Contaminant Exposure Risk to Developing Cultus Lake Sockeye Embryos: Part I. Metals, pesticides and polycyclic aromatic hydrocarbons

Summary report *Prepared for:*

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ABSTRACT

Anadromous Pacific sockeye salmon (*Oncorhynchus nerka*) are an important fish species of Canada's west coast. Cultus Lake sockeye have recently been designated as an endangered species by COSEWIC. This study reports on concentrations of several environmental contaminants of concern in water and sediments collected from spawning habitat in Cultus Lake of this endangered sockeye population. The results show concentrations of polycyclic aromatic hydrocarbons (PAHs), pesticides, pharmaceuticals and personal care products (PPCPs) and metals in water and sediments from Cultus Lake and a nearby reference site (Chilliwack Lake) were comparable to, or in some cases lower than, concentrations of these contaminants in other British Columbia freshwater environments. In a number of samples, concentrations of three metals (Fe, Mn, Zn) and two PAHs (acenaphthene, fluorene) slightly exceeded sediment quality guidelines (SQGs) used by the British Columbia Ministry of Environment (BC-MOE).. Concentrations of several other metals (Hg, Al, Ba, Pb) and several PAHs (naphthalene, phenanthrene, pyrene and 2-Methylnaphthalene), which were slightly below SQGs,, exhibited 95 % confidence limits that exceeded corresponding guidelines. However,, those concentrations did not exceed probable effects levels (PEL) for those compounds.. One exception was iron (Fe), where ambient concentrations in Cultus/Chilliwack Lake sediments (range: 23,000-52,900 μg/g dry wt.) and upper 95% CL (91,700 μg/g dry wt.) exceeded the severe effects level established for this metal (43,766 μg/g dry wt.). The consequences of these ambient Fe levels on developing Cultus Lake sockeye embryos is not clear from results of the present study. Further investigation into the toxicological effects of Fe and other contaminants on developing Pacific sockeye embryos is warranted and could include laboratory-based assays using field collected spawning substrate. An Addendum report will be submitted to PSC when final results (slightly delayed by the analytical laboratory) become available for persistent compounds; these include PCBs, PBDEs and PCDDs/Fs.

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1. Introduction

Anadromous Pacific sockeye salmon (*Oncorhynchus nerka*) are important components of both marine and freshwater ecosystems on Canada's west coast. British Columbia's Fraser River, flowing over 1,400 km through agricultural, industrial and urbanized lands, is a major migration route and spawning grounds for several Pacific sockeye stocks. After hatching, juvenile sockeye tend to remain in fresh water for 1 to 2 years before a 2-3 year open-ocean feeding migration. During spring/summer adults return to their natal streams to spawn. This upstream migration can span several hundred kilometers (Groot and Margolis, 1991; Ewald et al., 1998). For example, Cultus Lake sockeye travel approximately 112 km upstream from the Strait of Georgia (SoG) to their spawning grounds (Cultus Lake).

In recent years there have been concerns regarding the health of several Fraser River sockeye stocks. For example, the Cultus Lake sockeye is designated as endangered by COSEWIC. Also, Weaver Creek sockeye (a late-run timing group) returning to the Fraser River have exhibited abnormal migration behaviour, elevated in-river mortality and reduced spawning success (Pacific Salmon Commission, 2001).

The Cultus Lake sockeye recovery plan identifies contaminant exposure of Cultus Lake sockeye in the freshwater environment (Cultus Lake) as one potential threat to population recovery. Contaminants that represent an exposure risk to this population include mercury (Hg) and other trace metals, polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzo furans (PCDFs) and polybrominated diphenyl ethers (PBDE's) and pharmaceuticals & personal care products (PPCPs).

Potential sources of PAHs include combustion, petroleum spills, industrial and waste-water effluents, urban runoff. In particular, heavy boating activity on Cultus Lake may be an important source of PAHs to this freshwater system. Other organic contaminants such as pesticides, PCB's, PCDD/Fs, PBDE flame retardants and PPCPs may be deposited atmospherically through long range transport and/or discharged via septic fields, wastewater or runoff. Hg and other, trace elements in the environment can originate from both anthropogenic sources such as mining and combustion of fossil fuels as well as natural sources such as bedrock, volcanoes, forest fires (Nriagu, 1988). Elements are generally classified as being non-essential (e.g., Pb, Hg, Cd, Ni, As) or essential/beneficial (Mg, Mn, Cu, Zn, Se, Co). Potential toxic effects of these various environmental contaminants in fish include impacts on olfactory function and migration behaviour (Moore and Waring, 1996) and reproductive success (Guiney et al., 1979; Zitko and Saunders, 1979; Niimi, 1983; Walker and Peterson, 1991; Miller, 1993; Giesy et al., 2002).

This study investigates the occurrence, levels and toxicological implications of key environmental contaminants in water and sediments from Cultus Lake sockeye spawning grounds. These environmental compartments represent the two primary exposure routes for developing Cultus Lake Sockeye embryos and alevins. Contaminants investigated include mercury (Hg) and other trace elements, PAH's, PCDD/Fs, PCBs, PBDEs, PPCPs, and several legacy pesticides (e.g. DDTs, chlordane and mirex) as well as current use pesticides (CUPs) such as atrazine and chlorpyriphos.

2. Study Objectives

Cultus Lake sockeye are currently designated as endangered by the Committee on the Status of Endangered Wildlife (COSEWIC) in Canada. The COSEWIC status report for Cultus sockeye salmon identified degradation of the groundwater water quality from human sources as a potential threat to recovery. In the Draft Recovery Plan for Cultus Lake sockeye salmon, pollution is identified as an unknown threat to the egg and alevin stages. The primary objectives of the study are to:

- determine concentrations of several key environmental contaminants of concern at known spawning locations of Cultus Lake sockeye.

- assess potential contaminant related biological impacts on Cultus Lake sockeye eggs and alevins.

2.1. Investigative Team members

This project was funded by Southern Boundary Restoration & Enhancement Fund of the Pacific Salmon Commission, grant SF-2007-H-18. Investigative team members were:

Christine Tovey – Project Support Biologist, DFO - Cultus Lake Lab.
Mike Bradford – Research Scientist, quantitative ecologist, DFO - SFU.
Jeremy Hume – Research Biologist, DFO - Cultus Lake Lab.
Peter S. Ross – Research Scientist, ecotoxicologist, DFO - IOS.
Lyse Godbout – Research Biologist, DFO PBS.
Jules Blais – Associate Professor, University of Ottawa.
Sue Grant – Assessment Biologist, DFO - Fraser River / BC Interior Area.
Neil Dangerfield – Technician, Marine Environment Quality, DFO - IOS
Cathy McPherson – Golder Associates Ltd. - Laboratory Manager – Field collection, water properties and sample shipment.
Kalai Pillay – Axys Analytical - Lab manager, Current Use Pesticides, pharmaceuticals, PAH analyses.
Brooks Rand – Contract Lab, Seattle, Washington – metals analyses.

3. Methods

3.1. Sampling

Samples were collected by Golder Associates Ltd. on November 7 to 9, 2007. Water temperature, pH, turbidity and dissolved oxygen were measured on site. Water samples were collected from two locations near the main spawning grounds on Cultus and Chilliwack Lake from the water column. Sediment samples were collected from four spawning locations on Cultus Lake (Lindell Beach A and B, Spring Bay, Mallard Bay/Army Camp) and from the two spawning areas on Chilliwack Lake (Chilliwack 1 and 2). Maps of sampling locations on Cultus and Chilliwack Lakes are shown in Appendix I and II, respectively. Each sediment sample was a composite of three ponar grabs of the upper surface layer (5-10 cm). Sediment samples were homogenized, stored in appropriate laboratory containers and subsequently shipped for processing and analysis.

3.2. Contaminant Analysis

Water and sediment samples were analyzed for concentrations of mercury (Hg) and 22 other trace elements (Ag, Al, As, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Sb, Se, Ti, V, Zn) at Brooks-Rand laboratories, Seattle, WA. Chemical analysis of total mercury (Hg) and other trace elements was conducted using inductive coupled plasma mass spectrometry (ICP-MS), following standard methods (U.S. Environmental Protection Agency Method 6031), (USEPA, 1986). Sediment samples were analyzed for multi-residue pesticides, PPCPs and PAHs at AXYS analytical laboratories in Sidney, BC. Extraction, cleanup and quantification of PPCPs, pesticides and PAHs were conducted using standard operating procedures at AXYS analytical. Sediment samples were also analyzed for polychlorinated dibezno-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polychlorinated biphenyls (PCBs), polybrominated diphenyl ether flame retardants (PBDEs) at the DFO trace contaminants laboratory at the Institute of Ocean Sciences (IOS) in Sidney, BC. Analytical methods for the analysis of PCBs, PCDD/Fs and PBDEs at the IOS laboratory are presented elsewhere (Ikonomou et al., 2001, Ikonomou et al., 2002).

3.3. Data Analysis

Contaminant concentrations were evaluated and compared to current environmental quality standards derived by domestic regulatory agencies, including the British Columbia Ministry of Environment (BC-MOE), Canadian Council of Ministers of the Environment (CCME) and the Ontario Ministry of Environment (OMOE, 1987; Nagpal et al., 1998; CCME, 1999) as well as other regulatory standards such as the United States Environmental Protection Agency (USEPA) and New York State Department of Environmental Conservation (NYSDEC), (NYSDEC, 1994; USEPA, 1997). The results from Cultus Lake were also compared to a reference system (i.e,, Chilliwack Lake). Chilliwack Lake has a persistent lake shore sockeye spawning population and limited anthropogenic disturbances (e.g. residential and commercial development, boating, etc.) relative to Cultus Lake.

