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U.S. FISH AND WILDLIFE SERVICE
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ENVIRONMENTAL CONTAMINANTS PROGRAM
ON-REFUGE CLEAN-UP INVESTIGATIONS SUB-ACTIVITY

WA-Preliminary Assessment to Determine Superfund Site Impacts on the Ridgefield National Wildlife Refuge

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by

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INTRODUCTION

The Ridgefield National Wildlife Refuge (NWR) is located in Ridgefield, Washington, along the lower Columbia River (Figure 1). The refuge provides important wintering habitat for waterfowl and is used extensively by migratory shorebirds, wading birds, and passerines during fall and spring migrations. The refuge is also used as a roosting area for lesser sandhill cranes (*Grus canadensis*) and a roosting and foraging area for tundra swans (*Cygnus columbianus*). Federally threatened and endangered species such as bald eagles (*Haliaeetus leucocephalus*) use the refuge as foraging and nesting habitats, and peregrine falcons (*Falco peregrinus*) are also known to forage on the refuge. Due to its proximity to the Columbia River, anadromous fish use nearshore habitats along the refuge boundaries.

The northern unit of the refuge (Carty Unit) is bordered by the Pacific Wood Treatment (PWT) facility, a Washington State Model Toxics Control Act (MTCA) cleanup site contaminated with wood-treating related chemicals. The PWT site is located immediately south of Carty Lake, which is part of the refuge located at the southern end of the Carty Unit and east of Lake River (Figure 1). Wood-treating operations at the PWT site began in 1964 and involved a variety of chemical preservatives including pentachlorophenol (PCP), creosote, chromated copper arsenate, and copper napthenate. Until the 1980s, chemicals were allowed to drain directly onto the open ground as part of the wood treatment process. The PWT site began preliminary investigations in 1986. The site Work Plan by Hart Crowser (1992) identified potential contaminants of concern as petroleum hydrocarbons; volatile and semi-volatile organics; chlorinated phenols and related compounds; trace elements such as arsenic, chromium, and copper; and dioxins and furans. Studies overseen by the Washington Department of Ecology (DOE) indicated there was extensive onsite soil contamination from creosote wood treatment operations, as well as contaminated groundwater and surface water. Contaminants documented onsite included PCP, volatile and semi-volatile organics, copper, chromium, and arsenic (Kleinfelder 1993).

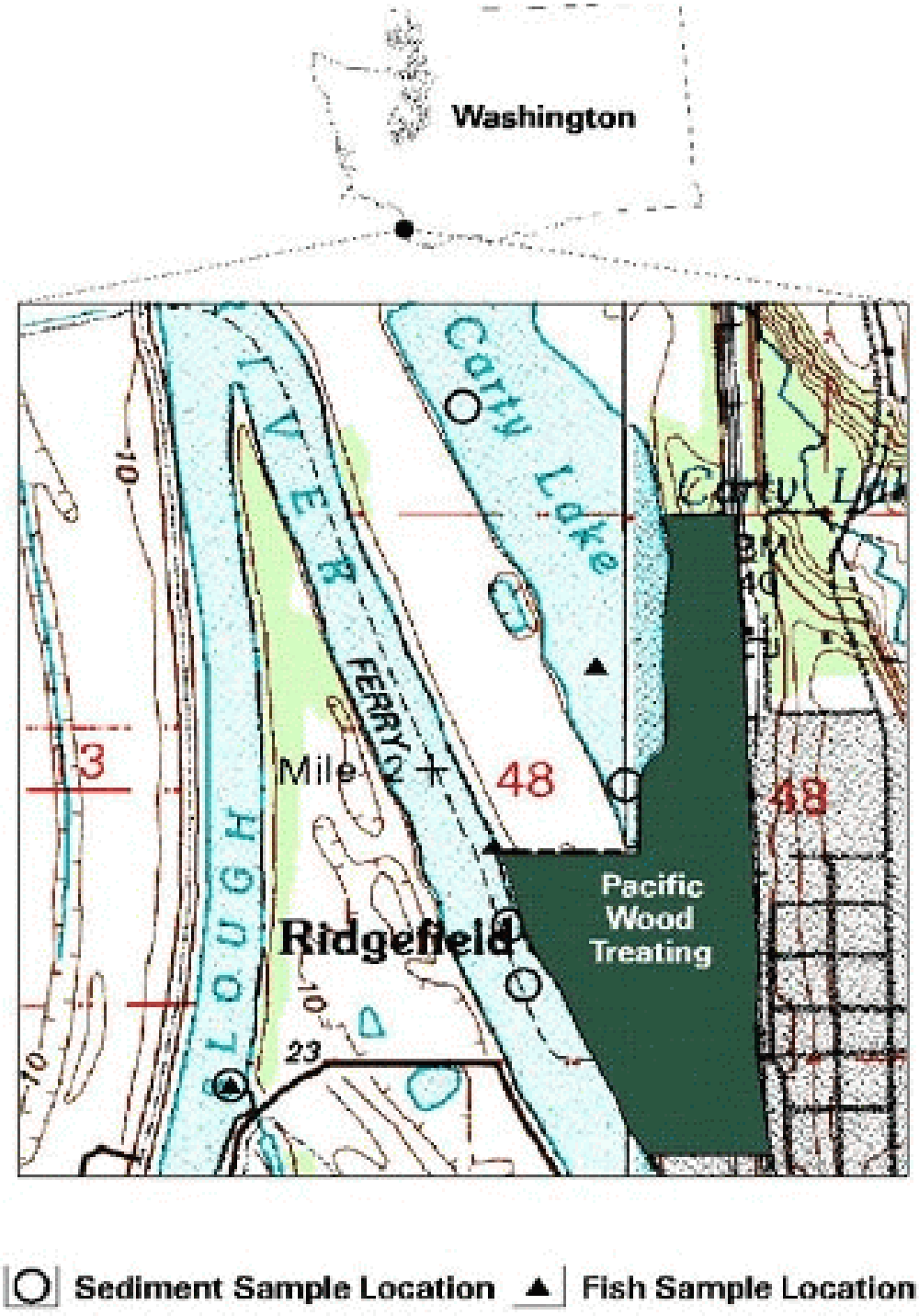
Contaminants originating from the PWT site have migrated off-site and into Refuge lands, including Carty Lake and adjacent wetlands (Ecology and Environmental 1996). Kleinfelder (1993) documented wood-treating chemicals in sediment and water in and around surface water outfalls in both Carty Lake and Lake River. Site contaminants have contacted soil, sediment, surface water, and groundwater on the Refuge, and a single release of a PCP-containing liquid from a overflowing tank was observed entering the refuge in 1995 (Ecology and Environment 1996). Groundwater in wells installed on the border of the refuge and the site at Carty Lake contained up to 12 µg/L of PCP, which was well above the risk-based concentration for PCP of 0.56 µg/L (Ecology and Environment 1996).

