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Vancouver Lake PCBs, Chlorinated Pesticides, and Dioxins in Fish Tissue and Sediment

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Abstract

This 2005-06 study was conducted to investigate the current levels of PCBs, chlorinated pesticides, and dioxins in fish tissue and sediment from Vancouver Lake. Contaminants in Lake River fish and sediment also were assessed.

Two previous studies conducted by the Washington State Department of Ecology identified elevated levels of polychlorinated biphenyls (PCBs) and a chlorinated pesticide, 4,4'-DDE (a metabolite of DDT), in fish tissue from Vancouver Lake. Contaminant levels higher than the U.S. Environmental Protection Agency's National Toxics Rule (NTR) human health criteria have been reported, but historically with a mix of high and low results.

Largescale suckers, common carp, and largemouth bass samples were analyzed. Results indicated PCBs were elevated in all three fish species, exceeding the NTR criterion. Other compounds found exceeding NTR criteria in fish tissue were 4,4'-DDE; 2,3,7,8- tetrachlorodibenzo-p-dioxin (TCDD); toxaphene; and dieldrin.

In addition to the fish tissue samples, sediment samples were collected from Vancouver Lake and the Lake River. Vancouver Lake sediments were low for PCBs and chlorinated pesticides; only four of the 186 total analyses were reported above detection limits, well below proposed sediment quality guidelines. No target compounds were detected in Lake River sediments.

As a result of this study, the following recommendations are made:

- Address total PCBs and dioxin in Vancouver Lake and Lake River fish tissue through a statewide assessment.
- Consider a Total Maximum Daily Load (TMDL; water cleanup plan) study for 4,4'-DDE, toxaphene, and dieldrin in Vancouver Lake.
- Collect fish from the Lake River in five years to see if a TMDL is warranted for the river.
- Continue to include Vancouver Lake on the 2002/2004 federal Clean Water Act Section 303(d) list for total PCBs. Add Vancouver Lake to the list for 2,3,7,8-TCDD, 4,4'-DDE, toxaphene, and dieldrin.
- Add Lake River to the 2006 Section 303(d) list for total PCBs, 2,3,7,8-TCDD, 4,4'-DDE, and dieldrin.

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Introduction

Vancouver Lake is located adjacent to, and northwest of, Vancouver, Washington. Situated along the east side of the Columbia River (Figure 1), the lake is roughly three miles long, two and one-half miles wide, and covers 2,414 acres. Vancouver Lake is very shallow. Historically described as ranging from one to four feet deep, during the early 1980s areas of the lake were dredged to roughly between five and 10 feet deep.

The lake's west side is bounded by the low-lying floodplain of the Columbia River. The major surface water source is Burnt Bridge Creek flowing in from the east. Outflow is to the north into the Lake River, ultimately discharging to the Columbia River. The two major tributaries discharging to the Lake River are Salmon Creek and Whipple Creek.

A restoration plan for Vancouver Lake proposed development of a flushing channel to bring higher quality water from the Columbia River to the lake. In 1982, a channel roughly one-mile long was completed near the southwest extent of Vancouver Lake connecting the Columbia River with the lake (Figure 1). Due to tidal influence on the Columbia River through the study area, the flushing channel is controlled by tide gates (Caromile et al., 2000). When the water level of the lake is higher than the Columbia River, the tide gates close, restricting flow back to the Columbia River.

The Lake River does not have tide gates. During flood tides, the direction of flow in the Lake River is reversed causing discharge back into Vancouver Lake. Considering the flushing channel and tidal impacts, the Columbia River is a potential source of pollutants to Vancouver Lake and the Lake River.

Limited sampling of edible fish tissue has been conducted for polychlorinated biphenyls (PCBs) and chlorinated pesticides in Vancouver Lake. Historical results have been mixed. One 5-fish composite of largemouth bass collected in 1993 for an Ecology statewide assessment (Davis et al., 1995) reported total PCBs and 4,4'-DDE exceeding the National Toxics Rule (NTR) human health criteria at 110 and 47 *u*g/Kg, respectively (NTR = 5.3 *u*g/Kg for total PCBs and 31.6 *u*g/Kg for 4,4'-DDE). A 2002 Ecology study for the Washington State Toxics Monitoring Program (Seiders and Kinney, 2004) analyzed one 5-fish composite of largemouth bass fillet from Vancouver Lake and reported total PCBs just over the NTR criteria at 6.0 *u*g/Kg and 4,4'-DDE at 2.7 *u*g/Kg. Differences between total PCB levels in largemouth bass from Vancouver Lake collected in 1993 and 2002 could have been due to factors such as size of fish, lipid content, analytical methods, capture location, or changes in PCB availability.

The Ecology Water Quality Program requested the present 2005-06 study to (1) evaluate the federal Clean Water Act 303(d) listing for the lake, (2) determine the need for a TMDL to address contamination, and (3) evaluate if a fish consumption advisory is needed. The goal of the study is to determine the levels of PCBs, chlorinated pesticides, and dioxin/furans in edible fish fillets from Vancouver Lake and Lake River. Vancouver Lake is on the recently approved 2002/2004 303(d) list for total PCBs. Dioxins and furans are often high in fish tissue when PCBs are elevated. Ecology took the opportunity to determine dioxin and furan levels in edible fish fillet along with the other pollutants of concern.

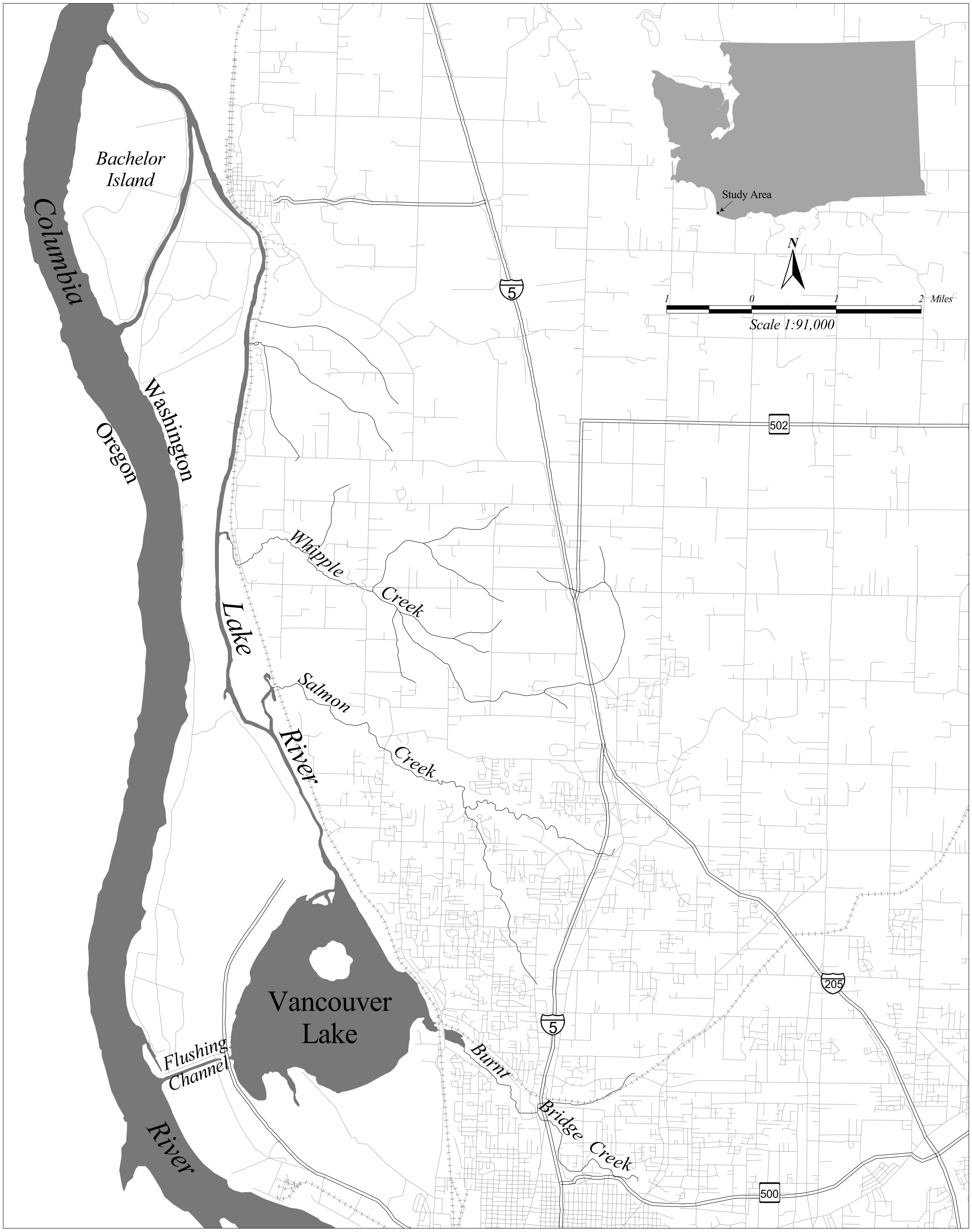

Figure 1. Study Area.

Current 2002/2004 303(d) listings for toxic chemicals in Vancouver Lake are shown in Table 1. The Lake River has no listings for toxic chemicals. Only categories 1 and 5 are shown. Category 1 is applied when a specific pollutant has no exceedances in the most recent data for that pollutant. Category 5 is applied when the pollutant is on the formal 303(d) list where a Total Maximum Daily Load (TMDL) assessment is required to be submitted to the U.S. Environmental Protection Agency for approval.

Table 1. Vancouver Lake 2002/2004 303(d) List for Toxics in Fish Tissue (Category 1 and 5 only).

303(d) Listed Parameter	On 1996 303(d) List	On 1998 303(d) List	2002/2004 303(d) Category
Total PCBs	No	No	**5**
4,4'-DDD	No	No	1
4,4'-DDE	No	No	1
4,4'-DDT	No	No	1
alpha-BHC	No	No	1
beta-BHC	No	No	1
Chlordane	No	No	1
Endosulfan I	No	No	1
Endosulfan II	No	No	1
Endrin	No	No	1
Gamma-BHC (Lindane)	No	No	1
Heptachlor	No	No	1
Heptachlor epoxide	No	No	1
Hexachlorobenzene	No	No	1
Mercury	No	No	1
Toxaphene	No	No	1

Bolded = Requires TMDL

The study area included all of Vancouver Lake and the Lake River. Three species of fish were sampled. Species selection was based on discussions with the Washington Department of Fish and Wildlife, targeting the fish most often caught and consumed. A total of 12 fish fillet samples were analyzed. In addition, five sediment samples were collected and analyzed from the study area, four from Vancouver Lake and one from the Lake River (Figure 2).

Objectives of the study are:

- Evaluate appropriate 303(d) listing status for Vancouver Lake and the Lake River.
- Determine the need for a TMDL study to address contamination.
- Provide data to the Washington State Department of Health (WDOH) to evaluate the need for a fish consumption advisory for these areas.

The results of this 2005-06 study were forwarded to WDOH to evaluate the need for a fish consumption advisory. The results of the WDOH evaluation will be available after this report is published.

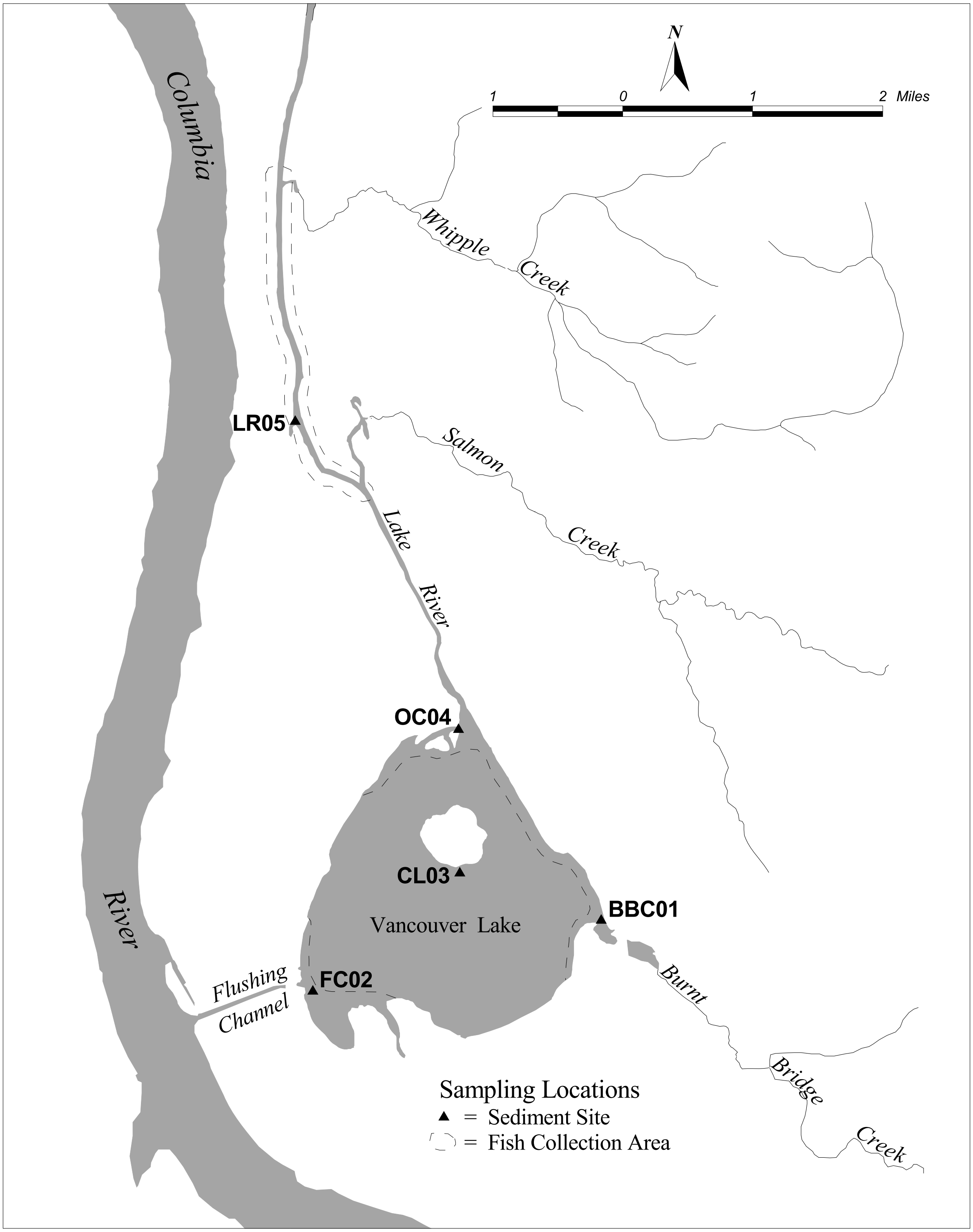

Figure 2. Vancouver Lake and Lake River Fish and Sediment Sampling Sites.

