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Lake Chelan DDT and PCBs in Fish Total Maximum Daily Load Study

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Lake Chelan
DDT and PCBs in Fish
Total Maximum Daily Load Study

by
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Olympia, Washington 98504-7710

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Waterbody Numbers:
Lake Chelan – 1203526480372 (WA-47-9020)
Roses (Alkali) Lake – 1201529479042 (WA-47-9037)

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Abstract

Lake Chelan is included on Washington State's 1998 303(d) list as being water-quality-limited for 4,4'-DDE, PCB-1254, and PCB-1260 in edible fish tissue. Roses Lake is listed for 4,4'-DDE. In response, the Department of Ecology developed a Total Maximum Daily Load (TMDL) study for DDT and PCBs in Lake Chelan and Roses Lake fish tissue.

Sampling was conducted from May through November 2003. Fish tissue, water, and sediment were analyzed for DDT and its metabolites DDE and DDD, as well as for PCBs. Limited analysis also was conducted for dioxin in fish tissue.

- Total DDT in fish tissue was high, ranging from 6 – 2,400 *u*g/Kg. The highest concentrations were reported in mackinaw. Total DDT concentrations in burbot from the Wapato basin of Lake Chelan were more than an order of magnitude higher than in burbot from the Lucerne basin of the lake.
- Semipermeable membrane device results showed total DDT concentrations in the Wapato basin were approximately six times higher in May and June, averaging 5.2 ng/L, than in October and November, averaging 0.94 ng/L. Total DDT measured in water from tributaries and agricultural drains to Lake Chelan routinely exceeded aquatic life criteria.
- Total DDT concentrations in surface sediments from Wapato and Lucerne basins averaged 560 and 120 *u*g/Kg, respectively.
- PCBs were generally low in fish tissue, water, and sediment.

Based on study results, load allocations were developed to meet water quality standards for fish tissue and water discharging to the lakes.

- Mackinaw from the Wapato basin require a 97% reduction in total DDT, a 63% reduction in total PCBs, and a 90% reduction in dioxin toxic equivalent quotients.
- Rainbow trout from Roses Lake require a 67% reduction in total DDT.
- Tributaries and drains to the lakes require reductions in total DDT loads from up to 97% for Lake Chelan and 95% for the orchard drain to Roses Lake.

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- Dave McBride and Joanne Prado of the Washington State Department of Health processed fish in preparation for analysis.
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    - Dale Norton assisted with age dating of the sediment cores.
    - Art Johnson, Dale Norton, and David Schneider reviewed the report and provided valuable comments.
    - Carolyn Lee input the project data into Ecology's Environmental Information Management System.
    - Joan LeTourneau formatted and edited the final report.

Executive Summary

Background

Lake Chelan has been listed by Washington State under Section 303(d) of the federal Clean Water Act for non-attainment of the U.S. Environmental Protection Agency (EPA) human health criteria for 4,4'-DDE, PCB-1254, and PCB-1260 in edible fish tissue. Roses Lake, located adjacent to Lake Chelan, has also been listed for 4,4'-DDE in edible fish tissue.

The compound 4,4'-DDE is a breakdown product of the insecticide DDT, and polychlorinated biphenyls (PCBs) were used in a number of industrial applications. These chemicals are no longer used in the United States, and were banned in 1972 and 1978, respectively.

The Clean Water Act requires states to set priorities for cleaning up 303(d) listed waters and to conduct a Total Maximum Daily Load (TMDL) assessment for each. A TMDL is an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards.

This report describes the results of a field study that monitored levels of DDT compounds and PCBs in Lake Chelan and Roses Lake drainages from the spring through the fall of 2003. It forms the basis of the TMDL evaluation and the assessment for meeting human health criteria in fish tissue and water in the Wapato basin of Lake Chelan.

Lake Chelan is located in north-central Washington State. It is the longest and deepest natural lake in the state and considered pristine with its ultra-oligotrophic nutrient conditions. The Lake Chelan watershed drains a 924-square-mile area. The lake itself is divided into two distinct basins, the Lucerne and Wapato basins. Roses Lake, located about a mile north of the town of Manson, is one of a cluster of three small lakes draining to Lake Chelan.

Uses of Lake Chelan include domestic and irrigation water supply, fisheries, power production, transportation, and water recreation. Ninety percent of the basin is forested or open lands, the majority of which is managed by the U.S. Forest Service and National Park Service. Agriculture and orchard lands comprise 3% of the watershed's land area, almost all of which is located in the Wapato basin. Irrigated fruit crops cover approximately 11,600 acres. Historical use of DDT on fruit crops in the Wapato basin has been the main source to Lake Chelan and Roses Lake.

Results of Field Study

Water

Five water sample surveys from Lake Chelan tributaries and agricultural drains were conducted between May and November of 2003. Samples were analyzed for 4,4'-DDT and its metabolites 4,4'-DDE and 4,4'-DDD (*i.e.*, total DDT). Total DDT concentrations in the Wapato basin discharges ranged from 0.13 to 36 ng/L. DDT and its metabolites were not detected in discharges to the Lucerne basin. Human health and aquatic life (chronic exposure) water quality criteria for DDT (0.59 and 1.0 ng/L, respectively) were routinely exceeded in the Wapato basin. PCBs were not analyzed for in water samples.

Total DDT loads (mg/day) from Wapato basin discharges to Lake Chelan were calculated using total DDT concentrations and flows (i.e., total DDT concentration times instantaneous flow). The Keupkin Street site ranked highest at 43 mg/day, followed by Buck Orchards and Purtteman Creek at 6.1 and 5.8 mg/day, respectively. Water from the Keupkin Street site was collected from an irrigation drain manhole in an orchard area above Manson. The annual total DDT load to Lake Chelan from discharges sampled during the study was estimated at 25 grams per year.

The dissolved fraction (portion available for biological uptake) of DDT plus metabolites and PCBs in Lake Chelan was measured by use of semipermeable membrane devices (SPMDs). One SPMD was deployed in each basin for about a month during May, July, and October of 2003. Estimates of lake water concentrations between 180 and 200 feet depth found total DDT was higher in the Wapato basin than in the Lucerne basin. Total DDT concentrations were highest in May and June, followed by July and August, and October and November. During May and June, estimated concentrations of total DDT in the Wapato basin were two orders of magnitude higher than in the Lucerne basin. PCBs were generally not detected in SPMDs.

Estimated total DDT concentrations from SPMDs were compared to human health and aquatic life (chronic exposure) water quality criteria. Levels of total DDT estimated for the Wapato basin from SPMDs exceeded human health standards throughout the study and exceeded aquatic life criteria during the May and July sample periods. The Lucerne basin results were consistently within criteria.

Sediment

Surface sediments were collected at 20 locations within Lake Chelan. Three of these sites were alluvial, collected at the mouths of Railroad Creek, First Creek, and the Stehekin River. First Creek had the only alluvium sample with detectable total DDT, at a concentration of 11 *u*g/Kg. Concentrations of total DDT in Wapato basin sediments averaged 560 *u*g/Kg, compared to 120 *u*g/Kg in the Lucerne basin. Results for PCBs were low, ranging from 1.2 to 2.7 *u*g/Kg, and were mainly detected in the Wapato basin.

Two shallow (0 – 40 cm) sediment cores were collected, one each from the Lucerne and Wapato basins. Sedimentation rates were estimated using Pb^{210}, Cs^{137}, and stable Pb (lead) methods. The sedimentation rate for the Lucerne basin was estimated at 0.19 cm/yr. The Wapato basin rate (0.092 cm/yr) was estimated at about half the rate estimated for the Lucerne basin. These sedimentation rates are at the low end of the range reported for other Washington lakes. Total DDT concentrations in the Wapato core were an order of magnitude higher than sediment of roughly the same age from the Lucerne core. PCBs were not detected in cores.

The accumulation pattern for total DDT in the Lucerne basin core was similar to a recent core Ecology collected from Lake Osoyoos. Accumulation patterns for the Wapato core suggest sediment disturbance to the record or possibly changes in sedimentation rates.

Fish

A total of 200 game fish were collected and analyzed from Lake Chelan and Roses Lake. Species included burbot, mackinaw, kokanee, rainbow trout, and black crappie. Samples were analyzed as five-fish composites of fillet tissue. Some mackinaw and rainbow trout were also analyzed individually. The fish tissue criteria for protection of human health from DDT and metabolites are 32 *u*g/Kg for DDT and DDE, and 45 *u*g/Kg for DDD. The Washington State Department of Health is currently analyzing the data collected to determine if a fish advisory is warranted.

Concentrations of total DDT ranged from 6 to 2400 *u*g/Kg in Wapato basin fish tissue. The highest concentrations were found in mackinaw, followed by burbot, kokanee, and rainbow trout. The burbot from the Wapato basin were more than an order of magnitude higher for total DDT (146 to 499 *u*g/Kg) than burbot from the Lucerne basin (10 to 31 *u*g/Kg). Concentrations of total PCBs in fish tissue were much lower than total DDT, ranging from < 2 to 48 *u*g/Kg.

When compared to other fish tissue studies conducted in eastern Washington, average concentrations of total DDT in Lake Chelan fish were about four times higher. In contrast, concentrations of PCBs in Lake Chelan fish were only a fraction of the levels found in other eastern Washington studies.

A subset of mackinaw and burbot samples was also analyzed for polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). Analysis for PCDD and PCDF in tissue showed 2,3,7,8 TCDD toxic equivalent quotients (TEQs) from mackinaw tissue were an order of magnitude above criterion, while burbot tissue from the Lucerne basin averaged only slightly above. A TMDL strategy for TCDD TEQs in fish tissue was developed.

Bioaccumulation factors (BAFs) were calculated for total DDT in Lake Chelan fish using tissue concentrations and estimated dissolved water concentrations from SPMDs. The mean Lake Chelan BAF for total DDT was calculated at 207,190. In the development of the state adopted human health criteria for DDT in fish tissue, EPA used a bioconcentration factor (BCF) of 53,600. The BAF calculated from this study's data suggests that EPA's BCF is not protective for average consumers of fish.

Water Quality Targets

Water quality targets for Lake Chelan and Roses Lake TMDLs are the National Toxics Rule (NTR) human health criteria for edible fish tissue. The NTR has separate criterion for DDT, DDE, and DDD in fish tissue (see Table 3). This TMDL used the DDT and DDE criterion as the target for reductions needed in fish tissue compared to the mean total DDT concentration. The approach is conservative but serves to satisfy the margin of safety requirement for a TMDL. The levels not to exceed are 32 *u*g/Kg for total DDT, 5.3 *u*g/Kg for total PCBs, and 0.07 ng/Kg for dioxin TEQs in edible fish tissue. Water quality targets for discharges to Lake Chelan and Roses Lake are based on Washington State's standard, 1.0 ng/L, for the protection of aquatic life from DDT and metabolites in the water column.

A percent reduction approach in fish tissue contaminant concentrations was used for meeting the NTR human health targets. Mackinaw and burbot from Lake Chelan and rainbow trout from Roses Lake were used to determine the reductions needed to meet water quality targets. These fish represent the species with the highest mean concentration of total DDT and total PCBs sampled from each waterbody.

Percent reduction calculations for fish tissue from the Wapato basin and Roses Lake are as follows:

Wapato Basin Fish

% Reduction total DDT = [(943 *u*g/Kg – 32 *u*g/Kg) / (943 *u*g/Kg)] x 100 = **97 %**
% Reduction total PCBs = [(14.5 *u*g/Kg – 5.3 *u*g/Kg) / (14.5 *u*g/Kg)] x 100 = **63 %**
% Reduction dioxin TEQs = [(0.74 ng/Kg – 0.07 ng/Kg) / (0.74 ng/Kg)] x 100 = **90%**

Roses Lake Fish

% Reduction total DDT = [(96 *u*g/Kg – 32 *u*g/Kg) / (96 *u*g/Kg)] x 100 = **67 %**

Tributaries and agricultural drains to the Wapato basin were also assigned needed percent reductions of current loads to meet water quality targets. These percent reductions represent the amount of the total daily pollutant load that the tributaries and drains must be reduced to meet water quality criteria. Results from seasonal water sampling and harmonic mean flows were used to calculate TMDL loads.

The current mean contaminant loads, allowable TMDL loads, and load reductions needed to meet water quality criteria for discharges to Lake Chelan are shown in Table 1.

Table 1. Lake Chelan Tributary and Drains Current Total DDT Load and Reductions Needed.

Tributary or Drain Site	Current Total DDT Load (mg/day)	Allowable Load (mg/day)	Needed Load Reduction (mg/day)	Needed Percent Reduction
First Creek - SS01	2.2	12	0	0
Knapp Coulee - SS02	2.4	0.39	2.0	84
Culvert at Crystal View - NS13	0.14	0.04	0.10	71
Purtteman Creek - NS15	5.8	2.3	3.5	60
Culvert at Veroske's - NS16	3.0	0.21	2.8	93
Cooper drainage - NS18	1.5	0.10	1.4	93
Bennet Road - NS19	0.29	0.13	0.16	55
Keupkin Street - NS21	43	1.5	42	97
Buck Orchards - NS22	6.1	0.46	5.6	92
Wapato Lake + Joe Creek - NS23	0.04	0.22	0	0
Stink Creek - NS24	1.9	1.1	0.80	42
Mill Bay boat ramp - NS30	0.02	0.05	0	0
Totals	66.4	18.5	58.4	

See Figure 2 for sample site locations.

Roses Lake has only one major input – an agricultural drain. Current loads, allowable loads, and reductions needed to meet criteria for the Roses Lake orchard drain are shown in Table 2.

Table 2. Roses Lake Orchard Drain Current Total DDT Load and Reductions Needed to Meet Water Quality Standards.

Drain Site	Current Total DDT Load (mg/day)	Allowable Load (mg/day)	Needed Load Reduction (mg/day)	Needed Percent Reduction
ST11 Orchard drain	3.2	0.15	3.1	95

Margin of Safety

As required by the Clean Water Act, TMDLs must include a margin of safety (MOS) to take into account scientific uncertainties. The Lake Chelan/Roses Lake TMDL incorporated the MOS through use of conservative assumptions, including using the fish species most contaminated to base reduction targets, and using the NTR criterion for individual metabolites compared to total DDT. They are discussed further in the *Margin of Safety* section near the end of this report.

Monitoring Plan and Recommendations

A discussion outlining suggestions for post-TMDL monitoring and recommendations for reducing total DDT and total PCBs is included at the end of the report. The following is a short summary of these recommendations:

- Monitor contaminants in fish tissue, especially mackinaw, every five years to track progress towards meeting targets.
- Use natural attenuation for management of total DDT and total PCBs in sediments within Lake Chelan and Roses Lake.
- Conduct sub-basin investigations of potential total DDT sources to surface water.
- Implement wetland treatment, where feasible, to aid in reducing total DDT inputs from discharges to Lake Chelan and Roses Lake.
- Conduct an evaluation of total DDT concentrations in the water column from the Wapato basin to better quantify spatial and temporal variations.
- Evaluate the importance of total DDT loading from groundwater to the Wapato basin of Lake Chelan.

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Introduction

Lake Chelan has been listed by Washington State under Section 303(d) of the federal Clean Water Act for non-attainment of the U.S. Environmental Protection Agency (EPA) human health criteria for 4,4'-DDE (a breakdown product of DDT), as well as PCB-1254 and PCB-1260 (polychlorinated biphenyls), in edible fish tissue. Roses Lake, near Lake Chelan, is listed for 4,4'-DDE only.

These listings are based on tissue samples of kokanee, rainbow trout, and smallmouth bass collected by the Washington State Department of Ecology (Ecology) in 1992 and 1994 (Davis and Johnson, 1994; Serdar et al., 1994; Davis and Serdar, 1996). Currently the quality of Lake Chelan and Roses Lake fish tissue is being impacted by persistent chlorinated pesticides and PCBs. These organic chemicals do not occur naturally in the environment and are the result of anthropogenic (human-caused) activities.

The Clean Water Act requires states to set priorities for cleaning up 303(d) listed waters and to conduct a Total Maximum Daily Load (TMDL) assessment for each. A TMDL is an analysis of how much of a pollutant load a waterbody can assimilate without violating water quality standards.

This report describes the results of a technical study that monitored levels of DDT compounds, PCBs, and dioxin in Lake Chelan and Roses Lake drainages from May through November of 2003. It forms the basis of the TMDL evaluation and the assessment for meeting the human health criteria in fish tissue and water in the Lake Chelan basin.

Basin Description

Lake Chelan is located in north-central Washington State (Figure 1). It is the longest and deepest natural lake in the state and is considered pristine with its ultra-oligotrophic nutrient conditions. The Lake Chelan watershed drains a 924 square mile area. The lake is divided into two distinct basins, partially separated by a glacial sill (Kendra and Singleton, 1987). The larger of the two, the Lucerne basin, contains over 92% of the total lake volume and reaches a maximum depth of approximately 1,500 feet. The smaller Wapato basin receives most of its water input from the Lucerne basin and has a maximum depth of 400 feet (Patmont et al., 1989).

The two major water sources to Lake Chelan include the Stehekin River, contributing roughly 70% of the total input (Williams and Pearson, 1985) at the northern terminus of the lake, and Railroad Creek, accounting for about 10%, also located in the upper Lucerne basin. In addition, there are more than 50 smaller tributaries to the lake, many of which are ephemeral. A dam was constructed at the outlet of Lake Chelan in 1927 for power production; this raised the potential water level of the lake 21 feet. Operation of the dam maintains lake levels seasonally. Full-pool lake levels are generally maintained during summer months, while the lake is drawn down during the winter.

Roses Lake is one of a cluster of three small lakes often referred to as Manson Lakes. These lakes are located about a mile east of the Lucerne and Wapato basin divide and north of the city of Manson (Figure 2). The other two are Wapato Lake and Dry Lake. The Manson Lakes drain by way of Stink Creek to Lake Chelan. Stink Creek is made up from the outflow of Dry Lake and the discharge from Wapato Lake wetlands which include Joe Creek.

Lake Chelan uses include domestic and irrigation water supply, fisheries, power production, transportation, and water recreation.

Ninety percent of the basin is forested or open lands, the majority of which is managed by the U.S. Forest Service and National Park Service. Orchard and other agricultural lands comprise 3%, almost all of which are located in the Wapato basin. Irrigated fruit crops cover approximately 11,600 acres. Urban areas make up less than 1% and include the cities of Chelan and Manson in the Wapato basin and the smaller villages of Stehekin, Lucerne, and Holden in the Lucerne basin (Patmont et al., 1989; Lake Chelan Reclamation District, 1998; Chelan County Conservation District, 2000).

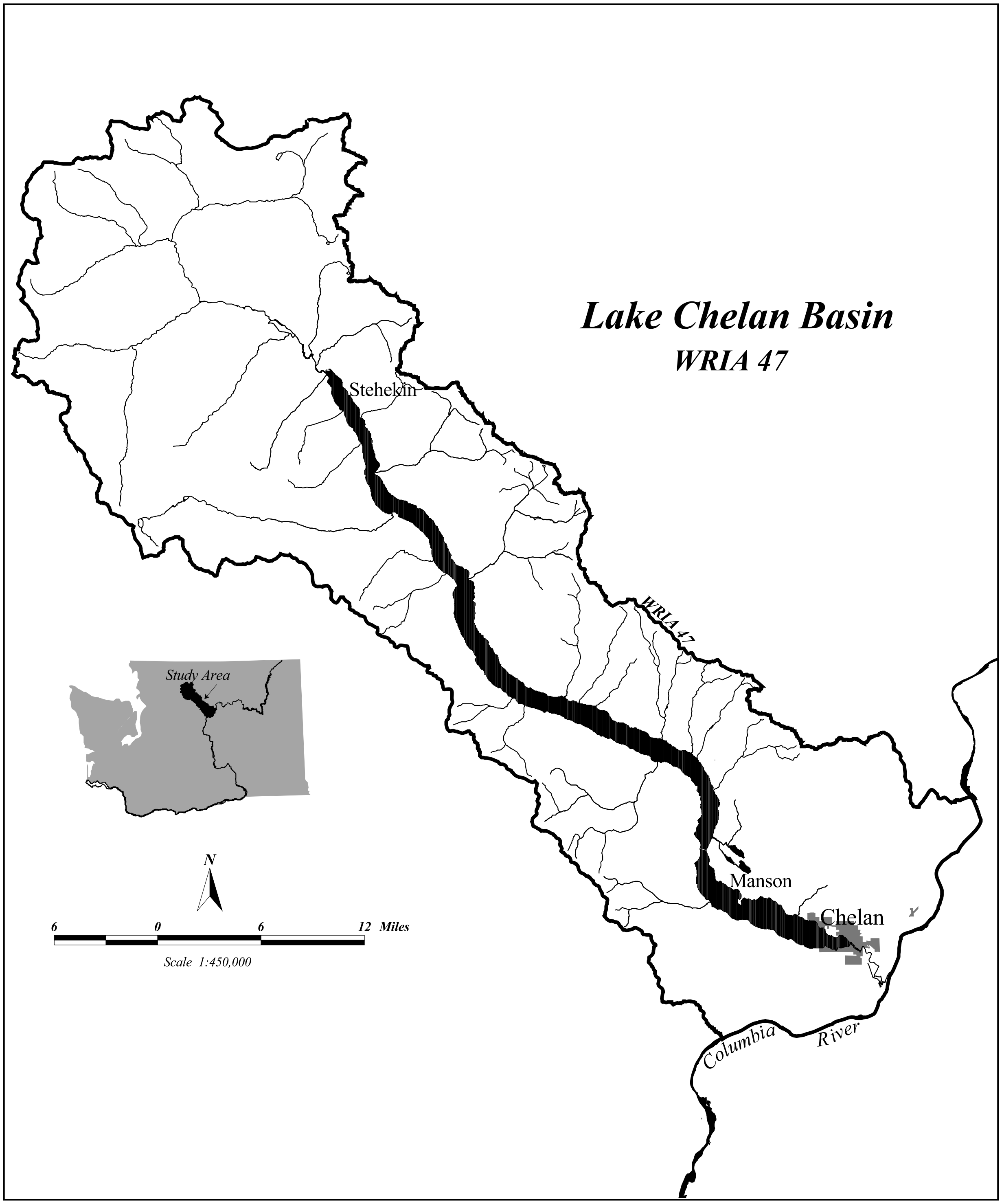

Figure 1. Lake Chelan Basin

Historical DDT and PCBs Data

DDT is a chlorinated insecticide that was used heavily in orchard lands throughout Washington State, including the Lake Chelan basin, from the 1940s until it was banned in 1972.

PCBs are chlorinated compounds that were widely used in industrial applications as insulating fluids, plasticizers, carbonless paper ink, heat transfer and hydraulic fluids, as well as a variety of other uses. Congress banned the use of PCBs in 1978. Specific sources of PCBs in Lake Chelan are unknown.

DDT and its breakdown products (DDE and DDD) and PCBs have been widely shown to be persistent in the environment. In aquatic environments, these contaminants are often found in the greatest concentrations in the fatty tissues of fish and other organisms. Concentrations can increase at higher trophic levels in the aquatic food chain, a process known as biomagnification. The sport fishery may be at most risk, as predatory fish species are near the top of the aquatic food chain.

Water

Table C1 in Appendix C compares data on DDT and metabolites in water from Lake Chelan, tributaries, and drains collected from 1996 to the present. The DDT and metabolites data are compared to Washington State aquatic life criteria for acute and chronic toxicity (Chapter 173-201A WAC) and the National Toxics Rule (NTR) human health water column criteria. The aquatic life criteria apply to the total of DDT, DDE, and DDD (total DDT[1]), whereas the NTR criteria apply to both DDT and metabolites.

In June 2002, through preliminary sampling for the present DDT/PCB TMDL, Lake Chelan and several tributary water samples were analyzed for DDT and metabolites DDE and DDD. No DDT forms were found above the 0.16 ng/L detection level, in Lake Chelan or in tributary samples from the Lucerne basin, including the Stehekin River. DDT and metabolites were, however, detected in three small discharges to the Wapato basin: a drainage sampled at Veroske's bus stop along Highway 150 (total DDT = 15.3 ng/L), a culvert roughly 0.2 miles east of the entrance to Crystal View development along Highway 150 (total DDT = 4.66 ng/L), and Stink Creek (total DDT = 1.45 ng/L).

Much higher total DDT concentrations were found in a study conducted by the Chelan County Conservation District (CCCD) in 1996 and 1997 along the south shore (Chelan County Conservation District, 2000). They reported DDE concentrations up to 110 ng/L; almost an order of magnitude higher than Ecology's June 2002 samples and two orders of magnitude higher than the chronic aquatic life criterion of 1.0 ng/L and the NTR criterion of 0.59 ng/L. These unusually high concentrations were from samples collected during run-off from agricultural drainages that included orchard lands.

[1] Refers to DDT as the total of 4,4' forms (i.e., 4,4'-DDT + 4,4'-DDE + 4,4'-DDD).

No useful data exist on PCB concentrations in water from Lake Chelan, Manson Lakes, or tributaries. Due to their low solubility, PCB concentrations are expected to be very low in water.