Several trace elements were detected in surface water samples collected from four outfalls that drain stormwater from the PWT site into Lake River, and from a fifth outfall draining into Carty Lake. Kleinfelder (1993) originally reported that the Carty Lake outfall drained surface water from the PWT site under a National Pollution Discharge Elimination System. However, the outfall may have been part of the City of Ridgefield s sewage treatment system and not associated with the PWT site (Dan Alexanian, Toxics Cleanup Program, Department of Ecology, pers. comm.). Reif (1989) found trace element concentrations in stormwater in 1986 and 1987,

which exceeded U.S. Environmental Protection Agency (EPA) standards for protection of aquatic life. Rainbow trout (*Oncorhynchus mykiss*) sustained 100 % mortality when exposed to water from three outfalls at 65 % of the runoff concentration (Reif 1989). While PWT was still in operation, PCP was detected in sediment samples collected from Lake River and the Ridgefield NWR. Concentrations of 34 to 38 µg PCP/kg were detected on the refuge and near the stormwater outfall. The highest PCP concentrations were 410 and 2,200 µg/kg found in sediment near two outfalls draining into Lake River (Kleinfelder 1993). To evaluate sediment conditions, the *Data Summary Report, RFI Site Characterization* (Kleinfelder 1993) used the State of Washington s Marine Sediment Standards for PCP and equilibrium theory based on chronic ambient freshwater criteria for comparison. Both comparisons indicated a potential for adverse effects to benthic organisms from the 2,200 µg/kg concentration. The results from these investigations document that contaminants have moved off the PWT site and could potentially harm trust resources.

The former PWT company is bankrupt, so any refuge cleanup that may be necessary must be implemented by the current landowner, the Port of Ridgefield, under the DOE Toxics Cleanup Program and the MTCA. In 1996, the Port of Ridgefield signed an Agreed Order with DOE to conduct investigations and remediation of the site. That year, the Port began removal of onsite contaminated sediment in the stormwater system. In 1997, some contaminated soils were removed and others were stockpiled on site in the former tank farm treatment cell. The purpose of the present study was to document in a timely manner any contamination migrating onto the refuge in order to request appropriate cleanup activities from the Port. Because the refuge supports migratory birds, threatened and endangered species, as well as anadromous fish, it is critical that any contamination on or near the refuge is remediated such that trust species are protected. Without these data the Service will have no recourse to address potential adverse affects to trust species. The results also will help determine the future involvement of the Service in cleanup activities related to the PWT site.

The primary objective for this study was to document environmental contaminants which may have entered the refuge from the PWT site. The primary vectors for contaminant migration onto the refuge are considered to be groundwater and surface water, with sediment as the expected reservoir for contaminants. This investigation included chemical analysis of sediment and fish collected adjacent to the PWT site and on Ridgefield NWR. The primary contaminants of concern for this study were PCP and trace elements, but organochlorine pesticides, total PCBs, and chlorophenoxy herbicides were evaluated as well. Organochlorine compounds are persistent, widespread contaminants and have been found in biota near Ridgefield NWR and other areas along the lower Columbia River (U.S. Fish and Wildlife Service 1999, Thomas and Anthony 1999, U.S. Fish and Wildlife Service, Oregon State Office, unpubl. data). Ecology and Environment (1996) reported the majority of soil and water samples evaluated at the site for organochlorine pesticides were below detection limits, although a few samples contained DDE. Chlorophenoxy herbicides could be associated with past use, but are primarily reported here because they are chemically analyzed along with PCP.


Washington
Carty Lake
SLOUGH
RIVER
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Mile
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Sediment Sample Location
Fish Sample Location

METHODS

Site location and Sample Collection

Sediment and fish samples were collected in June and July, 1999, from areas adjacent to the PWT site, on the refuge, and from a reference area near the refuge. An attempt was made to collect clam (*Corbicula sp.)* samples from the sites, but no clams were found at any site. Sediment was collected from nearshore, depositional areas at one location at Bachelor Island Slough (122°W 45 27" by 45°N 49 07"), in Lake River adjacent to the PWT site at Lake River North (122°W 45 08" by 45°N 49 15") and Lake River South (122°W 45 07" by 45°N 49 12"), and on the refuge in Carty Lake at Carty Lake North (122°W 45 11" by 45°N 49 41") and Carty Lake South (122°W 45 00" by 45°N 49 22"; Figure 1). Fish samples were collected at Bachelor Island Slough (122°W 45 27" by 45°N 49 07"), Lake River (122°W 45 09" by 45°N 49 19"), and Carty Lake (122°W 45 02" by 45°N 49 28"; Figure 1). The Bachelor Island Slough samples served as reference samples.

At each site, three sediment grab samples were collected up to a depth of approximately 30 cm with a stainless-steel Ekman dredge on June 15, 1999. The three grab samples were mixed with a stainless steel spoon and composited in a stainless steel bowl, and then transferred into chemically-cleaned jars.

Split samples, made by transferring material from the bowl into two chemically-clean containers, were collected at the Bachelor Island Slough site and the Carty Lake South site. Sampling equipment was decontaminated between sites to prevent cross contamination of samples by washing with detergent, followed by rinses with de-ionized water and acetone. Samples were transferred on wet ice to the Oregon State Office and stored at -13°C until overnight shipment to contract laboratories.