Methods

Sampling Design

As with most screening studies, a biased sample design was used. The intent was to conduct a cost effective sampling to determine if a more detailed study is needed.

Fish species were targeted that have been sampled in the past and are most likely to be consumed.

Most sediment sampling sites were set up near inputs to the lake where contaminants were expected to accumulate. A background station (CL03) was located in the center of the lake just south of the island as a comparison for other sediment sites (Figure 2).

Fish

Fish samples from Vancouver Lake and the Lake River were collected using a Smith-Root Model SR16 electrofishing boat and gill nets. Only fish of a size expected to be consumed by anglers were retained for analysis (see Appendix A for biological data on fish). General areas of the fish collection are shown on Figure 2.

Collection of fish samples started just after dusk on December 5, 2005 and continued through the late evening. Three 200-foot gill nets were set in Vancouver Lake, and electrofishing was conducted around the perimeter of the lake. In Lake River electrofishing was conducted along both banks from Whipple Creek to Salmon Creek. Only largescale suckers were available in December so completion of fish collection was delayed until April 3, 2006. The same areas were sampled during both periods.

All fish collected for analysis were given a unique identification number. Fish length and weight were recorded in the field following collection. Fish were double wrapped in aluminum foil, with the dull side contacting the fish, and sealed in zip-lock bags. All fish samples were kept in coolers on ice until return from the field. Once back from the field, fish samples were frozen to -18^{o} C until processed.

Preparation of tissue samples followed Environmental Protection Agency (EPA, 2000) guidance. Techniques were employed to minimize the possibility of sample contamination. All persons processing tissue samples used non-talc gloves and aprons. Work surfaces were covered with heavy grade aluminum foil. Gloves, aluminum foil, and dissection tools were changed between composite samples.

Composite samples were made up using equal weight aliquots of edible fillet from five fish. Fish of similar size (i.e., the smallest fish was at least 75% as long as the largest) were used to make up composites. After sorting for similar size groups, composites were formed randomly. Fillets were prepared by scaling and removal of one whole side per fish from the gill arch to the caudal peduncle. Fillets included dark tissue along the lateral line and fat from the belly flap.

Sex was determined for each fish. Scales, otoliths, opercles, and dorsal spines were collected for determination of age.

Fillets were placed in a Kitchen Aid blender and homogenized individually to a uniform color and consistency. Samples were thoroughly mixed by hand following each of three passes through the blender. Homogenates were stored frozen (-18^{o} C) in two 8-oz. glass jars with Teflon liners, cleaned to EPA (1990) QA/QC specifications, and certified for trace organic analyses. One container was submitted to the laboratory for analysis, and the other was archived at Ecology headquarters.

All equipment used in the preparation of tissue samples was washed thoroughly with tap water and Liquinox detergent, followed by sequential rinses of hot tap water, de-ionized water, pesticide-grade acetone, and finally, pesticide-grade hexane. All equipment was then air dried on clean aluminum foil under a fume hood until used. The full decontamination procedure was repeated between subsequent composite samples. Chain-of-custody was maintained throughout the sampling and analysis process.

Sediment

To the extent possible, sampling methods followed PSEP (1996) protocols. Surface sediment samples were collected from a Wooldridge 16-foot aluminum jet sled outfitted with a manual crank davit and 0.05 m^2 stainless steel Ponar grab. All sediment stations were located by a global positioning system (GPS) and recorded in field logs. Station position, relative to significant on-shore structures, was also recorded. Locations of sediment collection are shown on Figure 2, and their coordinates are listed in Appendix B.

Information about each sediment grab was recorded in the field log. A grab was considered acceptable if it was not overfilled, overlaying water was present but not overly turbid, the sediment surface appeared intact, and the grab reached the desired sediment depth.

Overlying water was siphoned off prior to sub-sampling. Equal volumes of the top 2-cm of sediment was removed from each of three grabs per site. Dedicated stainless steel spoons and bowls were used for sub-sampling and to homogenize sediments from each station to a uniform consistency and color. Debris on the sediment surface or materials contacting the sides of the Ponar grab was not retained for analysis.

Homogenized sediments from each station were placed in 8-oz. glass jars with Teflon-lined lids for analysis of PCBs and chlorinated pesticides. Sample containers were cleaned to EPA (1990) QA/QC specifications and certified for trace organic analyses. Additionally, 2-oz. glass jars were filled with homogenate for total organic carbon (TOC) analysis, while 8-oz. plastic jars were filled for determination of grain size.

All equipment used to collect sediment samples were washed thoroughly with tap water and Liquinox detergent, followed by sequential rinses of hot tap water, de-ionized water, pesticide-grade acetone, and finally, pesticide-grade hexane. All equipment was then air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure was used on the grab prior to going into the field. To avoid cross-contamination between sample stations, the grab was thoroughly brushed down with on-site water at the next sample location.

Immediately following collection, sediment samples were placed in coolers on ice at 4^{o} C and transported to Ecology's Manchester Environmental Laboratory within 24 hours. Chain-of-custody was maintained throughout the sampling and analysis process.

Analytical Methods

Sample preparation and analytical methods used for the analysis of fish tissue and sediments for the project are shown in Table 2. The full suite of compounds can be found in Appendix C.

Table 2. Sample Preparation and Analytical Methods for Detected Compounds in Fish Tissue and Sediments Collected from Vancouver Lake and the Lake River.

Analyte	Sample Preparation Method	Analytical Method
Fish Tissue		
PCB - 1242	EPA 3540/3620/3665	EPA 8082
PCB - 1254	"	"
PCB - 1260	"	"
trans-Chlordane (*gamma*)	EPA 3540/3620	EPA 8081
cis-Chlordane (*alpha*-Chlordane)	"	"
Dieldrin	"	"
4,4'-DDE	"	"
4,4'-DDD	"	"
4,4'-DDT	"	"
2,4'-DDD	"	"
Oxychlordane	"	"
Toxaphene	"	"
trans-Nonachlor	"	"
Hexachlorobenzene	"	"
2,3,7,8-TCDD	EPA 1613b	EPA 1613b
1,2,3,7,8-PeCDD	"	"
1,2,3,6,7,8-HxCDD	"	"
2,3,7,8-TCDF	"	"
Sediment		
PCB - 1248	EPA 3540/3620/3360b/3665	EPA 8082
PCB - 1254	"	"
4,4'-DDE	"	EPA 8081
4,4'-DDD	"	"

Data Quality Summary

Manchester Laboratory provides written case narratives of data quality for each data package analyzed in-house or from contract laboratories. Case narratives include descriptions of analytical methods and a review of holding times, instrument calibration checks, blank results, surrogate recoveries, matrix spike recoveries, laboratory control samples, and laboratory duplicate analyses.

Manchester Laboratory staff conducted the quality assurance review to verify that laboratory performance met quality control specifications outlined in the analytical methods and the Contract Laboratory Program (CLP) National Functional Guidelines for the Organic Data Review. In cases where data required qualification based on more than one issue, the more restrictive qualifier was applied.

Overall, a review of the data quality control and quality assurance from laboratory case narratives indicates the data are useable as qualified by Manchester Laboratory. Most data met measurement quality objectives established in the Quality Assurance Project Plan (Coots, 2006).

A summary of Manchester Laboratory's review is presented in Appendix C. The narratives and the complete data report are available by request from the study author.

Results on field replicate and laboratory duplicate sample pairs and their associated relative percent differences (RPDs) for the study can also be found in Appendix C.

Results and Discussion

Fish Availability

In early December 2005, largescale suckers were the overwhelming majority of adult fish encountered in Vancouver Lake and Lake River. Gill nets only produced one other specie, an immature largemouth bass not meeting size requirements. Because only largescale suckers were available for collection in December, further sampling was delayed until spring.

In April 2006, additional species were available. Electrofishing produced largescale suckers, common carp, grass carp, largemouth bass, and shad. Gill nets held sturgeon, channel catfish, common carp, and largescale suckers.

The Washington Department of Fish and Wildlife (Caromile, pers. comm.) was consulted on the low diversity of species found in December. During spring a spawning migration occurs. The Columbia River is directly connected to Vancouver Lake and Lake River and can act as a backwater. It is not clear whether species other than largescale suckers (1) leave the near-shore areas of Vancouver Lake and the Lake River in the winter for deeper, warmer waters within Vancouver Lake or (2) migrate to the Columbia River. Because we do not yet understand the movement of the fish within the system, it is difficult to determine if the fish collected in April came from Vancouver Lake, the Lake River, or the Columbia River. Further investigation would be required to determine if the fish collected reflect conditions in Vancouver Lake.

Chemicals Detected in Fish Tissue

Three composite samples of 5 fish each from target species were collected from Vancouver Lake and the Lake River. Largescale sucker (*Catostomidae macrocheilus)* and common carp (*Cyprinus carpio)* were the most abundant species and collected for analysis. In addition, one 5-fish composite of largemouth bass (*Micropterus salmoides*) was also collected from Vancouver Lake, allowing comparison to earlier studies.

Biological statistics for the individual fish and the sample composites used in the study are presented in Appendix A. Reporting limits for the laboratory analysis of fish tissue are shown in Appendix C. Background information on detected compounds from Vancouver Lake and the Lake River are in Appendix D. The entire data set of tissue results reported for the study is presented in Appendix E.

PCBs and Pesticides

Vancouver Lake

Table 3 summarizes PCBs and chlorinated pesticides detected in Vancouver Lake fish fillets. Total PCBs (sum of detected Aroclor equivalents) were elevated, ranging from an estimated 28 to 185 *u*g/Kg wet weight. Common carp had the highest levels of total PCBs, ranging from an estimated 51 to 185 *u*g/Kg, while largescale suckers had the lowest, ranging from an estimated 28 to 54 *u*g/Kg. The total PCB concentration for common carp sample 06194217 was estimated at 185 *u*g/Kg. This result is more than twice the next highest reported for all fillet samples.

The PCB mixture detected in fish fillets most closely resembled Aroclors 1254 and 1260, the two PCB Aroclors most often reported in fish tissue. Aroclor 1242 was also detected in the bass composite, the only other PCB Aroclor identified (Table 3).

Table 3. Summary of PCBs and Chlorinated Pesticides Detected in Vancouver Lake Fish Fillet Samples (*u*g/Kg, wet weight). Each sample is a composite of 5 fish.

	Largescale Sucker			Common Carp			Largemouth Bass
Sample ID (06):	194210	194209	194208	194217	194215[1]	194216	194211[1]
Lipid (%)	2.08	1.38	1.52	3.23	1.19	9.73	2.17
PCB - 1242	4.8 U	4.8 U	5.0 U	9.6 UJ	4.7 U	4.9 U	**8.0**
PCB - 1254	**29 J**	**18 J**	**33 J**	**185 J**	**25 J**	**62 J**	**53**
PCB - 1260	**16 J**	**10 J**	**21 J**	77 UJ	**26 J**	**20 J**	**22 J**
Total PCBs	**45 J**	**28 J**	**54 J**	**185 J**	**51 J**	**82 J**	**83 J**
4,4’-DDE	**24**	**10**	**23**	**96 J**	**27**	**37 J**	**34**
4,4’-DDD	**3.8**	**1.4**	**3.5**	**22 J**	**1.4**	**7.0 J**	**5.2**
4,4’-DDT	**1.4 J**	0.48 U	**1.7 J**	**3.3 J**	**1.1 J**	**1.4 J**	**2.6 J**
2,4’-DDD	**0.55**	0.48 U	0.50 U	**3.8 J**	**0.52**	**1.4 J**	**0.75**
Total DDT	**30**	**11.4**	**28**	**125 J**	**30**	**47 J**	**43**
trans-Chlordane	0.48 U	0.48 U	0.50 U	**1.5 J**	0.47 U	**0.71 J**	0.47 U
cis-Chlordane	0.48 U	0.48 U	0.50 U	**2.5 J**	0.47 U	**1.3 J**	0.47 U
Oxychlordane	0.48 U	0.48 U	0.50 U	0.52 UJ	0.47 U	0.49 U	**0.47**
trans-Nonachlor	**0.58**	0.48 U	0.50 U	**3.9 J**	**1.1**	**2.2 J**	**2.3**
Total Chlordanes	**0.58**	0.48 U	0.50 U	**7.9 J**	**1.1**	**4.2 J**	**2.8**
Dieldrin	0.48 UJ	0.48 UJ	0.50 UJ	0.48 UJ	0.94 UJ	0.49 UJ	**1.1 J**
Toxaphene	9.6 UJ	9.7 UJ	9.9 UJ	96 UJ	9.4 UJ	9.9 UJ	**28 J**
Hexachlorobenzene	0.48 UJ	0.48 UJ	0.50 UJ	**1.4 J**	0.47 UJ	**1.3 J**	0.47 U

1 = Mean of duplicate sample pair.
U = Compound not found at the value shown.
UJ = Not found at the estimated detection limit shown.
Bold = Visual aid for detected compounds.
J = Compound positively identified; result is an estimate.

PCBs are ubiquitous in the environment due to their persistence, ability to transport by air over large distances, and their potential to bioaccumulate and biomagnify in the food chain. Sources of PCBs may be local or from a global atmospheric pool.

One major input of PCBs to freshwater systems is from the atmosphere (Bremle, 1997). Aerial flux of PCBs to the earth’s surface occurs from rainfall, scrubbing vapors and particles from the air. In addition to this direct input to surface waters, PCB deposition to terrestrial areas within a basin also reach surface water in run-off.

Surface water management can be difficult for PCBs, and other compounds that act similarly such as dioxins and furans, because the major source may be from the global pool. Because Total Maximum Daily Load (TMDL) studies are developed to guide water cleanup plans, a statewide assessment is likely the most efficient way to deal with contaminants originating from global sources.