4. Results and Discussion

Field collections of water and surface sediments from Cultus and Chilliwack Lake sampling sites were obtained successfully. All water samples have been analyzed for Hg and trace element concentrations. All sediment samples have been analyzed for Hg and trace elements as well as PAHs and pesticides. The following sections detail observed levels and toxicological implications of those environmental contaminants in Cultus Lake sockeye spawning habitat.

4.1. Mercury and Other Trace Elements

Measured concentrations of mercury and 22 other trace elements in water and sediments from Cultus and Chilliwack Lake sampling sites are shown in Appendix III and IV, respectively. Levels of Hg in water ranged from 460-1,140 pg/L. Compared to Hg, concentrations of other key metals of concern (As, Cd, Pb) in water were relatively low and ranged between 0.005 and 2.39 pg/L. Concentrations of Hg in sediment samples ranged from 0.017-0.144 μg/g dry wt. Arsenic concentrations in sediments ranged between 2.92 and 23.3 μg/g dry wt. Concentrations of other key metals (Cd, Pb, Cu) ranged between 0.17 and 18.4 μg/g dry wt.

The pattern of metals in water was dominated by Hg at all sites (Figure 1A). Conversely, concentrations of Fe, Al and Ti dominated in sediments at all sites (Figure 1B). Figure 1 reveals that while the pattern of metal contamination was generally comparable between the various sampling locations, concentrations can vary substantially between sites. For example, Hg concentration in water at Spring Bay (1,140 pg/L) was approximately 3 times higher than Hg water concentrations on Chilliwack 1 site (460 pg/L). No clear differences in sediment or water metal concentrations is apparent between Cultus and Chilliwack Lakes.

Figure 2 shows concentrations of Hg and other trace metals in Cultus and Chilliwack Lakes are comparable to previous reported Hg levels reported in sediments from six British Columbia Lakes (Kamloops, Harrison, and Moose Lakes) during the 1990s (Macdonald, 2003). For example, observed concentrations (μg/g dry wt) of Hg (range: 0.017-0.144), As (range: 2.92-23.3), Cd (range: 0.177-1.22) and Pb (range: 4.55-18.4) in Cultus and Chilliwack Lake sediments were comparable to previous levels reported in BC lakes (Figure 2).

Figure 1. Concentrations of metals in water (A) and sediments (B) at various sampling locations on Cultus and Chilliwack Lakes. Water concentrations are reported as pg/L and sediments as μg/g dry wt.

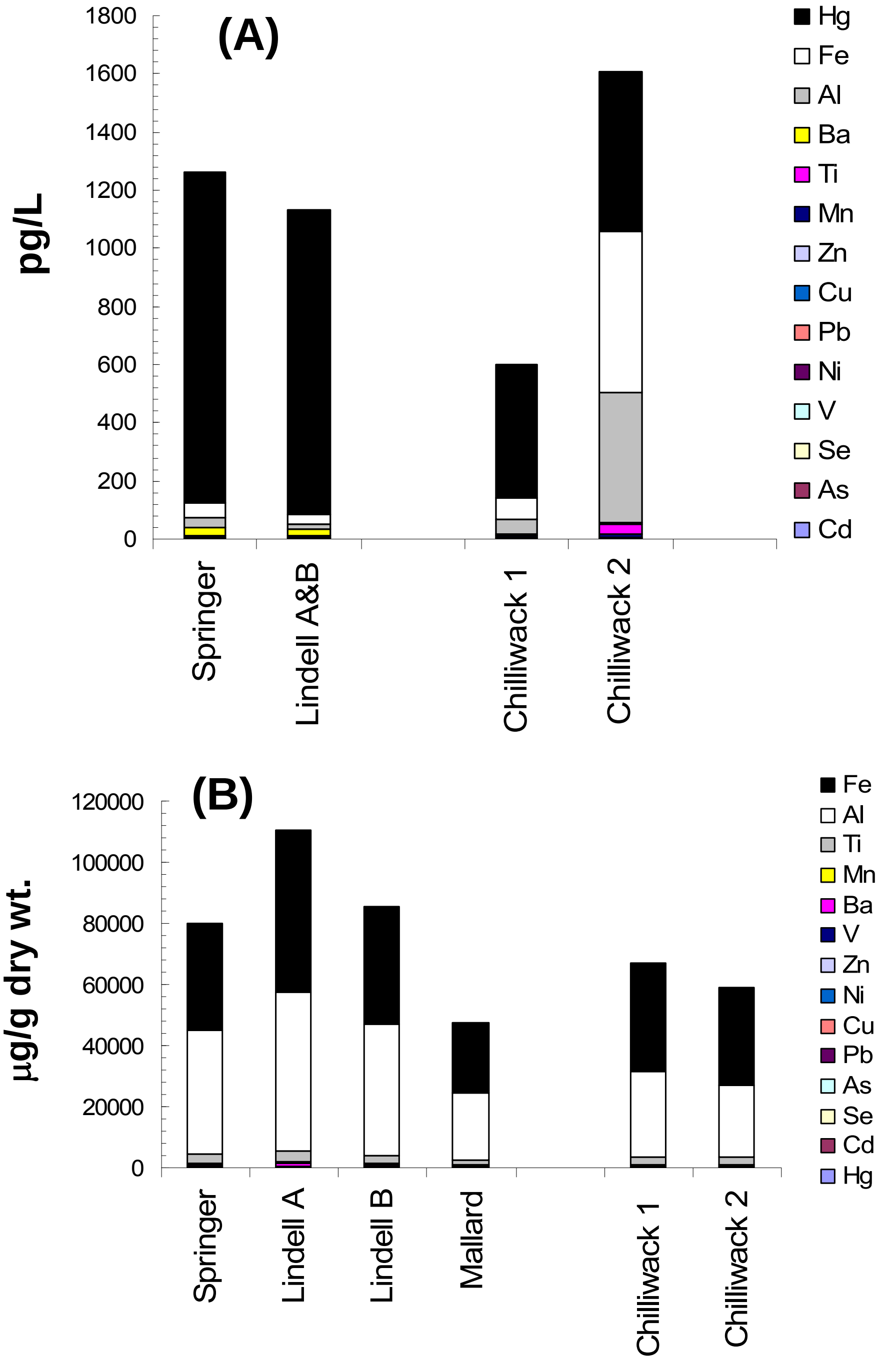

Figure 2. Concentrations of several environmental contaminants in Cultus/Chilliwack Lake sediments compared to concentrations previously reported in Harrison Lake, Kamloops Lake and Moose Lake in British Columbia (Macdonald, 2003, Gallagher, 2003). Metals are reported as μg/g dry wt. PAHs and DDT are reported as ng/g dry wt. Error bars represent range of 1 standard deviation of the calculated geometric mean of Cultus and Chilliwack Lake sites.

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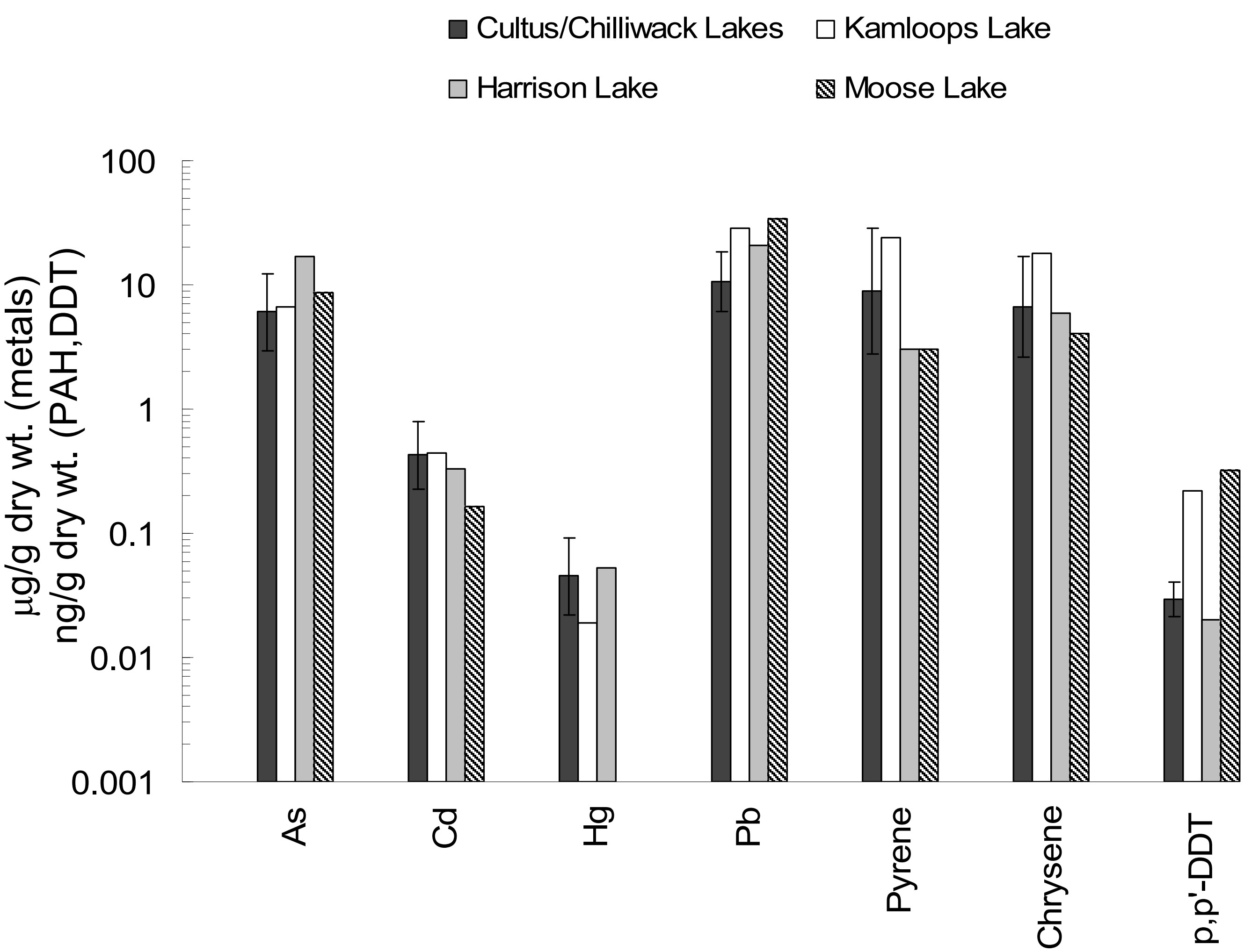


