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

Prepared in cooperation with
The Unified Sewerage Agency of Washington County, Oregon

Selected Elements and Organic Chemicals in Bed Sediment and Tissue of the Tualatin River Basin, Oregon, 1992–96

Water-Resources Investigations Report 99–4107

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U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

Front cover photographs: Left, Gales Creek near Glenwood is in the Coast Range Mountains and serves as a reference site for the Tualatin River Basin; upper right, bed sediment is composited before analysis; lower right, a Torrent sculpin is collected for tissue analysis.

All photographs by Dennis A. Wentz, U.S. Geological Survey

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CONCENTRATION UNITS

Abbreviation	Unit	Equivalent dimensionless unit
%	percent	parts per hundred
mg/g	milligram per gram	parts per thousand
μg/g	microgram per gram	parts per million
ng/g	nanogram per gram	parts per trillion

LENGTH UNITS

Abbreviation	Unit	Definition
mm	millimeter	10^{-3} meter
μm	micrometer	10^{-6} meter

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BY BERNADINE A. BONN

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CONTENTS

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By Bernadine A. Bonn

SIGNIFICANT FINDINGS

- Concentrations of trace elements in Tualatin Basin sediments and fish tissue, including arsenic, chromium, copper, lead, mercury, nickel, selenium, and zinc, were generally similar to those found in the Willamette Basin and were toward the lower end of the range of national concentrations.
- No exceedances of U.S. Environmental Protection Agency (USEPA) Tier 1 sediment screening values for any trace element were observed in the Tualatin Basin.
- Concentrations of chromium, copper, and nickel exceeded USEPA Tier 2 screening values at all sites in the basin. Copper and nickel concentrations were highest at the background sites and probably were related to basin geology.
- Polyaromatic hydrocarbons (PAHs) were detected more frequently in Tualatin Basin sediment than in either the Willamette Basin or the Nation. The higher frequency of PAH detection in the Tualatin Basin probably occurs because of the large number of urban sites in the basin. When detected, however, PAH concentrations in the Tualatin Basin sediments were similar to those observed elsewhere.
- In general, few organochlorine pesticides were detected in bed sediment or tissue in the Tualatin Basin. Chlordanes and *p,p'*-DDE were commonly detected in both sediment and fish tissue. Dieldrin was also commonly detected in fish tissue.
- Correlations of concentrations in bed sediment with those in tissue were poor for most elements and weak, at best, for organochlorine compounds. Concentrations of organochlorine compounds in tissue usually exceeded those in bed sediment concentrations by at least tenfold.
- Contamination patterns that were consistent with urban sources—high concentrations of PAHs, lead, and some phthalates—were found at Ash Creek at Greenburg Road, Fanno Creek at Nicol Road, Fanno Creek at Denny Road, and McKay Creek at Hornecker Road.
- High levels of organochlorine pesticides in both sediment and fish tissue were found at two sites in largely residential areas (Fanno Creek at Nicol Road and Fanno Creek at Denny Road). Concentrations of total chlordane, dieldrin, and p,p'-DDE in sediment at these sites exceeded USEPA Tier 2 screening values. Concentrations of total chlordane in fish tissue exceeded both the National Academy of Science/National Academy of Engineering (NAS/NAE) guidelines and the New York State criteria. Organochlorine concentrations were much lower downstream of these sites where the land use changed to light industrial; concentrations of trace elements, however, increased.
- The most contaminated bed sediment found in this study was collected from the most urban site (Beaverton Creek at Cedar Hills Boulevard). USEPA sediment screening values were exceeded for four organochlorine pesticides, six polyaromatic PAHs, two phthalates, *p*-cresol, and eight metals (including arsenic, cadmium, lead, and mercury). Levels of polychlorinated biphenyls in the few fish found at this site exceeded the NAS/NAE guidelines for fish tissue.

INTRODUCTION

A variety of elements and organic compounds have entered the environment as a result of human activities. Such substances find their way to aquatic sediments from direct discharges to waterways, atmospheric emissions, and runoff. Some of these chemicals are known to harm fish or wildlife, either by direct toxicity, by reducing viability, or by limiting reproductive success. In aquatic systems, sediments become the eventual sink for most of these chemicals. Analyzing the sediments provides a first step in a chemical inventory that can lead to an assessment of potential biological impacts (Kennicutt and others, 1994).

Many elements (iron, aluminum, calcium, and others) enter the environment from the natural weathering of rock. Additional amounts of elements have been contributed by human activities such as mining, metals production and processing, fossil fuel combustion, municipal waste incineration, and transportation-related sources. The environmental presence of some elements, such as lead and mercury, is almost entirely due to human activity. Lead is often associated with the use of leaded gasoline and from the manufacture and disposal of lead storage batteries. Mercury was used historically in a variety of industrial processes and as a pesticide. Nriagu and Pacyna (1998) concluded that human activity is the “most important element in the global biogeochemical cycling of the trace metals.”

The number of organic compounds in existence and their total production has more than tripled in the last century. Many of these compounds enter the environment directly as pesticides; others are inadvertently discharged. Some organic compounds have natural sources. Three general classes of organic compounds will be discussed: organochlorine compounds, polyaromatic hydrocarbons, and phthalates.

Almost all organochlorine compounds are man-made. Many are pesticides that were used widely in the 1950s–60s (DDT and chlordanes, for example). Use of most organochlorine pesticides was restricted or banned in the United States in the 1970s–80s. Polychlorinated biphenyls (PCBs) are also organochlorine compounds; they were used for a variety of applications, but most commonly as insulators in electrical transformers and other equipment. In general, organochlorine compounds degrade very slowly in the environment and therefore, are routinely found in environmental samples, despite the fact that they are no longer used in the United States. They are hydrophobic, that is they do not dissolve readily in water and, in aquatic systems, are almost exclusively associated with sediments or tissue. Because these compounds cause a variety of adverse health effects in wildlife, the U.S. Environmental Protection Agency (USEPA) has listed many as priority pollutants. Organochlorine compounds also have been implicated as endocrine disrupters—chemicals that can interfere with the normal function of hormones.

Polyaromatic hydrocarbons (PAHs) are found in sediments throughout the world (Hites and others, 1980). Their presence is thought to be primarily anthropogenic. PAHs occur naturally in petroleum products and also are produced during combustion. They enter the environment from fuel spills, tar coatings, coal and other fossil fuel usage, road dust, and from the atmospheric deposition of combustion products (Prahl and others, 1984; Wakeham and others, 1980). Urban areas often have high concentrations of PAHs because of transportation-related sources (vehicle exhaust, paving materials, and releases of fuel or oil). Natural sources, such as forest fires, may contribute small amounts of PAHs. Several PAHs are known carcinogens (benzo[*a*]pyrene, for example); 16 are listed as USEPA priority pollutants.

Phthalate compounds are often associated with urban areas. They are used in a wide variety of industrial applications and in inks, adhesives, resins, and as plasticizers (chemicals that increase the flexibility of plastics). In aquatic systems, phthalates are found mostly in sediments where they degrade very slowly. Phthalates are thought to be endocrine disrupters; Jobling and others (1995) found that some phthalates were weakly estrogenic. USEPA considers some phthalates to be possible carcinogens.

This report describes the results of a reconnaissance survey of elements and organic compounds found in bed sediment and fish tissue in streams of the Tualatin River Basin. The basin is in northwestern Oregon to the west of the Portland metropolitan area (fig. 1). The Tualatin River flows for about 80 miles, draining an area of about 712 square miles, before it enters the Willamette River. Land use in the basin changes from mostly forested in the headwaters, to mixed forest and agriculture, to predominately urban. The basin supports a growing population of more than 350,000 people, most of whom live in lower parts of the basin. Water quality in the Tualatin River and its tributaries is expected to be affected by the increasing urbanization of the basin.

STUDY PURPOSE AND DESIGN

The U.S. Geological Survey (USGS) has worked cooperatively with the Unified Sewerage Agency of Washington County (USA) since 1990 to assess water quality in the Tualatin River Basin. This study, a reconnaissance survey of contaminants in bed sediment and fish tissue in the basin, was done as part of that work. The objectives of this study were to:

- assess the occurrence and magnitude of trace element and selected organic contaminants in streams of the Tualatin River Basin,
- compare contaminant levels found in Tualatin River Basin streams with published guidelines for the protection of aquatic life,
- place the contaminant levels found in the Tualatin River Basin streams in context, regionally and nationally, by comparing them with those found in the Willamette Basin and by the USGS National Water-Quality Assessment (NAWQA) Program,
- compare contaminant concentrations in bed sediment with those in fish tissue, and
- identify contaminant patterns that would help managers make decisions regarding future monitoring and the implementation of pollution prevention and abatement programs.

This study began in 1992 as a survey of contaminants in bed sediment. It was expanded in 1996 to include the analysis of fish tissue. Two more sites were added at that time. In addition, this study was designed to utilize data that had been collected in the basin in 1992–93 by the NAWQA Program.

Sample collection and processing

Bed sediment samples were collected from 15 sites in the Tualatin Basin; fish tissue samples were collected at 9 sites (fig. 1, table 1). Many of the sampled streams drain largely urban areas that include a mixture of commercial and residential land. Chicken, Dairy, and McKay Creeks are the only sampled streams with appreciable agricultural land in their basins that do not also have significant urban influences. Gales Creek drains mostly forested land and is minimally affected by anthropogenic inputs; it represents background concentrations.

At wadeable sites, the top 1–2 cm of fine grained sediment was collected with a Teflon scoop. Sediment was removed from several depositional areas within a reach and composited. At nonwadeable sites (Tualatin River above Dairy Creek and Tualatin River at Elsner Road), the same approach was used, except that the method was applied to sediment sections that had been obtained using an Eckman dredge. In all cases, about 8 L of wet sediment was collected from each site. The reach length sampled varied among sites from about 40 to 1,200 ft. Sediment samples destined for organics analysis were sieved through a 2-mm stainless steel sieve to remove twigs, pebbles, and other debris. Samples destined for elemental analysis were sieved through a 63 µm nylon screen to remove the sand fraction as well as larger debris. Because trace elements are not expected to significantly sorb to the sand-sized fraction, sieving at 63 µm effectively “normalizes” samples to the size fraction having the highest concentrations of trace elements. Samples were kept at 4 °C until analysis. The sediment collection and preparation method is described in detail by Shelton and Capel (1994).

Fish were collected by electrofishing and then euthanized by a sharp blow to the head. Each sample consisted of 4–20 whole fish. All fish were sculpin. Samples destined for elemental analysis were placed in resealable polyethylene freezer bags; samples destined for organics analysis were wrapped in aluminum foil. All samples were frozen until analysis. The fish were thawed, homogenized, and subsampled by the USGS National Water Quality Laboratory (Arvada, Colorado).

Chemical analyses

Sediment samples were analyzed for major and minor elements, organochlorine pesticides, pesticide metabolites, PCBs, and semivolatile organic compounds such as PAHs, phthalates, and phenols. Fish tissue samples were analyzed for major and minor elements, organochlorine pesticides, pesticide metabolites, and PCBs. The chemical analyses and analytical methods are summarized in table 2. In addition, for sediment samples, organic carbon content and fraction of grain size less than 63 µm were determined; for fish samples, lipid content and moisture content were determined. All analyses were performed by the USGS. Elemental analyses of sediment were done by the Geologic Division Laboratory (Lakewood, Colorado); sediment size fraction analyses were done by the laboratory at the Cascades Volcano Observatory (Vancouver, Washington); all other analyses were done by the National Water Quality Laboratory.

Censored semiquantitative data— Nondetection of an analyte in a sample does not indicate that the concentration of the analyte in the sample equalled zero. The smaller the concentration of analyte in a sample, the greater the chance that it will not be detected even if it is present. Different types of statistics were used to communicate the analytical limits of different methods.

A minimum reporting level (MRL) was used for elements, organochlorine pesticides, and PCBs. Data for these analytes are censored at the MRL; that is, concentrations less than the MRL are reported as nondetections. When the concentration is greater than or equal to the MRL, the sample is assumed to be reliably different from a blank sample. When the analyte is not detected in the sample, the concentration is assumed to be less than the MRL. MRLs are based on a variety of factors, including method performance and analyst judgement.

A method detection limit (MDL) was used for semivolatile compounds, such as PAHs, phthalates, and phenols. Unlike the MRL, the MDL does not censor

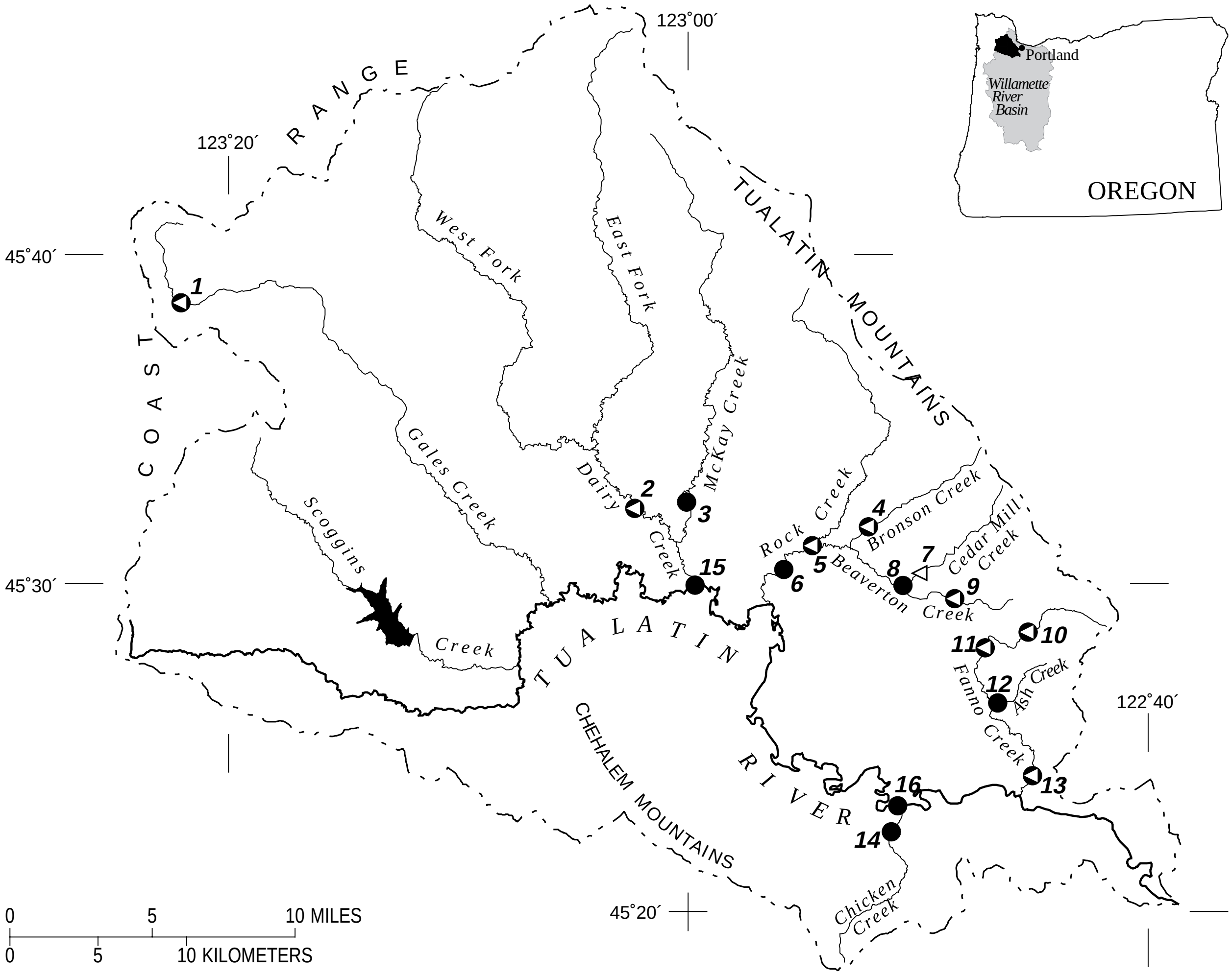


Figure 1. Map of Tualatin River Basin with locations of sampling sites. Sample types are ● bed sediment, ◁ fish tissue, and ◀ both bed sediment and fish tissue. See table 1 for site names and sample details. (Map modified from 1:100,000 Digital Line Graphs (DLGs) and other digital sources. Universal Transverse Mercator projection, Zone 10, North American Datum 1927.)

data; that is, concentrations less than the MDL may be reported. In addition, the MDL is statistically based. The chance of a blank sample being reported as a concentration greater than the MDL (a false positive) is no more than 1 percent. Concentrations less than the MDL are reported if observed; however, they have a greater chance of being false positives. The concentration of an analyte that was not detected in a sample is assumed to be less than 2×MDL (2 times the MDL). The chance of not detecting analyte in a sample with a true concentration equal to 2×MDL is no more than 1 percent. Reported concentrations that are less than the 2×MDL are semiquantitative—that is, they have greater uncertainty than higher concentrations. MDLs are calculated from the standard deviation of laboratory replicates. The concentration of replicates used to determine the MDLs given in this report was higher than optimal and therefore the MDLs also may be slightly high (Furlong and others, 1996).

Table 1. Sampling summary

[Abbreviations: mi^2, square miles; agri, agricultural land; —, not sampled. Land use percentages may not add to 100 due to rounding.]

Map ID	Site Name	Drainage Area (mi^2)	Land Use (percent)			Sampling Dates and Media	
			Urban	Agri	Forest	Bed Sediment	Tissue
12	Ash Cr at Greenburg Rd	4.0	100	0	0	9/92	—
9	Beaverton Cr at Cedar Hills Blvd	6.2	98	0	2	8/96*	9/96*
4	Bronson Cr at Walker Rd	4.5	54	22	23	9/92	8/96
7	Cedar Mill Cr at Jenkins Rd	8.1	78	4	18	—	9/96
8	Cedar Mill Cr at mouth	8.5	75	6	20	9/92	—
14	Chicken Cr near Sherwood	15.3	6	65	29	9/92	—
2	Dairy Cr at Susbauer Rd	150.1	1	35	64	9/92	8/96*
11	Fanno Cr near Denny Rd	9.6	100	0	0	9/96*	9/96*
13	Fanno Cr at Durham Rd	31.0	92	2	5	9/92, 10/93*	9/92, 9/93*, 8/96
10	Upper Fanno Cr at Nicol Rd	6.6	100	0	0	9/92	8/96
1	Gales Cr near Glenwood	7.0	0	0	100	9/92	9/92, 9/96
3	McKay Cr at Hornecker Rd	61.4	5	42	53	9/92	—
6	Lower Rock Cr at Brookwood Rd	63.0	56	26	17	9/92*	—
5	Upper Rock Cr at Baseline Rd	26.3	26	42	32	9/92	8/96
15	Tualatin R above Dairy Cr	230.3	3	26	71	9/92	—
16	Tualatin R at Elsner Rd	586.6	9	38	53	9/92	—

*Replicate samples were obtained.

Table 2. Elements and compounds analyzed in this study

[Shaded areas indicate that the medium was analyzed for the listed element or compound; ● indicates that a guideline or criterion exists for this analyte–medium combination and is given in this report (see table 5); letters identify the analytical method (see footnotes); — indicates that no CAS number exists for the given analyte. Abbreviations: Sed, sediment; Tis, tissue; CAS, Chemical Abstracts Service registry number.]