Total DDT (i.e., 4,4'-DDT + 4,4'-DDE + 4,4'-DDD + 2,4'-DDD) was detected in all three species from Vancouver Lake. Total DDT concentrations ranged from 11 to 125 *u*g/Kg. The DDT metabolite 4,4'-DDE accounted for the majority of the total DDT in fish tissue. As the most persistent of the DDT metabolites (Lindsey et al., 1998), DDE commonly accounts for the majority of total DDT concentration in fish.

Other chlorinated pesticides detected in fish tissue were *trans*-chlordane, *cis*-chlordane, oxychlordane, *trans*-nonachlor, dieldrin, toxaphene, and hexachlorobenzene.

Technical chlordane consists of over 100 related compounds. *Trans*-chlordane, *cis*-chlordane, and *trans*-nonachlor are all major constituents. Between 60 and 85% of technical chlordane is composed of the stereoisomers t*rans*-chlordane and *cis*-chlordane (ATSDR, 1994). Oxychlordane is a metabolite of chlordane and is considered the most persistent of the breakdown products (WHO, 1984). The detected concentrations of these compounds were summed and are discussed below as total chlordane.

Only one of the three largescale sucker composites from Vancouver Lake had chlordane residuals detected. A low concentration of trans-nonachlor was reported in sample 06194210 (Table 3). All three common carp composites had trans-nonachlor detected, and two of the three had t*rans*-chlordane and *cis*-chlordane. The total chlordane concentrations in common carp were low, ranging from 1.1 to 7.9 *u*g/Kg. The bass composite had oxychlordane and trans-nonachlor reported at low levels for a total chlordane concentration of 2.8 *u*g/Kg.

The chlorinated pesticides dieldrin and toxaphene were detected in the bass composite. It was the only fish tissue sample from Vancouver Lake where these chemicals were detected. Both pesticides were detected at significant levels. Dieldrin was reported at an estimated concentration of 1.1 *u*g/Kg, and toxaphene was estimated at 28 *u*g/Kg.

Hexachlorobenzene was found at low concentrations in two common carp samples, estimated at 1.4 and 1.3 *u*g/Kg.

Lake River

PCB and chlorinated pesticide concentrations in fish from the Lake River are shown in Table 4. Total PCBs in fish fillet were elevated, ranging from an estimated 31 to 81 *u*g/Kg. Common carp had the higher levels of total PCBs, ranging from an estimated 57 to 81 *u*g/Kg, while the largescale suckers had the lowest, ranging from an estimated 31 to 35 *u*g/Kg.

As in Vancouver Lake, the PCBs detected in fish fillets most closely resembled Aroclors 1254 and 1260.

DDT compounds were detected in both largescale suckers and common carp from the Lake River (Table 4). Total DDT ranged from 19 to 41 *u*g/Kg. The DDT metabolite 4,4'-DDE accounted for the majority of the total DDT concentrations, as it did in Vancouver Lake.

Table 4. Summary of PCBs and Chlorinated Pesticides Detected in Lake River Fish Fillet Samples (*u*g/Kg, wet weight). Each sample is a composite of 5 fish.

	Largescale Sucker			Common Carp		
Sample ID (06):	194207	194206	194205[1]	194214	194213	194212[1]
Lipid (%)	1.37	1.04	2.23	1.80	2.31	1.24
PCB - 1254	**18 J**	**19 J**	**21 J**	**51 J**	**34 J**	**34**
PCB - 1260	**13 J**	**14 J**	**14 J**	**30 J**	**24 J**	**23 J**
Total PCBs	**31 J**	**33 J**	**35 J**	**81 J**	**58 J**	**57 J**
4,4'-DDE	**17**	**17**	**16**	**34**	**34**	**27**
4,4'-DDD	**1.8**	**2.4**	**3.3**	**2.2**	**5.7**	**5.8**
4,4'-DDT	4.8 U	0.50 U	**1.4 J**	**1.9 J**	**1.3 J**	**2.3 J**
2,4'-DDD	4.8 U	0.50 U	**0.56**	**0.59**	**0.92**	**1.0**
Total DDT	**19**	**19**	**21**	**39**	**42**	**36**
cis-Chlordane	4.8 U	0.50 U	0.49 U	0.48 U	**0.69 J**	0.48 U
trans-Nonachlor	4.8 U	0.50 U	**0.56 J**	**1.1**	**1.1**	**1.3**
Total Chlordane	4.8 U	0.50 U	**0.56 J**	**1.1**	**1.8 J**	**1.3**
Dieldrin	0.48 UJ	0.50 UJ	0.49 UJ	0.97 UJ	0.89 UJ	**0.76 J**
Hexachlorobenzene	0.48 UJ	0.50 UJ	**0.51 J**	0.48 UJ	0.44 UJ	0.48 UJ

1 = Mean of a duplicate sample pair.
Bold = Visual aid for detected compounds.
J = Compound positively identified; result is an estimate.
U = Not detected at the detection limit shown.
UJ = Not detected at the estimated detection limit shown.

Other chlorinated pesticides detected in fish fillet from Lake River were *cis*-chlordane, *trans*-nonachlor, dieldrin, and hexachlorobenzene.

Only one of the three largescale sucker composites from Lake River had chlordane residuals detected. A low concentration of trans-nonachlor was reported in one sample. Trans-nonachlor was detected in all three common carp composites, and one of the three also had *cis*-chlordane. The total chlordane concentrations in common carp, ranging from 1.1 to 1.8 *u*g/Kg, were lower than results reported for Vancouver Lake common carp.

Dieldrin and hexachlorobenzene were each detected in one composite sample. Dieldrin was detected in common carp at an estimated concentration of 0.76 *u*g/Kg. Hexachlorobenzene was reported just above detection in largescale suckers at an estimated concentration of 0.51 *u*g/Kg.

Dioxins and Furans

Dioxins and furans are the common names associated with polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). One sample each of largescale suckers and common carp fillet were analyzed for dioxins and furans from Vancouver Lake and the Lake River. Samples were composites of 5 fish each. The data are summarized in Table 5. The complete set of results can be found in Appendix E.

Dioxins and furans were detected in all of the samples analyzed. Levels of dioxins from both largescale suckers and common carp fillets were largely made up of the less chlorinated tetra-, and penta- congeners. The largescale suckers fillets averaged 0.11 ng/Kg, for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), while the common carp fillets averaged 0.12 ng/Kg. The only PCDF congener detected was 2,3,7,8-tetrachlorodibenzofuran (TCDF). The Lake River fillets were higher for PCDD and PCDF congeners than Vancouver Lake fillets for the same fish specie.

Dioxin and furan compounds have different levels of toxicity. To allow overall assessment of toxicity, a system using toxic equivalent factors (TEFs) based on their relative toxicity compared to 2,3,7,8-TCDD was developed. The TEFs from dioxin and furan compounds in a sample are summed for a total or toxic equivalent quotient (TEQ), which can be compared to available criteria on 2,3,7,8-TCDD. Tables 5 shows TEQs calculated for Vancouver Lake and the Lake River.

Table 5. Summary of Dioxin and Furan Compounds Detected in Vancouver Lake and Lake River Fish Fillet Samples (ng/Kg, wet weight). Samples are composites of 5 fish.

NTR criteria: 2,3,7,8, TCDD = 0.07 ng/Kg	TEF[1]	Vancouver Lake		Lake River	
		Largescale Suckers	Common Carp	Largescale Suckers[2]	Common Carp
Sample ID (06):		194209	194215	194206	194213
% Lipids		2.2 %	1.1 %	1.7 %	2.0 %
2,3,7,8-TCDD	1	**0.10**	**0.069**	**0.11**	**0.18**
1,2,3,7,8-PeCDD	1	**0.089**	0.050 UJ	**0.32**	**0.51**
1,2,3,6,7,8-HxCDD	0.1	0.080 UJ	0.080 UJ	0.080 UJ	**0.36**
PCDD TEQ[3]		**0.19**	**0.069**	**0.43**	**0.73**
2,3,7,8-TCDF	0.1	**0.10**	**0.10**	**0.12**	**0.27**
PCDF TEQ		**0.010**	**0.010**	**0.012**	**0.027**
TEQ		**0.20**	**0.079**	**0.44**	**0.76**
% 2,3,7,8-TCDD		52%	87 %	26 %	24%
% PCDDs		95%	87 %	97 %	96%
% PCDFs		5%	13 %	3 %	4%

1 = Toxic Equivalent Factor.
2 = Mean of a duplicate sample pair.
Bold = Visual aid for detected compounds.
3 = Toxic Equivalent Quotient.

The Lake River had higher TEQs than Vancouver Lake for the same fish species. The largescale sucker TEQ from the Lake River was about twice the TEQ reported for suckers from Vancouver Lake. The common carp TEQ from the Lake River was nearly an order of magnitude higher than the carp TEQ from Vancouver Lake. The average percent of the total TEQ attributed to 2,3,7,8- TCDD for Vancouver Lake fish was about 70%, and about 25% for the Lake River.

Comparison to NTR Criteria and 303(d) Listing

In 1992, EPA established water quality criteria for priority pollutants for the protection of human health, referred to as the National Toxics Rule (40 CFR 131.36(14)). Ecology adopted the National Toxics Rule (NTR) for water quality human health criteria, as required by the EPA for states without sufficient human health criteria for priority pollutants. In Washington, human health criteria are calculated for an increased lifetime cancer risk of one in one million (10^{-6}) from the consumption of fish or fish and water.

Three composite samples each of largescale sucker and common carp were collected from Vancouver Lake. In addition, one composite sample of largemouth bass was also collected. Results from the present study show PCB concentrations exceeded the NTR criterion of 5.3 *u*g/Kg (parts per billion; ppb) in all samples analyzed. Average concentrations exceeded the criterion by 8 times for largescale suckers, 20 times for the common carp, and over 15 times for the single composite of bass.

Of the three DDT species with NTR criteria, only 4,4'-DDE was above the 31.6 *u*g/Kg criterion. Two common carp composites and the largemouth bass composite exceeded the NTR criterion. The largemouth bass and one of the common carp composites were slightly above criterion, while the other common carp sample was about 3 times the criterion.

Results for 2,3,7,8-TCDD from largescale suckers and common carp collected from Vancouver Lake showed largescale suckers about 1½ times the 0.07 ng/Kg NTR criterion, and the common carp slightly under. Levels of 2,3,7,8-TCDD were lower in Vancouver Lake common carp than the Lake River common carp, which exceeded the criterion by about 2½ times. Levels in largescale suckers were about the same.

The only other contaminants to exceed the NTR criteria in Vancouver Lake fish samples were dieldrin and toxaphene detected in the largemouth bass composite. The estimated concentration for toxaphene was almost 3 times the 9.8 *u*g/Kg NTR criterion, while the estimated concentration for dieldrin was about 1½ times the 0.65 *u*g/Kg criterion.

Three composite samples of largescale sucker and common carp were collected from the Lake River. PCB concentrations exceeded the NTR criterion in all samples. The criterion was exceeded by 6 times for largescale suckers, and 12 times for the common carp.

Results for 2,3,7,8-TCDD in the Lake River fish composites showed the NTR criterion of 0.07 ng/Kg was exceeded in largescale suckers by about 1½ times, and in the common carp about 2½ times. Levels of 2,3,7,8-TCDD were higher in common carp from the Lake River than from Vancouver Lake.

As in Vancouver Lake, the only DDT metabolite detected above the NTR criterion in the Lake River was DDE. Two of the three common carp composites only slightly exceeded the 31.6 *u*g/Kg NTR criterion. Largescale suckers were within the NTR criteria for DDT and its metabolites.

The only other contaminant found above the NTR criteria from the Lake River was dieldrin. One of the three common carp composites had a concentration reported only slightly above the NTR criterion of 0.65 *u*g/Kg.

This 2005-06 study confirmed that the majority of the category 1 listed compounds are still meeting water quality standards in Vancouver Lake fish. Two compounds previously listed under category 1 of the 303(d) list and 2 new compounds not before listed, exceeded criteria and are recommended for listing under category 5. Based on study results, 303(d) listing recommendations for Vancouver Lake and the Lake River are presented in Table 6.

Table 6. 303(d) Listing Status and Recommendations for Fish Tissue from Vancouver Lake and the Lake River.

Waterbody	Compounds Not Meeting Standards (Category 5)	Compounds Meeting Standards (Category 1)
Vancouver Lake	Total PCBs	4,4'-DDD
	4,4'-DDE (formerly category 1)	4,4'-DDT
	Toxaphene (formerly category 1)	alpha-BHC
	2,3,7,8-TCDD (new listing)	beta-BHC
	Dieldrin (new listing)	Chlordane
		Endosulfan I
		Endosulfan II
		Endrin
		gamma-BHC (Lindane)
		Heptachlor
		Heptachlor epoxide
		Hexachlorobenzene
Lake River	Total PCBs (new listing)	
	2,3,7,8-TCDD (new listing)	
	4,4'-DDE (new listing)	
	Dieldrin (new listing)	

Category 1 = the most recent data for the pollutant indicates no exceedances of standards.
Category 5 = the pollutant is on the federal Clean Water Act Section 303(d) list.

Statewide Comparison

To put the fish tissue results into perspective, study data were compared to PCB and DDT data from 25 other Washington State studies conducted over the past 20 years. Ecology and EPA studies reporting total PCB and total DDT data from muscle fillet tissue samples collected between 1985 and 2005 were compared. Data from the past studies were pooled and are presented in Figures 3 and 4. Only results from freshwater species of fish reported above detection limits are shown.

Figures 3 and 4 present cumulative frequency plots which display the data as percentiles. The Y axis is in units of micrograms per kilogram of contaminant plotted on a logarithmic scale.

References for Figures 3 and 4 are listed under the References section of this report.

PCBs

As shown in Figure 3, all study results from Vancouver Lake and the Lake River for total PCBs exceed the NTR criterion of 5.3 *u*g/Kg. Generally, the results range from about the 30th percentile to the 50th percentile compared to other values from around Washington State. One common carp sample from Vancouver Lake was at about the 71st percentile.

DDT

Figure 4 shows results from Vancouver Lake and the Lake River generally fell between the 20th to the 50th percentiles for statewide results. The same common carp sample from Vancouver Lake that was much higher for total PCBs was also higher for total DDT, near the 65th percentile. The majority of the total DDT results were near the NTR criteria for DDT and metabolites.