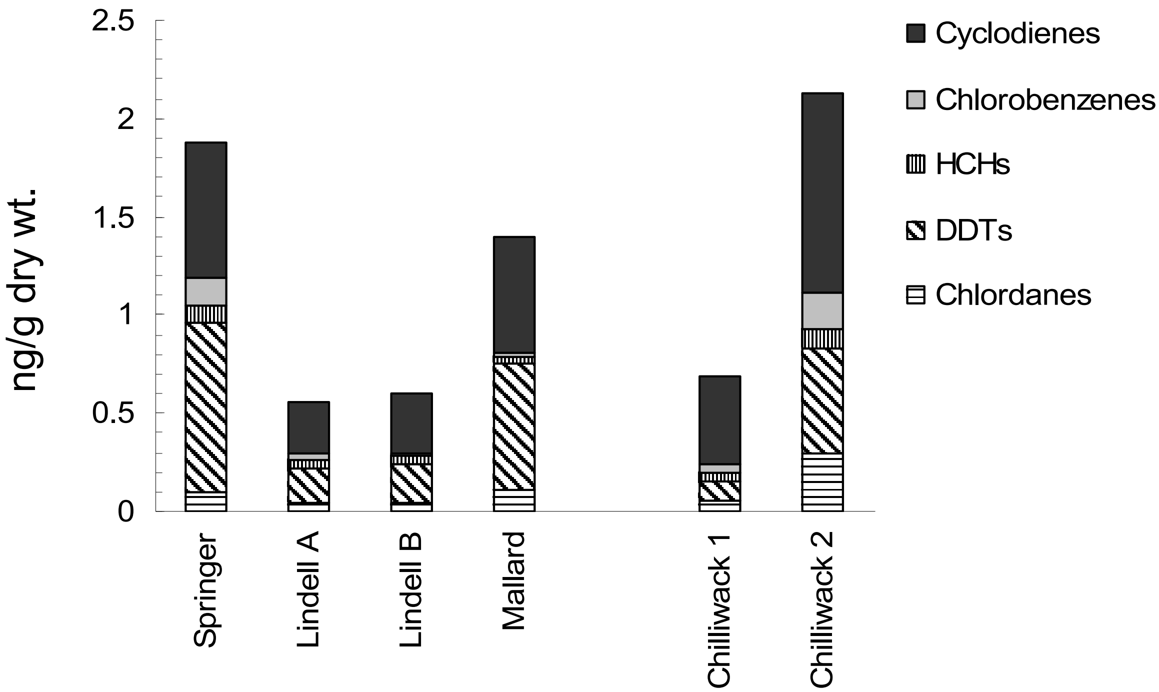
4.2. Pesticides and Pharmaceuticals & Personal Care Products (PPCPs)

Pesticide concentrations in sediments from Cultus Lake and Chilliwack Lake are summarized in Appendix V. Pesticides detected in sediments consisted mainly of organochlorine compounds such as chlorobenzenes, cyclodienes (endosulfan, mirex, dieldrin), hexachlorocyclohexanes (HCHs), DDTs and Chlordanes. Concentrations of individual pesticides ranged from approximately 0.01 to 0.5 ng/g dry wt. (Appendix V). None of the 71 pharmaceuticals and personal care products (PPCPs) analyzed as part of this study (Appendix VI) were detected in Cultus Lake or Chilliwack sediments. Method detection limits for PPCPs in sediments are shown in Appendix VI.

Figure 3 illustrates that cyclodienes and DDTs were the predominant pesticides in Cultus Lake and Chilliwack Lake sediments, generally contributing > 80% of the total pesticide burden. While the pesticide pattern was comparable among sampling locations, concentrations varied substantially between sites (Figure 3). For example, the mean ∑cyclodiene concentration at Chilliwack 2 site (1.01 ng/g dry wt) was approximately 3 times higher than mean ∑cyclodienes in sediments at Lindell A (0.26ng/g dry wt). No clear difference in pesticide concentrations between Cultus and Chilliwack Lakes sites is evident from these data.

Harris et al., (2008) recently presented measured concentrations of legacy and current-use pesticides in sediments from salmon bearing tributaries (Musqueam and Nathan Creek) of the Fraser River. Concentrations of legacy organochlorine pesticides such as hexachlorobenzene, mirex and endosulfans and endrin in sediments reported by Harris et al. are comparable to levels observed in Cultus/Chilliwack Lake sediments. Conversely, concentrations of Chlordanes in Cultus/Chilliwack Lake sediments were substantially lower than concentrations reported by Harris et al. (2008). For example, *trans*-chlordane levels in Cultus/Chilliwack Lake sediments (mean = 0.021, CI = 0.007-0.066 ng/g dry wt.) were 20 and 200 times lower than *trans*-chlordane levels at Nathan Creek and Musqueam Creek, respectively. Similarly, levels of *p,p’* DDT in Cultus/Chilliwack Lake sediments ranged between 0.02-0.04 ng/g dry wt., which is approximately 10 times lower than *p,p’* DDT levels previously reported in sediments from Kamloops and Moose Lakes (Figure 2).

Figure 3. Concentrations (ng/g dry wt.) of different classes of pesticides in Cultus Lake and Chilliwack lake sampling locations.



4.3. Polycyclic aromatic hydrocarbons (PAHs)

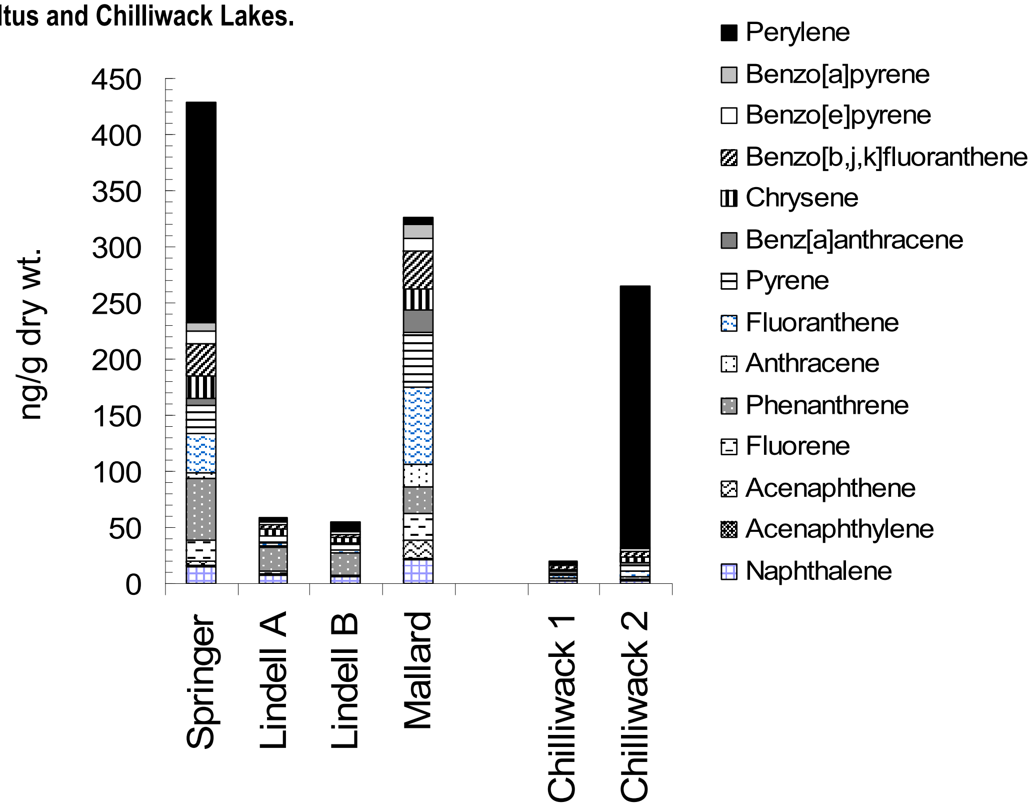
Concentrations of PAHs in sediments from Cultus Lake and Chilliwack Lake are shown in Appendix VI. PAHs are commonly classified low molecular weight PAHs (LPAH) or high molecular weight PAHs (HPAH). Differences in the structure and size of individual PAHs result in substantial variability in the physicochemical properties and hence environmental fate and partitioning of these substances. LPAH concentrations in Cultus Lake and Chilliwack Lake sediments ranged from 6.01 to 117 ng/g dry wt., while HPAH concentrations ranged from 10.0-172 ng/g dry wt.

