled in both years (Table 5-27)

Nickel was not measured in USFWS-NCBP or EPA-NSCRF, so no comparison of nickel concentrations with national studies is possible. However, nickel was reported in STORET, geometric means for samples collected from the lower Columbia (0.202 mg/kg), the Willamette (0.411 mg/kg), the Lewis (0.200 mg/kg), the Cowlitz (0.200 mg/kg), and the Kalama (0.300 mg/kg) are similar to the reconnaissance survey geometric mean of 0 369 mg/kg (Table 5-28). No reference levels are currently available for comparison with reconnaissance survey data

Selenium–Selenium was detected in 33% of 1993 samples (Table 4-19), with concentrations ranging from 0 040 to 0 207 mg/kg Selenium was not detected in 1991 samples, however, probably due to higher detection limits, which ranged from 0 033 to 0 046 mg/kg in 1993 compared to 0.24 to 0 64 mg/kg in 1991.

Selenium was not detected in crayfish or sucker samples at either of the stations sampled in both years, except for one Carrolls Channel sucker sample (Table 5-27)

Selenium was reported in USFWS-NCBP, with a geometric mean concentration of 0.42 mg/kg. Selenium was frequently reported in STORET (Table 5-28) The geometric mean selenium concentration of samples collected from the lower Columbia was 0 178 mg/kg and from the middle Columbia, 0.437 mg/kg For the Willamette, the figure was 0 164 mg/kg. Selenium was not detected in the single samples reported in STORET for the Cowlitz, Kalama, and Lewis Rivers. The geometric mean for the reconnaissance survey data was 0 107 mg/kg, lower than the geometric means of samples collected nationwide and from other reaches of the Columbia.

Selenium criteria have not been established for the protection of benthic aquatic life or piscivorous wildlife However, Lemly (1993) has suggested a biological effects threshold for the health and reproductive success of freshwater and anadromous fish of 4 mg/kg (whole-body, dry weight). No crayfish of fish samples were found to exceed this value. The highest selenium concentration measured was 0.207 mg/kg wet weight for a largescale sucker. Assuming a 25% solids value, the dry weight concentration would be 0.828 mg/kg, well below the suggested reference level.

Silver– Silver was detected infrequently in fish samples analyzed from both surveys Silver was detected in the majority of crayfish samples collected: 80% in 1991 and 93% in 1993. Although the frequency of detection for silver in crayfish samples was similar between the two surveys, the detected concentrations differed substantially Concentrations reported in 1991 ranged from 0.34 to 1.54 mg/kg compared to 0 018 to 0.103 mg/kg in 1993. Detection limits achieved for the 1993 survey were substantially lower than in 1991 and the concentrations detected in largescale sucker and carp in 1993 were below the lower limits of detection reported for the 1991 survey (Tables 4-19 and 5-26) Silver concentrations measured in sucker and carp samples ranged from 0 004 to 0 006 mg/kg

Silver in crayfish samples was higher in 1991 at the two stations sampled in both years. Silver was not detected in sucker samples for either year at these stations (Table 5-27).

Silver was not measured in USFWS-NCBP or EPA-NSCRF, so no comparison with national studies is possible. Silver was not reported in STORET. No reference levels are currently available for comparison with reconnaissance survey data.

Zinc--Zinc was detected in all tissue samples for both reconnaissance surveys. Concentrations ranged from 17.3 to 133 7 mg/kg in 1991 and from 12.3 to 92.1 mg/kg in 1993 For both surveys, the maximum concentration was measured in a carp sample.

The mean concentration of zinc measured in crayfish was significantly higher (ANOVA, $P<0.05$) in 1993 samples (38.3 mg/kg) than in 1991 samples (26.7 mg/kg). The concentrations of zinc measured in sucker samples were not significantly different between the two surveys (Table 5-29). Although zinc content was significantly greater in crayfish than in sucker in 1993 (ANOVA, $P<0$ 001), there were no significant differences in the zinc concentrations of the two species in 1991 and in the combined data

Zinc concentrations in crayfish and sucker were similar between 1991 and 1993 at the two stations sampled in both years (Table 5-27).

Zinc was reported in USFWS-NCBP, with a geometric mean concentration of 21.7 mg/kg. Zinc was also frequently reported in STORET (Table 5-28). The geometric mean zinc concentration of samples collected in the lower Columbia was 15.8 mg/kg; for the middle Columbia it was 17.3 mg/kg. The geometric mean concentration for the Lewis was 0.200 mg/kg, and for the Willamette, 19.2 mg/kg. These concentrations are similar to the geometric mean concentration of the reconnaissance survey data, 21.7 mg/kg. No reference levels are currently available for comparison with reconnaissance survey data.

5.3.2.2 Relationships Between Conventional Variables and Biota Metal Content. To determine if the conventional variables (average length, weight, and lipid content) measured for each composite biota sample could explain at least some of the variation of the metals concentrations measured in the same samples, simple correlation and linear regression analyses were performed No statistically significant ($P > 0.05$) relationships were found These results indicate that the observed variation in tissue metal content cannot be attributed to variation in the conventional variables measured. It is possible that the variability in conventional variables within a composite sample could have masked any significant relationship with metals concentrations Analysis of individual fish was not included in the study design, so a more precise determination of any possible correlation is not possible

The lack of a significant correlation should not be understood to imply that there is no relationship between whole-body tissue metal content of individual fish specimens and length or weight For example, Evans et al (1993) demonstrated the relationships between fish length and liver metal content and the importance of adjusting tissue metals data for covarying factors (such as length or lipid content) to reduce bias and increase the power of statistical testing for trends and differences among sampling sites

5.3.3 Semi-Volatile Organic Compounds

A total of 63 semi-volatile organic compounds, including phenols, halogenated ethers, nitroaromatics, polynuclear aromatic hydrocarbons (PAHs), chlorinated naphthalene and benzenes, benzidine, and phthalate esters, were analyzed in crayfish, largescale sucker, and carp samples for the 1993 backwater reconnaissance survey A total of 52 semi-volatile organic compounds within the same groups were analyzed in crayfish, largescale sucker, carp, peamouth, and white sturgeon samples for the 1991 reconnaissance survey. All concentrations are reported on a wet-weight basis. Some investigators have suggested that since many organic compounds tend to exhibit high lipid solubility, lipid-normalization of tissue organic contaminant content may reduce the variation in measured contaminant concentrations both within a species and among different species (Randall et al. 1991). Although survey data was too limited to determine whether concentrations of particular semi-volatile compounds correlated with lipid content, lipid-normalized concentrations (μg/g lipid) are also summarized below.

In general, semi-volatile organic compounds were detected infrequently in tissue samples collected in the two surveys The most frequently detected compounds were phenol, di-n-butyl phthalate, naphthalene, 2-methylnaphthalene, and bis(2-ethylhexyl)phthalate which were detected in 6, 10, 12, 19, and 47% of the samples analyzed, respectively (Table 5-30).

TABLE 5-30 SEMI-VOLATILE ORGANICS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993.[a]

(Page 1 of 3)

Compound	Units	Crayfish 1991 N=18	 1993 N=15	Largescale Sucker 1991 N=18	 1993 N=16	Carp 1991 N=9	 1993 N=2	Peamouth [b] 1991 N=10	White Sturgeon [b] 1991 N=18
Phenol									
Concentration range	µg/kg	c	100 - 690	c	c	5000	c	c	c
Concentration range (lipid norm.)	µg/g lipid	NA	10 8 - 69 0	NA	NA	220	NA	NA	NA
Frequency of detection		(5 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
2-Chlorophenol									
Concentration range	µg/kg	c	c	c	c	4200	c	c	c
Concentration range (lipid norm.)	µg/g lipid	NA	NA	NA	NA	185	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
4-Chloro-3-methylphenol									
Concentration range	µg/kg	c	c	c	c	5600	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	247	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
4-Nitrophenol									
Concentration range	µg/kg	c	c	c	c	4000	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	176	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
2,4-Dinitrotoluene									
Concentration range	µg/kg	c	c	c	c	1000	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	44	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
N-Nitrosodi-n-propylamine									
Concentration range	µg/kg	c	d	c	d	2900	d	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	128	NA	NA	NA
Frequency of detection		(0 / 18)		(0 / 18)		(1 / 9)		(0 / 10)	(0 / 18)
Acenaphthene									
Concentration range	µg/kg	c	7 3	c	c	3800	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	0 7	NA	NA	167	NA	NA	NA
Frequency of detection		(1 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)

TABLE 5-30 SEMI-VOLATILE ORGANICS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993 [a]

(Page 2 of 3)

		Crayfish		Largescale Sucker		Carp		Peamouth [b]	White Sturgeon [b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	**Units**	N=18	N=15	N=18	N=16	N=9	N=2	N=10	N=18
Fluorene									
Concentration range	µg/kg	c	5 3	c	c	c	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	0 5	NA	NA	NA	NA	NA	NA
Frequency of detection		(1 / 33)		(0 / 34)		(0 / 11)		(0 / 10)	(0 / 18)
Naphthalene									
Concentration range	µg/kg	c	9 5 - 57 0	c	6 6 - 13 0	220	c	c	c
Concentration range (lipid norm.)	µg/g lipid	NA	0 5 - 4 8	NA	0 1 - 0 3	5 5	NA	NA	NA
Frequency of detection		(7 / 33)		(5 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
Pyrene									
Concentration range	µg/kg	c	c	c	c	5200	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	229	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
2-Methylnaphthalene									
Concentration range	µg/kg	c	7 7 - 20 0	140	8 8 - 23 0	101 - 230	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	0 3 - 2 5	6 09	0 1 - 0 6	4 4 - 5 8	NA	NA	NA
Frequency of detection		(10 / 33)		(6 / 34)		(2 / 11)		(0 / 10)	(0 / 18)
Dibenzofuran									
Concentration range	µg/kg	d	3 6	d	c	d	c	d	d
Concentration range (lipid norm)	µg/g lipid	NA	0 4	NA	NA	NA	NA		
Frequency of detection		(1 / 15)		(0 / 16)		(0 /2)			
1,4-Dichlorobenzene									
Concentration range	µg/kg	c	c	c	c	1800	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	79	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
1,2,4-Trichlorobenzene									
Concentration range	µg/kg	c	c	c	c	3100	c	c	c
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	137	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)

TABLE 5-30 SEMI-VOLATILE ORGANICS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993 [a]

(Page 3 of 3)

		Crayfish		Largescale Sucker		Carp		Peamouth [b]	White Sturgeon [b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	**Units**	N=18	N=15	N=18	N=16	N=9	N=2	N=10	N=18
Di-n-butyl phthalate									
Concentration range	µg/kg	110	240	c	430	130 - 160	c	c	110 - 190
Concentration range (lipid norm.)	µg/g lipid	10	30	NA	12 6	4 6 - 4 9	NA	NA	2 0 - 38
Frequency of detection		(2 / 33)		(1 / 34)		(2 / 11)		(0 / 10)	(5 / 18)
Benzyl butyl phthalate									
Concentration range	µg/kg	c	c	c	c	c	c	c	990
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	NA	NA	NA	12
Frequency of detection		(0 / 33)		(0 / 34)		(0 / 11)		(0 / 10)	(1 /18)
Bis(2-ethylhexyl) phthalate									
Concentration range	µg/kg	110 - 3100	c	370 - 1100	400 - 760	450 - 1500	c	180 - 770	190 - 1500
Concentration range (lipid norm)	µg/g lipid	5 3 - 203	NA	17 - 36	4.8 - 11 5	8 1 - 44	NA	2 6 - 9 5	10 - 813
Frequency of detection		(13 / 33)		(10 / 34)		(8 / 11)		(9 / 10)	(10 / 18)
Isophorone									
Concentration range	µg/kg	110 - 430	c	c	c	c	c	c	c
Concentration range (lipid norm.)	µg/g lipid	6 7 - 22 0	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(7 / 33)		(0 / 34)		(0 / 11		(0 / 10)	(0 / 18)

[a] Concentrations are reported on a wet weight basis

[b] Samples were not collected for the 1993 study.

[c] Compound was not detected in any sample

[d] Compound was not analyzed.

NA: Not Applicable

As these compounds were detected infrequently, detailed comparisons of tissue concentrations among species and between the two surveys are not possible. Therefore, the 1991 and 1993 reconnaissance survey data are discussed below by compound groups (e.g., phenols). Where possible, differences in contaminant levels among the species sampled and between the two surveys will be discussed. Data from the two national studies used for comparison are also limited (Table 5-28). EPA-NSCRF measured a limited number of semi-volatile organic compounds in aquatic species, primarily chlorinated benzenes. Of the twelve semi-volatile organic compounds measured in the EPA-NSCRF, three were analyzed in the reconnaissance surveys, and none of these three was detected (Table 5-28).

STORET data on the concentration of semi-volatile compounds in biota sampled in the lower and middle reaches of the Columbia and in lower river tributaries were also relatively limited (Table 5-28). The concentrations of several of the semi-volatile compounds detected in the reconnaissance surveys were not reported or were below laboratory detection limits. Exceptions included the detection of naphthalene in 1 of 15 samples and isophorone in 6 of 15 samples collected from the lower Columbia, the detection of bis(2-ethylhexyl)phthalate in single samples collected from the Lewis, Kalama, and Cowlitz Rivers and in 7 of 9 samples collected from the Willamette River, and the detection of 1,2,4-trichlorobenzene in 1 of 13 samples collected from the Willamette (Table 5-28).

Reference levels for tissue concentrations of semi-volatile organic compounds were available for four compounds measured in the 1993 survey: hexachlorobutadiene, hexachlorobenzene, pentachlorophenol, and 1,2,4-trichlorobenzene (Table 2-8). These compounds were not detected in any sample.

5.3.3.1 ***Phenolic Compounds.*** Phenol was the only phenolic compound detected in 1993 samples (Table 5-30). Concentrations ranged from 100 to 690 μg/kg (10.8 to 69.0 μg/g lipid) and were detected in crayfish samples collected between RM 29 and RM 88 (Table 5-30). Four phenolic compounds (phenol, 2-chlorophenol, 4-chloro-3-methylphenol, and 4-nitrophenol) were detected in one carp sample collected in the 1991 survey from the Portland/Vancouver area near the mouth of the Willamette (RM 101). The concentration of phenol [5,000 μg/kg (220 μg/g lipid)] measured in this carp sample was higher than those measured in the crayfish samples collected from backwater areas in 1993 (Table 5-30).

Crayfish and largescale sucker samples were collected from Carrolls Channel and Camas Slough for both reconnaissance surveys However, no phenolic compounds were detected in tissue samples from these locations in either survey

5.3.3.2 ***Halogenated Ethers.*** Five halogenated ether compounds were analyzed in tissue samples for both surveys None of these compounds was detected.

5.3.3.3 ***Nitroaromatics.*** Only one nitroaromatic was detected 2,4-dinitrotoluene was detected in a carp sample collected in 1991 from RM 101, near the mouth of the Willamette River (Table 5-30)

5.3.3.4 ***Polynuclear Aromatic Hydrocarbons.*** Five PAHs (acenaphthene, fluorene, naphthalene, 2-methylnaphthalene, and dibenzofuran), with concentrations ranging from 3 6 to 57 0 μg/kg (0 4 to 4.8 μg/g lipid), were detected in the 1993 survey (Table 5-30). Four PAHs (acenaphthene, naphthalene, 2-methylnaphthalene, and pyrene), with concentrations ranging from 101 to 5,200 μg/kg (4.4 to 229 μg/g lipid), were detected in the 1991 survey (Table 5-30) All of the PAHs detected in 1991 were in carp samples, whereas no PAHs were detected in carp in 1993. The majority of the PAHs detected in 1993 were in crayfish samples. The detection limits achieved for PAHs in the 1993 survey were much lower than in 1991. 9.3 to 10 μg/kg compared to 100 to 400 μg/kg in 1991. No PAHs were detected at the sites sampled in both surveys.

5.3.3.5 ***Chlorinated Naphthalene and Chlorinated Benzenes.*** One chlorinated naphthalene compound and eight chlorinated benzene compounds were analyzed for the reconnaissance surveys (Table 5-30) The only detection was in one 1991 carp sample, which had detectable levels of 1,4-dichlorobenzene (1,800 μg/kg, 79 μg/g lipid) and 1,2,4-trichlorobenzene (3,100 μg/kg; 137 μg/g lipid) This sample was collected from RM 101, near the mouth of the Willamette River.

1,2,4-trichlorobenzene, hexachlorobenzene, and hexachlorobutadiene were detected in EPA-NSCRF (U.S. EPA 1992d). Hexachlorobenzene and hexachlorobutadiene were detected in less than 50% of the samples collected nationally, making the median concentrations of these compounds lower than the reported laboratory detection limits for their analysis These two compounds were not detected the reconnaissance surveys. The concentration of 1,2,4-trichlorobenzene (3,100 μg/kg) measured in a 1991 carp sample from RM 101 is 12 times higher than the maximum EPA-NSCRF value of 264.8 μg/kg and over

22,000 times higher than the EPA-NSCRF median concentration of this compound calculated from fish samples from 362 sites

Reference levels are not available for these compounds, except for a 1,300 μg/kg reference level for 1,2,4-trichlorobenzene, for the protection of piscivorous wildlife. The concentration of this compound in the 1991 carp sample from RM 101 exceeded this reference level

5.3.3.6 ***Benzidines.*** One benzidine compound, 3,3'-dichlorobenzidine, was analyzed in biota samples collected for both surveys This compound was not detected in any sample (Table 5-30).