Analyte name (s)	Sed	Tis	CAS
Major elements			
aluminum (Al)	a	g3	7429–90–5
calcium (Ca)	a		7440–70–2
iron (Fe)	a	g1	7439–89–6
magnesium (Mg)	a		7439–95–4
phosphorus (P)	a		7723–14–0
potassium (K)	a		7440–09–7
sodium (Na)	a		7440–23–5
sulfur (S)	e		7704–34–9
titanium (Ti)	a		7440–32–6
Minor elements			
antimony (Sb)	●, b	g2	7440–36–0
arsenic (As)	●, b	g2	7440–38–2
barium (Ba)	a	g3	7440–39–3
beryllium (Be)	a	g3	7440–41–7
bismuth (Bi)	a		7440–69–9
boron (B)		g1	7440–42–8
cadmium (Cd)	●, c	g3	7440–43–9
cerium (Ce)	a		7440–45–1
chromium (Cr)	●, a	g3	7440–47–3
cobalt (Co)	a	g2	7440–48–4
copper (Cu)	●, a	g3	7440–50–8
europium (Eu)	a		7440–53–1
gallium (Ga)	a		7440–53–3
gold (Au)	a		7440–57–5
holmium (Ho)	a		7440–60–0
lanthanum (La)	a		7439–91–0
lead (Pb)	●, a	g3	7439–92–1
lithium (Li)	a		7439–93–2
manganese (Mn)	a	g3	7439–96–5
mercury (Hg)	●, d	●, g4	7439–96–5
molybdenum (Mo)	a	g3	7439–98–7
neodymium (Nd)	a		7440–00–8
nickel (Ni)	●, a	g3	7440–02–0
niobium (Nb)	a		7440–03–1
scandium (Sc)	a		7440–20–2
selenium (Se)	b	g2	7782–49–2
silver (Ag)	●, c	g3	7440–22–4
strontium (Sr)	a	g1	7440–24–6
tantalum (Ta)	a		7440–25–7
thorium (Th)	f		7440–29–1
tin (Sn)	a		7440–31–5
uranium (U)	f	g2	7440–61–1
vanadium (V)	a	g2	7440–62–2
ytterbium (Yb)	a		7440–64–4
yttrium (Y)	a		7440–65–5
zinc (Zn)	●, a	g3	7440–66–6
Organochlorine pesticides			
aldrin	h	●, i	309–00–2
cis-chlordane	●, h	●, i	5103–71–9
trans-chlordane	●, h	●, i	5103–74–2
chlorneb (Demosan, Soil fungicide 1823)	h		2675–77–6
dacthal (DCPA, chlorthaldimethyl)	h	i	1862–32–1
o,p’-DDD (*o,p’*-DDT metabolite)		i	53–19–0
p,p’-DDD (*p,p’*-DDT metabolite)		i	72–54–8
o,p’-DDE (*p,p’*-DDT metabolite)	●, h	i	3424–82–6
p,p’-DDE (*o,p’*-DDT metabolite)	●, h	●, i	72–55–9
o,p’-DDT		i	789–02–6
p,p’-DDT		i	50–29–3
dieldrin	●, h	●, i	60–57–1
endosulfan I (α-endosulfan, Thiodan)	●, h		959–98–8
endrin	●, h	●, i	72–20–8
α-HCH (α-Lindane, *alpha*-hexachlorocylohexane, α-BHC)	●, h	i	319–84–6
β-HCH (*beta*-hexachlorocylohexane, β-BHC)	●, h	i	319–85–7
δ-HCH (*delta*-hexachlorocylohexane, δ-BHC)		i	319–86–8
γ-HCH (Lindane, *gamma*-hexachlorocylohexane, γ-BHC)	●, h	i	58–89–9
heptachlor (Velsicol 104)	h	●, i	76–44–8
heptachlor epoxide (heptachlor metabolite)	h	●, i	1024–57–3
isodrin (Compound 711)	h		465–73–6
o,p’-methoxychlor	h	i	30667–99–3
p,p’-methoxychlor (Marlate)	●, h	i	72–43–5
mirex (dechlorane)	h	●, i	2385–85–5
cis-nonachlor	●, h	i	5103–73–1
trans-nonachlor	●, h	i	39765–80–5
oxychlordane	●, h	i	27304–13–8
cis-permethrin (Ambush, Astro, Pounce, Pramex, Pertox, Ambush-Fog, Kafil, Perthrine, Picket, Picket-G, Dragnet, Talcord, Outflank, Stockade, Elsmin, Coopex, Peregin, Stomoxin, Stomoxin P, Qamlin, Corsair, Tornade)	h		61949–76–6
trans-permethrin (same trade names as for *cis*-permethrin)	h		61949–77–7
toxaphene	●, h	i	8001–35–2
PAHs (polyaromatic hydrocarbons)			
acenaphthene	●, j		83–32–9
acenaphthylene	●, j		208–96–8
anthracene	●, j		120–12–7
benz[*a*]anthracene	●, j		56–55–3
benzo[*a*]pyrene	●, j		50–32–8
benzo[*b*]fluoranthene	●, j		205–99–2
benzo[*ghi*]perylene	●, j		191–24–2
benzo[*k*]fluoranthene	●, j		207–08–9
chrysene	●, j		218–01–9
dibenz[*a,h*]anthracene	●, j		53–70–3
fluoranthene	●, j		206–44–0
9H-fluorene	●, j		86–73–7
indeno[1,2,3-*cd*]pyrene	●, j		193–39–5
naphthalene	●, j		91–20–3
phenanthrene	●, j		85–01–8
pyrene	●, j		129–00–0

Table 2. Elements and compounds analyzed in this study—Continued

[Shaded areas indicate that the medium was analyzed for the listed element or compound; ● indicates that a guideline or criterion exists for this analyte–medium combination and is given in this report (see table 5); letters identify the analytical method (see footnotes); — indicates that no CAS number exists for the given analyte. Abbreviations: Sed, sediment; Tis, tissue; CAS, Chemical Abstracts Service registry number.]

Analyte name (s)	Sed	Tis	CAS
Alkyl-PAHs			
1,2-dimethylnaphthalene	j		573–98–8
1,6-dimethylnaphthalene	j		575–43–9
2,6-dimethylnaphthalene	j		581–42–0
2-ethylnaphthalene	j		939–27–5
1-methyl-9H-fluorene	j		1730–37–6
1-methylphenanthrene	j		832–69–9
1-methylpyrene	j		2381–21–7
2-methylanthracene	j		613–12–7
4,5-methylenephenanthrene	j		203–64–5
2,3,6-trimethylnaphthalene	j		829–26–5
Azaarines			
acridine	j		260–94–6
benzo[*c*]cinnoline	j		230–17–1
2,2'-biquinoline	j		119–91–5
9H-carbazole	j		86–74–8
isoquinoline	j		119–65–3
phenanthridine	j		229–87–8
quinoline	j		91–22–5
Phthalates			
bis(2-ethylhexyl)phthalate	●, j		117–81–7
butylbenzylphthalate	●, j		85–68–7
diethylphthalate	●, j		84–66–2
dimethylphthalate	●, j		131–11–3
di-*n*-butylphthalate	●, j		84–74–2
di-*n*-octylphthalate	●, j		117–84–0

Analyte name (s)	Sed	Tis	CAS
Phenols			
C8-alkylphenol	j		—
2-chlorophenol	j		95–57–8
4-chloro-3-methylphenol	j		59–50–7
p-cresol	●, j		106–44–5
3,5-dimethylphenol	j		108–68–9
phenol	●, j		108–95–2
Chlorinated aromatic compounds			
2-chloronaphthalene	j		91–58–7
1,2-dichlorobenzene	●, j		95–50–1
1,3-dichlorobenzene	●, j		541–73–1
1,4-dichlorobenzene	●, j		106–46–7
hexachlorobenzene	●, h	●, i	118–74–1
pentachloroanisole	h	i	1827–21–4
pentachloronitrobenzene	j		82–68–5
polychlorinated biphenyls (total-PCB)	●, h	●, i	—
1,2,4-trichlorobenzene	●, j		120–82–1
Other			
anthraquinone	j		84–65–1
azobenzene	j		103–33–3
bis(2-chloroethoxy)methane	j		111–91–1
4-bromophenyl-phenylether	●, j		101–55–3
4-chlorophenyl-phenylether	j		7005–72–3
dibenzothiophene	j		132–65–0
2,4-dinitrotoluene	j		121–14–2
isophorone	j		78–79–1
nitrobenzene	j		98–95–3
N-nitrosodiphenylamine	●, j		86–30–6
N-nitrosodi-*n*-propylamine	j		621–64–7

a—Homogenized bed sediment was digested using a mixture of hydrochloric, nitric, perchloric and hydrofluoric acids at low temperature. The resulting solution was evaporated to dryness, dissolved in aqua regia, and analyzed by ICP-AES (inductively coupled plasma/atomic emission spectrometry). (Briggs, 1990)

b—Homogenized bed sediment was digested using a mixture of nitric, perchloric and hydrofluoric acids at 105–110°C. The resulting solution was analyzed by HG-AAS (hydride generation atomic absorption spectrophotometry). (Welsch and others, 1990)

c—Homogenized bed sediment was digested with hydrofluoric acid, hydrochloric acid, and hydrogen peroxide. The resulting solution was extracted into an organic phase which was analyzed using FAA (flame atomic absorption spectrometry). (O'Leary and Viets, 1986).

d—Homogenized bed sediment was digested using nitric acid and sodium dichromate. Mercury in the digest was reduced to elemental form and analyzed by continuous-flow CV-AAS (cold-vapor atomic absorption spectrophotometry). (O'Leary and others, 1990)

e—Homogenized bed sediment was analyzed by combustion with infrared absorption detection using an automated sulfur analyzer. (Curry, 1990)

f—Homogenized bed sediment was irradiated with neutrons. Delayed neutrons from the sample were counted. (McKown and Knight, 1990)

g—Homogenized tissue was digested using nitric acid followed by hydrogen peroxide. The resulting solution was dried, reconstituted with nitric acid and filtered. The filtrate was analyzed by (1) ICP-AES, (2) ICP-MS (inductively coupled plasma/mass spectrometry), (3) both ICP-AES and ICP-MS with the reported result depending on the magnitude of the concentration, or (4) CV-AAS. (Hoffman, 1996)

h—Homogenized bed sediment was Soxhlet extracted. Gel permeation chromatography was used to remove inorganic sulfur and large natural molecules. The extract was fractionated using alumina/silica adsorption. The extracts were analyzed by GC-ECD (gas chromatography with electron capture detection). (Foreman and others, 1995)

i—Homogenized tissue was Soxhlet extracted. Lipid was removed by gel permeation chromatography and the extract was fractionated using alumina/silica adsorption. The extracts were analyzed by GC-ECD. (Leiker and others, 1995)

j—Homogenized bed sediment was Soxhlet extracted. Gel permeation chromatography was used to remove inorganic sulfur and large natural molecules. The extract was analyzed by GC-MS (gas chromatography with mass spectrometry). (Furlong and others, 1996)

Variability— Four sets of replicate bed sediment samples were collected and analyzed. All replicate sets include the variability associated with sample preparation (homogenization, sieving) and with the chemical analysis itself. However, because the method of collection for the replicate sets varied, some sets include more sources of variability than others. For example, the replicates from the Fanno Creek at Durham site were collected from different subreaches, and therefore also include spatial variability and the variability associated with the collection of separate samples. The characteristics of the replicate sample sets are summarized and compared in table 3.

For both elements and organic chemicals, the replicate set with the greatest variability was the one that included a spatial variability component. The increased variability was conspicuous for the organic compounds; the variability in this replicate set exceeded that in all the other replicate sets for every organic compound that could be compared. Because spatial variability appears to be important, data from the Fanno Creek at Durham replicate set was averaged to make it more comparable with other samples in the data set, and the average value was used in data analysis and interpretation. The variability for the Lower Rock Creek replicate set, which incorporated a sample collection component, exceeded that of simple split replicate sets, but only for elements—not for organic compounds. The composite sample from the Lower Rock Creek replicate set was used in data analysis.

Analytical uncertainty was estimated for each analyte as the maximum range among replicate sets (other than the Fanno Creek at Durham sediment set). These values are given in Appendices B and D. For most elements in sediment, analytical uncertainty ranged from less than 5 percent to about 20 percent. Results near the reporting limits have greater uncertainty. For the organic compounds in sediment, analytical uncertainty was somewhat higher, generally 10–30 percent with greater uncertainty at low concentrations. In several instances, an individual organic analyte was detected in some, but not all, samples in the replicate set.

Replicate ranges for tissue samples were higher than those for sediment samples. For elements, ranges were about 20–200 percent; for organochlorine compounds, ranges were about 10–70 percent. Greater uncertainty for tissue samples is expected because each replicate was a composite of different individual fish (not a split of homogenized tissue) and because tissue matrices are inherently difficult to analyze. Ranges among the tissue replicate sets were not statistically different from each other.

Table 3. Comparison of replicate sediment samples

[N is the number of replicates in the set. Sets that have different group identifier letters are statistically different (α=0.05); those with the same letters are not statistically different. In this case, group A denotes the largest variability and group C denotes the least variability. Group identifiers for the elements are independent of those for the organic compounds. The procedure used to determine group identifiers is explained in detail in Appendix A.]

Replicate set			Variability				Statistical comparison (group identifier)	
Site	N	Description	Sample collection	Sample preparation	Analytical	Spatial location	Elements (36)	Organic compounds (8)
Beaverton Cr (1996)	2	Split of composite sample		×	×		C	B
Fanno Cr at Denny Rd (1996)	2	Split of composite sample		×	×		C	C
Fanno Cr at Durham Rd (1993)	3	Three composited samples obtained at three different subreaches at the same site	×	×	×	×	A	A
Lower Rock Cr (1992)	3	Two samples obtained by different personnel; third sample composite of first two	×	×	×		B	C

Contamination— Field blanks were not submitted because no suitable material exists for sediment or tissue. To assess contamination, the laboratory routinely analyzed blanks consisting of sodium sulfate. No contamination problems were reported for elements or for organochlorine pesticides. For five semivolatile organic compounds, contamination was relatively common, occurring in 30–80 percent of laboratory blanks (Lopes and others, 1998). Those compounds and the 95th percentile concentration of laboratory blank samples (B95) are bis(2-ethylhexyl)phthalate (100 ng/g), butylbenzylphthalate (64 ng/g), diethylphthalate (25 ng/g), di-*n*-butylphthalate (54 ng/g), and phenol (27 ng/g). To minimize the risk of overestimating environmental concentrations of these analytes, environmental concentrations less than the B95 value were not considered detections. Environmental concentrations greater than the B95 value were adjusted by subtracting the B95 value.

Analytical method performance— As part of the analytical method for organic compounds (organochlorine pesticides and the semivolatile compounds), environmental samples are spiked at the laboratory with several surrogate compounds. These compounds, which are often deuterated, are not expected to be present in a natural environmental sample. The percent recovery of the surrogate compounds provides an indication of the overall method performance for that sample. Surrogate recoveries cannot be used to adjust concentrations in a sample because the surrogates were not chosen to closely mimic the behavior of any individual analyte. Surrogate recoveries for bed sediment samples in this study were comparable to typical laboratory performance (table 4). Surrogate recoveries from fish tissue, however, were occasionally much poorer than typical laboratory performance, including nine instances in which the percent recovery equalled zero. All but one of these cases occurred for samples collected in 1992–1993 and analyzed when the laboratory was inexperienced in the use of this analytical method. Therefore, it is possible that the environmental concentrations measured in some of these tissue samples are biased low.

Data analysis

Comparisons to guidelines and other data—

Data obtained in this study were compared to a variety of published values (table 5). Concentrations of elements and organic compounds in bed sediment were compared to screening values used by the USEPA for

Table 4. Comparison of surrogate recovery for Tualatin data with expected laboratory performance

[Means, standard deviations, and ranges all in units of percent; N is the number of samples.]

Compound	Tualatin data				Laboratory performance			
	Mean	Standard deviation	Range	N	Mean	Standard deviation	Range	N
GC-ECD Method —Sediment (for organochlorine pesticides and total PCB)								
3,5-dichlorobiphenyl	61	5	52–71	20	61	16	11–105	121
α-HCH-d_6	71	9	40–85	20	67	14	34–110	121
PCB-204	66	12	46–85	20	74	20	32–135	119
GC-MS Method—Sediment (for semivolatile organic compounds such as PAHs, phthalates, and phenols)								
2-fluorobiphenyl	64	23	29–120	20	65	20	13–107	132
nitrobenzene-d_5	63	15	30–80	20	64	22	13–107	132
terphenyl-d_{14}	79	19	38–100	16	75	17	25–129	132
GC-ECD Method—Tissue (for organochlorine pesticides and total PCB)								
3,5-dichlorobiphenyl	41	28	0–75	17	66	22	35–113	114
α-HCH-d_6	64	40	0–95	15	76	18	11–160	121

Table 5. Screening values and guidelines for elements and organic compounds assayed in this study

[Sediment screening values from National Sediment Quality Survey (U.S. Environmental Protection Agency, 1997). Tissue guidelines from National Academy of Sciences/National Academy of Engineering (NAS/NAE, 1973), and New York State criteria (NY) for fish in the Niagara River (Newell and others, 1987). Abbreviations are as follows: μg/g org C, microgram per gram of organic carbon; μg/g, microgram per gram.]

Chemical	USEPA sediment screening values (type[a])			Fish tissue guidelines/criteria (μg/g wet weight)	
	Tier 1[b]		Tier 2[c] (μg/g)	NAS/NAE[d]	NY State[e]
	(μg/g org C)	(μg/g)			
Elements					
antimony			150 (AETL)		
arsenic		70 (ERM)	7.24 (TEL)		
cadmium[f]			0.68 (TEL)		
chromium		270 (ERM)	52.5 (TEL)		
copper[f]			18.7 (TEL)		
lead[f]			30.2 (TEL)		
mercury		0.71 (ERM)	0.13 (TEL)	0.5	
nickel[f]			15.9 (TEL)		
silver		3.7 (ERM)	0.73 (TEL)		
zinc[f]			124 (TEL)		
Organochlorine pesticides					
aldrin				0.1	
total chlordane[g]			0.00226 (TEL)	0.1	0.5
dieldrin	11 (SQC)		0.00071 (TEL)	0.1	0.12
o,p'-DDE		0.027 (ERM)	0.00207 (TEL)		
p,p'-DDE		0.027 (ERM)	0.00207 (TEL)		0.2
endosulfan I	0.29 (SQAL)			0.1	
endrin	4.2 (SQC)			0.1	0.025
α-HCH			0.00032 (TEL)		
β-HCH			0.00032 (TEL)		
γ-HCH (lindane)	0.37 (SQAL)		0.00032 (TEL)		
heptachlor				0.1	0.2
heptachlor epoxide				0.1	0.2
p,p'-methoxychlor	1.9 (SQAL)				
mirex					0.33
toxaphene	10 (SQAL)				
Polyaromatic hydrocarbons (PAHs)					
acenaphthene	130 (SQC)	0.5 (ERM)	0.00671 (TEL)		
acenaphthylene		0.64 (ERM)	0.00587 (TEL)		
anthracene		1.1 (ERM)	0.0469 (TEL)		
benz[*a*]anthracene		1.6 (ERM)	0.0748 (TEL)		
benzo[*a*]pyrene		1.6 (ERM)	0.0888 (TEL)		
benzo[*b*]fluoranthene			3.6 (AETL)		
benzo[*ghi*]perylene			0.72 (AETL)		
benzo[*k*]fluoranthene			3.6 (AETL)		
chrysene		2.8 (ERM)	0.108 (TEL)		
dibenz[*a,h*]anthracene		0.26 (ERM)	0.00622 (TEL)		
fluoranthene	620 (SQC)	5.1 (ERM)	0.113 (TEL)		
9H-fluorene	54 (SQAL)	0.54 (ERM)	0.0212 (TEL)		
indeno[1,2,3-*cd*]pyrene			0.69 (AETL)		
naphthalene	47 (SQAL)	2.1 (ERM)	0.0346 (TEL)		
phenanthrene	180 (SQC)	1.5 (ERM)	0.0867 (TEL)		
pyrene		2.6 (ERM)	0.153 (TEL)		

Table 5. Screening values and guidelines for elements and organic compounds assayed in this study—Continued

[Sediment screening values from National Sediment Quality Survey (U.S. Environmental Protection Agency, 1997). Tissue guidelines from National Academy of Sciences/National Academy of Engineering (NAS/NAE, 1973), and New York State criteria (NY) for fish in the Niagara River (Newell and others, 1987). Abbreviations are as follows: µg/g org C, microgram per gram of organic carbon; µg/g, microgram per gram.]

Chemical	USEPA sediment screening values (type[a])			Fish tissue guidelines/criteria (µg/g wet weight)	
	Tier 1[b]		Tier 2[c] (µg/g)		
	(µg/g org C)	(µg/g)		NAS/NAE[d]	NY State[e]
Phthalates					
bis(2-ethylhexyl)phthalate		2.65 (PEL)	0.182 (TEL)		
butylbenzylphthalate	1100 (SQAL)		0.9 (AETL)		
diethylphthalate	63 (SQAL)		0.2 (AETL)		
dimethylphthalate			0.16 (AETL)		
di-*n*-butylphthalate	1100 (SQAL)		1.4 (AETL)		
di-*n*-octylphthalate			6.2 (AETL)		
Phenols					
p-cresol			0.67 (AETL)		
phenol			0.42 (AETL)		
Chlorinated aromatic compounds					
1,2-dichlorobenzene	34 (SQAL)		0.05 (AETL)		
1,3-dichlorobenzene	170 (SQAL)				
1,4-dichlorobenzene	34 (SQAL)		0.05 (AETL)		
hexachlorobenzene			0.022 (AETL)		0.33
total PCB		0.189 (PEL)	0.0216 (TEL)	0.5	0.11
1,2,4-trichlorobenzene	920 (SQAL)		0.051 (AETL)		
Other organic compounds					
4-bromophenyl-phenylether	130 (SQAL)				
N-nitrosodiphenylamine			0.028 (AETL)		

a—Type refers to the original sources of the guideline, abbreviated as follows: ERM, effects range median; AETL, apparent effects threshold–low; PEL, probable effects level; TEL, threshold effects level; SQC, sediment quality criteria; SQAL, sediment quality advisory level.

b—"Tier 1" is defined by the USEPA as "associated adverse effects to aquatic life or human health are probable."

c—"Tier 2" is defined by the USEPA as "associated adverse effects to aquatic life or human health are possible, but expected infrequently."

d—"Recommended maximum tissue concentration for the protection of fish and wildlife."

e—"Criteria for the protection of piscivorous wildlife."

f—Tier 1 screening values for these elements are not given here because they based on the difference between the element concentration and the acid volatile sulfide concentration.

g—Total chlordane is the sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane.

their National Sediment Quality Inventory (U.S. Environmental Protection Agency, 1997). For the elements cadmium, copper, lead, nickel and zinc, the USEPA Tier 1 screening values are not based solely on element concentration, but also involve the acid-volatile sulfide concentration. This is because these elements form highly insoluble sulfide compounds, and therefore, have low bioavailability. The acid-volatile sulfide concentration was not measured in this study. For a few organic compounds, the organic carbon content is taken into account by using sediment quality criteria (SQCs) or sediment quality advisory levels (SQALs), both of which normalize concentrations to organic carbon. SQCs and SQALs have not been set for most organic compounds.