Largescale sucker (*Catostomus macrocheilus*) were collected with a gill net from Carty Lake on June 15, 1999, and by electroshocking at the other sites on July 2, 1999. Three fish of similar size were collected and composited at each of the Lake River and Bachelor Island Slough sites, and two fish were composited at the Carty Lake site. Individual whole body samples were wrapped in acetone-rinsed aluminum foil and composites were placed in plastic bags. Composite sample masses were 2,741 g for Carty Lake samples, and 1,909 and 1,938 g for the Lake River and Bachelor Island Slough samples, respectively. Fish composites were transferred on wet ice to the Oregon State Office and stored at -13°C until overnight shipment to contract laboratories.

Chemical analysis

Trace elements other than mercury, selenium, and arsenic were extracted from sediment (Method 3050A; EPA 1986a) and tissues (Method 245.6; EPA 1991a) using nitric acid and hydrogen peroxide, and concentrations were determined with a Thermo Jarrell Ash Model 61E simultaneous inductively coupled plasma (ICP) emission spectrometer (Method 6010A; EPA 1986b). The method detection limits in sediment ranged from 0.01 to 8.0 µg/g dry weight, and 0.003 to 1.2 µg/g wet weight for fish tissue.

Mercury determination in sediment and fish tissue samples followed EPA Methods 1620 and

245.6, respectively (EPA 1989a;1991a). Samples were digested in sulfuric and nitric acids. Concentrations were determined by cold vapor atomic absorption spectrometry using a PSA Merlin Plus mercury analyzer. The method detection limit in sediment was <0.10 µg/g dry and <0.03 µg/g wet weight in tissue.

Selenium and arsenic were extracted from sediment (Method 3050A; EPA 1986a) and tissue (Method 200.3; EPA 1991b) using nitric acid and hydrogen peroxide, and concentrations determined using a Varian SpectrAA Graphite Fumace Zeeman corrected, single element atomic absorption spectrometer (Method 7000; EPA 1986c). The detection limit for arsenic ranged from 0.21 to 4.4 µg/g dry weight in sediment and <0.06 µg/g wet weight in tissues. The selenium detection limit was <0.15 µg/g dry weight in sediment and <0.06 µg/g wet weight in tissues.

Analysis of fish tissue for organochlorine pesticides and total PCBs included tissue homogenization and preparation by grinding with anhydrous sodium sulfate. Analytes were recovered by Soxhlet extraction using the solvent hexane. Samples were cleaned-up and analytes were separated using Florisil chromatography with petroleum ether as the solvent. Additional cleanup to separate PCBs from other organochlorines was conducted using Silica gel chromatography. Quantification of analytes was performed by packed or capillary column, electron capture gas chromatography (CGC). The detection limit in sediment was <0.04 µg/g dry weight for most organochlorines, and limits ranged from 0.09 to 0.22 µg/g dry weight for toxaphene and total PCBs. The detection limit for organochlorine compounds in fish samples was 0.01 µg/g wet weight except for toxaphene and total PCBs, which was 0.05 µg/g wet weight.

PCP and chlorophenoxy acid herbicides in sediment and fish tissue were extracted following U.S. EPA guidelines (1980) and cleaned-up following the methods of Shafik et al. (1973). Sediment preparation and analysis included separation and fractionation of organochlorine pesticides and total PCBs during this procedure. Sediment samples were adjusted to pH 2 with sulfuric acid, and centrifuged with the solvents acetone and petroleum ether/diethyl ether. The liquid was decanted into a separatory funnel and re-extracted with petroleum ether/diethyl ether, centrifuged, and the liquid decanted into a separatory funnel and adjusted to pH 12. The water layer was re-extracted with petroleum ether/diethyl several more times and decanted, with the initial ether extracts containing the organochlorine pesticides and total PCB fractions, and the next layers (after adjustment to pH 2) containing chlorophenoxy herbicides and PCP. Acid and base extracts were concentrated with Kuderna-Danish evaporators. The basic fraction (organochlorine pesticides and total PCBs) was cleaned up by Florisil chromatography. Chlorophenoxy acid herbicides in the acid fraction were derived by ethylation using diazoethane and hexane, and cleaned-up using deactivated silica-gel chromatography. PCP was separated from the other herbicides using hexane and benzene washes. Preparation and extraction of PCP and chlorophenoxy herbicide from fish tissue included homogenizing and grinding with hydrochloric acid and diethyl ether and centrifuging. Derivitization, fractionation and cleanup in tissue followed the methods described above for sediment. Concentrations were determined by electron capture gas chromatography for all sample types. The detection limit in fish samples was <0.01 µg/g wet weight, and limits ranged from 0.02 to 0.04 µg/g dry weight in sediment.

Quality Assurance/Quality Control

Accuracy and precision of analytical chemistry data were measured by matrix spike recoveries and duplicate sample analysis. Matrix spike recoveries for organochlorine pesticides were within normal bounds, ranging from 86 to 126 %. Spiked samples were not analyzed for total PCBs or toxaphene because their multipeak components interfere with other recoveries and confound results. Matrix spike recoveries for most chlorophenoxy acid herbicides were low, ranging from 42 to 85 %, which is typical for these compounds. Recovery of PCP was 91 % and 71 % in sediment and tissue, respectively. Duplicate results for the organic constituents were within normal bounds for the study, and no organic constituents were detected in blank samples.

Matrix spike recoveries for trace elements ranged from 78 to 117 % except for magnesium, which was 222 % and exceeded the normal limits. Duplicate results for trace elements were within normal limits except for strontium in fish tissue, which exhibited a high relative difference of 35 %. Recoveries of spiked standard reference materials (oyster tissue and Buffalo river sediment) were within normal limits except for aluminum and chromium in oyster tissue, which exhibited typically low recoveries for this matrix. Results from procedural blanks were acceptable except for strontium, which was higher than normal but insignificant based on the concentrations observed in the samples.