5.3.3.7 ***Phthalate Esters.*** Six phthalate esters were analyzed in biota samples collected for the two surveys. Two of these compounds, di-n-butyl phthalate and bis(2-ethylhexyl)phthalate, were detected in the three species collected for both surveys (Table 5-30). The highest concentration of di-n-butyl phthalate (430 μg/kg) was measured in a 1993 sucker sample from Svensen Island. Bis(2-ethylhexyl)-phthalate was detected relatively frequently in tissue samples at concentrations ranging from 110 to 3,100 μg/kg (Table 5-30). The highest concentrations of bis(2-ethylhexyl)phthalate were measured in the 1991 survey, with the highest in a crayfish sample RM 92 5

5.3.4 Pesticides and PCBs

Twenty-six pesticides and six PCB Arochlor mixtures were analyzed in crayfish, largescale sucker, and carp samples for the 1993 survey Twenty-nine pesticides and seven PCB Arochlor mixtures were analyzed in crayfish, largescale sucker, carp, peamouth, and white sturgeon samples for the 1991 survey. DDT compounds (p,p'-DDT, p,p'-DDE, and p,p'-DDD) and PCB Arochlor mixtures were detected in both surveys. A number of additional pesticides were detected in the 1991 survey, including the o,p'-forms of DDT, DDD, and DDE, plus endrin, endosulfan II, endosulfan sulfate, methoxychlor, endrin aldehyde, parathion, methyl parathion, and mirex. All concentrations are reported on a wet-weight basis.

Findings were lipid-normalized, analysis indicated only one statistically significant linear relationship between tissue concentration of these compounds and percent lipid (crayfish p,p'-DDE content, $P=0.0193$). Lipid-normalized concentrations (μg/g lipid) are also summarized below.

The general pattern among species for p,p'-DDE concentration is shown in Figure 5-39 Concentrations tended to be highest in peamouth and lowest in crayfish, but did not appear to be directly related to lipid content Although lipid content may correlate with tissue burden of p,p'-DDE, other factors such as feeding habits (whole-sediment, detritus, or selective bottom feeding), and metabolism (uptake and excretion efficiencies) may also control the accumulation of this pesticide by different aquatic organisms.

Although a relatively large number of pesticides and PCBs were detected, individual compounds were detected infrequently in each species, precluding rigorous statistical comparisons among the species sampled and between sampling years. Where possible, such differences are discussed below

Both of the national include results of analyses for a number of pesticides and PCBs that were also analyzed in the reconnaissance surveys (Table 5-28). EPA-NSCRF measured alpha and gamma-BHC (lindane), gamma-chlordane, p,p'-DDE, dieldrin, dicofol, endrin, methoxychlor, mirex, and total PCBs. USFWS-NCBP measured the same pesticides (except dicofol and methoxychlor), plus p,p'-DDD and p,p'-DDT, and the PCB Arochlors 1254 and 1260 Data were also reported in STORET for all pesticides and PCBs detected in the reconnaissance surveys (Table 5-28).

Reference levels were available for tissue concentrations of the following compounds isomers of BHC (lindane), aldrin, chlordane, dieldrin, endrin, heptachlor, heptachlor epoxide, DDT compounds and metabolites, and total PCBs (Table 2-8). These reference levels are from the New York State guidelines for the protection of fish-eating wildlife and are discussed below where appropriate

5.3.4.1 ***Pesticides.*** Twenty-two pesticides were detected in the 1991 survey (3 0 to 91 μg/kg), compared to three pesticides detected in 1993 (2.4 to 180 μg/kg) (Table 5-31).

The pesticides p,p'-DDD, p,p'-DDE, and p,p'-DDT were detected in 50% of the 1991 samples and 67% of the 1993 samples (Table 5-31). Of the two isomers of DDT (o,p'-DDT and p,p'-DDT), p,p'-DDT is more toxic to both target and nontarget organisms (Murty 1986). No concentrations of o,p'-DDT or its degradation products were detected in 1993, but in 1991, o,p'-DDD and o,p'-DDE were detected in 42% of the sucker samples and 22% of the carp samples. p,p'-DDE was detected in a higher proportion of samples and at higher concentrations than the DDT and DDD isomers. A relatively higher detection frequency of p,p'-DDE was also noted by Schmitt et al. (1990) in USFWS-NCBP.

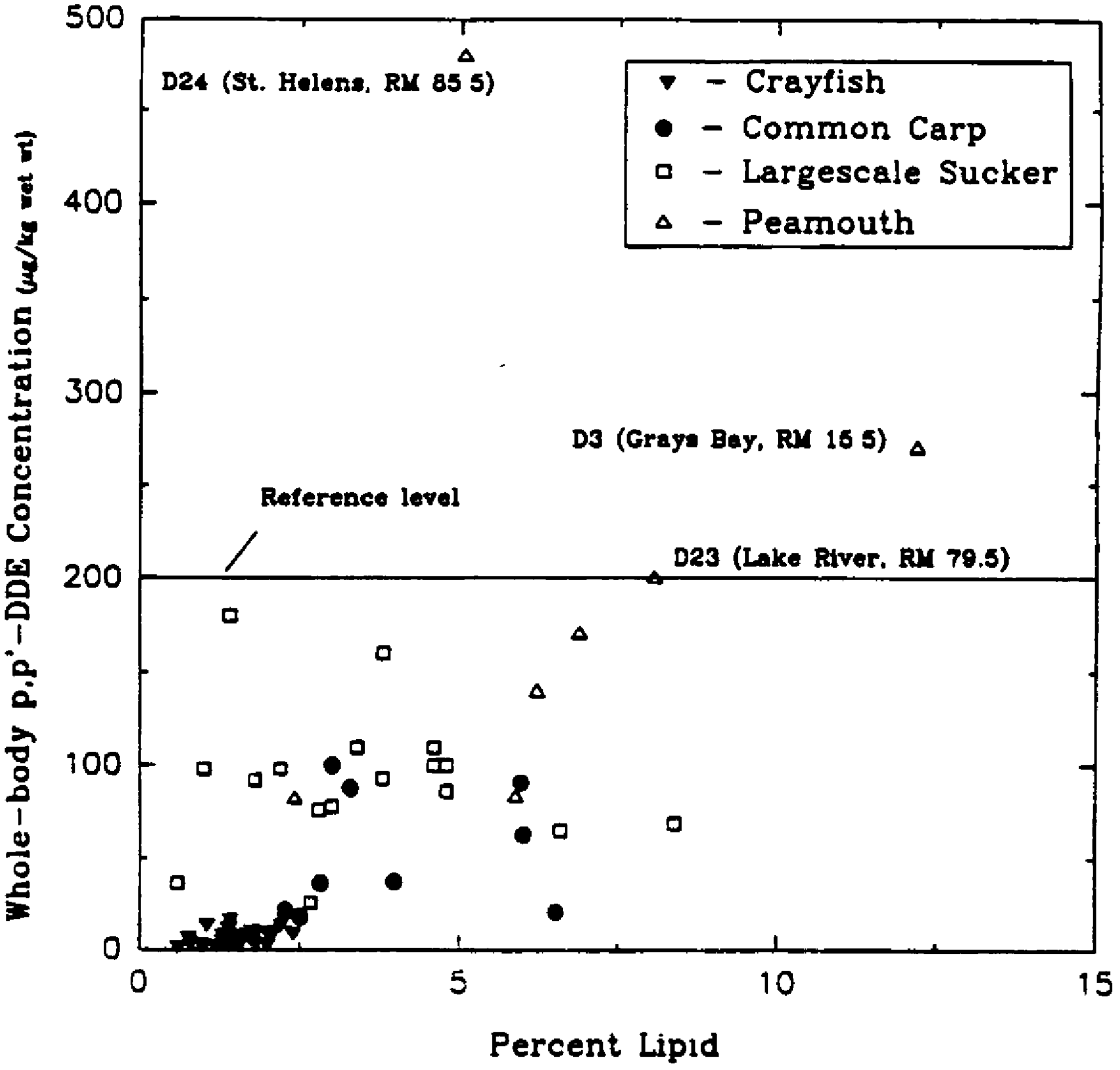


Figure 5-39. Scatterplot of Composite Sample Percent Lipid Content vs. Whole-Body Composite Sample p,p'-DDE Concentration. *Reference level is the New York State guideline (200 µg/kg) for the protection of fish-eating wildlife.*

TABLE 5-31. PESTICIDES DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993.[a]

(Page 1 of 4)

		Crayfish		Largescale Sucker		Carp		Peamouth [b]	White Sturgeon [i]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	Units	N=18	N=15	N=17	N=16	N=9	N=2	N=10	N=18
Alpha-BHC									
Concentration range	µg/kg	c	c	3.0 - 3.7	c	c	c	c	c
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.12 - 0.13	NA	NA	NA	NA	NA
Frequency of detection		(0 / 33)		(2 / 33)		(0 / 11)		(0 / 10)	(0 / 18)
Beta-BHC									
Concentration range	µg/kg	4.1 - 5.6	c	4.1	c	c	c	13 - 150	c
Concentration range (lipid norm.)	µg/g lipid	0.18 - 0.36	NA	0.17	NA	NA	NA	0.31 - 2.18	NA
Frequency of detection		(2 / 33)		(1 / 33)		(0 / 11)		(2 / 10)	(0 / 18)
Gamma-BHC (Lindane)									
Concentration range	µg/kg	c	c	3.1 - 7.7	c	3.5	c	14	c
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.10 - 0.32	NA	0.06	NA	0.24	NA
Frequency of detection		(0 / 33)		(3 / 33)		(1 / 11)		(1 / 10)	(0 / 18)
Heptachlor									
Concentration range	µg/kg	4.5	c	c	c	c	c	c	c
Concentration range (lipid norm.)	µg/g lipid	0.20	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(1 / 33)		(0 / 33)		(0 / 11)		(0 / 10)	(0 / 18)
Aldrin									
Concentration range	µg/kg	c	c	3.0 - 5.6	c	9.6	c	3.7 - 42	c
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.11 - 0.80	NA	0.42	NA	0.06 - 0.61	NA
Frequency of detection		(0 / 33)		(3 / 33)		(1 / 11)		(3 / 10)	(0 / 18)
Endosulfan I									
Concentration range	µg/kg	c	c	3.3	c	c	c	45 - 85	4.9
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.09	NA	NA	NA	0.37 - 1.05	0.07
Frequency of detection		(0 / 33)		(1 / 33)		(0 / 11)		(3 / 10)	(1 / 18)
Dieldrin									
Concentration range	µg/kg	6.6	c	4.5	c	3.6 - 5.6	c	32 - 35	3.0 - 12
Concentration range (lipid norm.)	µg/g lipid	0.47	NA	0.15	NA	0.09 - 0.11	NA	0.40 - 0.51	0.04 - 0.28
Frequency of detection		(1 / 33)		(1 / 33)		(2 / 11)		(2 / 10)	(5 / 18)

TABLE 5-31 PESTICIDES DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993 [a]

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Compound	Units	Crayfish		Largescale Sucker		Carp		Peamouth [b]	White Sturgeon [b]
		1991	1993	1991	1993	1991	1993	1991	1991
		N=18	N=15	N=17	N=16	N=9	N=2	N=10	N=18
p,p'-DDD									
Concentration range	µg/kg	9 6 - 9 9	c	5 6 - 26	9 4 - 47	3 5 - 23	20 - 21	38 - 72	6 5 - 11
Concentration range (lipid norm)	µg/g lipid	0 61 - 0 65	NA	0 21 - 1 03	0 2 - 2 2	0 07 - 0 39	0 30 - 0 70	0 61 - 0 89	0 15 - 0 47
Frequency of detection		(2 / 33)		(32 / 33)		(7 / 11)		(3 / 10)	(3 / 18)
p,p'-DDE									
Concentration range	µg/kg	3 3 - 17	2 4 - 14	26	37 - 180	18 - 91	63 - 100	82 - 480	3 9 - 51
Concentration range (lipid norm)	µg/g lipid	0 22 - 2 40	0 2 - 0 9	0 97	0 8 - 12 9	0 32 - 2 67	1.1 - 3 3	1 41 - 9 50	0 28 - 2 56
Frequency of detection		(30 / 33)		(17 / 33)		(9 / 11)		(7 / 10)	(15 / 18)
p,p'-DDT									
Concentration range	µg/kg	3 0	c	3 9 - 16	6 3 - 56	3 5 - 11	3 7 - 3 9	c	3 1 - 16
Concentration range (lipid norm)	µg/g lipid	0 17	NA	0 12 - 0 54	0 1 - 1 9	0 12 - 0 77	0 1	NA	0 05 - 0 89
Frequency of detection		(1 / 33)		(28 / 33)		(7 / 11)		(0 / 10)	(8 / 18)
o,p-DDD									
Concentration range	µg/kg	c	c	18 - 29	c	3 3	c	49	5 4 - 9 1
Concentration range (lipid norm)	µg/g lipid	NA	NA	0 78 - 1 07	NA	0 15	NA	0 40	0 10 - 0 30
Frequency of detection		(0 / 33)		(6 / 33)		(1 / 11)		(1 / 10)	(2 / 18)
o,p-DDE									
Concentration range	µg/kg	c	c	10 - 42	c	11 - 17	c	47	14
Concentration range (lipid norm)	µg/g lipid	NA	NA	0 44 - 1 80	NA	0 18 - 0 39	NA	0 39	0 33
Frequency of detection		(0 / 33)		(9 / 33)		(3 / 11)		(1 / 10)	(1 / 18)
o,p-DDT									
Concentration range	µg/kg	3 0	c	c	c	6 9	c	c	30
Concentration range (lipid norm)	µg/g lipid	0 29	NA	NA	NA	0 24	NA	NA	0 70
Frequency of detection		(1 / 33)		(0 / 33)		(1 / 11)		(0 / 10)	(1 / 18)
Endrin									
Concentration range	µg/kg	c	c	6 7 - 12	c	3 9	c	c	3 2 - 5 1
Concentration range (lipid norm)	µg/g lipid	NA	NA	0 28 - 0 54	NA	0 12	NA	NA	0 03 - 0 06
Frequency of detection		(0 / 33)		(2 / 33)		(1 / 11)		(0 / 10)	(2 / 18)

TABLE 5-31 PESTICIDES DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

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Compound	Units	Crayfish 1991 N=18	Crayfish 1993 N=15	Largescale Sucker 1991 N=17	Largescale Sucker 1993 N=16	Carp 1991 N=9	Carp 1993 N=2	Peamouth[b] 1991 N=10	White Sturgeon[b] 1991 N=18
Endosulfan II									
Concentration range	µg/kg	7.6	c	c	c	c	c	c	c
Concentration range (lipid norm.)	µg/g lipid	0.36	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(1 / 33)		(0 / 33)		(0 / 11)		(0 / 10)	(0 / 18)
Endosulfan sulfate									
Concentration range	µg/kg	c	c	3.5	c	c	c	c	5.5
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.15	NA	NA	NA	NA	0.06
Frequency of detection		(0 / 33)		(1 / 33)		(0 / 11)		(0 / 10)	(1 / 18)
Methoxychlor									
Concentration range	µg/kg	32 - 34	c	65	c	c	c	c	50 - 180
Concentration range (lipid norm.)	µg/g lipid	2.04 - 2.62	NA	2.21	NA	NA	NA	NA	0.70 - 4.20
Frequency of detection		(2 / 33)		(1 / 33)		(0 / 11)		(0 / 10)	(3 / 18)
Endrin aldehyde									
Concentration range	µg/kg	c	c	4.2	c	c	c	40	7.0 - 8.4
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.14	NA	NA	NA	0.58	0.08 - 0.09
Frequency of detection		(0 / 33)		(1 / 33)		(0 / 11)		(1 / 10)	(2 / 18)
Parathion									
Concentration range	µg/kg	c	d	7.5 - 15	d	c	d	26	c
Concentration range (lipid norm.)	µg/g lipid	NA	NA	0.21 - 1.09	NA	NA	NA	0.21	NA
Frequency of detection		(0 / 18)		(3 / 17)		(0 / 9)		(1 / 10)	(0 / 18)
Methyl parathion									
Concentration range	µg/kg	10 - 38	c	c	c	c	c	c	10 - 22
Concentration range (lipid norm.)	µg/g lipid	0.64 - 2.88	NA	NA	NA	NA	NA	NA	0.22 - 0.94
Frequency of detection		(3 / 33)		(0 / 34)[e]		(0 / 11)		(0 / 10)	(3 / 18)

TABLE 5-31 PESTICIDES DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

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		Crayfish		Largescale Sucker		Carp		Peamouth[b]	White Sturgeon[b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	**Units**	N=18	N=15	N=17	N=16	N=9	N=2	N=10	N=18
Mirex									
Concentration range	μg/kg	c	d	c	d	8 8	d	c	c
Concentration range (lipid norm)	μg/g lipid	NA	NA	NA	NA	0 15	NA	NA	NA
Frequency of detection		(0 / 18)		(0 / 17)		(1 / 9)		(0 / 10)	(0 / 18)

[a] Concentrations are reported on a wet weight basis.

[b] Samples were not collected for the 1993 study.

[c] Compound was not detected in any sample

[d] Compound was not analyzed.

[e] Eighteen largescale sucker samples were analyzed for methyl parathion in 1991

NA Not Applicable

Crayfish and sucker samples were collected from Carrolls Channel and Camas Slough for both surveys. Concentrations of DDT and its metabolites in crayfish and sucker were relatively similar between the two surveys at both locations. Higher detection limits in 1991 contributes to the variation in p,p'-DDE. p,p'-DDD was not measured in crayfish from Carrolls Channel or Camas Slough in either survey. The concentrations of p,p'-DDD detected in sucker from Carrolls Channel was 13 and 19 µg/kg (0.95 and 1.1 µg/g lipid) in 1991 and 1993, respectively. In 1991, the concentration of p,p'-DDD detected in sucker from Camas Slough was 8.5 µg/kg (0.37 µg/g lipid); in 1993 the concentration of this compound ranged from 21 to 31 µg/kg (0.9 to 2.2 µg/g lipid) in the three field replicate samples from Camas Slough.