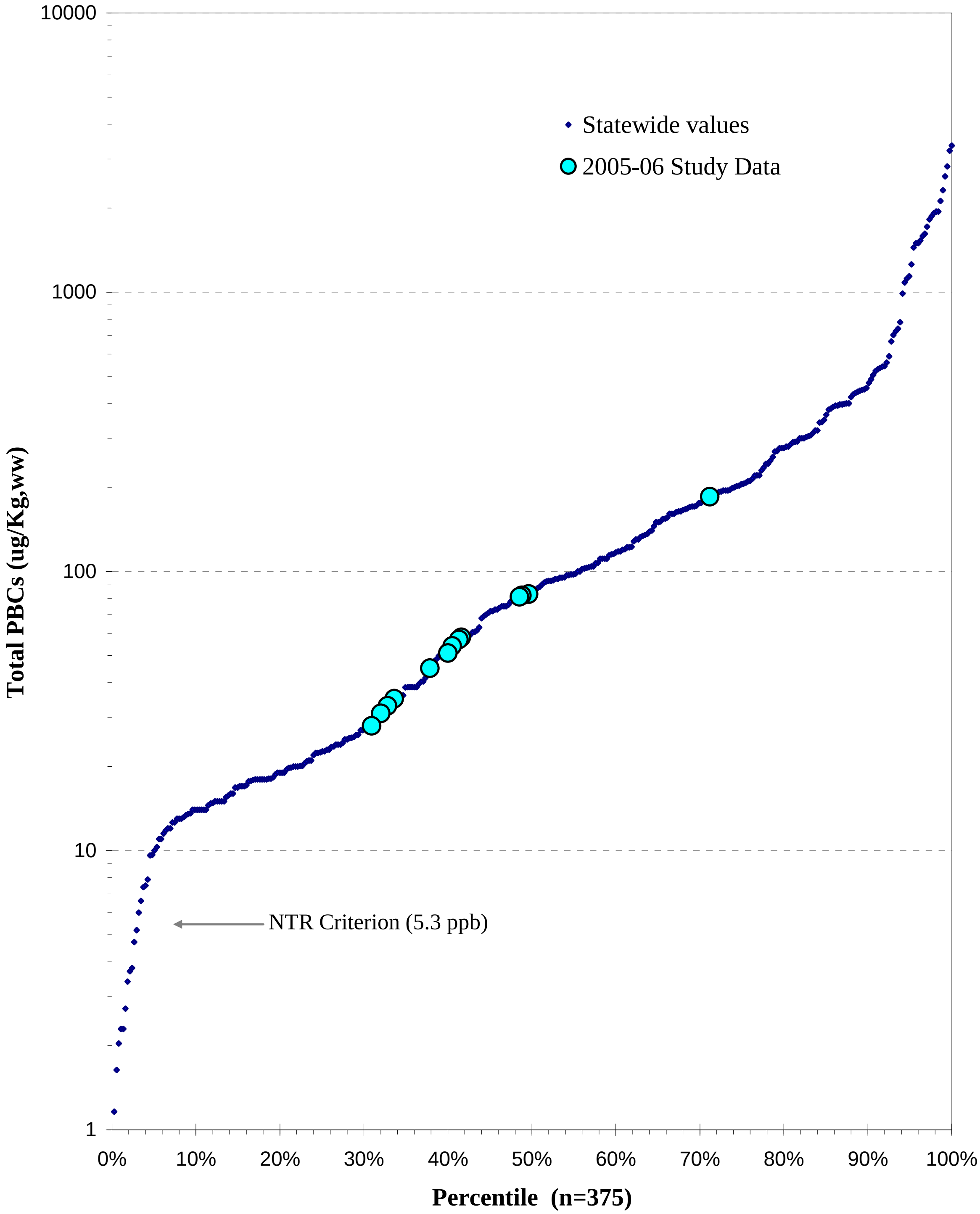

Figure 3. Cumulative Frequency Distribution of Total PCBs in Edible Fish Tissue from Vancouver Lake and the Lake River Compared to Statewide 1985-2005 Data.

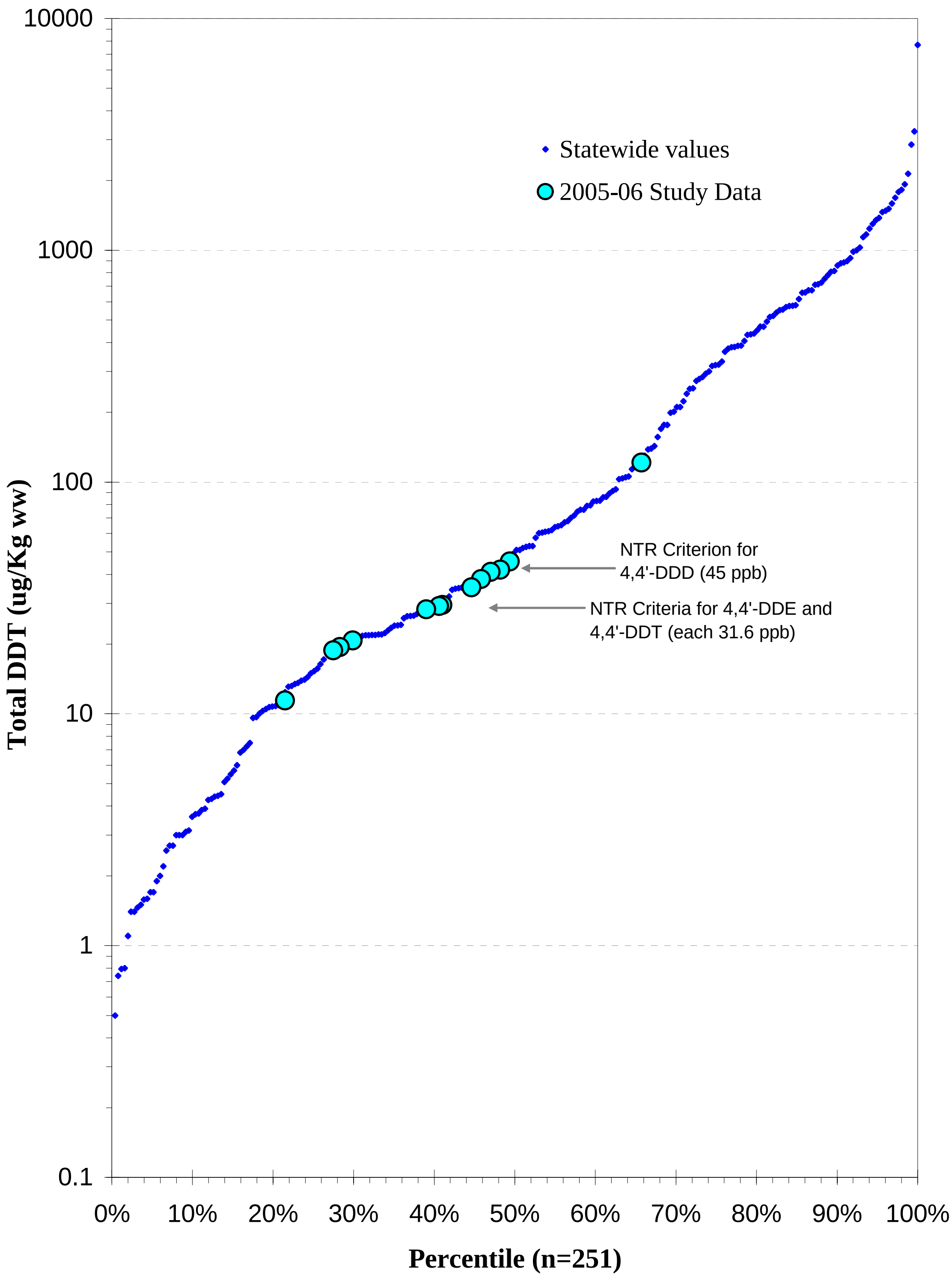

Figure 4. Cumulative Frequency Distribution of Total DDT in Edible Fish Tissue from Vancouver Lake and the Lake River Compared to Statewide 1985-2005 Data.

Chemicals Detected in Sediments

Table 7 summarizes detected compounds from the chemical analysis of sediment samples collected from Vancouver Lake and the Lake River. Reporting limits are in Appendix C. The complete data set is in Appendix E.

Table 7. PCBs and Chlorinated Pesticides Detected in Vancouver Lake and Lake River Surface Sediment Samples, February 1, 2006 (*u*g/Kg, dry weight).

Site	Burnt Bridge Creek (BBC01)	Flushing Channel (FC02)	Center Lake (CL03)	Outlet Channel (OC04)[1]	Lake River (LR05)	Sediment Quality Guidelines LAET[2]
Sample No. (06-)	054030	054031	054032	054033/5	054034	
TOC 70°C (%)	2.01	0.36	0.68	0.93	1.04	9.82
Fines (%)	76.7	33.5	62.5	24.4	47.4	
PCB-1248	13 UJ	3.9 U	4.3 U	**5.0 J**	4.5 U	62[3]
PCB-1254	**14 J**	3.9 U	4.3 U	4.5 U	4.5 U	230
4,4'-DDE	**3.3**	0.79 U	0.85 U	0.89 U	0.91 U	21
4,4'-DDD	**1.6**	0.79 U	0.85 U	0.89 U	0.91 U	96

1 = Average reported for the replicate pair.
2 = Lowest Apparent Effects Threshold (Avocet Consulting, 2003).
3 = Proposed standard is for total PCBs. No LAET was available for Aroclor 1248.
TOC = Total organic carbon
UJ = Not detected at the estimated detection limit shown.
U = Not detected at the detection limit shown.
Bold = Visual aid for detected compounds.

Sediments were analyzed for 31 different PCB and chlorinated pesticide compounds. Only four of the possible 31 compounds were detected. Less than 3% of the analyses detected target chemicals above reporting limits. Two chlorinated pesticides, DDE and DDD, and two PCB Aroclors were found in surface sediments from Vancouver Lake. No target compounds were detected in surface sediments from the Lake River site.

The concentrations of DDE, DDD, and PCBs were low. Sediments collected near the Burnt Bridge Creek discharge to Vancouver Lake (Figure 2) included the DDT metabolites, 4,4'-DDE and 4,4'-DDD, and PCBs resembling PCB-1254. Three of the four compounds detected in sediments were from this site.

The Outlet Channel (OC04) site near the entrance to Lake River was the only other sediment site with a target compound detected, PCBs. The PCB mixture most closely resembled Aroclor 1248. This result was verified with the results from a replicate sample (Appendix C). Reporting limits for the target compounds were generally good, ranging from 3.9 to 6.6 *u*g/Kg for the PCB analysis, and from 0.79 to 1.3 *u*g/Kg for chlorinated pesticides (Appendix C).

Comparison to Sediment Quality Guidelines

Currently, there are no Washington State sediment standards or national EPA criteria for chemical contaminants in freshwater sediments. Under Washington Administrative Code (WAC) 173-204-340, Freshwater Sediment Standards, Ecology has the authority and "will determine on a case-by-case basis the criteria, methods, and procedure necessary to meet the intent of this chapter."

The levels of chemicals found in sediments during this 2005-06 study are compared to these proposed sediment quality standards in Table 7. Avocet Consulting (2003) has proposed sediment quality standards for Washington State as a part of Ecology's effort to develop freshwater sediment quality criteria. These values are presented for discussion purposes only, as none have been adopted, and values eventually selected could be different than Avocet's.

The proposed standards are based on effects thresholds (i.e., the concentration below which harmful effects to sediment-dwelling organisms are not expected to occur). The lowest apparent effects threshold (LAET) was used as the guideline to compare results for detected chemicals. As Table 7 shows, results were well below proposed sediment quality standards and not expected to cause adverse effects to the benthic community.

Summary and Recommendations

Vancouver Lake

This 2005-06 study found that contaminant levels in fish from Vancouver Lake were higher than (exceeded) the National Toxics Rule (NTR) human health criteria for total PCBs, 4,4'-DDE, 2,3,7,8-TCDD, toxaphene, and dieldrin. Total PCBs were elevated in all fish tissue samples from Vancouver Lake. The highest levels of total PCBs and total DDT were in common carp samples. The DDT metabolite, 4,4'-DDE, accounted for the majority of total DDT concentrations in tissue. Recommendations for 303(d) listings for Vancouver Lake are presented in Table 8.

Table 8. Recommended 303(d) Listings for Vancouver Lake Fish Tissue.

303(d) Listing Parameter	Listing Species	303(d) Listing Category	
		Current	Proposed
Total PCBs	Common Carp, Largemouth Bass, Largescale Sucker	5	5
4,4'-DDE	Common Carp, Largemouth Bass	1	5
Toxaphene	Largemouth Bass	1	5
2,3,7,8-TCDD	Largescale Suckers	Not Listed	5
Dieldrin	Largemouth Bass	Not Listed	5

Category 1 = the most recent data for the pollutant indicates no exceedances of standards.
Category 5 = the pollutant is on the federal Clean Water Act Section 303(d) list.

Total PCBs is the only category 5 listing on the 2002/2004 303(d) list for Vancouver Lake. This study verified the category 5 listing for total PCBs should remain. In addition, 4,4'-DDE and toxaphene should be moved from category 1 on the 303(d) list to category 5, while 2,3,7,8-TCDD and dieldrin should be added to the list under category 5. All other chlorinated pesticides listed under category 1 (Table 1) should remain under category 1.

Concentrations of target contaminants were low in sediments. Surface water from Vancouver Lake, the flushing channel, and Burnt Bridge Creek should be evaluated for PCBs and chlorinated pesticides to determine if contaminant concentrations in fish tissue are driven by levels in surface water.

Recommendations for Vancouver Lake

- A surface water quality study for PCBs and chlorinated pesticides should be conducted for Vancouver Lake, the flushing channel, and Burnt Bridge Creek.
- Total PCBs and 2,3,7,8-TCDD in Vancouver Lake fish tissue should be addressed through a statewide assessment.
- A Total Maximum Daily Load (TMDL) study should be considered for 4,4’-DDE, toxaphene, and dieldrin in Vancouver Lake fish if follow-up sampling indicates potential pollutant sources are present.
- Fish should be monitored for PCBs and chlorinated pesticides again in five years.

Lake River

This 2005-06 study found that contaminant levels in fish from the Lake River exceeded the NTR human health criteria for total PCBs, 4,4’-DDE, 2,3,7,8-TCDD, and dieldrin. The highest levels of total PCBs and total DDT were in common carp samples. The DDT metabolite, 4,4’-DDE, accounted for the majority of total DDT concentrations in tissue. Recommendations for 303(d) listings for the Lake River are presented in Table 9.