Relatively few guidelines exist for the concentrations of contaminants in fish tissue. Many of those that do exist pertain to human health concerns and are limited to contaminant concentrations in muscle fillets of edible fish. Such guidelines are not appropriate for this study because sculpin are not likely to be used for human consumption, and because all tissue samples analyzed in this study were whole-body. The New York State criteria (Newell and others, 1987) and the National Academy of Sciences/National Academy of Engineering (NAS/NAE) guidelines (NAS/NAE, 1973) are for the protection of fish and wildlife and therefore apply in this study.

To place the concentrations of elements and organic compounds found in the Tualatin Basin in context, in this report they will be compared to values reported for the Willamette Basin and also to a national distribution. Both the Willamette data and the national data were collected by the USGS National Water-Quality Assessment Program (NAWQA) between 1992 and 1995 (Wentz, Bonn, and others, 1998). The national distribution contains data from 20 large river basins, and includes the Willamette data. In general, both the Willamette data and the national data are from mostly agricultural sites; relatively few urban sites are included in either data set. Differences between the Tualatin data and either of these data sets may be caused by the preponderance of urban sites in the Tualatin Basin.

Influence of sample processing methods on data interpretation— Contaminant concentrations can be influenced by the methods used to collect and process samples. When comparing the data in this report to published guidelines or to data from other studies, it is important to consider differences in collection and processing methods.

Trace element concentrations reported in this study are probably higher than they would have been had the samples not been sieved at 63 µm. This is because sieving at 63 µm removes the sand-sized fraction, which is not expected to significantly sorb trace elements. The amount of material excluded from analysis by sieving at 63 µm ranged from about 20 to 80 percent, with one exception. The amount of sand-sized particles at the Gales Creek site was larger than that of any other site—93 percent.

Concentrations of organic compounds were probably not changed significantly by sieving at 2 mm. Sieving at 2 mm removes very little material—only pebbles and debris—and is not expected to alter the organic carbon content of the sample. Because samples that naturally contain more organic carbon might also contain more organic contaminants, concentrations of organic compounds are often normalized to organic carbon content. The organic carbon content of samples ranged from less than 1 percent to about 4 percent.

The USEPA sediment screening values apply to unsieved sediment samples. Because the samples analyzed for elements were sieved at 63 µm, the likelihood of exceeding a screening value is increased. It is possible for the element concentration in a sieved sample to exceed a screening value when the concentration in the unsieved sample does not. In contrast, exceedances of USEPA screening values for organic compounds are probably not changed by sieving at 2 mm.

The sample collection and processing methods used in this study were the same as those used by the NAWQA program. Therefore, comparisons between these three data sets should not be affected by sampling methods.

Statistical methods— Nonparametric procedures and statistics were used extensively in this report. Such procedures do not rely on an assumption that the data are normally distributed—an assumption that is not likely to be met. Summary statistics were generally limited to percentiles. Most correlations were performed using the Spearman rank technique; when graphical examination showed approximate linearity, Pearson correlation (a parametric method) was used.

Summary statistics were calculated using the observed data combined with “fill in” values (calculated using probability plot procedures) for nondetections (Helsel and Hirsch, 1992). This method avoids the problems of either simple substitution for nondetections or of assuming a distributional shape. When an MRL was used by the laboratory, it was used as the upper limit of nondetections to calculate summary statistics; when an MDL was used by the laboratory, 2×MDL was used as the upper limit of nondetections.

Principal components analysis— Principal components analysis (PCA) was used as an exploratory tool to reveal patterns among chemical constituents. PCA is a multivariate technique that is frequently used to reduce the dimensionality of data sets with many variables (Davis, 1973; Joliffe, 1986). Although PCA is a parametric method, its use here is limited to data exploration and not extended to modeling. All PCA were performed three ways: on raw data, on log-transformed data (to improve normality), and on data ranks (to approximate a nonparametric test). Differences among results of the three methods were negligible, indicating that any lack of normality did not alter the validity or the nature of patterns identified by PCA. Only the results from the PCA using raw data are presented in this report.

RESULTS

Overview of concentrations

Bed sediment— Summary statistics for concentrations of elements in sediment are given in table 6. Trace element concentrations were similar to those found in Willamette Basin sediment and toward the lower end of the national distribution (fig. 2). USEPA Tier 1 screening values for arsenic, chromium, and mercury were never exceeded. However, every sample, including those from the most remote sites such as Gales Creek, exceeded the Tier 2 screening values for chromium, copper, and nickel. These elements may have natural as well as anthropogenic sources. Other elements, such as lead and cadmium, also exceeded Tier 2 screening values, but only at sites with urban influences. Comparisons to Tier 1 screening values could not be made for cadmium, copper, lead, nickel, and zinc because the acid-volatile sulfide concentration was not known.

Most organochlorine compounds were not detected in Tualatin Basin sediments (table 7, p. 16-17). When organochlorines were detected, concentrations were similar to those elsewhere in the Willamette Basin and the Nation (fig. 3, p. 18-19). The most commonly detected organochlorine was p,p'-DDE, which was detected at about two-thirds of the sites. This compound is a metabolite of the insecticide DDT, which was banned from use in the United States in 1972. The fact that it is detected relatively frequently demonstrates the persistence of this family of compounds in the environment. Concentrations of p,p'-DDE were generally low, but did exceed the USEPA Tier 2 screening value at four sites. Chlordanes (*cis*- and *trans*-chlordane and *cis*- and *trans*-nonachlor) were detected at about one-third of the sites. The USEPA Tier 2 screening value for total chlordane was exceeded at five sites. Total chlordane is the sum of *cis*- and *trans*-chlordane, *cis*- and *trans*-nonachlor, and oxychlordane.

The most commonly detected semivolatile compounds were PAHs, phthalates, and *p*-cresol (table 7). PAHs were detected in sediment more frequently in the Tualatin Basin than in either the Willamette Basin or the Nation (table 8, p. 20). This is probably because the Tualatin data set contains more sites with urban influence than either the Willamette Basin or national data sets, which contained predominantly agricultural sites. The concentration data are consistent with this explanation: when PAHs were detected, concentrations in the Tualatin sediments were similar to those elsewhere (fig. 3). PAH concentrations frequently exceeded USEPA Tier 2 screening values, but never exceeded Tier 1 values.

Phthalate concentrations in Tualatin Basin sediments appear to be high compared with Willamette Basin or national values. At several sites, concentrations of bis(2-ethylhexyl)phthalate, butylbenzylphthalate, and di-*n*-octylphthalate exceeded the Willamette Basin ranges and were near the upper end of the national ranges. These three phthalates were also more frequently detected in Tualatin basin sediments (data not shown). Concentrations of bis(2-ethylhexyl)phthalate exceeded the USEPA Tier 2 screening value at eight sites, two of which had concentrations that exceeded the Tier 1 value. This was the only compound which had an exceedance of a Tier 1 screening value.

Fish tissue— Summary statistics for element concentrations in fish tissue are given in table 9 (p. 20). Trace element concentrations in fish tissue were similar to those for the Willamette Basin and toward the lower end of the national ranges (fig. 4, p. 21). Some of the differences may be because only sculpin were collected for the Tualatin study whereas several kinds of fish were collected for the other studies.

As in sediment, most organochlorine compounds were not detected in fish tissue from Tualatin Basin streams (table 10, p. 22). Generally, the organochlorines that were detected in tissue were the same ones that were detected in sediment—*p,p'*-DDE and chlordanes. Dieldrin, however, was detected in fish tissue at eight sites, but in sediment from only three sites. Detection frequencies were greater for the Tualatin Basin tissue samples than for the Willamette Basin tissue samples (table 11, p. 22). Concentrations of organochlorine pesticides in fish tissue were similar to those in a nationwide sample, but occasionally higher than those in the Willamette Basin (fig. 5, p. 23). Two compounds, α-HCH and heptachlor epoxide, were found in Tualatin Basin fish tissue, but not in Willamette Basin fish tissue. Total chlordane concentrations at three Tualatin Basin sites exceeded the Willamette Basin range; at two of these sites the NAS/NAE guideline was also exceeded. The greater detection frequency and concentration of organochlorine pesticides in the Tualatin Basin compared to those in the Willamette Basin may reflect the large proportion of sites with urban influences in the Tualatin Basin data set. PCBs were relatively common in fish tissue, but concentrations were similar to those in the Willamette Basin. The New York State criterion for PCBs in fish tissue was exceeded at three sites.

Table 6. Summary statistics for element concentrations in bed sediment

[Concentrations of major elements in milligram per gram (mg/g); minor elements in microgram per gram (µg/g); all concentrations are expressed on a dry weight basis and are given to one or two significant digits. Abbreviations: P10, P25, P75, and P90, the 10th, 25th, 75th, and 90th percentiles, respectively.]

Element	Minimum	P10	P25	Median	P75	P90	Maximum
Major elements (mg/g)							
aluminum	65	65	68	72	74	76	78
calcium	11	12	13	14	18	20	26
iron	40	40	42	52	56	67	85
magnesium	6.5	6.6	6.9	7.5	8.7	15	22
phosphorus	0.9	1.1	1.2	1.4	1.8	2.0	2.0
potassium	8	10	12	13	15	15	15
sodium	9	10	12	14	15	16	16
sulfur*	< 0.5	< 0.5	< 0.5	0.6	0.7	0.9	1.0
titanium	6.7	6.8	7.1	8.3	9.8	14	19
Minor elements (µg/g)							
antimony	0.7	0.7	0.9	1.0	2.0	2.0	3.0
arsenic	2.0	3.5	4.4	7.0	9.0	10	16
barium	280	280	580	640	680	690	730
beryllium	< 1	< 1	1	2	2	2	2
cadmium	0.2	0.2	0.2	0.3	0.8	1.1	1.2
cerium	48	53	62	66	76	80	87
chromium	59	65	71	75	80	100	140
cobalt	17	18	21	22	25	29	40
copper	20	20	24	32	45	55	67
gallium	16	17	18	18	20	22	22
lanthanum	28	32	38	40	44	46	48
lead	<4	7	18	30	54	63	130
lithium*	20	20	20	20	30	30	30
manganese	880	1000	1100	1400	1600	2100	2200
mercury	< 0.02	0.03	0.05	0.07	0.11	0.24	0.30
neodymium*	25	32	34	35	38	42	43
nickel	18	21	22	25	28	40	50
niobium	11	12	12	14	17	21	35
scandium	14	14	15	18	20	23	25
selenium	< 0.1	0.1	0.2	0.2	0.3	0.6	0.9
silver	< 0.1	< 0.1	0.2	0.2	0.4	0.9	1.3
strontium	200	200	220	250	260	280	300
thorium*	5.8	8.2	11	12	14	16	16
uranium	1.5	2.7	2.9	3.4	3.7	4.1	4.6
vanadium	110	120	130	160	170	240	280
yttrium	21	23	24	27	28	30	32
ytterbium*	2	2	2	2	3	3	3
zinc	120	120	130	150	220	340	400

The following elements were not detected in bed sediment samples: bismuth, europium, gold, holmium, molybdenum, tantalum, tin.

*The estimated analytical precision equals or exceeds the interquartile range.

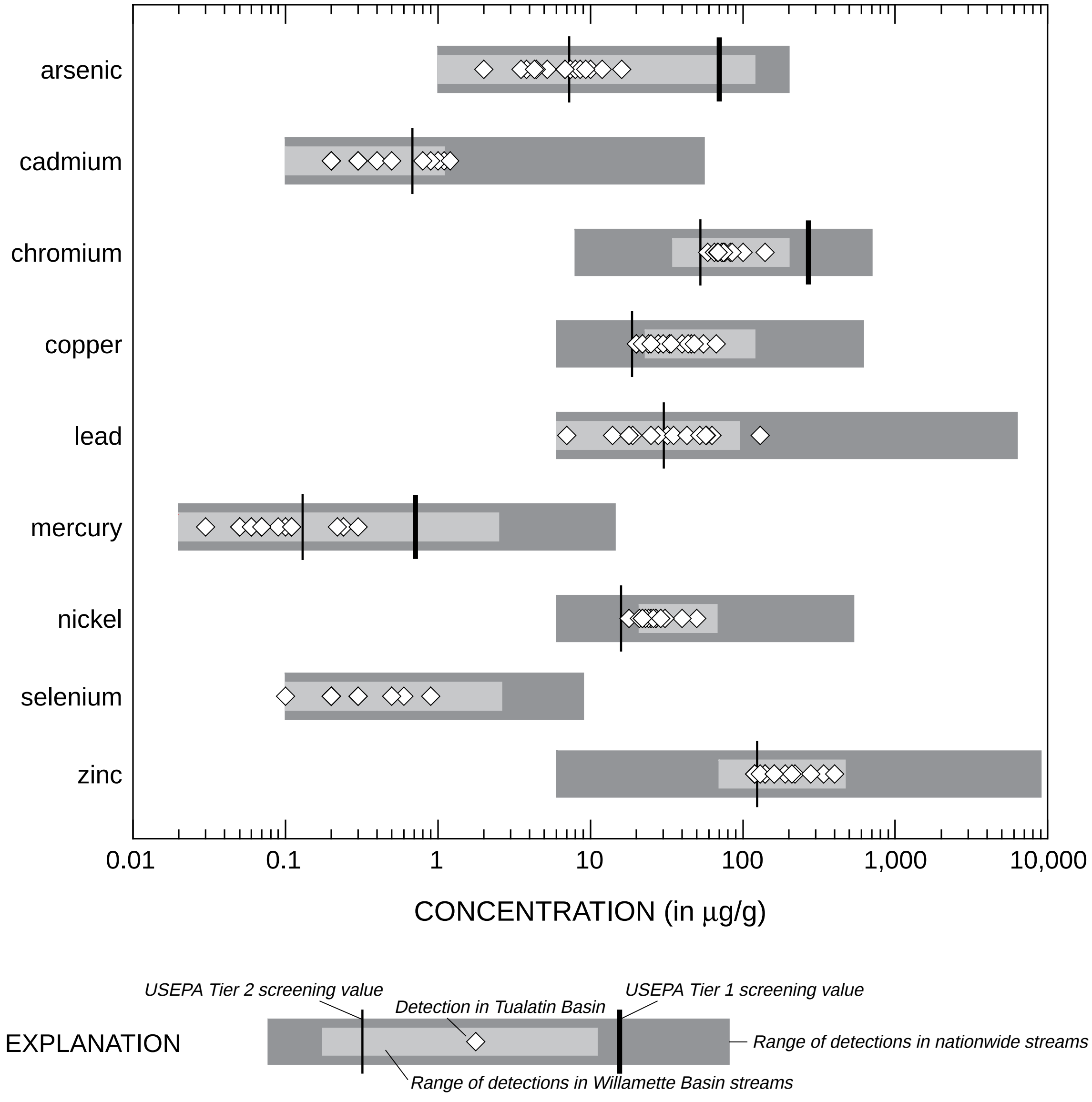


Figure 2. Comparison of concentrations of selected elements in bed sediment of the Tualatin River Basin with Willamette Basin concentrations, nationwide concentrations, and U.S. Environmental Protection Agency (USEPA) sediment quality screening values (USEPA, 1997). Elements are shown if national ranges were available. National ranges are from the first 20 study units of the National Water-Quality Assessment Program (Wentz, Bonn, and others, 1998). USEPA Tier 1 screening values for cadmium, copper, lead, nickel, and zinc are not shown on the figure because they require subtraction of the acid-volatile sulfide concentration. There are no USEPA screening values for selenium.

Table 7. Summary statistics for organic chemical concentrations in bed sediment

[All concentrations in nanogram per gram dry weight (ng/g). Abbreviations: MDL, method detection limit; MRL, minimum reporting level; P25, 25th percentile; P75, 75th percentile; B95, 95th percentile of laboratory blanks. When MRL is given, detection frequency is number of detections/number of analyses; when MDL is given, detection frequency is number of detections greater than MDL/total number of detections/number of analyses. When a population statistic is not given, it is less than either the MRL or 2×MDL, and therefore indeterminate.]

Organic chemical	MDL *[MRL]* (ng/g)	Detection frequency	Maximum (ng/g)	Population statistics (ng/g)		
				P25	Median	P75
Organochlorine pesticides						
cis-chlordane	*[1.0]*	6/16	9.8			1.8
trans-chlordane	*[1.0]*	5/16	8.6			1.4
dieldrin	*[1.0]*	3/16	6.5			
o,p'-DDE	*[1.0]*	2/16	3.9			
p,p'-DDE	*[1.0]*	11/16	10.0		1.0	2.1
heptachlor epoxide	*[1.0]*	1/16	1.4			
cis-nonachlor	*[1.0]*	4/16	2.4			1.1
trans-nonachlor	*[1.0]*	5/16	7.8			1.5
The following organochlorine pesticides were not detected in bed sediment: aldrin, chlorneb, dacthal, endosulfan I, endrin, α-HCH, β-HCH, γ-HCH (lindane), heptachlor, isodrin, *o,p'*-methoxychlor, *p,p'*-methoxychlor, mirex, oxychlordane, *cis*-permethrin, *trans*-permethrin, toxaphene.						
PAHs (polyaromatic hydrocarbons)						
acenaphthene	31	0/4/15	17			
acenaphthylene	29	2/5/15	38			
anthracene	28	9/11/15	130			
benz[*a*]anthracene	23	14/14/16	480		60	110
benzo[*a*]pyrene	19	9/9/16	560		54	120
benzo[*b*]fluoranthene	20	14/14/16	680	53	72	120
benzo[*ghi*]perylene	64	4/5/16	470			
benzo[*k*]fluoranthene	33	14/14/16	300		80	140
chrysene	24	14/14/16	670	49	89	180
dibenz[*a,h*]anthracene	25	1/2/15	35			
fluoranthene	29	14/14/16	890		100	260
9H-fluorene	32	0/5/15	29			
indeno[1,2,3-*cd*]pyrene	25	10/10/16	470		61	82
naphthalene	26	0/3/15	25			
phenanthrene	30	9/12/16	250			150
pyrene	27	14/14/16	1100	59	110	250
Alkyl-PAHs						
1,2-dimethylnaphthalene	27	0/1/15	7			
1,6-dimethylnaphthalene	28	0/1/15	11			
2,6-dimethylnaphthalene	26	10/13/15	120			70
1-methylphenanthrene	30	3/6/15	53			
1-methylpyrene	25	4/6/15	70			
2-methylanthracene	25	1/1/15	89			
4,5-methylenephenanthrene	29	7/9/15	62			
The following alkyl-PAHs were not detected in bed sediment: 2-ethylnaphthalene, 1-methyl-9H-fluorene, 2,3,6-trimethylnaphthalene.						

Table 7. Summary statistics for organic chemical concentrations in bed sediment—Continued

[All concentrations in nanogram per gram dry weight (ng/g). Abbreviations: MDL, method detection limit; MRL, minimum reporting level; P25, 25th percentile; P75, 75th percentile; B95, 95th percentile of laboratory blanks. When MRL is given, detection frequency is number of detections/number of analyses; when MDL is given, detection frequency is number of detections greater than MDL/total number of detections/number of analyses. When a population statistic is not given, it is less than either the MRL or 2×MDL, and therefore indeterminate.]

Organic chemical	MDL *[MRL]* (ng/g)	Detection frequency	Maximum (ng/g)	Population statistics (ng/g)		
				P25	Median	P75
Azaarines						
acridine	24	1/3/15	37			
2,2’-biquinoline	50	2/2/15	56			
9H-carbazole	28	1/4/15	50			
isoquinoline	28	1/1/15	32			
phenanthridine	26	2/2/15	64			
quinoline	30	0/1/15	14			
The following azaarine was not detected in bed sediment: benzo[*c*]cinnoline.						
Phthalates						
* bis(2-ethylhexyl)phthalate (B95=100)	31	*12/16	*9,900	*8	*140	*860
* butylbenzylphthalate (B95=64)	27	*12/16	*1,300	*1	*9	*94
* diethylphthalate (B95=25)	31	*1/15	*14			
* di-*n*-butylphthalate (B95=54)	28	*10/15	*36		*16	*23
di-*n*-octylphthalate	25	9/9/16	820		72	97
The following phthalate was not detected in bed sediment: dimethylphthalate.						
Phenols						
p-cresol	32	12/12/16	880			155
3,5-dimethylphenol	31	1/1/15	43			
* phenol (B95=27)	20	*2/15	*31			
The following phenols were not detected in bed sediment: C8-alkylphenol, 2-chlorophenol, 4-chloro-3-methylphenol.						
Chlorinated aromatic compounds						
The following chlorinated organic compounds were not detected in bed sediment: 2-chloronaphthalene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobenzene, pentachloroanisole, pentachloronitrobenzene, total PCB, 1,2,4-trichlorobenzene.						
Other						
anthraquinone	30	5/6/15	100			
dibenzothiophene	28	1/4/15	31			
N-nitrosodiphenylamine	27	1/2/15	28			
The following other compounds were not detected in bed sediment: azobenzene, bis(2-chloroethoxy)methane, 4-bromophenyl-phenylether, 4-chlorophenyl-phenylether, 2,4-dinitrotoluene, isophorone, nitrobenzene, N-nitrosodi-*n*-propylamine.						