Sediment

Table C2 in Appendix C summarizes existing DDT and metabolite data from Lake Chelan and Manson Lakes sediment. Wapato Lake and Roses Lake sediments have historically contained the highest concentrations of total DDT found in the Lake Chelan basin, with an average total DDT concentration of 1,196 *u*g/Kg (Serdar et al., 1994; Johnson, 1997). Conversely, a recent survey conducted by the Lake Chelan Reclamation District (Burgoon and Cross, 2004) and Ecology found the average total DDT sediment concentration of these lakes to be two orders of magnitude lower at 46 *u*g/Kg. This apparent lowering of concentrations over a ten-year period indicates surface sediment concentrations in Manson Lakes may have improved.

The most extensive survey of total DDT concentrations in Lake Chelan sediments came from the Lake Chelan Water Quality Assessment, where concentrations of total DDT were found to be 20 times higher in Wapato basin than in the Lucerne basin. It was concluded that DDT-laden sediments from orchard activities had spread into the Wapato basin, but had not moved up-lake into the Lucerne basin (Patmont et al., 1989). The most recent sediment sample analyzed from Lake Chelan (1994) contained 20 *u*g/Kg total DDT (Davis and Serdar, 1996). The sample was taken near Wapato Point, an area where the 1986-87 study found concentrations of total DDT between 51 and 699 *u*g/Kg (Patmont et al., 1989).

A recent Ecology report evaluated freshwater sediment quality values for possible regulatory use in Washington State (Ecology, 2002). Eight existing data sets were compiled from agency staff in the United States and Canada known to be active in regulating sediments. The analysis considered only ecological effects, not human health effects. The sediment quality document presents a range of numerical criteria for total DDT from 1.2 to 570 *u*g/Kg in freshwater. This may help put levels of total DDT in sediments from Lake Chelan and Roses Lake into perspective.

Fish

Table C3 in Appendix C summarizes data on total DDT and PCBs analyzed in fish collected from Lake Chelan and Manson Lakes. Data are compared to the NTR criteria. These human health criteria are based on EPA bioconcentration factors (BCF) which were developed in the laboratory by analysis of tissue from fish equilibrated to a known concentration of a contaminant in the surrounding water. The BCF was calculated by dividing the tissue concentration by the water concentration. The NTR example is: DDT fish tissue concentration of 31.6 *u*g/Kg for 4,4'-DDE divided by a water column concentration 0.00059 *u*g/L equals a BCF of 53,600. The criteria apply to edible fish fillet.

Ecology first discovered elevated concentrations of DDT compounds in fish from Lake Chelan in 1982 as part of the Basic Water Monitoring Program (Hopkins et al., 1985). Since then, other

Ecology studies have shown that total DDT concentrations in Lake Chelan and Roses Lake fish have remained high, exceeding NTR human health criteria.

In the 1987 Water Quality Assessment of Lake Chelan (Patmont et al., 1989), the geometric mean for total DDT in 22 fish samples collected from 1982 through 1986 was compared to the nationwide geometric mean for total DDT during 1980 through 1981 (Schmitt et al., 1985). Fish from Lake Chelan were roughly three times higher (1,000 *u*g/Kg vs. 300 *u*g/Kg) than what was found nationally. However, the Lake Chelan total DDT concentrations were comparable to concentrations found in certain other areas of Washington State, such as the lower Yakima, Middle Columbia, and Okanogan River basins, where DDT has been used historically on orchards (Patmont et al., 1989).

More recently, EPA found total DDT levels in Lake Chelan fish to be very high among over 140 other lakes tested as part of their National Fish Tissue Study (EPA, 2002 unpublished). Mackinaw (lake trout) fillet was reported with levels of 1,481 *u*g/Kg. The study is ongoing, so the findings have not yet been published.

Very little information is available on total DDT levels in Roses Lake fish. In 1992, an Ecology study found levels of total DDT in rainbow trout fillets at 103 *u*g/Kg (Serdar et al., 1994). Based on Ecology data, this was slightly less than twice the state median of 60 *u*g/Kg total DDT (Davis, 1996). These findings led to the 303(d) listing for 4,4'-DDE in Roses Lake.

Information on PCB concentrations in Lake Chelan fish tissue is even more limited. Fish analyzed by Ecology in 1992 and 1994 contained PCB levels ranging from 12 to 99 *u*g/Kg and were the basis for the PCB fish tissue listings for Lake Chelan in 1996 and 1998 (Davis and Johnson, 1994; Davis and Serdar, 1996). The EPA National Fish Tissue Study also reported mackinaw contained PCB concentrations of 32.6 *u*g/Kg and dioxin TEQs[2] at 1.7 ng/Kg (parts per trillion), both at levels of concern.

An important issue pointed out in Ecology studies of Lake Chelan was the considerable differences in total DDT levels among various species, age/size classes within the same species, lipid content, and type of tissue analyzed (whole body vs. fillet vs. eggs).

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[2] The World Health Organization and EPA have adopted a toxic equivalency (TEQ) system to estimate the toxicity of the 17 different dioxin congeners, compared to 2,3,7,8 TCDD. Each of the seventeen 2,3,7,8 TCDD congeners has been assigned a toxicity equivalence factor (TEF). The 2,3,7,8, TCDD is considered most toxic and has a value of one. A congener 1,000 times less toxic than 2,3,7,8 TCDD would have a TEF of 0.001.

Applicable Water Quality Standards

Chapter 173-201A of the Washington Administrative Code (WAC) classifies the surface waters of Lake Chelan as "lake class". Under these standards, feeder streams to a lake are classified as Class AA (extraordinary). The characteristic uses defined in the WAC for lake class and Class AA waters, include but are not limited to the following (Chapter 173-201A-030[5] WAC):

(i) Water supply (domestic, industrial, agricultural).
(ii) Stock watering.
(iii) Fish and shellfish:
Salmonid migration, rearing, spawning, and harvesting.
Other fish migration, rearing, spawning, and harvesting.
Clam and mussel rearing, spawning, and harvesting.
Crayfish rearing, spawning, and harvesting.
(iv) Wildlife habitat.
(v) Recreation(primary contact recreation, sport fishing, boating, and aesthetic enjoyment).
(vi) Commerce and navigation.

Toxic substances are addressed in the water quality standards under WAC 173-201A-030(c)(vii):

Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristics water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health, as determined by the department (see WAC 173-201A-040 and 173-201A-050).

Other passages addressing toxic substances found in WAC 173-201A-040 are as follows:

(1) Toxic substances shall not be introduced above natural background levels in waters of the state which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic toxicity to the most sensitive biota dependent on those waters, or adversely affect public health, as determined by the department.

(2) The department shall employ or require chemical testing, acute and chronic toxicity testing, and biological assessments, as appropriate, to evaluate compliance with subsection (1) of this section and to ensure that aquatic communities and the existing and characteristic beneficial uses of waters are being fully protected.

(5) Concentrations of toxic, and other substances with toxic propensities not listed in subsection (3) of this section shall be determined in consideration of USEPA Quality Criteria for Water, 1986, and as revised, and other relevant information as appropriate. Human health-based water quality criteria used by the state are contained in 40 CFR 131.36 (known as the National Toxics Rule).

(6) Risk-based criteria for carcinogenic substances shall be selected such that the upper-bound excess cancer risk is less than or equal to one in one million.

In 1992, EPA established water quality criteria for the protection of human health from priority pollutants, referred to as the National Toxics Rule (40 CFR 131). The federal Clean Water Act required states without sufficient human health criteria for priority pollutants to adopt the National Toxics Rule (NTR). Human health criteria are calculated for an increased lifetime cancer risk of one in one million (10^{-6}) from the consumption of fish or water. Water quality criteria that apply to the 303(d) listed chemicals addressed in this TMDL for Lake Chelan basin are shown in Table 3.

Table 3. Washington State Water Quality Criteria for DDT and Its Metabolites, PCBs, and 2,3,7,8 TCDD.

	Criteria for Protection of Aquatic Life		Criteria for Protection of Human Health		
Chemical	Freshwater Acute (ng/L)	Freshwater Chronic (ng/L)	Water and Fish Consumption (ng/L)	Fish Consumption (ng/L)	Fish Tissue
4,4'-DDT			0.59	0.59	32 *ug*/Kg
4,4'-DDE			0.59	0.59	32 *ug*/Kg
4,4'-DDD			0.83	0.84	45 *ug*/Kg
DDT and metabolites	1,100	1.0			
PCBs	2,000	14	0.17	0.17	5.3 *ug*/Kg
2,3,7,8 TCDD			0.000014		0.07 ng/Kg

Washington State has not formally adopted freshwater sediment quality standards. Instead recommended numerical Freshwater Sediment Quality Values (FSQVs) are used as guidelines. The recommended guidelines are intended for the protection of sediment-dwelling organisms from toxic effects of chemical contaminants. Until formal adoption as standards, Ecology evaluates freshwater sediments on a case-by-case basis through use of biological testing (bioassays or benthic community analysis) or comparison to available FSQVs.

Many FSQVs have been used in North America to evaluate pesticides and PCBs, ranging from levels known to always produce biological effects to levels which rarely cause biological effects. Five effect levels are presented in Table 4, for comparison to study data (Avocet Consulting, 2002; 2003).

Table 4. Selected Freshwater Sediment Quality Values for Total DDT and Total PCBs (ug/Kg, dw).

Freshwater Sediment Quality Value	Total DDT	Total PCBs	Effects Level
Apparent Effects Threshold (AET)	NA	21	Level above which biological effects have always been observed.
Floating Percentile Method (FPM)	NA	60	Proposed level which optimizes reliability and sensitivity in predicting adverse biological effects.
Probable Effects Level (PEL)	4.8	280	Level at which adverse biological effects are frequently seen.
Lowest Effects Level (LEL)	7	70	Level at which adverse biological effects are seen in 5% of benthic species.
Threshold Effects Level (TEL)	1.2	34	Level below which adverse biological effects rarely occur.

NA = Data not available.

Scope of the TMDL

Geographic Area

This TMDL assessment covers all of Lake Chelan watershed, including discharges to the lake, from the headwaters of the Stehekin River to the point of discharge to the Columbia River (Water Resource Inventory Area 47).

Pollutants

The following chemicals found in sediments, water, and fish tissue are included in this TMDL study:

- 4,4'-DDT
- 4,4'-DDE (a DDT metabolite)
- 4,4'-DDD (a DDT metabolite)
- PCBs as Aroclors or total PCBs
- Dioxins and furans as TEQs

The waterbodies, along with the associated waterbody identification numbers from the Lake Chelan basin and the specific TMDL parameters from the 1998 303(d) list, are presented in Table 5. Copies of the decision matrices for these 303(d) listings can be found in Appendix A.

The basis for the 303(d) listing of Lake Chelan for 4,4'-DDE, PCB-1254, and PCB-1260 in edible fish tissue is from the Ecology study by Davis and Serdar (1996) conducted in 1994. Roses Lake is listed for 4,4'-DDE in edible fish tissue based on the Ecology study by Serdar et al. (1994) conducted in 1992. Dioxin in fish tissue was included in the TMDL evaluation when results from the EPA's *National Fish Tissue Study* (2002) found levels of concern.

Table 5. Lake Chelan and Roses Lake 1998 303(d) Listings for Edible Fish Tissue.

Waterbody	New WBID	Old WBID	Parameter	Listed in 1996
Lake Chelan	292NWR	WA-47-9020	4,4'-DDE PCB-1254 PCB-1260	Yes
Roses Lake	370XQC	WA-47-9037	4,4'-DDE	Yes

Study Design

Strategy and Objectives

Samples were collected and analyzed for a TMDL assessment of total DDT and PCBs in Lake Chelan from May through November 2003. The overall goals of the project were to (1) develop a TMDL strategy based on an understanding of the levels and distribution of total DDT and PCBs in the Lake Chelan basin, and (2) determine if contaminant sources can be controlled or reduced to acceptable levels in the lake sport fishery. How to deal with potential loading reductions will be addressed in the implementation phase of the TMDL process.

Historically, DDT was applied to orchard lands in the basin, though specific sources have not been identified. Sources of PCBs in the lake fish are unclear, as significant sources within the basin are not obvious and have not been identified. Atmospheric transport from areas outside the basin may be an important source. The levels of PCBs in Lake Chelan fish are low compared to the levels of total DDT.

Traditionally, TMDLs determine the maximum contaminant load a waterbody can accept and still meet water quality standards. Portions of that load are then allocated to sources, so that in total they do not exceed water quality standards. The 303(d) listings addressed in this TMDL assessment are for fish tissue. Because a complex relationship exists between concentrations of total DDT and PCBs in fish, water, and sediment, allocating loads between sources is difficult. Lake Chelan sediments act as a sink for DDT compounds and PCBs from decades of use. These sediments likely act as a major source of contaminants to the fish via the food chain.

Although the entire Lake Chelan basin was included in the project area, Wapato basin was the focus of this TMDL study. Water Quality studies of Lake Chelan by Patmont et al. (1989) and Ecology (Coots and Era-Miller, 2003) have suggested loading of DDT compounds is a lower lake issue. The historical land uses and the urban setting in the lower basin direct the primary focus on the Wapato basin. The Lucerne basin does have limited agricultural land use but it is minimal compared to the Wapato basin. Most of the Lucerne basin is in national forest or a designated wilderness area.

Three sampling elements were employed to develop the TMDL assessment:

- Determine current total DDT, PCBs, and dioxin concentrations in edible fish tissue from Lake Chelan.
- Assess current levels of total DDT and total PCBs in water and sediment in Lake Chelan and Roses Lake from tributaries and irrigation drain inputs.
- Construct a history of total DDT and total PCB inputs to Lake Chelan sediments by use of dated sediment cores.

Sections that follow detail the study design for collection and analysis of water, sediment, and fish samples.

Water

Water samples were collected to (1) identify sources of DDT compounds and PCBs, (2) assess compliance with aquatic life and human health criteria, and (3) calculate pollutant loading.

Tributaries and Drains

The preliminary sampling effort by Ecology, conducted June 10-12, 2002, evaluated water column concentrations of DDT compounds in Lake Chelan and tributaries or drains entering the lake; 11 sites were sampled for DDT, DDE, and DDD. One water sample was collected from the Chelan River near the lake outlet and from each major tributary. Two culverts were found flowing to the lake and were also sampled during the survey. The Ecology Manchester Environmental Laboratory (MEL) analyzed the samples using the "large volume injection" technique to achieve detection limits of 0.16-0.17 ng/L. Sample results are summarized in Table C1 in Appendix C.

Analysis of preliminary surface water samples detected DDT compounds in three of the 11 sites sampled. Results from a small drainage sampled at Veroske's bus stop along Highway 150, a small culvert roughly 0.2 miles east of the entrance to Crystal View development along Highway 150, and Stink Creek exceeded the NTR criteria for DDT compounds (Figure 2, and Table C1, Appendix C). Detected concentrations of total DDT ranged from 0.52 - 15 ng/L. No DDT compounds were detected from drainages in the Lucerne basin above Stink Creek. Samples were collected in the upper basin during snow melt to evaluate possible DDT and metabolite contributions. Antecedent precipitation was very low prior to sampling, and very few tributaries were discharging in the Wapato basin.

Based on the preliminary round of sampling, 11 tributaries, 6 drains, and Lake Chelan near the outlet were selected for sampling. Water samples were collected on five occasions from May through November 2003. Sites in the Lucerne basin where DDT compounds were not detected during the preliminary sample survey were subsequently not sampled. Results were used to establish a loading regime for the lake. Pollutant loads were determined by multiplying the pollutant concentration by the instantaneous stream flow. Flow was determined at all sample sites. For streams where a flow measurement by wading was not an option, flow was estimated. The U.S. Geological Survey (USGS) maintains a long-term gaging station on the Stehekin River.

In addition to DDT compounds, samples for total suspended solids (TSS), turbidity, and total organic carbon (TOC) were also collected. Locations of water sample sites are shown on Figures 2 and 3.

The Lake Chelan Reclamation District (LCRD) concurrently conducted a study on the Manson Lakes, which includes Roses Lake (Burgoon and Cross, 2004). In the LCRD study, surface water inputs to the Manson Lakes were sampled for DDT compounds and ancillary parameters. Data generated from the study were used to develop the TMDL load allocations for Roses Lake.

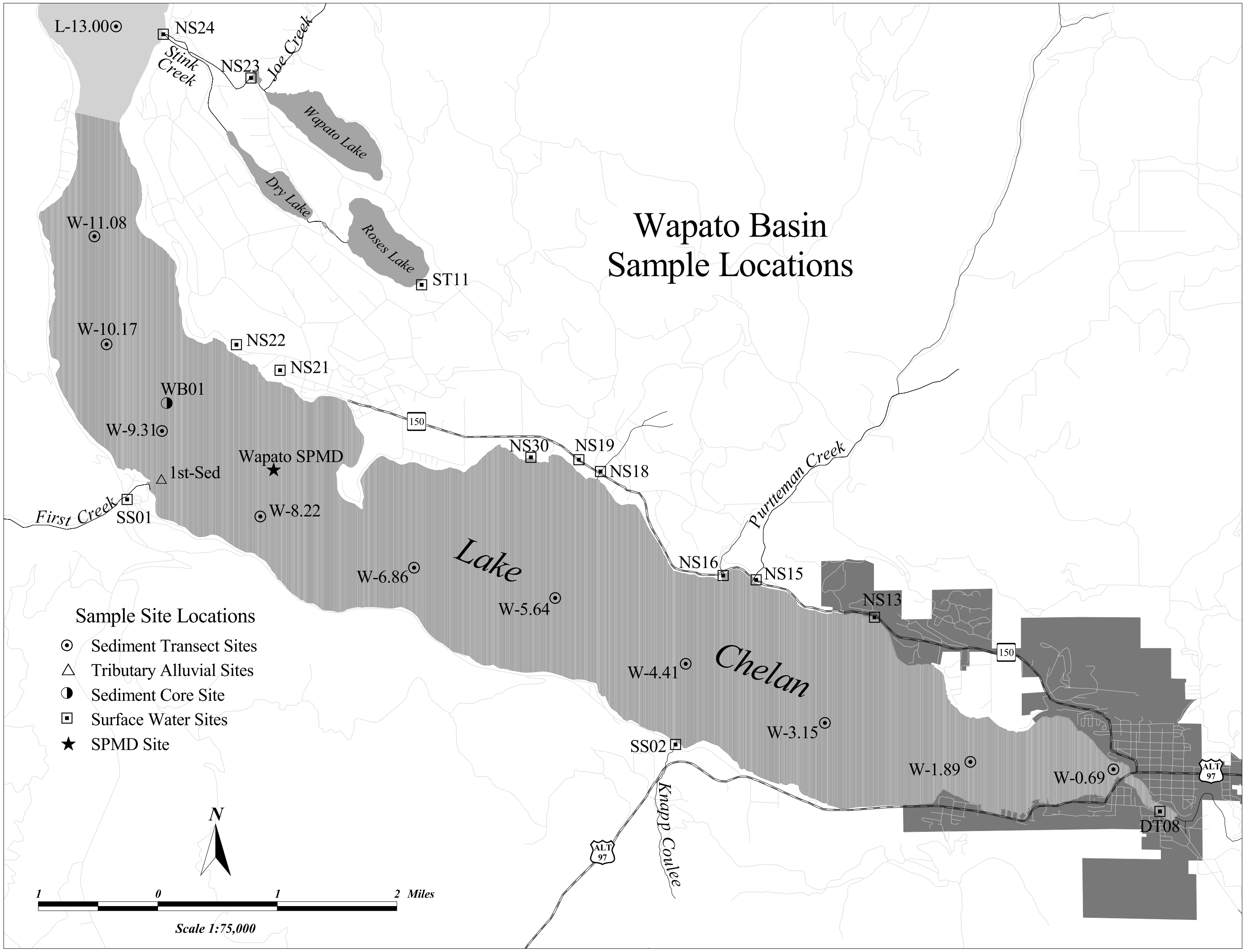

Figure 2. Wapato Basin Sample Locations

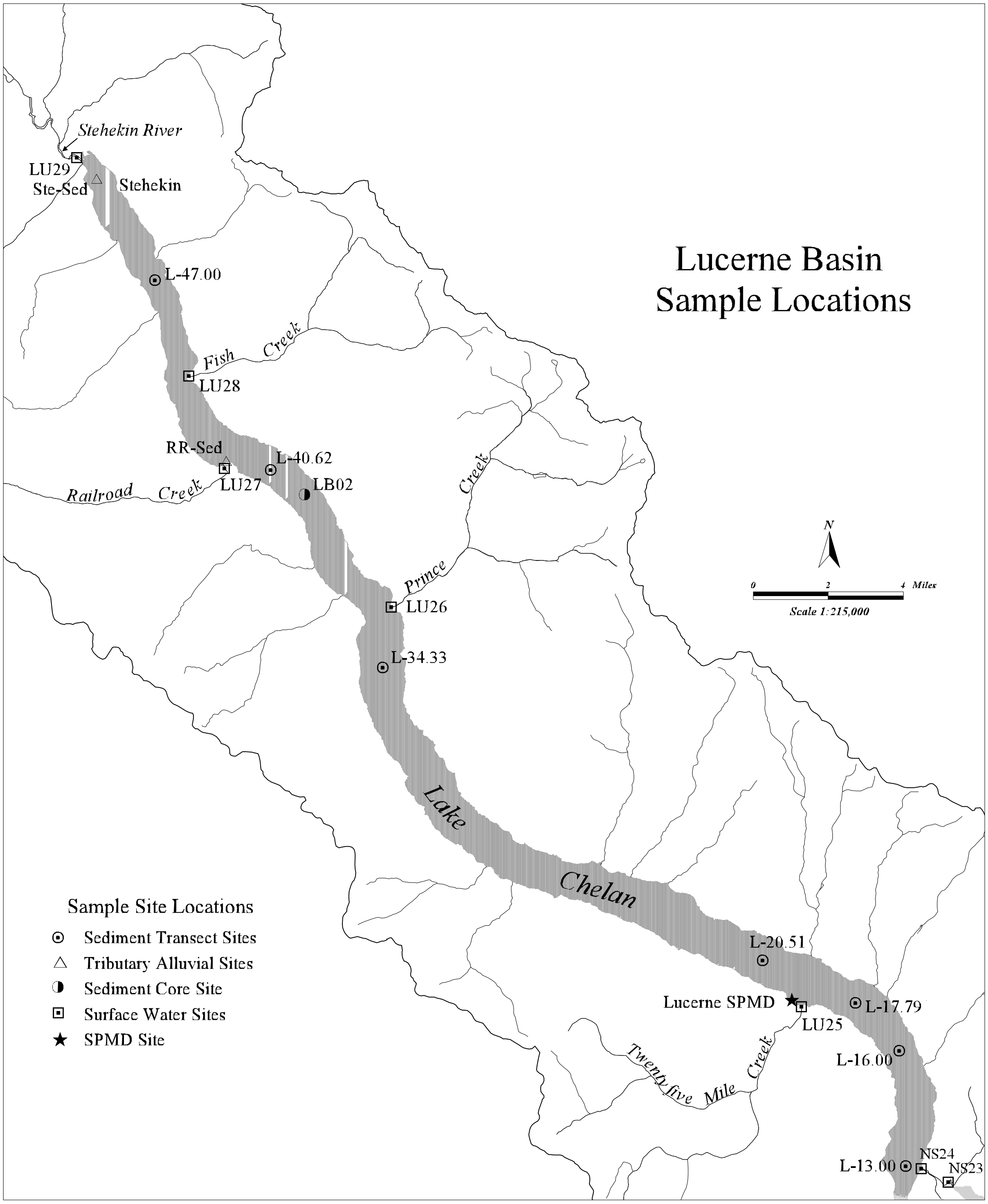

Figure 3. Lucerne Basin Sample Locations

Semipermeable Membrane Devices

Water column data were generally unavailable for DDT compounds and PCBs in Lake Chelan. Because of low solubility, quantification of DDT compounds and PCBs in the lake required special sampling and analytical methods. Semipermeable membrane devices (SPMDs) were used to quantify the pollutants. SPMDs are passive samplers which concentrate hydrophobic organic chemicals and provide a time-weighted average of the bioavailable fraction (dissolved) of the contaminants. SPMDs were developed by the USGS, Columbia Environmental Research Center and commercially available through Environmental Sampling Technologies (EST), St. Joseph, Missouri (www.spmds.com). Details of SPMD construction and use can be found at wwwaux.cerc.cr.usgs.gov/spmd.

SPMDs are made up of a flat low-density polyethylene tube (91 x 2.5 cm) containing triolein, a neutral lipid. When submerged in water, only the dissolved fraction of the lipophilic contaminants are diffused through the membrane wall and concentrated. SPMDs are usually deployed for 20-30 days. After retrieval, the SPMDs are extracted and analyzed for target chemicals. SPMDs have been used in other local studies for detecting trace organic contaminants in water (EILS, 1995; McCarthy and Gale, 1999; Johnson et al., 2004).

Sampling rates of SPMDs have been determined in the laboratory for a number of organic compounds. Sampling rate is dependent on temperature, water velocity, and biofouling. Permeability/Performance Reference Compounds (PRCs) are used to make adjustment for the effect of water velocity and biofouling on sampling rates. PRCs are compounds not normally found among the target analytes, with the ability to escape through the SPMDs membrane wall. Loss rates of PRCs during deployment are related to the target analyte uptake. By measuring PRC loss rates during laboratory calibration and field deployment, an exposure adjustment factor is determined.