Concentrations of p,p'-DDE in crayfish from Carrolls Channel were 11 and 2.8 µg/kg (0.63 and 0.3 µg/g lipid) for the 1991 and 1993 surveys, respectively. The concentration of p,p'-DDE in sucker sampled in 1991 was below the laboratory detection limit of 45 µg/kg; in 1993 a concentration of 92 µg/kg was measured. The 1991 concentration of p,p'-DDE in crayfish from Camas Slough was below the detection limit of 3 µg/kg; in 1993, concentrations ranged from 10 to 13 µg/kg in the three field replicate samples. The 1991 concentration of p,p'-DDE in suckers from Camas Slough was below the detection limit of 50 µg/kg; in 1993 the concentrations ranged from 78 to 180 µg/kg.

Concentrations of p,p'-DDT measured in crayfish from Carrolls Channel were 3.0 µg/kg and below the detection limit of 5 µg/kg for the 1991 and 1993 surveys, respectively. For suckers, the concentrations were 5.8 and 6.3 µg/kg (0.42 and 0.4 µg/g lipid) for 1991 and 1993, respectively. p,p'-DDT was not detected in crayfish sampled from Camas Slough in either survey. The 1991 concentration of p,p'-DDT in sucker from Camas Slough was 3.9 µg/kg (0.17 µg/g lipid); in 1993 the concentrations ranged from 7.5 to 27 µg/kg (0.3 to 1.9 µg/g lipid). Two additional pesticides were detected in a 1991 sample sucker sample from Camas Slough: endosulfan sulfate (3.5 µg/kg) and o,p'-DDD (18 µg/kg).

Median concentrations of p,p'-DDE for the 1993 survey were 5.0, 95.5, and 81.5 µg/kg for crayfish, sucker, and carp, respectively. The median concentrations for sucker and carp exceeded the median concentration of p,p'-DDE in EPA-NSCRF, which was 58.2 µg/kg (Table 5-28). However, the geometric mean concentration of the 1991 and 1993 reconnaissance survey, 18 µg/kg, was much lower than the geometric mean concentration from USFWS-NCBP (190 µg/kg) and the median concentration (23 µg/kg) was lower than the EPA-NSCRF median of 58 µg/kg (Table 5-28). The geometric mean concentration of DDT measured in the reconnaissance surveys was generally lower than the geometric mean of the STORET data

The relative proportions of DDT, DDE, and DDD in the reconnaissance surveys are consistent with proportions in various other studies In fish samples collected from the Po River (Italy), p,p'-DDE was the major constituent of DDT and its metabolites (Murty 1986) DDE was also the most frequently detected component of DDT in fish collected from the Smoky Hill River (Kansas), Lake Paijänne (Finland) (Murty 1986), and the lower Mississippi River (Leiker et al. 1991). For both reconnaissance surveys, DDE was the most frequently detected DDT component, followed by DDD and DDT (Table 5-31).

The State of New York is currently using fish flesh criteria, originally proposed by Newell et al. (1987), as guidelines for the protection of piscivorous wildlife. Reference levels have been proposed for the three pesticides p,p'-DDD, p,p'-DDE, and p,p'-DDT (Table 2-8) Of these three pesticides, p,p'-DDE was the only compound detected at concentrations exceeding the New York State guideline of 200 µg/kg. These exceedances were noted in three 1991 peamouth samples.

5.3.4.2 ***PCBs.*** Three Arochlor mixtures were detected in 1993 samples. Arochlor 1232, Arochlor 1254, and Arochlor 1260 (Table 5-32) Three Arochlors were detected in 1991 samples· Arochlor 1242, Arochlor 1254, and Arochlor 1260 (Table 5-32) Arochlors were not detected in any crayfish sample. Relatively higher concentrations of PCBs, ranging from 55 to 520 µg/kg (1.0 to 10.3 µg/g lipid), were measured in 1991 samples (Table 5-32) Concentrations in 1993 samples ranged from 26 to 170 µg/kg (0 5 to 5.7 µg/g lipid), with the exception of 2,700 µg/kg of Arochlor 1254 detected in a sucker sample from Scappoose Bay Total PCB concentrations in fish samples ranged from 55 to 520 µg/kg (1 0 to 10 3 ng/g lipid) in 1991 and 26 to 2,700 µg/kg (0.5 to 56.3 µg/g lipid) in 1993.

Arochlor compounds detected in sucker were relatively similar between 1991 and 1993 at the two stations sampled in both years. Concentrations of Arochlor 1254 detected in samples of sucker from Carrolls Channel were 130 and 55 µg/kg (9.5 and 3 1 µg/g lipid) for the 1991 and 1993 surveys, respectively; at Camas Slough, the concentrations were 55 µg/kg (2 4 µg/g lipid) in 1991 and ranged from 26 to 170 µg/kg (2.6 to 5.7 µg/g lipid) in the three replicate samples collected in 1993. Concentrations of Arochlor 1260 detected in samples from Carrolls Channel ranged from below detection (50 µg/kg) in

TABLE 5-32 PCBs DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

		Crayfish		Largescale Sucker		Carp		Peamouth[b]	White Sturgeon[b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	Units	N=18	N=15	N=18	N=16	N=9	N=2	N=10	N=18
Aroclor - 1016[c]									
Concentration range	µg/kg	d	d	d	d	d	d	d	d
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(0 / 11)		(0 / 10)	(0 / 18)
Aroclor - 1221									
Concentration range	µg/kg	d	d	d	d	d	d	d	d
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(0 / 11)		(0 / 10)	(0 / 18)
Aroclor - 1232									
Concentration range	µg/kg	d	d	d	d	d	30	d	d
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	NA	0 5	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(1 / 11)		(0 / 10)	(0 / 18)
Aroclor - 1242[c]									
Concentration range	µg/kg	d	d	d	d	d	d	78 - 99	d
Concentration range (lipid norm.)	µg/g lipid	NA	NA	NA	NA	NA	NA	0 8 - 3 2	NA
Frequency of detection		(0 / 33)		(0 / 34)		(0 / 11)		(2 / 10)	(0 / 18)
Aroclor - 1248									
Concentration range	µg/kg	d	d	d	d	d	d	d	d
Concentration range (lipid norm)	µg/g lipid	NA	NA	NA	NA	NA	NA	NA	NA
Frequency of detection		(0 / 33)		(0 / 34)		(0 / 11)		(0 / 10)	(0 / 18)
Aroclor - 1254									
Concentration range	µg/kg	d	d	55 - 380	26 - 2700	60 - 270	36 - 65	d	57 - 500
Concentration range (lipid norm)	µg/g lipid	NA	NA	2 2 - 10 6	0.5 - 56.3	1 5 - 9.6	1.1 - 1 2	NA	1 1 - 11 7
Frequency of detection		(0 / 33)		(33 / 34)		(7 / 11)		(0 / 10)	(4 / 18)
Aroclor - 1260									
Concentration range	µg/kg	d	d	130	31 - 56	62 - 110	30	80 - 520	d
Concentration range (lipid norm.)	µg/g lipid	NA	NA	3.5	0.6 - 4 0	1 0 - 2.8	0 5	2 0 - 10.3	NA
Frequency of detection		(0 / 33)		(10 / 34)		(5 / 11)		(10 / 10)	(0 / 18)

[a] Concentrations are reported on a wet weight basis.

[b] Samples were not collected for the 1993 study.

[c] Analyses conducted in 1993 could not distinguish between Aroclor 1242 and Aroclor 1016

[d] Comp[illegible] was not detected in any sample

NA N[illegible]pplicable

1991 and 31 µg/kg (1.7 µg/kg lipid) in 1993, at Camas Slough, concentrations were below detection (50 µg/kg) in 1991 and ranged from 37 to 56 µg/kg (1.2-4.0 µg/kg lipid) in the three field replicate samples analyzed in 1993.

The geometric mean concentrations of Arochlors 1254 and 1260 reported by USFWS-NCBP for fish collected in 1984 were 210 and 150 µg/kg, respectively (Table 5-28). The geometric mean concentrations of Arochlor 1254 (44 µg/kg) and Arochlor 1260 (36 µg/kg) in the reconnaissance surveys were approximately five times lower than the geometric mean of data obtained from the national study (Table 5-28).

EPA-NSCRF, which measured total PCB concentrations in fish tissues collected throughout the United States, obtained a median concentration of 208 µg/kg and a maximum concentration of 1,242 µg/kg (detected in a white sucker sample collected from the Hudson River, New York) (U.S. EPA 1992d). The results obtained from the reconnaissance surveys are comparable to the U.S. EPA study (median=130 µg/kg), except for the 1993 sucker sample from Scappoose Bay with a concentration of Arochlor 1254 of 2,700 µg/kg (Table 5-28).

The State of New York is currently using fish flesh criteria, originally proposed by Newell et al. (1987), as guidelines for the protection of piscivorous wildlife. Reference levels have not been proposed for individual Arochlor mixtures but levels have been proposed for total PCBs (the summation of all Arochlor compounds detected). The current guideline for total PCBs, 110 µg/kg, was exceeded at 18 stations in 1991 and 5 stations in 1993. Exceedances occurred in samples collected throughout the study area and the frequency of exceedance was highest in the largescale sucker samples.

5.3.5 Dioxins and Furans

Seven dioxin and ten furan congeners were analyzed in crayfish, sucker, and carp samples for both reconnaissance surveys. These congeners were also analyzed in peamouth and white sturgeon samples collected in the 1991 survey. All concentrations are reported on a wet-weight basis.

Dioxins and furans were generally detected at higher concentrations and with greater frequency in 1991 samples. For example, concentrations of the most toxic congener (2,3,7,8-TCDD) in 1991 suckers ranged from 0.49 to 1.56 ng/kg (0.019-0.055 ng/g lipid), compared to 0.7 to 0.9 ng/kg (0.01 to

0 07 ng/g lipid) in 1993 (Table 5-33). Concentrations of 2,3,7,8-TCDF were also generally higher in 1991 (Table 5-33). The highest concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF were measured in peamouth sampled in 1991 [4 41 and 58.8 ng/kg, respectively, at Station D24 (RM 85.5) in St. Helens]. However, concentrations of two furan congeners, 1,2,3,7,8-PeCDF and 1,2,3,7,8,9-HxCDF, were considerably higher in 1993 sucker samples (Table 5-33).

The six dioxin congeners other than 2,3,7,8-TCDD were detected in 56% of the crayfish samples in 1991 compared to 5% in 1993 The ten furan congeners were detected in 56% of the crayfish samples in 1991 compared to 11% in 1993 Dioxin and furan detections were widely distributed throughout the study area, with greater frequency in sucker samples. Individual congeners were detected in all sucker samples in 1991 and 40% of the samples in 1993 The pattern of detection of individual congeners in crayfish, largescale sucker, and carp varied between the two surveys, except for OCDD and 2,3,7,8-TCDF, which had relatively similar frequency and concentration patterns in the two surveys.

Toxicity equivalency concentrations (TEcs) were calculated for survey results to provide an overall measure of dioxins and furans. In the 1993 survey, carp had the highest median TEC, 1 74 ng/kg, followed by sucker with 1 71 ng/kg, and crayfish with 0.82 ng/kg. These results are similar to the corresponding TECs obtained from the 1991 survey data, although the 1991 TECs were somewhat higher. The highest median TEC in 1991 was for peamouth (2 7 ng/kg)

The concentrations of dioxins and furans in crayfish and sucker samples from the two stations sampled in both surveys was generally lower in 1993, except for a few furan congeners. One-half the detection limit was used as the value for compounds reported as below detection) The TEC for crayfish from Carrolls Channel was 1.3 ng/kg in 1991 and 0 49 ng/kg in 1993. In crayfish from Camas Slough the TEC was 1 6 ng/kg in 1991 and ranged from 0.53 to 1.6 ng/kg in the three 1993 field replicate samples. The TEC in sucker collected from Carrolls Channel was 1.5 ng/kg in 1991 and 0.92 ng/kg in 1993. In sucker from Camas Slough the TEC was 2.0 ng/kg in 1991 and ranged from 1.0 to 2.5 ng/kg in the three 1993 field replicate samples.

Evaluation of dioxin and furan data indicated only one statistically significant relationship between tissue furan concentration and percent lipid (crayfish 2,3,7,8-TCDF content, $P=0.0057$). Lipid-normalized concentrations (ng/g lipid) are also summarized below

TABLE 5-33 DIOXINS AND FURANS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

(Page 1 of 3)

		Crayfish		Largescale Sucker		Carp		Peamouth[b]	White Sturgeon[b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	Units	N=12	N=15	N=12	N=16	N=5	N=2	N=7	N=8
DIOXINS									
2,3,7,8-TCDD									
Concentration range	ng/kg	0.27 - 0.86	0.7 - 1.0	0.49 - 1.56	0.7 - 0.9	1.28 - 2.1	c	1.44 - 4.41	1.66
Concentration range (lipid norm.)	ng/g lipid	0.018 - 0.041	0.03 - 0.10	0.019 - 0.055	0.01 - 0.07	0.025 - 0.085	NA	0.024 - 0.087	0.017
Frequency of detection		(15 / 27)		(14 / 28)		(5 / 7)		(7 / 7)	(1 / 8)
1,2,3,7,8-PeCDD									
Concentration range	ng/kg	0.48	c	0.40 - 1.1	0.5	0.84 - 1.89	c	0.31 - 2.04	c
Concentration range (lipid norm.)	ng/g lipid	0.036	NA	0.013 - 0.030	0.05	0.024 - 0.061	NA	0.005 - 0.040	NA
Frequency of detection		(1 / 27)		(13 / 28)		(5 / 7)		(7 / 7)	(0 / 8)
1,2,3,4,7,8-HxCDD									
Concentration range	ng/kg	0.15 - 0.39	c	0.13 - 0.53	0.3 - 0.5	0.26 - 1.45	0.3	0.11 - 0.87	c
Concentration range (lipid norm.)	ng/g lipid	0.006 - 0.030	NA	0.005 - 0.015	0.01 - 0.13	0.006 - 0.041	0.02	0.002 - 0.017	NA
Frequency of detection		(3 / 27)		(15 / 28)		(6 / 7)		(7 / 7)	(0 / 8)
1,2,3,6,7,8-HxCDD									
Concentration range	ng/kg	0.31 - 0.89	c	0.33 - 1.42	0.5 - 0.6	0.73 - 4.82	0.6	0.31 - 1.16	c
Concentration range (lipid norm.)	ng/g lipid	0.012 - 0.068	NA	0.008 - 0.039	0.01 - 0.02	0.028 - 0.078	0.01	0.007 - 0.024	NA
Frequency of detection		(5 / 27)		(14 / 28)		(6 / 7)		(7 / 7)	(0 / 8)
1,2,3,7,8,9-HxCDD									
Concentration range	ng/kg	0.15 - 0.76	c	0.11 - 0.92	c	0.12 - 0.50	c	0.12 - 0.29	c
Concentration range (lipid norm.)	ng/g lipid	0.014 - 0.058	NA	0.005 - 0.025	NA	0.004 - 0.008	NA	0.002 - 0.009	NA
Frequency of detection		(3 / 27)		(12 / 28)		(4 / 7)		(6 / 7)	(0 / 8)
1,2,3,4,6,7,8-HpCDD									
Concentration range	ng/kg	0.42 - 5.21	c	1.04 - 4.36	0.4 - 3.8	1.59 - 9.81	1.2 - 3.8	0.24 - 2.81	0.35 - 0.50
Concentration range (lipid norm.)	ng/g lipid	0.027 - 0.308	NA	0.045 - 0.125	0.01 - 0.13	0.064 - 0.328	0.04 - 0.06	0.003 - 0.076	0.005 - 0.028
Frequency of detection		(11 / 27)		(28 / 28)		(7 / 7)		(7 / 7)	(2 / 8)
OCDD									
Concentration range	ng/kg	1.62 - 79.1	6.7 - 23.7	0.79 - 21.3	1.5 - 36.9	2.71 - 30.6	3.9 - 7.5	3.62 - 18.1	0.25 - 3.61
Concentration range (lipid norm.)	ng/g lipid	0.072 - 3.066	0.8 - 4.0	0.021 - 1.00	0.06 - 1.09	0.109 - 1.055	0.13	0.048 - 0.358	0.004 - 1.388
Frequency of detection		(14 / 27)		(28 / 28)		(7 / 7)		(7 / 7)	(7 / 8)

TABLE 5-33 DIOXINS AND FURANS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

(Page 2 of 3)