Data Analysis

A variety of guidelines were used in this study to assess the potential hazards to fish and wildlife from exposure to contaminants found at the site. Sediment concentrations were compared to sediment benchmarks including the Threshold Effects Level (TEL) and Probable Effects Level (PEL) approach (MacDonald 1994, Long et al. 1995). The TEL is the geometric mean of the 15^{th} percentile in the effects data set and the 50^{th} percentile in the no effects data set, and the PEL is the geometric mean of the 50^{th} percentile in the effects data set and the 85^{th} percentile in the no effects data set. The TEL value represents the concentrations below which adverse effects are expected to occur only rarely. The PEL represents the level above which adverse effects are frequently expected. Sediment results were also compared to Apparent Effects Thresholds (AETs). AETs are derived from the sediment concentration of a selected chemical above which statistically significant biological effects always occur (EPA 1989b), or the highest no effect concentration. AETs represent concentrations above which adverse biological impacts would always occur for a particular bioindicator based on exposure to the reported chemical. AETs are based on results from specific sediment bioassays or benthic community surveys (e.g., diminished benthic infaunal abundance). Sediment screening values used to evaluate suitability of dredged material for in water disposal, as reported in the *Dredged Material Evaluation Framework-Lower Columbia River Management Area* (DMEF 1998), were also used for comparison. All sediment comparisons were based on freshwater sediment benchmarks and reported as µg/g dry weight unless otherwise noted. Sediment benchmark guidelines were obtained from Buchman (1999) as reported through the internet at the website http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.html.

Organochlorine constituents in fish samples were compared to the geometric means determined in 1984 for whole-body fish samples collected at 112 stations in the National Contaminant Biomonitoring Program (NCBP) administered by the U.S. Fish and Wildlife Service (Schmitt et al. 1990). Trace elements in fish tissue were compared to geometric means, or the 85th percentile for the distribution of geometric station mean concentrations, gathered from 109 stations during the NCBP (Schmitt and Brumbaugh 1990). The NCBP values do not incorporate toxicity to fish, but allow for comparisons to other sites on a nationwide basis. NBCP values representing the 85th percentile for the distribution of geometric station means were also used because they were more indicative of contaminated sites. Contaminants in suckers were also compared to concentrations found in largescale suckers collected from six sites (including a location near Ridgefield NWR) in the lower Columbia River in 1991 (U.S. Fish and Wildlife Service, Oregon State Office, unpubl. data).

Sufficient sediment benchmark values were available to compare arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc. Other trace elements were not evaluated in this report because comparison guidelines or background concentrations were unavailable. The trace elements aluminum, selenium, and vanadium were compared to background concentrations because no sediment toxicity comparison benchmarks are available.

RESULTS AND DISCUSSION

Organochlorine Compounds

Sediment samples from all sites did not contain detectable concentrations of organochlorine compounds with the exception of one sample at Carty Lake South, which contained hexachlorobenzene at the detection limit (Table 1). Likewise, most organochlorine compounds were below detection limits in samples of largescale sucker (Table 1). Detectable concentrations of organochlorines in sucker were generally similar at the reference sites compared to the sites adjacent to the PWT site. Gamma BHC was found at the detection limit in the Lake River sucker sample, and concentrations of total PCBs were found in suckers at the Bachelor Island Slough and Lake River sites. DDE and DDD were found in fish from all three locations (Table 1). DDE concentrations were highest in Carty Lake and were similar to concentrations in suckers from the other two sites, whereas DDD was at the detection limit at all three sites. No pattern was discernable between sediment and fish concentrations because most sediment values were below detection limits.

DDE concentrations in suckers were lower (Table 1) than the geometric mean concentrations (0.19 µg/g wet weight) in fish sampled during the 1984 NCBP (Schmitt et al. 1990). DDE concentrations were very similar to concentrations found in largescale sucker, carp (*Cyprinus carpio*), and peamouth chub (*Mylocheilus caurinus*) sampled in 1991 from the lower Columbia River near Ridgefield NWR (U.S. Fish and Wildlife Service, Oregon State Office, unpubl. data). Total PCBs in sucker were well below the geometric mean concentrations of 0.39 µg/g wet weight found in fish sampled during the NCBP (Schmitt et al. 1990). Total PCBs in largescale sucker sampled in 1991 from six locations in the lower Columbia River were <0.05 µg/g wet

weight, although the geometric mean in carp sampled near Ridgefield NWR was 0.06 µg/g wet weight and similar to values found in sucker from the Lake River and reference sites. DDE and total PCB concentrations were not high enough to impact fish directly, but the fish could contribute to contaminant loading in fish-eating birds due to biomagnification. Currently, bald eagles nesting on the refuge exhibit elevated DDE and total PCBs in eggs, and these compounds have been associated with poor breeding success for eagles nesting along the lower Columbia River (U.S. Fish and Wildlife Service 1999).

Organochlorine compounds such as dioxins and furans are associated with wood treating chemicals, but were not evaluated in this study due to cost limitations. Previous investigations have documented dioxins and furans as potential contaminants of concern at the site (Hart Crowser 1992, Kleinfelder 1993) and Ecology and Environment (1996) documented some limited contamination from dioxin-like chemicals in soil samples based on induction of P450 in the Reporter Gene System bioassay. Foster et al. (1999) sampled sediment and fish in Lake River from approximately 1 km upstream from The PWT site, and adjacent the facility, and 1 km downstream from The PWT site. Both sediment and whole body carp contained significantly higher concentrations of some higher chlorinated dioxins and furans than in samples from a nearby bleached Kraft pulp mill (Foster et al. 1999), indicating some dioxins and furans are more available to biota in the region of the PWT site. Biota near the PWT site appear to be exposed to dioxins and furans released from the site, but additional samples would be needed to determine if the exposure has resulted in impacts to fish and wildlife in the area.