Two PRCs were spiked into each SPMD for the Lake Chelan study – PCB-4 (2,2'-dichlorobiphenyl) and PCB-29 (2,4,5-trichlorobiphenyl). These congeners are not present at significant amounts in commercial mixtures of PCB Aroclors.

The contaminant concentration in the SPMD, laboratory calibration data, PRCs recovery, and field temperature are used to determine the average dissolved concentrations in the water column (Huckins et al., 2002).

SPMDS were deployed in Lake Chelan at two locations: one in the middle Wapato basin and one in the lower Lucerne basin at an approximate sample depth between 180 and 200 feet. Sample locations were selected that were accessible throughout the sample period, relatively flat at the target depth, and would generally represent the basin. These sites are shown on Figures 2 and 3. Three periods were targeted: May, July, and October. May and October were chosen as potential run-off periods, while July was selected to capture the dry season. Deployment for all three events averaged 28 days. SPMD extracts were analyzed for DDT, DDE, DDD, and PCB Aroclors, with one subset of samples analyzed for PCB congeners.

Temperature was monitored throughout each SPMD deployment period. Ancillary parameters were also collected at the beginning and end of each deployment for turbidity and TOC.

Sediment

A combination of surface sediments and core samples were collected to (1) determine the spatial extent of DDT compounds and PCB contamination in Lake Chelan, (2) assess current impacts from selected tributaries to the lake, and (3) evaluate the depositional history of DDT compounds and PCBs in the Wapato and Lucerne basins.

Limited data, previously discussed, suggested levels of DDT compounds and PCBs may be declining, but current levels and the spatial extent of contamination were unknown. Historical sediment samples targeted drain discharges in the Wapato basin and a few tributaries in the Lucerne basin.

Sediment Transect

No previous studies have conducted a comprehensive look at DDT compounds and PCBs in surface sediments throughout Lake Chelan. Only one sediment sample had been analyzed for PCBs, and the few results on DDT compounds in the Lucerne basin were over 15 years old (Table C2, Appendix C).

To fill this data gap, 17 surface sediment samples were collected from the top 2 cm and distributed along a longitudinal transect within Lake Chelan. Results from the sediment transect allow for an evaluation of the concentration gradient along the axis of the lake. Other studies have shown the Wapato basin is the primary area of concern, and pesticides have not migrated up-lake (Patmont et al., 1989). A total of ten sediment samples were collected from the Wapato basin, and seven samples from the Lucerne basin. Starting in the Wapato basin near the lake outlet, sediment samples were collected roughly every 1.25 mile up-lake to the basin sill (Figure 2). Collection of sediments from the Lucerne basin started near Stehekin, with sites distributed roughly every five miles representing much larger segments of the lake (Figure 3). Conditions in the Lucerne basin were expected to be more homogenous than those in the Wapato basin.

Sediment sample locations are shown on Figures 2 and 3, and their associated coordinates are presented in Table E2 in Appendix E.

Tributary Discharged Sediments

Surface sediments were also collected adjacent to major tributaries to assess if contaminants are continuing to be discharged into the lake and to determine if DDT compounds and PCBs are associated with Lucerne basin drainages. Estimates of pollutant loading cannot be calculated from analysis of discharged sediments, but the presence or absence of target analytes in surface sediments can help prioritize pollution control activities.

Surface sediments from the alluvium of tributary discharges to Lake Chelan were analyzed for DDT compounds, PCBs, TOC, and grain size. The alluvium sediment survey collected a total of three composite samples (three individual grabs per composite), one each from First Creek, Railroad Creek, and the Stehekin River sediments in Lake Chelan (Figure 1). Initially, sediments from Twenty-Five Mile, Prince, Fish, and Stink creeks were proposed for sampling, but fine sediments could not be located for sampling, so these sites were abandoned. Tributary sediment sample locations are shown on Figures 2 and 3, and their associated coordinates are presented in Table E3 in Appendix E.

Sediment Cores

Decades have passed since the manufacture and use of DDT and PCBs were banned in the United States. Over time, concentrations of these persistent chemicals are expected to decline. However, current data were not available to evaluate contaminant trends in Lake Chelan. To evaluate the depositional history of these contaminates, two sediment cores were collected from Lake Chelan at one site each in the Wapato and Lucerne basins. Deep locations provide the most undisturbed sediment record. With consideration to sampling conditions and equipment limitations, cores were collected at the deepest point possible in each basin.

Sediment cores were collected with a 50-cm box core. Individual one-centimeter horizons were sliced from each core. Horizons were analyzed for DDT compounds, PCBs, ^{210}Pb, ^{137}Cs, total lead, and TOC. The final selection of horizons for analysis of DDT compounds and PCBs was determined after core dating using ^{210}Pb and ^{137}Cs techniques. Horizons not initially analyzed were archived for potential analysis at a later date.

Sediment core sample locations are shown on Figure 2 and 3, and their associated coordinates are presented in Table E4.

Fish

The purpose of collecting fish tissue samples was to (1) determine current levels of DDT compounds and PCBs in edible fish tissue, (2) compare current levels in fish tissue to the NTR Criteria for Human Health to determine if criteria are still being exceeded, (3) evaluate if the NTR Human Health water quality criteria are appropriate for Lake Chelan or if site-specific water quality standards are needed, and (4) provide data to the Washington State Department of Health (WDOH) for a human health assessment and for a fish consumption advisory.

Collection and analysis of fish tissue samples targeted three geographical areas: Wapato basin, Lucerne basin, and Roses Lake. These areas represent the urban/industrial population center of the Wapato basin; the rural, mostly natural and unpopulated area of the Lucerne basin; and the agriculturally dominated drainage of Roses Lake.

The Washington Department of Fish & Wildlife (WDFW) biologists in the area were consulted to help determine what species of fish to collect for tissue samples. Discussions and recommendations for target species were based on a number of issues such as sport species most often caught and consumed, previous fish collections, availability, and 303(d) listings.

According to the WDFW (Art Viola, personal communication, 2002), the three most commonly caught and consumed sportfish species from Lake Chelan are mackinaw, commonly called lake trout (*Salvelinus namaycush*); kokanee, which are landlocked sockeye salmon (*Oncorhynchus nerka*); and rainbow trout (*Oncorhynchus mykiss*). In addition to the three most often consumed species, burbot (*Lota lota*) was also sampled and analyzed. The burbot fishery has experienced an increased interest in recent years. Burbot are bottom-dwelling predators and the only member of the freshwater cod family. Usually consumed when caught, burbot have a high quality white flesh.

Fish consumption patterns were less clear for Roses Lake. The WDFW currently plants three fish species in Roses Lake: rainbow trout, brown trout (*Salmo trutta*), and black crappie (*Pomoxis nigromaculatus*). Rainbow trout and black crappie samples were collected. Brown trout proved difficult to collect. They are hard to catch on hook and line, and are not known to inhabit the shallows which would allow collection by electro-shocking.

Skin-on fillets from mackinaw, rainbow, kokanee, and black crappie, and skin-off fillets from burbot, were analyzed for DDT compounds, PCBs, and percent lipids. The analysis of DDT compounds included 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD. PCBs were analyzed as Aroclor equivalents[3], with a subset of the samples analyzed for individual PCB congeners. Lower limits of detection are possible with PCB congener analysis than Aroclor analysis, and allow quantification of individual PCB compounds that have different levels of toxicity. The co-planar PCB compounds are much more toxic than planar PCBs and may be important to WDOH's health risk assessment. Lipid analysis was conducted for assessing the bioconcentration potential between and within fish species.

In addition to the above mentioned analyses, Ecology took the opportunity to evaluate dioxin levels in the sport fishery by analyzing a subset of tissue samples. Although not 303(d) listed, the EPA's National Fish Tissue Study found dioxins at levels of potential concern in Lake Chelan fish (EPA, 2002 unpublished). Results from the dioxin analysis were also forwarded to the WDOH to determine if a health advisory is warranted for Lake Chelan.

Each of the four fish species collected from Lake Chelan was analyzed as composites consisting of five fish. In addition to the composite samples, 50 individual mackinaw and four rainbows were also analyzed. Table 6 summarizes the number and location of the fish samples. Table D1 in Appendix D presents biological information for fish collected during the study.

Table 6. Distribution of Fish Species and Locations of Collection.

Location	Species	Scientific Name	Tissue Type	Number of Samples	
				Composites*	Individuals
Lake Chelan					
Wapato basin	Mackinaw	*Salvelinus namaycush*	Skin-on fillet	10	50**
	Kokanee	*Oncorhynchus nerka*	Skin-on fillet	7	
	Burbot	*Lota lota*	Skin-off fillet	7	
	Rainbow Trout	*Oncorhynchus mykiss*	Skin-on fillet	3	4
Lucerne basin	Burbot	*Lota lota*	Skin-off fillet	3	
Roses Lake	Rainbow Trout	*Oncorhynchus mykiss*	Skin-on fillet	1	
	Black Crappie	*Pomoxis nigromaculatus*	Skin-on fillet	1	

* Composites of 5 fish each.
** 30 individuals for analysis of DDT compounds, and 20 individuals for analysis of PCB congeners.

[3] Monsanto developed and sold PCB mixtures under the trade name Aroclors. PCBs are typically analyzed as equivalent concentrations of commercial Aroclor mixtures (*e.g.*, PCB-1260) or as individual compounds, referred to as PCB congeners.

Methods

Field Procedures

Water

Surface Water

Water samples collected for DDT compounds and ancillary parameter analysis from tributaries and agricultural drains were depth and width integrated, when possible. In most cases the water sources were too small or shallow for a depth integrated sampler, so samples were hand composited. Field personnel used extra sample jars to transfer sample aliquots. The transfer jars were cleaned to EPA (1990) QA/QC specifications and certified for trace organic analyses.

Sampling personnel wore non-talc nitrile gloves while collecting samples. Sample water was composited at each site by hand, splitting it into individual sample bottles. Sample containers were filled one-third from each of the composite sub-samples. Samples collected for DDT compounds were collected in one-gallon glass bottles. Grab samples for TSS and turbidity were collected in 1,000 and 500 mL poly bottles, respectively.

At sample sites that were wadable, flow was measured using a Marsh-McBirney 201 velocity meter and standard top-setting wading rod. Operating procedures for determining discharge followed those described in WAS (1993). In the larger Lucerne basin tributaries, where a flow measurement by wading was not an option due to depth or velocities, flow was estimated as a percentage of the Stehekin River discharge, based on the ratio of the drainage area average annual precipitation for the Stehekin River compared to the tributary. To determine discharge at sample sites where flow was too small to use wading techniques, bucket and stopwatch methods were employed. At the Bennet Road and Keupkin Street manhole sites, flows were estimated by "The California Pipe Method of Water Measurement" (Vanleer, 1922) using the equation:

$$Q = 8.69(1-a/d)^{1.88}\, d^{2.48}$$

where: a = distance above water to inside top of pipe
d = internal diameter of pipe
Q = discharge (ft^3/second)

Sample site locations were determined by hand-held GPS and recorded in field log books. Samples were placed in coolers immediately following collection, and kept on ice until delivered to the MEL under chain-of-custody the following day. Requirements for containers, preservation, and holding times are listed in Table 7.

Table 7. Containers, Preservatives, and Holding Times for TMDL Samples (PSEP, 1996).

Analyte	Container[1]	Preservation	Holding Time
DDT in Water	Certified 1-gallon Glass Teflon Lid Liner	Cool to 4° C	7 Days Extraction 40 Days to Analysis
TOC in Water	60 mL n/m Poly	HCl to pH<2, 4° C	7 Days
TSS in Water	1-liter w/m Poly	Cool to 4° C	28 Days
Turbidity	500 mL Poly	Cool to 4° C	48 Hours
DDT/PCB SPMDs	1-gallon metal can[1]	Freeze, -18° C	1 Year Frozen
DDT, PCBs in Sediment	Certified 4-oz Glass, Teflon Lid Liner	Cool to 4° C	7 Days Extraction 40 Days to Analysis[2]
Sediment ^{210}Pb	Polystyrene	Freeze, -18° C Cool to 4° C	NA
Sediment ^{137}Cs	Polystyrene	Freeze, -18° C Cool to 4° C	NA
Sediment Total Lead	4-oz Glass	Freeze, -18° C Cool to 4° C	2 Years 6 Months
TOC in Sediment	Glass or Polyethylene	Freeze, -18° C Cool to 4° C	6 Months 14 Days
Grain Size	Glass or Polyethylene	Cool to 4° C	6 Months
DDT, PCBs in Fish	Certified 4-oz Glass Teflon Lid Liner	Cool to 4° C	7 Days Extraction 40 Days to Analysis[2]
Lipids in Fish	Certified 4-oz Glass Teflon Lid Liner		NA
Dioxins in Fish	Certified 8-oz Amber Glass Teflon Lid Liner[1]	Freeze, -18° C Cool to 4° C	7 Days Extraction 40 Days to Analysis

[1] Containers were obtained from MEL, except SPMD and dioxin containers were supplied by the contract laboratories
[2] One year if frozen
NA = Not applicable

Semipermeable membrane devices

SPMDs were deployed and retrieved following guidance found in Huckins et al. (2000).

The SPMD membranes, and stainless steel canisters to house the membranes, were purchased from Environmental Sampling Technologies (EST). SPMD membranes were preloaded onto spindles by EST in a clean room and shipped in solvent-rinsed metal cans filled with argon gas. Each SPMD canister deployed had a total of five membranes. The SPMD membranes were kept frozen until deployment.

At the sample site, cans containing SPMD membranes were carefully pried open. Five of the SPMD membrane spindles were slid into each canister, and the canister closed by screwing on the lid. Loading the SPMDs into the canisters was completed as quickly as possible as they are known to be potent air samplers. The SPMDs were anchored to the bottom at approximately 180 to 200 feet, suspended in the water column by float above the substrate surface. SPMDs remained submerged until retrieval. During deployment and retrieval, field personnel wore nitrile gloves to avoid contact with membranes.

SPMDs were deployed for an average of 28 days. Retrieval followed a reverse order of deployment. Care was taken not to damage seals on the cans used to hold and ship the membranes to prevent contamination. SPMD field blanks were used as a means to correct samples for contamination from the ambient air.

Each SPMD was spiked with 200 ng of each congener prior to field deployment. The EST laboratory spiked SPMDs with the PRC solution provided by MEL just prior to shipping for field deployment.

Companion temperature and TOC data was needed for calculations to determine dissolved total DDT and PCB concentrations from the SPMDs. A Tidbit temperature logger was attached to SPMD canisters to log water temperature on the half hour. At deployment and retrieval, a TOC and turbidity sample was collected at each SPMD location. A hand-held GPS unit was used to establish latitude and longitude for each SPMD deployment, and noted in field logs.

SPMDs were maintained at or near freezing until they arrived at the EST laboratory for extraction. SPMD membranes were shipped under chain-of-custody to EST by overnight Federal Express, in coolers packed with chemical ice and frozen containers of water. Other water samples were returned to Ecology Headquarters under chain-of-custody for transportation to MEL the following day.

Field parameters, PRC values, and target analyte concentrations were entered into an Excel spreadsheet calculator developed by David Alvarez, USGS. PCB-29 was used as the PRC for calculating water concentrations of target analytes, because its K_{ow} is closest to the target compounds. The spreadsheet can be found at wwwaux.cerc.cr.usgs.gov/spmd/SPMD-Tech_Tutorial.htm, and an example spreadsheet is shown in Appendix B.

Sediment

Surface Sediments

To the extent possible, sampling methods followed PSEP (1996) protocols. Surface sediment samples were collected from Ecology's 26' research vessel, R.V. Skookum, using a 0.1 m^2 stainless steel van Veen grab. All sediment stations were located by differentially corrected GPS and recorded in field logs (Figures 2 and 3).

Following collection of each sediment grab, an evaluation of acceptability was made. Information about each grab was recorded in a field log (Table E2 and E3 in Appendix E). 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 grab. 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 was carefully removed prior to subsamples, and materials contacting the sides of the van Veen grab were not retained for analysis.

Homogenized sediments from each station were placed in 4-ounce glass jars with Teflon-lined lids for analysis of DDT compounds and PCBs. Sample containers were cleaned to EPA (1990) QA/QC specifications and certified for trace organic analyses. Additionally, 2-ounce glass jars were filled with homogenate for TOC analysis, while 8-ounce plastic jars were filled for determination of grain size.

Equipment used to collect sediment samples was washed thoroughly with tap water and Liquinox detergent, followed by sequential rinses of hot tap water, de-ionized water, and pesticide-grade acetone. Sample equipment was then air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure was used on the van Veen 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. In the Lucerne basin, samples were collected from the least contaminated area near Stehekin, down-lake to the basin sill. In the Wapato basin, samples were collected from the outflow of Chelan River up-lake roughly every 1.25 mile to the basin sill (Figures 2 and 3).

Sediment samples were placed in coolers on ice at 4^{o} C immediately following collection, and transported to MEL within 72 hours. Requirements for containers, preservation, and holding times are listed in Table 7. The chain-of-custody was maintained for sediment samples.

Sediment Cores

Sediment cores were collected using a Wildco stainless steel box corer fitted with a 13 cm x 13 cm x 50 cm acrylic liner. Patmont et al. (1989) estimated sedimentation rates for Lake Chelan average 0.36 ± 0.10 cm/yr. These estimated rates are within the average reported for several other Washington lakes, ranging from 0.18 cm/yr to 0.45 cm/yr (Yake, 2001). Based on the estimated sedimentation rates, the corer needed to reach a minimum penetration depth between 21 cm and 38 cm to ensure the entire record of DDT compounds and PCB loading to the lake was represented.

After retrieving the core, overlying water was carefully siphoned off, and the acrylic liner removed from the corer. The sediment-filled liner was placed on an extruder table outfitted with a gear-driven piston to push sediments up and out of the liner. Sediment layers were sliced with thin aluminum plates to a uniform thickness of 1 cm. Materials in contact with the liner were excluded from the sample. Each sample layer was placed in 8-oz glass jars, sealed in zip-locked plastic bags, and stored in coolers on ice until returned from the field, where they were frozen at -18^{o} C until subjected to laboratory analysis.

Prior to analysis for DDT compounds and PCBs, selected sediment layers were analyzed for radioisotopes ^{210}Pb, ^{137}Cs, and total lead to estimate sediment age. Based on age estimates, sediments deposited before the use of DDT and PCBs were not analyzed. Sub-samples were selected for analysis that represented recent conditions (top layer), background conditions which are used to calibrate the ^{210}Pb and ^{137}Cs dating (bottom layer), and equally divided layers throughout the period when DDT and PCBs were in use. No significant visual markers in the cores were found, e.g., an ash layer from the eruption of Mt. St. Helens. Sediments were generally homogenous throughout the cores from both the Lucerne and Wapato basins. Layers not selected for chemical analysis were archived frozen for possible analysis at a later time.

Sediment layers selected for analysis were homogenized and split into sub-samples for analysis of DDT compounds and PCBs (4-oz. glass jars); TOC (2-oz. glass jars); total lead (4-oz. jars), and ^{210}Pb and ^{137}Cs (polystyrene containers) for dating.

Utensils used in collection and manipulation of core samples were washed thoroughly with tap water and Liquinox detergent, followed by sequential rinses of hot tap water, de-ionized water, and pesticide-grade acetone. Equipment was then air dried and wrapped in aluminum foil until used in the field. The same cleaning procedure was used on the core liners prior to going into the field. New acrylic liners were used for each sediment core, pre-cleaned using the procedure described above. To avoid cross-contamination between sample stations, the corer was thoroughly brushed down with on-site water at the next sample location prior to collection of the subsequent sample.

Fish

Fish sampling in Lake Chelan required multiple collection methods to obtain the number and types of fish needed to meet project objectives. Limited fish samples were collected using a Smith-Root Model SR16 electrofishing boat. In Lake Chelan this proved not to be an effective option, but electrofishing did have some success in Roses Lake. The habits of some of the targeted species did not lend themselves to electrofishing techniques. Mackinaw is a deep-water fish that required sampling by hook and line. Also, burbot are bottom dwellers and have historically been fished by set line but can be jigged at certain times of the year. Due to the size of Lake Chelan and the number of fish needed for the WDOH human health assessment, Ecology relied on assistance from the WDFW and locals for fish collection.

The local Sportsman Association held a Lake Chelan mackinaw derby on May 17 and 18, 2003. Ecology coordinated with the WDFW and the Sportsman Association for donations of derby fish to the study. Mackinaw used for the study were collected May 17 and caught in the Wapato basin. Study fish were weighed and measured in the field upon arrival at the derby check-in.

Only mackinaw weighing at least one pound or of a size expected to be consumed when caught were collected for analysis. This was not an issue because very few immature mackinaw were caught. It appeared the overwhelming majority of the fish brought into the derby ranged in size from three to eight pounds (Art Viola, personal communication).

All fish collected for analysis were given a unique identification number that corresponded to the data entered into field logs. Fish were double wrapped in aluminum foil, with the dull side contacting the fish. The smaller fish were sealed in zip-lock bags, while the larger fish were double wrapped in plastic bags and sealed with tape. All fish samples were kept in the dark on ice until returned from the field. Once back from the field, fish samples were frozen to -18^{o} C until processed.

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

Each fillet composite consisted of five fish, roughly the same size. The smallest fish in a composite was at least 75% as long as the largest. Composites made up of similar size fish allow an assessment of correlations between contaminant levels and fish size. Composites were formed randomly, after sorting for similar size groups. Fillets were prepared by scaling and removing 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. When possible, sex was determined through observations of internal organs. Scales from fish other than burbot and otoliths were taken for age determination.

Fillets were placed in a Kitchen Aid or Hobart commercial blender and homogenized individually to a uniform color and consistency. Tissue samples were thoroughly mixed by hand following each of three passes through the blender. Composite samples were made up from equal weight aliquots from each fish. Homogenates were stored frozen (-18^{o} C) in two 8-ounce 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, and pesticide-grade acetone. All equipment was then air dried on aluminum foil in a fume hood prior to use. The full decontamination procedure was repeated between subsequent composite samples.

Requirements for sample containers, preservation, and holding times are listed in Table 7. The chain-of-custody was maintained throughout the study.

Laboratory Procedures

A list of the target analytes, sample matrix, sample preparation methods, method references, and the laboratory conducting the analysis is shown in Table 8. Manchester Environmental Laboratory (MEL) conducted sample analysis for the project or an accredited laboratory selected and contracted by MEL personnel.

Table 8. Target Analytes, Sample Matrix, Preparation Methods, and Method References.

Analyte	Sample Matrix	Sample Prep Method	Method Reference	Analytical Laboratory
DDT/DDE/DDD[1]	fish tissue	SW3540/3620/3665[2]	SW8081	EPA-MEL
PCB Aroclors	fish tissue	SW3540	SW8082	EPA-MEL
PCB Congeners	fish tissue	EPA 1668A	EPA 1668A	Pace Analytical
Percent Lipid	fish tissue	extraction	EPA 608.5	EPA-MEL
Dioxins	fish tissue	Silica-gel clean-up	EPA 8290	Pace Analytical
DDT/DDE/DDD[1]	sediment/cores	EPA 8081	EPA 8081	Ecology-MEL
PCB Aroclors	sediment/cores	EPA 8081	EPA 8081	Ecology-MEL
TOC	sediment/cores	combustion/NDIR	PSEP, 1986	Ecology-MEL
Grain size	sediment	sieve and pipet	PSEP, 1986	Rosa-Environmental
Total Lead	cores	NA	EPA 200.8	Ecology-MEL
^{210}Pb	cores	NA	Gamma Detection	STL Richland
^{137}Cs	cores	NA	Gamma Detection	STL Richland
DDT/DDE/DDD[1]	whole water	SW3510/3620/3665	SW8081	Ecology-MEL
TOC	whole water	NA	EPA 415.1	Ecology-MEL
TSS	whole water	NA	EPA 160.2	Ecology-MEL
Turbidity	whole water	NA	EPA 180.1	Ecology-MEL
DDT/DDE/DDD[1]	SPMD extract	dialysis/GPC[3]	SW 8081	Ecology-MEL
PCB Aroclors	SPMD extract	dialysis/GPC[3]	SW 8082	Ecology-MEL
PCB Congeners	SPMD extract	EPA 1668A	EPA 1668A	Ecology-MEL

[1] 4,4'-DDT, 4,4'-DDE, 4,4'-DDD.
[2] and corresponding MEL SOPs and modifications.
[3] EST SOPs E14, E15, E19, E21, E33, E44, E48.

The EST laboratory was contracted to conduct dialysis of the SPMDs and perform GPC clean-up on the extract. The EST dialysis is a patented procedure. Extracts were packaged and shipped to MEL for final analysis. The dialysis and GPC methods are documented in standard operating procedures (SOPs) E14, E15, E19, E21, E33, E44, and E48, on file at Ecology.

The PCB congener analysis of fish tissue was also contracted through MEL. Method 1668A allows determination of more than 150 PCB congeners by isotope dilution high resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The contractor reported total PCBs, homologs, and individual congeners.

Data Quality

MEL 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. Narratives and the complete data report are kept at Ecology headquarters in Lacey are available by request through the study authors.