PAH concentrations and patterns differed substantially between sampling sites (Figure 4). For example, the concentration of perylene at Spring Bay (196 ng/g dry wt.) and Chilliwack 2 (232 ng/g dry wt.) were orders of magnitude higher than sediments at other sites. Similarly, fluoranthene concentrations varied substantially from a low of 2.26 ng/g dry wt. at Chilliwack 1to 34.8 ng/g dry wt. at Spring Bay and 68.9 ng/g dry wt. at Mallard. No clear PAH concentration differences between Cultus Lake and Chilliwack Lake was observed.

PAH concentrations in Cultus Lake and Chilliwack Lake sediments are comparable to PAH levels observed in sediments from other BC Lakes (Macdonald, 2003). For example, mean concentrations of pyrene (8.84, CI = 1.39-56.1) and chrysene (6.68, CI=1.32-33.7) in Cultus/Chilliwack Lake sediments is similar to concentrations of those compounds observed in Harrison, Kamloops and Moose Lakes (Figure 2).

PAHs can also be classified as petroleum PAHs (e.g.C1-C4 Napthalenes) or combustion PAHs such as fluoranthene and benzo[a]pyrene (BaP). Combustion PAHs in Cultus and Chilliwack Lake sediments are relatively low compared to levels observed in samples from Fraser River estuary and Vancouver harbour (Yunker et al., 1999). For example, combustion PAH levels in Cultus/Chilliwack Lake sediments (mean = 0.04, CL range: 0.01-0.29 μg/g wet wt.) is nearly 300 times lower than those levels reported in Burrard Inlet (11.3 ± 16.7μg/g wet wt) and 8 times lower than levels in the Fraser River estuary (0.36± 0.19 μg/g wet wt).

Figure 4. Concentrations of various PAHs in sediments (ng/g dry wt.) at various sampling locations on Cultus and Chilliwack Lakes.



4.4. Toxicological Implications

Contaminant exposure in fish can occur via water, sediments and/or food (Gobas, 1993; Morrison et al., 1996; Russell et al., 1999; Arnot and Gobas, 2004). Perhaps the life-history stage most vulnerable to contaminant exposure are the embryo and alevin stages (Guiney et al., 1979; Zitko and Saunders, 1979; Niimi, 1983; Walker and Peterson, 1991; Miller, 1993; Giesy et al., 2002). After deposition by spawning sockeye salmon, the egg and subsequent alevin stages incubate in spawning gravel substrate on the lake bottom. These stages may be exposed to contaminants in surrounding water and sediment. Both the development and survival of these stages can be affected by exposure to contaminants and can therefore affect subsequent recruitment (Guiney et al., 1979; Zitko and Saunders, 1979; Niimi, 1983; Walker and Peterson, 1991; Miller, 1993; Giesy et al., 2002).

Water quality guidelines (WQGs) and sediment quality guidelines (SQGs) are commonly used criteria used to assess contaminant related risks to aquatic life (Magliette et al., 1995; March et al., 2007; Apitz et al., 2007). Table 1 shows a comparison of the observed concentration range and upper 95% confidence limits (CL) for metals in Cultus/Chilliwack Lake water versus current WQGs for metals used by the British Columbia Ministry of Environment (BC-MOE) for the protection of aquatic life. The data indicate that observed concentrations in Cultus/Chilliwack Lake were below WQG.

Table 2 shows a comparison of the observed concentration range and upper 95% confidence limits (CL) for metals in Cultus/Chilliwack Lake sediments (μg/g dry wt.) versus current SQGs for metals used by the BC-MOE. The data indicate that the majority of observed concentrations were below SQG. However, all 6 sediment samples had levels of Fe that exceeded the SQG, while a number of samples exhibited levels of Mn and Zn that exceeded SQG concentrations. The upper bound 95% CL concentrtation of several metals (Hg, Al, Ba, Fe, Mg, Pb and Zn) in Cultus/Chilliwack Lake sediments exceeded the corresponding guidelines for the protection of freshwater organisms.

Observed concentration ranges and upper 95% CLs for PAHs and pesticides in Cultus/Chilliwack Lake sediments compared to current SQGs used by the BC-MOE are shown in Table 3. The majority of sediment samples exhibited concentrations below SQG values. However, in some cases, the 95% CL of several PAHs (2-methylnaphthalene, acenaphthene, fluorene, naphthalene, phenanthrene, pyrene) in Cultus/Chilliwack Lake sediments exceeded the SQG levels derived to protect freshwater organisms.

In a number of samples, concentrations of three metals (Fe, Mn, Zn) and two PAHs (acenaphthene, fluorene) slightly exceeded BC-MOE sediment quality guidelines (SQGs). Concentrations of several other metals (Hg, Al, Ba, Pb) and several PAHs (naphthalene, phenanthrene, pyrene and 2-Methylnaphthalene), which were slightly below SQGs, exhibited 95 % CLs that exceeded corresponding guidelines.

SQGs are typically conservative estimates, derived by applying a series of safety factors to observed toxicological thresholds, and are generally below probable effect levels (PELs). For example, although the upper 95% CL of Hg in Cultus/Chilliwack Lake sediments (0.18 μg/g dry wt.) exceeds the current SQG (0.17 μg/g dry wt.), the PEL for

Hg in freshwater sediments is 0.486 μg/g dry wt. Thus, concentrations of Hg in Cultus/Chilliwack Lake sediments do not appear to be sufficiently high to cause Hg related toxic effects. Similarly, upper bound 95% CLs of other contaminants that appear to be of concern in Cultus/Chilliwack Lake sediments (Pb, Al and various PAHs) do not exceed PEL of those compounds in freshwater organisms.

One exception however is Fe. Fe concentrations in Cultus/Chilliwack Lake sediments (range: 23,000-52,900 μg/g dry wt.) and upper 95% CL (91,700 μg/g dry wt.) exceeded the severe effects level for Fe in sediments (43,766 μg/g dry wt.). While Fe concentrations in Cultus/Chilliwack Lake sediments exceeds toxicological threshold concentrations, those levels are comparable to other BC freshwater systems (Macdonald, Unpublished Data).

Table 1. Comparison of metal concentrations in water from Cultus and Chilliwack Lakes (μg/L) and British Columbia's Ministry of Environment (BC-MOE) water quality guidelines (WQGs)

	Water Quality Assessment				
	Cultus/ Chilliwack Lake Water Range (pg/L)	Cultus/ Chilliwack Lake Water Upper 95% CL (pg/L)	BC-MOE Water Quality Guideline (pg/L)	Number of samples exceeding WQG *n*=4	Concentrations Exceed WQG
Hg	460-1140	2340	2.0×10^4	0/4	-
Ag	0.005-0.014	0.0216	1.0×10^5	0/4	-
Al	17.7-446	499	1.0×10^8	0/4	-
As	0.20-0.260	0.540	5.0×10^6	0/4	-
Ba	4.82-26.7	59.4	1.0×10^9	0/4	-
Be	0.012-0.012	0.0240	5.30×10^6	0/4	-
Cd	0.0070-0.0270	0.045	1.0×10^4	0/4	-
Co	0.035-0.208	0.306	1.1×10^8	0/4	-
Cr	0.090-0.323	0.537	1.0×10^6	0/4	-
Cu	0.720-2.190	3.89	9.40×10^4	0/4	-
Fe	29.2-554	632	3.0×10^8	0/4	-
Mn	2.45-11.1	15.7	8.0×10^8	0/4	-
Ni	0.27-0.95	1.99	2.5×10^7	0/4	-
Pb	0.36-2.39	3.71	7.0×10^2	0/4	-
Sb	0.043-0.073	0.150	2.0×10^7	0/4	-
Se	0.09-1.01	2.27	2.0×10^6	0/4	-
Ti	0.88-29.0	30.3	2.0×10^9	0/4	-
V	0.21-1.38	1.81	6.0×10^6	0/4	-
Zn	2.41-3.54	6.93	1.0×10^7	0/4	-

Table 2. Comparison of concentrations of metals in sediments from Cultus and Chilliwack Lakes (µg/g dry wt.) and British Columbia's Ministry of Environment (BC-MOE) sediment quality guidelines (SQGs).

Sediment Quality Assessment

	Cultus/ Chilliwack Lake Sediment Range (µg/g dry wt.)	Cultus/ Chilliwack Lake Sediment Upper 95% CL (µg/g dry wt.)	BC-MOE Sediment Quality Guideline (µg/g dry wt.)	Number of samples with concentrations exceeding SQG *n*=6	Concentrations Exceed SQG
Hg	0.017-0.144	0.18	0.17	0/6	YES *
Ag	0.092-0.373	0.67	0.5	0/6	-
Al	22200-52000	94,500	58,000 [a]	0/6	YES *
As	2.92-23.3	24.53	7.24	0/6	-
Ba	116-761	1,360	20 [a]	0/6	YES *
Be	0.354-0.985	1.66	NA	0/6	NA
Cd	0.177-1.22	1.60	0.6	0/6	-
Co	7.48-19.6	34.6	50 [b]	0/6	-
Cr	21.5-303	320	37.3	0/6	-
Cu	25.8-77.4	135	35.7	0/6	-
Fe	23000-52900	91,700	21,200	6/6	YES **
Mn	418-736	1360	460	5/6	YES **
Ni	14.7-133	190	16	0/6	-
Pb	4.55-18.4	37.1	35	0/6	YES *
Sb	0.339-0.895	1.47	3.2 [c]	0/6	-
Se	0.478-7.83	7.05	5	0/6	-
Ti	1430-3690	6930	NA	0/6	NA
V	67.4-165	289	NA	0/6	NA
Zn	72.9-153	276	123	2/6	YES **

[a] sediment quality guideline from USEPA, 1997
[b] sediment quality guideline from Ontario Ministry of Environment (OMOE)
[c] sediment quality guideline from NYDEC, 1994
* 95% CL exceeded SQG
** actual measured concentrations exceeded SQG.