		Crayfish		Largescale Sucker		Carp		Peamouth[b]	White Sturgeon[b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	Units	N=12	N=15	N=12	N=16	N=5	N=2	N=7	N=8
FURANS									
2,3,7,8-TCDF									
Concentration range	ng/kg	4.10 - 12.4	0.63 - 2.62	2.46 - 11.4	1.6 - 6.5	4.37 - 12.2	3.6 - 3.9	22.2 - 58.8	1.54 - 22.8
Concentration range (lipid norm.)	ng/g lipid	0.215 - 0.579	0.05 - 0.20	0.150 - 0.368	0.04 - 0.34	0.070 - 0.507	0.06 - 0.13	0.377 - 1.343	0.077 - 2.914
Frequency of detection		(27 / 27)		(27 / 28)		(7 / 7)		(7 / 7)	(8 / 8)
1,2,3,7,8-PeCDF									
Concentration range	ng/kg	0.11 - 1.02	c	0.14 - 0.49	0.3 - 9.9	0.21 - 0.76	2.3 - 3.9	0.24 - 0.86	0.73
Concentration range (lipid norm.)	ng/g lipid	0.006 - 0.052	NA	0.004 - 0.014	0.02 - 0.22	0.006 - 0.014	0.04 - 0.13	0.004 - 0.017	0.008
Frequency of detection		(8 / 27)		(24 / 28)		(7 / 7)		(7 / 7)	(1 / 8)
2,3,4,7,8-PeCDF									
Concentration range	ng/kg	0.20 - 3.05	c	0.31 - 1.21	1.0 - 1.8	0.46 - 1.37	0.2	0.55 - 2.46	0.49
Concentration range (lipid norm.)	ng/g lipid	0.011 - 0.127	NA	0.012 - 0.033	0.17 - 0.18	0.014 - 0.047	0.01	0.009 - 0.049	0.005
Frequency of detection		(12 / 27)		(14 / 28)		(6 / 7)		(7 / 7)	(1 / 8)
1,2,3,4,7,8-HxCDF									
Concentration range	ng/kg	0.21 - 0.36	c	0.08 - 0.45	c	0.12 - 0.66	c	0.12 - 0.56	c
Concentration range (lipid norm.)	ng/g lipid	0.011 - 0.028	NA	0.002 - 0.013	NA	0.003 - 0.018	NA	0.002 - 0.011	NA
Frequency of detection		(4 / 27)		(12 / 28)		(5 / 7)		(5 / 7)	(0 / 8)
1,2,3,6,7,8-HxCDF									
Concentration range	ng/kg	0.18 - 0.32	c	0.09 - 0.36	5.2	0.09 - 0.57	c	0.05 - 0.44	c
Concentration range (lipid norm.)	ng/g lipid	0.010 - 0.025	NA	0.004 - 0.011	0.11	0.002 - 0.014	NA	0.001 - 0.009	NA
Frequency of detection		(4 / 27)		(13 / 28)		(5 / 7)		(5 / 7)	(0 / 8)
1,2,3,7,8,9-HxCDF									
Concentration range	ng/kg	0.13 - 0.23	c	0.09 - 0.60	0.8 - 4.5	0.05	2.3 - 2.5	c	c
Concentration range (lipid norm.)	ng/g lipid	0.010 - 0.018	NA	0.004 - 0.017	0.02 - 0.20	0.003	0.04 - 0.08	NA	NA
Frequency of detection		(2 / 27)		(27 / 28)		(3 / 7)		(0 / 7)	(0 / 8)
2,3,4,6,7,8-HxCDF									
Concentration range	ng/kg	0.21 - 7.26	c	0.40 - 2.77	0.3 - 5.2	0.26 - 5.7	0.7 - 1.0	0.23 - 0.32	c
Concentration range (lipid norm.)	ng/g lipid	0.012 - 0.281	NA	0.018 - 0.083	0.01 - 0.11	0.006 - 0.121	0.02	0.004 - 0.013	NA
Frequency of detection		(11 / 27)		(25 / 28)		(7 / 7)		(5 / 7)	(0 / 8)

TABLE 5-33 DIOXINS AND FURANS DETECTED IN FIVE SPECIES COLLECTED FOR THE LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993[a]

(Page 3 of 3)

		Crayfish		Largescale Sucker		Carp		Peamouth[b]	White Sturgeon[b]
		1991	1993	1991	1993	1991	1993	1991	1991
Compound	Units	N=12	N=15	N=12	N=16	N=5	N=2	N=7	N=8
1,2,3,4,6,7,8-HpCDF									
Concentration range	ng/kg	0.27 - 0.70	5.2	0.23 - 1.79	0.4 - 5.5	0.18 - 1.31	c	0.16 - 0.74	c
Concentration range (lipid norm.)	ng/g lipid	0.012 - 0.054	0.4	0.008 - 0.055	0.01 - 0.40	0.004 - 0.045	NA	0.003 - 0.018	NA
Frequency of detection		(8 / 27)		(16 / 28)		(5 / 7)		(6 / 7)	(0 / 8)
1,2,3,4,7,8,9-HpCDF									
Concentration range	ng/kg	0.19	c	0.06 - 0.43	c	0.12	c	0.04 - 0.18	c
Concentration range (lipid norm.)	ng/g lipid	0.015	NA	0.003 - 0.012	NA	0.003	NA	0.001 - 0.007	NA
Frequency of detection		(1 / 27)		(12 / 28)		(1 / 7)		(4 / 7)	(0 / 8)
OCDF									
Concentration range	ng/kg	0.42 - 1.24	c	0.30 - 10.6	0.3 - 2.7	0.84 - 2.45	c	0.31 - 2.03	c
Concentration range (lipid norm.)	ng/g lipid	0.023 - 0.048	NA	0.013 - 0.284	0.01 - 0.20	0.014 - 0.084	NA	0.006 - 0.042	NA
Frequency of detection		(6 / 27)		(18 / 28)		(3 / 7)		(6 / 7)	(0 / 8)
TEC									
Concentration range	ng/kg	1.1 - 3.8	0.3 - 3.2	1.5 - 3.8	0.9 - 3.1	2.9 - 5.2	1.4 - 2.1	4.2 - 13.3	1.8 - 5.6

[a] Concentrations are reported on a wet weight wet basis.

[b] Samples were not collected for the 1993 study

[c] Compound was not detected in any sample

NA: Not Applicable

The general pattern among species of 2,3,7,8-TCDF concentrations is shown in Figure 5-40 Relatively high concentrations were measured in crayfish, carp, and sucker, and lower concentrations were measured in peamouth, the concentrations did not appear to be directly related to lipid content Although lipid content may correlate weakly with the tissue burden of 2,3,7,8-TCDF, other factors such as feeding habits (whole-sediment, detritus, or selective bottom feeding), and metabolism (uptake and excretion efficiencies) may also control the accumulation of this compound by different aquatic organisms. To illustrate how these factors might vary by species and congener, percent lipid vs whole-body tissue burdens of 2,3,7,8-TCDD and OCDD are presented in Figures 5-41 and 5-42 The concentration of 2,3,7,8-TCDD is higher in peamouth than in the other species, while the concentration of OCDD is relatively similar across species, except for the high concentration in one crayfish sample

The median concentration of 2,3,7,8-TCDD in EPA-NSCRF is 1.38 ng/kg, which is higher than the reconnaissance survey median of 0.70 ng/kg (Table 5-28). However, the reconnaissance survey median concentration of 2,3,7,8-TCDF (4.81 ng/kg) is higher than the EPA-NSCRF median of 2.97 ng/kg. The available data in STORET (primarily from EPA-NSCRF) generally reported higher concentrations of dioxins and furans in the lower and middle reaches of the Columbia and Willamette rivers than were measured in the reconnaissance surveys. The higher concentrations reported for the lower Columbia may be due to the proximity of EPA-NSCRF sampling stations to known sources of dioxins and furans (e.g , municipal wastewater treatment plants and pulp and paper mills)

The State of New York is currently using fish flesh criteria, originally proposed by Newell et al (1987), as guidelines for the protection of piscivorous wildlife. Reference levels have not been proposed for individual dioxin congeners (except 2,3,7,8-TCDD), but a level has been proposed for TECs The current guideline for dioxin TEC, 3 0 ng/kg, was exceeded at 11 stations in 1991 reconnaissance survey and 2 stations in 1993. The relationship between tissue lipid content and TEC is shown in Figure 5-43 Exceedances occurred in samples collected throughout the study area. Several species exceeded the reference value at Longview (RM 63) and at the Lake Vancouver flushing channel (RM 98).

5.3.6 Butyltin Compounds

Butyltin compounds comprise a small subset of organotin compounds. These compounds enter the aquatic environment through use as active biocides contained in antifouling paints. Butyltins, particularly tributyltin, exhibit sufficient toxicity and potential for bioaccumulation to be of interest when evaluating

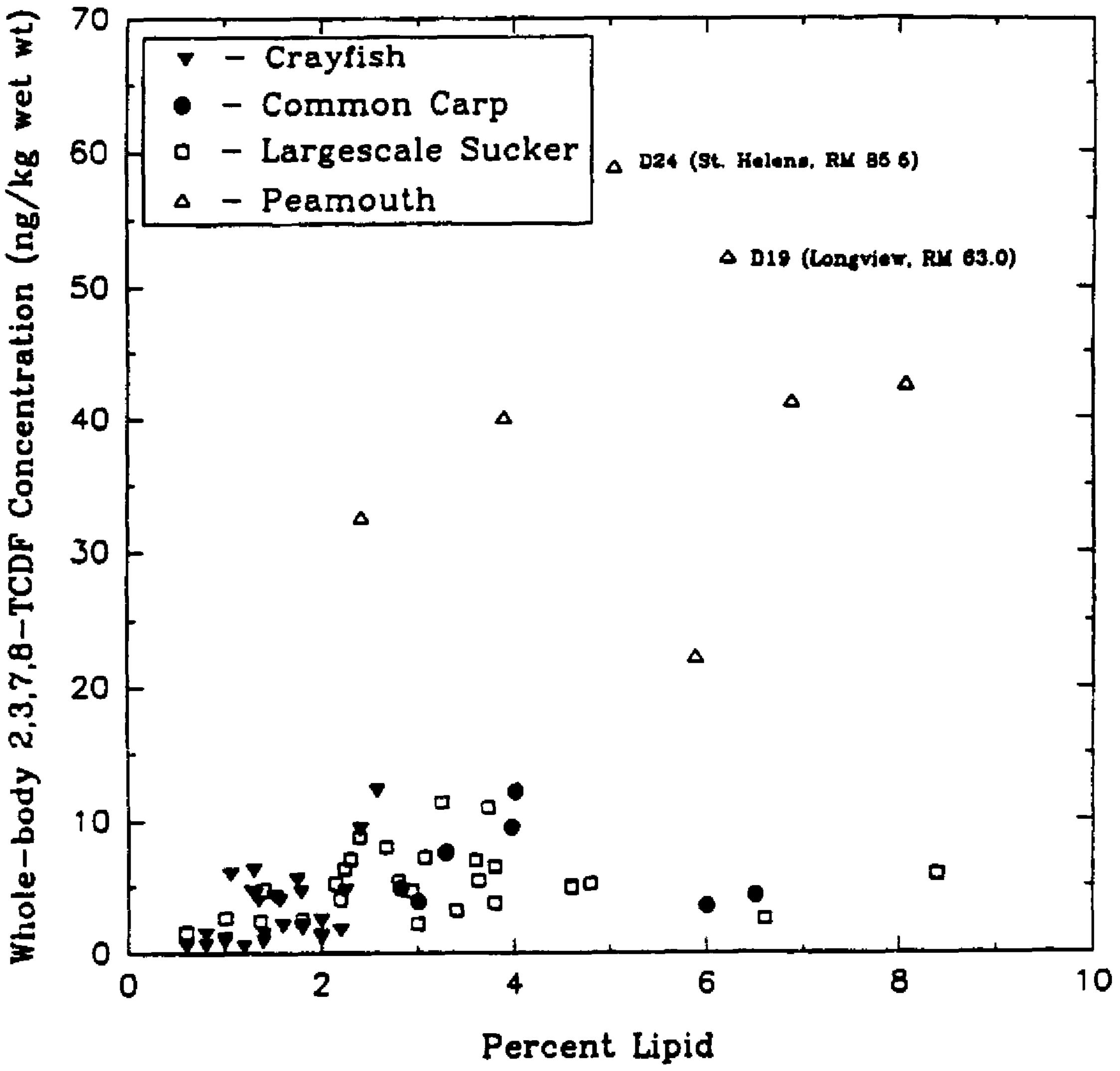

Figure 5-40. Scatterplot of Composite Sample Percent Lipid Content vs. Whole-Body Composite Sample 2,3,7,8-TCDF Concentration.

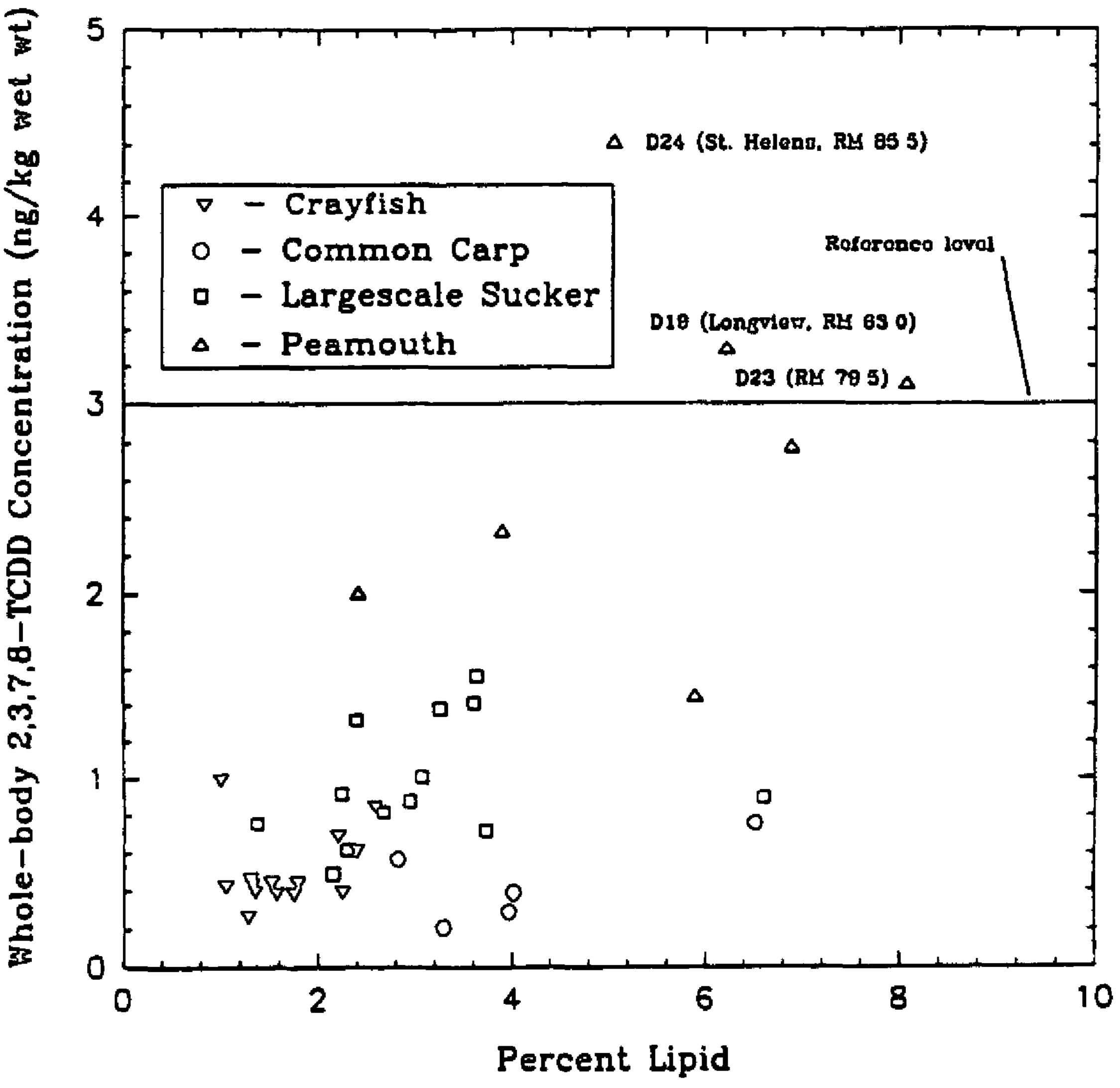

Figure 5-41. Scatterplot of Composite Sample Percent Lipid Content vs. Whole-Body Composite Sample 2,3,7,8-TCDD Concentration. *Dashed line is the New York State guideline (3 ng/kg) for the protection of fish-eating wildlife.*

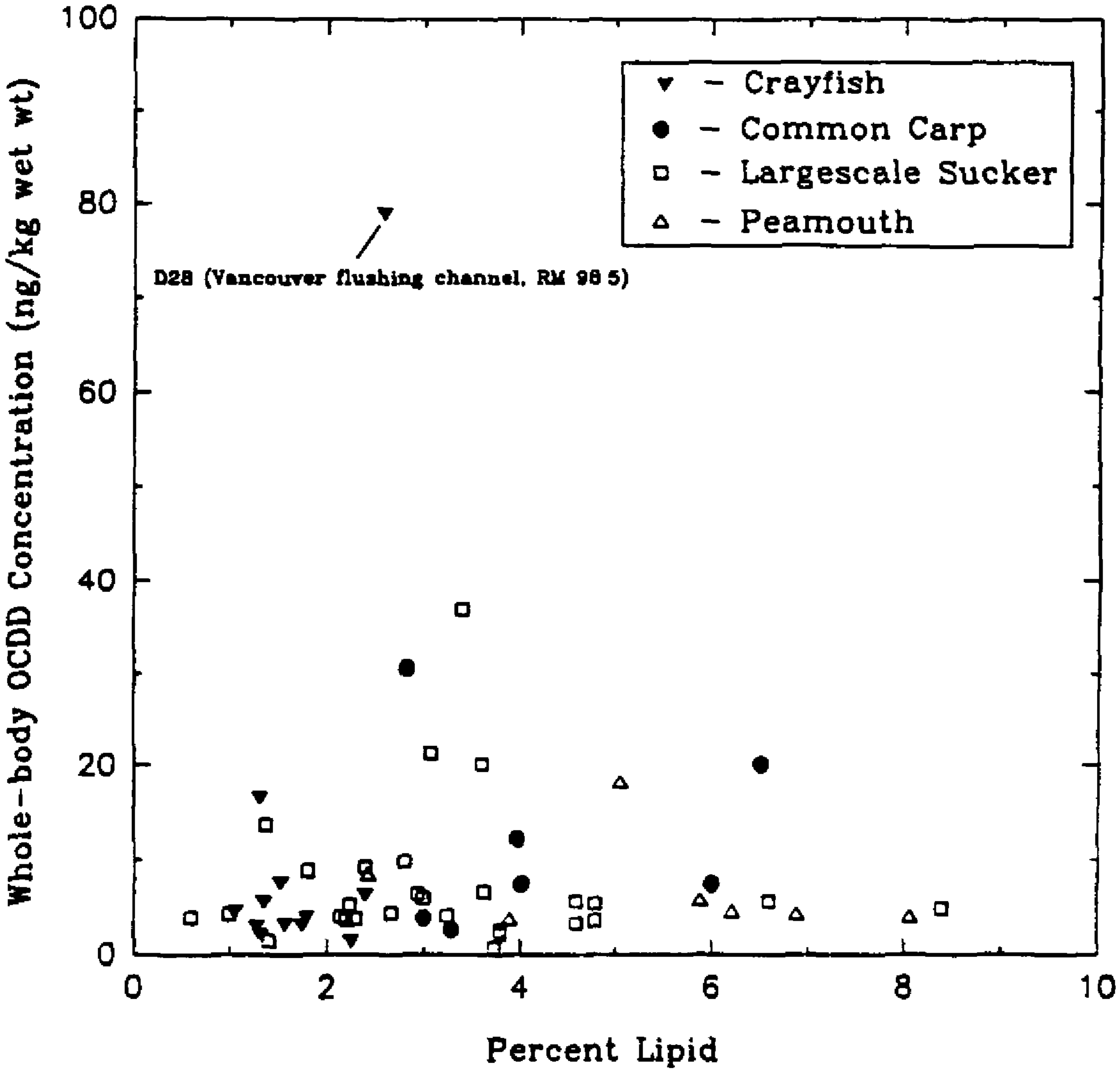

Figure 5-42. Scatterplot of Composite Sample Percent Lipid Content vs. Whole-Body Composite Sample OCDD Concentration.