PCP and chlorophenoxy acid herbicides

PCP and dichlorprop were detected in sediment at the two locations adjacent to the PWT facility, whereas concentrations were at or below detection limits in sediment from the reference area (Table 2). The herbicides 2,4,5-T (2,4,5-trichlorophenoxyacetic acid), 2,4-D (2,4-dichlorophenoxyacetic acid), 2,4-DB (4-(2,4-dichlorophenoxy)butyric acid), dichlorprop (2-(2,4-dichlorophenoxy)propionic acid), dicamba (2-methoxy-3,6-dichlorobenzoic acid), and silvex (2-(2,4,5-trichlorophenoxy)proprionic acid) were at or below detection limits in sediment and were considered to be below concentrations threatening aquatic biota. PCP and the chlorophenoxy acid herbicides were not detected in sucker samples from any location (Table 2).

The Carty Lake South site exhibited the highest PCP concentrations (0.43 µg/g) in sediment, followed by the Lake River South and Lake River North sites (Table 2). Similarly, Kleinfelder (1993) reported nearshore sediment samples from Carty Lake contained concentrations below detection in one sample towards the north end of the lake, and ranged from 0.034 to 0.41 µg/g PCP at the south end of the lake. The highest concentration of PCP in Carty Lake was found in sediment adjacent to The PWT site at the south end (Kleinfelder 1993). Kleinfelder (1993) also found PCP as high as 2.2 µg/g in one location (outfall 4) in Lake River, indicating some PCP entered into the river from this outfall.

Guidelines for the protection of aquatic life were not available for PCP in freshwater sediment, but the Carty Lake South PCP concentrations were well above the AET values of 0.017 µg/g in

marine sediment based on tests with bivalves (Buchman 1999). Sediment samples at this location were also above Washington State sediment quality standard of 0.36 µg/g for marine and estuarine sediments (Washington State Sediment Management Standards, Chapter 173.204 WAC; Ginn and Pastorak 1992). Results indicate a potential exists for impacts to aquatic organisms, such as benthic invertebrates, in sediment from the south end of Carty Lake based on elevated sediment PCP concentrations. Benthic organisms could also be at risk from sediment PCP in parts of Lake River. Although benthic organisms are likely threatened at these locations from PCP exposure, limited data from this study suggest that higher organisms such as largescale sucker are not accumulating PCP at these sites. The sensitivity of suckers exposed to PCP in sediment and their ability to metabolize the compound is unknown. However, uptake and excretion of PCP is rapid in (reviewed by Eisler 1989), and PCP could impact earlier life stages (eggs or juveniles) of suckers or other fish if present in the area.

Trace elements

Sediment concentrations of aluminum exceeded background levels (0.26% or 2,600 µg/g) at all sites, and approached or exceeded the TEL value (2.55% or 25,500 µg/g) for *Hyallela azteca* at the Carty Lake sites (Table 3). In contrast, sucker samples at the Carty Lake South site exhibited the lowest aluminum concentrations of the three sites (Table 3). The sources of aluminum in Carty Lake may not have been due to PWT operations, as aluminum was above background levels at all sites and could be a widespread contaminant associated with the aluminum industry along the Columbia River. The discrepancies in fish concentrations of aluminum could have been attributed to the aluminum foil used to contain samples during transport. Additional sampling would be required before a determination could be made regarding aluminum impacts to fish at the sites.

Arsenic in sediment exceeded the TEL of 5.9 µg/g at the Lake River South and Carty Lake sites. Arsenic approached the PEL of 17 µg/g at the Lake River South site and were 2 to 3 times the PEL at Carty Lake South. Sediment concentrations did not exceed the DMEF (1998) screening levels of 57 µg/g. Kleinfelder (1993) reported that arsenic in one water sample from Carty Lake was just above detection limits, but arsenic was not evaluated in sediment. The PWT site is likely the source of the arsenic at the Carty Lake South site, as evidenced by its presence in Carty Lake water (Kleinfelder 1993) and sediment (this study) immediately adjacent to the PWT site, and low sediment concentrations in the Carty Lake North site. In fish, arsenic was only detected at the reference site, indicating arsenic may not be available to fish near the former wood-treating facility. Arsenic in fish at the reference site was slightly above the geometric mean of 0.14 µg/g wet weight for fish species sampled in the NCBP (Schmitt and Brumbaugh 1990)

Cadmium concentrations in sediment were relatively similar at all sites. All sites exceeded the TEL for cadmium of 0.596 µg/g, but no sites exceeded the PEL of 3.53 µg/g or the DMEF (1998) screening levels of 5.1 µg/g. Cadmium in suckers was similar among sites and highest at the reference site. Cadmium in suckers at all sites was similar to or exceeded the 85th percentile for the distribution of geometric station means of 0.05 µg/g wet weight in the NCBP (Schmitt and Brumbaugh 1990). Cadmium was well below concentrations of 2 µg/g wet weight indicative

of tissue accumulation, and well below values (5 µg/g wet weight) that are acutely toxic to some organisms (Eisler 1985).

Concentrations of chromium in sediment were similar among the reference, Lake River, and Carty Lake North sites and were highest at the Carty Lake South site. Concentrations at the latter site exceeded the TEL of 37.7 µg/g and approached the PEL of 90 µg/g. Chromium screening levels were not available in the DMEF (1998). Chromium concentrations in suckers were similar among all sites, and were well below values in fish of 4 µg/g reported by Eisler (1986) as evidence of contamination. Little information is available concerning the acute or chronic impacts of chromium at tissue concentrations observed at the sites.

Copper in sediment was highest at the Carty Lake site and exceeded the TEL of 35.7 µg/g and approached the AET of 86.0 µg/g for infaunal community impacts. Copper concentrations at the other sites were lower, but values at Lake River and Carty Lake North approached the TEL of 28 µg/g based on the *H. azteca* bioassay (Table 3). Copper concentrations in sediment at all sites were well below the PEL of 197 µg/g and the DMEF (1998) screening level of 390 µg/g. Copper in sucker samples were similar at all sites. Copper concentrations in suckers were at or above the geometric mean concentration of 0.65 µg/g wet weight from the NCBP, but were below the 85th percentile for the distribution of geometric station means of 1.0 µg/g wet weight (Schmitt and Brumbaugh 1990).