Table 3. Comparison of Cultus and Chilliwack Lake water concentrations (μg/L) of pesticides and PAHs in sediment (ng/g dry wt.) with British Columbia's Ministry of Environment (BC-MOE) sediment quality guidelines.

Sediment Quality Assessment					
	Cultus/ Chilliwack Lake Sediment Range (ng/g dry wt.)	**Cultus/ Chilliwack Lake Sediment Upper 95% CL** (ng/g dry wt.)	**BC-MOE Sediment Quality Guideline** (ng/g dry wt.)	**Number samples exceeding SQG** ***n*=6**	**Concentrations Exceed SQG**
Pesticides					
Hexachlorobenzene	0.014-0.183	0.219	10	0/6	-
Heptachlor	0.014-0.025	0.043	0.6	0/6	-
α-HCH	0.01-0.073	0.082	6.0	0/6	-
Chlordane[a]		0.26	4.5	0/6	-
Heptachlor Epoxide	0.01-0.016	0.03	0.6	0/6	-
α-Endosulphan	0.087-0.138	0.285	2.9 [b]	0/6	-
β-Endosulphan	0.0277-0.129	0.282	14[b]	0/6	-
Endrin	0.01-0.012	0.021	2.67	0/6	-
Dieldrin	0.01-0.229	0.181	0.71	0/6	-
2,4'-DDE	0.01-0.051	0.066	1.42	0/6	-
4,4'-DDE	0.038-0.515	0.907	1.42	0/6	-
Mirex	0.01-0.021	0.156	7	0/6	-
PAHs					
2-Methylnaphthalene	1.04-18.8	40.63	20.2	0/6	YES *
Acenaphthene	0.382-16	11.13	6.71	1/6	YES**
Acenaphthylene	0.159-1.54	2.21	5.87	0/6	-
Anthracene	0.211-20	11.82	46.9	0/6	-
Benzo(a)anthracene	0.431-20.2	20.02	31.7	0/6	-
Benzo(a)pyrene	0.331-12.6	16.34	31.9	0/6	-
Chrysene	1.82-20.4	33.7	57.1	0/6	-
Dibenz(a,h)anthracene	0.64-3.22	5.47	6.2	0/6	-
Fluoranthene	2.26-68.9	65.72	111	0/6	-
Fluorene	0.398-24.5	32.58	21.2	1/6	YES **
Naphthalene	2.31-20.9	31.88	34.6	0/6	YES *
Phenanthrene	1.58-55.7	94.28	41.9	1/6	YES *
Pyrene	2.09-49.3	56.34	53	0/6	YES *
LPAHs	6.01-117	240	100	2/6	YES **
HPAHs	10.0-172	190	1000	0/6	-

[a] Chlordane consists of the sum of *trans*-chlordane, *cis*-chlordane, *trans*-nonachlor and *cis*-nonachlor
[b] sediment quality guideline from USEPA, 1997
* 95% CL exceeded SQG
** actual measured concentrations exceeded SQG.
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5. Conclusions and Recommendations

As a preliminary assessment of contaminant exposure risks to developing Cultus Lake sockeye embryos, this study reports on the occurrence and levels of several environmental contaminants of concern in water and sediments collected from spawning habitat for this endangered Pacific sockeye population. The results demonstrate that contaminant levels for metals, pesticides and PAHS in Cultus Lake sockeye spawning habitat (Cultus and Chilliwack Lakes) are generally comparable to, or in some cases lower than, concentrations in other British Columbia freshwater ecosystems. However, recent evidence that current environmental levels from a Fraser Valley watershed (Nicomekl River) of complex pesticide mixtures affect rainbow trout olfaction and olfactory-mediated behaviours suggest that some concern exists about water quality and salmon health in this region (Tierney et al 2006; Tierney et al., 2008). Further research is warranted to further delineate risks to salmon health associated with complex contaminant mixtures.

The evaluation of ambient contaminant concentrations (i.e., levels in water and sediment) from Cultus/Chilliwack Lakes in relation to WQGs and SQGs for the protection of aquatic life provides for some insight into the potential for toxicological implications for developing Cultus Lake sockeye embryos. In particular, these analyses indicate that Fe levels exceed toxicological thresholds for the protection of freshwater organisms.

The consequences of ambient Fe levels on developing Cultus Lake sockeye embryos is not clear from results of the present study. It is important to note that predicting biological effects from observed concentrations and SQGs and PELs is difficult due to other environmental and biological factors such as pH, bioavailability, species sensitivity, lifestage sensitivity and toxicological endpoints. Regardless, these results indicate ambient Fe sediment concentrations are sufficiently high to warrant further investigation. Future studies to better asses toxicological effects of ambient concentrations of Fe and other contaminants on developing Pacific sockeye embryos should include laboratory-based assays using field collected spawning substrate.

6. Future Reporting and Publication

The present document summarizes measurements and risk analyses of several environmental contaminants, including Hg and other trace elements, pesticides and PAHs in field collected samples of water and sediments from Cultus and Chilliwack Lakes.

High resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) analyses of PCDD/Fs, PCBs and PBDEs in these samples are still in progress. This past winter, DFO moved forward with the national restructuring of three DFO analytical laboratories into a *Centre of Expertise.* As a result, there was a slight delay in processing of these Cultus Lake samples. We expect these outstanding data by September, 2008, at which point we will submit an Addendum to PSC.

This addendum will present details of the occurrence, levels and toxicological implications of the outstanding compounds (PCBs, PBDEs, PCDDs and PCDFs) in Cultus Lake Sockeye spawning habitat. We also plan on preparing a short scientific article summarizing the occurrence, levels and toxicological implications of all the environmental contaminants investigated (PCBs, PCDD/Fs and PBDEs, PAHs, pesticides and metals) at that time.