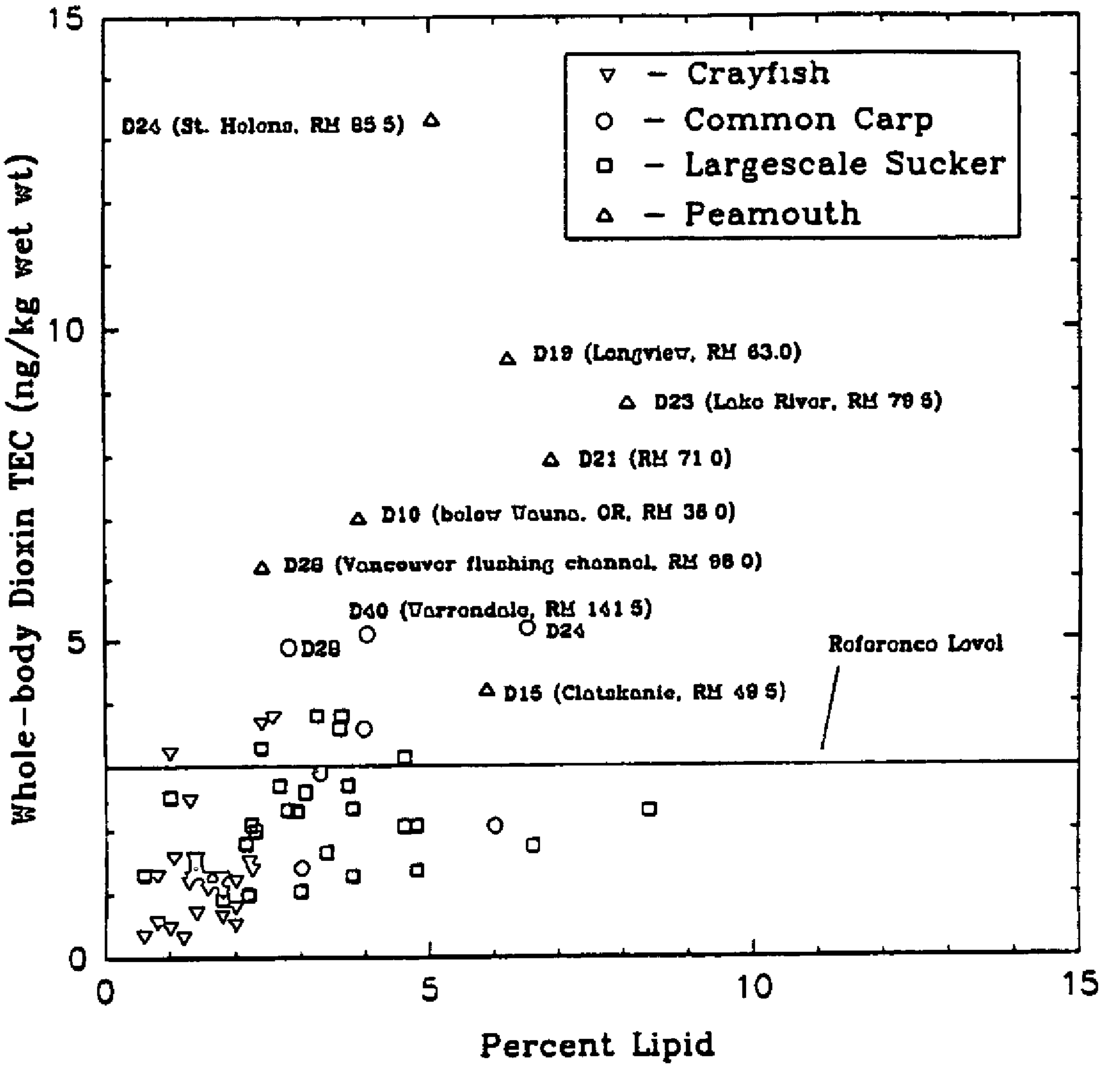

Figure 5-43. Scatterplot of Composite Sample Percent Lipid Content vs. Whole-Body Composite Dioxin TEC. *Dashed line is the New York State guideline (3 ng/kg) for the protection of fish-eating wildlife*

accumulation levels in aquatic biota (Fent and Hunn 1991) Tributyltin (TBT) is more toxic to aquatic biota than its degradation products, monobutyltin and dibutyltin All three of these compounds were analyzed in crayfish, largescale sucker, and carp samples in 1993 Butyltins were not measured in 1991

Butyltins were detected most frequently in sucker samples and were not detected in crayfish (Table 4-25) Monobutyltin was not detected in any sample , TBT was detected in 75% and 50% of the sucker and carp samples, respectively Dibutyltin was detected at concentrations ranging from 2.0 to 4 0 μg Sn/kg in sucker and carp samples TBT concentrations ranged from 8 to 68 μg Sn/kg, the samples with the five highest concentrations were from Elochoman Slough (RM 36), Cathlamet Bay (RM 21), Youngs Bay (RM 14), Lewis & Clark NWR (RM 29), and Scappoose Bay (RM 88) Marinas near Youngs Bay, Elochoman Slough, and Scappoose Bay are possible sources of butyltin compounds Shipping and boat traffic in these areas are also possible sources.

No relevant data was obtained from USFWS-NCBP, EPA-NSCRF, or STORET. so no comparisons with these sources are possible.

Several studies have measured butyltin compounds in marine species (Langston et al. 1990, Lee 1991, Moore et al 1991; Page and Widdow 1991, and Uhler et al. 1993), however, little information is available for concentrations in freshwater fish species Fent and Hunn (1991) measured butyltin concentrations in a cyprinid fish species (*Leuciscus cephalus*) from Lake Murten, Switzerland The concentrations of monobutyltin, dibutyltin, and TBT measured in the muscle tissue of this fish were 3 μg/kg, 20 μg/kg, and 170 μg/kg, respectively. This pattern of decreasing concentration of TBT degradation products was also observed for the reconnaissance survey data.

No reference levels for butyltin concentrations in aquatic biota have been established in either the United States or Canada.

5.3.7 Radionuclides

Eight long-lived radionuclides were analyzed in tissue samples for the 1993 survey. Radionuclides were not measured in the 1991 survey Plutonium 239/240 (Pu-239/240), plutonium 238 (Pu-238), and cesium 137 (Cs-137) were the only radionuclides detected. No radionuclides were detected in crayfish samples. Pu-239/240 was detected in 81% of the sucker samples and both carp samples at concentrations ranging from 0.001 to 0.003 pCi/g. Pu-238 was detected in one sucker sample from Youngs Bay at a concentration of 0.011 pCi/g. Cs-137 was detected in two sucker samples from Burke Slough and Camas Slough at 0.016 and 0.020 pCi/g, respectively.

Neither USFWS-NCBP, EPA-NSCRF, nor STORET analyzed fish tissue samples for radionuclides, so comparisons with survey data are not possible.

No reference levels for radionuclide concentrations in aquatic biota have been established in either the United States or Canada.

5.3.8 Summary of Crayfish and Fish Tissue Quality

The following metals and organic compounds were frequently detected in whole-body composite samples of crayfish or fish: barium, cadmium, chromium, copper, lead, mercury, zinc, p,p'-DDD, p,p'-DDE, p,p'-DDT, Arochlor 1254, dioxins and furans, and tributyltin. Relatively few organic compounds (including butyltins) were detected in crayfish samples, but metals were detected more frequently and in higher concentrations in crayfish.

Reference levels for tissue concentrations of these contaminants are not well developed. No guidelines were available for metals (excluding selenium), the majority of semi-volatile organics, individual PCB congeners, butyltins, or radionuclides. Of the compounds detected in tissue samples for which guidelines were available, exceedances (primarily for dioxin, total PCBs, and p,p'-DDE) occurred at 18 of 28 stations sampled for whole fish and at 1 of 8 locations sampled for sturgeon filets in 1991, and at 7 of 15 stations sampled for whole fish in 1993 (Figure 5-44)

A limited number of statistically significant relationships were found between the conventional variables (average weight, average length, and percent lipid content) and the levels of contaminants in tissue samples. Although probable relationships exist between specific conventional variables and tissue burdens of metals and organic contaminants should be considered in the design of future aquatic biota sampling efforts, other variables such as feeding habits and contaminant metabolism also affect tissue burdens, and should be considered. The most important factors controlling contaminant accumulation in aquatic biota of the lower Columbia River should be identified to improve the ability to predict the effect of changes in contaminant inputs to the river as a result of current or future resource management activities.

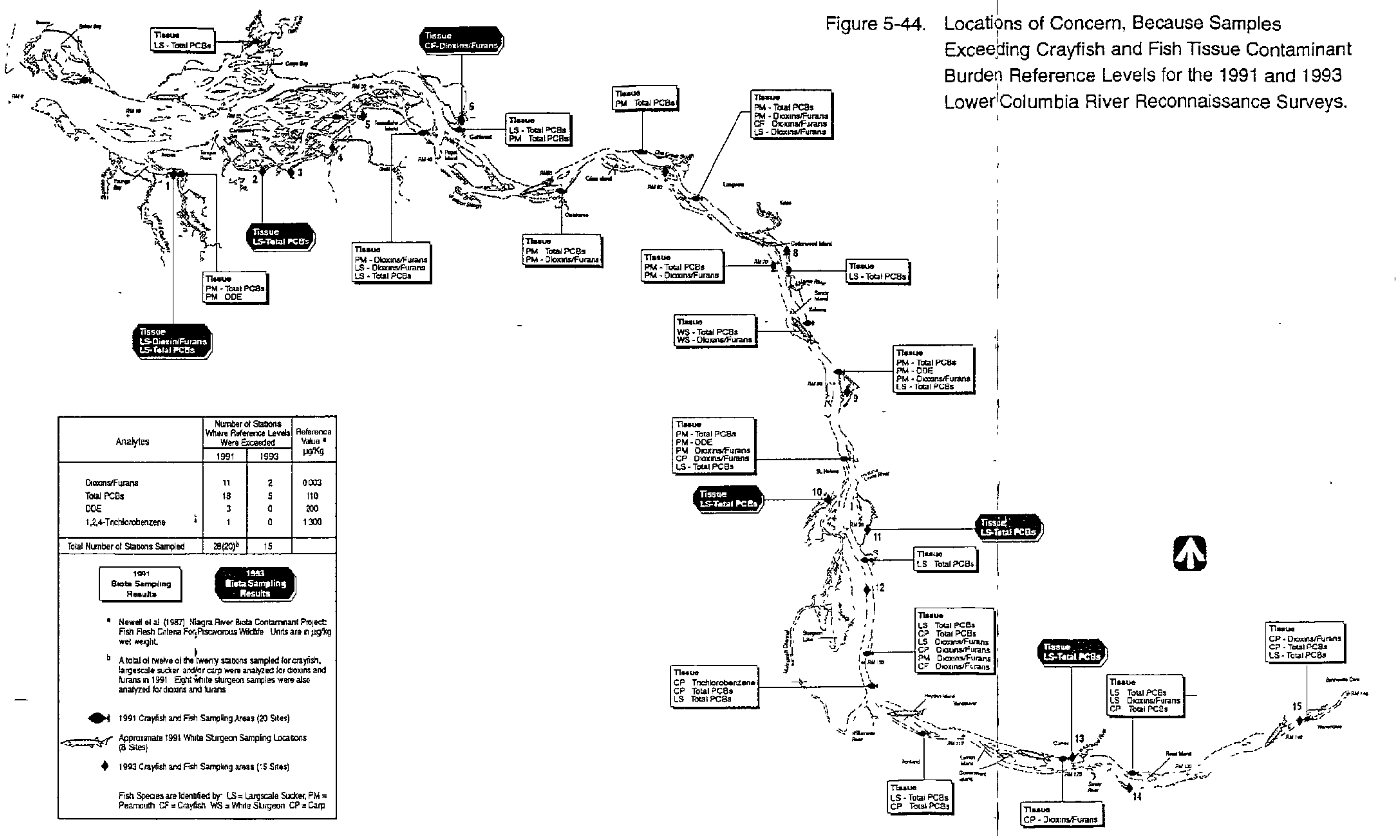

Figure 5-44. Locations of Concern, Because Samples Exceeding Crayfish and Fish Tissue Contaminant Burden Reference Levels for the 1991 and 1993 Lower Columbia River Reconnaissance Surveys.

Analytes	Number of Stations Where Reference Levels Were Exceeded		Reference Value [a] µg/Kg
	1991	1993	
Dioxins/Furans	11	2	0.003
Total PCBs	18	5	110
DDE	3	0	200
1,2,4-Trichlorobenzene	1	0	1 300
Total Number of Stations Sampled	28(20)[b]	15	

1991 Biota Sampling Results

1993 Biota Sampling Results

[a] Newell et al. (1987) Niagra River Biota Contaminant Project: Fish Flesh Criteria For Piscivorous Wildlife. Units are in µg/kg wet weight.

[b] A total of twelve of the twenty stations sampled for crayfish, largescale sucker and/or carp were analyzed for dioxins and furans in 1991. Eight white sturgeon samples were also analyzed for dioxins and furans.

1991 Crayfish and Fish Sampling Areas (20 Sites)

Approximate 1991 White Sturgeon Sampling Locations (8 Sites)

◆ 1993 Crayfish and Fish Sampling areas (15 Sites)

Fish Species are Identified by: LS = Largscale Sucker, PM = Peamouth, CF = Crayfish, WS = White Sturgeon, CP = Carp

Comparison of the lower Columbia River reconnaissance survey data with concentrations measured in aquatic biota sampled throughout the United States (EPA-NSCRF and USFWS-NCBP) indicate that the median and geometric mean levels of contaminants measured in the reconnaissance surveys are generally lower than corresponding levels measured nationwide. However, the highest tissue concentrations of two compounds (1,2,4-trichlorobenzene and Arochlor 1254) measured in the reconnaissance surveys exceeded the highest concentrations of these compounds measured in any sample collected nationwide in the national studies

The tissue concentrations of contaminants reported in STORET for the lower and middle reaches of the Columbia and lower river tributaries were generally comparable to the results of the reconnaissance surveys. However, the concentrations of dioxins and furans reported in STORET for the lower and middle reaches of the Columbia were generally higher than the concentrations measured in the reconnaissance surveys. The dioxin and furan data available in STORET for these regions of the Columbia River basin are primarily from EPA-NSCRF. Therefore, these higher concentrations may be due to the proximity of EPA-NSCRF sampling stations to known sources of dioxin and furan compounds.

5.4 RELATIONSHIPS AMONG MEDIA

Currently, there is some debate on the relative importance of various routes of contaminant uptake by aquatic organisms (e.g., Van Hattum et al. 1991, Miller et al. 1992; Laws 1993). These routes include direct uptake of dissolved constituents from the water column, uptake of dissolved constituents via exposure to contaminated sediment pore waters, and uptake via ingestion of contaminated sediment or food[1]. For example, an increase in tissue contaminant level with increasing trophic level ("food chain biomagnification") has been attributed to consumption of contaminated prey, with increasing accumulation of contaminants at higher food chain levels. However, some studies have indicated that the increase of contaminants in the tissues of some carnivorous organisms may be due more to simple chemical equilibrium between dissolved contaminant concentrations in water and the fatty tissues of the organism (e.g., Hamelink et al. 1971). Differences in contaminant concentrations among various organisms would

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[1] The accumulation of dissolved contaminants via diffusion across tissue surfaces is termed bioconcentration, and the accumulation of contaminants via ingestion of food (including sediment) is termed bioaccumulation.

then be due to difference in fat (lipid) content, age, and metabolic activity. Food-chain transfer, however, is still considered an important uptake route for fish-eating birds and mammals

This debate is relevant for several reasons. An understanding of the relative importance of various contaminant accumulation pathways allows for the development of scientifically sound water and sediment quality criteria that can provide effective protection for aquatic organisms and the health of fish-eating humans and wildlife (e g , Parkerton et al 1993) The relative importance of sediment and water contaminant exposure pathways is also important for determining the appropriate medium for routine monitoring and for establishing cleanup priorities A greater understanding of contaminant accumulation pathways will also aid in developing relevant models to predict future tissue contaminant levels based on projected changes in the amounts of contaminants released to the environment and long-term degradation of previously released persistent chemicals.