The analysis for DDT compounds and PCBs as Aroclors in fish tissue was conducted by EPA-MEL. The EPA staff conducted the quality assurance review to verify laboratory performance met quality control specifications outlined in the analytical methods and the 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.

Analyses for PCBs, dioxins, and furan congeners were conducted by Pace Analytical Services. Low-level blank contamination was detected in tissue analysis. During PCB congener analysis, some target compounds were detected at low levels in method blanks. When these congeners were also detected in the samples at less than 10 times the concentration detected in method blanks, the result was qualified with "UJ". The "UJ" qualified analytes were shown in report tables and used in subsequent analysis as "not-detected". When sample concentrations were greater than 10 times the level found in the blank, the concentration in the blank was considered insignificant compared to the sample concentration. In this case, the data were not qualified.

During the analysis of dioxins and furans, some target compounds were detected in the laboratory method blank below the calibration range. These analytes were also detected in the samples. Because all detections were less than 10 times the concentration detected in the method blank, all detected results for 1,2,3,4,6,7,8-HpCDD, OCDD, 1,2,3,4,6,7,8-HpCDF, and OCDF were qualified with "BJ". This qualifier is defined as: the analyte was positively identified but the concentration was less than 10 times the method blank level. The "BJ" qualified analytes were presented in report tables and used in toxic equivalent quotient (TEQ) calculations. The toxic equivalent factors (TEFs) for these analytes are 0.01 for HpCDD and HpCDF, and 0.001 for OCDD and OCDF, so impacts to the total TEQ would be minimal.

Overall, a review of the data quality control and quality assurance from laboratory case narratives indicate analytical performance was generally good. Most data met measurement quality objectives established in the Quality Assurance Project Plan (Coots and Era-Miller, 2003). Some data had to be qualified due to analytical difficulties. No data were rejected, and all results were useable as qualified. A more detailed review of data quality is contained in Appendix F.

Results and Discussion

Water

Runoff Conditions

The Wapato basin of Lake Chelan is known for its arid climate. The average yearly precipitation totals 10.8 inches at Lakeside (WRCC, 2004). Throughout the May through November study period, precipitation was infrequent and no rainfall occurred during collection for the five water sample surveys. Figure 4 shows the rainfall in relation to the days water samples were collected.

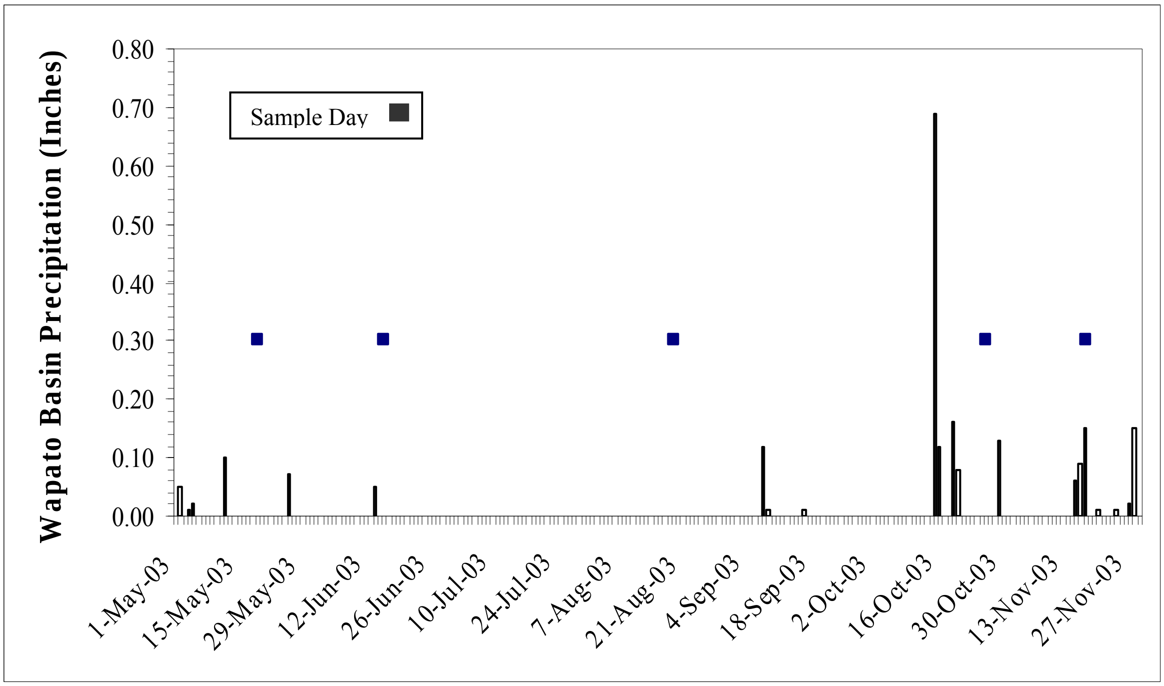

Figure 4. Precipitation and Sample Days in the Wapato Basin of Lake Chelan.

DDT in Lake Chelan Tributaries and Irrigation Drains

Results for DDT compounds in water samples from Lake Chelan tributaries and drains are summarized in Table 9. The complete results, including flow and ancillary data collected in conjunction with the pesticide samples, can be found in Appendix G. PCBs were not analyzed from the surface water samples due to the difficulty achieving detection with normal analytical techniques.

Water samples were collected from a total of 18 sites in the watershed during May, June, August, October, and November 2003, and analyzed for 4,4'-DDT and its major metabolites 4,4'-DDE and 4,4'-DDD (Figures 2 and 3). This included five sites from the Lucerne basin and 13 from the Wapato basin. Samples from the Lucerne basin verified significant up-lake sources were not present. DDT compounds were not detected in water samples collected in May from any of the five Lucerne basin sites. Consequently, subsequent water sample surveys were focused on the Wapato basin and Stink Creek. The small, unnamed stream located next to the Mill Bay boat ramp (NS30) in the Wapato basin was sampled in May only. After the May collection, the flow decreased to the point where it was not possible to sample during the remainder of the study.

The only surface water samples collected from Lake Chelan were from site DT08, located at the Riverwalk Park boat launch near the lake outlet. All other water samples were collected from tributaries or irrigation drains to the lake, except for the Wapato Lake + Joe Creek site (NS23) which does not discharge directly to the lake. It is one of the two major tributary sources of Stink Creek. Water samples from this site represent discharge from a small wetland made up of Wapato Lake outflow combined with Joe Creek, flowing from the north.

Table 9. Total DDT Concentrations and Loads in Lake Chelan Tributaries and Irrigation Drains, May – November 2003.

Location	Site ID	Study Mean Flow (cfs)	Study Range t-DDT (ng/L)	Study Mean t-DDT (ng/L)	Study Mean Load (mg/day)
First Creek	SS01	9.2	0.20J	0.20J	2.2
Knapp Coulee	SS02	0.17	4.6 – 8.7	6.2	2.4
Chelan River	DT08	NS	0.072J[a]	0.072J[a]	NC
Culvert near Crystal View	NS13	0.016	3.4 – 4.6	3.8	0.14
Purtteman Creek	NS15	0.95	1.6 – 3.9	2.6	5.8
Culvert at Veroske's	NS16	0.10	11 – 18	14	3.0
Cooper drainage	NS18	0.07	11 – 25	15	1.5
Bennet Road	NS19	0.09	1.7 – 3.3	2.2	0.29
Keupkin Street	NS21	0.65	22 – 36	28	43
Buck Orchards	NS22	0.19	7.7 – 17	13	6.1
Wapato Lake + Joe Creek	NS23	1.1	0.13J – 0.26J	0.20J	0.04
Stink Creek	NS24	0.60	1.4J – 2.1	1.8	1.9
Mill Bay boat ramp	NS30	0.020[b]	0.48J	0.48J	0.020
Twenty-Five Mile Creek	LU25	80[b]	ND	ND	NC
Prince Creek	LU26	74[b]	ND	ND	NC
Railroad Creek	LU27	160[b]	ND	ND	NC
Fish Creek	LU28	54[b]	ND	ND	NC
Stehekin River	LU29	4460[b]	ND	ND	NC

J = Result is an estimate.
NS = Flow not estimated – lake site.
[a] = Sample collected from an active boat ramp dock; result likely reflects disturbance from launching.
[b] = Flow estimate is for one sample event.
ND = Not detected.
NC = Not calculated.

Comparison to Water Quality Standards

Figure 5 compares total DDT concentrations reported from the five water sample surveys from Lake Chelan tributaries and irrigation drains to the NTR human health water quality criteria and the Washington State aquatic life criteria (see Table 3). As described earlier, the human health water quality criteria are based on a 1-in-1-million chance of increased lifetime cancer risk from consumption of fish and water. Slightly less restrictive than the human health criteria, the aquatic life criterion is based on chronic toxicity to the most sensitive biota. The summed DDT plus metabolite concentrations from all surveys were used for comparison to water quality criteria. Lucerne basin sites are not included in Figure 4. Only detected concentrations from samples are presented in the graph. The human health and aquatic life criteria for DDT and metabolites are 0.59 ng/L and 1.0 ng/L, respectively.

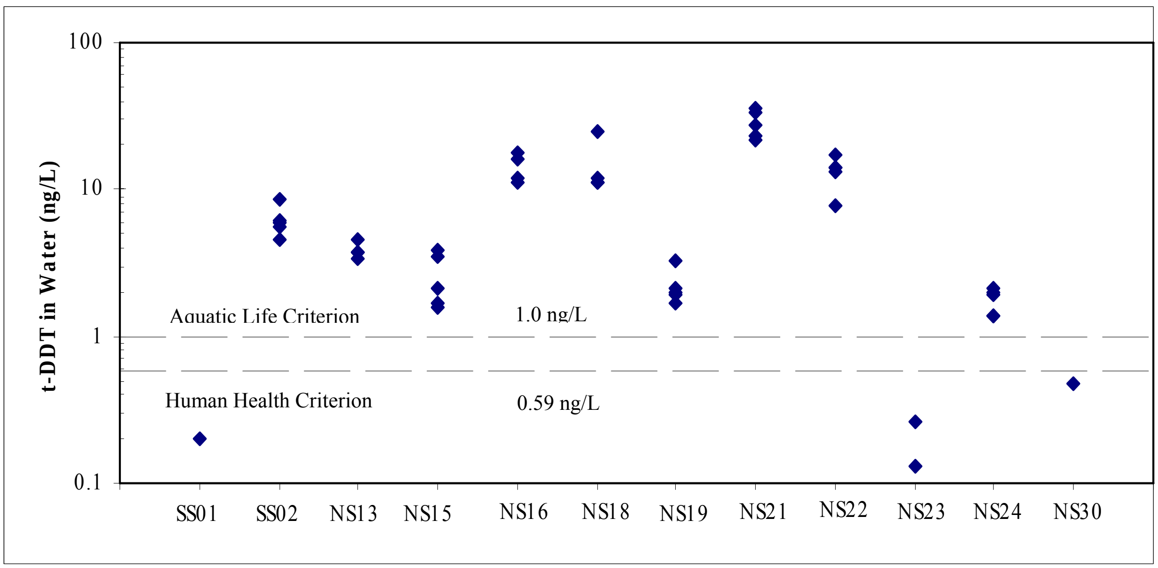

Figure 5. Exceedances of Human Health Water Quality Criteria and Aquatic Life Criteria in the Lake Chelan Drainage, May – November 2003 (ng/L).

As shown in Figure 5, the human health and aquatic life criteria for total DDT were routinely exceeded in the Wapato basin. Only First Creek (SS01), Wapato Lake + Joe Creek (NS23), and the small discharge at the Mill Bay boat ramp (NS30) sites were within criteria. All other tributary and drain samples exceeded criteria for both human health and aquatic life. Detected total DDT concentrations in tributaries to Lake Chelan ranged from an estimated 0.13 ng/L to a high of 36 ng/L.

Sample results from the Keupkin Street site (NS21) above Manson were consistently above 20 ng/L total DDT. Only one other water sample collected during the study exceeded 20 ng/L total DDT.

Storm Event Sampling

Often nonpoint source pollutant loading is highest during storm events, particularly for pollutants known to have an affinity to sediments. Currently no storm event data exist for levels of DDT compounds in water from discharges on the north shore of the lake. This study initially planned to sample during storm events, but that approach proved to be a logistical problem. The few rain events during the early stages of the study, and the need to be on site while it was raining to get run-off from the usually dry drain-ways, made a change to routine sampling necessary.

The local water quality managers are in a better position to collect samples during storm events. Many of the drain-ways to the lake are dry except during storms or snow melt. Local water quality managers should consider including storm event sampling for any future DDT studies in discharges to Lake Chelan. Comparisons could then be made between loads produced during storm events to the loads routinely discharged, and possibly identify other significant sources. The routine surface water samples from tributaries and drains collected during this TMDL study did not show any clear seasonal pattern for total DDT concentrations.

Water Quality Ranking

To help identify potential management priorities, sites were ranked for total DDT based on the relative exceedance above criteria and the pollutant load. Loads were averaged for each site based on the reported total DDT concentration multiplied by the estimated flow for the sample day. Only detected concentrations of DDT compounds were used in averages. Table 10 shows a ranking of study sites for both mean total DDT concentrations and the associated loads.

Table 10. Lake Chelan Basin Surface Water Sites Ranked for Total DDT Concentration and Load, May – November 2003.

Location	Site ID	Study Mean Total DDT Conc. (ng/L)	Total DDT Conc. Rank	Study Mean Total DDT Load (mg/day)	Total DDT Load Rank
Keupkin Street	**NS21**	**28**	1	43	1
Buck Orchards	**NS22**	**13**	4	6.1	2
Purtteman Creek	**NS15**	**2.6**	7	5.8	3
Culvert at Veroske's	**NS16**	**14**	3	3.0	4
Knapp Coulee	**SS02**	**6.2**	5	2.4	5
First Creek	SS01	0.20	11	2.2	6
Stink Creek	**NS24**	**1.8**	9	1.9	7
Cooper drainage	**NS18**	**15**	2	1.5	8
Bennet Road	**NS19**	**2.2**	8	0.29	9
Culvert near Crystal View	**NS13**	**3.8**	6	0.14	10
Wapato Lake + Joe Creek	NS23	0.20	11	0.04	11
Mill Bay boat ramp	NS30	0.48	10	0.02	12

Bolding identifies sites and concentrations exceeding water quality criteria.

As shown in Table 10, the Keupkin Street site (NS21) ranks highest for both mean study concentration and load. The Keupkin Street load averaged over seven times the load of the next highest sites. Samples were collected from a deep manhole in the concentrated orchard area above Manson (Figure 2). The irrigation drain's primary purpose is to control perched groundwater levels, but it also accepts stormwater run-off. No run-off events were encountered during the five routine sample surveys in tributaries and irrigation drains.

The common mechanism for transport of DDT compounds is adsorption to sediment particles associated with run-off. DDT is generally considered to be immobile in most soils, remaining near the surface if undisturbed. Mobility is related to the soil content of organic matter. The higher the organic content, the more likely DDT compounds will remain in place. Data from Keupkin Street, Bennet Road, and the culvert near Crystal View, however, suggest DDT compounds are moving through the soil profile.

The Lake Chelan Reclamation District (LCRD) study of Manson Lakes (Burgoon and Cross, 2004) also found high total DDT concentrations in irrigation drains low in suspended sediments. One element of the LCRD study evaluated total DDT levels through the soil profile, to a depth of 90 cm. Three test holes were dug in older orchard areas with irrigation drains. All three test holes found total DDT was high throughout the soil profile. Two of the three test holes had higher concentrations deeper in the profiles, while the other test hole had similar concentrations throughout. Burgoon and Cross (2004) hypothesized the DDT and metabolites are being transported through the soil profile attached to colloids into the irrigation drains. The downward movement of total DDT through soils means shallow groundwater is impacted by historical application of DDT. Shallow groundwater is a likely source of water to the lakes and tributaries.

DDT Loading to Lake Chelan

The total volume of water from sample sites discharging into Lake Chelan compared to the outflow from the lake to the Columbia River ranged from 1.4% in May to 0.36% in November. Using the five sample events to represent the average total DDT load discharged to the Wapato basin throughout the year, the load from all sample sites total 0.068 grams of total DDT per day, or roughly 25 grams per year. This estimate would not be the total for all possible inputs to the lake because not all sources were sampled.

Groundwater discharge directly to the lake is likely a significant unaccounted for source contributing total DDT. Other unaccounted for sources that may also be contributing are private bulkhead drains, culverts of roadside ditches, and other stormwater conveyances around the Wapato basin including Chelan's stormwater collection system. Clearly, for the identified sources sampled, this is not a large load when compared to the volume of Lake Chelan. The targeted sample sites for the study were perennial streams and irrigation drains flowing May through November.

Storm event samples were not collected, which could produce higher short-term loads, particularly from the surface water discharges. Although for the average yearly loads, any short-term storm event increases above the average are likely offset by the end of irrigation and winter freezing conditions lowering discharge and water movement.

Inputs of DDT compounds to Lake Chelan will likely be a management issue for many years. DDT is persistent in the environment, and well documented with a reported half-life ranging from 2 – 15 years. Agricultural soils tend to degrade DDT at a much slower rate than aquatic environments (Harris et al., 2000). Routes of loss and degradation include volatilization, photolysis, and biodegradation. These processes are very slow acting, and in grass-covered orchards where tillage is normally not used, volatilization and photolysis are likely less effective than biodegradation in DDT removal. If 15 years is assumed to be the soil half-life of DDT in the Lake Chelan basin, for every 100 pounds of DDT historically applied to orchards there would still be one pound available 100 years after application.

Dissolved DDT and PCBs in Lake Chelan

Monthly estimated averages of dissolved total DDT and PCB concentrations from the SPMD samples are shown in Table 11. The table also presents a yearly estimated average calculated from the monthly concentrations. SPMDs were deployed in May, July, and October of 2003. An example of the spreadsheet calculator used to estimate water column concentrations of target compounds is shown in Appendix B. Results from analysis of SPMD extracts and conventional water quality parameters associated with SPMD deployments can be found in Tables G2, G3, and G4 in Appendix G.

Table 11. Average Total DDT and Total PCBs in Estimated Concentrations from SPMDs Deployed in Lake Chelan, May – November 2003 (ng/L dissolved; ppt).

Sampling Period	Lucerne Basin Off Twenty-Five Mile Creek	Wapato Basin Off Wapato Point[1]
May – June 2003		
Sample No.	0263000	0263001/2
Total DDT	0.049	5.2
Total PCBs (Aroclors)	<0.3	0.008
July – August 2003		
Sample No.	Sample Lost	0434083/4
Total DDT	NA	3.5
Total PCBs (Aroclors)	NA	<0.4
October – November 2003		
Sample No.	04054982	04054978/9
Total DDT	0.13	0.94
Total PCBs (Aroclors)	<0.4	0.003[2]
Annual Averages		
Total DDT	0.09	3.2
Total PCBs (Aroclors)	<0.35	0.006

[1] Reporting a mean of a duplicate pair.
NA = No analysis - sample lost.
[2] The Wapato basin total PCB estimate was taken from SPMD congener analysis.

Estimated concentrations of total DDT were much higher than total PCBs. The PCBs were generally not detected. Only the May to June SPMD samples detected the PCB Aroclor 1248 (Table G2 in Appendix G). The air blank contained slightly more than the level found in the Lucerne sample and slightly less than the level found in the Wapato sample, suggesting air deposition is a source for PCBs in the basin.

Basin Comparisons

During May and June, estimated concentrations of total DDT in the Wapato basin averaged about two orders of magnitude higher than concentrations measured in the Lucerne basin (Table 11). During October and November, Wapato basin total DDT was much lower, averaging about seven times the estimated concentration found in the Lucerne basin.

Basin comparisons could not be made for the July to August sample period. The Lucerne basin SPMD was lost during deployment, most likely due to recreational boating which peaks in the lake during this time of year.

Seasonal Patterns

The total DDT concentrations measured in the Wapato basin followed a seasonal pattern. Average concentrations were highest in May and June, followed by July and August. The average concentration in October and November was less than a quarter of the level found in July and August.

The higher springtime total DDT concentration likely results from a combination of the start of irrigation, wet season precipitation, and snowmelt. With the suspension of irrigation in early fall, and the low flow and freezing conditions through winter, the in-lake concentration would be expected to drop until seasonal rain and irrigation begins in late winter/early spring.

The decline in total DDT from spring through fall suggests irrigation water may be driving Wapato basin total DDT concentrations. Obviously, one sample site in a waterbody the size of the Wapato basin is inadequate to draw any distinct conclusions about seasonal loading, but does suggest more study is needed. Concentrations of total DDT from tributaries and irrigation drains did not show the high to low response from spring to fall like in-lake concentrations (Table G1, Appendix G).

Figure 6 shows the irrigation water usage in the Manson area during the study period compared to the total DDT concentration measured by SPMDs in the Wapato basin.

The total DDT load estimates from tributaries and drains suggest there are other significant sources of DDT compounds in the basin, like groundwater entering the lake. This seasonal pattern for total DDT found in the Wapato basin was not seen in the Lucerne basin.

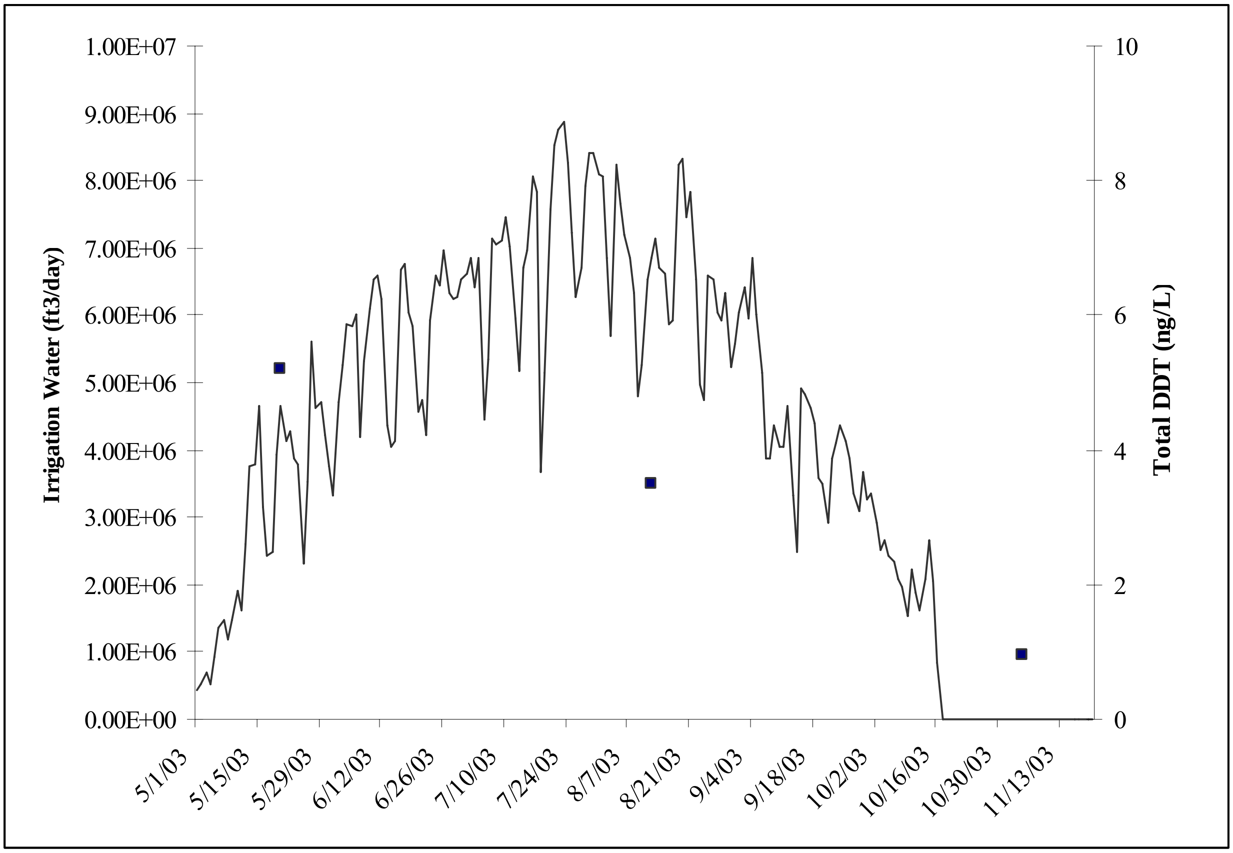

Figure 6. Irrigation Water Usage and Wapato Basin Total DDT Concentration Measured by SPMDs, 2003.

Dissolved vs Particulate

Chlorinated pesticides like DDT partition into dissolved and particulate fractions in water. Concentrations estimated from the SPMDs represent the dissolved form only. Total DDT concentration can be estimated using results from the dissolved fraction, the total organic carbon (TOC) levels in water, and the equilibrium partition coefficient of the contaminant. The water column TOC in Lake Chelan was very low throughout the study, with results below detection for all but one sample collected in August from the Wapato basin, reported at 1.3 mg/L. Results for water column turbidity throughout the study were below detection. The low TOC and turbidity results imply that the majority of the water column total DDT concentration is in the dissolved form. These results may have implications for bioaccumulation. With low TOC and solids in the water column, the dissolved total DDT is more likely to bind to other sinks, like sediments or fish tissue. Organic carbon cycling in the system is an important transfer mechanism.