*Blank contamination was common for this analyte (Lopes and others, 1998). Detection frequency is given as number of detections above 95th percentile of laboratory blanks (B95). Maximum value and population statistics have been adjusted by subtracting the B95 value.

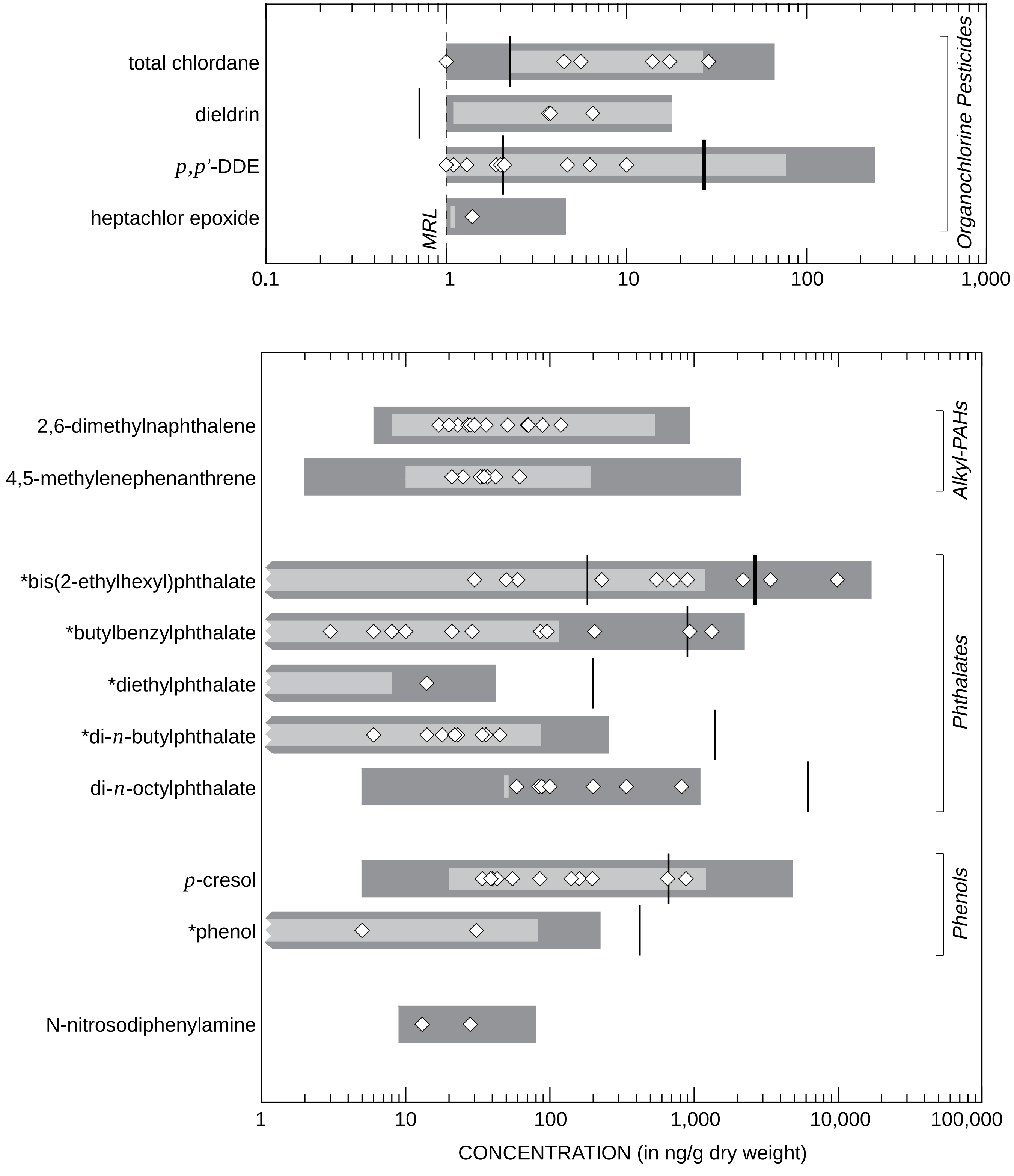
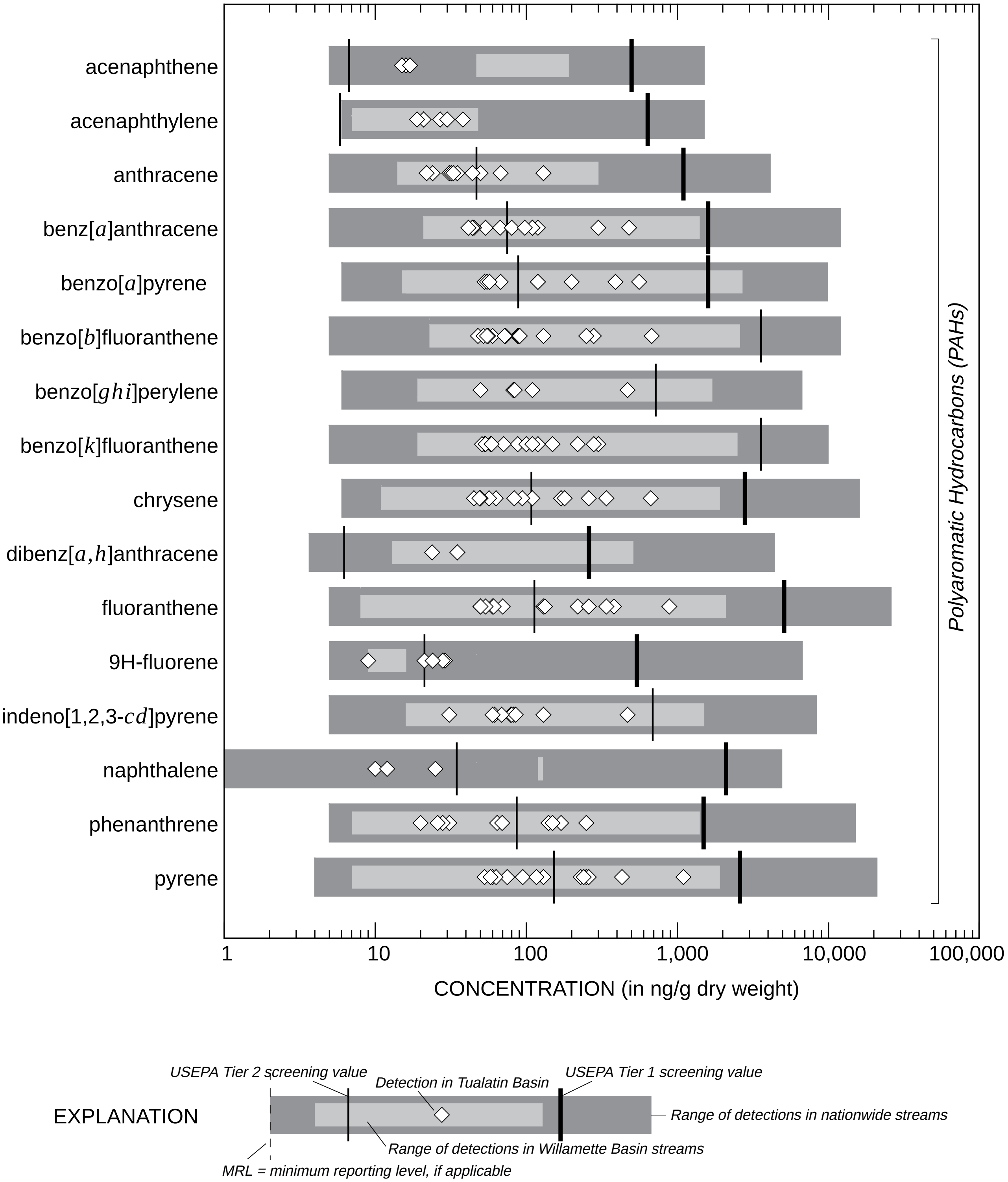


Figure 3. Comparison of concentrations of selected organic compounds in bed sediment of the Tualatin River Basin with Willamette Basin concentrations, nationwide concentrations, and U.S. Environmental Protection Agency (USEPA) sediment quality screening values (USEPA, 1997). All organochlorine pesticides that were detected in this study are shown, except *o,p'*-DDE for which national ranges are not available. Total chlordane is



** Blank contamination was common for this analyte; values shown have been blank subtracted; jagged left edge indicates indeterminate lower limit.*

the sum of *cis*-chlordane, *trans*- chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane. Other organic compounds that were detected are shown if they were detected in at least half of the samples or if USEPA screening values apply. National ranges are from the first 20 study units of the National Water-Quality Assessment Program (Wentz, Bonn, and others, 1998).

Table 8. Comparison of detection frequencies of polyaromatic hydrocarbons

[N is the number of samples. Willamette data from National Water Quality Assessment Program (Wentz, Bonn, and others, 1998). National data from Lopes and others (1998).]

Polyaromatic hydrocarbon	Detection frequency (percent)		
	Tualatin (N=12)	Willamette (N=27)	National (N=370–433)
acenaphthene	27	7	25
acenaphthylene	33	19	34
anthracene	73	30	44
benz[*a*]anthracene	88	33	50
benzo[*a*]pyrene	56	37	49
benzo[*b*]fluoranthene	88	37	56
benzo[*ghi*]perylene	31	30	32
benzo[*k*]fluoranthene	88	37	55
chrysene	88	37	51
dibenz[*a*,*h*]anthracene	13	15	23
fluoranthene	88	56	65
9H-fluorene	33	15	31
indeno[1,2,3-*cd*]pyrene	56	33	39
naphthalene	20	4	18
phenanthrene	75	44	52
pyrene	88	52	62

Table 9. Summary statistics for element concentrations in fish tissue

[Concentrations are in microgram per gram dry weight (µg/g). Abbreviations: P25, 25th percentile; P75, 75th percentile. Mean moisture content was 76.8%. All fish were sculpin.]

Element	Detection frequency	Maximum (µg/g)	Population statistics (µg/g)		
			P25	Median	P75
aluminum	10/10	180	19	28	58
arsenic	7/10	0.4	<0.2	0.2	0.3
barium	10/10	22	7.7	10	11
boron	10/10	3.5	0.8	1.2	2.6
chromium	10/10	2.0	1.7	1.9	1.9
cobalt	10/10	0.6	0.3	0.3	0.6
copper	10/10	3.8	2.0	2.8	3.4
iron	10/10	280	65	83	160
lead	6/10	0.9	<0.2	0.3	0.7
manganese	10/10	78	15	28	40
mercury	8/10	1.0	0.1	0.3	0.5
nickel	10/10	3.7	0.4	0.6	2.0
selenium	8/10	2.5	1.1	1.5	1.9
strontium	10/10	120	80	88	110
vanadium	10/10	2.4	1.0	1.2	1.6
zinc	10/10	110	83	95	110

The following elements were not detected in fish tissue: antimony, beryllium, cadmium, molybdenum, silver, uranium

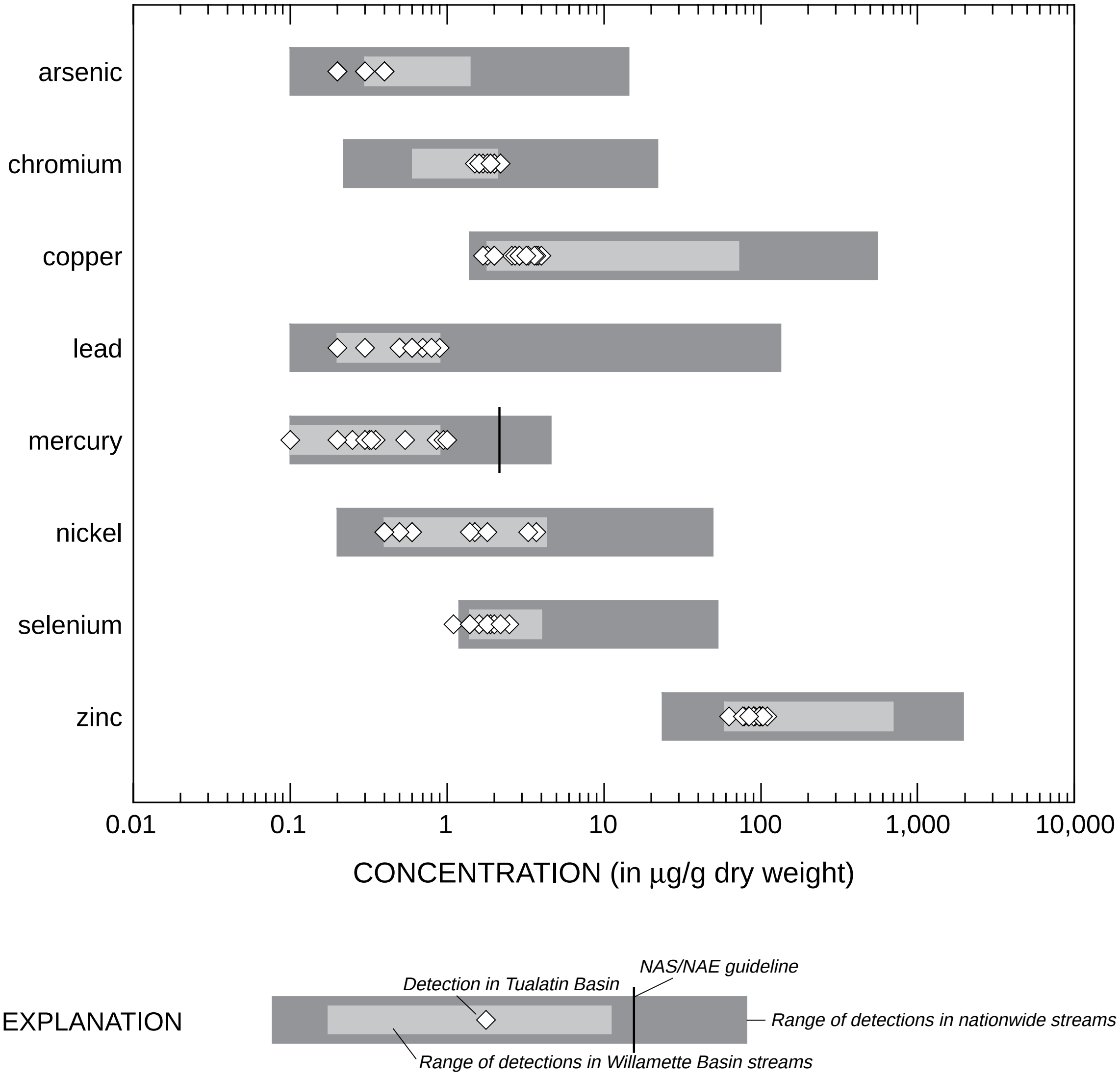


Figure 4. Comparison of concentrations of selected elements in fish tissue from the Tualatin River Basin with Willamette Basin concentrations, nationwide concentrations, and National Academy of Sciences/National Academy of Engineering (NAS/NAE) guidelines (NAS/NAE, 1973). Elements are shown if national ranges were available. National ranges are from the first 20 study units of the National Water-Quality Assessment Program (Wentz, Bonn, and others, 1998). The only NAS/NAE guideline for elements was for mercury. The guideline units were converted to dry weight by assuming a moisture content of 77%, which was the average for fish sampled in this study.

Table 10. Summary statistics for organochlorine concentrations in fish tissue.

[Concentrations are in nanogram per gram wet weight (ng/g wet wt). Abbreviations: P25, 25th percentile; P75, 75th percentile. P25, median, and P75 are given when detection frequencies are at least 75%, 50%, and 25%, respectively. Mean moisture content was 76.8%. All fish were sculpin.]

Element	Detection frequency	Maximum (ng/g wet wt)	Population statistics (ng/g wet wt)		
			P25	Median	P75
Organochlorine pesticides					
cis-chlordane	8/12	84		13	26
trans-chlordane	7/12	25		6.3	12
cis-nonachlor	5/12	14			8.9
trans-nonachlor	10/12	74	2.9	18	28
oxychlordane	4/12	35			8.6
total chlordane	10/12	210	10	38	67
dieldrin	10/12	86	6.8	14	20
p,p'-DDD	4/12	24			5.8
p,p'-DDE	10/12	21	7.5	14	18
p,p'-DDT	6/12	8.6		4.6	5.8
α-HCH	1/12	6.6			
heptachlor epoxide	4/12	20			9.9
Other organochlorine compounds					
total PCB	8/12	380		75	120
pentachloroanisole	6/12	22		4.0	7.2

The following organochlorine compounds were not detected in fish tissue: aldrin, dacthal, *o,p'*-DDD, *o,p'*-DDE, *o,p'*-DDT, endrin, β-HCH, δ–HCH, γ-HCH (lindane), heptachlor, *p,p'*-methoxychlor, *o,p'*-methoxychlor, mirex, toxaphene, hexachlorobenzene.

Table 11. Comparison of detection frequencies of organochlorine compounds in fish tissue.

[All Tualatin Basin fish samples were sculpin; fish species varied for Willamette Basin samples. N is the number of samples.]

Organochlorine	Detection frequency (percent)	
	Tualatin (N=12)	Willamette (N=19)
total chlordane	83	53
dieldrin	83	42
p,p'-DDE	83	63
α-HCH	8	0
heptachlor epoxide	33	0
total PCB	67	37
pentachloroanisole	50	11

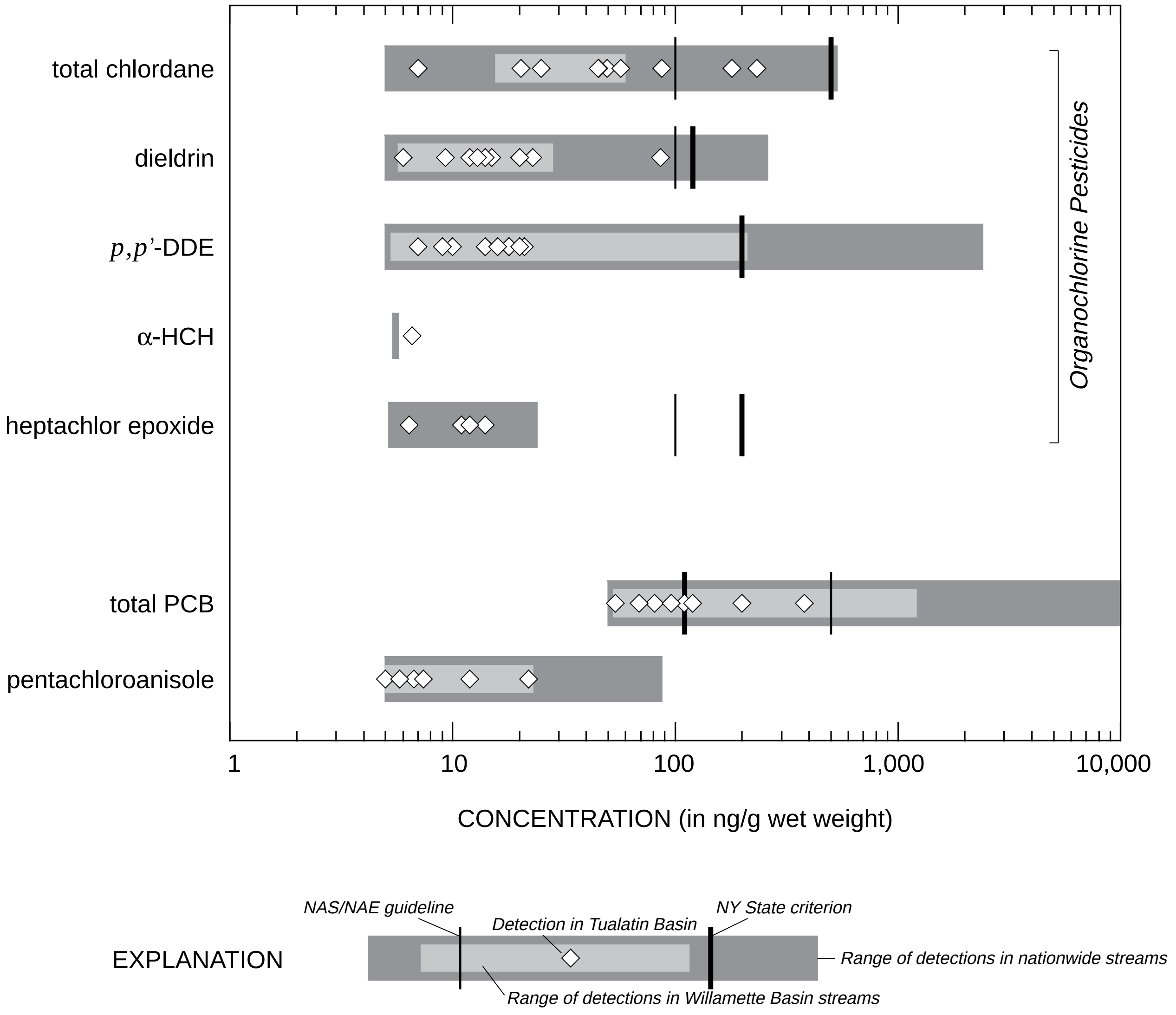


Figure 5. Comparison of concentrations of selected organochlorine compounds in fish tissue from the Tualatin River Basin with Willamette Basin concentrations, nationwide concentrations, National Academy of Sciences/ National Academy of Engineering (NAS/NAE) guidelines (NAS/NAE, 1973), and New York State criteria for fish in the Niagara River (Newell and others, 1987). All organic compounds that were detected in this study are shown, except *p,p*'-DDT and *p.p*'-DDD, for which national ranges were not available. Total chlordane is the sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, *trans*-nonachlor, and oxychlordane. National ranges are from the first 20 study units of the National Water-Quality Assessment Program (Wentz, Bonn, and others, 1998). The compounds α-HCH and heptachlor epoxide were not detected in Willamette Basin fish.