Generally, routine monitoring programs or reconnaissance surveys sample sediments and/or water instead of aquatic biota. Water and sediment can be collected more easily and inexpensively; besides the physical difficulties of catching live organisms, methodology is made more complex by the necessity of choosing appropriate sampling methods (compositing vs. analysis of individual organisms), target species (commercial species vs. bottom fish), and target tissues (liver vs. whole-body analysis). Sediment sampling is often preferred over water sampling because of the relative difficulty of detecting low-level concentrations of trace elements and organic contaminants in water samples. Sediments are also generally considered to integrate contaminant inputs over longer periods of time (e.g., months to years) requiring less intensive and frequent sampling to determine ambient contaminant concentrations. Water-borne contaminant levels tend to vary over shorter temporal periods of hours to months. Recent modeling studies have indicated that, at least for some relatively hydrophobic chemicals, sediment transfer may be the most important route of accumulation (e.g., Thomann et al. 1992; Gobas 1993). However, for the metals copper and zinc, water concentrations have been shown to be the best predictors of fish tissue concentrations in one study (Miller et al. 1992).

The lower Columbia River reconnaissance surveys sampled the water column, sediments, and biota for trace metals, organic contaminants, and selected long-lived radionuclides. However, the sampling for water column concentrations of trace metals and organic contaminants was relatively limited and no water column samples were collected for radionuclide analysis. Water column sampling for organic contaminants was limited to five sampling locations and one two-month period. Sampling for trace metals was more extensive, but still limited to two short periods (August-September 1991 and June-July 1993) Furthermore, water concentrations of contaminants were generally below laboratory detection limits, especially for semi-volatile organic compounds, pesticides, and PCBs in 1991 Trace metal levels were also generally below detection limits, only aluminum, barium, and iron were detected at all stations, with lead and zinc also being detected relatively frequently

Trace metals and organic contaminants were detected more frequently in the sediment and tissue samples in the reconnaissance surveys. Some constituents were detected frequently in sediments, but not in tissue samples (e.g., PAHs, radionuclides); and some constituents were detected frequently in tissue samples, but not in sediments (e g , PCBs) Although a complicated bioaccumulation modeling effort is beyond the scope of a reconnaissance survey data summary report, it would be interesting to explore the possibility that relatively simple linear relationships exist between concentrations of sediment trace metal and organic contaminants and tissue concentrations of these contaminants. Although relationships are likely to exist between concentrations of contaminants in the water column and in tissues, water data from the reconnaissance surveys are not considered suitable for this use because of the infrequent detection of most constituents in the water column and the narrow time-band of sampling.

5.4.1 Trace Metals

Simple relationships between metal concentrations in sediments and concentrations in deposit/detritus feeding animals have been weakly significant, at best (Luoma 1989). A number of chemical and physical factors can influence the transfer and accumulation of metals from the sediments to the tissues of aquatic organisms, complicating this relationship. Biological and biochemical factors also influence the amount of trace metals accumulated, and the specific tissues where accumulation occurs. These factors are outlined below

The bioavailability of sediment trace metals appears to be related to sediment physical and chemical variables (herein referred to as sediment geochemistry), although methods for explaining or predicting the effect of sediment geochemistry on metal bioavailability are not well understood (Luoma 1989). Geochemical factors known to influence trace metal bioavailability include sediment particle surface area, grain size, chemical partitioning between solid and dissolved phases in sediment pore waters, and sediment organic matter content (Luoma 1989). Chemical partitioning between solid and dissolved phases is in turn affected by such chemical factors such as pore-water pH, oxidation-reduction potential (related to bacterial activity in the sediment), and the occurrence of metal oxides, hydroxides, and other precipitates

Biological factors that appear to influence trace metal accumulation include body weight, age, metabolic rate, lipid content, and trophic feeding level The organisms metabolic and trace metal processing and transport pathways also determine in which tissues (e g., fat, liver, or bone) certain trace metals may concentrate

Luoma (1989) has outlined three types of situations in which significant correlations would be expected between sediment and tissue trace metal content.

- ☐ Comparisons made across geochemically similar environments.
- ☐ Species that feed selectively, limiting exposure to one predominant form of the metal
- ☐ Large gradients in sediment metal concentrations, with species that do not respond dramatically to changes in bioavailable metal.

One approach that has been used to account for geochemical variation is chemically extracting and quantifying the bioavailable metal fraction in the sediments. This approach has shown some success, but the extraction is likely no more than an operational definition and may not accurately reflect the quantity of bioavailable metal present (Luoma 1989). Normalization of trace metal concentrations to weak-acid extractable iron, which is presumably an estimate of iron-oxide sediment coatings that bind sediment trace metals, has also been shown to result in improved correlations with aquatic biota tissue concentrations, at least for a few metals (Luoma 1989).

To explore the possibility that relatively simple linear relationships exist between levels of trace metals in sediment and tissue samples in the reconnaissance surveys, correlation coefficients were determined between sediment and tissue trace metal concentrations. All available trace metal data from the two reconnaissance surveys were pooled for regression analysis. Only trace metals that were detected relatively frequently in both sediments and tissues were considered for analysis, excluding antimony, arsenic, selenium, and silver due to their infrequent detection in sediments and/or biota Linear regressions were performed (using sediment trace metal content as the independent variable) for correlation coefficients greater than 0 30 Statistical significance was determined at the 5% level (a=0 05) (Table 5-34)

To explore the possibility that most of the geochemical variability could be explained by variation in grain size or sediment surface area, correlations between sediment trace metal concentrations normalized to sediment aluminum content [a surrogate variable for sediment grain size or surface area (Horowitz 1991)] to tissue trace metal concentration were also performed. Correlations were also determined using lipid-normalized tissue trace metal concentrations, but the correlation coefficients for these relationships were generally low and statistically insignificant ($P>0.05$), with the exception of largescale sucker lipid-normalized tissue mercury concentrations (Table 5-34) Very large differences in measured crayfish barium content between 1991 and 1993 were noted which cannot be explained by the variation in the measured sediment barium content, so these data were treated separately. Biota samples in 1991 were not analyzed for chromium, and therefore only the 1993 tissue data for this trace metal were used.

In general, most correlation coefficients between crayfish tissue and sediment trace metals concentrations were weakly negative or positive, and statistically insignificant (Table 5-34). In the case of crayfish trace metal tissue concentrations, statistically significant negative relationships were found for bulk sediment concentrations and whole-body tissue concentrations (Table 5-34 and Figure 5-45). There is no known causal relationship to explain these negative correlations The presence of copper-containing hemocyanin in crayfish could affect the relationship between sediment and tissue copper levels (Rainbow 1988, Van Hattum et al 1991). The only statistically significant positive linear relationship between sediment and crayfish tissue trace metal concentrations was for lead (Table 5-34 and Figure 5-45).

In general, most correlations between sucker tissue and sediment trace metals concentrations were weakly negative or positive, and statistically insignificant (Table 5-34) However, several statistically significant positive relationships were found between sucker tissue trace metal concentrations and sediment trace metal concentrations normalized to aluminum [i.e., barium, mercury (to lipid-normalized tissue concen-

TABLE 5-34. CORRELATIONS AND LINEAR REGRESSION RELATIONSHIPS BETWEEN SEDIMENT AND BIOTA METALS CONCENTRATIONS LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

Note Regressions were performed only for relationships showing a correlation coefficient greater than 0.30

A. Sediment total recoverable metals concentrations vs. crayfish tissue metal concentrations

Bulk sediment metals concentration	Number of samples	correlation coefficient	r-square	P-value	Sediment metals normalized to Al	correlation coefficient	r-square	P-value
Ba (1991)	18	0.2715	--	--	Ba/Al (1991)	0.1705	--	--
Ba (1993)	13	-0.1539	--	--	Ba/Al (1993)	-0.2373	--	--
Cd	30	**-0.4915**	**0.2416**	**0.0057**	Cd/Al	-0.1074	--	--
Cr (1993)	13	0.2855	--	--	Cr/Al (1993)	-0.2255	--	--
Cu	31	**-0.6774**	**0.4589**	**0.00003**	**Cu/Al**	**-0.3918**	**0.1535**	**0.0290**
Pb	23	**0.5534**	**0.3062**	**0.0060**	Pb/Al	-0.2343	--	--
Hg (lipid normalized)	17	0.1759	--	--	Hg/Al	0.0545	--	--
Ni	13	-0.5207	0.2711	0.0660	Ni/Al	0.5113	0.2614	0.0720
Zn	31	0.2021	--	--	Zn/Al	-0.2249	--	--

B. Sediment total recoverable metals concentrations vs. largescale sucker tissue metal concentrations

Bulk sediment metals concentration	Number of samples	correlation coefficient	r-square	P-value	Sediment metals normalized to Al	correlation coefficient	r-square	P-value
Ba	31	-0.2753	--	--	**Ba/Al**	**0.5542**	**0.3071**	**0.0012**
Cd	31	0.1990	--	--	Cd/Al	0.2887	--	--
Cr (1993)	13	-0.1876	--	--	Cr/Al (1993)	0.0261	--	--
Cu	31	-0.2096	--	--	Cu/Al	0.1274	--	--
Pb	19	0.2257	--	--	Pb/Al	0.3331	0.1110	0.1624
Hg (lipid normalized)	17	0.2543	--	--	**Hg/Al**	**0.5916**	**0.3500**	**0.0118**
Ni	8	**-0.9061**	**0.8211**	**0.0012**	**Ni/Al**	**0.7899**	**0.6239**	**0.0160**
Zn	29	0.1045	--	--	**Zn/Al**	**0.5122**	**0.2623**	**0.0031**

Note: Statistically significant linear regression relationships ($P<0.05$) shown in bold type.

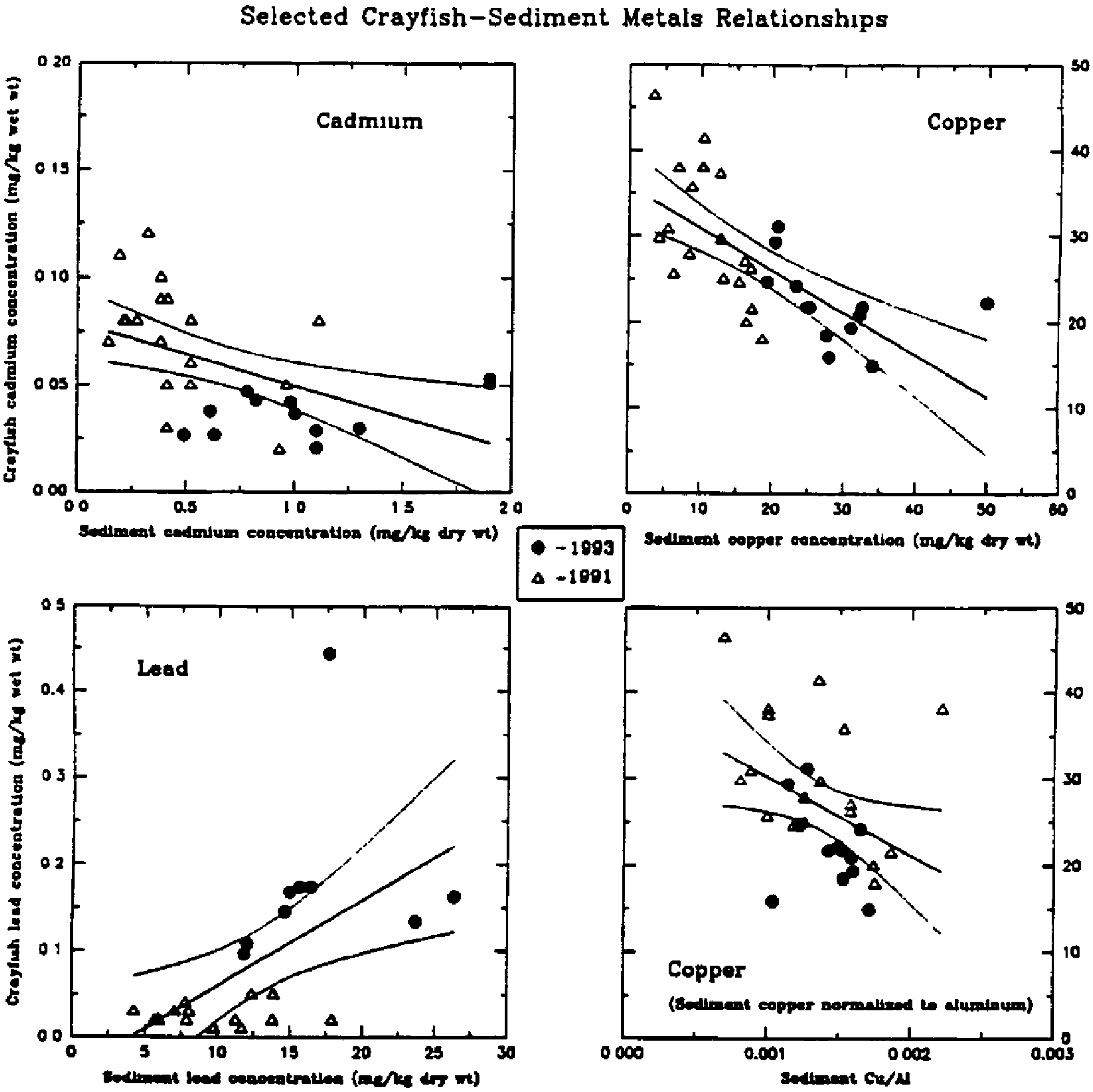

Figure 5-45. Scatterplots and Linear Regressions for Sediment vs. Crayfish Whole-Body Burdens of Cadmium, Copper, and Lead. *Dashed lines indicate 95% confidence intervals.*

tration), nickel, and zinc] A statistically significant negative relationship was found between sucker tissue and bulk sediment concentrations of nickel (Table 5-34 and Figure 5-46)

What is perhaps surprising is that so many relatively strong and statistically significant relationships were found between sediment and biota metals concentrations By contrast, a multiple linear regression model of sediment and biota tissue concentrations for cadmium, copper, lead, and zinc could explain only 37% of the variance in benthic invertebrate metal levels measured in various aquatic habitats in the Netherlands (Van Hattum et al. 1991) The extent to which these significant regression relationships are spurious is not known; further field sampling and more detailed statistical analyses are required to test these simple relationships. However, the higher number of significant positive relationships for sucker tissue trace metal and aluminum-normalized sediment trace metal concentrations suggests that relatively simple geochemical variables could be used to monitor and predict the effects of trace metal contaminants in lower Columbia sediments on sucker tissue metal contamination. Future studies that include sampling of sediments and biota for trace metals should attempt to expand and elaborate on these analyses In addition, the collection of additional fish species with different life history patterns should be considered for future studies.

5.4.2 Organic Compounds

The bioavailability of sediment-bound organic contaminants to aquatic biota, particularly persistent hydrophobic compounds, appears to be related to the partitioning of the contaminant between the particulate organic carbon in the sediment and the sediment pore water (e.g., Landrum and Robbins 1990; Di Toro et al 1991; Farrington 1991, Jaffé 1991) Other factors appear to modify this relationship including the concentration of dissolved and colloidal organic matter in the sediment pore water (e.g., Socha and Carpenter 1987) and the character of the sediment organic carbon (e.g., Lake et al. 1990).

Organic compounds, particularly persistent lipophilic compounds, tend to bioconcentrate and bioaccumulate in biota tissues (Esser 1986; Connell 1988; Farrington 1991; Jaffé 1991). Variables affecting this accumulation include lipid content; age of the organism; feeding habits; exposure level; chemical bioavailability; dissolved, colloidal, and particulate organic carbon content of water and sediment; uptake and elimination rates; and the migration pattern of the organism (e.g., Branson et al. 1985; Adams 1987; Barron 1990, Farrington 1991; Gobas 1993; Sijm et al. 1993).