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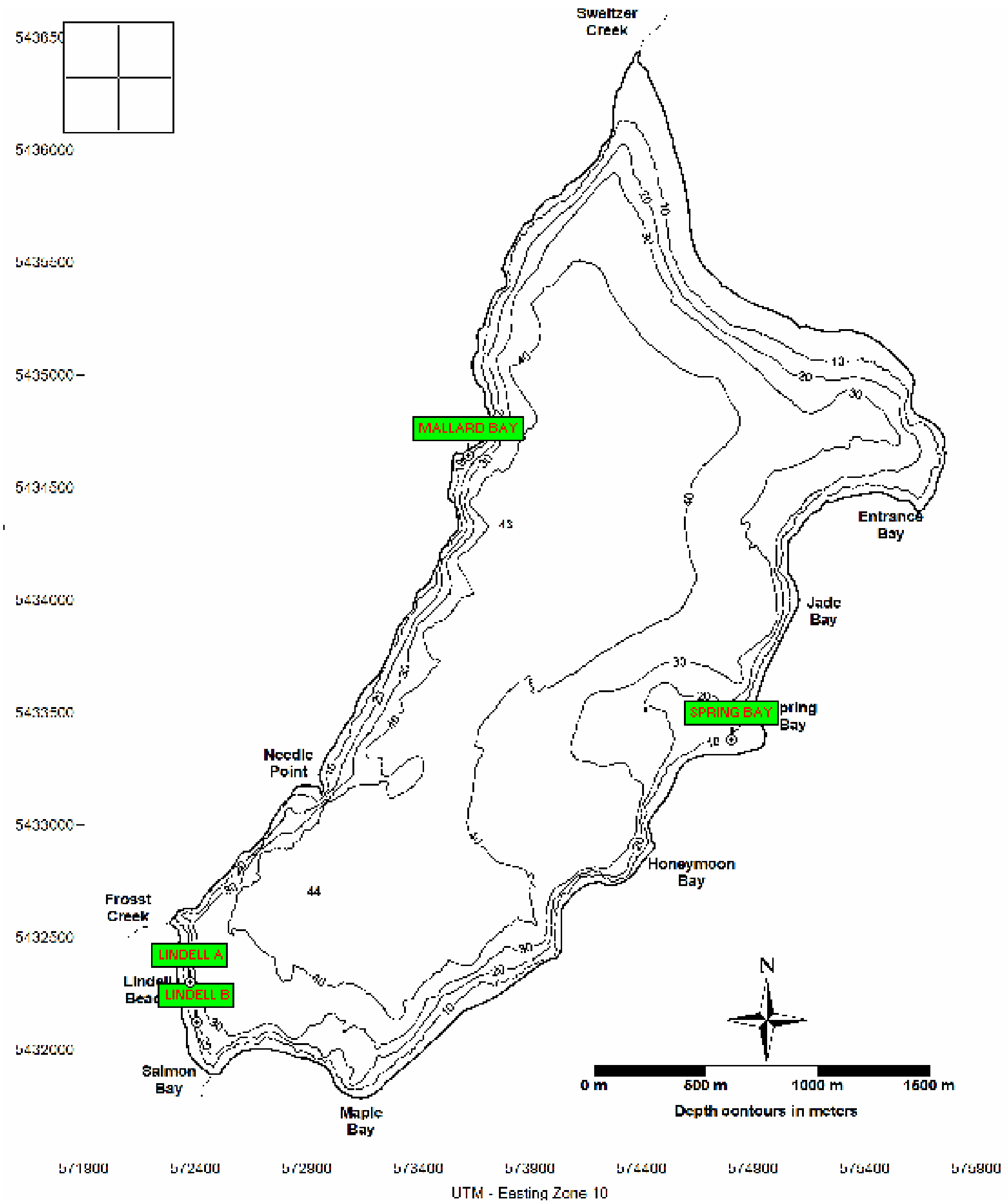
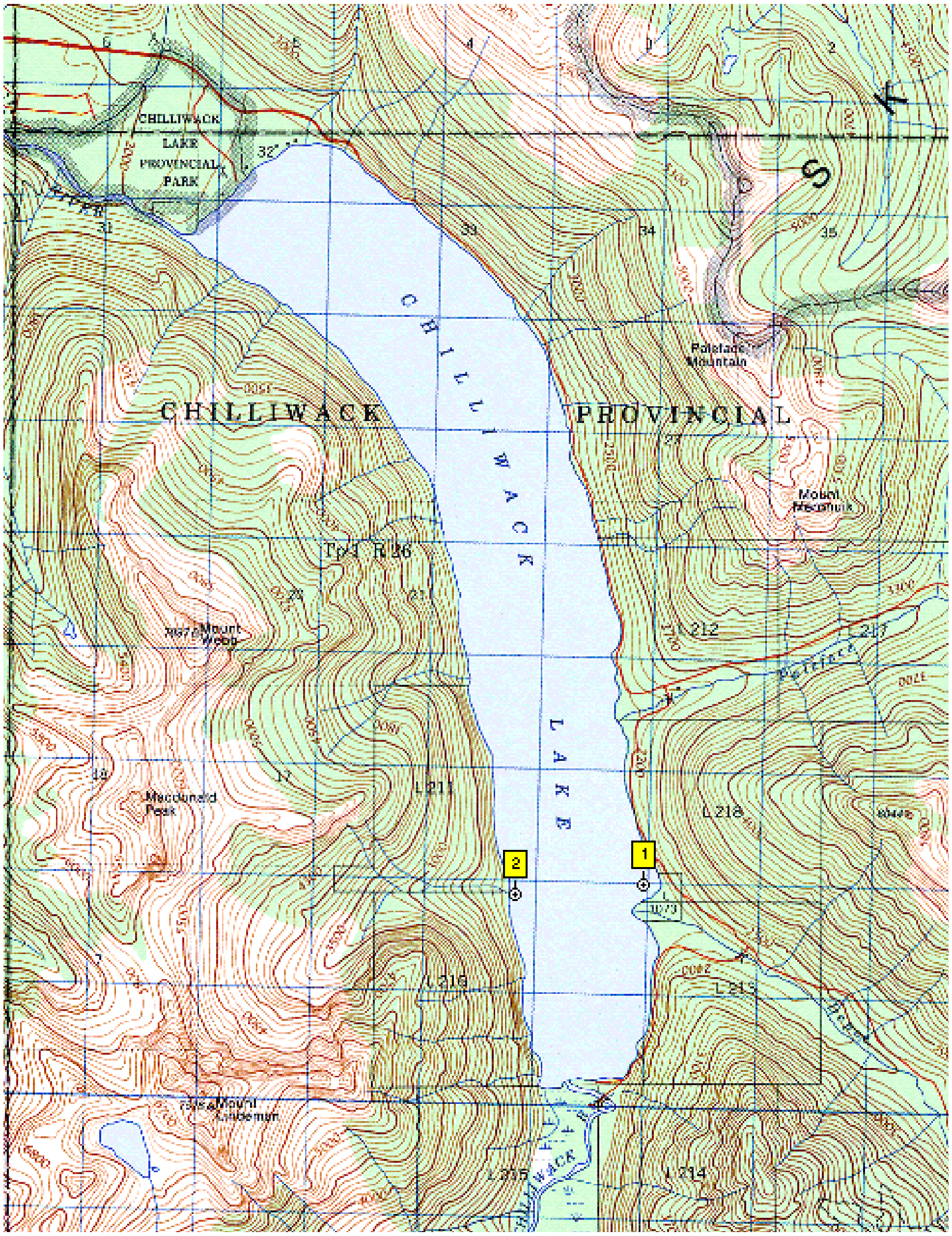
8. Appendices

Appendix I. Map showing sampling locations on Cultus Lake.



Appendix II. Map showing sampling locations on Chilliwack Lake.



Appendix III. Concentrations of mercury and other trace elements in water (pg/L) collected from Cultus and Chilliwack Lakes. Values following < symbol represent method detection limits. NQ = Not quantifiable. GM = geometric mean. 95% CL = 95 % confidence limits.

	Spinger	Lindell A & B	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
Hg	1140	1050	460	550	460-1140	741 (235-2340)
Ag	0.005	0.014	0.005	0.005	0.005-0.014	0.0065 (0.0019-0.0216)
Al	33.7	17.7	54.8	446	17.7-446	61.7 (7.64-499)
As	0.24	0.26	0.2	0.26	0.20-0.260	0.238 (0.10-0.54)
Ba	26.7	25.3	4.82	7.8	4.82-26.7	12.6 (2.67-59.4)
Be	0.012	0.012	0.012	0.012	0.012-0.012	0.012 (0.006-0.024)
Ca	33100	31500	3110	3070	3070-33,100	9990 (1290-77,400)
Cd	0.007	0.008	0.015	0.027	0.0070-0.0270	0.012 (0.0033-0.045)
Co	0.063	0.059	0.035	0.208	0.035-0.208	0.072 (0.017-0.306)
Cr	0.17	0.11	0.09	0.323	0.090-0.323	0.15 (0.043-0.537)
Cu	1.42	0.79	0.72	2.19	0.720-2.190	1.15 (0.34-3.89)
Fe	50.6	29.2	72	554	29.2-554	87.6 (12.1-632)
K	441	457	454	554	441-554	474 (213-1050)
Mg	2880	2890	399	499	399-2890	1130

	Spinger	Lindell A & B	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
						(192-6690)
Mn	3.02	2.45	2.88	11.1	2.45-11.1	3.92 (0.974-15.7)
Na	3160	2990	967	915	915-3160	1700 (428-6740)
Ni	0.27	0.79	0.95	0.52	0.27-0.95	0.569 (0.163-1.99)
Pb	2.39	0.8	0.36	0.77	0.36-2.39	0.853 (0.19-3.71)
Sb	0.072	0.073	0.045	0.043	0.043-0.073	0.056 (0.0211-0.15)
Se	1.01	0.89	0.09	0.09	0.09-1.01	0.292 (0.037-2.27)
Ti	2.47	0.88	2.08	29	0.88-29.0	3.38 (0.37-30.4)
V	0.26	0.21	0.28	1.38	0.21-1.38	0.381 (0.080-1.81)
Zn	2.41	2.86	3.54	3.11	2.41-3.54	2.95 (1.26-6.93)

Appendix IV. Concentrations of mercury and other trace elements in sediments (ug/g dry wt.) collected from Cultus and Chilliwack Lakes. Values following < symbol represent method detection limits. NQ = Not quantifiable. GM = geometric mean. 95% CL = 95 % confidence limits.

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% moisture	81.24	32.99	26.0	35.09	58.46	76.94		
Hg	0.144	0.0487	0.0435	0.0171	0.030	0.0524	0.017-0.144	0.045 (0.011-0.182)
Ag	0.373	0.239	0.203	0.092	0.241	0.217	0.092-0.373	0.210 (0.066-0.67)
Al	40900	52000	43200	22200	23400	27700	22200-52000	33100 (11600-94500)
As	6.39	5.22	4.32	2.92	23.3	4.77	2.92-23.3	6.01 (1.47-24.5)
Ba	577	761	548	187	116	167	116-761	310 (70.5-1360)
Be	0.533	0.985	0.838	0.354	0.385	0.434	0.354-0.985	0.544 (0.178-1.66)
Ca	12400	15400	18100	5660	7800	8740	5660-18100	10500 (3370-32600)
Cd	1.22	0.521	0.397	0.177	0.378	0.351	0.177-1.22	0.425 (0.113-1.59)
Co	15.8	19.6	13.2	7.48	9.36	11.0	7.48-19.6	12.1 (4.27-34.5)
Cr	38.7	303	135	33.6	28.7	21.5	21.5-303	56.7 (10.0-320)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% moisture	81.24	32.99	26.0	35.09	58.46	76.94		
Cu	55.2	50.2	39.1	25.8	49.7	77.4	25.8-77.4	47.0 (16.2-135)
Fe	34700	52900	38500	22900	31900	35400	23000-52900	35000 (13300-91700)
K	7580	9450	6670	4800	2420	3980	2420-9450	5300 (1620-7360)
Mg	8203	25600	18900	7160	8020	11900	7160-25600	11800 (3510-39800)
Mn	639	736	607	418	482	469	418-736	547 (220-1360)
Na	832	910	435	516	1570	1670	435-1670	874 (2520-3050)
Ni	49.5	132	84.8	24.1	16.1	14.7	14.7-133	38.4 (7.75-190)
Pb	17.5	6.59	4.55	10.7	18.4	13.6	4.55-18.4	10.6 (3.03-37.1)
Sb	0.533	0.895	0.554	0.339	0.578	0.434	0.339-0.895	0.531 (0.192-1.46)
Se	7.83	1.19	1.40	0.478	0.746	1.344	0.478-7.83	1.35 (0.26-7.04)
Ti	2650	3690	2440	1433	2820	2750	1430-3690	2540 (927-6930)
V	125	165	111	67.4	84.2	105	67.4-165	105 (38.6-288)
Zn	134	153	110	88.2	80.0	72.9	72.9-153	102 (38.1-276)

Appendix V. Pesticide concentrations in sediments (ng/g dry wt.) collected from Cultus and Chilliwack Lakes. Values following < symbol represent method detection limits. NQ = Not quantifiable. NDR = not detectable due to isotope ratio on HRMS. GM = geometric mean. 95% CL = 95 % confidence limits.