Comparisons between bed sediment and fish tissue

Concentrations in bed sediment and fish tissue were compared for evidence of bioaccumulation and to determine if concentrations in one medium were a good predictor of concentrations in the other medium.

For most elements, concentrations in tissue were one to three orders of magnitude lower than those in sediment (fig. 6). Two exceptions were mercury and selenium. Even when their concentrations were normalized to organic carbon (sediment) and lipid (tissue), the tissue concentration exceeded the sediment concentration, an indication of bioaccumulation of these elements. This finding for mercury and selenium is not surprising because both elements have organometallic forms. Other elements, such as arsenic and lead, also form organometallic compounds, but these elements did not appear to accumulate in tissue. These observations are consistent with those reported for the Willamette Basin (Wentz, Waite, and Rinella, 1998).

In contrast to the elements, tissue concentrations of organochlorines usually exceeded bed sediment concentrations by at least tenfold, indicating that bioaccumulation is likely (fig. 6). After normalization to organic carbon and lipid, tissue/sediment concentration ratios were still greater than 1, generally between 2 and 10.

Correlations between bed sediment and tissue concentrations were poor for most elements and weak for organochlorines (table 12). Normalizing to organic carbon and lipid did not significantly improve the correlations. However, graphical examination showed that such normalization slightly increased the linearity of the relation for the organochlorines. Even for the analytes that show the best correlations between tissue and sediment concentrations (lead and *cis*-chlordane), the

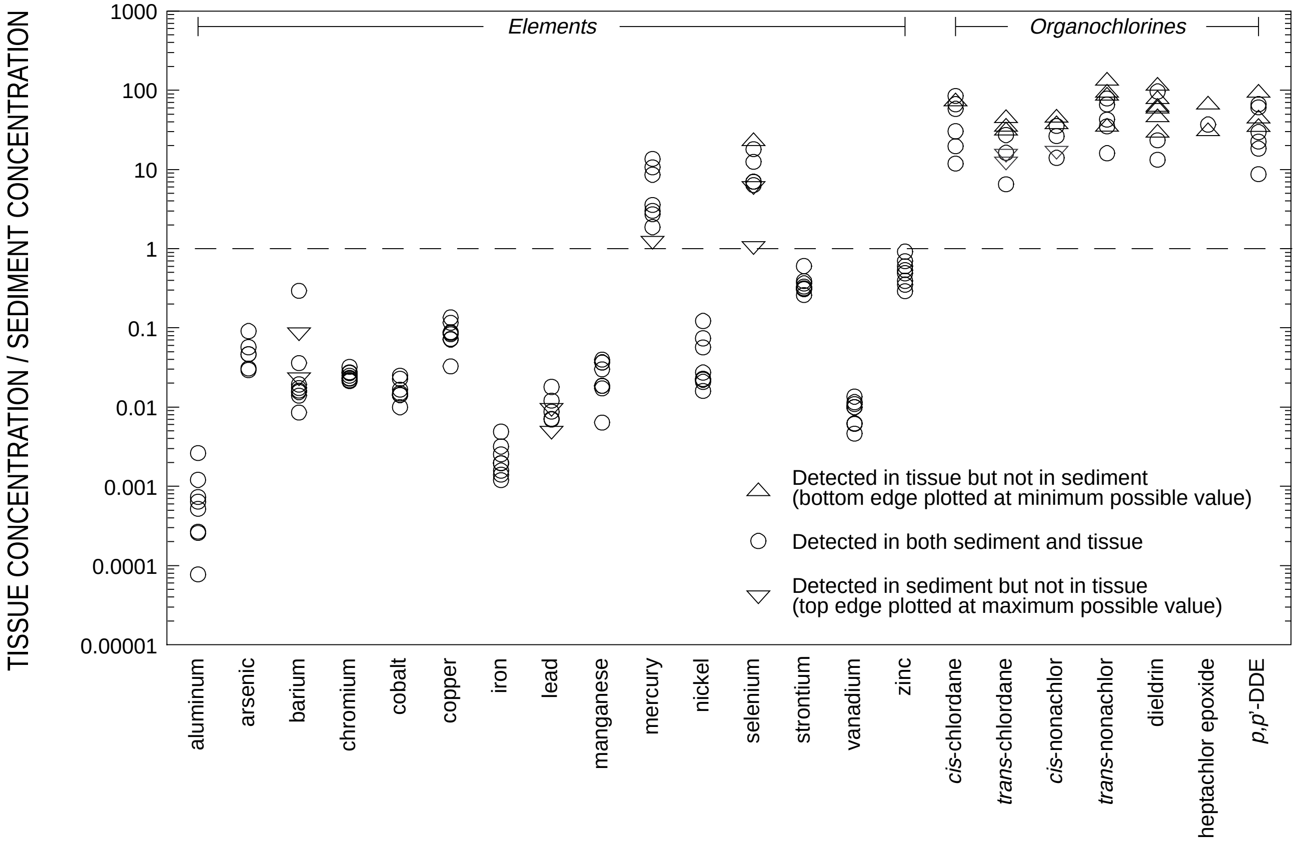


Figure 6. Ratio of concentrations in tissue to concentrations in sediment. Concentrations were in the same units, making the resulting ratio dimensionless.

relation is not strong enough to be quantitatively predictive. Even simple detection was not well correlated for most organochlorines. Detection of an organochlorine in sediment was usually a good predictor of detection in tissue, but nondetection in sediment was not an accurate predictor of nondetection in tissue (table 13). Detection of organochlorines in tissue when they were not detected in sediment from the same site was common, but the reverse never occurred.

Table 12. Correlations between concentrations in sediment and tissue.

[Spearman correlation coefficients (ρ) shown in boldface type are statistically significant at α=0.05; ρ= 1.0 or –1.0 indicates a perfect monotonic relation; ρ=0 indicates no relation. Normalized indicates that sediment and tissue concentrations were normalized to organic carbon and lipid content, respectively. N is the number of samples.]

Chemical	N	Spearman correlation coefficient (ρ)	
		Original data	Normalized
Elements			
aluminum	8	0.04	**0.81**
arsenic	8	0.47	0.11
barium	8	0.02	–0.50
chromium	8	0.04	–0.07
cobalt	8	**0.87**	0.64
copper	8	0.13	0.00
iron	8	0.71	**0.86**
lead	8	**0.85**	**0.88**
manganese	8	0.41	0.33
mercury	8	0.29	–0.50
nickel	8	**0.76**	0.71
selenium	8	–0.44	–0.50
strontium	8	0.13	0.02
vanadium	8	0.51	0.62
zinc	8	0.12	–0.33
Organochlorines			
cis-chlordane	10	**0.78**	**0.83**
trans-chlordane	10	0.53	0.57
cis-nonachlor	10	0.63	0.64
trans-nonachlor	10	**0.70**	**0.71**
dieldrin	10	0.59	**0.65**
heptachlor epoxide	10	0.50	0.64
p,p'-DDE	10	**0.70**	0.59

Table 13. Use of organochlorine detection in sediment as a predictor of organochlorine detection in tissue.

[Explanation: In column two, 3/5 =60% indicates that the analyte was detected in sediment at 5 sites, 3 of which had also detection in tissue—a correct prediction rate of 60 percent. In column three, 1/4=25% indicates that the analyte was not detected in sediment at 4 sites, 1 of which had a detection in tissue—an incorrect prediction rate of 25 percent.]

Analyte	Detection in tissue *given* detection in bed sediment	Detection in tissue *given* nondetection in bed sediment
Organochlorine pesticides		
cis-chlordane	6/6 = 100%	1/4 = 25%
trans-chlordane	3/5 = 60%	3/5 = 60%
cis-nonachlor	3/4 = 75%	2/6 = 33%
trans-nonachlor	5/5 = 100%	4/5 = 80%
oxychlordane	no detections in sediment	3/10 = 30%
dieldrin	3/3 = 100%	6/7 = 86%
p,p'-DDE	6/6 = 100%	3/4 = 75%
α-HCH	no detections in sediment	1/10 = 10%
heptachlor epoxide	1/1 = 100%	2/9 = 22%
Other organochlorine compounds		
PCBs	no detections in sediment	7/10 = 70%
pentachloroanisole	no detections in sediment	6/10 = 60%

Site-specific findings

Beaverton Creek— High levels of organic contaminants distinguished the Beaverton Creek site from all other sites sampled in this study. This site was one of two that had an exceedance of a USEPA Tier 1 screening value (for bis(2-ethylhexyl)phthalate). USEPA Tier 2 screening values were exceeded for 21 chemicals, including various elements, organochlorine pesticides, PAHs, phthalates and phenols (table 14). Moreover, comparisons to screening values could not be made for a number of semivolatile compounds because chemical interferences compromised the analyses of the Beaverton Creek samples. It is likely that Tier 2 screening values would be exceeded for some of these compounds. The frequency of chemical interferences at this site was probably caused by the overall high concentration of contaminants. No other site yielded samples that had such extensive interference problems. The concentration of PCBs in fish tissue at this site exceeded the NAS/NAE guideline, but was not the highest value found in this study.

Table 14. Exceedances of guidelines.

[Symbol meanings are as follows: ●, exceeds US Environmental Protection Agency (USEPA) Tier 1 sediment guideline; •, exceeds USEPA Tier 2 sediment guideline; ▲, exceeds National Academy of Sciences/National Academy of Engineering or New York State criteria for fish tissue; —, not analyzed]

Site	Sediment																												Tissue	
	Elements									Organochlorines				Polyaromatic hydrocarbons											Phthalates, phenols, & other compounds					
	arsenic	cadmium	chromium	copper	lead	mercury	nickel	silver	zinc	total chlordane	dieldrin	o,p'-DDE	p,p'-DDE	acenaphthene	acenaphthylene	anthracene	benz[*a*]anthracene	benzo[*a*]pyrene	chrysene	dibenz[*a,h*]anthracene	fluoranthene	9H-fluorene	phenanthrene	pyrene	bis(2-ethylhexyl)phthalate	butylbenzylphthalate	*p*-cresol	N-nitrosodiphenylamine	total chlordane	polychlorinated biphenyl
Ash Cr	•	•	•	•	•		•		•					•	•	•	•	•	•	•	•	•	•	•	●	•			—	—
Beaverton Cr	•	•	•	•	•	•	•		•	•	•	•	•	—	—	—	•	•	•	—	•	—	•	•	●	•	•	—		▲
Bronson Cr			•	•	•		•		•	•							•								•			•		
Cedar Mill Cr			•	•			•		•																•					
Chicken Cr			•	•		•	•		•				•																—	—
Dairy Cr	•		•	•			•																							
Fanno Cr (at Denny Rd)			•	•	•		•		•	•	•		•		•		•	•	•		•		•	•	•				▲	
Fanno Cr (at Durham, 1992)	•	•	•	•	•		•	•	•								•	•	•	•	•		•	•						▲
Fanno Cr (at Durham, 1993)	•	•	•	•	•		•	•	•												•				•					▲
Upper Fanno Cr (at Nicol Rd)			•	•	•		•		•	•	•		•	•	•		•	•	•		•		•	•	•				▲	▲
Gales Cr			•	•			•																							
McKay Cr	•		•	•		•	•							•	•	•	•		•		•	•	•	•					—	—
Lower Rock Cr			•	•			•		•																				—	—
Upper Rock Cr		•	•	•	•		•		•	•				•	•	•					•	•			•					
Tualatin R (above Dairy Cr)			•	•			•																						—	—
Tualatin R (at Elsner Rd)	•		•	•			•		•																				—	—

The following compounds were detected in sediment at least once, but concentrations never exceeded USEPA sediment guidelines: antimony, benzo[b]fluoranthene, benzo[*ghi*]perylene, benzo[*k*]fluoranthene, indeno[1,2,3-*cd*]pyrene, naphthalene, diethylphthalate, di-*n*-butylphthalate, di-*n*-octylphthalate, phenol.

The following compounds have USEPA sediment guidelines, and were not detected in sediment: α-HCH, β-HCH, γ-HCH (lindane), *p,p'*-methoxychlor, toxaphene, dimethylphthalate, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, hexachlorobenzene, PCB (total), 1,2,4-trichlorobenzene, 4-bromophenyl-phenylether.

The following compounds were detected in tissue at least once, but concentrations never exceeded tissue criteria: dieldrin, *p,p'*-DDE, heptachlor epoxide, pentachloroanisole.

The following compounds have tissue criteria, and were not detected in fish tissue: aldrin, endrin, heptachlor, mirex.

The Beaverton Creek site was somewhat unusual in that the levels of all classes of contaminants were elevated. For the 22 organic compounds that could be compared among sites, the highest concentrations were found at the Beaverton Creek site in 18 cases. In nine of these, concentrations at the Beaverton Creek site exceeded the next highest value by a factor of two or more. The compounds included chlorinated pesticides, PAHs, phthalates, and *p*-cresol. The highest concentrations of lead and zinc found in this study were also from the Beaverton Creek site.

Biological effects were also evident at the Beaverton Creek site. Few fish were present. Although more than 300 feet of stream were sampled, only four sculpin were collected. Three-spine stickleback and redside shiner were present, about half of which had visible external abnormalities, primarily white tumors. This level of fish abnormality was unusually high compared to other sites in the Tualatin and Willamette River Basins (I.R. Waite, USGS, written commun., 1997).

Fanno Creek— The Fanno Creek sites (Nicol Road, Denny Road, Durham, and Ash Creek) provided an opportunity to follow contaminant patterns along a single urban stream. The Ash Creek site is located just above the confluence of Ash and Fanno Creeks. The land use along this stretch of Fanno Creek changes from mostly residential (Nicol Road site), to commercial (Ash Creek site) to light industrial (Durham site).

Concentrations of organochlorine pesticides in sediment were highest at the uppermost sites on Fanno Creek (Nicol Road and Denny Road) (fig. 7). Organochlorine contamination at these sites was second only to that found at Beaverton Creek, both in terms of total concentration and the variety of pesticides found.

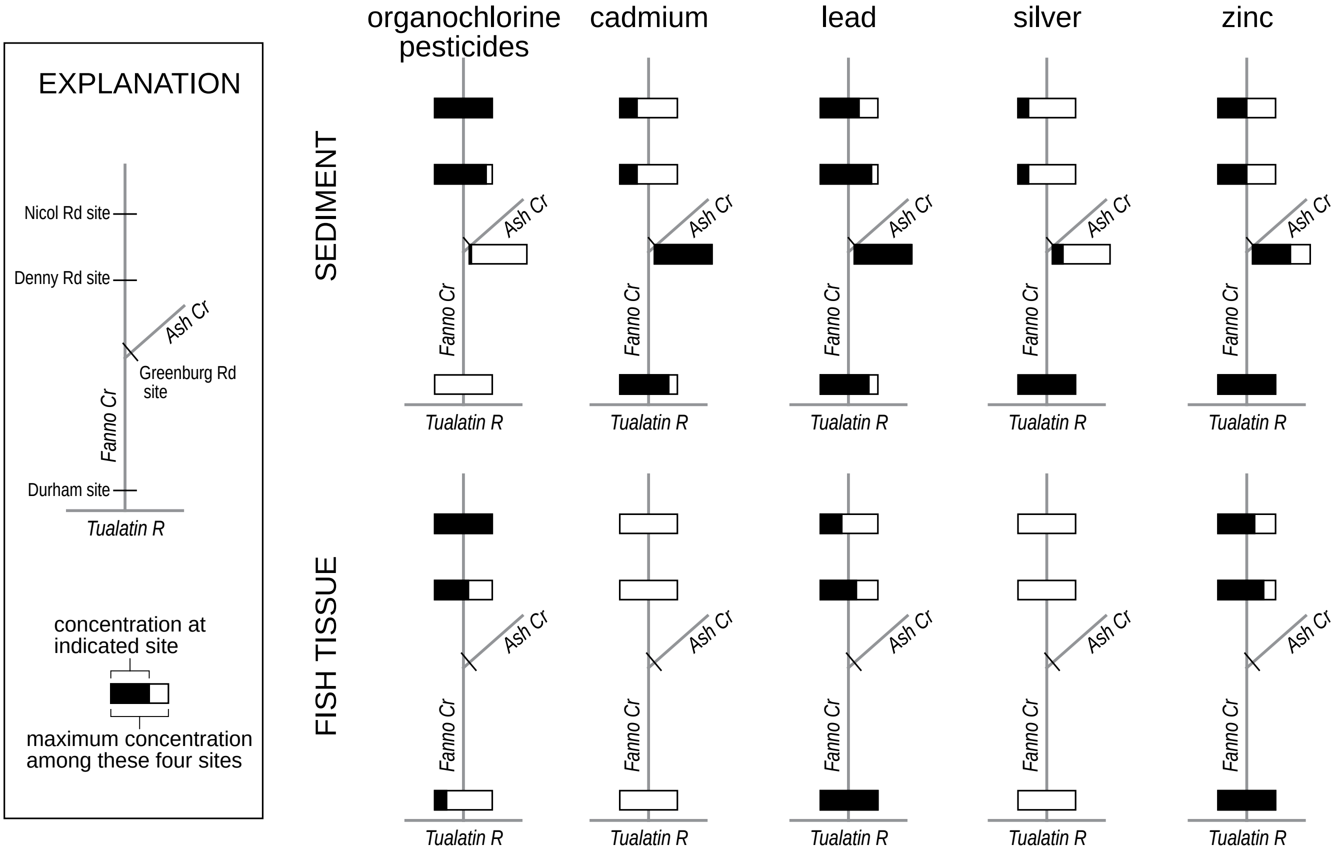


Figure 7. Variation in concentration of organochlorine pesticides and selected metals in the Fanno Creek system. Silver and cadmium were not detected in fish tissue at these sites. The Nicol Road site was sampled in 1992 for sediment and 1996 for fish; the Denny Road site was sampled in 1996 for both sediment and fish; the Greenburg Road site was sampled in 1992 for sediment only; the Durham site was sampled in 1992 and 1993 for both sediment and fish, the average is shown.

Exceedances of USEPA Tier 2 screening values occurred at these two sites for total chlordane, dieldrin and *p,p'*-DDE (table 14). In contrast, no organochlorines were detected at the Durham site in either 1992 or 1993. Only *p,p'*-DDE was detected at Ash Creek, and the concentration was low—equal to the reporting limit.

For elements in sediment, the contaminant pattern was reversed—metals concentrations at the Durham site generally exceeded those found in the upstream sites. Silver concentrations at the Durham site were the highest found in this study, exceeding those found at Beaverton Creek by a factor of two. Cadmium and zinc concentrations were elevated at both the Durham site and the Ash Creek site. Lead concentrations, however, were relatively high throughout the Fanno Creek system. Tier 2 screening values for lead were exceeded at all of the Fanno Creek sites.

Contaminant patterns in fish tissue in the Fanno Creek system mimicked those found in sediment. Concentrations of organochlorine pesticides in fish tissue decreased upstream to downstream; metals concentrations (lead and zinc) increased upstream to downstream. Fish were much less abundant at the Nicol Road and Denny Road sites than at the Durham site. The lower fish abundance at the upper Fanno Creek sites may be related to stream size and habitat differences, but exposure to organochlorine pesticides could also be important.

Concentrations of organochlorine pesticides in fish tissue were particularly high at the Nicol Road and Denny Road sites. Total chlordane concentrations in fish tissue at these two sites were the highest found in this study—more than double the next highest concentration, which was found in Beaverton Creek fish tissue. These were the only two sites where the total chlordane concentration in fish tissue exceeded the NAS/NAE guideline. The dieldrin concentration found in Nicol Road fish tissue was 86 ng/g—more than three times the next highest concentration. The pesticide α-HCH, which was not found in the Willamette Basin study and found only once in the national study, was found at the Nicol Road site.