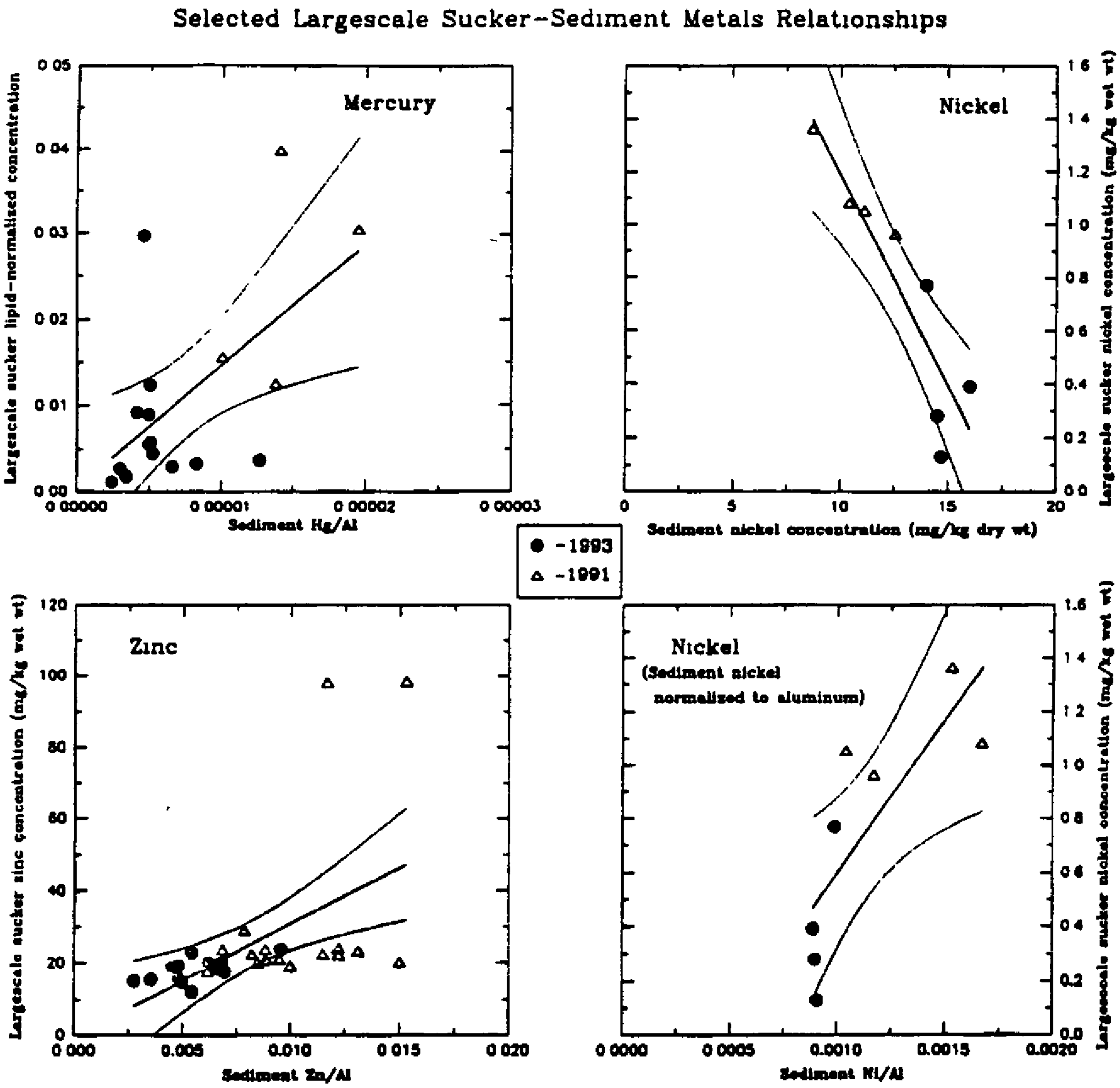

Figure 5-46. Scatterplots and Linear Regressions for Sediment vs. Largescale Sucker Whole-Body Burdens of Mercury, Nickel, and Zinc. *Dashed lines indicate 95% confidence intervals.*

To explore the possibility that relatively simple linear relationships exist between levels of organic contaminants in sediment and tissue samples in the reconnaissance surveys, correlation coefficients were determined between sediment and tissue organic contaminant concentrations All available organic contaminant data from the two reconnaissance surveys were pooled for regression analysis. Only contaminants detected relatively frequently in both sediments and biota were considered for analysis, limiting analyses to a few PAHs, pesticides, and dioxin and furan compounds Tributyltin was detected frequently only in sucker samples, so correlations of sediment tributyltin with tissue burdens were conducted only for this organism Linear regressions were performed (using sediment organic contaminant concentration as the independent variable) for correlation coefficients greater than 0 30. Statistical significance was determined at the 5% level (a=0 05) (Tables 5-35 and 5-36)

To explore the possibility that most of the geochemical variability could be explained by variation in sediment organic carbon content, correlations between sediment contaminant concentrations normalized to sediment organic carbon content were also determined. Correlations were also performed using lipid-normalized tissue contaminant concentrations. Analyses in 1991 did not include tributyltin, so correlations for TBT were based on 1993 data.

All correlation coefficients between crayfish tissue and sediment organic contaminant concentrations were weakly negative or positive and statistically insignificant, except for a positive correlation between sediment and lipid-normalized concentrations of 1,2,3,4,6,7,8-HpCDD (Table 5-35)

Most correlation coefficients between sucker tissue and sediment organic compound concentrations were weakly negative or positive, and statistically insignificant (Table 5-36) Statistically significant negative relationships were found between sediment and lipid-normalized tissue concentrations of p,p'-DDD and 1,2,3,4,7,8-HxCDF (Table 5-36; Figures 5-47 and 5-48). Statistically significant positive relationships were found between sucker tissue and sediment concentrations of 2-methylnaphthalene, naphthalene, and four dioxin and furan congeners (Table 5-36; Figures 5-47 and 5-48). No significant relationships were found for TBT. Statistically significant relationships were found for all combinations of normalized and non-normalized tissue and sediment contaminant concentrations, although the strongest relationships for dioxin and furan concentrations were generally found between organic carbon-normalized sediment and whole body tissue (Table 5-36)

TABLE 5-35 CORRELATIONS AND LINEAR REGRESSION RELATIONSHIPS BETWEEN SEDIMENT AND CRAYFISH TISSUE ORGANIC CONTAMINANT CONCENTRATIONS LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

Note Regressions were performed only for relationships showing a correlation coefficient greater than 0.30

	Number of samples	Bulk sediment concentration			Sediment concentration TOC-normalized		
		correlation coefficient	r-square	P-value	correlation coefficient	r-square	P-value
PAHs							
2-Methylnaphthalene	11						
bulk tissue concentration		0.1547	–	–	-0.1591	–	–
lipid-normalized		0.4552	0.2072	0.1561	0.2484	–	–
Naphthalene	4						
bulk tissue concentration		-0.2723	–	–	-0.4236	0.1794	0.3361
lipid-normalized		-0.0014	–	–	-0.1574	–	–
Pesticides							
p,p'-DDE	7						
bulk tissue concentration		-0.1167	–	–	-0.1047	–	–
lipid-normalized		0.1814	–	–	0.1430	–	–
Dioxins and Furans							
2,3,7,8-TCDD	11						
bulk tissue concentration		-0.3633	0.1320	0.2692	-0.0759	–	–
lipid-normalized		0.1175	–	–	-0.3119	0.0973	0.3479
1,2,3,4,6,7,8-HpCDD	11						
bulk tissue concentration		0.5172	0.2675	0.1000	0.5066	0.2567	0.1084
lipid-normalized		**0.7270**	**0.5285**	**0.0099**	0.6789	0.4609	0.0197
OCDD	14						
bulk tissue concentration		0.1702	–	–	0.1733	–	–
lipid-normalized		0.0921	–	–	0.0468	–	–
2,3,7,8-TCDF	12						
bulk tissue concentration		-0.0915	–	–	0.3250	0.1056	0.3004
lipid-normalized		0.3803	0.1446	0.2201	0.4276	0.1828	0.1629
2,3,4,7,8-PeCDF	11						
bulk tissue concentration		0.0466	–	–	0.5865	0.3440	0.0549
lipid-normalized		0.1967	–	–	0.5777	0.3338	0.0597
2,3,4,6,7,8-HxCDF	11						
bulk tissue concentration		-0.1869	–	–	-0.2562	–	–
lipid-normalized		-0.1591	–	–	-0.3063	0.0938	0.3571

Note. Statistically significant linear regressions ($P<0.05$) in bold type.

TABLE 5-36. CORRELATIONS AND LINEAR REGRESSION RELATIONSHIPS BETWEEN BETWEEN SEDIMENT AND LARGESCALE SUCKER TISSUE ORGANIC CONTAMINANT CONCENTRATIONS

LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

(Page 1 of 3)

Note Regressions were performed only for relationships showing a correlation coefficient greater than 0.30

	Numbers of samples	Bulk sediment concentration			Sediment TOC-normalized concentration		
		correlation coefficient	r-square	P-value	correlation coefficient	r-square	P-value
PAHs							
2-Methylnapthalene	4						
Bulk tissue concentration		0.4572	0.2090	0.5198	0.9113	0.8305	0.0521
lipid-normalized		0.2715	--	--	**0.9738**	**0.9482**	**0.0090**
Naphthalene	4						
Bulk tissue concentration		**0.9340**	**0.8723**	**0.0344**	0.7783	0.6057	0.1779
lipid-normalized		0.5716	0.3267	0.3972	**0.9210**	**0.8483**	**0.0442**
Pesticides							
p,p'-DDD	7						
Bulk tissue concentration		-0.1177	--	--	0.6531	0.4265	0.1021
lipid-normalized		**-0.8241**	**0.6791**	**0.0174**	-0.6030	0.3637	0.1419
p,p'-DDE	4						
Bulk tissue concentration		-0.2592	--	--	-0.3283	0.1078	0.6568
lipid-normalized		0.5538	0.3067	0.4163	0.2027	--	--
Butyltins							
Tributyltin	9						
Bulk tissue concentration		-0.0184	--	--	-0.1637	--	--
lipid-normalized		-0.0436	--	--	-0.1718	--	--

TABLE 5-36 CORRELATIONS AND L[illegible]AR REGRESSION RELATIONSHIPS BETWEEN BETWEEN SEDIMENT AND LARGESCALE SUCKER TISSUE ORGANIC CONTAMINANT CONCENTRATIONS LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

(Page 2 of 3)

Note Regressions were performed only for relationships showing a correlation coefficient greater than 0.30

		Bulk sediment concentration			Sediment TOC-normalized concentration		
	Numbers of samples	correlation coefficient	r-square	P-value	correlation coefficient	r-square	P-value
Dioxins and Furans							
2,3,7,8-TCDD	11						
Bulk tissue concentration		-0.1086	--	--	0.0678	--	--
lipid-normalized		-0.1951	--	--	-0.0722	--	--
1,2,3,7,8-PeCDD	9						
Bulk tissue concentration		0.0477	--	--	0.0351	--	--
lipid-normalized		-0.1551	--	--	-0.1775	--	--
1,2,3,4,7,8-HxCDD	11						
Bulk tissue concentration		**0.7909**	**0.6256**	**0.0031**	**0.8124**	**0.6600**	**0.0019**
lipid-normalized		**0.6140**	**0.3769**	**0.0418**	**0.6069**	**0.3683**	**0.0450**
1,2,3,6,7,8-HxCDD	12						
Bulk tissue concentration		0.1567	--	--	0.3700	0.1369	0.2340
lipid-normalized		-0.0449	--	--	0.2128	--	--
1,2,3,7,8,9-HxCDD	12						
Bulk tissue concentration		**0.6407**	**0.4105**	**0.0230**	**0.7991**	**0.6386**	**0.0015**
lipid-normalized		0.4032	0.1626	0.1910	0.5651	0.3193	0.0532
1,2,3,4,6,7,8-HpCDD	12						
Bulk tissue concentration		0.4144	0.1717	0.1778	0.5232	0.2738	0.0782
lipid-normalized		0.2930	--	--	0.4322	0.1868	0.1579
OCDD	17						
Bulk tissue concentration		**0.7263**	**0.5275**	**0.0009**	**0.7477**	**0.5590**	**0.0005**
lipid-normalized		**0.6280**	**0.3944**	**0.0065**	**0.6326**	**0.4002**	**0.0060**
2,3,7,8-TCDF	12						
Bulk tissue concentration		-0.4983	0.2483	0.0965	-0.0835	--	--
lipid-normalized		-0.3933	0.1547	0.2032	0.0527	--	--
1,2,3,7,8-PeCDF	11						
Bulk tissue concentration		0.0444	--	--	0.1576	--	--
lipid-normalized		-0.2293	--	--	-0.0120	--	--

TABLE 5-36. CORRELATIONS AND LINEAR REGRESSION RELATIONSHIPS BETWEEN BETWEEN SEDIMENT AND LARGESCALE SUCKER TISSUE ORGANIC CONTAMINANT CONCENTRATIONS LOWER COLUMBIA RIVER RECONNAISSANCE SURVEYS, 1991 AND 1993

(Page 3 of 3)

Note Regressions were performed only for relationships showing a correlation coefficient greater than 0.30

	Numbers of samples	Bulk sediment concentration			Sediment TOC-normalized concentration		
		correlation coefficient	r-square	P-value	correlation coefficient	r-square	P-value
Dioxins and Furans (cont')							
2,3,4,7,8-PeCDF	11						
Bulk tissue concentration		0.1430	--	--	0.1468	--	--
lipid-normalized		-0.1632	--	--	0.0519	--	--
1,2,3,4,7,8-HxCDF	12						
Bulk tissue concentration		-0.3066	--	--	-0.0212	--	--
lipid-normalized		**-0.5981**	**0.3577**	**0.0378**	-0.2639	--	--
1,2,3,6,7,8-HxCDF	12						
Bulk tissue concentration		0.0805	--	--	0.4126	0.1703	0.1798
lipid-normalized		-0.3128	0.0978	0.3201	0.0071	--	--
2,3,4,6,7,8-HxCDF	12						
Bulk tissue concentration		-0.0136	--	--	**0.6792**	**0.4613**	**0.0138**
lipid-normalized		-0.1876	--	--	0.4716	0.2224	0.1189
1,2,3,7,8,9-HxCDF	8						
Bulk tissue concentration		-0.5637	0.3178	0.1385	-0.2702	--	--
lipid-normalized		-0.5844	0.3415	0.1211	-0.2801	--	--
1,2,3,4,6,7,8-HpCDF	12						
Bulk tissue concentration		-0.1069	--	--	0.0456	--	--
lipid-normalized		-0.2301	--	--	-0.1432	--	--
1,2,3,4,7,8,9-HpCDF	11						
Bulk tissue concentration		0.1309	--	--	0.0277	--	--
lipid-normalized		0.0031	--	--	-0.2087	--	--
OCDF	12						
Bulk tissue concentration		0.0789	--	--	0.2317	--	--
lipid-normalized		0.0740	--	--	0.2076	--	--

Note: Statistically significant (P<0.05) linear regression relationships shown in bold type

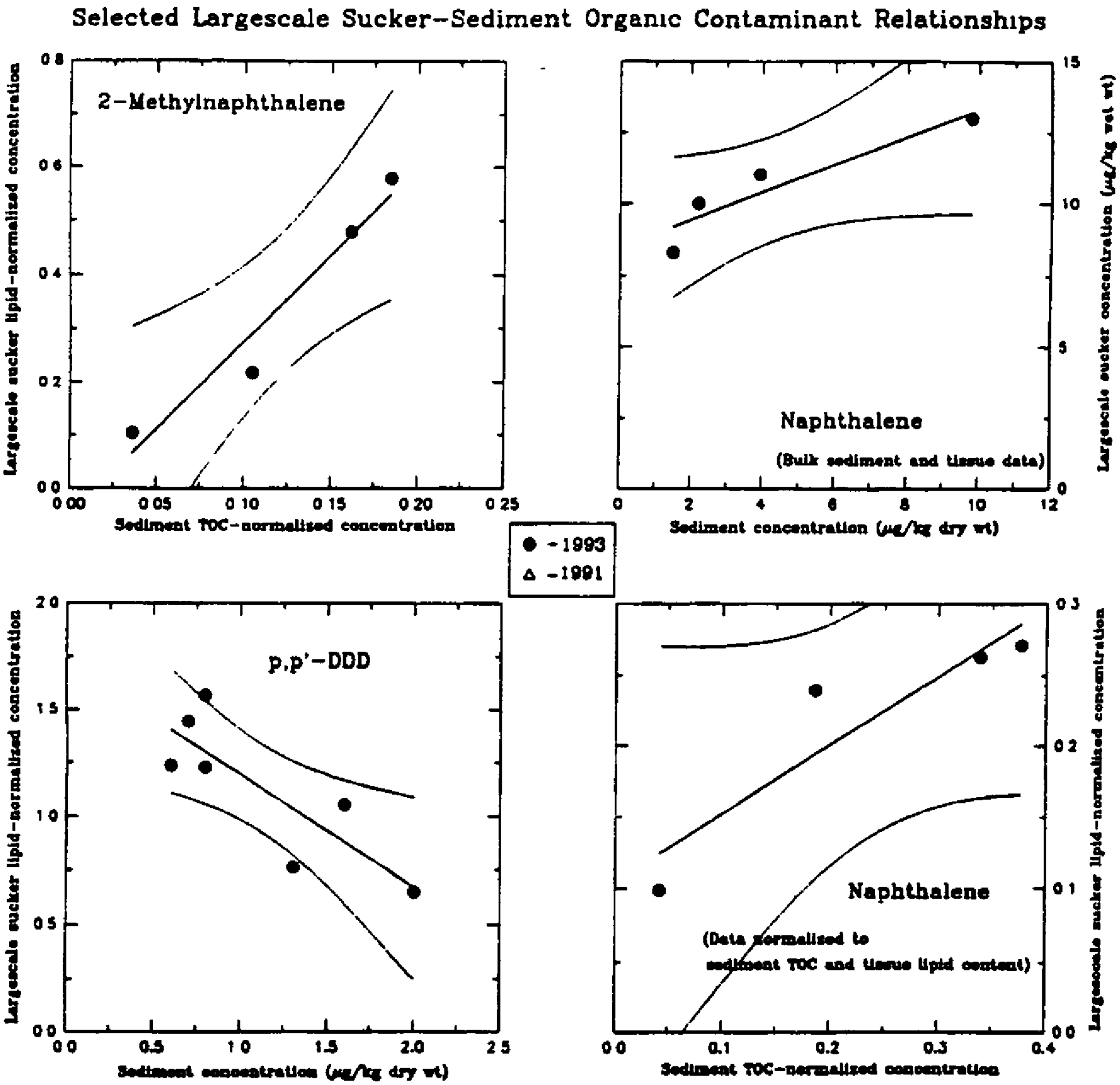

Figure 5-47. Scatterplots and Linear Regressions for Sediment vs. Largescale Sucker Whole-Body Burdens of 2-Methylnaphthalene, Naphthalene, and p,p'-DDD. *Dashed lines indicate 95% confidence intervals.*