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% Moisture:	72.1	21.3	21.9	23.7	49.3	64.8		
Organochlorines (OC)								
Hexachlorobenzene	0.139	0.032	0.016	0.014	0.039	0.183	0.014-0.183	0.044 (0.009-0.219)
Heptachlor	0.022	0.017	0.018	0.014	0.016	0.025	0.014-0.025	0.018 (0.008-0.043)
α-HCH	0.058	< 0.01	< 0.01	< 0.01	0.011	0.073	0.01-0.073	0.019 (0.004-0.082)
γ-HCH	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	-
β-HCH	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	-
δ-HCH	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	-
Quintozene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Octachlorostyrene	< 0.0181	< 0.01	< 0.01	< 0.01	< 0.01	< 0.011	-	-
Oxychlordane	< 0.0135	< 0.01	< 0.0146	< 0.01	< 0.01	< 0.0175	-	-
Heptachlor Epoxide	0.017	< 0.01	< 0.01	< 0.01	< 0.01	0.016	0.01-0.016	0.012 (0.005-0.030)
trans-Chlordane	0.027	< 0.0115	< 0.0125	0.026	< 0.0117	0.075	0.0115-0.075	0.021 (0.007-0.066)
cis-Chlordane	0.037	< 0.0103	< 0.0112	0.026	< 0.0105	0.083	0.0103-0.083	0.021 (0.006-0.078)
trans-Nonachlor	0.022	< < 0.0109	< 0.0118	0.043	0.019	0.087	0.0109-0.087	0.024 (0.007-0.084)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% Moisture:	72.1	21.3	21.9	23.7	49.3	64.8		
cis-Nonachlor	0.015	< 0.01	< 0.0116	0.017	< 0.0111	0.045	0.01-0.045	0.016 (0.006-0.039)
α-Endosulphan	0.156	0.102	0.087	0.106	0.113	0.138	0.087-0.138	0.115 (0.046-0.285)
β-Endosulphan	0.1	< 0.0277	0.082	0.071	0.129	0.113	0.0277-0.129	0.079 (0.022-0.282)
Endosulphan Sulphate	0.049	< 0.0232	< 0.0271	0.027	0.101	0.36	0.0232-0.36	0.056 (0.015-0.206)
Aldrin	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	-	-
Endrin	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.012	0.01-0.012	0.010 (0.005-0.021)
Endrin Ketone	< 0.0341	< 0.0193	< 0.0184	< 0.0161	< 0.022	< 0.0375	-	-
Dieldrin	0.021	< 0.01	< 0.01	0.229	< 0.01	0.034	0.01-0.229	0.023 (0.003-0.181)
2,4'-DDD	0.074	0.011	0.013	0.041	< 0.01	< 0.01	0.011-0.041	0.026
4,4'-DDD	0.306	0.059	0.091	0.15	< 0.01	< 0.01	0.059-0.15	0.125
2,4'-DDE	0.014	< 0.01	< 0.01	0.051	< 0.01	0.025	0.01-0.051	0.016 (0.004-0.066)
4,4'-DDE	0.393	0.052	0.038	0.356	0.093	0.515	0.038-0.515	0.154 (0.026-0.907)
2,4'-DDT	0.0249	< 0.0118	< 0.0177	< 0.0128	NQ	NQ	-	-
4,4'-DDT	0.051	0.037	< 0.0239	0.026	NQ	NQ	0.0239-0.037	0.033
Methoxychlor	< 0.4	< 0.0446	< 0.1	< 0.0436	NQ	NQ	-	-
Mirex	0.21	0.015	< 0.01	0.011	0.015	0.021	0.01-0.021	0.022 (0.003-0.156)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% Moisture:	72.1	21.3	21.9	23.7	49.3	64.8		
Triazines (TZ)								
Desethylatrazine	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Simazine	< 0.194	< 0.1	< 0.1	< 0.1	< 0.1	< 0.106	-	-
Atrazine	< 0.239	< 0.1	< 0.1	< 0.1	< 0.118	< 0.231	-	-
Ametryn	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Metribuzin	< 0.164	< 0.1	< 0.1	< 0.1	< 0.1	< 0.261	-	-
Cyanazine	< 0.214	< 0.127	< 0.1	< 0.1	< 0.255	< 0.312	-	-
Hexazinone	< 0.158	< 0.1	< 0.1	< 0.1	< 0.202	< 2.07	-	-
Organophospates (OP)								
Methamidophos	< 1.07	< 0.502	< 0.47	< 0.497	< 0.647	< 1.1	-	-
Phorate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Terbufos	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Diazi non-Oxon	< 0	< 0			0		-	-
Diazinon	< 0.163	< 0.1	< 0.1	< 0.1	< 0.116	< 0.156	-	-
Disulfoton							-	-
Fonofos	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Dimethoate	< 0.359	< 0.236	< 0.2	< 0.271	< 0.214	< 0.287	-	-
Chlorpyriphos-Methyl	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Parathion-Methyl	< 0.767	< 0.314	< 0.27	< 0.253	< 0.221	< 0.382	-	-
Pirimphos-Methyl	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Chlorpyriphos	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Fenitrothion	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Malathion	< 0.794	< 0.371	< 0.331	0.435	< 0.3	< 0.494	-	-
Parathion-Ethyl	< 0.109	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Chlorpyriphos-Oxon	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% Moisture:	72.1	21.3	21.9	23.7	49.3	64.8		
Disulfoton Sulfone	NQ	NQ	NQ	NQ	NQ	NQ	-	-
Ethion	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Phosmet	< 0.106	< 0.1	< 0.1	< 0.1	< 0.17	< 0.153	-	-
Azinphos-Methyl	< 0.362	<0.0872	< 0.053	< 0.0957	< 0.296	< 2.28	-	-
Other								
Tecnazene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Dacthal	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Captan	NQ	NQ	NQ	NQ	NQ	NQ	-	-
Trifluralin	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Linuron	< 0.589	< 0.25	< 0.149	< 0.219	< 0.145	< 0.449	-	-
Alachlor	< 0.377	< 0.1	< 0.1	< 0.1	1	11.9	-	-
Methoprene	< 17.2	< 43.8	< 20.1	< 13.8	< 16	< 71	-	-
Butralin	< 0.874	< 0.158	< 0.194	< 0.117	< 0.216	< 0.517	-	-
Flufenacet	< 1.26	< 0.1	< 0.1	< 0.1	< 0.1	< 0.928	-	-
Metolachlor	< 0.216	< 0.1	< 0.1	< 0.1	< 0.1	< 0.341	-	-
Pendimethalin	< 1.9	< 0.122	< 0.225	< 0.114	< 0.339	< 0.941	-	-
Flutriafol	< 0.462	< 0.1	< 0.1	< 0.234	< 0.1	< 2.14	-	-
Tebuconazol	< 1.04	< 0.1	< 0.1	< 0.105	< 0.104	< 0.403	-	-
Chlorothalonil	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Triallate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Dimethenamid	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Permethrin	< 0.315	< 0.1	< 0.1	< 0.1	< 0.257	< 3.14	-	-
Cypermethrin	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Butylate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Ethalfluralin	< 0.111	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	-	-
Perthane	< 0.656	< 0.167	< 0.203	< 0.137	< 0.352	< 1.38	-	-

Appendix VI. List of pharmaceutical compounds analyzed in Cultus and Chilliwack Lake sediments. DL = detection limit (ng/g dry wt.)

Compound	DL (ng/g dry wt.)	Compound	DL (ng/g dry wt.)	Compound	DL (ng/g dry wt.)
Anhydrochlortetracycline	18.1	Ciprofloxacin	4.24	Penicillin G	2.57
Anhydrotetracycline	6.77	Clarithromycin	0.673	Penicillin V	5.14
Chlortetracycline	2.69	Clinafloxacin	7.44	Roxithromycin,Sarafloxacin	0.435
Demeclocycline	6.73	Cloxacillin	1.35	Sulfachloropyridazine	1.28
Doxycycline	2.69	Codeine	1.35	Sulfadiazine	1.28
4-Epianhydrochlortetracycline	42.5	Cotinine	1.12	Sulfadimethoxine	0.513
4-Epianhydrotetracycline	6.73	Dehydronifedipine	0.269	Sulfamerazine	0.514
4-Epichlortetracycline	7.89	Diphenhydramine	0.269	Sulfamethazine	1.35
4-Epioxytetracycline	5.34	Diltiazem	0.135	Sulfamethizole	0.514
4-Epitetracycline	5.55	Digoxin	8.62	Sulfamethoxazole	0.514
Isochlortetracycline	2.69	Digoxigenin	2.69	Sulfanilamide	12.8
Minocycline	26.9	Enrofloxacin	2.01	Sulfathiazole	1.28
Oxytetracycline	2.69	Erythromycin-H2O	0.135	Thiabendazole	1.28
Tetracycline	2.9	Flumequine	0.673	Trimethoprim	1.28
Albuterol	0.3	Fluoxetine	0.673	Tylosin	16.8
Cimetidine	0.6	Lincomycin	1.35	Virginiamycin	17.5
Metformin	30	Lomefloxacin	1.35	1,7-Dimethylxanthine	128
Ranitidine	0.6	Miconazole	0.673	Gemfibrozil	0.673
Acetaminophen	26.9	Norfloxacin	6.79	Ibuprofen	6.73
Azithromycin	0.673	Norgestimate	1.35	Naproxen	1.35
Caffeine	6.73	Ofloxacin	0.673	Triclocarban	1.35
Carbadox	0.673	Ormetoprim	0.269	Triclosan	26.9
Carbamazepine	0.673	Oxacillin	1.35	Warfarin	0.673
Cefotaxime	3.04	Oxolinic Acid	0.181		

Appendix VII. Polycyclic aromatic hydrocarbon (PAH) concentrations in sediments (ng/g dry wt.) collected from Cultus and Chilliwack Lakes. Values following < symbol represent method detection limits. NQ = Not quantifiable. NDR = not detectable due to isotope ratio on HRMS. GM = geometric mean. 95% CL = 95 % confidence limits.