Lead in sediment was highest at the Carty Lake South and approached the TEL of 35 µg/g (Table 3). Other sites contained lead well below the TEL value. Lead at the Carty Lake South site was well below the PEL of 91.3 µg/g and the DMEF (1998) of 450 µg/g. Lead was below detection limits in suckers from all sites, although detection limits were elevated compared to 85th percentile geometric station mean of 0.22 µg/g wet weight for fish samples analyzed in the NCBP (Schmitt and Brumbaugh 1990).

Mercury was below detection limits in sediment from all sites (Table 3), and detection limits were well below TEL values of 0.17 µg/g and other guidance criteria. Suckers from Carty Lake exhibited the highest concentrations of mercury (Table 3). Wet weight mercury concentrations (0.10 ug/g) in suckers at this site were within the range of geometric mean concentrations (0.07 to 0.12 ug/g wet weight) found in suckers sampled at six lower Columbia River sites (including Ridgefield NWR) in 1991 (U.S. Fish and Wildlife Service, Oregon State Office, unpubl. data). Mercury in suckers at all sites was below the geometric mean (0.10 µg/g wet weight) and 85th percentile geometric of the station mean (0.17 µg/g wet weight) in the NCBP (Schmitt and Brumbaugh 1990). Residues also were below the mercury concentration Eisler (1987) indicates would protect sensitive species of birds and mammals that regularly consume fish and other aquatic organisms.

Nickel in sediment was highest at the Carty Lake South and North sites, and exceeded the TEL of 18.0 µg/g at both Carty Lake locations and approached the TEL at the reference site. All sediment values were well below the PEL of 91.3µg/g and the DMEF (1998) screening value of

140 µg/g. Nickel concentrations in sucker samples were very similar at all sites, with lowest values from the Carty Lake South site. Guidance values for nickel in fish are not available.

Selenium concentrations in sediment exceeded the background value of 0.29 µg/g (Buchman 1999) at all sites except at the Carty Lake sites, where the background value was slightly exceeded (Table 3). Benchmarks for comparison of selenium toxicity in freshwater sediment were not available for comparison. Selenium in suckers was highest at the reference site (Table 3). Selenium in suckers at the Lake River and Carty Lake sites was below the geometric mean (0.42 µg/g wet weight) in fish samples from the NBCP (Schmitt and Brumbaugh 1990), although the concentration in suckers from the reference sample approached this level.

Sediment concentrations of vanadium exceeded background values of 50 µg/g (Buchman 1999) at the Carty Lake South and North sites, and were slightly below background at the other sites. Concentrations at the Carty Lake sites exceeded the AET value of 57 µg/g for marine sediments based on *Neanthes* bioassays. Vanadium in suckers were lowest at the Carty Lake site compared to the reference and Lake River sites. Guidance values for vanadium in fish are unavailable for comparison.

Concentrations of zinc in sediment were highest in the Carty Lake South site, whereas the concentration at the reference site was nearly half the Carty Lake South values and similar to the Lake River and Carty Lake North sites. Concentrations at the Lake River South and Carty Lake South sites exceeded the TEL of 123 µg/g, but values at all sites were well below the PEL of 315 µg/g and the DMEF (1998) screening values of 410 µg/g. Zinc in suckers was similar at all three sites, and was below the geometric mean of 21.7 µg/g wet weight for fish sampled in the NBCP (Schmitt and Brumbaugh 1990).

The highest concentrations for every trace element evaluated occurred in sediment from the two Carty Lake sites (Table 3). Trace elements were highest at Carty Lake South, whereas concentrations in Carty Lake North were more similar to the reference samples for most elements except nickel, vanadium, and lead. In Lake River, sediment concentrations of trace elements were generally similar to or within one order of magnitude of the reference area, although arsenic concentrations in the Lake River South site were more than three times concentrations from the reference samples. Previous investigations (Kleinfelder 1993) stated that trace elements were not found in sediment from Carty Lake or Lake River; however, no detection limits or concentration values for trace elements were reported for any of the sediment samples collected. The history of contamination and pattern of accumulation at the Carty Lake South site suggests that the trace elements arsenic, copper, chromium, and possibly lead and zinc originated from the PWT site.

In contrast to sediment results, sucker samples from Carty Lake exhibited trace element concentrations lower than or similar to suckers from the reference or Lake River sites (Table 3). Trace element concentrations seemed to be lowest in fish at the same site (Carty Lake) where the highest sediment concentrations were found. This indicates that the trace elements in sediment in Carty Lake are not available to suckers or their prey items, or the suckers have recently entered

the system and have not equilibrated to the trace element concentrations in sediment.

SUMMARY AND CONCLUSIONS

Ridgefield NWR, located in Washington along the lower Columbia River, provides important wintering habitat for waterfowl, shorebirds, wading birds, passerines, threatened and endangered species, and is a primary roosting area for tundra swans and lesser sandhill cranes. The refuge is adjacent to the Pacific Wood Treating (PWT) facility, a Washington State MTCA cleanup site contaminated with wood-treating related compounds including pentachlorophenol (PCP), volatile and semi-volatile organics, copper, chromium, and arsenic. These contaminants have been documented in soil, surface water, and groundwater at the site. In 1999, the Service collected sediment and fish from Carty Lake on the refuge, Lake River adjacent to the PWT site, and a nearby reference area to determine if contaminants associated with the PWT site were migrating onto the refuge or adjacent areas and posing a threat to fish and wildlife resources. Whole-body fish (largescale sucker) and sediment samples were analyzed for organochlorine pesticides, total PCBs, PCP, chlorophenoxy acid herbicides, and trace elements.