Table 9. Recommended 303(d) Listings for the Lake River Fish Tissue.

303(d) Listing Parameter	Listing Species	303(d) Listing Category	
		Current	Proposed
Total PCBs	Common Carp, Largescale Suckers	Not Listed	5
2,3,7,8-TCDD	Common Carp, Largescale Suckers	Not Listed	5
4,4'-DDE	Common Carp	Not Listed	5
Dieldrin	Common Carp	Not Listed	5

Category 5 = the pollutant is on the federal Clean Water Act Section 303(d) list.

The Lake River had no fish tissue listings on the 2002/2004 303(d) list for toxics. This study showed total PCBs, 2,3,7,8-TCDD, 4,4’-DDE, and dieldrin should be placed on the 303(d) list for the Lake River under category 5.

The average 4,4’-DDE concentration from common carp was reported very near the NTR criterion, and dieldrin concentrations were just slightly over the criterion. It may be worthwhile to resample Lake River fish in five years to determine if a TMDL study is warranted.

No PCBs or chlorinated pesticides were detected in sediments collected from Lake River.

Recommendations for the Lake River

- A surface water quality study for PCBs and chlorinated pesticides should be conducted for the Lake River and inputs from Salmon Creek, Whipple Creek, and the Columbia River.
- Total PCBs and 2,3,7,8-TCDD in Lake River fish should be addressed through a statewide assessment.
- A TMDL study should be considered for 4,4'-DDE and dieldrin in Lake River fish if follow-up sampling indicates potential pollutant sources are present.
- Fish should be monitored for PCBs and chlorinated pesticides again in five years.

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References

ATSDR, 1994. Agency for Toxic Substances and Disease Registry. Public Health Statement for Chlordane, CAS# 12789-03-6. May 1994. www.atsdr.cdc.gov/toxprofiles/phs31.html

ATSDR, 1997. Agency for Toxic Substances and Disease Registry. ToxFAQs for Toxaphene, CAS# 8001-35-2. September 1997. www.atsdr.cdc.gov/tfacts94.html

ATSDR, 2002a. Agency for Toxic Substances and Disease Registry. ToxFAQs for Dieldrin, CAS# 60-57-1. September 2002. www.atsdr.cdc.gov/tfacts1.html

ATSDR, 2002b. Agency for Toxic Substances and Disease Registry. ToxFAQs for Hexachlorobenzene, CAS# 118-74-1. September 2002. www.atsdr.cdc.gov/toxprofiles/tp90-c5.pdf

Avocet Consulting, 2003. Development of Freshwater Sediment Quality Values for Use in Washington State – Phase II Final Report: Development and Recommendations of SQVs for Freshwater Sediments in Washington State. Prepared for the Washington State Department of Ecology under contract to Science Applications International Corporation. Publication No. 03-09-088. www.ecy.wa.gov/biblio/0309088.html

Bremle, G., 1997. Polychlorinated biphenyls (PCBs) in a river ecosystem. PhD Thesis. Department of Ecology, Chemical Ecology and Ecotoxicology, Lund University, Lund, Sweden.

Caromile, S.J., W.R. Meyer and C.S. Jackson, 2000. 1998 Warmwater Fish Survey of Vancouver Lake, Clark County. Warmwater Enhancement Program, Washington Department of Fish and Wildlife, Olympia, WA. April 2000.

Caromile, S.J., 2006. Personal communication. Washington Department of Fish and Wildlife, Olympia, WA. April 2006.

Coots, R., 2006. Vancouver Lake PCBs, Chlorinated Pesticides, and Dioxins Fish Tissue Investigation, Quality Assurance Project Plan. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-101. www.ecy.wa.gov/biblio/0603101.html

Davis, D., A. Johnson, and D. Serdar 1995. Washington State Pesticide Monitoring Program – 1993 Fish Tissue Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 95-356. www.ecy.wa.gov/biblio/95356.html

EPA, 1990. Specifications and Guidance for Obtaining Contaminant-Free Sample Containers. U.S. Environmental Protection Agency. OSWER Directive #93240.0-05.

EPA, 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories. Vol. 1, Fish Sampling and Analysis. U.S. Environmental Protection Agency, Office of Water. EPA-823-B-00-007.

Lindsey, B.D., Breen, K.J., Bilger, M.D., and Brightbill, R.A., 1998. Water Quality in the Lower Susquehanna River Basin, Pennsylvania and Maryland, 1992-95: U.S. Geological Survey. Updated June 22, 1998. http://pubs.usgs.gov/circ/circ1168/nawqa91.c.html

PSEP, 1996. Puget Sound Estuary Program (PSEP): Recommended Protocols for Measuring Selected Variables in Puget Sound. U.S. Environmental Protection Agency, Region 10, Office of Puget Sound, Seattle, WA.

Seiders, K. and K. Kinney, 2004. Washington State Toxics Monitoring Program: Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2002. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-040. www.ecy.wa.gov/biblio/0403040.html

World Health Organization (WHO), 1984. Chlordane. Environmental Health Criteria 34. World Health Organization, Geneva, Switzerland. 82 pages.

References for Figures 3 and 4: Historical studies, 1985-2005

Washington State Department of Ecology – 22 studies

Davis, D. and A. Johnson, 1994. Washington State Pesticide Monitoring Program: Reconnaissance Sampling of Fish Tissue and Sediments (1992). Washington State Department of Ecology, Olympia, WA. Publication No. 94-194. www.ecy.wa.gov/biblio/94194.html

Davis, D., A. Johnson, and D. Serdar 1995. Washington State Pesticide Monitoring Program – 1993 Fish Tissue Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 95-356. www.ecy.wa.gov/biblio/95356.html

Davis, D. and D. Serdar, 1996. Washington State Pesticide Monitoring Program: 1994 Fish Tissue and Sediment Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 96-352. www.ecy.wa.gov/biblio/96352.html

Davis, D., D. Serdar, and A. Johnson, 1998. Washington State Pesticide Monitoring Program – 1995 Fish Tissue Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 98-312. www.ecy.wa.gov/biblio/98312.html

Ecology, 1995. Department of Ecology 1993-94 Investigation at PCBs in the Spokane River. Washington State Department of Ecology, Olympia, WA. Publication No. 95-310. www.ecy.wa.gov/biblio/95310.html

Era-Miller, B. and K. Kinney, 2005. Verification of 303(d) Listings for Fish Tissue in the Skagit and Pend Oreille Rivers. Washington State Department of Ecology, Olympia, WA. Publication No. 05-03-017. www.ecy.wa.gov/pubs/0503017.pdf

Hopkins B., D. Clark, M. Schlender, and M. Stinson, 1985. Basic Water Monitoring Program: Fish Tissue and Sediment Sampling for 1984. Washington State Department of Ecology, Olympia, WA. Publication No. 85-7. www.ecy.wa.gov/biblio/857.html

Hopkins, B., 1991. Basic Water Monitoring Program: Fish Tissue and Sediment Sampling for 1989. Washington State Department of Ecology, Olympia, WA. Publication No. 91-e14. www.ecy.wa.gov/biblio/91e14.html

Jack, R. and M. Roose, 2002. Analysis of Fish Tissue from Long Lake (Spokane River) for PCBs and Selected Metals. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-049. www.ecy.wa.gov/biblio/0203049.html

Johnson, A. and D. Norton, 1990. 1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Olympia, WA. Publication No. 90-e35. www.ecy.wa.gov/biblio/90e35.html

Johnson, A., 1997. 1996 Results on PCBs in Upper Spokane River Fish. Memo to C. Nuechterlein and D. Knight, Eastern Regional Office. Washington State Department of Ecology, Olympia, WA. Publication No. 97-e04. www.ecy.wa.gov/biblio/97e04.html

Johnson, A., 2000. Results from Analyzing PCBs in 1999 Spokane River Fish and Crayfish Samples. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-040. www.ecy.wa.gov/biblio/0003040.html

Johnson, A., B. Era-Miller, R. Coots, and S. Golding, 2004. A Total Maximum Daily Load Evaluation for Chlorinated Pesticides and PCBs in the Walla Walla River. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-032. www.ecy.wa.gov/biblio/0403032.html

Rogowski, D., 2000. Verifying 303(d) DDT/DDE and Dieldrin Listings for the Upper Yakima River. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-023. www.ecy.wa.gov/biblio/0003023.html

Seiders, K. and K. Kinney, 2004. Washington State Toxics Monitoring Program: Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2002. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-040. www.ecy.wa.gov/biblio/0403040.html

Seiders, K., 2005. Unpublished Data from: Washington State Toxics Monitoring Program – Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2003. Washington State Department of Ecology, Olympia, WA.

Serdar, D., A. Johnson, and D. Davis, 1994. Survey of Chemical Contaminants in Ten Washington Lakes. Washington State Department of Ecology, Olympia, WA. Publication No. 94-154. www.ecy.wa.gov/biblio/94154.html

Serdar, D., B. Yake, and J. Cubbage, 1994. Contaminant Trends in Lake Roosevelt. Washington State Department of Ecology, Olympia, WA. Publication No. 94-185. www.ecy.wa.gov/biblio/94185.html

Serdar, D., 1998. DDT in Osoyoos Lake Fish. Washington State Department of Ecology, Olympia, WA. Publication No. 98-337. www.ecy.wa.gov/biblio/98337.html

Serdar, D. and D. Davis, 1999. Lake Whatcom Watershed Cooperative Drinking Water Protection Project: Results of 1998 Water, Sediment and Fish Tissue Sampling. Washington State Department of Ecology, Olympia, WA. Publication No. 99-337. www.ecy.wa.gov/biblio/99337.html

Serdar, D., 1999. PCB Concentrations in Fish from Ward Lake (Thurston County) and the Lower Elwha River. Washington State Department of Ecology, Olympia, WA. Publication No. 99-338. www.ecy.wa.gov/biblio/99338.html

Serdar, D., 2003. TMDL Technical Assessment of DDT and PCBs in the Lower Okanogan River Basin. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-013. www.ecy.wa.gov/biblio/0303013.html

U.S. Environmental Protection Agency – 3 studies

EPA, 1992. National Study of Chemical Residues in Fish – Volumes I and II. U.S. Environmental Protection Agency, Office of Science and Technology, Washington DC. EPA 823-R-92-008.

EPA, 2002a. Columbia River Basin Fish Contaminant Survey – 1996-1998. U.S. Environmental Protection Agency, Region 10, Seattle, WA. EPA 910/R-02-006.

EPA, 2002b. National Study of Chemical Residues in Fish Tissue. U.S. Environmental Protection Agency, Office of Water, Washington D.C. First and Second Year (1999-2001) Results: Preliminary Data Released to States. www.epa.gov/waterscience/fishstudy/overview.htm

Appendices

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Appendix A. Biological Data for Fish Samples

Table A1. Biological Information on Fish Samples from Vancouver Lake.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)	Total Weight (gm)	Fillet Weight (gm)	Age	Sex
4/17/2006	VLLSS1	194210	Lg Scale Sucker	534	1354	249	11	F
12/5/2005	VLLSS1	194210	Lg Scale Sucker	470	903	165	16	F
12/5/2005	VLLSS1	194210	Lg Scale Sucker	469	930	179	10	F
12/5/2005	VLLSS1	194210	Lg Scale Sucker	466	1014	175	13	F
12/5/2005	VLLSS1	194210	Lg Scale Sucker	466	1003	187	12	F
4/17/2006	VLLSS2	194209	Lg Scale Sucker	464	985	173	NA	M
12/5/2005	VLLSS2	194209	Lg Scale Sucker	463	855	147	NA	F
4/17/2006	VLLSS2	194209	Lg Scale Sucker	461	940	162	NA	F
12/5/2005	VLLSS2	194209	Lg Scale Sucker	457	859	155	NA	F
12/5/2005	VLLSS2	194209	Lg Scale Sucker	445	844	157	NA	F
12/5/2005	VLLSS3	194208	Lg Scale Sucker	434	756	150	NA	F
12/5/2005	VLLSS3	194208	Lg Scale Sucker	431	847	154	NA	M
12/5/2005	VLLSS3	194208	Lg Scale Sucker	415	796	154	NA	M
4/17/2006	VLLSS3	194208	Lg Scale Sucker	355	365	153	NA	F
4/17/2006	VLLSS3	194208	Lg Scale Sucker	327	320	131	NA	U
4/3/2006	VLCCP1	194217	Common Carp	636	3106	577	12	M
4/3/2006	VLCCP1	194217	Common Carp	632	2802	478	13	F
4/3/2006	VLCCP1	194217	Common Carp	632	3572	568	13	F
4/3/2006	VLCCP1	194217	Common Carp	622	3445	615	9	F
4/3/2006	VLCCP1	194217	Common Carp	603	3285	527	15	F
4/3/2006	VLCCP2	194215	Common Carp	505	1806	245	6	F
4/3/2006	VLCCP2	194215	Common Carp	496	1619	213	10	F
4/3/2006	VLCCP2	194215	Common Carp	493	1788	251	7	F
4/3/2006	VLCCP2	194215	Common Carp	492	1435	249	10	M
4/3/2006	VLCCP2	194215	Common Carp	480	1320	167	9	F
4/4/2006	VLCCP3	194216	Common Carp	292	440	81	4	M
4/4/2006	VLCCP3	194216	Common Carp	286	400	64	4	F
4/4/2006	VLCCP3	194216	Common Carp	245	290	105	4	F
4/4/2006	VLCCP3	194216	Common Carp	234	259	83	3	F
4/4/2006	VLCCP3	194216	Common Carp	227	240	94	3	M
4/4/2006	VLLMB1	194211	Lg Mouth Bass	513	2818	561	12	F
4/17/2006	VLLMB1	194211	Lg Mouth Bass	482	2410	493	11	F
4/4/2006	VLLMB1	194211	Lg Mouth Bass	453	1770	374	11	F
4/4/2006	VLLMB1	194211	Lg Mouth Bass	448	1820	382	6	F
4/4/2006	VLLMB1	194211	Lg Mouth Bass	445	2025	452	12	M

NA = Age data not available due to sample loss at laboratory.