Comparison to Water Quality Standards

Dissolved total DDT concentrations measured in Lake Chelan were compared to the NTR human health water quality criteria (Table 12). The dissolved data, rather than total concentrations, were used in this comparison because dissolved data more accurately reflect the chemical fraction available for uptake by fish (EPA, 2000) and fish consumption is the primary concern behind the 303(d) listings. There is also greater uncertainty about the accuracy of the total concentrations, since they are estimates based on partitioning theory.

Table 12. Comparison of Water Quality Criteria to Total DDT and PCBs Found in SPMDs from Lucerne and Wapato Basins, May – November 2003 (ng/L, dissolved).

Chemical	Lucerne Basin	Wapato Basin	NTR Criteria[1]	Aquatic Life Criteria[2]
Total DDT			0.59	1.0
May - June 03	0.049	5.2		
July – August 03	NA	3.5		
October – November 03	0.13	0.94		
Total PCBs			0.17	14
May - June 03	<0.3	0.008		
July - August 03	NA	<0.4		
October - November 03	<0.4	0.003		

[1] For comparison purposes 0.59 ng/L is used from NTR criteria. See Table 3 for metabolite criterion.
[2] Aquatic life criteria are for chronic exposure.

Table 12 shows that total DDT in the bottom waters of Wapato basin exceed the NTR criterion for protection of human health. Exceedance ranged from about nine times the standard during May and June, to about one and a half times in October and November. In contrast, the Lucerne basin results for total DDT were low, at about one tenth the NTR criterion during May and June to about one fifth the standard in October and November.

The less restrictive Washington State aquatic life criteria were also compared to water column concentrations of total DDT. Exceedance of the chronic exposure criterion was limited to the Wapato basin, ranging from five times to slightly under the criterion through the May to November study period. The acute exposure criterion was never approached in any samples. The SPMD results for Wapato basin total DDT have been forwarded to the WDOH for an assessment of any drinking water implications.

Water column PCBs were low throughout the study. PCBs were not detected in four of the five SPMD samples analyzed for Aroclors. The Wapato basin SPMD sample for May and June had an estimated total PCB concentration reported at 0.008 ng/L. The Wapato basin SPMD samples from October and November were analyzed for PCB congeners, allowing lower limits of detection. The Wapato basin SPMD for October and November had an estimated total PCB concentration of 0.003 ng/L. During the study, neither of these samples exceeded the NTR criterion of 0.17 ng/L or the chronic aquatic life criterion of 14 ng/L.

Sediment

Surface Sediments

Surface sediments were collected at 20 locations in Lake Chelan. Seventeen of those samples were collected along a transect to determine the longitudinal gradient of total DDT and PCB contamination in the lake. Three alluvial sites were dedicated to large tributaries (Railroad Creek, First Creek, and the Stehekin River) to screen for recent inputs. A total of 10 sites were sampled in the Wapato basin, and seven sites in the Lucerne. Four additional alluvial samples were planned for Twenty-Five Mile, Prince, Fish, and Stink creeks, but fine sediments could not be located. The complete set of results for DDT compounds, PCBs, TOC, and grain size for surface sediments from Lake Chelan can be found in Tables G5 and G6 in Appendix G.

TOC concentrations ranged from 0.42% to 3.17% for all Lake Chelan transect samples, with a mean of 2.02%. The average TOC for the Wapato basin was 1.80%, while slightly higher at 2.34% for the Lucerne. Alluvial samples from First Creek, Railroad Creek, and the Stehekin River had the highest TOC, averaging 4.67%. Significant amounts of organics/wood debris were noted in field logs from all alluvial samples.

Grain size for transect surface sediments were fairly consistent. All of the transect samples except the two closest to the lake outlet above the dam had ≥60% fines (fines < 62.5 microns). The two transect sites closest to the lake outlet were dominated by sand, as were the alluvial samples from First Creek and Railroad Creek.

Summary statistics for total DDT and PCBs from Lake Chelan transect and alluvium surface sediments are presented in Table 13. Results for total DDT found in transect sediments are graphically displayed on Figure 7.

Table 13. Summary of Total DDT and PCB Concentrations (ug/Kg) in Lake Chelan Surface Sediments, June 2003.

	Total DDT			Total PCBs		
Basin	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Wapato			n=10			n=6
Transect	2.4	1100	560	1.2	2.7	1.8
Alluvium	11	11	11	ND	ND	ND
*Lucerne**			n=7			n=1
Transect	3.2	540	120	1.4	1.4	1.4
Alluvium	ND	ND	ND	ND	ND	ND
All Data	2.4	1100	380	1.2	2.7	1.8

* Data from L-13.00 was included in the Lucerne basin, though a majority of the drainage is within the Wapato basin. This site coincides with Stink Creek discharge, just above the basin sill.

ND = Not detected.

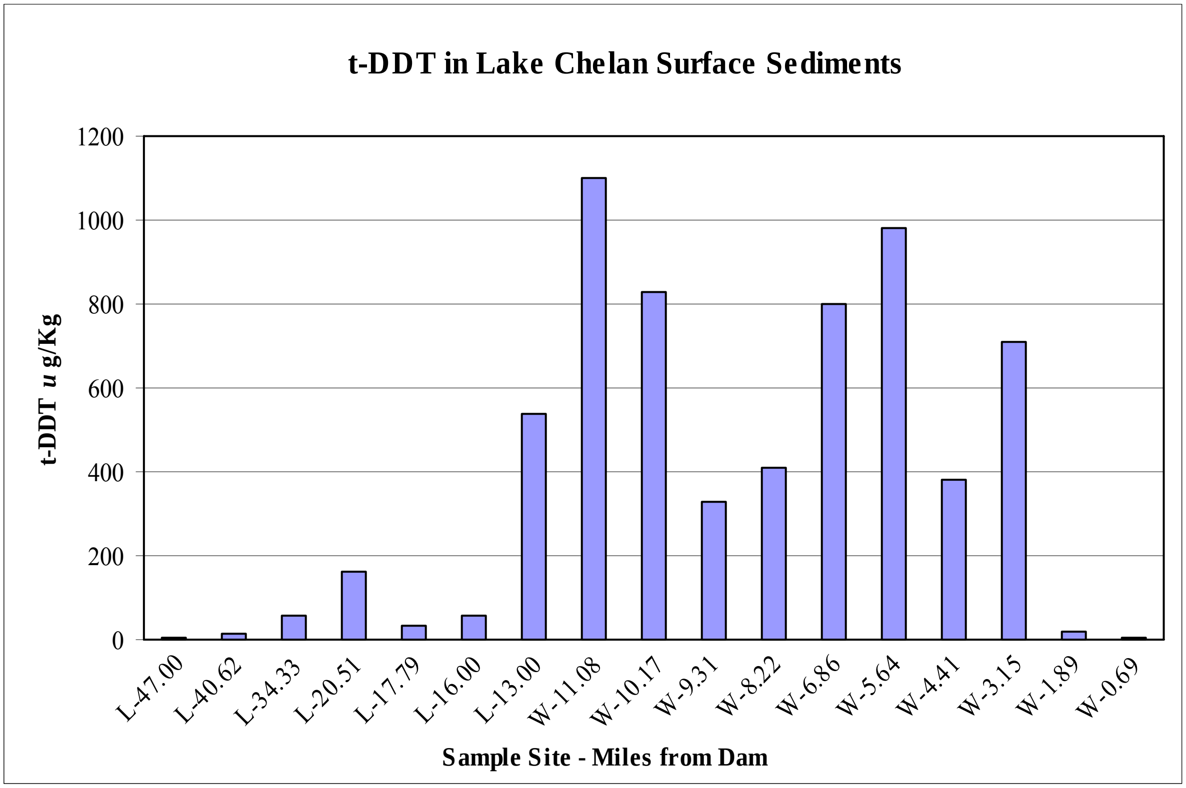

Figure 7. Total DDT Concentrations in Transect Surface Sediments, Lake Chelan.

Concentrations of total DDT in surface sediments were much higher in the Wapato basin than Lucerne (Figure 7). The total DDT concentration for the whole lake ranged from 2.4 to 1,100 *u*g/Kg, averaging 380. In the Wapato basin the W-11.08 site had the highest concentration of total DDT in surface sediments (1,100 *u*g/Kg). Site L-13.00 just above the basin sill is adjacent to the discharge from Stink Creek and had the highest concentration in the Lucerne basin (540 *u*g/Kg). The majority of the Stink Creek drainage is within the Wapato basin. The high total DDT concentration from the L-13.00 site more than doubles the average for the Lucerne basin. Other Lucerne basin sites were much lower. Even with the high total DDT level reported from L-13.00 driving the Lucerne basin average the total DDT in surface sediments from the Wapato basin were more than four times higher than levels found in the Lucerne basin, averaging 560 *u*g/Kg,. This finding is consistent with historical data. First Creek, in the Wapato basin was the only alluvium site that had detectable total DDT at a concentration of 11 *u*g/Kg.

Results from two sediment samples collected in 1986 (Patmont et al., 1989) were compared to results from sediment samples collected in the same general area during this study. Near the lake outlet Patmont et al. (see Table C2 and Figure C1 in Appendix C) reported a total DDT concentration of 170 *u*g/Kg (station 1), while station W-1.89 from this study found 19 *u*g/Kg in sediments. A deep lake site outside Manson Bay in the 1986 study was 272 *u*g/Kg total DDT (station 4), compared to 330 *u*g/Kg reported from site W-9.31. Surface sediments outside Manson Bay appear to be slightly higher now for total DDT, although results are probably within the spatial variability for sediments.

The yearly total DDT load currently discharged into the Wapato basin was estimated from transect and core results. Generally total DDT is most associated with fines (silts and clays). Sands or larger materials were found on the substrate surface near shore and around the lake outlet, so the percentage of the Wapato basin with soft sediments was estimated. To help estimate the area with fine sediments, grain size results were evaluated from transect samples along with depth. The information suggested soft sediments would be expected at depths greater than 50 feet. GIS analysis and lake bathymetry were used to estimate the Wapato basin area having a depth greater than 50 feet. Based on water depth $\geq$ 50 feet, the area covered by fine sediments was estimated at 75% of the basin (2.60E+11 cm^2). The sedimentation rate was estimated by analysis of the sediment core for the Wapato basin at 0.042grams/cm^2/year (see the following section).

Using the Wapato basin total DDT average of 560 *u*g/Kg reported in the top 2 cm from transect samples and 75% of the Wapato basin area, there is roughly 13.5 pounds (6,120 grams/year) of total DDT discharged yearly into the Wapato basin. This is in contrast to the 25 grams per year measured in discharges (basin tributaries and irrigation drains) to the Wapato basin. The 6,120 grams/year may be somewhat overestimated. The most recently deposited sediments are likely lower in concentration than the average for the top 2 cm of surface sediments from transect samples used in the analysis. It is clear, however, that estimated inputs from tributary and irrigation drains do not support the estimated recent flux rate of total DDT to the Wapato basin. This suggests that either current loadings are much lower than historical levels or other unmeasured sources of total DDT are impacting the lake.

Results for PCBs in transect sediments were low, ranging from 1.2 to 2.7 *u*g/Kg. PCBs were detected in only one transect sample from the Lucerne basin, with an estimated concentration of 1.4 *u*g/Kg. The PCB mixture most closely resembled Aroclor-1254. PCBs were not detected in alluvium samples.

DDT and PCBs in Sediment Cores

Sediment cores were collected from the Lucerne and Wapato basins to examine the depositional history of total DDT and PCBs. Results of analyzing the cores can be found in Tables 14 and 15.

Sediments were collected to a depth of approximately 40 cm for each of the two cores. Texture was consistent for each, composed largely of silts and clays. Sedimentation rates for each of the basins were estimated from age dating information.

To estimate sedimentation rates for each of the two cores, Pb^{210}, Cs^{137}, and stable Pb (lead) methods were used. A naturally occurring decay product of radon gas (Rn^{222}), Pb^{210} is primarily produced in the atmosphere. Once Pb^{210} is formed, it adsorbs to aerosol particles and is deposited on land and water surfaces. After being deposited from the atmosphere, Pb^{210} adsorbs to particulates which settle from the water column and incorporate into the bottom sediments. Both the rates of sedimentation and decay of Pb^{210} are assumed to be constant over time. Since the half-life of Pb^{210} is known, by determining the Pb^{210} activity at different depths of the core, the rate of sediment accumulation and date of deposition can be estimated. Because small amounts of Rn^{222} are also present in the sediments, these levels need to be subtracted from the total to get the net amount added to the water column from the atmosphere. By plotting the corrected Pb^{210} levels by depth of the sediment accumulated, the slope of the line represents the sedimentation rate (Schell and Nevissi, 1980).

Table 14. Concentrations of DDT Compounds and PCBs from a Wapato Basin Sediment Core, June 4, 2003.

Sample No (03)-	Depth Interval (cm)	% TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	Total DDT	Total PCBs
517050	0-1	2.35 J	**160**	**76**	**40**	**276**	8.8U
517051	1-2	1.81 J	**190**	**130**	**68**	**388**	7.6U
517052	2-3	1.70 J	**260**	**220**	**40**	**520**	7.4U
517053	3-4	1.76 J	**280**	**300**	**52**	**632**	7.4U
517054	4-5	1.75 J	**230**	**340**	**46**	**616**	7.6U
517055	5-6	1.70 J	**270**	**510**	**110**	**890**	7.7U
517056	6-7	1.69 J	**250**	**590**	**90**	**930**	8.1U
517057	7-8	1.63 J	**220**	**610**	**100**	**930**	7.0U
517058	8-9	1.56 J	**170**	**560**	**110**	**840**	7.1U
517061	21-22	1.16 J	0.67U	**0.49J**	0.67U	**0.49**	6.7U

J = Analyte was positively identified. The associated numerical result is an estimate.
U = Not detected at the detection limit shown.

Table 15. Concentrations of DDT Compounds and PCBs in a Lucerne Basin Sediment Core, June 3, 2003.

Sample No (03)-	Depth Interval (cm)	% TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	Total DDT	Total PCBs
517062	1-2	3.04 J	**8.8**	**1.4**	**0.81J**	**11**	11U
517063	2-3	2.95 J	**10**	**2.0**	**0.54J**	**12**	10U
517064	3-4	2.67 J	**12**	**2.6**	1.2U	**15**	12U
517065	4-5	2.53 J	**17**	**4.5**	**1.3**	**23**	9.2U
517066	5-6	2.49 J	**18**	**7.0**	0.65U	**25**	8.5U
517067	6-7	2.35 J	**36**	**25**	**2.3J**	**63**	7.2U
517068	7-8	2.34 J	**31**	**50**	**2.5**	**84**	7.3U
517069	8-9	2.26 J	**11**	**38**	0.58U	**49**	6.6U
517070	9-10	2.50 J	**3.1**	**19**	0.33U	**22**	6.1U
517073	22-23	2.16 J	0.27U	0.27U	0.27U	ND	2.7U

J = Analyte was positively identified. The associated numerical result is an estimate.
U = Not detected at the detection limit shown.

Pb^{210} results were used as the primary means of estimating sedimentation rates. The Cs^{137} and stable Pb were used as markers to verify Pb^{210} estimates. First produced by atmospheric testing of nuclear weapons in about 1953, the Cs^{137} concentrations peaked in 1964. The peak for stable Pb is typically around 1975.

The sedimentation rate for the Lucerne basin was measured at 0.074 gm/cm^2/yr, which equals 0.19 cm/yr. Sedimentation rates for the Wapato basin are about half the Lucerne basin, at 0.042 gm/cm^2/yr or 0.092 cm/yr.

The higher sedimentation rate for the Lucerne basin is likely due to a number of factors. The Lucerne core was collected down-lake of the two largest inputs to the lake, Stehekin River and Railroad Creek (Figure 3). Sediment focusing plays more of a role in the Lucerne basin, where the lake bed slope is greater for moving fine sediment to depth. The Lucerne basin is narrower and deeper, with mountainous uplands higher in elevation and drastic slopes prone to event related inputs, like weather-induced mass wasting and higher annual rainfall.

The sedimentation rates for Lake Chelan are low compared to other lakes reported in Washington. However, they seem appropriate considering the lake size and sediment sources within each basin. The rates estimated for the Lake Chelan basins are at the low end of the range for other Washington lakes, 0.18 cm/yr to 0.45 cm/yr (Yake, 2001). Table 16 compares this study's estimated sedimentation rates to a recent study that estimated rates from Lake Whatcom and other surrounding lakes (Norton, 2004).

Table 16. Estimated Sedimentation Rates for Lake Chelan and other Washington Lakes from Dated Sediment Cores.

Waterbody	Mass Accumulation (g/cm^2/year)	Linear Accumulation (cm/year)
Lake Chelan:		
Wapato Basin	0.042	0.092
Lucerne Basin	0.074	0.19
Lake Osoyoos	-	0.50
Lake Whatcom	0.042	0.25
Lake Terrell	0.031	0.36
Wiser Lake	0.048	0.041
Fazon Lake	0.039	0.52
Lake Samish	0.072	0.47
Baker Lake	0.37	0.99

A historical profile was developed based on the estimated sedimentation rate and measured concentrations of DDT and metabolites (Figure 8).

Concentrations of total DDT in the Wapato core were more than an order of magnitude higher in sediments of roughly the same age from the Lucerne core. Accumulation patterns of total DDT for the Lucerne and Wapato basins were also different. The Lucerne basin total DDT concentrations rose sharply during the 1960s, peaking in the early 1970s, then declining sharply to the mid-1980s (Figure 8). From the 1980s, total DDT concentrations have declined by roughly half. Since around 1990, the rate of change has declined. The total DDT peak in the early 1970s and sharp decline coincide with EPA banning the insecticide in 1972.

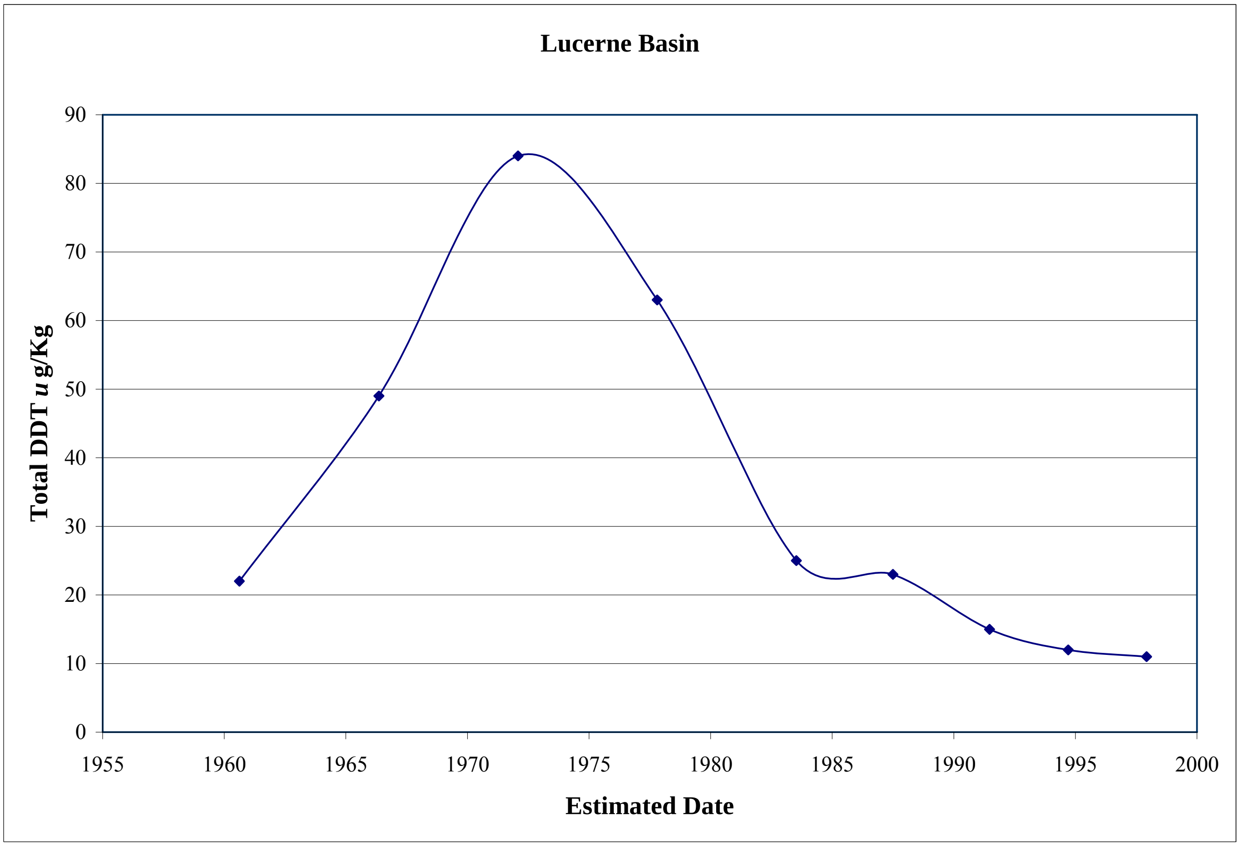

Figure 8. Total DDT Concentration in a Sediment Core from the Lucerne Basin of Lake Chelan.

The concentration profile for total DDT in the Lucerne basin is consistent with a profile from Lake Osoyoos collected during an Ecology study on the lower Okanogan River basin in 2001 (Serdar, 2003). The sediment core was collected from the southern end of Lake Osoyoos. Concentrations of total DDT were higher in the Lake Osoyoos sediments, but the estimated date and profile showed good agreement with findings from the Lucerne basin.

Accumulation patterns of total DDT in the Wapato basin suggest disturbance to the sediment record. Age dating estimates showed high concentrations of total DDT from the mid 1920s. Production of DDT in the United States did not start until 1943. The bulk of DDT application in the basin was between the mid-1940s through the 1960s. Disturbance by physical mixing or changes in the rate of sedimentation is problematic to historical records.

The concentration of total DDT in the sediment core from the Wapato basin peaked at 930 *u*g/Kg. Since the peak concentration, there has been a fairly consistent decline. The concentration of total DDT in the cores surface sediments is currently about 30% of the peak concentration. The mean total DDT concentration from Wapato basin transect surface sediments is about 60% of the core's peak concentration. The results from the surface layer sediments from basin core samples generally agree with total DDT concentrations from the nearest sediment transect sites.

The Wapato basin core showed a consistent decline in total DDT concentrations in the top four centimeters of the most recently deposited sediments. Like cores from the Lucerne basin (Figure 8) and Lake Osoyoos, total DDT loads typically decline following suspension of DDT application and then level out after 10 or 15 years, suggesting equilibrium has been reached. The total DDT concentrations found in the Wapato basin core were much higher than the Lucerne basin and Lake Osoyoos, and have not shown this leveling out of total DDT loads. Results from the Lucerne core showed a 35%, 20%, and 8.3% rate of change between the three most recently deposited sediment horizons analyzed. If these rates of change from the Lucerne basin were applied to future concentrations in surface sediments for the Wapato basin, estimates range between 95 and 120 years before total DDT concentrations would meet the freshwater sediment quality values lowest effects level (LEL) of 7 *u*g/Kg in the Wapato basin. Sediment cores used for comparison are from areas that have not implemented management strategies for reduction in total DDT loads, suggesting implementation of any control strategy for total DDT inputs could potentially speed up recovery.

Comparing Roses Lake Sediments

Very little sediment data exists from Roses Lake. Besides the three sediment samples collected in 2002 for the Lake Chelan Reclamation District (LCRD) study (Burgoon and Cross, 2004), only two other sediment samples, collected in 1992, have been analyzed (Serdar et al., 1994). The total DDT concentrations from the 1992 samples averaged 1622 *u*g/Kg, compared to the 61 *u*g/Kg average from the three samples collected in June 2002 (see Table C2 in Appendix C). Current total DDT concentrations in surface sediments appear to be only about 4% of the levels measured 12 years ago. Little is known about the spatial distribution of surface sediments in Roses Lake to know if this comparison is valid. A drop of this magnitude in total DDT concentration in surface sediments was not expected.

The sediments collected from Roses Lake were a gold color and had an unconsolidated loose organic consistency. The sediment TOC was high, averaging 13.1%. Based on phosphorus data from the LCRD study, Roses Lake is eutrophic (Burgoon and Cross, 2004). Roses Lake has a dense macrophyte community. Lake productivity and senescent macrophytes may be diluting the total DDT concentration in surface sediments. Results for DDT compounds and percent TOC for the sediment samples collected from Roses Lake in 2002 are presented in Table 17, and site locations shown on Figure C1.

Table 17. DDT and Metabolite Concentrations in Roses Lake Sediments, June 2002.

Station ID	Depth (cm)	% TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	Total DDT
			(*u*g/Kg dry weight)			
R1S	2-5	9.8	29.3	13.8	39	82
R2S	2-5	13	48.2	21.6	ND	70
R3S	2-5	16.5	12.1	19.0	ND	31

ND = not detected at or above the detection limit.