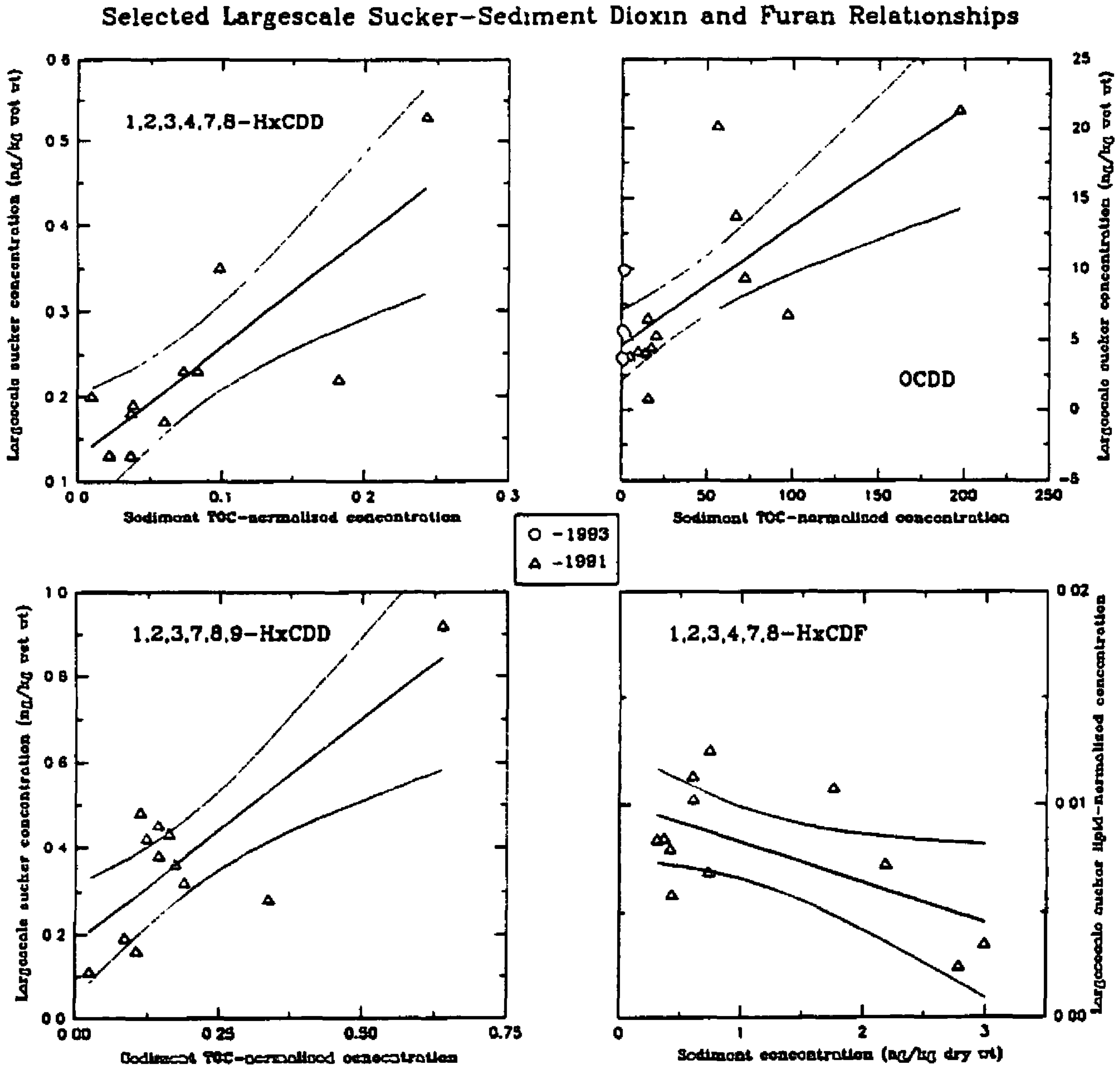

Figure 5-48. Scatterplots and Linear Regressions for Sediment vs. Largescale Sucker Whole-Body Burdens of Selected Dioxins and Furans.
Dashed lines indicate 95% confidence intervals.

The extent to which the significant regression relationships are spurious is not known, further field sampling and more detailed statistical analyses are required to test these simple relationships However, the relatively higher number of significant positive relationships for sucker organic contaminant and organic carbon-normalized sediment contaminant concentrations suggests that relatively simple geochemical variables could be used to monitor and predict the effects of organic contaminants in lower Columbia sediments on sucker tissue contamination Future studies that include sampling of sediments and biota for organic contaminants should attempt to expand and elaborate on these analyses

5.4.3 Summary

If the general relationships revealed above are considered valid, future investigations of the lower Columbia River should focus on sediment variables such as grain size distribution and organic carbon content Although only a limited number of relationships appeared to be explained by lipid-normalization, it should be noted that, at least qualitatively, organic contaminants sampled in the reconnaissance surveys were more frequently detected in sucker, peamouth, and carp, which had relatively higher lipid content than crayfish. The extent to which these differences are due to other variables including feeding habits, migration patterns, or metabolic levels should also be addressed in future studies.

The importance of sampling both sediments and biota in a reconnaissance level survey can be emphasized by the fact that while PCBs were detected at only 3 of 69 stations sampled for sediment in the two surveys, they were detected in all fish samples in both surveys The reference level indicating the potential for adverse effects on fish-eating wildlife for total PCBs (110 μg/kg wet weight) was exceeded in tissue samples collected from 9 of 10 stations sampled for peamouth, 5 of 11 stations sampled for carp, and 22 of 32 stations sampled for sucker These findings are consistent with those of Anthony et al. (1993) who suggested that relatively low reproductive success of bald eagles in the Columbia River estuary was linked to accumulation of DDT and PCB compounds, and possibly dioxin, via consumption of contaminated prey species. Clearly, no indication of the broad distribution of PCBs and levels of potential concern would have been noted if the reconnaissance level study had focused on sediment sampling only.

6.0 CONCLUSIONS

The 1991 and 1993 lower Columbia River reconnaissance surveys were designed to provide a preliminary assessment of water quality in the 146 mile stretch of river between the Bonneville Dam and the Pacific Ocean The results of the two surveys were compared to determine whether backwater areas with fine-grained sediments sampled in 1993 were generally more contaminated than the mainstem locations sampled in 1991 A summary of the results and conclusions drawn based on each of the primary objectives of the backwater reconnaissance survey are outlined below

- Extend the water quality database of the 1991 reconnaissance survey to additional fresh-water and estuarine backwater areas with fine-grained sediments

Water column, sediment, and aquatic biota samples were collected for the 1993 backwater survey from fifteen stations with relatively fine-grained sediments. Water samples were analyzed for field-measured and conventional parameters (e.g , dissolved oxygen and particulate organic carbon), nutrients and chlorophyll *a*, metals, and indicator bacteria. Surficial sediment composites and whole-body composite samples of crayfish, largescale sucker, and carp were analyzed for conventional parameters, metals (and cyanide in sediments), semi-volatile organic compounds, pesticides and PCBs, dioxins and furans, butyltin compounds, and selected long-lived radionuclides. Sediment toxicity tests were also performed on composite sediment samples.

In general, sediment concentrations of toxic pollutants in the fine-grained backwater sediments were relatively similar to the concentrations in the more coarse-grained sediments of the original reconnaissance survey.

- Expand the list of analytes to include additional contaminants of concern based on results of the 1991 reconnaissance survey.

Water column sample analyses for dissolved (i e , filtered) metals were added to provide data for comparison with Washington's dissolved metals standards Dissolved concentrations of cadmium, copper, lead, nickel, and zinc did not exceed the Washington standards for the dissolved concentrations of these metals. Water column sampling for the indicator bacterium *Escherichia coli* was also added. Concentrations of this indicator did not exceed the EPA-recommended criterion of 126 organisms per 100 mL at any station sampled in 1993

Thirteen additional parameters (chromium, three butyltin compounds, and eight long-lived radionuclides) were analyzed in tissue samples collected for the backwater survey Chromium, 2 of the 3 butyltin compounds (di- and tributyltin), and 3 of the 8 long-lived radionuclides were detected in tissue samples However, no reference values were available for evaluating the potential adverse effects of the measured tissue concentrations on aquatic organisms or wildlife

□ Measure and evaluate the toxicity of Columbia River sediments using established bioassay protocols, as a tool for assessing/interpreting the results of sediment chemistry analyses

Sediment toxicity was assessed using two tests, the solid-phase Microtox- toxicity test and the 10-day amphipod (*Hyalella azteca*) toxicity test. Results were mixed. the *Hyalella* test showed no sediment samples to be toxic, while the Microtox_ text initially identified five stations as toxic compared to the established reference station (in a stretch of the river judged to be "clean"). Further statistical testing did not show these elevated toxicities to be significant, nor were their measured levels of specific contaminants high enough to single them out as being potentially more toxic overall Except for one station located in the estuary (Youngs Bay), sediment toxicities did not exceed reference values

□ Confirm the results of the 1991 reconnaissance survey for a limited number of fine-grained sediment/backwater locations to confirm results of the 1991 reconnaissance survey.

In order to make comparisons, three areas were used as sampling stations for both surveys: Youngs Bay, Carrolls Channel, and Camas Slough. Sediment and tissue samples from these three sites were compared, but not water column data. The highly transient nature of river water precludes meaningful comparisons of the relatively limited water column data collected.

In general, the sediments sampled at these three stations contained similar concentrations of contaminants in the two surveys when differences in sediment grain size, organic carbon content, and laboratory detection limits between the two studies are considered. One exception two dioxin congeners measured considerable lower in the 1993 backwater survey (1,2,3,4,6,7,8-HpCDD and OCDD).

Crayfish and largescale sucker were collected from Carrolls Channel and Camas Slough for both surveys In general, tissue burdens of contaminants were similar, considering differences in laboratory detection limits between surveys However, two furan congeners (1,2,3,7,8-PeCDF and 1,2,3,7,8,9-HxCDF) measured higher in largescale sucker samples in 1993, on both bulk tissue and lipid-normalized bases

- Evaluate the potential for adverse effects to aquatic biota and wildlife using screening level concentrations adopted for the measured levels of water, sediment, and tissue contaminants.

<u>Water Column Quality</u>--EPA criteria and Washington and Oregon state water quality standards were used as screening levels to assess potential adverse effects from contaminants in water samples The parameters measured which exceeded screening levels include chlorophyll *a*, dissolved oxygen, dissolved oxygen percent saturation, pH, temperature, fecal coliform bacteria, and some metals (aluminum, copper, iron, lead, mercury, and silver).

Temperature and pH standards were only exceeded at backwater survey stations. This is probably due to warmer summer temperatures, higher primary productivity, and the more limited water exchange in backwater areas. Exceeding Washington's 20° C water temperature standard has already been recognized as a chronic problem in the lower Columbia. The degree to which these exceedances are due to pollutant discharges and/or human-induced changes in river flow has not been determined.

Water quality standards for dissolved oxygen were also exceeded in 1991 at a number of locations. The most serious exceedances were below Skamokawa, WA sampled in 1991 in Burke Slough (RM 81) in 1993. Higher pH concentrations in 1993 generally coincided with relatively high dissolved oxygen concentrations. This indicates that the high pH was probable due to high summer primary productivity of algae and aquatic plants, which has been noted in historical studies of the mainstem of the lower river

Although there are currently no reference levels to assess the environmental significance of the nutrient levels measured in the backwater survey, the concentrations of phosphorus and nitrogen approached levels that, given enough light and calm water can cause nuisance algal blooms in lakes (Hileman et al. 1975; Welch 1980) These blooms can adversely effect aquatic life by depleting oxygen and affect the aesthetic quality of the water for human uses Chlorophyll *a* concentrations measured in backwater areas in 1993 also exceeded Oregon's action level of 15 µg/L at 5 of the 15 locations (see Figure 5-1). It is possible that the relatively high concentrations of algae present are not nuisance blue-green forms; additional sampling (including algal species identification and enumeration) could be conducted to assess the potential impairment of these backwater areas of the river. The degree to which nutrient levels have been elevated due to pollutant inputs has not been determined.

Relatively limited sampling for indicator bacteria was conducted for the backwater survey, precluding adequate comparison to previous reconnaissance studies performed by Tetra Tech in 1991 and the Washington Department of Ecology in 1992 Future studies of bacteria should focus on the season in which recreational use of the river is greatest, and include sampling for both enterococcus and *E. coli*, indicator bacteria that have been recommended by EPA and are currently being considered for incorporation into state water quality regulations in Oregon.

The metals that frequently exceeded chronic water quality criteria or standards, and therefore present a potential for chronic toxicity to aquatic organisms include aluminum, iron, copper, and lead However, water column concentrations of aluminum and iron are likely distributed primarily in mineral and particulate forms that are not readily available to aquatic biota: dissolved concentrations for both of these metals were low, consistently below available criteria and standards. The fact that the dissolved concentrations of copper and lead were also generally below the detection limits, and below Washington's dissolved metals standards for copper and lead, further indicates that these metals may not pose a chronic problem for aquatic biota The degree to which metals levels have been elevated due to pollutant inputs has not been determined.

Additional water column sampling of metals should focus on aluminum, iron, copper, and lead, and include an assessment of the potentially toxic forms and concentrations of these metals. Further analyses of mercury and silver are also warranted, but will require more sensitive (and probably more costly) analytic methode to achieve the low detection limits necessary for these metals.

Sediment Quality--Fewer criteria, standards, or guidelines are available to evaluate sediment quality However, freshwater sediment criteria and standards are in the development process or have been adopted by resource agencies (e g , New York State Department of Environmental Conservation and Ontario Ministry of the Environment) Long and Morgan (1990) have developed screening concentrations for the National Oceanic and Atmospheric Administration (NOAA) as part of the National Status and Trends Program The states of Washington and Oregon do not presently have draft or final freshwater sediment criteria, although the Washington Department of Ecology (WDOE) is in the process of developing freshwater sediment criteria for the protection of benthic organisms and human health. Therefore, the lowest effects-based concentrations available from the sources identified above were used as reference values to identify potential problem areas and chemicals based on the reconnaissance survey sediment data.

Sediment analytes for the backwater survey that exceeded reference levels include arsenic, cadmium, chromium, copper, iron, mercury, nickel, silver, and zinc, cyanide, p,p'-DDD, and p,p'-DDT (see Figure 5-38).

Except for metals, contaminants detected in lower Columbia River sediments did not appear to be more concentrated in the relatively finer-grained sediments that were collected from backwaters. The use of metal normalization techniques to account for the general association of trace metals with the fine sediment revealed potential human-caused elevation of several metals in both fine backwater sediments (e.g., arsenic) and in relatively coarse-grained mainstem sediments (e g , copper) Although a relationship with sediment organic carbon content was found for at least a few PAHs, the highest PAH concentrations did not occur in backwater areas with higher sediment TOC content, the high concentrations of PAHs occurred instead in the vicinity of urban and industrial sources of these compounds Sediment pesticides were detected relatively infrequently throughout the study area in both surveys at relatively low concentrations, probably from diffuse agricultural sources located in upper and lower river tributary basins as well as local nearshore sources. PCBs were also detected infrequently; the highest sediment PCB concentration was measured near urban and industrial sources of these compounds near Longview

The highest concentrations of dioxins and furans occurred below bleach kraft pulp and paper mills that are known sources of these compounds. Although butyltin compounds were detected relatively frequently, the potential environmental significance of the sediment concentrations measured cannot be determined and may warrant further study The selected long-lived radionuclides analyzed for the 1993 survey were generally detected infrequently Although the potential environmental significance of the levels detected cannot be assessed, the maximum concentrations measured are generally lower than or similar to concentrations measured above Hanford—the largest potential direct source of these radionuclides in the river basin.

Biota Tissue Quality--Even more limited criteria, standards, or guidelines are available to assess tissue burdens of contaminants for potential adverse effects. The guidelines used in this study primarily address chlorinated organic compounds (chlorinated semi-volatile compounds, pesticides, PCBs, and dioxin) and were developed by Newell et al. (1987) for the Niagara River Biota Contaminant Project. These guidelines are for the protection of fish-eating wildlife. Selenium guidelines for the dietary toxicity threshold for fish and wildlife, and the health and reproductive success of freshwater and anadromous fish suggested by Lemly (1993) were also adopted for use in evaluating survey data.

Compared to fish, crayfish samples contained relatively few organic compounds, but more trace metal, and at higher concentrations. The compounds that were frequently detected in tissue samples included barium, cadmium, chromium, copper, lead, mercury, zinc, p,p'-DDD, p,p'-DDE, p,p'-DDT, Arochlor 1254, dioxins and furans, and tributyltin.

Dioxin and total PCBs exceeded reference levels occurred at 7 of the 15 stations sampled (see Figure 5-44). Adverse effects on fish-eating wildlife are possible based on the concentrations detected Dioxin and furan reference levels were exceeded in a crayfish sample from Elochoman Slough and a largescale sucker sample from Youngs Bay Reference levels for total PCBs were exceeded in largescale sucker samples from five stations: Youngs Bay, Cathlamet Bay, Scappoose Bay, and Camas Slough.

The reconnaissance survey results were generally similar to concentrations of these compounds measured in national studies conducted by the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service. It is difficult to assess the potential adverse effects of the measured levels of most of the contaminants detected in tissue samples due to the very limited criteria or guidelines currently available for these substances.

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