Basinwide patterns

Geologic pattern— Principal components analysis was applied to the element data (sediment only) to identify any patterns among sites. Most of the major elements strongly correlated with iron (table 15). The first principal component (PC1) accounts for 78 percent of the variability in the concentrations of the major elements. PC1 varies with the geologic characteristics of the Tualatin Basin (fig. 8).

Table 15. Correlations between concentrations of iron (Fe) and other major elements in sediment.

[All are significant at α=0.05, number of samples=16).]

Element	Spearman (ρ)	Pearson (r)
aluminum (Al)	0.57	0.59
calcium (Ca)	0.58	0.81
magnesium (Mg)	0.75	0.91
potassium (K)	–0.90	–0.95
sodium (Na)	–0.63	–0.77
titanium (Ti)	0.82	0.91

Sites associated with Coast Range geology have more calcium, iron, magnesium, and titanium and less potassium and sodium than sites associated with the Tualatin or Chehalem Mountains. These differences are consistent with the fact that rocks of the Coast Range are older and more weathered than the others. Although the geologic pattern in the concentrations of major elements is striking, these elements are not usually of concern. However, many trace elements correlated well with PC1, suggesting that their concentrations are also strongly influenced by basin geology (fig. 9). This finding is particularly important for copper and nickel, which had concentrations exceeding USEPA Tier 2 screening values; it suggests that the levels of these elements can be attributed to the natural mineral matrix. The highest concentrations of copper and nickel occurred at sites dominated by Coast Range geology (Gales Creek and Tualatin River above Dairy Creek) which are also sites where only background levels are expected.

Urban pattern— Principal components analyses of a reduced data set revealed a pattern that is probably associated with urban influences. The reduced data set did not contain data for the major elements and their correlates (to eliminate the geologic pattern) or for Beaverton Creek (because of the large number of missing values from interferences). The first principal component, which accounted for about 30 percent of the variability, was dominated by PAHs (unsubstituted), with smaller contributions from lead and several phthalates. PAH concentrations in sediment have been shown to be higher in more urbanized areas (Kennicutt and others, 1994).

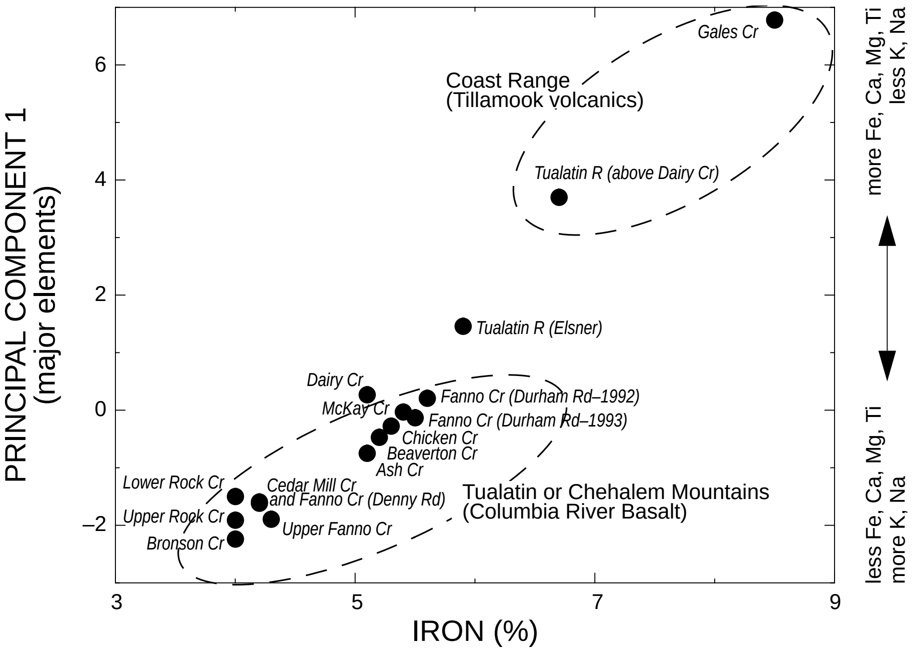


Figure 8. Principal component 1 (PC1) from analysis of bed sediment concentrations of major elements (aluminum, calcium, iron, magnesium, potassium, sodium, and titanium). PC1 accounts for 78 percent of the variability. Dotted enclosures indicate the highland drained by the stream and its underlying geologic formation (Wilson, 1997). Dairy Creek and the Tualatin River at Elsner Road drain highlands from both enclosed groups.

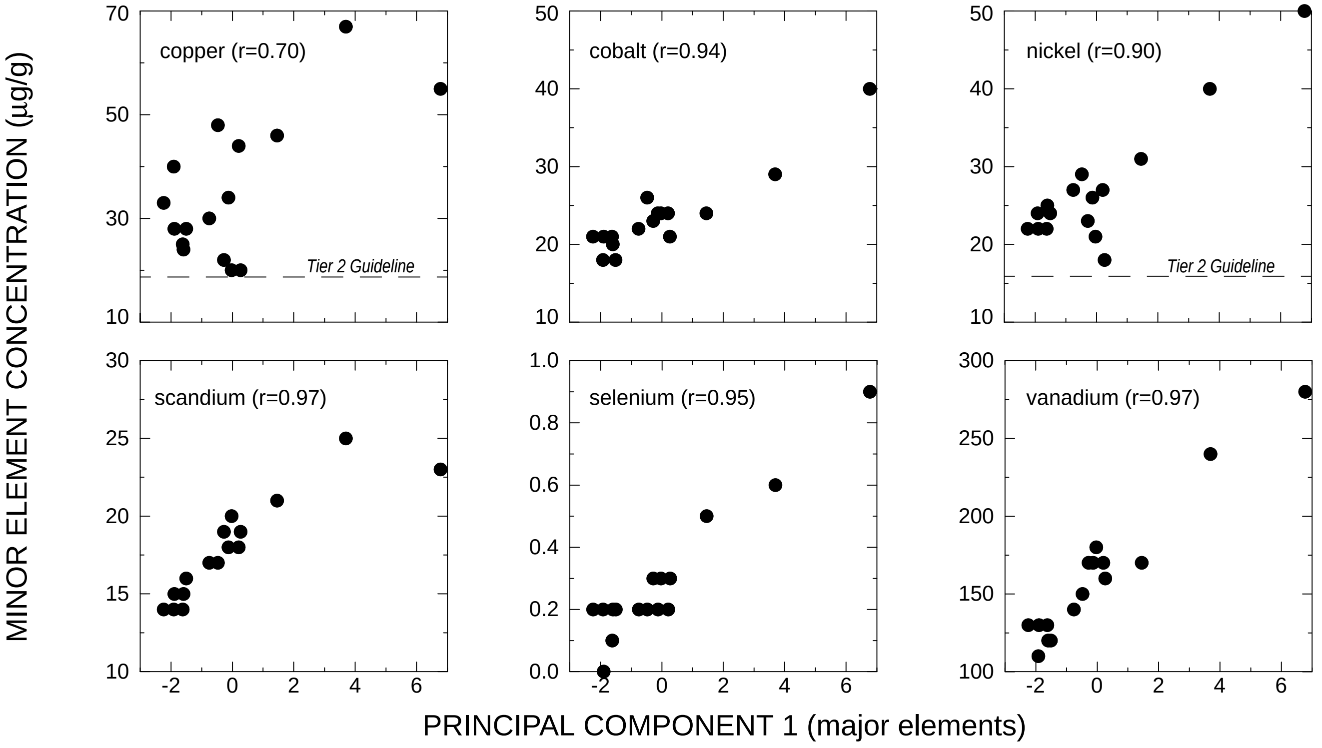


Figure 9. Relation between bed sediment concentrations of selected minor elements and the principal component 1 of major elements (fig. 8). [All Pearson’s correlation coefficients (r) shown are statistically significant (α=0.01), number of samples=16.]

The PAHs were highly correlated with one another; among the 12 PAHs that were detected at least 5 times, Spearman rank correlations (ρ) were significant (α=0.01) for all 66 possible correlations and exceeded 0.7 for 51 correlations. Correlations of PAH concentrations with lead and phthalates were weaker, but still significant. Sites with the highest scores for PC1 were Ash Creek, Fanno Creek at Nicol Road, Fanno Creek at Denny Road, and McKay Creek. All of these sites had exceedances of USEPA Tier 2 screening values for numerous PAHs and for lead (table 14). In contrast, PAHs and phthalates were not detected at background sites (Gales Creek and Tualatin River above Dairy Creek); lead concentrations at these sites were the lowest found (undetected and 7 µg/kg, respectively).

Sources of PAHs include combustion, road dust, and petroleum products. The type of PAH found can provide some indication of the most likely sources. Petroleum products generally contain significant amounts of alkyl-substituted PAHs, but combustion products do not (Hites and others, 1980). In this data set, alkylated PAHs contributed very little to PC1 and generally did not correlate well with the unsubstituted PAHs. This indicates that combustion products such as vehicle exhaust are a more important source of PAHs at these sites than are fuel spills or other releases of free petroleum. PAHs probably are transported to the sediments by atmospheric deposition or runoff of road dust. The strong correlation between total PAHs and lead (ρ=0.9, α=0.01) also supports the importance of vehicle exhaust as a source.

Although lead is associated with a general urban contamination pattern, other data indicate that it probably arises from at least one other source. Basinwide, lead correlated well with PAHs and with elements such as zinc, cadmium, and silver, but the correlations between PAHs and those three elements were much weaker. This indicates that a source exists that contributes lead and other trace elements, but not PAHs.

Implications for monitoring and management

Concentrations of chromium, copper, and nickel in bed sediment exceeded USEPA Tier 2 screening values at all sites tested, but exceedances of screening values could have resulted partially from sample processing procedures. Concentrations of trace elements are probably higher than they would have been had the sediment not been sieved at 63 µm. Analysis of unsieved sediment would provide a better comparison to the USEPA screening values. An additional measurement, the acid-volatile sulfide concentration, would allow comparison to USEPA Tier 1 screening values for elements with low bioavailability, such as cadmium, copper, lead, nickel, and zinc. The most likely source of copper and nickel in the Tualatin River Basin is weathering of the native geologic material.

Contamination at the Beaverton Creek site was substantial. Additional monitoring would help determine the areal extent of the problem and assess potential sources. Chemicals of concern at this site included cadmium, lead, mercury, zinc, chlordanes, DDT and its metabolites, dieldrin, PAHs, phthalates, *p*-cresol, and PCBs. Given the observations made during this study concerning the low numbers of fish and the high incidence of tumors on the fish that were present, an assessment of the biological community and documentation of abnormalities could help determine if these problems are persistent or widespread.

Concentrations of organochlorine pesticides in the upper regions of Fanno Creek were some of the highest found in this study; levels of chlordanes, DDT metabolites, and dieldrin exceeded USEPA Tier 2 screening values. Concentrations in sediment at the downstream Durham Road site were substantially lower. Continued monitoring of Fanno Creek upstream of its confluence with Ash Creek to determine trends would indicate if organochlorine pesticide concentrations are slowly decreasing (as expected) or if a present-day source of these compounds is important. DDT use was banned by USEPA in 1972. Use of chlordanes and dieldrin, for termite control only, was permitted until 1988. It is possible that some homeowner use of these pesticides continues in this mostly residential area.

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APPENDICES

Appendix A. Explanation of statistical comparison of replicate ranges.

Comparisons of the variability of chemical analyses among sites is complicated because the magnitude of the concentration differs among analytes. Because of this, ranks of concentration ranges, rather than absolute ranges, were compared. Only compounds that were detected in all replicate samples were considered. Replicate ranges for the organic compounds and their corresponding ranks among sites are given in table A-1. Data for elements was treated identically, but the replicate ranges are not shown here.

Sites were compared by performing a Tukey multiple comparisons test on the ranks of the replicate ranges (Helsel and Hirsch, 1992; SAS Institute, 1989). In this test, the mean rank for each site is computed, then the mean ranks are tested to determine if there are any significant differences among them. If the mean ranks of two groups are not significantly different, they are assigned the same letter. Groups with significantly different mean ranks are assigned different letters. The results for the organic compounds and the elements are summarized in table A-2.

Table A–1. Range (maximum value minus minimum value) of values for each replicate set.

[Value in brackets is the rank of the replicate range among sites; each analyte is ranked separately.]

Organic compound	Range of replicate values [Rank among sites]			
	Beaverton Cr	Fanno Cr at Denny Rd	Lower Rock Cr	Fanno Cr at Durham Rd
pyrene	100 [3]	30 [2]	14 [1]	218 [4]
benzo[k]fluoranthene	50 [3]	0 [1]	7 [2]	131 [4]
phenanthrene	50 [3]	20 [2]	14 [1]	133 [4]
butylbenzylphthalate	80 [3]	17 [2]	3 [1]	738 [4]
bis(2-ethylhexyl)phthalate	0 [1]	100 [3]	10 [2]	1057 [4]
benz[a]anthracene	40 [3]	2 [1]	9 [2]	87 [4]
benzo[b]fluoranthene	60 [3]	9 [2]	7 [1]	130 [4]
fluoranthene	70 [3]	20 [2]	19 [1]	270 [4]

Table A–2. Mean rank of replicate ranges.

[Values in parentheses identify groups that are significantly different (α=0.05, Tukey test). Only analytes that were quantified for all samples in each replicate set were used in this analysis. Group A denotes the site with the largest variability and group C denotes the least variability.]

	N	Beaverton Cr	Fanno Cr at Denny Rd	Lower Rock Cr	Fanno Cr at Durham Rd
Organic compounds	8	2.8 (B)	1.9 (C)	1.4 (C)	4.0 (A)
Elements	36	1.8 (C)	2.1 (C)	2.8 (B)	3.4 (A)

Appendix B. Bed sediment data

Site abbrev	USGS station name	Date	Time[a]	Code[b]	USGS station	Latitude (degrees)	Longitude (degrees)
Pcode	*parameter code for this constituent in USGS database*						
Units	*concentration units for chemical constituents*						
MRL	*minimum reporting level: minimum value reported for this constituent by the laboratory*						
MDL	*method detection limit: statistic associated with 1% chance of a false positive; 2×MDL is associated with 1% chance of false negative*						
Reprod	*estimate of reproducibility: maximum replicate range for this analyte in this study*						
Ash	Ash Creek at Greenberg Road	9–14–1992	10:00	P	14206930	452627	1224641
Bvtn	Beaverton Creek at Cedar Hills Blvd	8–29–1996	11:25	P	452937122483400	452937	1224834
Bvtn-r	same	same	11:26	R	same	same	same
Bronson	Bronson Creek at Walker Road	9–16–1992	10:30	P	14206300	453149	1225218
Cedar	Cedar Mill Creek at mouth	9–18–1992	10:30	P	14206311	453002	1225003
Chicken	Chicken Creek near Sherwood, OR	9–18–1992	12:00	P	14206750	452230	1225057
Dairy	Dairy Creek at Susbauer Road	9–15–1992	10:00	P	14205850	453220	1230226
FanDen	Fanno Creek near Denny Road	8–29–1996	9:40	P	452807122471400	452807	1224714
FanDen-r	same	same	9:41	R	same	same	same
Fan-92	Fanno Creek at Durham, OR	9–1–1992	15:00	P	14206950	452413	1224513
Fan-93a	same	10–1–1993	9:00	L	same	same	same
Fan-93b	same	same	10:00	L	same	same	same
Fan-93c	same	same	10:30	L	same	same	same
UpFan	Upper Fanno Creek at Nicol Road	9–14–1992	11:30	P	14206920	452822	1224544
Gales	Gales Creek near Glenwood, OR	9–9–1992	10:30	P	14203750	453837	1232209
McKay	McKay Creek at Hornecker Road	9–15–1992	12:00	P	14206120	453235	1230010
LoRock	Lower Rock Creek at Brookwood Road	9–17–1992	12:00	P	14206448	453030	1225557
LoRock-a	same	same	11:00	C	same	same	same
LoRock-b	same	same	11:30	C	same	same	same
UpRock	Upper Rock Creek at Baseline Road	9–16–1992	12:00	P	14206447	453114	1225444
UpTual	Tualatin River above Dairy Creek	9–22–1992	12:00	P	14204895	453002	1225948
Tual-Els	Tualatin River at Elsner Rd near Sherwood, OR	9–21–1992	12:00	P	14206740	452318	1225102

a—Time is a sample label and was not the exact sampling time. Together, USGS station, date and time, uniquely identify a sample.

b—Code for sample type: P=primary sample; R=replicate sample, L=location sample (different subreaches), C=collection sample (different personnel).

Appendix B. Bed sediment data—continued

[Abbreviations: mm, millimeters; µm, micrometers; mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Organic carbon (<2mm)	Organic carbon (<63 µm)	Fraction finer than 63 µm	Aluminum	Calcium	Iron	Magnesium	Phosphorus	Potassium	Sodium
P-Code	49271	49266	80164	34790	34830	34880	34900	34935	34940	34960
Units	percent	percent	percent	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/g
MRL	0.02	0.01	—	0.05	0.05	0.05	0.05	0.05	0.5	0.05
MDL	—	—	—	—	—	—	—	—	—	—
Reprod	0.2	0.16	7	3	<1	1	0.3	0.3	1	<1
Ash	3.0	2.62	79	73	14	51	7.4	1.8	14	14
Bvtn	4.1	3.91	81	68	17	52	8.3	1.8	13	14
Bvtn-r	4.2	3.86	—	68	17	52	8.2	1.9	12	14
Bronson	3.2	2.36	82	65	13	40	6.8	1.1	15	15
Cedar	2.0	1.81	71	73	13	42	7.2	1.1	15	15
Chicken	2.3	2.24	53	72	12	53	7.3	1.4	14	12
Dairy	3.0	2.60	33	76	11	51	7.5	1.2	13	10
FanDen	1.9	1.61	78	65	16	42	6.5	0.9	13	16
FanDen-r	2.0	1.54	—	65	16	42	6.5	0.6	13	16
Fan-92	1.5	3.15	24	69	18	56	8.9	2.0	12	14
Fan-93a	1.0	2.91	20	68	18	55	8.4	1.8	12	14
Fan-93b	1.3	2.69	27	68	18	55	8.1	1.9	13	14
Fan-93c	1.7	2.28	45	71	21	61	9.1	1.5	12	15
UpFan	2.3	1.74	76	67	14	43	6.6	1.2	15	16
Gales	0.82	5.73	7	75	26	85	22	1.8	7.7	9.1
McKay	2.1	2.76	28	71	13	54	6.8	1.4	13	12
LoRock	2.6	1.87	53	73	14	41	7.6	1.1	15	14
LoRock-a	2.5	1.71	54	70	14	40	7.3	1.0	15	14
LoRock-b	2.7	1.89	47	70	14	41	7.4	1.1	15	14
UpRock	3.2	1.95	69	66	14	40	6.9	1.2	15	14
UpTual	1.5	2.04	34	78	20	67	15	1.3	9.9	11
Tual-Els	2.1	2.90	47	76	16	59	10	2.0	12	11

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Sulfur	Titanium	Antimony	Arsenic	Barium	Beryllium	Bismuth	Cadmium	Cerium	Chromium
P-Code	34970	49274	34795	34800	34805	34810	34816	34825	34835	34840
Units	mg/g	mg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MRL	0.5	0.05	0.1	0.1	1	1	10	0.1	4	1
MDL	—	—	—	—	—	—	—	—	—	—
Reprod	<0.6	0.5	0.3	0.6	30	<1	—	0.1	10	7
Ash	0.7	7.0	1.0	16	690	2	ND	1.0	71	77
Bvtn	1.0	7.2	2.0	9.3	610	1	ND	1.2	53	77
Bvtn-r	1.0	7.2	2.0	9.5	610	1	ND	1.1	55	78
Bronson	0.8	6.9	2.0	5.2	670	2	ND	0.4	64	68
Cedar	0.5	6.7	0.7	4.4	680	2	ND	0.2	76	76
Chicken	ND	9.7	1.0	6.8	730	2	ND	0.2	61	140
Dairy	ND	8.7	2.0	7.4	620	2	ND	0.2	80	59
FanDen	ND	7.4	0.7	4.3	630	1	ND	0.3	73	69
FanDen-r	ND	6.9	0.7	4.3	620	1	ND	0.3	63	67
Fan-92	0.9	8.1	2.0	8.6	630	ND	ND	0.9	76	75
Fan-93a	0.8	8.4	0.8	9.9	660	1	ND	0.8	87	75
Fan-93b	0.7	8.5	0.8	12	660	1	ND	0.8	91	76
Fan-93c	0.6	8.5	0.9	7.3	630	1	ND	0.7	83	68
UpFan	ND	8.4	1.0	3.5	670	2	ND	0.3	64	73
Gales	0.6	19	1.0	2.0	280	ND	ND	0.2	64	74
McKay	ND	10	3.0	10	660	2	ND	0.3	67	65
LoRock	ND	7.5	0.7	7.1	690	2	ND	0.5	77	75
LoRock-a	0.5	7.5	1.0	6.6	670	2	ND	0.5	71	80
LoRock-b	0.6	7.3	1.0	7.2	660	2	ND	0.6	74	73
UpRock	0.6	6.8	1.0	6.8	650	2	ND	1.1	65	83
UpTual	ND	14.0	1.0	3.8	460	ND	ND	0.2	48	100
Tual-Els	0.7	9.9	2.0	8.0	550	2	ND	0.3	55	85