Fish

DDT and PCB Concentrations

In total, nearly 200 fish were collected and analyzed for the study. Mackinaw, burbot, kokanee, and rainbow trout were collected from the Wapato basin of Lake Chelan in 2003. Burbot were also collected from the Lucerne basin for comparison. Rainbow trout and black crappie samples were collected from Roses Lake. Fish collected for the study represent a range of habitats and food sources. Mackinaw, kokanee, rainbow trout, and black crappie are pelagic fishes, while the burbot is a bottom dweller. Mackinaw are the apex predator in Lake Chelan, generally found in deep water environments. As adults, mackinaw, burbot, and black crappie are piscivorous, but during juvenile stages tend to be insectivors. Rainbow trout are known to eat a number of foods including aquatic insects, worms, and fish eggs, while kokanee are plankton feeders but also known to eat insect larvae.

Fish were collected to represent the most often caught and consumed species for the lakes. The majority of the samples were analyzed as composites of five fish each. Fifty mackinaw and four rainbow trout were also analyzed as individuals. Fish were sorted by size for composite samples as a possible factor in identifying contaminant accumulation. Results from tissue analysis for DDT compounds, PCBs, and lipids from Lake Chelan and Roses Lake are summarized in Table 18, and the complete set of results can be found in Table G7 in Appendix G.

Concentrations of total DDT ranged from 6 to 2,400 *u*g/Kg in Wapato basin fish tissue. The highest concentrations were measured in mackinaw, followed by burbot, kokanee, and rainbow trout. Burbot from the Wapato basin were more than an order of magnitude higher for total DDT (146 to 499 *u*g/Kg) than burbot from the Lucerne basin (10 to 31 *u*g/Kg).

Table 18. Total DDT and PCB Concentrations in Fillets from Lake Chelan and Roses Lake Fish Collected March - October 2003.

Species:	Mackinaw (Lake Trout)	Burbot	Kokanee	Rainbow
Wapato Basin				
No. of Individuals	50	0	0	4
No. of 5-Fish Composites	10	7	7	3
Mean Age (years)	6.2	10.4	2.2	1
Mean Total Length (mm)	566	566	266	281
Mean Total Weight (grams)	1,805	1,078	164	230
Percent Lipids	2.7	0.24	1.86	0.19
Total DDT (*u*g/Kg, ww)	943	315	57	14
Total PCBs (*u*g/Kg, ww)	14.5	0.91	0.83	4.0
Lucerne Basin				
No. of Individuals	-	0	-	-
No. of 5-Fish Composites	-	3	-	-
Mean Age (years)	-	7.6	-	-
Mean Total Length (mm)	-	537	-	-
Mean Total Weight (grams)	-	885	-	-
Percent Lipids	-	0.67	-	-
Total DDT (*u*g/Kg, ww)	-	22	-	-
Total PCBs (*u*g/Kg, ww)	-	ND	-	-
Species: Sample Number:	Rainbow 03394400	Black Crappie 03334350		
Roses Lake				
No. of Individuals	0	0		
No. of 5-Fish Composites	1	1		
Mean Age (years)	1	3.8		
Mean Total Length (mm)	228	245		
Mean Total Weight (grams)	134	244		
Percent Lipids	0.5	0.1		
Total DDT (*u*g/Kg, ww)	96	32		
Total PCBs (*u*g/Kg, ww)	ND	ND		

ND = Not detected.

Table 19 compares fish tissue results for total DDT and PCBs from this study to results from previous fish tissue samples collected from Lake Chelan. The range of total DDT concentrations from the Wapato basin burbot samples collected in this study bracket the concentration reported from one burbot sample collected in 1987. In the Lucerne basin, burbot concentrations of total DDT are lower now than the concentration reported from one sample in the 1987 study. Concentrations of total DDT in kokanee and total DDT and total PCBs in rainbow trout from the Wapato basin are also lower now than results reported from 1992 and 1994 samples.

Table 19. Comparison of Total DDT and PCB Concentrations in Fish Tissue from Lake Chelan to Historical Studies (*u*g/kg, ww).

Basin	Sample Date	Fish Species	Total DDT		Total PCBs		Reference for Historical Data
			Historical	2003	Historical	2003*	
Wapato	Sep-87	Burbot	478	146 - 499	NA	5.4	1
Wapato	Sep-92	Rainbow trout	57	5.6 - 26	15	2.1 - 8.8	2
Wapato	Sep-94	Rainbow trout	56	5.6 - 26	80	2.1 - 8.8	3
Wapato	Sep-92	Kokanee	417	27 - 111	12	ND	2
Wapato	Sep-94	Kokanee	164	27 - 111	99	ND	3
Lucerne	Sep-87	Burbot	61	10 - 31	NA	ND	1

* = Aroclor equivalents.
1 = Patmont et al., 1989.
2 = Davis and Johnson, 1994.
3 = Davis and Serdar, 1996.
4 = EPA National Fish Tissue Study – unpublished, 2002.
NA = Not analyzed.
ND = Not detected.

Regression analysis showed total DDT concentrations in mackinaw tissue were not reliably predictable based on percent lipids (r^2=0.15), total fish length (r^2=0.03), total fish weight (r^2=-0.09), or fish age (r^2=0.29). Lipid content was expected to correlate to total DDT concentrations in mackinaw because of their higher content than other species and status in the food chain. The absence of a predictable relationship is likely due to the habits of individual fish and their localized feeding habitats. In contrast, lipid content in kokanee tissue, the second highest for the species analyzed, appears to have a strong predictable relationship to total DDT concentrations (r^2=0.85).

Levels of total PCBs in fish tissue were much lower than total DDT, ranging from less than 2 to 48 *u*g/Kg. PCB Aroclors were not detected in kokanee, Lucerne basin burbot, and Roses Lake rainbow trout and black crappie, accounting for nearly three quarters of the samples analyzed.

The PCB mixture in Lake Chelan fish most closely resembled Aroclors 1254 and 1260. In Wapato basin rainbow trout, only Aroclor 1254 was detected. All of the rainbow samples were from the same age class, planted the prior year. They may have received the PCBs from hatchery food prior to stocking in Lake Chelan. There is currently ongoing debate around the country regarding fish food as a source of PCBs in hatchery-raised rainbow trout. Ecology is currently developing a study to determine PCB and DDT levels in hatchery food and fish.

PCBs generally occur as commercial mixtures of congeners called Aroclors. Detection limits for an Aroclor analysis are often near or above the NTR criteria, which can be problematic for health assessments. An analysis for PCB congeners offers lower detection limits and quantifies individual compounds that have different levels of toxicity, but at a significantly higher cost per sample.

A total of 24 muscle fillet samples from Wapato basin fish were analyzed for PCB congeners. Results for each PCB congener sample provided information for each of the 209 congeners. The total data set for PCB congeners were not included in the report, but can be obtained through the Ecology EIM data management system (www.ecy.wa.gov/eim/) or by contacting the report authors. Table 20 summarizes the results for PCB congeners in fish muscle samples from Lake Chelan.

As Table 20 shows, mackinaw tissue were much higher in concentrations of PCBs than burbot or kokanee tissue. Total PCB concentrations based on congener analysis of mackinaw ranged from 13.4 to 48 *u*g/Kg, with a mean of 26.7 *u*g/Kg. The mean PCB concentration in mackinaw tissue was about five times the NTR human health standard for consumption of fish. Lipids in mackinaw tissue ranged from 3.37 to 15.4%. Like total DDT, the total PCB congeners in mackinaw tissue did not have a predictable relationship with lipid content ($r^2 = -0.047$).

PCB congener profiles in tissue had similar patterns between species, although concentrations were much higher in the mackinaw. Penta- and hexa-PCB homologs made up 75% of the total concentrations from all fish samples. All three species of fish had the greatest proportions of the more highly chlorinated penta-, hexa-, and hepta-PCB homolog groups.

Co-eluting congeners[4] PCB 129/138/163 and PCB 153/168 were found in the highest concentrations in Lake Chelan fish. The most toxic congeners are PCB 77, PCB 126, and PCB 169. Analysis of burbot and kokanee tissue did not detect any of these congeners. PCB 77 and PCB 126 were detected in two of the 22 mackinaw samples, averaging 45 ng/Kg and 21.4 ng/Kg, respectively. PCB 169 was not detected.

[4] Co-eluting congeners peak on the chromatograph near the same location; summed and reported as a single result.

Table 20. PCB Congeners in Fish Tissue from Lake Chelan, Wapato Basin, 2003 (*u*g/Kg, ww).

Species: Lab ID	Percent Lipids	PCB Homolog Groups for Mackinaw Tissue										Total PCBs
		Mono-	Di-	Tri-	Tetra-	Penta-	Hexa-	Hepta-	Octa-	Nona-	Deca-	
Mackinaw												
214330[1]	5.91	ND	ND	0.203	1.89	6.31	10.0	2.58	0.415	ND	ND	21.4
214331	7.62	ND	ND	0.138	2.80	11.0	17.1	4.51	0.731	0.053	ND	36.4
214332	10.2	ND	ND	0.114	2.68	10.4	11.1	3.74	0.717	0.063	ND	28.8
214333	5.42	ND	ND	0.104	1.83	7.77	11.8	3.66	0.552	ND	ND	25.7
214334	8.30	ND	ND	0.051	2.74	10.6	15.6	4.42	0.649	0.052	ND	34.2
214335	3.37	ND	ND	ND	1.66	6.97	8.03	2.48	0.428	0.060	ND	19.6
214336	8.18	ND	ND	0.115	1.45	6.15	10.3	2.99	0.435	ND	ND	21.4
214337	8.01	ND	ND	ND	1.02	4.82	8.26	2.43	0.367	ND	ND	16.9
214338	3.55	ND	ND	0.116	4.10	15.7	20.4	6.29	1.28	0.149	0.055	48.1
214339	6.64	ND	ND	ND	0.798	4.16	6.27	1.91	0.229	ND	ND	13.4
214340	8.66	ND	ND	0.123	2.59	10.8	12.4	3.39	0.456	0.064	ND	29.7
214341	15.4	ND	ND	0.107	2.24	9.37	12.8	3.83	0.920	0.154	0.06	29.5
214342	7.44	ND	ND	ND	1.35	5.08	8.34	2.27	0.318	ND	ND	17.4
214343	10.3	ND	ND	ND	1.32	6.29	7.06	2.55	0.327	ND	ND	17.5
214344	9.58	ND	ND	0.110	1.96	8.20	9.09	2.88	0.476	ND	ND	22.7
214345	7.02	ND	ND	0.051	1.14	5.29	5.91	1.95	0.242	ND	ND	14.6
214346	8.25	ND	0.051	0.168	2.64	11.8	12.3	4.33	0.838	0.071	ND	32.2
214347	4.69	ND	ND	0.105	2.92	15.4	19.5	6.21	0.989	0.15	ND	45.3
214348	6.00	ND	ND	0.056	1.62	8.12	7.91	2.45	0.373	ND	ND	20.5
214349	6.98	ND	ND	0.063	1.57	7.01	7.26	2.26	0.325	ND	ND	18.5
424001[2]	8.70	ND	ND	0.405	4.91	12.2	16.7	5.58	0.840	0.096	0.029	40.8
424002[2]	10.8	ND	0.022	0.294	3.36	9.99	12.8	5.97	0.941	0.144	0.040	33.6
Burbot												
424000[2]	0.30	ND	0.024	0.059	0.491	1.48	1.93	0.556	0.082	ND	ND	4.62
Kokanee												
424003[1/2]	9.6	ND	0.028	0.108	0.572	2.19	2.50	1.05	0.107	ND	ND	6.55

[1] Mean of duplicate pair.
[2] Composites of five fish.
ND = Not detected.

Comparison to Other Studies

To put fish tissue levels of total DDT and PCBs collected from Lake Chelan and Roses Lake into perspective, data from this study were compared to data from other Ecology studies. Results of total DDT and PCBs from fish tissue fillets from five eastern Washington studies conducted from 1992 to 2001 were used for comparison. Data from the other studies detecting DDT compounds and PCBs were pooled and presented in Table 21, along with the Lake Chelan and Roses Lake fish tissue data.

Table 21. Comparison of Total DDT and PCB Concentrations in Fish Tissue from Lake Chelan and Roses Lake to Other Eastern Washington Studies (*u*g/Kg ww; parts per billion).

Chemical	Total DDT			Total PCB		
	Lake Chelan	Roses Lake	Ecology Studies[1]	Lake Chelan[2]	Roses Lake	Ecology Studies[1]
No. of Samples	64	2	25	66	2	9
Mean	633	64	157	9.5	ND	121
Median	539	-	57	17	ND	30
Maximum	2,362	96	901	48	ND	720
90th Percentile	1,426	90	406	29.1	ND	252

[1] Serdar et al., 1994; Davis and Johnson, 1994; Davis et al., 1995; Davis et al., 1998; and Seiders, 2003.
[2] Includes congener and Aroclor data.
ND = Analyte was not detected.

Average concentrations of total DDT in Lake Chelan fish tissue were about four times the levels found in fish from other eastern Washington studies. Clearly, concentrations of total DDT in Lake Chelan fish are reason for concern, and may represent the highest average for edible fish tissue collected for an Ecology study to date.

Generally PCBs are considered products of urban or industrial activities. Even though the city of Chelan surrounds the lower Wapato basin, PCBs in tissue samples were generally low. Concentrations of total PCBs in Lake Chelan muscle fillets were only a fraction of the total PCBs other eastern Washington studies have reported.

Comparing Roses Lake Fish

Only one edible fish tissue sample from Roses Lake has previously been analyzed for DDT compounds. Serdar et al. (1994) analyzed one rainbow trout fillet in the 1992 study. The total DDT concentration was reported at 103 *u*g/Kg. This current TMDL study analyzed one five-fish composite sample, reporting a concentration of 96 *u*g/Kg. Even with the large reduction in surface sediment concentrations of total DDT, it appears there is little change in the tissue concentrations for rainbow trout.

Dioxin/Furan Concentrations

Dioxins and furans are the common names associated with polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). Formed as an unintended byproduct of incomplete combustion or industrial processes, they are ubiquitous in the environment, resistant to metabolism, and have a high affinity to lipids. Ecology took the opportunity to evaluate dioxin in the sport fishery because of the levels found during EPA's National Fish Tissue Study (EPA, 2002 unpublished).

Summary statistics for dioxins and furans from Lake Chelan mackinaw and burbot are presented in Tables 22 and 23. The complete set of results can be found in Tables G9 and G10, Appendix G. Three samples each of mackinaw and burbot tissue were analyzed for dioxins and furans. Samples were composites of five fish each. Dioxins and furans were detected in all of the samples analyzed. Burbot tissue had the more highly chlorinated forms of the PCDD congeners, hexa-, hepta-, and octa-, while analysis of mackinaw detected all of the PCDD homologs except penta-. The PCDF congeners detected were generally the same for both species, although concentrations of 2,3,7,8 TCDF were much higher in mackinaw.

Table 22. Dioxin and Furan TEQ Estimates in Mackinaw Tissue from Lake Chelan, 2003.

NTR criteria: 2,3,7,8, TCDD = 0.07 ng/Kg	Wapato Basin		
% Lipids	4.82 %	2.82 %	4.29 %[1]
PCDD TEQ	0.46	0.50	0.66[1]
PCDF TEQ	0.16	0.23	0.20[1]
Total TEQ	0.63	0.74	0.85
% 2,3,7,8 TCDD	51 %	46 %	54 %
% PCDDs	74 %	68 %	77 %
% PCDFs	26 %	32 %	23 %

[1] = Mean of duplicate (split) samples 03218247 and 03218248

Table 23. Dioxin and Furan TEQ Estimates in Burbot Tissue from Lake Chelan, 2003.

NTR criteria: 2,3,7,8, TCDD = 0.07 ng/Kg	Lucerne Basin	Wapato Basin	
% Lipids	0.05 %	0.10 %	0.21 %
PCDD TEQ	0.007	0.004	0.055
PCDF TEQ	0.078	0.046	0.022
Total TEQ	0.085	0.050	0.077
% 2,3,7,8 TCDD	0 %	0 %	0 %
% PCDDs	8 %	8 %	71 %
% PCDFs	92 %	92 %	29 %

The total PCDD and PCDF concentration ranged from 3.4 to 18.8 ng/Kg for all samples. The average lipid content was 3.98% for the mackinaw and 0.12% for the burbot. The mackinaw tissue averaged 0.37 ng/Kg for 2,3,7,8 TCDD. In burbot tissue 2,3,7,8 TCDD was not detected.

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 tetrachlorodibenzo-p-dioxin (TCDD) was developed. The TEFs from detected dioxin and furan compounds in a sample are summed for a toxic equivalent quotient (TEQ), which can be compared to available criteria on 2,3,7,8 TCDD. Tables 22 and 23 show the results of mackinaw and burbot tissue analysis for dioxins and furans, and the calculated TEQs for each.

The TCDD/TCDF estimated TEQs for mackinaw were much higher than for burbot. The burbot averaged 0.071 ng/Kg TEQ, while the mackinaw averaged about an order of magnitude higher at 0.74 ng/Kg TEQ. In mackinaw half of the total TEQ was attributed to 2,3,7,8 TCDD.

The National Toxics Rule (NTR) fish tissue criterion for 2,3,7,8 TCDD is 0.07 ng/Kg. The TEQ for Wapato basin burbot was within the NTR criterion, averaging 0.064 ng/Kg, while the burbot sample from the Lucerne basin was 0.085 ng/Kg, slightly above the criterion. In contrast, the TEQ for mackinaw averaged an order of magnitude above the standard at 0.74 ng/Kg.

Bioaccumulation Factors

The state-adopted NTR standards for the protection of human health are based on bioconcentration factors (BCFs). The BCFs are an indication of the potential fish have to accumulate pollutants, and are calculated as the ratio of the pollutant concentration in the organism to that in the surrounding water. Because BCFs do not take into account food as a source of contaminants, the EPA BCFs were compared to site-specific data generated from this study to see if they and, by extension, the human health criteria, are appropriate and protective for consumers of Lake Chelan fish.

The EPA now recommends using bioaccumulation factors (BAFs) over BCFs when site-specific data are available, because the former accounts for uptake through contaminated food or sediment (EPA, 2000). Site-specific concentrations of total DDT from the water column and fish tissue were used to calculate BAFs for Lake Chelan. Table 24 compares the calculated BAFs for total DDT from Lake Chelan to the EPA BCFs used to develop the NTR criteria adopted as the state standards.

Table 24. Calculated BAFs for Total DDT in Lake Chelan Fish Compared to EPA BCFs Used to Calculate State Human Health Water Quality Criteria.

Fish Species	Basin	Mean Fish Tissue Concentration[1] (ug/Kg, ww)	Mean Water Column Concentration[2] (ng/L)	Lake Chelan BAF	EPA BCF
All species	Wapato	663	3.2	207,200	53,600
Mackinaw	Wapato	943	3.2	294,700	53,600
Burbot	Wapato	315	3.2	98,400	53,600
Kokanee	Wapato	57	3.2	17,800	53,600
Rainbow	Wapato	14	3.2	4,400	53,600
Burbot	Lucerne	22	0.09	244,400	53,600

[1] Mean of all reported results for total DDT pooled for all species or per each individual species.
[2] Estimated from May through November SPMD results.

Water column data used to calculate BAFs were average Wapato and Lucerne basin dissolved total DDT concentrations from the SPMD deployments, May through November 2003 (see Table 11). The EPA recommends using the dissolved fraction of pollutants to determine bioaccumulation because it is the fraction available for uptake (EPA, 2000). These averages should be generally representative of the water concentrations fish are exposed throughout the year. Fish samples were collected during the same time period as water samples. Separate BAFs were calculated for the Wapato and Lucerne basin burbot.

As calculated BAFs show in Table 24, BCFs used in the NTR water quality criteria (state standard) are underestimating levels of total DDT that would be protective of an average Lake Chelan fish consumer. The mean Lake Chelan BAF for total DDT is higher than the BCF, 207,200 vs. 53,600. On an individual species basis, the BAF for Wapato basin mackinaw was much higher than the EPA BCF, 294,700 vs. 53,600. Other Wapato basin fish species had considerable variation in site-specific BAFs, lower than the EPA BCF, from factors near 12 in rainbow trout to about 3 in kokanee. It is clear the EPA BCF substantially underestimates the bioaccumulation of DDT in Lake Chelan fish other than rainbow trout and kokanee.

Site-specific BAFs for PCBs were not calculated. A reasonable estimate for BAFs was not calculated because the number of detection results for PCBs in the water column was insufficient.

Fish Consumption Advisory

The Washington State Department of Health (WDOH) is currently evaluating the fish tissue results and will issue a decision on a health advisory at a later date.

TMDL Calculations

Water Quality Targets

Water quality targets for the Lake Chelan and Roses Lake TMDLs will be expressed in terms of meeting the water quality goals for fish tissue, which was the basis for the 303(d) listing. The water surrounding the fish also needs to be addressed as it plays a role in tissue concentrations. The NTR criteria for edible fish tissue and water column concentrations have been adopted by Washington State for protection of human health. For the Lake Chelan and Roses Lake TMDLs, a target concentration of 32 *u*g/Kg for total DDT, 5.3 *u*g/Kg for total PCBs, and 0.07 ng/Kg TEQ for dioxins will be used for edible fish tissue.

Although 303(d) listings for Lake Chelan and Roses Lake fish are for 4,4'-DDE, TMDLs were calculated based on total DDT, to use as a margin of safety. Generally, DDE was the major DDT metabolite reported in tissue and water.

In addition to the fish tissue target, Washington State's surface water standard for total DDT will be applied to tributaries and drains discharging to Lake Chelan and Roses Lake. A water quality target concentration of 1.0 ng/L will be required to assure that when tissue targets are eventually attained, they are not compromised by degraded inputs.

Critical Conditions

Critical conditions in TMDLs are those environmental conditions that will be used to develop the maximum allowable loads from inputs that give protection and attainment of criteria during all other conditions. The concept of critical conditions does not fit well with fish tissue contamination. The time it takes contaminants to reach equilibrium in fish tissue is generally very long. Compounds with low solubility like DDT and its metabolites or PCBs tend to have the longest time to reach equilibrium. Seasonal variability and short-term episodes are less important to fish tissue concentrations because fish at the higher trophic levels receive their pollutant load from their food sources and surrounding water over a period of months or years.

The environmental conditions that will be used to calculate allowable loads from tributaries and drains discharging to Lake Chelan and Roses Lake need to be identified. DDT is listed as a probable carcinogen, and human health criteria developed for carcinogens assume exposure over a lifetime. When applying criteria to toxics, EPA recommends using the harmonic mean flow when averaging hydrology over a long period of time (EPA, 1991). Representing long-term averages, the harmonic mean flow is consistent with use of criteria that are based on long-term exposure which incorporates any short-duration, high concentration load. For the tributaries and drains discharging to Lake Chelan and Roses Lake, harmonic mean flow will be used as the critical condition to establish loading limits.

The primary focus of the Lake Chelan and Roses Lake TMDLs is DDT compounds and PCBs in fish tissue. There is no direct link between water column, sediments, and tissue concentrations for developing load allocations for fish tissue. These toxic pollutants accumulate in fish over a long period of time, based on water concentrations, feeding habits, food source, fish age and size, and other environmental factors that do not lend themselves to a typical load allocation strategy. For this reason a percent reduction in fish-tissue approach is used instead of a load-allocation approach for fish tissue.

Current Loads and Required Reductions in Lake Chelan Fish

The current total DDT, PCBs, and dioxin concentrations in Lake Chelan fish were determined through analysis of roughly 200 fish samples. This represents a large sample number for Ecology studies and provides a good estimate of contaminant levels in fish.

While the TMDL focus is DDT compounds in fish tissue that resulted from historical orchard application, there are several tributaries and drains around the Wapato basin that currently contribute to the total DDT load to the lake. Through pesticide application from the 1940s through the 1960s, DDT and metabolites have made their way to lake sediments which are acting as a sink and reservoir to the aquatic food chain. Loading of DDT compounds to the lake has been an ongoing process since application through irrigation drains, groundwater, runoff, and soil erosion. The total DDT load in fish is likely from a combination of lake sediments, through the food chain, and to a lesser extent the water column. The fate and transport of total DDT, PCBs, and dioxin from water and sediments to fish tissue is complex and influenced by local biological and chemical conditions.

The sources of PCBs and dioxin within the basin are not obvious. Potential sources include air deposition, soil erosion, and surface run-off. PCBs have historical applications like heat transfer and hydraulic fluids, pesticide extenders, lubricants, and plasticizers. PCBs are found throughout the environment having the ability to volatilize and travel great distances from their industrialized urban sources. Winds can transport PCBs from warmer latitudes to condense and deposit in cooler latitudes through atmospheric deposition. Dioxins are unintended by-products of many chemical industrial and combustion processes.

TMDLs are defined as the summed total of permitted loads from point sources, nonpoint sources, and the natural background level of the contaminant. Load allocations refer to the allowable pollutant load from nonpoint sources plus the natural background level. When load allocations are developed for TMDLs, a portion of the total allowable load is required to be dedicated to the natural background. Man-made synthetic compounds like DDT, PCBs, and dioxins have no natural sources. Because all sources are anthropogenic, the background load of these pollutants is zero.