Table A2. Biological Information on Fish Samples from Lake River.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)	Total Weight (gm)	Fillet Weight (gm)	Age	Sex
12/5/2005	LRLSS1	194207	Lg Scale Sucker	521	1431	295	9	F
12/5/2005	LRLSS1	194207	Lg Scale Sucker	521	1111	212	11	M
12/5/2005	LRLSS1	194207	Lg Scale Sucker	499	1269	259	11	F
12/5/2005	LRLSS1	194207	Lg Scale Sucker	491	1246	229	12	F
12/5/2005	LRLSS1	194207	Lg Scale Sucker	486	1040	188	10	F
12/5/2005	LRLSS2	194206	Lg Scale Sucker	477	838	170	NA	F
12/5/2005	LRLSS2	194206	Lg Scale Sucker	475	1003	196	NA	F
12/5/2005	LRLSS2	194206	Lg Scale Sucker	471	965	196	NA	F
12/5/2005	LRLSS2	194206	Lg Scale Sucker	463	1030	221	NA	F
12/5/2005	LRLSS2	194206	Lg Scale Sucker	460	841	149	NA	F
12/5/2005	LRLSS3	194205	Lg Scale Sucker	449	943	177	NA	F
12/5/2005	LRLSS3	194205	Lg Scale Sucker	429	780	150	NA	F
12/5/2005	LRLSS3	194205	Lg Scale Sucker	419	695	147	NA	F
12/5/2005	LRLSS3	194205	Lg Scale Sucker	397	578	137	NA	M
12/5/2005	LRLSS3	194205	Lg Scale Sucker	395	624	133	NA	F
4/4/2006	LRCCP1	194214	Common Carp	559	2211	425	7	M
4/4/2006	LRCCP1	194214	Common Carp	530	1962	273	10	F
4/4/2006	LRCCP1	194214	Common Carp	524	1832	196	7	F
4/4/2006	LRCCP1	194214	Common Carp	522	2236	306	8	F
4/4/2006	LRCCP1	194214	Common Carp	498	1640	255	10	M
4/4/2006	LRCCP2	194213	Common Carp	495	1814	238	6	F
4/4/2006	LRCCP2	194213	Common Carp	493	1854	245	10	F
4/4/2006	LRCCP2	194213	Common Carp	480	1823	222	7	F
4/4/2006	LRCCP2	194213	Common Carp	480	1392	249	6	M
4/4/2006	LRCCP2	194213	Common Carp	475	1410	264	5	M
4/4/2006	LRCCP3	194212	Common Carp	472	1252	198	9	M
4/4/2006	LRCCP3	194212	Common Carp	457	1152	199	5	M
4/4/2006	LRCCP3	194212	Common Carp	449	1289	205	5	M
4/4/2006	LRCCP3	194212	Common Carp	447	1198	201	5	M
4/4/2006	LRCCP3	194212	Common Carp	441	1213	227	5	M

NA = Age data not available due to sample loss at laboratory.

Table A3. Biological Data on Fish Tissue Composites from Vancouver Lake and Lake River.

Waterbody	Composite Sample No. (06-)	Species	Mean Length (mm±SD)	Mean Weight (gm±SD)	Mean Age (years)	Lipid (%)
Vancouver Lake	194208	Lg Scale Sucker	392±48	617±253	NA	1.52
Vancouver Lake	194209	Lg Scale Sucker	458±7.8	897±62.5	NA	1.38
Vancouver Lake	194210	Lg Scale Sucker	481±30	1041±181	12.4	2.08
Vancouver Lake	194211	Lg Mouth Bass	468±29	2169±442	10.4	2.17
Vancouver Lake	194215	Common Carp	493±9.0	1594±214	8.4	1.19
Vancouver Lake	194216	Common Carp	257±30	326±89	3.6	9.73
Vancouver Lake	194217	Common Carp	625±13	3242±302	12.4	3.23
Lake River	194205	Lg Scale Sucker	418±23	724±144	NA	2.23
Lake River	194206	Lg Scale Sucker	469±7.4	935±90	NA	1.04
Lake River	194207	Lg Scale Sucker	504±16	1219±152	10.6	1.37
Lake River	194212	Common Carp	453±12	1221±52	5.8	1.24
Lake River	194213	Common Carp	485±8.8	1659±236	6.8	2.31
Lake River	194214	Common Carp	527±22	1976±253	8.4	1.80

NA = Age data not available due to sample loss at laboratory.

Appendix B. Sediment Sample Site Locations

Table B1. Vancouver Lake and Lake River Sediment Sample Locations (NAD 83).

Location	Site ID	Latitude	Longitude	Description
Burnt Bridge Creek	BBC01	45.677006	-122.695115	Within the inlet area of Burnt Bridge Creek
Flushing Channel	FC02	45.668877	-122.741490	Just south of the flushing channel to the lake
Lake Center	CL03	45.682863	-122.717163	Just south of the lake center large island
Outlet Chanel	OC04	45.698441	-122.718228	Between the two small islands at the outlet
Lake River	LR05	45.732235	-122.745999	Just north of heron rookery on the left bank

See Figure 2 for station locations.

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Appendix C. Data Quality Summary, Reporting Limits, and Results for the Field and Laboratory Quality Assurance Sample Analysis

Data Quality Summary

The complete set of reporting limits, sample preparation, and analytical methods for this 2005-06 study can be found in Tables C1 and C2. Results for duplicate sample pairs and their associated relative percent differences (RPDs) for the study can be found in Table C3.

Fish Tissue

Manchester Environmental Laboratory conducted the PCB and pesticide analysis of fish tissue for the study. A contract laboratory, Pacific Rim Laboratories Inc., analyzed fish tissue for dioxin/furans. All tissue samples were analyzed within recommended holding times for the analytical method used.

Precision of fish tissue results was estimated by calculating the RPD of duplicate sample pairs. The complete set of RPDs for duplicate sample pair results is presented in Appendix C. Laboratory duplicates were prepared for samples 06194205, 06194212, 06194215, and 06194217. All four sets of duplicates had an average RPD of 25% or lower. All individual compounds had RPDs below the criteria established in the Quality Assurance Project Plan for the study (Coots, 2006). Overall, the precision of tissue analysis for PCBs and chlorinated pesticides was generally good, with an average RPD of 10.8%.

A few compounds were qualified due to continuing calibration verification (CCV) standards outside the recovery limits of 85% - 115%. Compounds not detected were qualified with “UJ”. The CCV recoveries for hexachlorobenzene at times fell outside control limits; therefore, all results for hexachlorobenzene were qualified as estimates: “J” when detected, or “UJ” if not detected.

No target compounds were detected in laboratory method blanks with the exception of endosulfan sulfate in method blank OB06136T2, and octachlorodibenzo-p-dioxin and octachlorodibenzofuran (OCDD/F) in sample DF06290B. Endosulfan sulfate was not detected in any samples so no results were qualified. OCDD/F appeared to be a spurious contamination because all study samples except one were reported as not detected for these compounds.

Surrogate recovery for dibutylchlorendate was generally low. The high lipid content was thought to have overwhelmed the chromatographic column, causing the low recoveries. Of the compounds affected by the low recoveries, only dieldrin in sample number 06194212 was detected and qualified as an estimated concentration, “J”. This result should be considered biased low.

Sample 06194211 had 0% recovery of dibutylchlorendate. It appeared the compounds were destroyed by acid treatment; therefore, all acid sensitive compound results were rejected and re-analyzed. In sample 06194216, the surrogate recoveries for tetrachloro-m-xylene, 4,4-dibromo-octafluorobiphenyl, and decachlorobiphenyl were above quality control (QC) limits. Results for this sample reported above detection limits were qualified as estimates, "J", and should be considered biased high. Sample 06194217 had low recoveries for decachlorobiphenyl. Results for this sample were qualified as estimates: "J" if detected and at estimated detection limits, "UJ" if not detected. These results should be considered biased low.

Matrix spike samples 06194210 and 06194216 were prepared in triplicate. The following compounds for sample 06194216 were recovered below acceptable limits: b-BHC, d-BHC, aldrin, heptachlor epoxide, endosulfan I, 4,4' DDE, dieldrin, 4,4' DDD, 4,4' DDT, cis-nonachlor, 2,4' DDE, 2,4' DDE, 2,4' DDT, endrin, endosulfan II, endrin aldehyde, endrin ketone, endosulfan sulfate, and methoxychlor. All sample results for 06194216 were qualified as estimates: "J" when detected or with estimated reporting limits, "UJ" when not detected. The results for this sample should be considered biased low.

A Standard Reference Material (SRM), National Institute of Standards & Technology (NIST) 1946, Lake Superior Fish Tissue, was analyzed with each batch of samples. Two SRM samples, OC06136T1 and OC06137T1, were prepared, extracted, and analyzed along with study samples. The extract for SRM OC06136T1 emulsified when treated with sulfuric acid due to high lipid content. The sample had to be diluted with iso-octane to create free solvent. Because of uncertainty with dilution corrections, results were not qualified due to recoveries of this SRM. The SRM OC06137T1 performed better, although the average recovery was 69%. This is below the recommended QC limit of 70%. A-BHC, heptachlor epoxide, a-chlordane, trans-nonachlor, Mirex, 4,4' DDD, and 2,4' DDT had recoveries below 70%. The recovery of dieldrin in both SRMs was very low. All project results for dieldrin were qualified as estimates: "J" if detected, or "UJ" if reported at the reporting limit. The low recovery of dieldrin was thought to be related to the lipid interference of the matrix.

The PCB Aroclor 1254 was the most prominent Aroclor found in the study samples. Aroclor 1260 was detected in most samples at lower concentrations. Aroclor 1254 obscured the 1260 results, and consequently all Aroclor 1260 results were qualified as estimates, "J", and should be considered biased high due to the interference from Aroclor 1254.

Sediment

Manchester Environmental Laboratory conducted the analysis of sediments for the study. All sediment samples were analyzed within recommended holding times for the analytical method used.

The PCB continuing calibration verification (CCV) standards for Aroclors 1016, 1254, and 1260 recovered above the 85% - 115% limits throughout the analysis. Because of this high recovery, the reported results for Aroclor 1254 were estimated, "J", and should be considered biased high. Several CCVs had reported recoveries below 85% for endrin ketone and methoxychlor. All study sample results for these two compounds were qualified as reported at an estimated reporting limit, "UJ".

There were no target compounds detected in any of the laboratory method blanks.

As a way to assess accuracy and bias from laboratory analysis, one pair of matrix spike samples was analyzed along with study samples. Two duplicates of sample 06054035 were spiked with 100 ng of chlorinated pesticides and 500 ng of toxaphene, Aroclor 1016 and Aroclor 1260. Alpha-BHC, aldrin, endrin aldehyde, and endosulfan sulfate had recoveries below the established QC limits in one or both matrix spike samples. Results for theses compounds were reported as an estimated reported limit, “UJ”. All RPDs for the matrix spike samples were within the QC limits established by the quality assurance plan directing the study (Coots, 2006) with the exceptions of endrin aldehyde and toxaphene. These two compounds were not detected in study samples.

A laboratory control sample was prepared by spiking analytically clean Ottawa sand with 100 ng of chlorinated pesticides and 500 ng of toxaphene, Aroclor 1016 and Aroclor 1260. This sample was processed and analyzed along with other study samples. All laboratory control sample recoveries were within established QC limits with the exception of alpha-BHC, aldrin, delta-BHC, endrin aldehyde, and endosulfan sulfate. These compounds were not detected in study samples, and results were qualified with estimated reporting limits, “UJ”.

All results for Aroclors detected in study samples were qualified as estimates, “J”, due to interference and the increasing sensitivity of the electron capture detectors (ECDs) to the heavy PCB congener compounds as the analysis progressed. All detected results for Aroclors should be considered biased high.

Table C1. Reporting Limits, Sample Preparation, and Analytical Methods for Fish Tissue Analysis Conducted for Vancouver Lake and Lake River Samples.

Analyte	Reporting Limits (*u*g/Kg, ww)	Sample Preparation Method	Analytical Method
PCB - 1016	4.7 - 9.6	EPA 3540/3620/3665	EPA 8082
PCB - 1221	4.7 - 9.6	"	"
PCB - 1232	4.7 - 9.6	"	"
PCB - 1242	4.7 - 9.6	"	"
PCB - 1248	4.8 - 38	"	"
PCB - 1254	4.4 - 4.8	"	"
PCB - 1260	4.7 - 77	"	"
PCB - 1262	4.8 - 19	"	"
PCB - 1268	4.7 - 5.0	"	"
alpha-BHC	0.47 - 0.50	EPA 3540/3620	EPA 8081
beta-BHC	0.47 - 0.50	"	"
gamma-BHC (Lindane)	0.47 - 0.50	"	"
delta-BHC	0.47 - 0.50	"	"
Heptachlor	0.47 - 0.50	"	"
Aldrin	0.47 - 0.50	"	"
Heptachlor Epoxide	0.48 - 0.94	"	"
trans-Chlordane	0.47 - 0.50	"	"
cis-Chlordane	0.47 - 0.50	"	"
Endosulfan I	0.48 - 0.94	"	"
Dieldrin	0.48 - 0.94	"	"
Endrin	0.48 - 0.94	"	"
Endrin Ketone	0.48 - 0.97	"	"
Endosulfan II	0.48 - 0.97	"	"
Endrin Aldehyde	0.48 - 0.97	"	"
Endosulfan Sulfate	0.48 - 1.5	"	"
4,4'-DDE	0.44 - 0.48	"	"
4,4'-DDD	0.44 - 0.48	"	"
4,4'-DDT	0.44 - 0.48	"	"
2,4'-DDE	0.47 - 3.8	"	"
2,4'-DDD	0.48 - 0.50	"	"
2,4'-DDT	0.47 - 0.50	"	"
Methoxychlor	0.48 - 1.9	"	"
Oxychlordane	0.47 - 0.52	"	"
cis-Nonachlor	0.77 - 6.2	"	"
Toxaphene	9.4 - 96	"	"
trans-Nonachlor	0.48 - 0.50	"	"
Mirex	0.47 - 0.50	"	"
Chlordane (Tech)	4.7 - 9.6	"	"
Hexachlorobenzene	0.47 - 0.50	"	"

Table C1 cont. Reporting Limits, Sample Preparation, and Analytical Methods for Fish Tissue Analysis Conducted for Vancouver Lake and Lake River Samples.