Sediment samples indicated that organochlorine contaminants and chlorophenoxy acid herbicides were at or below detection limits, or similar to concentrations in sediment from the reference area. However, PCP and some trace elements were elevated at some sites in comparison to the reference area and sediment guidance values. PCP was elevated in Lake River sediment compared to the reference area, and exceeded aquatic protection guidelines established for marine sediment at the site on the refuge closest to the PWT site (Carty Lake South site). In addition, all trace elements evaluated except manganese, mercury, and molybdenum were highest at Carty Lake South in comparison to the other sites. The trace elements aluminum, arsenic, cadmium, chromium, copper, lead, nickel, and zinc approached or exceeded the Threshold Effects Level (TEL) at the Carty Lake South site, and arsenic exceeded the Probable Effects Level (PEL). Cadmium, nickel, and zinc also exceeded the TEL at other sites. The data indicate that PCP and the trace elements arsenic, chromium, copper, and possibly lead and zinc are elevated on the refuge as a result of contaminant migration from the PWT site. These contaminants were found at the highest concentrations on the refuge site adjacent to the PWT site compared to reference or Lake River sites, and previous investigations documented PCP, arsenic, copper, chromium, and zinc in water samples from Carty Lake near the PWT site. PCP and some trace elements in sediment at the south end of Carty Lake could be impacting or limiting the occurrence of some benthic fauna in the area adjacent to the PWT facility. PCP concentrations, based on sediment levels from this study and water concentrations from previous investigations, could also impact fish eggs, developing embryos, or sensitive fish species such as trout and other salmonids.

Similar to the sediment samples, fish did not exhibit elevated concentrations of organochlorine contaminants, and all constituents except total PCBs, DDE, and DDD were below detection limits. PCP and chlorophenoxy acid herbicides were also below detection in fish, although these chemicals are rapidly metabolized by organisms and are not likely to accumulate in tissues. In

contrast to sediment, fish tissues exhibited very little accumulation of trace elements, and most elements were higher at the reference or Lake River sites than in fish from Carty Lake. Geometric mean concentrations of trace elements found in fish collected in 1984 from stations throughout the United States, as reported by the National Contaminant Biomonitoring Program, were exceeded at all sites for cadmium and copper and at the reference site for arsenic. Trace elements at all other sites were below these nationwide means. The accumulation pattern between sediment and fish suggests that trace elements are not available to fish in Carty Lake, although sample sizes of fish were limited.

RECOMMENDATIONS

The results of this study revealed that PCP and some trace elements are elevated on Ridgefield NWR in Carty Lake sediments. PCP and several trace elements exceeded the sediment toxicity guidelines, and the pattern of contamination indicated that the compounds originated from the PWT facility. Sediment contamination in Lake River site was less than in Carty Lake samples, but PCP and arsenic were found at concentrations well above reference values and further evaluation should be conducted near the outfalls. In addition, studies conducted by the Oregon Department of Environmental Quality (Foster et al. 1999) and Ecology and Environment (1996) suggest that dioxins and furans are present and may be available to biota at the site. The contaminant evidence suggests further sampling and characterization of the site is warranted, and cleanup actions are necessary to adequately protect aquatic life in the area. Specific recommendations are outlined below.

1) Because sediment results in this study are based on only a limited number of samples, additional sampling should be conducted around the Carty Lake South location to determine the extent and depth of PCP and trace element contamination. Once the depth and extent of contamination are characterized, sediment should be removed or evaluated in toxicity assessments to ensure the contaminants are not available to aquatic organisms. Contaminated sediment at Carty Lake should be remediated to a level that would be protective of salmonids, since they could use the site following restoration activities.

2) Sediment in Lake River should be further characterized to determine if cleanup is necessary. Limited sampling suggested that PCP and arsenic could pose a problem to resources at the site. Additional sampling should be conducted near the outfalls to better evaluate if cleanup is warranted.

3) Sediment should be evaluated in Carty Lake and Lake River for the presence of dioxins and furans or overall dioxin-like activity. Dioxin and furans or dioxin-like activity should be below values that could impact benthic organisms or accumulate in biota.

4) Polyaromatic hydrocarbons (PAHs) should be evaluated in sediment and groundwater wells in Carty Lake and associated wetlands. Diesel-oil containing PAHs was used as a carrier for PCPs and could be associated with PCP contamination at the site.

5) Additional groundwater wells should be installed in Carty Lake, adjacent to the wood-treating facility. These wells should be sampled periodically for contaminants during the clean-up phase to evaluate the success of groundwater treatment, and to ensure that pressure created during the groundwater treatment does not force contaminants back onto the refuge.

6) Restoration efforts should occur in or near the Carty Lake site. The Service recommends that activities undertaken to clean up Carty Lake should also incorporate restoration activities if possible.

This study was conducted to determine potential risk of exposure to organisms associated with Ridgefield NWR. The study was not designed to evaluate conditions in soil or groundwater at the PWT site. Recommended actions should only be implemented after suitable source controls are in place at PWT site to prevent additional contamination of Ridgefield NWR or Lake River.

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Table 1. Concentrations of total polychlorinated biphenyls (PCBs) and organochlorine pesticides in sediment and whole body largescale sucker from Bachelor Island Slough (reference area), Lake River (west of wood treating facility), and Carty Lake (north of wood treating facility and part of Ridgefield National Wildlife Refuge) in 1999.

	Sediment [a] (µg/g dry weight)							Largescale sucker [b] (µg/g wet weight)		
Location	Bach. Is Slough[c]	Bach. Is Slough[c]	Lake River N.	Lake River S.	Carty Lake S[c]	Carty Lake S[c]	Carty Lake N.	Bach. Is Slough	Lake River	Carty Lake
Sample No.	sdc01	sdc02	sdlra	sdlrb	sdblind	sdcla	sdclb	LASUc	LASUlr	LASUcl
% Moisture	42.1	41.7	42.7	45.8	72.2	76.7	67.4	72.5	71.3	72.5
% Lipid								7.02	4.24	7.45
Organochlorine Contaminants										
PCB-TOTAL	< 0.09	< 0.09	< 0.09	< 0.09	< 0.18	< 0.22	< 0.15	0.09	0.06	< 0.05
p,p'-DDD	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	0.02	0.02	0.02
p,p'-DDE	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	0.08	0.07	0.12
p,p'-DDT	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
o,p'-DDD	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
o,p'-DDE	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
o,p'-DDT	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
alpha BHC	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
alpha chlordane	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
beta BHC	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
cis-nonachlor	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
delta BHC	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
dieldrin	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
endrin	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
gamma BHC	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	0.01	< 0.01
gamma chlordane	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
hexachlorobenzene	< 0.02	< 0.02	< 0.02	< 0.02	0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
heptachlor epoxide	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
mirex	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
oxychlordane	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
toxaphene	< 0.09	< 0.09	< 0.09	< 0.09	< 0.18	< 0.22	< 0.15	< 0.05	< 0.05	< 0.05
trans-nonachlor	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01

[a] One composite of three grab samples was collected from each site.
[b] Composite samples included two fish from Carty Lake and three fish from each of the other sites.
[c] Samples were split at this site.