To satisfy requirements of the TMDL in fish tissue, a percent reduction approach was used. The mean concentrations of total DDT (943 *u*g/Kg) and total PCBs (14.5 *u*g/Kg), and mean dioxin TEQ (0.74 ng/Kg) in mackinaw were calculated to represent the current contaminant load in fish tissue and the basis for the load reductions. Mackinaw had the highest mean contaminant concentrations in fish tissue, so basing reductions on mackinaw will allow a greater level of protection for consumers of all other species. The state criteria for the protection of human health in edible fish tissue is 32 *u*g/Kg for total DDT, 5.3 *u*g/Kg for total PCBs, and 0.07 ng/Kg for dioxin (see Table 3). This means a 97% reduction in total DDT, a 63% reduction in total PCBs, and a 90% reduction in dioxin concentrations is needed in edible fish tissue to meet the human health criteria in the Wapato basin. The percent reduction calculations for fish tissue from the Wapato basin are presented below.

Percent Reduction total DDT = [(943 *u*g/Kg - 32 *u*g/Kg) / (943 *u*g/Kg)] x 100 = **97%**
Percent Reduction total PCBs = [(14.5 *u*g/Kg – 5.3 *u*g/Kg) / (14.5 *u*g/Kg)] x 100 = **63%**
Percent Reduction dioxin TEQs = [(0.74 ng/Kg – 0.07 ng/Kg) / (0.74 ng/Kg)] x 100 = **90%**

The mean total DDT and total PCB concentrations in burbot from the Lucerne basin were within human health standards for edible fish tissue and will not require load reductions.

Lake Chelan Tributary and Irrigation Drain Assimilative Capacity

There are no NPDES permitted point sources discharging to the lake, so the pollutants are limited to nonpoint sources. Tributaries and drains were evaluated as close to the point of discharge as possible. To determine specific sources within sub-drainages would require further investigation.

As specified in Chapter 173-201A WAC, inputs to Lake Chelan are required to meet water quality standards at the point of discharge. This requires load allocations to be established for discharges to the lakes. To establish load allocations, the maximum allowable load or TMDL from each discharge must be determined. The loading capacity represents the total daily pollutant load the tributaries and drains are able to assimilate at a defined flow condition and still meet applicable water quality criteria. The TMDL can be expressed using the following equation:

$$TMDL = Q_h \times C_{std}$$

Where: TMDL = Total maximum daily load to meet water quality criteria (mass/time)
Q_h = Harmonic mean tributary-drain flow (volume/time)
C_{std} = State water quality criterion (mass/volume)

The maximum allowable total DDT loads for discharges to Lake Chelan are presented in Table 25. These total maximum daily loads (TMDLs) represent the allowable loads for each discharge sampled during the study, based on the harmonic mean flow and the state aquatic life criterion of 1.0 ng/L. The harmonic mean flow is always less than the arithmetic and geometric mean flow and can be expressed as $Q_h = n / \sum(1/Q_i)$ where n is the number of measured flows Q_i.

Table 25. Lake Chelan Tributary and Irrigation Drains Maximum Allowable Daily Loads to Meet Water Quality Standards.

Tributary or Irrigation Drain Discharge	Harmonic Mean Flow (feet^3/second)	Total DDT TMDL (mg/day)
First Creek - SS01	4.9	12
Knapp Coulee - SS02	0.16	0.39
Culvert at Crystal View - NS13	0.015	0.04
Purtteman Creek - NS15	0.93	2.3
Culvert at Veroske's - NS16	0.087	0.21
Cooper drainage - NS19	0.041	0.10
Bennet Road - NS19	0.054	0.13
Keupkin Street - NS21	0.62	1.5
Buck Orchards - NS22	0.19	0.46
Wapato Lake + Joe Creek - NS23	0.09	0.22
Stink Creek - NS24	0.44	1.1
Mill Bay boat ramp - NS30	0.02	0.05
	Total	18.5

See Figure 2 for sample site locations

Load Reductions Needed in Lake Chelan Tributaries and Drains

To calculate current and allowable loads, it was assumed that all total DDT loads to the lake are available for uptake and bioaccumulation by fish. The 12 tributary and drain sites to Lake Chelan were sampled on five occasions between May and November 2003. Sampling was conducted at different times of the year to incorporate the range of total DDT concentrations found in discharges around the Wapato basin. To compare allowable loads to existing loads into Lake Chelan, and to quantify the needed percent reductions to meet criterion, the mean instream study loads were calculated at the harmonic mean flow developed from the range of flow conditions. Table 26 presents current total DDT loads, the allowable loads to meet water quality standards, needed load reductions, and percent reduction of the current load needed to meet water quality standards.

Table 26. Lake Chelan Tributary and Irrigation Drains Current Loads and the Reductions Needed to Meet Water Quality Standards.

Tributary or Drain Site	Current Total DDT Load (mg/day)	Allowable Total DDT Load (mg/day)	Needed Load Reduction (mg/day)	Needed Percent Reduction
First Creek - SS01	2.2	12	0	0
Knapp Coulee - SS02	2.4	0.39	2.0	84
Culvert at Crystal View - NS13	0.14	0.04	0.10	71
Purtteman Creek - NS15	5.8	2.3	3.5	60
Culvert at Veroske's - NS16	3.0	0.21	2.8	93
Cooper drainage - NS18	1.5	0.10	1.4	93
Bennet Road - NS19	0.29	0.13	0.16	55
Keupkin Street - NS21	43	1.5	42	97
Buck Orchards - NS22	6.1	0.46	5.6	92
Wapato Lake + Joe Creek - NS23	0.04	0.22	0	0
Stink Creek - NS24	1.9	1.1	0.80	42
Mill Bay boat ramp - NS30	0.02	0.05	0	0
Totals	66.4	18.5	58.4	

See Figure 2 for sample site locations.

By far the highest average total DDT load per day was measured in the irrigation drain at Keupkin Street (NS21). The Keupkin Street load was seven times the next two highest average loads measured at Buck Orchards (NS22) and Purtteman Creek (NS15). Three of the 12 discharges require no load reduction to meet water quality criterion for total DDT, while five of the 12 will require at least an 84% reduction in the current average load.

Roses Lake TMDL Calculations

Water quality data used in the development of load allocations for the Roses Lake TMDL were from a study conducted by the Lake Chelan Reclamation District (LCRD), funded by a grant from Ecology. The study addressed the inputs and discharges from the drainage area of all three Manson Lakes which include Wapato, Dry, and Roses lakes (Burgoon and Cross, 2004). The LCRD study monitored levels of DDT compounds and phosphorus over a two-year period. Study objectives developed for the first year were to better understand total DDT and phosphorus distribution throughout the Manson Lakes. The study's second year coincided with this TMDL study and was coordinated with the intent to optimize collection and sharing of data.

Mackinaw have not been planted in Roses Lake so other species at or near the top of the food chain were selected for sampling and analysis. Roses Lake samples of rainbow trout and black crappie were collected by Ecology and WDFW personnel in August and September 2003 and analyzed for 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD. Statistics for the Roses Lake fish can be found in Table D1 in Appendix D, while the results for DDT compounds and flow are in Table G11 in Appendix G. The water quality data from Roses Lake used in this TMDL evaluation were collected monthly from March 2002 through January 2004 and included 4,4'-DDT, 4,4'-DDE, 4,4'-DDD, TOC, turbidity, and flow. Only data used to develop the Roses Lake TMDL are available in this report. Other data and information collected for the LCRD study can be obtained through the Ecology EIM database system or requested through the report authors.

Current Loads and Required Reductions in Roses Lake Fish

Concentrations of total DDT in Roses Lake rainbow trout and black crappie were determined through analysis of one five-fish composite sample per species. The concentration of total DDT in rainbow trout was used as the best representation of the load in need of reduction. Using total DDT levels from the higher of the two species allows a margin of safety for protection of human health and scientific uncertainty. The concentration of total DDT in rainbow trout tissue from Roses Lake was 96 *u*g/Kg. At the state criterion of 32 *u*g/Kg, a 67% reduction would be needed in edible fish tissue to meet the human health criteria in Roses Lake fish.

Percent Reduction Total DDT = [(96 *u*g/Kg - 32 *u*g/Kg) / (96 *u*g/Kg)] x 100 = **67%**

Concentrations of PCBs as Aroclors in Roses Lake fish were within the NTR human health criteria. They were analyzed but not detected in tissue samples. The detection limit ranged from 1.9 to 3.9 *u*g/Kg. Therefore, no load reduction would be required for PCBs.

Roses Lake Orchard Drain Assimilative Capacity

There are no NPDES permitted point sources discharging to Roses Lake so the total DDT inputs are limited to nonpoint sources. Only one orchard drain (ST11) discharges to Roses Lake, at its eastern end (Figure 2). The orchard drain was evaluated in the same manner as discharges to Lake Chelan. To determine contributions of total DDT from other sources like groundwater or road runoff would require further investigation. The assimilative capacity is the total daily total

DDT load the water flowing through the orchard drain is able to assimilate at a defined flow condition and still meet applicable water quality criteria. The total maximum daily load represents the allowable load for the discharge, based on the harmonic mean flow and the state water quality criterion of 1.0 ng/L. Table 27 shows the calculated harmonic mean flow and the total allowable total DDT load in milligrams per day for the ST11 orchard drain.

Table 27. Roses Lake Orchard Drain Maximum Allowable Daily Load to Meet Water Quality Standards.

Discharge	Harmonic Mean Flow (cfs)	Total DDT TMDL (mg/day)
ST11 Orchard drain	0.061	0.15

Load Reduction Needed in the Roses Lake Orchard Drain

The orchard drain (ST11) to Roses Lake was sampled monthly from March 2002 through January 2004. Sampling throughout the year incorporated the range of total DDT concentrations found in the discharge to Roses Lake. To compare allowable loads to current loads, and quantify the percent reduction needed to meet criteria, mean study loads were calculated at the harmonic mean flow. Table 28 presents current total DDT loads, the allowable loads to meet water quality standards, needed load reductions, and the percent of the current load reduction needed to meet water quality standards for orchard drain ST11.

Table 28. Roses Lake Orchard Drain Current Load and the Reductions Needed to Meet Water Quality Standards.

Discharge	Current Total DDT Load (mg/day)	Allowable Total DDT Load (mg/day)	Needed Load Reduction (mg/day)	Needed Percent Reduction
ST11 Orchard drain	3.2	0.15	3.1	95

The ST11 orchard drain carries a significant load for the volume of water transported. Current loads are over 20 times the allowable load. Comparing the load discharged from ST11 to the loads discharged to Lake Chelan, it would rank fourth highest after Keupkin Street manhole, Buck Orchards drain, and Purtteman Creek.

Margin of Safety

As required under the Clean Water Act and federal regulation, TMDLs must include a margin of safety (MOS) to take into account uncertainties in the scientific and technical understanding of pollutant sources and their biological and chemical association with water quality. Through guidance, the EPA has suggested two possible approaches to satisfy the MOS requirement (EPA, 1999): (1) It can be met explicitly by factoring in a percentage of the allowable load to the MOS, or (2) It can be satisfied implicitly by using conservative assumptions in developing the allowable loads.

This TMDL has incorporated the MOS implicitly through use of conservative assumptions. The following conservative assumptions were used:

- The average total DDT concentrations in mackinaw tissue from Lake Chelan and rainbow trout from Roses Lake were used in load reduction calculations. Using the total DDT concentrations from the most contaminated fish species would increase the MOS for other species.
- Load reductions needed in fish tissue were based on the average concentration of total DDT (4,4'-DDT + 4,4'-DDE + 4,4'-DDD) instead of individual metabolite criterion in the NTR.
- The mass of tributary and irrigation drain associated total DDT was assumed to be completely conserved. The allocation of total DDT to tributaries and drains assumes no loss by volatilization, photolysis, or biodegradation.
- DDT and metabolite loading from tributaries and irrigation drains was considered 100% available for uptake and bioaccumulation by fish. No sediment associated fraction was considered in load allocation calculations.

Post-TMDL Monitoring

Post-TMDL monitoring is needed to measure achievements in management activities and assure that water quality goals are met. Often nonpoint TMDLs use a phased approach because of the uncertainties in estimating nonpoint sources of pollution and effectiveness of nonpoint controls. Following implementation of control measures, monitoring is conducted to evaluate effectiveness, then revisions to control strategies can be made as necessary.

The goal of the post-TMDL monitoring will be to follow pollutant concentrations in Lake Chelan and Roses Lake fish and water to determine progress in meeting water quality targets established in this TMDL.

Recommendations for post-TMDL monitoring are as follows:

- Fish tissue from Lake Chelan and Roses Lake will require periodic monitoring for DDT and metabolites, PCBs, and dioxins for many years. Analysis of fish tissue should be conducted every five years to follow trends. The data will be used to evaluate the threat to human health and show any progress in reducing tissue concentrations to acceptable levels.

- When sampling plans are being developed for collection and analysis of fish tissue, the Washington State Department of Health should be consulted to verify that sample sizes are appropriate for statistical comparisons and to determine if fish consumption advisories are needed.

- Low level analytical techniques should be used for water samples to assure reporting limits are low enough to satisfy study objectives and to compare with previously collected data. If budgets allow, congener analysis should be conducted for PCBs. With the generally low PCB concentrations found in Lake Chelan fish tissue and sediments, much more information may be available using congener analysis.

- Storm event sampling should be conducted for discharges to the Wapato basin of Lake Chelan and to Roses Lake. In addition to the sites sampled for this study, other discharges should be evaluated that may flow only during storm events. Flow should be measured when water samples are collected, which will allow calculation of pollutant loads.

- For future data comparisons, post-TMDL monitoring should be as consistent as possible with sampling techniques and analytical methods used in the development of this TMDL.

Recommendations

The following recommendations are made to further protect human and environmental health in the Lake Chelan basin:

- The Washington State Department of Health should evaluate the need for fish consumption advisories for Lake Chelan and Roses Lake. If advisories are recommended, public notices should be posted at all public boat launches to the lakes. The public should be aware of potential problems from consuming fish in excess of recommended levels.
- DDT levels should be the primary focus for water quality managers in the Lake Chelan basin. PCB levels should be followed, but management options are more limited.
- Monitoring pollutant levels in mackinaw tissue allows an evaluation of the worst-case scenario for total DDT and PCBs in fish tissue. Until total DDT and PCBs in fish tissue are within acceptable levels, tissue concentrations should continue to be monitored. Because lake sediments act as a large source pool for pollutants, evaluating tissue concentrations will be required far into the future.
- Natural attenuation is the best management strategy for total DDT in Lake Chelan and Roses Lake sediments. Active removal of total-DDT-laden sediments from Lake Chelan is not an option, considering size and depth, disturbance to fish and invertebrate communities, and damage to habitat. Natural attenuation is also the least costly of management options. The rate of attenuation in Roses Lake may be much greater than would be expected in Lake Chelan. It seems that natural attenuation in Roses Lake will improve sediment conditions, although fish tissue concentrations have not responded well.
- Pollutant input to the Wapato basin of Lake Chelan and to Roses Lake should be controlled to the extent possible, to help in recovery and to avoid exacerbating conditions. It has been shown that tributary and irrigation drain sources require substantial load reductions to meet water quality criteria. The discharge point approach to load reduction does not identify specific sources. Loading could come from multiple sources that were quantified as one. Investigations of sub-basins would be required to identify any specific sources for load reductions.
- Load reductions could occur just prior to discharge through developed wetland treatment, if and where feasible. Developed wetlands may be one of the few treatment options available for reducing total DDT. Data from the Joe Creek site in the Lake Chelan Reclamation District study (Burgoon and Cross, 2000) and data from the Wapato Lake + Joe Creek site from this TMDL study suggest loads of total DDT through wetlands may be reduced to acceptable levels.
- An evaluation of total DDT concentrations in the water column from the Wapato basin should be conducted to better quantify spatial and temporal variations.
- An evaluation of the importance of total DDT loading from groundwater to the Wapato basin should be conducted.

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References

Avocet Consulting, 2002. Development of Freshwater Sediment Quality Values for Use in Washington State – Phase I Final Report. Prepared for the Washington State Department of Ecology under contract to Science Applications International Corporation. Publication No. 02-09-050. www.ecy.wa.gov/biblio/0209050.html

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

Burgoon, P. and P. Cross, 2004. Manson Lakes Water Quality Assessment: Lake Trophic Status and DDT and Phosphorus Load Evaluation. Lake Chelan Reclamation District (LCRD). Grant No. G020014, administered by the Washington State Department of Ecology, Olympia, WA.

Chelan County Conservation District, 2000. Lake Chelan Water Quality Project. Centennial Clean Water Fund Grant No. G9500203, administered by the Washington State Department of Ecology, Olympia, WA.

Coots, R. and B. Era-Miller, 2003. Quality Assurance Project Plan - Total Maximum Daily Load Study: DDT and PCBs in Lake Chelan. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-105. www.ecy.wa.gov/biblio/0303105.html

Cross, P.R., 2002. Quality Assurance Project Plan for the Manson Lakes. Lake Chelan Reclamation District. Unpublished. 20 pages.

Davis, D., 1996. Washington State Pesticide Monitoring Program - 1994 Surface Water Sampling Report. Washington State Department of Ecology, Olympia, WA. Publication No. 96-305.

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.

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.

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.

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, 2002. Development of Freshwater Sediment Quality Values For Use In Washington State, Phase 1 Task 6: Final Report. Prepared by Science Applications International Corporation and Avocet Consulting for the Washington State Department of Ecology. Publication No. 02-09-050. www.ecy.wa.gov/biblio/0209050.html

EILS, 1995. Department of Ecology 1993-94 Investigation of PCBs in the Spokane River. Environmental Investigations and Laboratory Services Program, Washington State Department of Ecology, Olympia, WA. Publication No. 95-310. www.ecy.wa.gov/biblio/95310.html

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

EPA, 1991. Technical Support Document for Water Quality-based Toxics Control. U.S. Environmental Protection Agency, Office of Water, EPA/505/2-90-001.

EPA, 1999. Draft Guidance for Water Quality Based Decisions: The TMDL Process (Second Edition). U.S. Environmental Protection Agency, Office of Water, EPA/841/D-99/001.

EPA, 2000. Ambient Water Quality Criteria Derivation Methodology Human Health, Technical Support Document. U.S. Environmental Protection Agency, Office of Water, EPA/822/B-98/005.

EPA, 2002 Unpublished. National Fish Tissue Study. Unpublished data. U.S. Environmental Protection Agency, Office of Water.

EPA, 2003. Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health (2000). Technical Support Document Volume 2: Development of National Bioaccumulation Factors. U.S. Environmental Protection Agency, Office of Water. EPA/822/R-30/030.

Harris, M.J., L.K. Wilson, J.E. Elliott, C.A. Bishop, A.D. Tomlin, and K.V. Henning, 2000. Transfer of DDT and metabolites from fruit orchard soils to American Robins (Turdus migratorius) twenty years after agricultural use of DDT in Canada. Archives of Environmental Contamination and Toxicology 39: 205-220.

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

Huckins, J.N., J.D. Petty, J.A. Lebo, F.V. Almeida, K. Booij, D.A. Alvarez, W.L. Cranor, R.C. Clark, and B.B. Mogensen, 2002. Development of the permeability/performance reference compound (PRC) approach for in situ calibration of semipermeable membrane devices (SPMDs). Environmental Science and Technology 36: 85-91.

Huckins, J.N., J.D. Petty, H.F. Prest, R.C. Clark, D.A. Alvarez, C.E. Orazio, J.A. Lebo, W.L. Cranor, and B.T. Johnson, 2000. A Guide to the Use of Semipermeable Membrane Devices (SPMDs) as Samplers of Waterborne Hydrophobic Organic Contaminants. USGS Columbia Environmental Research Center, Columbia, Missouri.

Johnson, A., 1997. Wapato Lake - Pesticides Levels, Sediment Bioassays, and Abundance of Benthic Macroinvertebrates. Memo to Max Linden and Bob Barwin, Central Regional Office. Washington State Department of Ecology, Olympia, WA. Publication No. 97-e05.

Johnson, A., B. Era-Miller, R. Coots, S. and Golding, 2004. 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

Kendra, W. and L. Singleton, 1987. Morphometry of Lake Chelan. Washington State Department of Ecology, Olympia, WA. Publication No. 87-1. www.ecy.wa.gov/biblio/871.html

Lake Chelan Reclamation District, 1998. Water Quality Trends and Characteristics of Agricultural Drains.

Lake Chelan Reclamation District, 2002 Unpublished. Manson Lakes Sediment Sampling for DDT.

McCarthy, K.A. and R.W. Gale, 1999. Investigation of the Distribution of Organochlorine and Polycyclic Aromatic Hydrocarbons in the Lower Columbia River Using Semipermeable Membrane Devices. USGS Water Resources Investigation Report 99-4051.

Norton, D., 2004. Mercury in Lake Whatcom Sediments: Spatial Distribution, Depositional History, and Tributary Inputs. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-019. www.ecy.wa.gov/biblio/0403019.html

Patmont, C., G. Pelletier, E. Welch, D. Banton, and C. Ebbesmeyer, 1989. Lake Chelan Water Quality Assessment. Prepared by Harper-Owes for the Washington State Department of Ecology, Olympia, WA. Publication No. 89-e37. www.ecy.wa.gov/biblio/89e37.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.

Schell, W.R. and A. Nevissi, 1980. Detrital Sedimentation in Lakes and Reservoirs. University of Washington, Laboratory of Radiation Ecology, College of Fisheries, Seattle, WA. Prepared for the Guidebook on Nuclear Techniques in Hydrology, International Atomic Energy Agency, Vienna, Austria.

Schmitt, C.J., J.L. Zajicek, and M.A. Ribick, 1985. National Pesticide Monitoring Program: Residues of organochlorine chemicals in freshwater fish, 1980-81. Archives of Environmental Contamination and Toxicology 14:225-260.

Seiders, K., 2003. Washington State Toxics Monitoring Program – Toxic Contaminants in Fish Tissue and Surface Water in Freshwater Environments, 2001. Washington State Department of Ecology, Olympia, WA. Publication No. 03-03-012. www.ecy.wa.gov/biblio/0303012.html

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

Vanleer, B.R., 1922. The California Pipe Method of Water Measurement. Engineering News Record, August 3, 1922 and August 21, 1924.

Viola, Art, 2002. Personal communication. Washington Department of Fish and Wildlife, Wenatchee, WA. October 2002.

Viola, Art, 2004. Personal communication. Washington Department of Fish and Wildlife, Wenatchee, WA. May 2004.

WAS, 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e04. www.ecy.wa.gov/biblio/93e04.html

Williams, J.R. and H.E. Pearson, 1985. Streamflow Statistics and Drainage Basin Characteristics for the Southwestern and Eastern Regions, Washington. USGS Open-file Report 84-145-B. U.S. Geological Survey, Tacoma, WA. 662 pages.

WRCC, 2004. Western Regional Climate Center. Precipitation Data for Lakeside, Washington – station 451350. Period of Record Climate Summary 7/24/1890 to 6/30/2004.

Yake, B., 2001. The Use of Sediment Cores to Track Persistent Pollutants in Washington State - A Review. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-001. www.ecy.wa.gov/biblio/0103001.html

Appendices

A. Decision Matrix for the 303(d) Listing in Fish Tissue.

B. Example Spreadsheet Calculator for SPMD Data.

C. Lake Chelan Basin Historical Water Quality Data for DDT/PCB.

D. Biological Data from Lake Chelan DDT/PCB TMDL Fish Samples.

E. Sample Site Locations.

F. Data Quality Summary and Results for the Field and Laboratory Quality Assurance Sample Analysis.

G. DDT/PCBs and Ancillary Results.

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Appendix A

Decision Matrix for the 303(d) Listing in Fish Tissue

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Water Name	CHELAN LAKE				
Parameter	PCB-1260			**Mediu**	Tissue
Place on 1998 List?	Yes	**Listed in 1996**	Yes	**Action Needed**	TMDL
New Segment ID #	292NWR	**Old Segment ID #**	WA-47-9020		
Stream Route #		**Water Resource Inventory Area**	47		
Township	27N	**Waterbody Grid #**	47120I1H6		
Range	22E	**Grid Latitude**	47.875		
Section	13	**Grid Longitude**	120.165		
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible fish tissue of Kokanee and Rainbow Trout during 1994.				
Remarks					

Water Name	CHELAN LAKE				
Parameter	4,4'-DDE			**Mediu**	Tissue
Place on 1998 List?	Yes	**Listed in 1996**	Yes	**Action Needed**	TMDL
New Segment ID #	292NWR	**Old Segment ID #**	WA-47-9020		
Stream Route #		**Water Resource Inventory Area**	47		
Township	27N	**Waterbody Grid #**	47120I1H6		
Range	22E	**Grid Latitude**	47.875		
Section	13	**Grid Longitude**	120.165		
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible fish tissue of Kokanee, Rainbow Trout, and Smallmouth Bass during 1994.				
Remarks					

Water Name	CHELAN LAKE		
Parameter	PCB-1254	**Mediu**	Tissue
Place on 1998 List?	Yes	**Listed in 1996**	Yes
Action Needed	TMDL		
New Segment ID #	292NWR	**Old Segment ID #**	WA-47-9020
Stream Route #		**Water Resource Inventory Area**	47
Township	27N	**Waterbody Grid #**	47120I1H6
Range	22E	**Grid Latitude**	47.875
Section	13	**Grid Longitude**	120.165
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible fish tissue of Kokanee, Rainbow Trout, and Smallmouth Bass during 1994.		
Remarks			

Tuesday, April 04, 2000

Water Name	ROSES (ALKALI) LAKE
Parameter	4,4'-DDE
Mediu	Tissue
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	370XQC
Old Segment ID #	WA-47-9037
Stream Route #	
Water Resource Inventory Area	47
Township	28N
Range	21E
Section	26
Waterbody Grid #	
Grid Latitude	
Grid Longitude	
Basis for Consideration of Listing	Serdar, et al. 1994. , excursions beyond the criterion in edible fish tissue.
Remarks	

Tuesday, April 04, 2000

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Appendix B

Example Spreadsheet Calculator for SPMD Data

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Appendix B. Estimated Water Concentration Calculator From SPMD Data

To calculate the estimated water concentrations (C_W) from SPMD data, enter the appropriate information into the highlighted yellow cells.