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
% moisture	73.2	22.5	22.3	24.1	52.8	67.7		
Naphthalene	14.6	7.46	5.77	20.9	2.31	2.64	2.31-20.9	6.56 (1.35-31.9)
Acenaphthylene	1.54	0.164	0.159	1.44	< 0.165	0.266	0.159-1.54	0.434
Acenaphthene	3.33	0.504	0.382	16	< 0.447	< 0.948	0.382-16	1.79
Fluorene	19.1	2.64	1.23	24.5	< 0.166	0.398	0.398-24.5	3.60
Phenanthrene	55.7	22.3	19.6	22.8	1.58	2.12	1.58-55.7	11.1 (1.30-94.3)
Anthracene	4.22	0.296	0.211	20	0.302	0.39 (NDR)	0.211-20	0.923 (0.072-11.8)
Fluoranthene	34.8	2.85	2.43	68.9	2.26	4.08	2.26-68.9	7.31 (0.814-65.7)
Pyrene	25.1	6.04	5.61	49.3	2.09	5.48	2.09-49.3	8.84 (1.39-56.3)
Benz[a] anthracene	6.65	0.475	0.431	20.2	1.58 (NDR)	2.79 (NDR)	0.431-20.2	2.22 (0.247-20.0)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
Chrysene	20.4	5.97	5.09	18.6	1.82	4.23	1.82-20.4	6.67 (1.32-33.6)
Benzo[b,j,k]fluoranthene	28.3	3.81	3.11	33	2.96	5.23	2.96-33	7.45 (1.22-45.3)
Benzo[e]pyrene	11.6	2.83	2.27	11.7	1.23	2.26	1.23-11.7	3.66 (0.717-18.7)
Benzo[a]pyrene	6.97	0.331	0.38	12.6	1.67	2.24 (NDR)	0.331-12.6	(1.85 0.211-16.3)
Perylene	196	3.27	8.78	6.34	1.51	232	1.51-232	15.2 (0.90-256)
Dibenz[a,h]anthracene 3	3.22 (NDR)	0.799	0.64	2.32 (NDR)	< 0.655	2.16 (NDR)	0.64-3.22	1.52
Indeno[1 ,2,3-c,d]-pyrene	14.1	0.725	0.595	8.44	1.77 (NDR)	2.28	0.595-14.1	2.43 (0.338-17.4)
Benzo[g,h,i]perylene	18.3	3.13	2.21	7.19	1.61 (NDR)	3.43 (NDR)	1.61-18.3	4.13 (0.85-20.0)
2-Methylnaphthalene	18.8	16.8	11.6	6.78	1.04	1.46	1.04-18.8	5.79 (0.8257-40.6)
1-Methylnaphthalene	8.11	5.17	3.8	3.42	0.486	0.613	0.486-8.11	2.33 (0.363-15.0)
C2 Phenanthrenes/Anthracenes	50.5	19.1	14.3	12	1.32	2.16	1.32-50.5	8.82 (1.10-70.3)
C1 Phenanthrenes/Anthracenes	51.1	34.8	29.2	23.3	2.21	7.09	2.21-51.1	16.3 (2.49-106)
C1-Naphthalenes	26.9	21.9	15.4	10.2	1.52	2.07	1.52-26.9	8.14 (1.19-55.6)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
Biphenyl	9.76	3.01	2.66	4.84	0.896	0.72	0.72-9.76	2.49 (0.46-13.4)
C2-Naphthalenes	45.6	26.5	18.2	18	3.67	7.81	3.67-45.6	14.9 (3.05-73.6)
2,6-Dimethylnaphthalene	17.3	10.4	7.17	7.62	0.726	1.18	0.726-17.3	4.51 (0.63-32.2)
C3-Naphthalenes	29.1	14.4	8.3	13.6	1.14	7.45	1.14-29.1	8.58 (1.42-51.6)
2,3,5-Trimethylnaphthalene	6.11	2.66	1.75	2.41	< 0.905	< 0.516	1.75-6.11	2.87
C4-Naphthalenes	17.5 (NDR)	5.92 (NDR)	3.81 (NDR)	6.71 (NDR)	2.95 (NDR)	9.5 (NDR)	2.95-17.5	6.48 (1.71-24.5)
Dibenzothiophene	1.73	0.27 (NDR)	0.22 (NDR)	6.48	< 0.18	< 0.209	0.22-6.48	0.903
C1-Dibenzothiophenes	1.85	0.434	0.211	2.22	< 0.217	< 0.374	0.211-2.22	0.783
C2-Dibenzothiophenes	12.4	1.27	1.18	3.43	1.82	7.93	1.18-12.4	3.11 (0.583-16.6)
1-Methylphenanthrene	13	3.21	2.94	3.03	2.21	7.09	2.21-13	4.24 (1.08-16.6)
4,5-Methylene phenanthrene	6.86	0.68	0.882	11.4	< 0.303	< 8.58	0.68-11.4	2.61
4,5-Methylene phenanthrene	6.86	0.68	0.882	11.4	< 0.303	< 8.58	0.68-11.4	2.61
3,6-Dimethylphenanthrene	5.71 (NDR)	2.51 (NDR)	1.85 (NDR)	1.39 (NDR)	< 0.371	< 0.682	1.39-5.71	2.46
C3-Phenanthrenes/Anthracenes	34.5	8.28	6.89	7.6	2.29	22.7 (NDR)	2.29-34.5	9.58 (1.83-50.1)
Retene	291	3.31	10.8	52.3	103	7700	3.31-7700	86.9 (2.87-2630)

	Spring Bay	Lindell A	Lindell B	Mallard	Chilliwack 1	Chilliwack 2	Range	GM (95% CL)
C4-Phenanthrenes/Anthracenes	339	13.9	19.3	79.2	108	7740	13.9-7740	134 (6.73-2,700)
C1-Fluoranthenes/Pyrenes	29.7	5.78	5.34	29.2	10.5	136	5.34-136	18.3 (2.66-126)
C2-Fluoranthenes/Pyrenes	28.4	9.43	8.35	10.6	3.22	8.8	3.22-28.4	9.35 (2.33-37.4)
C3-Fluoranthenes/Pyrenes	3.39 (NDR)	2.11 (NDR)	2.17 (NDR)	2.02 (NDR)	1.82	9.41	1.82-9.41	2.85 (0.764-10.6)
C4-Fluoranthenes/Pyrenes	2.37 (NDR)	0.53 (NDR)	0.66 (NDR)	1.04 (NDR)	1.22	< 1.97	0.53-2.37	1.01
LPAH [a]	117	50.1	38.9	6.01	8.22	112	6.01-117	32.9 (4.59-236)
HPAH [b]	97.1	16.4	14.5	10.0	20.98	171	10.0-172	30.8 (4.87-194)
Petroleum PAHs[c]	610	146	117	125	7,800	182	117-7,800	351 (34.2-3,600)
Combustion PAHs[d]	166	26.1	22.1	16.9	32.0	229	16.9-230	47.9 (7.85-292)

[a] Low molecular weight PAHs (LPAH) consist of Naphthalene, Acenaphthylene, Acenaphthene, Fluorene, Phenanthrene, Anthracene, 2-Methylnaphthalene.

[b] High molecular weight PAHs (HPAH) consist of Fluoranthene, Pyrene, Benz[a]anthracene, Chrysene.

[c] Petroleum PAHs (HPAH) consist of C2 Phenanthrenes/Anthracenes, C1 Phenanthrenes/Anthracenes, C1-Naphthalenes, C3-Naphthalenes, C4-Naphthalenes, Dibenzothiophene, C1-Dibenzothiophenes, C2-Dibenzothiophenes, C3-Phenanthrenes/Anthracenes C4-Phenanthrenes/Anthracenes

[d] Combustion PAHs consist of Fluoranthene,Pyrene,Benz[a]anthracene,Chrysene ,,Benzo[b,j,k]fluoranthene, Benzo[e]pyrene, Benzo[a]pyrene, Indeno[1 ,2,3-c,d]-pyrene, Benzo[g,h,i]perylene

Appendix VIII. Budget and expenditures

Contaminant exposure risk to developing Cultus Lake sockeye embryo's

	Items Identified in Budget	Actual Expenditures	Comment
PSC Funding			
Received June 2007	-$41,400		
Holdback - August 2008	-$4,600		
Total	-$46,000		
Project Support Biologist (hired externally)	$4,500	$4,479	DFO funded- C. Tovey salary
Field Sampling	$6,450	$9,278	Golder contract included most field costs
field crew travel to sites	$500		
boat rental and field sampling equipment	$500		
shipping and storage of samples	$500		
Laboratory analysis:	$33,550	$22,600	Axys Analytical - includes Brooks Rand
		$9,500	LEACA Analysis - IOS
Balance		-$143	