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Cobalt	Copper	Europium	Gallium	Gold	Holmium	Lanthanum	Lead	Lithium
P-Code	34845	34850	34855	34860	34870	34875	34885	34890	34895
Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MRL	1	1	2	4	8	4	2	4	2
MDL	—	—	—	—	—	—	—	—	—
Reprod	1	1	—	2	—	—	4	5	10
Ash	22	30	ND	18	ND	ND	43	63	20
Bvtn	26	48	ND	18	ND	ND	28	130	20
Bvtn-r	26	47	ND	18	ND	ND	30	130	20
Bronson	21	33	ND	18	ND	ND	38	32	20
Cedar	20	24	ND	17	ND	ND	44	28	20
Chicken	23	22	ND	22	ND	ND	39	18	30
Dairy	21	20	ND	21	ND	ND	48	18	30
FanDen	21	25	ND	16	ND	ND	38	57	20
FanDen-r	21	25	ND	14	ND	ND	34	52	20
Fan-92	24	44	ND	18	ND	ND	41	58	20
Fan-93a	25	41	ND	18	ND	ND	45	52	20
Fan-93b	24	34	ND	18	ND	ND	47	52	20
Fan-93c	30	37	ND	18	ND	ND	41	46	20
UpFan	21	28	ND	18	ND	ND	38	43	20
Gales	40	55	ND	22	ND	ND	40	ND	20
McKay	24	20	ND	21	ND	ND	42	19	20
LoRock	17	27	ND	18	ND	ND	46	24	30
LoRock-a	18	28	ND	18	ND	ND	43	25	30
LoRock-b	17	28	ND	18	ND	ND	43	28	20
UpRock	18	40	ND	18	ND	ND	39	35	20
UpTual	29	67	ND	20	ND	ND	32	7	30
Tual-Els	24	46	ND	20	ND	ND	34	14	30

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Manganese	Mercury	Molybdenum	Neodymium	Nickel	Niobium	Scandium	Selenium	Silver
P-Code	34905	34910	34915	34920	34925	34930	34945	34950	34955
Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MRL	4	0.02	2	4	2	4	2	0.1	0.1
MDL	—	—	—	—	—	—	—	—	—
Reprod	250	0.01	—	5	1	3	<1	<0.1	0.1
Ash	1300	0.09	ND	38	27	12	17	0.2	0.2
Bvtn	1900	0.22	ND	25	29	18	17	0.2	0.5
Bvtn-r	1900	0.21	ND	25	29	19	17	0.2	0.5
Bronson	1400	0.05	ND	34	22	12	14	0.2	0.2
Cedar	1000	0.11	ND	36	25	13	15	0.2	0.2
Chicken	2200	0.30	ND	35	23	12	19	0.3	0.2
Dairy	1200	0.03	ND	43	18	15	19	0.3	ND
FanDen	1000	0.07	ND	32	22	13	14	0.1	0.2
FanDen-r	1000	0.07	ND	27	21	10	14	0.1	0.2
Fan-92	1700	0.11	ND	35	27	11	18	0.2	1.3
Fan-93a	2700	0.06	ND	39	28	18	19	0.2	1.1
Fan-93b	2300	0.06	ND	41	26	18	18	0.2	0.9
Fan-93c	1400	0.04	ND	39	25	18	21	0.2	0.7
UpFan	880	0.07	ND	34	22	13	15	ND	0.2
Gales	1300	0.07	ND	42	50	35	23	0.9	0.2
McKay	1500	0.24	ND	38	21	14	20	0.3	ND
LoRock	1000	0.06	ND	39	25	14	16	0.2	0.3
LoRock-a	850	0.06	ND	37	24	12	16	0.2	0.3
LoRock-b	1100	0.07	ND	38	24	13	16	0.2	0.4
UpRock	1500	0.10	ND	35	24	12	14	0.2	0.5
UpTual	1400	ND	ND	32	40	21	25	0.6	ND
Tual-Els	1200	0.05	ND	34	31	16	21	0.5	0.3

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Strontium	Tantalum	Thorium	Tin	Uranium	Vanadium	Yttrium	Ytterbium	Zinc
P-Code	34965	34975	34980	34985	35000	35005	35010	35015	35020
Units	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g	µg/g
MRL	2	40	1	5	0.05	2	2	1	2
MDL	—	—	—	—	—	—	—	—	—
Reprod	10	—	3	—	0.35	10	2	1	10
Ash	250	ND	13	ND	2.76	140	30	3	210
Bvtn	250	ND	12	ND	2.93	150	30	2	400
Bvtn-r	250	ND	9.5	ND	2.83	140	30	2	400
Bronson	250	ND	12	ND	3.56	130	23	2	220
Cedar	260	ND	11	ND	3.53	120	23	2	140
Chicken	200	ND	12	ND	3.46	170	27	2	130
Dairy	200	ND	16	ND	4.60	160	26	3	120
FanDen	280	ND	14	ND	4.09	130	28	2	160
FanDen-r	280	ND	15	ND	4.20	130	27	2	160
Fan-92	260	ND	12	ND	2.94	170	25	2	340
Fan-93a	260	ND	12	6	3.17	170	25	2	300
Fan-93b	270	ND	11	ND	3.37	170	24	2	280
Fan-93c	280	ND	10	ND	3.03	190	27	3	260
UpFan	270	ND	16	ND (10)[c]	3.83	130	21	2	160
Gales	300	ND	5.8	ND	1.54	280	32	3	120
McKay	210	ND	14	ND	3.81	180	28	3	120
LoRock	230	ND	13	ND	3.41	130	27	3	140
LoRock-a	240	ND	12	ND	3.63	120	26	2	140
LoRock-b	240	ND	15	ND	3.28	120	25	2	150
UpRock	250	ND	13	ND	3.53	110	23	2	190
UpTual	220	ND	8.2	ND	2.66	240	27	3	120
Tual-Els	200	ND	10	ND	3.02	170	27	2	140

c—Analyst raised reporting level for this sample to value in parenthesis.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Aldrin	*cis*-Chlordane	*trans*-Chlordane	Chlorneb	Dacthal	*o,p'*-DDE	*p,p'*-DDE	Dieldrin	Endosulfan I
P-Code	49319	49320	49321	49322	49324	49327	49328	49331	49332
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	1.0	1.0	1.0	5.0	5.0	1.0	1.0	1.0	1.0
MDL	—	—	—	—	—	—	—	—	—
Reprod	—	1.4	0.7	—	—	0.4	0.3	0.9	—
Ash	ND	ND	ND	ND	ND	ND	1.0	ND	ND
Bvtn	ND (2.0)[c]	9.8	8.6	ND	ND	3.9	4.7	6.5	ND
Bvtn-r	ND (2.0)[c]	8.4	7.9	ND	ND	3.5	4.5	7.4	ND
Bronson	ND	1.7	1.2	ND	ND	ND	ND	ND	ND
Cedar	ND	1.0	ND	ND	ND	ND	1.0	ND	ND
Chicken	ND	ND	ND	ND	ND	ND	6.3	ND	ND
Dairy	ND	ND	ND	ND	ND	ND	1.0	ND	ND
FanDen	ND	5.8	5.2	ND	ND	1.6	2.1	3.8	ND
FanDen-r	ND (1.2)[c]	6.3	5.1	ND	ND	1.8	2.1	3.6	ND
Fan-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93a	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	4.1	3.8	ND	ND	ND	10	3.7	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	ND	ND	ND	ND	ND	1.1	ND	ND
LoRock	ND	ND	ND	ND	ND	ND	1.3	ND	ND
LoRock-a	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoRock-b	ND	ND	ND	ND	ND	ND	1.6	ND	ND
UpRock	ND	1.8	1.5	ND	ND	ND	1.9	ND	ND
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	2.0	ND	ND

c—Analyst raised reporting level for this sample to value in parenthesis.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Endrin	α-HCH	β-HCH	γ-HCH	Heptachlor	Heptachlor Epoxide	Isodrin	*o,p'*-Methoxychlor	*p,p'*-Methoxychlor
P-Code	49335	49338	49339	49345	49341	49342	49344	49347	49346
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	2.0	1.0	1.0	1.0	1.0	1.0	1.0	5.0	5.0
MDL	—	—	—	—	—	—	—	—	—
Reprod	—	—	—	—	—	0.1	—	—	—
Ash	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bvtn	ND	ND	ND	ND	ND	1.4	ND	ND	ND
Bvtn-r	ND	ND	ND	ND	ND	1.3	ND	ND	ND
Bronson	ND	ND	ND	ND	ND	ND	ND	—	—
Cedar	ND	ND	ND	ND	ND	ND	ND	—	—
Chicken	ND	ND	ND	ND	ND	ND	ND	—	—
Dairy	ND	ND	ND	ND	ND	ND	ND	—	—
FanDen	ND	ND	ND	ND	ND	ND	ND	ND	ND
FanDen-r	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93a	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	ND	ND	ND	ND	ND	ND	—	—
LoRock	ND	ND	ND	ND	ND	ND	ND	—	—
LoRock-a	ND	ND	ND	ND	ND	ND	ND	—	—
LoRock-b	ND	ND	ND	ND	ND	ND	ND	—	—
UpRock	ND	ND	ND	ND	ND	ND	ND	—	—
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	ND	—	—

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Mirex	*cis*-Nonachlor	*trans*-Nonachlor	Oxychlordane	*cis*-Permethrin	*trans*-Permethrin	Toxaphene	Acenaph-thene	Acenaph-thylene
P-Code	49348	49316	49317	49318	49349	49350	49351	49429	49428
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	1.0	1.0	1.0	1.0	5.0	5.0	200	—	—
MDL	—	—	—	—	—	—	—	31	29
Reprod	—	0.1	0.4	—	—	—	—	—	2
Ash	ND (2.0)[c]	ND	ND	ND	ND	ND	ND	17[d]	30
Bvtn	ND	2.4	7.8	ND	ND	I	ND	I	I
Bvtn-r	ND	2.3	7.4	ND	ND	I	ND	I	I
Bronson	ND	1.1	1.6	ND	ND	ND	ND	ND	ND
Cedar	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chicken	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dairy	ND	ND	ND	ND	ND	ND	ND	ND	ND
FanDen	ND	1.5	4.9	ND	ND	I	ND	ND	E19[d]
FanDen-r	ND	1.6	4.9	ND	ND	I	ND	ND	E21[d]
Fan-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93a	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	2.2	3.9	ND	ND	ND	ND	15[d]	21[d]
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	ND	ND	ND	ND	ND	ND	16[d]	38
LoRock	ND	ND (2.0)[c]	ND	ND	ND	ND	ND	ND	ND
LoRock-a	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoRock-b	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpRock	ND	ND (2.0)[c]	1.2	ND	ND	ND	ND	17[d]	27[d]
UpTual	ND (2.0)[c]	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	ND	ND	ND

c—Analyst raised reporting level for this sample to value in parenthesis.

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Anthracene	Benz[a]-anthracene	Benzo[*a*]-pyrene	Benzo[*b*]-fluoranthene	Benzo[*ghi*]-perylene	Benzo[*k*]-fluoranthene	Chrysene	Dibenz[*a,h*]-anthracene	Fluoranthene
P-Code	49434	49436	49389	49458	49408	49397	49450	49461	49466
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	28	23	19	20	64	33	24	25	29
Reprod	11	40	80	60	30	50	80	—	70
Ash	130	300	560	250	82	300	340	35	260
Bvtn	I	E480	E390	E680	470	E280	670	ND	890
Bvtn-r	I	E440	E310	E620	440	E330	590	ND	820
Bronson	ND	110	53	88	ND	88	110	ND	70
Cedar	31	45	ND	52	ND	71	57	ND	61
Chicken	32	44	ND	55	ND	51	49	ND	54
Dairy	35	54	ND	48	ND	58	63	ND	60
FanDen	E33	98	120	E91	84	110	E260	ND	340
FanDen-r	E44	100	130	E100	88	110	E270	ND	360
Fan-92	24 [d]	110	120	89	110	150	180	24 [d]	260
Fan-93a	13 [d]	23	35	66	23 [d]	28 [d]	61	ND	90
Fan-93b	37	94	130	140	63 [d]	140	190	ND	290
Fan-93c	16 [d]	7 [d]	7 [d]	10 [d]	ND	9 [d]	ND	ND	19 [d]
UpFan	44	80	200	280	50 [d]	220	170	ND	220
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	68	120	68	130	ND	120	170	ND	380
LoRock	31	43	ND	60	ND	54	50	ND	50
LoRock-a	32	45	ND	60	ND	58	50	ND	53
LoRock-b	34	52	ND	67	ND	61	60	ND	69
UpRock	50	67	55	73	ND	100	94	ND	130
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	44	ND	56	ND	53	45	ND	50

[d] Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	9H-Fluorene	Indeno[1,2,3-*cd*]pyrene	Naphthalene	Phenanthrene	Pyrene	1,2-Dimethyl-naphthalene	1,6-Dimethyl-naphthalene	2,6-Dimethyl-naphthalene	2-Ethyl-naphthalene
P-Code	49399	49390	49402	49409	49387	49403	49404	49406	49948
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	32	25	26	30	27	27	28	26	28
Reprod	—	10	—	50	100	—	—	9	—
Ash	24 [d]	130	10 [d]	170	260	ND	11 [d]	71	ND
Bvtn	I	E470	I	E250	1100	I	I	I	I
Bvtn-r	I	I	I	E200	1000	I	I	I	I
Bronson	ND	79	12 [d]	ND	95	ND	ND	120	ND
Cedar	ND	ND	ND	28 [d]	75	ND	ND	30	ND
Chicken	ND	ND	ND	26 [d]	63	ND	ND	36	ND
Dairy	ND	ND	ND	31	60	ND	ND	23 [d]	ND
FanDen	ND	69	ND	150	430	ND	ND	E30	ND
FanDen-r	ND	75	ND	170	460	ND	ND	E28	ND
Fan-92	9 [d]	85	ND	140	240	ND	ND	ND	ND
Fan-93a	ND	22 [d]	ND	41	89	ND	ND	29	ND
Fan-93b	ND	59	ND	150	240	ND	ND	38	ND
Fan-93c	ND	12 [d]	ND	17 [d]	22 [d]	ND	ND	86	ND
UpFan	20 [d]	80	ND	140	230	ND	ND	20 [d]	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	29 [d]	83	25 [d]	150	250	ND	ND	27	ND
LoRock	ND	60	ND	20 [d]	58	ND	ND	29	ND
LoRock-a	ND	ND	ND	23 [d]	60	ND	ND	28	ND
LoRock-b	ND	ND	ND	34	72	ND	ND	37	ND
UpRock	28 [d]	62	ND	64	130	7 [d]	ND	70	ND
UpTual	ND	ND	ND	ND	ND	ND	ND	17 [d]	ND
Tual-Els	ND	ND	ND	ND	53	ND	ND	89	ND

[d] —Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	1-Methyl-9H-fluorene	1-Methyl-phenanthrene	1-Methyl-pyrene	2-Methyl-anthracene	4,5-Methylene-phenanthrene	2,3,6-Trimethyl-naphthylene	Acridine	Benzo[*c*]-cinnoline	2,2'-Biquinoline
P-Code	49398	49410	49388	49435	49411	49405	49430	49468	49391
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	32	30	25	25	29	32	24	24	50
Reprod	—	—	—	—	3	—	—	—	—
Ash	ND	53	40	89	42	ND	ND	ND	ND
Bvtn	I	I	I	I	I	I	I	I	I
Bvtn-r	I	I	I	I	I	I	I	I	I
Bronson	ND	ND	70	ND	ND	ND	ND	ND	ND
Cedar	ND	ND	ND	ND	34	ND	ND	ND	ND
Chicken	ND	ND	48	ND	33	ND	ND	ND	ND
Dairy	ND	ND	ND	ND	37	ND	ND	ND	52
FanDen	ND	E27[d]	ND	ND	E35	ND	ND	ND	ND
FanDen-r	ND	E22[d]	E42	E25	E32	ND	ND	ND	ND
Fan-92	ND	16[d]	11[d]	ND	21[d]	ND	9[d]	ND	ND
Fan-93a	ND	8[d]	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	27[d]	ND	22[d]	ND	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	15[d]	15[d]	ND	25[d]	ND	ND	ND	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	50	55	ND	62	ND	37	ND	56
LoRock	ND	34	ND	ND	36	ND	ND	ND	ND
LoRock-a	ND	ND	ND	ND	35	ND	ND	ND	ND
LoRock-b	ND	ND	ND	ND	37	ND	ND	ND	ND
UpRock	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	ND	ND	ND

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	9H-Carbazole	Isoquinoline	Phenanthridine	Quinoline	bis(2-Ethylhexyl)-phthalate	Butylbenzyl-phthalate	Diethyl-phthalate	Dimethyl-phthalate	Di-*n*-butyl-phthalate
P-Code	49449	49394	49393	49392	49426	49427	49383	49384	49381
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	28	28	26	30	31	27	31	27	28
Reprod	—	—	—	—	100	80	—	—	10
Ash	23 [d]	ND	ND	ND	3500	1400	ND	ND	60
Bvtn	I	I	I	I	E10000	E1000	I	I	I
Bvtn-r	I	I	I	I	E10000	920	I	I	I
Bronson	ND	ND	64	ND	2300	150	19 [d]	ND	99
Cedar	ND	ND	ND	ND	330	67	18 [d]	ND	72
Chicken	ND	ND	ND	ND	130	64	18 [d]	ND	68
Dairy	ND	ND	ND	ND	100	70	21 [d]	ND	77
FanDen	ND	ND	ND	ND	E1000	93	E39	ND	E46
FanDen-r	E22 [d]	ND	ND	ND	E1100	110	ND	ND	E44
Fan-92	17 [d]	ND	ND	ND	59	54	ND	ND	88
Fan-93a	ND	ND	ND	ND	1100	760	7 [d]	ND	44
Fan-93b	29	ND	ND	ND	810	22 [d]	6 [d]	ND	48
Fan-93c	ND	ND	ND	ND	43	22 [d]	ND	ND	50
UpFan	12 [d]	ND	ND	ND	820	160	ND	ND	30
Gales	ND	ND	ND	ND	31	ND	ND	ND	21 [d]
McKay	50	32	32	14 [d]	160	72	22 [d]	ND	77
LoRock	ND	ND	ND	ND	150	74	21 [d]	ND	76
LoRock-a	ND	ND	ND	ND	160	72	20 [d]	ND	79
LoRock-b	ND	ND	ND	ND	150	75	21 [d]	ND	86
UpRock	ND	ND	ND	ND	330	85	21 [d]	ND	90
UpTual	ND	ND	ND	ND	38	ND	ND	ND	26 [d]
Tual-Els	ND	ND	ND	ND	160	70	19 [d]	ND	76

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Di-*n*-octyl-phthalate	C8-alkylphenol	2-Chloro-phenol	4-Chloro-3-methylphenol	*p*-Cresol	3,5-Dimethyl-phenol	Phenol	2-Chloro-naphthalene	1,2-Dichloro-benzene
P-Code	49382	49424	49467	49422	49451	49421	49413	49407	49439
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	25	30	24	26	32	31	20	29	28
Reprod	37	—	—	—	40	—	—	—	—
Ash	340	ND	ND	ND	39	ND	58	ND	ND
Bvtn	E820	I	I	I	880	I	I	I	I
Bvtn-r	I	I	I	I	840	I	I	I	I
Bronson	200	ND	ND	ND	160	ND	32	ND	ND
Cedar	ND	ND	ND	ND	40	ND	12[d]	ND	ND
Chicken	100	ND	ND	ND	ND	ND	7[d]	ND	ND
Dairy	88	ND	ND	ND	85	ND	25	ND	ND
FanDen	ND	ND	ND	ND	140	ND	ND	ND	ND
FanDen-r	E68	ND	ND	ND	180	ND	E24	ND	ND
Fan-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93a	54	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	20[d]	ND	13[d]	ND	ND
Fan-93c	ND	ND	ND	ND	570	ND	64	ND	ND
UpFan	59	ND	ND	ND	43	ND	16[d]	ND	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	88	ND	ND	ND	55	ND	22	ND	ND
LoRock	84	ND	ND	ND	33	ND	6[d]	ND	ND
LoRock-a	ND	ND	ND	ND	34	ND	7[d]	ND	ND
LoRock-b	87	ND	ND	ND	35	ND	9[d]	ND	ND
UpRock	88	ND	ND	ND	40	ND	13[d]	ND	ND
UpTual	ND	ND	ND	ND	ND	ND	16[d]	ND	ND
Tual-Els	ND	ND	ND	ND	660	43	18[d]	ND	ND