Analyte	Reporting Limits (ng/Kg, ww)	Sample Preparation and Analytical Method
Dioxins:		
2,3,7,8-TCDD	0.030	EPA 1613b
1,2,3,7,8-PeCDD	0.050	"
1,2,3,4,7,8-HxCDD	0.100	"
1,2,3,6,7,8-HxCDD	0.080	"
1,2,3,7,8,9-HxCDD	0.060	"
1,2,3,4,6,7,8-HpCDD	0.085	"
OCDD	0.230	"
Furans:		
2,3,7,8-TCDF	0.030	EPA 1613b
1,2,3,7,8-PeCDF	0.050	"
2,3,4,7,8-PeCDF	0.040	"
1,2,3,4,7,8-HxCDF	0.075	"
1,2,3,6,7,8-HxCDF	0.075	"
2,3,4,6,7,8-HxCDF	0.060	"
1,2,3,7,8,9-HxCDF	0.060	"
1,2,3,4,6,7,8-HpCDF	0.070	"
1,2,3,4,7,8,9-HpCDF	0.085	"
OCDF	0.200	"

Table C2. Reporting Limits, Sample Preparation, and Analytical Methods for Sediment Analysis Conducted for Vancouver Lake and Lake River Samples.

Analyte	Reporting Limits (*ug*/Kg, dw)	Sample Preparation Method	Analytical Method
PCB - 1016	3.9 - 6.6	EPA 3540/3620/3360b/3665	EPA 8082
PCB - 1221	3.9 - 6.6	"	"
PCB - 1232	3.9 - 6.6	"	"
PCB - 1242	3.9 - 6.6	"	"
PCB - 1248	3.9 - 13	"	"
PCB - 1254	3.9 - 4.5	"	"
PCB - 1260	3.9 - 4.5	"	"
PCB - 1262	3.9 - 4.5	"	"
PCB - 1268	3.9 - 4.5	"	"
alpha-BHC	0.79 - 1.3	"	EPA 8081
beta-BHC	0.79 - 1.3	"	"
gamma-BHC (Lindane)	0.79 - 1.3	"	"
delta-BHC	0.79 - 1.3	"	"
Heptachlor	0.79 - 1.3	"	"
Aldrin	0.79 - 1.3	"	"
Heptachlor Epoxide	0.79 - 1.3	"	"
trans-Chlordane	0.79 - 1.3	"	"
cis-Chlordane	0.79 - 1.3	"	"
Endosulfan I	0.79 - 1.3	"	"
Dieldrin	0.79 - 1.3	"	"
Endrin	0.79 - 1.3	"	"
Endrin Ketone	0.79 - 1.3	"	"
Endosulfan II	0.79 - 1.3	"	"
Endrin Aldehyde	0.79 - 1.3	"	"
Endosulfan Sulfate	0.79 - 1.3	"	"
4,4'-DDE	0.79 - 0.91	"	"
4,4'-DDD	0.79 - 0.91	"	"
4,4'-DDT	0.79 - 1.3	"	"
Methoxychlor	0.79 - 1.3	"	"
Toxaphene	7.9 - 13	"	"
Chlordane (Tech)	3.9 - 6.6	"	"

Table C3. Precision Estimates for Laboratory Quality Assurance Samples.

Sample ID		Matrix	Analysis	QA Type	Results		RPD[1]
No. 1	No. 2				No. 1	No. 2	
06194205	06194205	Tissue (ng/Kg,ww)	4,4'-DDE	lab dup.	18	15	18.2
06194205	06194205	Tissue (ng/Kg,ww)	4,4'-DDD	lab dup.	3.4	3.2	6.1
06194205	06194205	Tissue (ng/Kg,ww)	4,4'-DDT	lab dup.	1.4	1.3	7.4
06194205	06194205	Tissue (ng/Kg,ww)	2,4'-DDD	lab dup.	0.56	0.57	1.8
06194205	06194205	Tissue (ng/Kg,ww)	Trans-Nonachlor	lab dup.	0.60	0.53	12.4
06194205	06194205	Tissue (ng/Kg,ww)	PCB-1254	lab dup.	20	22	9.5
06194205	06194205	Tissue (ng/Kg,ww)	PCB-1260	lab dup.	15	14	6.9
06194211	06194211	Tissue (ng/Kg,ww)	Dieldrin	lab dup.	1.3	0.85	41.9
06194211	06194211	Tissue (ng/Kg,ww)	4,4'-DDE	lab dup.	35	32	9.0
06194211	06194211	Tissue (ng/Kg,ww)	4,4'-DDD	lab dup.	5.1	5.4	5.7
06194211	06194211	Tissue (ng/Kg,ww)	4,4'-DDT	lab dup.	2.7	2.5	7.7
06194211	06194211	Tissue (ng/Kg,ww)	2,4'-DDD	lab dup.	0.85	0.65	26.7
06194211	06194211	Tissue (ng/Kg,ww)	Toxaphene	lab dup.	28	28	0.0
06194211	06194211	Tissue (ng/Kg,ww)	Trans-Nonachlor	lab dup.	2.3	2.2	4.4
06194211	06194211	Tissue (ng/Kg,ww)	PCB-1254	lab dup.	56	50	11.3
06194211	06194211	Tissue (ng/Kg,ww)	PCB-1260	lab dup.	23	22	4.4
06194212	06194212	Tissue (ng/Kg,ww)	Dieldrin	lab dup.	1.0	0.51	64.9
06194212	06194212	Tissue (ng/Kg,ww)	4,4'-DDE	lab dup.	28	27	3.6
06194212	06194212	Tissue (ng/Kg,ww)	4,4'-DDD	lab dup.	6.2	5.5	12.0
06194212	06194212	Tissue (ng/Kg,ww)	4,4'-DDT	lab dup.	2.3	2.4	4.3
06194212	06194212	Tissue (ng/Kg,ww)	2,4'-DDD	lab dup.	0.99	1.2	19.2
06194212	06194212	Tissue (ng/Kg,ww)	Trans-Nonachlor	lab dup.	1.2	1.4	15.4
06194212	06194212	Tissue (ng/Kg,ww)	PCB-1254	lab dup.	35	34	2.9
06194212	06194212	Tissue (ng/Kg,ww)	PCB-1260	lab dup.	23	23	0
06194215	06194215	Tissue (ng/Kg,ww)	4,4'-DDE	lab dup.	27	26	3.8
06194215	06194215	Tissue (ng/Kg,ww)	4,4'-DDD	lab dup.	1.4	1.4	0
06194215	06194215	Tissue (ng/Kg,ww)	4,4'-DDT	lab dup.	1.1	1.1	0
06194215	06194215	Tissue (ng/Kg,ww)	2,4'-DDD	lab dup.	0.50	0.54	7.7
06194215	06194215	Tissue (ng/Kg,ww)	Trans-Nonachlor	lab dup.	1.1	1.0	9.5
06194215	06194215	Tissue (ng/Kg,ww)	PCB-1254	lab dup.	25	24	4.1
06194215	06194215	Tissue (ng/Kg,ww)	PCB-1260	lab dup.	26	25	3.9

Table C3 cont. Precision Estimates for Field and Laboratory Quality Assurance Samples.

Sample ID No. 1	Sample ID No. 2	Matrix	Analysis	QA Type	Results No. 1	Results No. 2	RPD[1]
06194217	06194217	Tissue (ng/Kg,ww)	Trans-Chlordane	lab dup.	1.4	1.5	6.9
06194217	06194217	Tissue (ng/Kg,ww)	Cis-Chlordane	lab dup.	2.5	2.5	0
06194217	06194217	Tissue (ng/Kg,ww)	4,4'-DDE	lab dup.	100	91	9.4
06194217	06194217	Tissue (ng/Kg,ww)	4,4'-DDD	lab dup.	22	22	0
06194217	06194217	Tissue (ng/Kg,ww)	4,4'-DDT	lab dup.	3.2	3.3	3.1
06194217	06194217	Tissue (ng/Kg,ww)	2,4'-DDD	lab dup.	3.2	4.4	31.6
06194217	06194217	Tissue (ng/Kg,ww)	Trans-Nonachlor	lab dup.	3.7	4.1	10.3
06194217	06194217	Tissue (ng/Kg,ww)	Hexachlorobenzene	lab dup.	1.3	1.4	7.4
06194217	06194217	Tissue (ng/Kg,ww)	PCB-1254	lab dup.	190	180	5.4
06194206	06194206	Tissue (ng/Kg,ww)	2,3,7,8-TCDF	lab dup.	0.104	0.136	26.7
06194206	06194206	Tissue (ng/Kg,ww)	2,3,7,8-TCDD	lab dup.	0.099	0.129	26.3
06194206	06194206	Tissue (ng/Kg,ww)	1,2,3,7,8-PeCDD	lab dup.	0.301	0.336	11.0
06194205	06194205	Tissue (%)	Lipids	lab dup.	2.39	2.07	14.3
06194212	06194212	Tissue (%)	Lipids	lab dup.	1.42	1.06	29.0
06194215	06194215	Tissue (%)	Lipids	lab dup.	1.10	1.28	15.1
06194217	06194217	Tissue (%)	Lipids	lab dup.	3.41	3.05	11.1
06054035	06054035	Sediment (ng/Kg, dw)	TOC	lab dup.	1.03	1.06	2.9
06054035	06054033	Sediment (ng/Kg, dw)	TOC	field rep.	0.95	0.91	4.3
06054033	06054035	Sediment (ng/Kg, dw)	PCB 1248	field rep.	4.9	5.1	4.0

[1] = relative percent difference (the difference, divided by the mean, times 100).
Lab dup = laboratory duplicate sample.
Field rep = field replicate sample.

Appendix D. Background Information on Vancouver Lake and Lake River Detected Compounds

Chlordane - A contact insecticide introduced in 1945 for agricultural crops, and lawns and gardens. It has also been used in control of termites, cockroaches, ants, and other household pests. Chlordane was banned in 1983 except for termite control, and then completely cancelled in the United States in 1988 (ATSDR, 1994).

DDT - Discovered in 1939 as an insecticide, DDT was initially used extensively during World War II to control mosquitoes from spreading malaria and typhus. In agriculture, DDT was historically used on a variety of crops for the control of insects before being banned in 1972. DDE and DDD are metabolites or breakdown products of DDT and are also toxic.

Dieldrin - Developed in 1945, dieldrin was mainly used for the control of soil insects for crops like corn and cotton. In 1970 the U.S. Department of Agriculture cancelled all uses of dieldrin due to concerns about severe damage to aquatic ecosystems and their potential carcinogenic properties. In 1972 the EPA lifted the cancellation for use in termite control. In 1987 dieldrin was banned for all uses (ATSDR, 2002a). The insecticide aldrin has similar chemical structure and commercial uses, and rapidly breaks down to dieldrin in plants and animals when exposed to sunlight or bacteria.

Dioxins and Furans - Formed as an unintended byproduct of incomplete combustion or industrial processes, dioxins and furans are ubiquitous in the environment, resistant to metabolism, and have a high affinity to lipids. Of the 210 individual dioxin and furan compounds, 17 (7 dioxins and 10 furans) are considered toxic. Toxicity of the different dioxin and furan compounds range over orders of magnitude.

Hexachlorobenzene - From the early 1900s, the major use of hexachlorobenzene has been as an agricultural fungicide. It has had particular use as a seed dressing to prevent fungal diseases of onions, grain, and other field crops. Use of hexachlorobenzene as a fungicide was discontinued with reductions beginning in the 1970s and voluntarily cancelled in 1984. Hexachlorobenzene also has industrial uses as a chemical intermediate, but represented only a relatively small proportion of the total production (ATSDR, 2002b).

PCBs – PCBs are a mixture of compounds widely used in industrial applications as insulating fluids, plasticizers, in inks and carbonless paper, as heat transfer and hydraulic fluids, and a variety of other uses. There are 209 different PCB congeners. Some PCBs have similar structure and properties of dioxins and furans and are referred to as dioxin-like compounds. PCBs were developed and sold as mixtures under the trade name Aroclors. The EPA started restrictions on the manufacture of PCBs in 1977 and by 1985 phased out use of PCBs through regulation.

Toxaphene - Introduced in 1949, toxaphene became the most heavily used chlorinated pesticide in the United States until it was cancelled for most uses in 1982. All uses of toxaphene were banned in 1990. Toxaphene was used to control many insects on cotton, corn, fruit, vegetables, and small grains. In addition, toxaphene was used to control livestock parasites such as lice, flies, and ticks (ATSDR, 1997).

Appendix E. PCBs, Chlorinated Pesticides, Dioxin, and Ancillary Results

Table E1. PCBs and Chlorinated Pesticides in Largescale Sucker and Common Carp Fillet from Vancouver Lake (*u*g/Kg, wet weight). Composite samples of five fish each.