Table 2. Concentrations of pentachlorophenol (PCP) and chlorophenoxy acid herbicides in sediment and whole body largescale sucker from Bachelor Island Slough (reference area), Lake River (west of wood treating facility), and Carty Lake (north of wood treating facility and part of Ridgefield National Wildlife Refuge) in 1999.

	Sediment [a] (µg/g dry weight)							Largescale sucker [b] (µg/g wet weight)		
Location	Bach. Is Slough[c]	Bach. Is Slough[c]	Lake River N.	Lake River S.	Carty Lake S[c]	Carty Lake S[c]	Carty Lake N.	Bach. Is Slough	Lake River	Carty Lake
Sample No.	sdc01	sdc02	sdlra	sdlrb	sdblind	sdcla	sdclb	LASUc	LASUlr	LASUcl
PCP	< 0.02	< 0.02	0.05	0.12	0.36	0.43	< 0.03	< 0.01	< 0.01	< 0.01
2,4,5-T	< 0.02	0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
2,4-D	< 0.02	0.02	0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
2,4-DB	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	0.04	< 0.03	< 0.01	< 0.01	< 0.01
dicamba	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01
dichlorprop	< 0.02	0.02	< 0.02	0.03	0.08	0.06	0.06	< 0.01	< 0.01	< 0.01
silvex	< 0.02	< 0.02	< 0.02	< 0.02	< 0.04	< 0.04	< 0.03	< 0.01	< 0.01	< 0.01

[a] One composite of three grab samples was collected from each site.
[b] Composite samples included two fish from Carty Lake and three fish from each of the other sites.
[c] Samples were split at this site.

Table 3. Concentrations of trace elements in sediment and whole body largescale sucker from Bachelor Island Slough (reference area), Lake River (west of wood treating facility), and Carty Lake (north of wood treating facility and part of Ridgefield National Wildlife Refuge) in 1999.

	Sediment[a] (µg/g dry weight)							Largescale sucker[b] (µg/g wet weight)		
Location	Bach. Is Slough[c]	Bach. Is Slough[c]	Lake River N.	Lake River S.	Carty Lake S[c]	Carty Lake S[c]	Carty Lake N.	Bach. Is Slough	Lake River	Carty Lake
Sample No.	sdc01	sdc02	sdlra	sdlrb	sdblind	sdcla	sdclb	LASUc	LASUlr	LASUcl
% Moisture	44.1	53.7	56.6	54.2	76.1	77.4	81.1	72.9	74.6	71.9
Trace elements										
Aluminum	13,800[d]	14,400[d]	12,900[d]	14,000[d]	**25,000**[d,e]	**25,000**[d,e]	**21,500**[d,e]	86.1	86.4	12.5
Arsenic	4.41	4.36	4.87	16.3	***36.2***[f]	***46.7***[f]	5.85	**0.17**[g]	<0.05	<0.06
Boron	1.90	1.39	2.34	2.91	9.63	10.5	3.56	0.17	0.21	0.17
Barium	153	163	146	151	185	190	189	1.56	1.83	0.77
Berylium	0.60	0.63	0.64	0.67	0.91	0.96	0.89	0.02	0.04	0.02
Cadmium	**1.04**[e]	**1.10**[e]	**0.82**[e]	**0.86**[e]	**1.03**[e]	**1.28**[e]	**1.02**[e]	***0.17***[g]	***0.11***[g]	***0.11***[g]
Chromium	18.7	19.5	24.2	26.5	**71.0**[e]	**73.6**[e]	29.0	0.73	0.79	0.61
Copper	19.5	21.2	21.0	26.2	**65.4**[e]	**67.4**[e]	28.8	**0.80**[g]	**0.64**[g]	**0.71**[g]
Iron	21,500	21,600	22,700	23,500	34,200	33,900	32,100	135	129	29.7
Lead	11.7	12.4	10.3	13.5	**33.4**[e]	32.8	19.8	<0.43	<0.42	<0.46
Manganese	4,650	4,860	4,120	4,120	4,440	4,520	5,070	337	336	288
Magnesium	348	361	395	432	500	520	791	5.36	6.28	3.79
Mercury	< 0.08	< 0.09	< 0.09	< 0.08	< 0.09	< 0.09	< 0.09	0.03	0.06	0.10
Molybdenum	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	<0.13	<0.13	<0.14
Nickel	16.8	**18.6**[e]	16.9	16.7	**21.0**[e]	**22.3**[e]	**22.1**[e]	0.38	0.37	0.26
Selenium	< 0.14	0.17	0.22	0.15	0.27	0.41	0.30	0.41	0.24	0.28
Strontium	46.3	47.6	42.5	44.3	58.3	59.9	52.9	8.53	8.34	6.56
Vanadium	47.5	48.6	45.9	48.8	82.3	84.2	63.1	0.46	0.47	0.20
Zinc	111	120	104	**134**[e]	**201**[e]	**206**[e]	107	14.9	15.7	15.3

[a] One composite of three grab samples was collected from each site.
[b] Composite samples included two fish from Carty Lake and three fish from each of the other sites.
[c] Samples were split at this site.
[d] Exceeded background concentrations (Buchman 1999).
[e] Near or exceeded Threshold Effects Level (TEL; in bold) (Buchman 1999).
[f] Exceeded Probable Effects Level (PEL; in bold italics) (Buchman 1999).
[g] Near or exceeded the geometric mean (bold) or 85th percentile for the distribution of geometric station means (bold italics) for fish species collected at stations throughout the U.S. (Schmitt and Brumbaugh 1990).