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	1,3-Dichloro-benzene	1,4-Dichloro-benzene	Hexachloro-benzene	Pentachloro-anisole	Pentachloro-nitrobenzene	Total PCB	1,2,4-Trichloro-benzene	Anthra-quinone	Azobenzene
P-Code	49441	49442	49343	49460	49446	49459	49438	49437	49443
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g
MRL	—	—	1.0	1.0	—	100	—	—	—
MDL	30	37	—	—	24	—	26	30	32
Reprod	—	—	—	—	—	—	—	21	—
Ash	ND	ND	ND	ND	ND	ND	ND	100	ND
Bvtn	I	I	ND	ND	I	ND	I	I	I
Bvtn-r	I	I	ND	ND	I	ND	I	I	I
Bronson	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cedar	ND	ND	ND	ND	ND	ND	ND	35	ND
Chicken	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dairy	ND	ND	ND	ND	ND	ND	ND	ND	ND
FanDen	ND	ND	ND	ND	ND	ND	ND	93	ND
FanDen-r	ND	ND	ND	ND	ND	ND	ND	72	ND
Fan-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93a	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	ND	ND	ND	40	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	ND	ND	ND	ND	ND	ND	23 [d]	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	ND	ND	ND	ND	ND	ND	94	ND
LoRock	ND	ND	ND	ND	ND	ND	ND	35	ND
LoRock-a	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoRock-b	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpRock	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	ND	ND	ND

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	bis(2-Chloroethoxy) methane	4-Bromo-phenyl-phenylether	4-Chloro-phenyl-phenylether	Dibenzo-thiophene	2,4-Dinitro-toluene	Isophorone	Nitrobenzene	N-Nitroso-diphenyl-amine	N-Nitroso-di-*n*-propyl-amine
P-Code	49401	49454	49455	49452	49395	49400	49444	49433	49431
Units	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/g	ng/n	ng/g
MRL	—	—	—	—	—	—	—	—	—
MDL	34	29	30	28	29	27	31	27	28
Reprod	—	—	—	—	—	—	—	—	—
Ash	ND	ND	ND	ND	ND	ND	ND	13 [d]	ND
Bvtn	I	I	I	I	I	I	I	I	I
Bvtn-r	I	I	I	I	I	I	I	I	I
Bronson	ND	ND	ND	ND	ND	ND	ND	28	ND
Cedar	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chicken	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dairy	ND	ND	ND	ND	ND	ND	ND	ND	ND
FanDen	ND	ND	ND	ND	ND	ND	ND	ND	ND
FanDen-r	ND	ND	ND	27 [d]	ND	ND	ND	ND	ND
Fan-92	ND	ND	ND	12 [d]	ND	ND	ND	ND	ND
Fan-93a	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93b	ND	ND	ND	ND	ND	ND	ND	ND	ND
Fan-93c	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpFan	ND	ND	ND	14 [d]	ND	ND	ND	ND	ND
Gales	ND	ND	ND	ND	ND	ND	ND	ND	ND
McKay	ND	ND	ND	31	ND	ND	ND	ND	ND
LoRock	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoRock-a	ND	ND	ND	ND	ND	ND	ND	ND	ND
LoRock-b	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpRock	ND	ND	ND	27 [d]	ND	ND	ND	ND	ND
UpTual	ND	ND	ND	ND	ND	ND	ND	ND	ND
Tual-Els	ND	ND	ND	ND	ND	ND	ND	ND	ND

d—Value is less than MDL. Likelihood of a false positive exceeds 1%.

Appendix B. Bed sediment data—continued

[Abbreviations: mg/g, milligram per gram; µg/g, microgram per gram; ng/g, nanogram per gram; ND, not detected; I, interference; E, estimated value; —, no value]

Site abbrev	Surrogate Compounds					
	3,5-Dichlorobiphenyl	α-HCH-d_6	PCB-204	2-Fluorobiphenyl	Nitrobenzene-d_5	Terphenyl-d_{14}
P-Code	49277	49275	49276	49279	49280	49278
Units	percent recovery	percent recovery	percent recovery	percent recovery	percent recovery	percent recovery
MRL	—	—	—	—	—	—
MDL	—	—	—	—	—	—
Reprod	4	5	6	14	29	10
Ash	64	70	73	50	59	58
Bvtn	58	72	48	120	65	—
Bvtn-r	57	70	47	120	36	—
Bronson	59	85	57	69	68	91
Cedar	61	61	69	71	72	99
Chicken	59	69	66	54	64	76
Dairy	65	74	58	59	79	93
FanDen	66	79	67	66	79	—
FanDen-r	62	75	61	51	80	—
Fan-92	59	40	46	29	30	38
Fan-93a	48	55	45	89	82	79
Fan-93b	58	63	54	92	84	78
Fan-93c	60	65	62	53	41	76
UpFan	66	77	78	39	43	54
Gales	52	73	82	36	39	58
McKay	66	74	85	66	78	89
LoRock	65	74	75	63	77	96
LoRock-a	64	76	74	65	69	100
LoRock-b	67	71	78	63	65	90
UpRock	60	69	60	60	72	93
UpTual	52	70	68	47	53	58
Tual-Els	71	75	76	66	70	89

Appendix C. Qualitative description of fish occurence and abundance

[Descriptions based on field notes made while collecting sculpin for tissue analysis. Sites were not sampled for fish assemblage information. Length of reach sampled varied among sites. “Abundant” means the species was seen in large numbers throughout the section of stream sampled; “common” means the species was observed frequently to occasionally, but not in large numbers; “present” means that at least one individual was observed.]

Site abbrev	USGS station name	Notes
Bvtn	Beaverton Creek at Cedar Hills Blvd	Few fish were present. Only 4 sculpin were collected. Three-spine stickleback were common. Redside shiner were present. Approximately half of the stickleback and shiners caught had visible signs of external abnormalities, primarily white tumors.
Bronson	Bronson Creek at Walker Road	Few fish. Only a couple of reticulate sculpin were collected (not enough for a complete sample—tissue was sent for organochlorine analysis, but not for element analysis). The most common fish was largemouth bass, redside shiners were present.
Cedar	Cedar Mill Creek at Jenkins Rd	High abundance of reticulate sculpin. Few, if any, other fish were observed because sculpin were so common that only a short section of river was sampled.
Dairy	Dairy Creek at Susbauer Road	Sculpin were abundant and redside shiners were present. Stream was dominated by reticulate sculpin.
FanDen	Fanno Creek near Denny Road	Few fish overall. Even sculpin were not abundant.
FanDen-r1	...	
FanDen-r2	...	
Fan-92	Fanno Creek at Durham, OR	High abundance of fish, 90% of which were reticulate sculpin. Redside shiner, speckled dace were common; largescale sucker, cutthroat trout, western brook lamprey, *gambusia*, and bluegill were present. Low occurrence of external fish abnormalities.
Fan-93	...	
Fan-93-r1	...	
Fan-93-r2	...	
Fan-96	...	
UpFan	Upper Fanno Creek at Nicol Road	Few fish overall. Even sculpin were not abundant and only a couple of other fish were seen. Redside shiner were present.
Gales-92	Gales Creek near Glenwood, OR	Mottled and reticulate sculpin were abundant, as were cutthroat trout. Rainbow trout were common.
Gales-96	...	
UpRock	Upper Rock Creek at Baseline Road	Few fish overall. Sculpin were common. Only a couple of other fish were seen.

Appendix D. Fish tissue data

Site abbrev	USGS station name	Date	Time[a]	Code[b]	USGS station	Latitude (degrees)	Longitude (degrees)
Pcode	*parameter code for this constituent in USGS database*						
Units	*concentration units for chemical constituents*						
MRL	*minimum reporting level: minimum value reported for this constituent by the laboratory*						
Reprod	*estimate of reproducibility: maximum replicate range for this analyte in this study*						
Bvtn	Beaverton Creek at Cedar Hills Blvd	9–5–1996	11:00	P	452937122483400	452937	1224834
Bronson	Bronson Creek at Walker Road	8–21–1996	11:00	P	14206300	453149	1225218
Cedar	Cedar Mill Creek at Jenkins Road	9–4–1996	13:0~0	P	453024122500500	453024	1225005
Dairy	Dairy Creek at Susbauer Road	8–19–1996	15:00	P	14205850	453220	1230226
Dairy-r	same	same	15:01	R	same	same	same
FanDen	Fanno Creek near Denny Road	9–4–1996	10:30	P	452807122471400	452807	1224714
FanDen-r1	same	same	10:31	R	same	same	same
FanDen-r2	same	same	10:32	R	same	same	same
Fan-92	Fanno Creek at Durham, OR	9–1–1992	15:00	P	14206950	452413	1224513
Fan-93	same	9–29–1993	12:00	P	same	same	same
Fan-93-r1	same	same	12:01	R	same	same	same
Fan-93-r2	same	same	12:02	R	same	same	same
Fan-96	same	8–20–1996	14:00	P	same	same	same
UpFan	Upper Fanno Creek at Nicol Road	8–20–1996	11:00	P	14206920	452822	1224544
Gales-92	Gales Creek near Glenwood, OR	9–9–1992	10:30	P	14203750	453837	1232209
Gales-96	same	8–19–1996	12:00	P	same	same	same
UpRock	Upper Rock Creek at Baseline Road	8–21–1996	14:30	P	14206447	453114	1225444

a—Time is a sample label and was not the exact sampling time. Together, USGS Ststion, date and time, uniquely identify a sample.

b—Code for sample type: P=primary sample; R=replicate sample

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Number of fish in sample		Moisture	Lipid	Aluminum	Iron	Antimony	Arsenic
	elements	organics						
P-Code	—	—	49273	49289	49237	49242	49246	49247
Units	number	number	percent	percent	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
MRL	—	—	—	—	1.0	1.0	0.2	0.2
Reprod	—	—	1.2	2.7	71.2	135	—	0.1
Bvtn	0	4	—	4.0	—	—	—	—
Bronson	0	7	—	4.3	—	—	—	—
Cedar	10	10	76.0	3.4	18.8	66.3	ND	0.4
Dairy	10	10	77.0	3.0	20.4	61.3	ND	ND
Dairy-r	0	10	—	3.6	—	—	—	—
FanDen	10	10	77.5	3.0	47.6	134	ND	0.2
FanDen-r1	10	10	77.6	2.8	15.4	57.4	ND	ND
FanDen-r2	10	10	78.4	3.5	27.8	97.9	ND	ND
Fan-92	10	10	76.8	5.0	44.2	110	ND	0.4
Fan-93	10	10	78.0	3.9	181	279	ND	0.3
Fan-93-r1	10	10	76.9	3.7	123	183	ND	0.3
Fan-93-r2	10	10	76.8	6.4	127	237	ND	0.4
Fan-96	10	10	77.0	3.3	18.9	80.2	ND	0.3
UpFan	10	10	75.9	6.5	34.8	84.3	ND	0.2
Gales-92	10	10	76.4	2.6	90.6	216	ND	ND
Gales-96	12	15	76.6	2.6	19.4	81.1	ND	ND
UpRock	10	10	76.6	3.1	5.1	56.1	ND	0.2

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese
P-Code	49238	49248	49239	49249	49240	49250	49241	49251	49243
Units	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
MRL	0.1	0.2	0.2	0.2	0.5	0.2	0.5	0.2	0.1
Reprod	3.4	—	8.6	—	0.6	0.1	1.5	0.4	38.1
Bvtn	—	—	—	—	—	—	—	—	—
Bronson	—	—	—	—	—	—	—	—	—
Cedar	11.0	ND	1.0	ND	1.9	0.2	2.0	0.2	17.3
Dairy	22.4	ND	0.3	ND	1.9	0.3	2.7	ND	22.2
Dairy-r	—	—	—	—	—	—	—	—	—
FanDen	11.0	ND	1.4	ND	1.9	0.3	2.9	0.5	36.6
FanDen-r1	10.1	ND	0.8	ND	1.6	ND	1.7	0.5	23.9
FanDen-r2	13.5	ND	2.4	ND	2.2	0.3	3.2	0.6	50.0
Fan-92	9.8	ND	2.5	ND	1.6	0.6	3.8	0.7	51.1
Fan-93	11.0	ND	2.8	ND	1.7	0.6	3.3	0.9	78.1
Fan-93-r1	10.9	ND	9.4	ND	1.6	0.5	4.0	0.5	49.9
Fan-93-r2	10.1	ND	0.8	ND	1.5	0.6	3.7	0.6	88.0
Fan-96	9.6	ND	3.5	ND	1.8	0.3	3.6	0.8	27.1
UpFan	9.4	ND	0.9	ND	1.6	0.3	2.0	0.3	34.9
Gales-92	2.4	ND	0.9	ND	2.0	0.6	1.8	ND	8.3
Gales-96	2.0	ND	0.5	ND	2.0	0.5	2.6	ND	9.7
UpRock	12.6	ND	1.5	ND	1.9	0.3	2.9	ND	27.9

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Mercury	Molybdenum	Nickel	Selenium	Silver	Strontium	Uranium	Vanadium	Zinc
P-Code	49258	49252	49253	49254	49255	49244	49257	49465	49245
Units	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)	µg/g (dry)
MRL	0.02	0.2	0.2	0.1	0.2	0.1	0.2	0.1	0.5
Reprod	0.46	—	3.3	0.4	—	26.5	—	0.7	26
Bvtn	—	—	—	—	—	—	—	—	—
Bronson	—	—	—	—	—	—	—	—	—
Cedar	0.33	ND	0.4	1.4	ND	80.9	ND	1.2	84.3
Dairy	0.32	ND	0.4	1.9	ND	121	ND	1.0	83.8
Dairy-r	—	—	—	—	—	—	—	—	—
FanDen	0.95	ND	0.6	1.8	ND	102	ND	1.5	78.4
FanDen-r1	1.0	ND	ND	1.8	ND	105	ND	1.2	77
FanDen-r2	0.54	ND	0.5	2.2	ND	118	ND	1.3	103
Fan-92	0.30	ND	3.3	ND (1.4)[c]	ND	82.6	ND	1.7	99.0
Fan-93	0.10	ND	1.5	1.4	ND	70.2	ND	2.4	98.4
Fan-93-r1	0.20	ND	1.4	ND (1.3)[c]	ND	80.4	ND	1.7	99.3
Fan-93-r2	ND (0.10)[c]	0.5	1.8	ND (1.3)[c]	ND	65.3	ND	2.0	89.5
Fan-96	0.35	ND	0.6	1.6	ND	86.2	ND	1.2	98.1
UpFan	0.25	ND	0.5	2.0	ND	89.8	ND	0.8	62.9
Gales-92	ND (0.10)[c]	ND	3.7	ND (1.1)[c]	ND	117	ND	1.3	110
Gales-96	ND (0.03)[c]	ND	0.4	1.1	ND	90.5	ND	0.6	91.3
UpRock	0.86	ND	0.5	2.5	ND	77.2	ND	1.2	102

c—Analyst raised reporting level for this sample to value in parenthesis.

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Adrin	*cis*-Chlordane	*trans*-Chlordane	*o,p'*-DDD	*p,p'*-DDD	*o,p'*-DDE	*p,p'*-DDE	*o,p'*-DDT	*p,p'*-DDT
P-Code	49353	49380	49379	49374	49375	49373	49372	49377	49376
Units	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)
MRL	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Reprod	—	6	23	—	2.2	—	6	—	2.0
Bvtn	ND	27	13	ND	E24.0	ND	20	ND	5.0
Bronson	ND	12	ND	ND	ND	ND	7	ND	ND
Cedar	ND	16	6.6	ND	ND	ND	16	ND	ND
Dairy	ND	ND	ND	ND	ND	ND	14	ND	E7.8
Dairy-r	ND	7.2	ND	ND	ND	ND	16	ND	9.4
FanDen	ND	76	19	ND	E6.0	ND	14	ND	5.8
FanDen-r1	ND	82	28	ND	E8.2	ND (7)[c]	14	ND	7.4
FanDen-r2	ND	78	ND	ND	E6.2	ND	12	ND	6.4
Fan-92	ND	ND	9.1	ND	ND	ND	9	ND	5.6
Fan-93	ND	14	6	ND	ND	ND	18	ND	5.7
Fan-93-r1	ND	15	8.4	ND	ND	ND	19	ND	7.4
Fan-93-r2	ND	15	6	ND	ND	ND	13	ND	5.4
Fan-96	ND	21	11	ND	ND	ND	18	ND	E8.6
UpFan	ND	84	25	ND	10.0	ND	21	ND	ND
Gales-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gales-96	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpRock	ND	8.3	ND	ND	E5.3	ND	10	ND	ND

c—Analyst raised reporting level for this sample to value in parenthesis.

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Dacthal	Dieldrin	Endrin	α-HCH	β-HCH	δ-HCH	γ-HCH	Heptachlor	Heptachlor epoxide
P-Code	49378	49371	49370	49366	49365	49364	49363	49369	49368
Units	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)
MRL	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Reprod	—	12	—	—	—	—	—	—	—
Bvtn	ND	20	ND (12)[c]	ND	ND	ND	ND	ND	E12
Bronson	ND	9.3	ND (26)[c]	ND	ND	ND	ND	ND	ND
Cedar	ND	13	ND (7)[c]	ND	ND	ND	ND	ND	E6.4
Dairy	ND	23	ND	ND	ND	ND	ND	ND	ND
Dairy-r	ND	15	ND (18)[c]	ND	ND	ND	ND	ND	ND
FanDen	ND	20	ND (6)[c]	ND	ND	ND	ND	ND	I
FanDen-r1	ND	32	ND (13)[c]	ND	ND	ND	ND	ND	I
FanDen-r2	ND	28	ND (11)[c]	ND	ND	ND	ND	ND	I
Fan-92	ND	12	ND	ND	ND	ND	ND	ND	ND
Fan-93	ND	15	ND	ND	ND	ND	ND	ND	ND
Fan-93-r1	ND	19	ND	ND	ND	ND	ND	ND	ND
Fan-93-r2	ND	14	ND	ND	ND	ND	ND	ND	ND
Fan-96	ND	14	ND	ND	ND	ND	ND	ND	11
UpFan	ND	86	ND	E6.6	ND	ND	ND	ND	14
Gales-92	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gales-96	ND	ND	ND (6)[c]	ND	ND	ND	ND	ND	ND
UpRock	ND	6	ND (6)[c]	ND	ND	ND	ND	ND	ND

c—Analyst raised reporting level for this sample to value in parenthesis.

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	*o,p*-Methoxychlor	*p,p*-Methoxychlor	Mirex	*cis*-Nonachlor	*trans*-Nonachlor	Oxychlordane	Toxaphene	Hexachlorobenzene	Pentachloroanisole	total PCB
P-Code	49362	49361	49360	49359	49358	49357	49355	49367	49356	49354
Units	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)	ng/g (wet)
MRL	5.0	5.0	5.0	5.0	5.0	5.0	200	5.0	5.0	50
Reprod	—	—	—	6	7	—	—	—	3.1	73
Bvtn	ND	ND	ND	7.8	29	E10	ND	ND	ND	120
Bronson	ND	ND	ND	ND	13	ND	ND	ND	ND	54
Cedar	ND	ND	ND	ND	18	E8.9	ND	ND	7.4	69
Dairy	ND	ND	ND	ND	7.0	ND	ND	ND	6.7	ND
Dairy-r	ND	ND	ND	ND	9.6	ND	ND	ND	8.4	ND
FanDen	ND	ND	ND	E12	73	I	ND	ND	5.8	96
FanDen-r1	ND	ND	ND	E18	74	I	ND	ND	8.9	150
FanDen-r2	ND	ND	ND	E15	67	I	ND	ND	7.4	77
Fan-92	ND	ND	ND	9.2	27	ND	ND	ND	5.0	200
Fan-93	ND	ND	ND	7.2	18	ND	ND	ND	ND	380
Fan-93-r1	ND	ND	ND	6.3	20	ND	ND	ND	ND	440
Fan-93-r2	ND	ND	ND	6.5	20	ND	ND	ND	ND	440
Fan-96	ND	ND	ND	ND	17	7.8	ND	ND	ND	81
UpFan	ND	ND	ND	14	74	35	ND	ND	22	110
Gales-92	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Gales-96	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
UpRock	ND	ND	ND	ND	12	ND	ND	ND	12	ND

Appendix D. Fish tissue data—continued

[Abbreviations: µg/g, microgram per gram; ng/g, nanogram per gram; dry, on a dry-weight basis; wet, on a wet-weight basis; ND, not detected; I, interference; E, estimated value; — , no value]

Site abbrev	Surrogate compounds	
	3,5-Dichlorobiphenyl	α-HCH-d_6
P-Code	49264	49261
Units	percent recovery	percent recovery
MRL	—	—
Reprod	35	14
Bvtn	54	85
Bronson	57	0
Cedar	51	95
Dairy	70	80
Dairy-r	45	82
FanDen	50	77
FanDen-r1	61	93
FanDen-r2	52	91
Fan-92	0	—
Fan-93	0	0
Fan-93-r1	0	0
Fan-93-r2	0	0
Fan-96	66	82
UpFan	75	94
Gales-92	0	—
Gales-96	59	86
UpRock	57	92