	Largescale Sucker						Common Carp					
Sample Identification (06):	194210		194209		194208		194217		194215		194216	
PCB – 1016	4.8	U	4.8	U	5.0	U	9.6	UJ	4.7	U	4.9	U
PCB – 1221	4.8	U	4.8	U	5.0	U	9.6	UJ	4.7	U	4.9	U
PCB – 1232	4.8	U	4.8	U	5.0	U	9.6	UJ	4.7	U	4.9	U
PCB – 1242	4.8	U	4.8	U	5.0	U	9.6	UJ	4.7	U	4.9	U
PCB – 1248	9.6	U	4.8	U	9.9	UJ	38	UJ	9.4	UJ	15	UJ
PCB – 1254	**29**	**J**	**18**	**J**	**33**	**J**	**185**	**J**	**25**	**J**	**62**	**J**
PCB – 1260	**16**	**J**	**10**	**J**	**21**	**J**	77	UJ	**26**	**J**	**20**	**J**
PCB – 1262	4.8	U	4.8	U	5.0	U	19	UJ	9.4	UJ	9.9	UJ
PCB – 1268	4.8	U	4.8	U	5.0	U	4.8	UJ	4.7	U	4.9	U
alpha-BHC	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	U
beta-BHC	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	UJ
gamma-BHC (Lindane)	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	U
delta-BHC	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	UJ
Heptachlor	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	U
Aldrin	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	UJ
Heptachlor Epoxide	0.48	UJ	0.48	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
trans-Chlordane	0.48	U	0.48	U	0.50	U	**1.5**	**J**	0.47	U	**0.71**	**J**
cis-Chlordane	0.48	U	0.48	U	0.50	U	**2.5**	**J**	0.47	U	**1.3**	**J**
Endosulfan I	0.48	UJ	0.48	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Dieldrin	0.48	UJ	0.48	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Endrin	0.48	UJ	0.48	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Endrin Ketone	0.48	UJ	0.97	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Endosulfan II	0.48	UJ	0.97	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Endrin Aldehyde	0.48	UJ	0.97	UJ	0.50	UJ	0.48	UJ	0.94	UJ	0.49	UJ
Endosulfan Sulfate	0.48	UJ	1.5	UJ	0.50	UJ	0.96	UJ	0.94	UJ	0.99	UJ
4,4'-DDE	**24**		**10**		**23**		**96**	**J**	**27**		**37**	**J**
4,4'-DDD	**3.8**		**1.4**		**3.5**		**22**	**J**	**1.4**		**7.0**	**J**
4,4'-DDT	**1.4**	**J**	0.48	U	**1.7**	**J**	**3.3**	**J**	**1.1**	**J**	**1.4**	**J**
2,4'-DDE	0.48	U	0.48	U	0.50	U	3.8	UJ	0.47	U	0.49	UJ
2,4'-DDD	**0.55**		0.48	U	0.50	U	**3.8**	**J**	**0.52**		**1.4**	**J**
2,4'-DDT	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	UJ
Methoxychlor	0.48	UJ	1.9	UJ	0.50	UJ	1.2	UJ	0.94	UJ	0.99	UJ
Oxychlordane	0.48	U	0.48	U	0.50	U	0.52	UJ	0.47	U	0.49	U
cis-Nonachlor	1.2	UJ	0.77	UJ	1.4	UJ	6.2	UJ	1.4	UJ	1.7	UJ
Toxaphene	9.6	UJ	9.7	UJ	9.9	UJ	96	UJ	9.4	UJ	9.9	UJ
trans-Nonachlor	**0.58**		0.48	U	0.50	U	**3.9**	**J**	**1.1**		**2.2**	**J**
Mirex	0.48	U	0.48	U	0.50	U	0.48	UJ	0.47	U	0.49	U
Chlordane (Tech)	4.8	U	4.8	U	5.0	U	9.6	UJ	4.7	U	4.9	U
Hexachlorobenzene	0.48	UJ	0.48	UJ	0.50	UJ	**1.4**	**J**	0.47	UJ	**1.3**	**J**

U = Not detected at the value shown.
UJ = Not detected above the estimated detection limit.
Bolded = Visual aid for detected compounds.
J = Analyte positively identified; result is an estimate.

Table E1 cont. PCBs and Chlorinated Pesticides in Largemouth Bass Fillet from Vancouver Lake (*u*g/Kg, wet weight). Composite sample of five fish each.

	Largemouth Bass	
Sample Identification (06):	194211	
PCB – 1016	4.7	UJ
PCB – 1221	9.4	UJ
PCB – 1232	9.4	UJ
PCB – 1242	**8.0**	
PCB – 1248	9.4	UJ
PCB – 1254	**53**	
PCB – 1260	**22**	**J**
PCB – 1262	9.4	UJ
PCB – 1268	9.4	UJ
alpha-BHC	0.47	U
beta-BHC	0.47	U
gamma-BHC (Lindane)	0.47	U
delta-BHC	0.47	UJ
Heptachlor	0.47	U
Aldrin	0.47	U
Heptachlor Epoxide	0.47	UJ
trans-Chlordane	0.47	U
cis-Chlordane	0.47	U
Endosulfan I	0.47	UJ
Dieldrin	**1.1**	**J**
Endrin	0.47	UJ
Endrin Ketone	0.47	UJ
Endosulfan II	0.47	UJ
Endrin Aldehyde	0.47	UJ
Endosulfan Sulfate	0.47	UJ
4,4’-DDE	**34**	
4,4’-DDD	**5.2**	
4,4’-DDT	**2.6**	**J**
2,4’-DDE	0.47	U
2,4’-DDD	**0.75**	
2,4'-DDT	0.47	U
Methoxychlor	0.47	UJ
Oxychlordane	**0.47**	
cis-Nonachlor	4.5	UJ
Toxaphene	**28**	**J**
trans-Nonachlor	**2.3**	
Mirex	0.47	U
Chlordane (Tech)	10	UJ
Hexachlorobenzene	0.47	U

U = Not detected at the value shown.
UJ = Not detected above the estimated detection limit.
Bolded = Visual aid for detected compounds.
J = Analyte positively identified; result is an estimate.

Table E2. PCBs and Chlorinated Pesticides in Largescale Sucker and Common Carp Fillets from the Lake River (*u*g/Kg, wet weight). Composite sample of five fish each.

	Largescale Sucker						Common Carp					
Sample Identification (06):	194207		194206		194205		194214		194213		194212	
PCB - 1016	4.8	U	5.0	U	4.9	U	4.8	U	4.4	U	4.8	U
PCB - 1221	4.8	U	5.0	U	4.9	U	4.8	U	4.4	U	4.8	U
PCB - 1232	4.8	U	5.0	U	4.9	U	4.8	U	4.4	U	4.8	U
PCB - 1242	4.8	U	5.0	U	4.9	U	4.8	U	4.4	U	4.8	U
PCB - 1248	9.7	UJ	10	UJ	9.8	UJ	9.7	UJ	8.9	UJ	9.6	UJ
PCB - 1254	**18**	**J**	**19**	**J**	**21**	**J**	**51**	**J**	**34**	**J**	**34**	
PCB - 1260	**13**	**J**	**14**	**J**	**14**	**J**	**30**	**J**	**24**	**J**	**23**	**J**
PCB - 1262	4.8	U	5.0	U	4.9	U	9.7	UJ	8.9	UJ	9.6	UJ
PCB - 1268	4.8	U	5.0	U	4.9	U	4.8	U	4.4	U	4.8	U
alpha-BHC	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
beta-BHC	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
gamma-BHC (Lindane)	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
delta-BHC	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
Heptachlor	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
Aldrin	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
Heptachlor Epoxide	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
trans-Chlordane	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
cis-Chlordane	0.48	U	0.50	U	0.49	U	0.48	U	**0.69**	**J**	0.48	U
Endosulfan I	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Dieldrin	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	**0.76**	**J**
Endrin	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Endrin Ketone	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Endosulfan II	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Endrin Aldehyde	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Endosulfan Sulfate	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
4,4'-DDE	**17**		**17**		**16**		**34**		**34**		**27**	
4,4'-DDD	**1.8**		**2.4**		**3.3**		**2.2**		**5.7**		**5.8**	
4,4'-DDT	0.48	U	0.50	U	**1.4**	**J**	**1.9**	**J**	**1.3**	**J**	**2.3**	**J**
2,4'-DDE	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
2,4'-DDD	0.48	U	0.50	U	**0.56**		**0.59**		**0.92**		**1.0**	
2,4'-DDT	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
Methoxychlor	0.48	UJ	0.50	UJ	0.49	UJ	0.97	UJ	0.89	UJ	0.96	UJ
Oxychlordane	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
cis-Nonachlor	0.97	UJ	1.0	UJ	1.0	UJ	1.9	UJ	1.6	UJ	1.5	UJ
Toxaphene	19	UJ	20	UJ	20	UJ	9.7	UJ	18	UJ	19	UJ
trans-Nonachlor	0.48	U	0.50	U	**0.56**	**J**	**1.1**		**1.1**		**1.3**	
Mirex	0.48	U	0.50	U	0.49	U	0.48	U	0.44	U	0.48	U
Chlordane (Tech)	4.8	U	10	U	4.9	U	4.8	U	4.4	U	4.8	U
Hexachlorobenzene	0.48	UJ	0.50	UJ	**0.51**	**J**	0.48	UJ	0.44	UJ	0.48	UJ

U = Not detected at the value shown.
J = Analyte positively identified; result is an estimate.
UJ = Not detected above the estimated detection limit.
Bolded = Visual aid for detected compounds.

Table E3. Dioxins and Furans in Largescale Sucker and Common Carp Fillets from Vancouver Lake and the Lake River (*u*g/Kg, wet weight). Composite samples of five fish each.

		Vancouver Lake				Lake River			
ID Number (06):		194209		194215		194206[2]		194213	
Fish Species:		Largescale Sucker		Common Carp		Largescale Sucker		Common Carp	
Feeding Habit:		Bottom		Bottom		Bottom		Bottom	
% Lipids:		2.2 %		1.1%		1.7 %		2.0 %	
	TEF[1]								
2,3,7,8-TCDD	1	**0.103**		**0.069**		**0.114**		**0.181**	
1,2,3,7,8-PeCDD	1	**0.089**		0.050	UJ	**0.318**		**0.508**	
1,2,3,4,7,8-HxCDD	0.1	0.100	UJ	0.100	UJ	0.100	UJ	0.100	UJ
1,2,3,6,7,8-HxCDD	0.1	0.080	UJ	0.080	UJ	0.080	UJ	**0.364**	
1,2,3,7,8,9-HxCDD	0.1	0.060	UJ	0.060	UJ	0.060	UJ	0.060	UJ
1,2,3,4,6,7,8-HpCDD	0.01	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ
OCDD	0.0001	0.230	UJ	0.230	UJ	0.230	UJ	0.479	UJ
2,3,7,8-TCDF	0.1	**0.102**		**0.101**		**0.120**		**0.274**	
1,2,3,7,8-PeCDF	0.05	0.050	UJ	0.050	UJ	0.050	UJ	0.050	UJ
2,3,4,7,8-PeCDF	0.5	0.040	UJ	0.040	UJ	0.040	UJ	0.040	UJ
1,2,3,4,7,8-HxCDF	0.1	0.075	UJ	0.075	UJ	0.075	UJ	0.075	UJ
1,2,3,6,7,8-HxCDF	0.1	0.075	UJ	0.075	UJ	0.075	UJ	0.075	UJ
2,3,4,6,7,8-HxCDF	0.1	0.060	UJ	0.060	UJ	0.060	UJ	0.060	UJ
1,2,3,7,8,9-HxCDF	0.1	0.060	UJ	0.060	UJ	0.060	UJ	0.060	UJ
1,2,3,4,6,7,8-HpCDF	0.01	0.070	UJ	0.070	UJ	0.070	UJ	0.070	UJ
1,2,3,4,7,8,9-HpCDF	0.01	0.085	UJ	0.085	UJ	0.085	UJ	0.085	UJ
OCDF	0.0001	0.200	UJ	0.200	UJ	0.200	UJ	0.200	UJ
TEQ[3]		**0.20**		**0.079**		**0.44**		**0.75**	
% 2,3,7,8-TCDD		52 %		87%		26 %		24 %	
% PCDDs		95 %		87%		97 %		96 %	
% PCDFs		5 %		13%		3 %		4 %	

[1] = Toxic Equivalent Factor – WHO, 1997.
[2] = Mean of duplicate (split) sample.
[3] = Toxic Equivalent Quotient.
UJ = Not detected at the estimated detection limit shown.

Table E4. PCBs and Chlorinated Pesticides in Surface Sediments from Vancouver Lake and the Lake River, February 1, 2006 (*u*g/Kg, dry weight).

	Burnt Bridge Creek (BBC01)	Flushing Channel (FC02)	Center Lake (CL03)	Outlet Channel (OC04)[1]	Lake River (LR05)
Sample No. (06-):	054030	054031	054032	054033/5	054034
TOC 70°C (%)	2.01	0.36	0.68	0.95/0.91	1.04
Fines (%)	76.7	33.5	62.5	24.1/24.8	47.4
PCB - 1016	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1221	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1232	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1242	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1248	13 UJ	3.9 U	4.3 U	**4.9 J / 5.1 J**	4.5 U
PCB - 1254	**14 J**	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1260	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1262	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
PCB - 1268	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U
alpha-BHC	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
beta-BHC	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
gamma-BHC (Lindane)	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
delta-BHC	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
Heptachlor	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Aldrin	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
Heptachlor Epoxide	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
trans-Chlordane	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
cis-Chlordane	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Endosulfan I	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Dieldrin	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Endrin	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Endrin Ketone	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
Endosulfan II	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Endrin Aldehyde	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
Endosulfan Sulfate	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
4,4'-DDE	**3.3**	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
4,4'-DDD	**1.6**	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
4,4'-DDT	1.3 U	0.79 U	0.85 U	0.88 U/0.89 U	0.91 U
Methoxychlor	1.3 UJ	0.79 UJ	0.85 UJ	0.88 UJ/0.89 UJ	0.91 UJ
Toxaphene	13 U	7.9 U	8.5 U	8.8 U/8.9 U	9.1 U
Chlordane (technical)	6.6 U	3.9 U	4.3 U	4.4 U/4.5 U	4.5 U

1 = Replicate sample.
U = Not detected at the value shown.
UJ = Not detected above the estimated detection limit.
Bolded = Visual aid for detected compounds.
J = Analyte positively identified; result is an estimate.

Table E5. Grain Size Distribution for Surface Sediments (percent retained in each size fraction).

Site ID[1] / Lab No. (06-)		Gravel	Very Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	Very Fine Sand	Coarse Silt	Medium Silt	Fine Silt	Very Fine Silt	Clay			**Percent Fines[2]**
	Phi Size:	> -1	-1 to 0	0 to 1	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7	7 to 8	8 to 9	9 to 10	< 10	
	Sieve Size: (microns):	> #10 (2000)	10 to 18 (2000-1000)	18-35 (1000-500)	35-60 (500-250)	60-120 (250-125)	120-230 (125-62)	62.5-31.0	31.0-15.6	15.6-7.8	7.8-3.9	3.9-2.0	2.0-1.0	<1.0	
BBC01 / 054030		0.1	0.0	0.6	2.0	6.5	13.9	41.3	20.4	7.8	2.9	1.3	0.8	2.2	76.7
FC02 / 054031		0.0	0.0	0.1	1.0	13.6	51.7	17.5	5.9	3.5	2.2	1.2	1.0	2.2	33.5
CL03 / 054032		0.0	0.0	0.3	0.9	6.2	30.0	33.8	13.4	6.8	3.1	0.3	0.3	4.8	62.5
OC04[3] / 054033/5		0.0/0.1	0.3/0.0	0.7/0.6	3.6/3.5	38.0/37.2	33.2/33.6	8.6/9.2	4.3/4.3	2.8/2.6	2.4/2.6	2.0/1.8	1.1/1.2	2.9/3.1	24.1/24.8
LR05 / 054034		0.2	0.5	1.3	3.9	4.1	42.5	30.4	7.3	2.2	2.1	1.7	0.6	3.1	47.4

[1] = Refer to Figure 2 for site locations.
[2] = Fines are defined as the total of silts and clays.
[3] = Results represent a field replicate pair.