Enter a temperature value (10, 18, or 26) in °C which most closely approximates the actual exposure water temperature.

Sample No. 03263002

Wapato Bottom

Temperature (°C) = 10   **Exposure Time (d) =** 29.9

mass of SPMD (g) = 22.5   (NOTE: a standard 81 cm SPMD has a mass of 4.5 g)

Volume of Lipid (L) = 0.005   **Volume of Membrane (L) =** 0.0185   **Volume of SPMD (L) =** 0.0235

(NOTE: a standard 81 cm SPMD has lipid volume of 0.001L, membrane volume of 0.0037L, and a total volume of 0.0047L.)

If a PRC was used, the $k_{e\text{-}PRC}$ can be calculated by $k_{e\text{-}PRC} = [\ln(C_{SPMDo}/C_{SPMD})]/t$. If a PRC was not used, enter the same number for the $k_{e\text{-}PRC}$ as for the $k_{e\text{-}cal}$.

$k_{e\text{-}PRC}$ (d^{-1})= 0.005044   PCB 29 = 0.86

The $k_{e\text{-}cal}$ value is the laboratory calibration value for the native PRC analog.

$k_{e\text{-}cal}$ (d^{-1})= 0.014   (NOTE: the $k_{e\text{-}cal}$ for D_{10}-Phenanthrene is 0.021 d^{-1})

Estimated water concentrations can not be calculated for all compounds.

For compounds in which laboratory R_s values do not exist, the term N/A will appear in place of a numerical value, indicating the inability to estimate the water concentration.

The final Estimated Water Concentration values appear in the light blue highlighted cells.

Project Name: **Lake Chelan DDT/PCB TMDL -- Wapato Bottom May-June 2003**

Compound	Log K_{ow}	K_{SPMD}	Laboratory R_s (L/d)	PRC corrected R_s (L/d)	Theoretical $t_{1/2}$	Total Analyte (ng/SPMD)	Estimated Water Conc. (pg/L)	Model Used
p,p'-DDE	6.14 [a]	2.50E+05	5.5	2.0	2056.3	671.9	11339.7	linear
p,p'-DDD	5.75 [a]	1.54E+05	3.1	1.1	2239.1	170.0	5090.4	linear
p,p'-DDT	5.47 [a]	1.04E+05	3.2	1.2	1462.3	63.8	1850.7	linear

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Appendix C

Lake Chelan Basin
Historical Water Quality Data
for DDT/PCB

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Table C1. Summary of Historical DDT Data on Water from Lake Chelan and Tributaries (ng/L, part per trillion)

Sample Date	Waterbody (Figure C1 and C2 Reference)	4,4'-DDT	4,4'-DDE	4,4'-DDD	tDDT[1]	Reference
May-1996	Knapp Coulee Creek (site G4)	ND	**110**	ND	**110**	CCCD report "Lake Chelan WQ Project 2000"
Jun-1996	Unnamed drainway (site 3)	ND	**110**	ND	**110**	CCCD report "Lake Chelan WQ Project 2000"
Jul-1997	Unnamed drainway (site 3)	ND	ND	**150**	**150**	CCCD report "Lake Chelan WQ Project 2000"
Jun-2002	Prince Ck-Sawtooth Wilderness (LU26)	0.16U	0.16U	0.16U	0.16U	Ecology preliminary sampling - not published
Jun-2002	Unnamed culvert discharge (NS13)	**0.95**	**3.5**	0.21	**4.66**	Ecology preliminary sampling - not published
Jun-2002	Lake Chelan (DT08)	0.16U	0.16U	0.16U	0.16U	Ecology preliminary sampling - not published
Jun-2002	Unnamed - At Veroske's (NS16)	**4.8**	**8.6**	**1.9**	**15.3**	Ecology preliminary sampling - not published
Jun-2002	First Creek (SS01)	0.16U	0.16U	0.16U	0.16U	Ecology preliminary sampling - not published
Jun-2002	Stink Creek (NS24)	0.24U	**1.2**	0.25	**1.45**	Ecology preliminary sampling - not published
Jun-2002	Wapato Lk + Joe Ck outflow (NS23)	0.25U	0.35	0.17	0.52	Ecology preliminary sampling - not published
Jun-2002	Twentyfive Mile Creek (LU25)	0.17U	0.17U	0.17U	0.17U	Ecology preliminary sampling - not published
Jun-2002	Railroad Creek (LU27)	0.17U	0.17U	0.17U	0.17U	Ecology preliminary sampling - not published
Jun-2002	Fish Creek - At Moore Point (LU28)	0.16U	0.16U	0.16U	0.16U	Ecology preliminary sampling - not published
Jun-2002	Stehekin River (LU29)	0.16U	0.16U	0.16U	0.16U	Ecology preliminary sampling - not published
WAC 173-201A - Acute					1100	
WAC 173-201A - Chronic 24 hour average					1.0	
National Toxics Rule (NTR) criteria		0.59	0.59	0.84		

See Figure C1 for sample site locations.

[1] tDDT = 4,4'-DDT + 4,4'-DDE + 4,4'-DDD

ND = Not detected.

Bolded values exceed one or more of the applicable criteria.

U = Not detected at the value shown.

Table C2. Summary of Historical DDT Data on Sediments from Lake Chelan and Manson Lakes (*u*g/Kg, dw – parts per billion)

Waterbody	Sample Date	Station Identification (Figure C1 and C2 Reference)	Water Depth (m)	Sediment Depth (cm)	4,4'-DDT	4,4'-DDE	4,4'-DDD	t-DDT[1]	Study Reference
Lake Chelan	Sep-1984	Outlet (O84)	5-10	0-15	10	32	53	95	Hopkins et al., 1985
Lake Chelan	Nov-1986	Urban drain 2 (UD2)	5	0-5	5	5	5	15	Patmont et al., 1989
Lake Chelan	Nov-1986	Station 1 (ST1)	7	0-5	73	47	50	170	Patmont et al., 1989
Lake Chelan	Nov-1986	Manson Urban Drain (MUD)	7	0-5	69	40	64	173	Patmont et al., 1989
Lake Chelan	Nov-1986	Orchard drain 8 (OD8)	7	0-5	58	55	287	400	Patmont et al., 1989
Lake Chelan	Nov-1986	Orchard drain 6 (OD6)	6	0-5	*nd*	1	*nd*	1	Patmont et al., 1989
Lake Chelan	Nov-1986	Orchard drain 8 (OD8D)	77	0-5	16	16	19	51	Patmont et al., 1989
Lake Chelan	Nov-1986	Orchard drain 6 (OD6D)	80	0-5	108	203	389	700	Patmont et al., 1989
Lake Chelan	Nov-1986	Station 4 (ST4)	124	0-5	44	120	108	272	Patmont et al., 1989
Lake Chelan	Nov-1986	Safety Harbor (SH)	2	0-5	*nd*	*nd*	*nd*	*nd*	Patmont et al., 1989
Lake Chelan	Nov-1986	Station 6 (ST6)	451	0-5	*nd*	8	3	11	Patmont et al., 1989
Lake Chelan	Nov-1986	Urban drain 1 (UD1)	7	0-5	8	13	15	36	Patmont et al., 1989
Lake Chelan	1987	North of Fish Creek (FC)						*nd*	Patmont et al., 1989
Lake Chelan	1987	In Stehekin aluv. Fan (SR)						*nd*	Patmont et al., 1989
Lake Chelan	1987	1 mile up Stehekin R (SR1)						2	Patmont et al., 1989
Roses Lake	Jun-1992	East End (RE92)	7	0-2	48	670	770	1488	Serdar et al., 1994
Roses Lake	Jun-1992	Outlet (RO92)	9	0-2	77	890	790	1757	Serdar et al., 1994
Lake Chelan	Sep-1994	Near Wapato Point (WP94)		0-2	*nd*	8	12	20	Davis and Serdar, 1996
Wapato Lake	Aug-1996	Lower Lake (WL96)	17	0-2	27	470	650	1147	Johnson, 1997
Wapato Lake	Aug-1996	Upper Lake (WU96)	17	0-2	*nd*	160	230	390	Johnson, 1997
Wapato Lake	Jun-2002	East end (W1S)			*nd*	*nd*	*nd*	*nd*	Burgoon and Cross, 2004
Wapato Lake	Jun-2002	Center (W2S)			*nd*	35	36	71	Burgoon and Cross, 2004
Wapato Lake	Jun-2002	West end (W3S)			*nd*	15	8	23	Burgoon and Cross, 2004
Roses Lake	Jun-2002	East end (R1S)			39	29	14	82	Burgoon and Cross, 2004
Roses Lake	Jun-2002	Center (R2S)			*nd*	48	22	70	Burgoon and Cross, 2004
Roses Lake	Jun-2002	West end (R3S)			*nd*	12	19	31	Burgoon and Cross, 2004
Dry Lake	Jun-2002	East end (D1S)			*nd*	49	55	104	Burgoon and Cross, 2004
Dry Lake	Jun-2002	Center (D2S)			*nd*	68	44	112	Burgoon and Cross, 2004
Dry Lake	Jun-2002	West end (D3S)			4	43	21	68	Burgoon and Cross, 2004
Freshwater Sediment Guidelines - Severe Effects Threshold (SEL)[2]					-	190	60	120	Ecology, 2002

[1] t-DDT is the sum of 4,4'-DDT + 4,4'-DDE + 4,4'-DDD
[2] Ecology, 2002
nd = not detected

Table C3. Summary of Historical DDT and PCB Data on Fish Tissue from Lake Chelan and Manson Lakes (*u*g/Kg, ww – parts per billion)

Waterbody	Basin (Ref Area)	Sample Date	Fish Species	Tissue Type	4,4'-DDT	4,4'-DDE	4,4'-DDD	tDDT[1]	PCB-1254	PCB-1260	tPCB	Reference
Lake Chelan	Wapato (2)	Sep-82	Bridgelip sucker	Whole body	418	3,200	850	4,468				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-82	Northern pike minnow	Whole body	48	1,380	104	1,532				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-83	Bridgelip sucker	Fillet	**113**	**473**	**193**	779				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-83	Bridgelip sucker	Whole body	140	1,189	510	1,839				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-83	Northern pike minnow	Fillet	21	**1,709**	**97**	1,827				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-83	Northern pike minnow	Whole body	*nd*	1,339	77	1,416				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-84	Bridgelip sucker	Fillet	**44**	**990**	**110**	1,144				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-84	Northern pike minnow	Fillet	**75**	**1,000**	31	1,106				Hopkins et al., 1985
Lake Chelan	Wapato (2)	Sep-87	Sucker	Whole body	13	290	39	342				Patmont et al., 1989
Lake Chelan	Wapato (2)	Sep-87	Northern pike minnow	Whole body	3	3,200	160	3,363				Patmont et al., 1989
Lake Chelan	Wapato (2)	Sep-87	Kokanee (sockeye)	Whole body	50	630	93	773				Patmont et al., 1989
Lake Chelan	Wapato (3)	Sep-87	Burbot (cod)	Fillet	20	**440**	18	478				Patmont et al., 1989
Lake Chelan	Wapato (3)	Sep-87	Northern pike minnow	Whole body	*nd*	3,600	150	3,750				Patmont et al., 1989
Lake Chelan	Wapato (3)	Sep-87	Sucker	Whole body	110	820	77	1,007				Patmont et al., 1989
Lake Chelan	Wapato (3)	Sep-87	Sucker	Whole body	95	650	89	834				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Kokanee (sockeye)	Whole body	25	260	36	321				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Chinook	Fillet	**110**	**2,800**	**190**	3,100				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Rainbow trout	Fillet	5	**780**	30	815				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Burbot (cod)	Fillet	*nd*	**59**	2	61				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Sucker	Whole body	24	370	81	475				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Northern pike minnow	Whole body	*nd*	1,400	80	1,480				Patmont et al., 1989
Lake Chelan	Lucerne (5)	Sep-87	Northern pike minnow	Whole body	*nd*	1,100	61	1,161				Patmont et al., 1989
Roses Lake		Aug-92	Brown bullhead	Whole body	6	388	86	480				Serdar et al., 1994
Roses Lake		Aug-92	Rainbow trout	Fillet	2	**75**	26	103				Serdar et al., 1994
Roses Lake		Aug-92	Brown bullhead	Fillet	2	**165**	19	186				Serdar et al., 1994

[1] t-DDT is the sum of 4,4'-DDT + 4,4'-DDE + 4,4'-DDD

Table C3 cont. Summary of Historical DDT and PCB Data on Fish Tissue from Lake Chelan and Manson Lakes (*u*g/Kg, ww–parts per billion)

Waterbody	Basin (Ref Area)	Sample Date	Fish Species	Tissue Type	4,4'-DDT	4,4'-DDE	4,4'-DDD	tDDT[1]	PCB-1254	PCB-1260	tPCB[2]	Reference
Lake Chelan	Wapato (1)	Sep-92	Largescale sucker	Whole body	5	133	29	167	17		17	Davis and Johnson, 1994
Lake Chelan	Wapato (1)	Sep-92	Rainbow trout	Fillet	2	**53**	2	57	**15**		**15**	Davis and Johnson, 1994
Lake Chelan	Wapato (1)	Sep-92	Kokanee (sockeye)	Fillet	19	**398**	17	434	**12**		**12**	Davis and Johnson, 1994
Lake Chelan	Wapato (1)	Sep-92	Kokanee (sockeye)	Eggs	82	1370	59	1,511	14	16	30	Davis and Johnson, 1994
Lake Chelan	Wapato (3)	Sep-94	Kokanee (sockeye)	Fillet	12	**140**	12	164	**84**	**15**	**99**	Davis and Serdar, 1996
Lake Chelan	Wapato (3)	Sep-94	Rainbow trout	Fillet		**56**		56	**65**	**15**	**80**	Davis and Serdar, 1996
Lake Chelan	Wapato (3)	Sep-94	Smallmouth bass	Fillet	28	**330**	34	392	**16**		**16**	Davis and Serdar, 1996
Lake Chelan	Wapato (3)	Sep-94	Largescale sucker	Whole body	53	800	93	946	34	35	69	Davis and Serdar, 1996
Wapato Lake		Sep-96	Rainbow trout (yr 1)	Fillet	4	15	2	21				Johnson, A., 1997
Wapato Lake		Sep-96	Rainbow trout (yr 2)	Fillet	4	28	3	35				Johnson, A., 1997
Wapato Lake		Sep-96	Rainbow trout	Whole body	11	50	6	67				Johnson, A., 1997
Lake Chelan	Lucerne (4)	Sep-00	Lake trout	Fillet	**46**	**1,394**	41	1,481				EPA National Fish Tissue Study
Lake Chelan	Wapato (1)	Aug-00	Largescale sucker	Whole body	24	728	2	754				EPA National Fish Tissue Study
National Toxics Rule (NTR) Human Health Criteria[3]					32	32	45				5.3	

[1] t-DDT is the sum of 4,4'-DDT + 4,4'-DDE + 4,4'-DDD.
[2] t-PCB is the sum of all Aroclors detected.
Bolded values exceed NTR human health criteria in edible tissue.
nd = not detected.
Boxed values are the basis for the 1998 303(d) listing.
[3] Based on EPA bioconcentration factors and National Toxics Rule water column criteria.

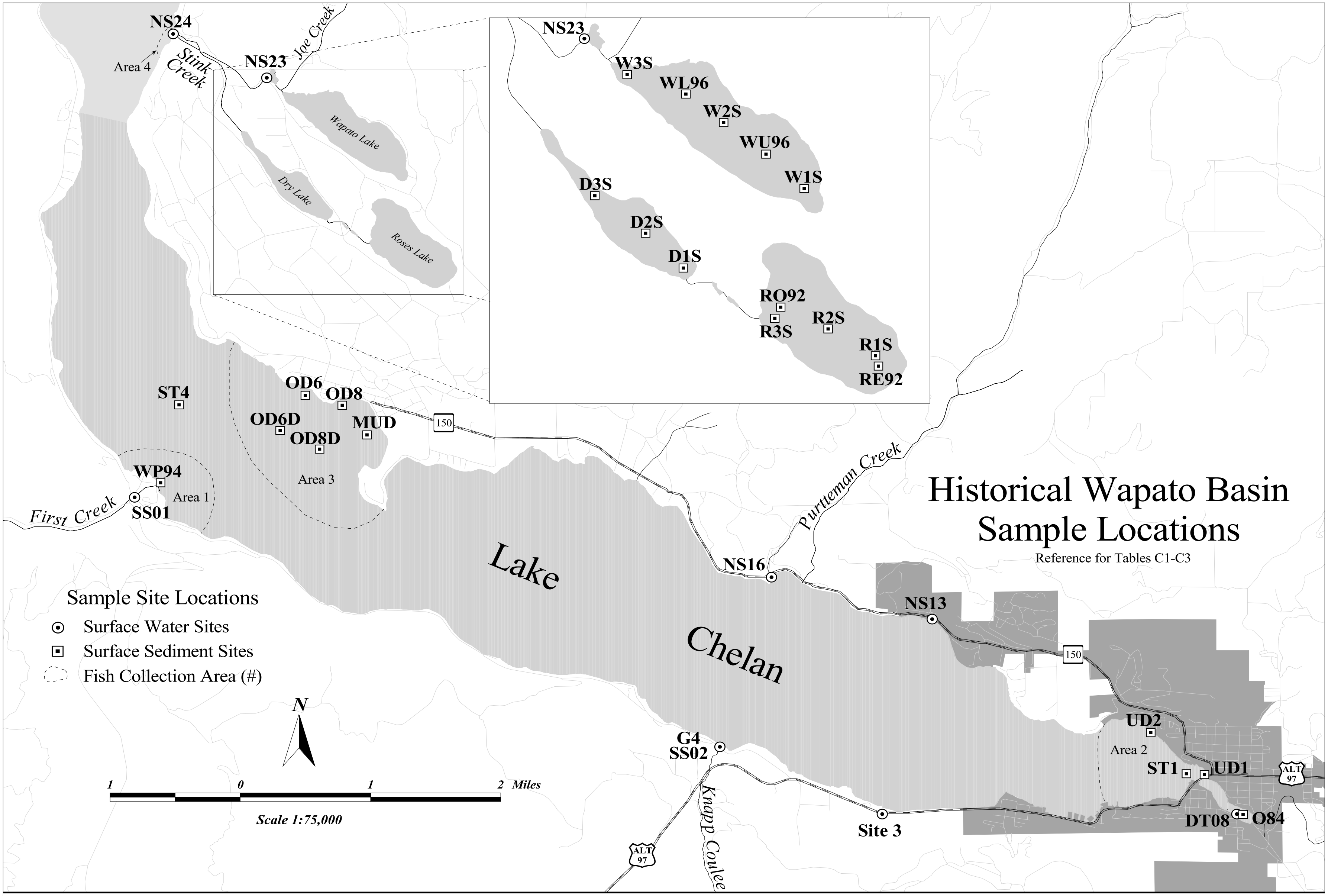

Figure C1. Historical Sampling Locations in the Wapato Basin of Lake Chelan.

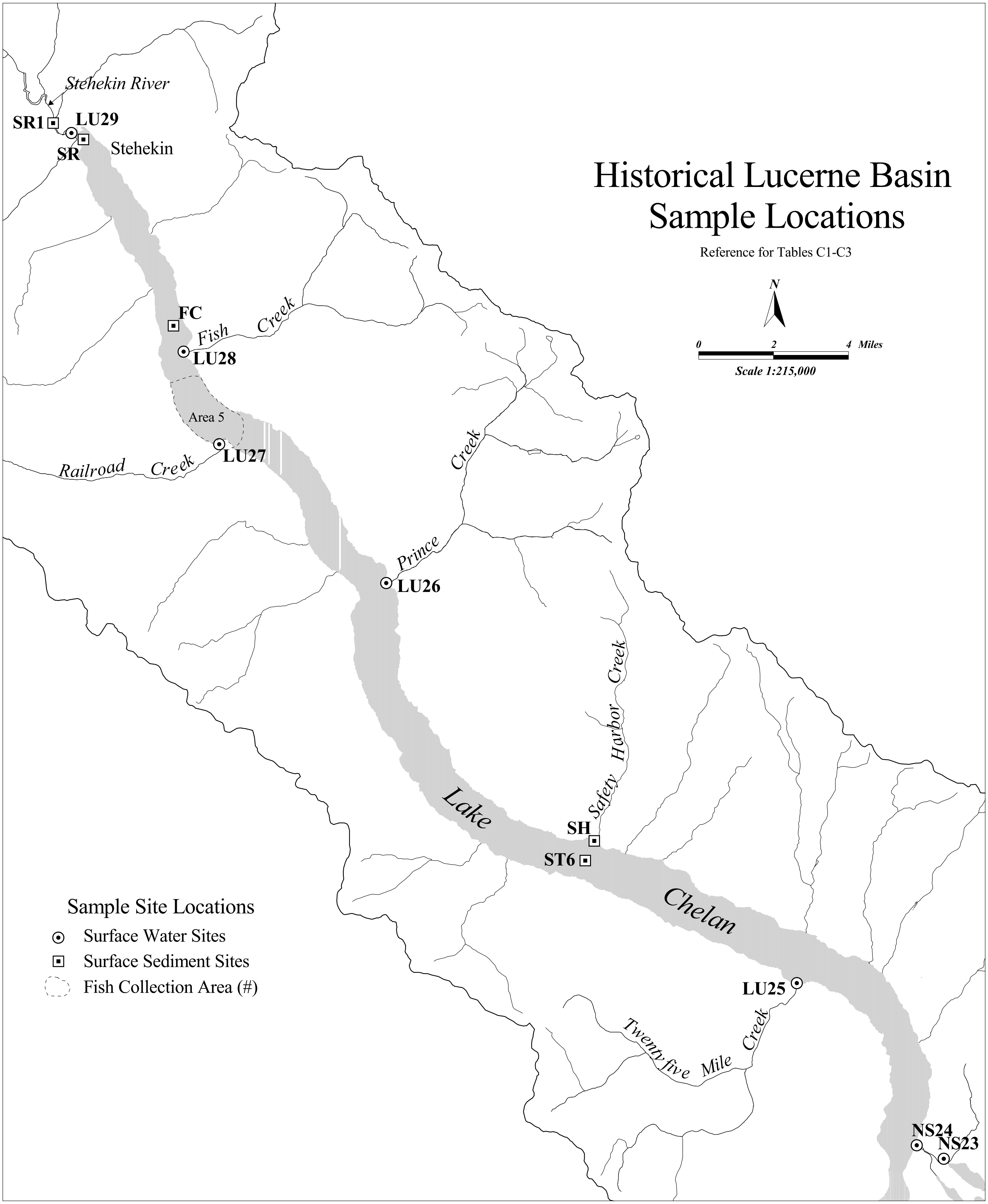

Figure C2. Historical Sampling Locations in the Lucerne Basin of Lake Chelan.

Appendix D

Biological Data from Lake Chelan DDT/PCB TMDL Fish Samples

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Table D1. Biological data on Lake Chelan DDT/PCB TMDL fish samples.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)[1]	Total Weight (gm)	Fillet Type skin-on/off	Fillet Weight (gm)	Sex[2]	Age (yrs)
5/17/2003	MACK wap Lg-1	3204200	Mackinaw	613	2100	on	357	F	6
5/17/2003	MACK wap Lg-1	3204200	Mackinaw	644	2184	on	447	M	7
5/17/2003	MACK wap Lg-1	3204200	Mackinaw	570	2242	on	335	U	6
5/17/2003	MACK wap Lg-1	3204200	Mackinaw	620	1947	on	309	F	8
5/17/2003	MACK wap Lg-1	3204200	Mackinaw	612	2031	on	391	F	6
5/17/2003	MACK wap Lg-2	3204201	Mackinaw	652	2759	on	472	U	6
5/17/2003	MACK wap Lg-2	3204201	Mackinaw	665	2545	on	450	F	7
5/17/2003	MACK wap Lg-2	3204201	Mackinaw	667	2608	on	470	U	7
5/17/2003	MACK wap Lg-2	3204201	Mackinaw	669	2650	on	432	M	5
5/17/2003	MACK wap Lg-2	3204201	Mackinaw	598	2342	on	410	U	5
5/17/2003	MACK wap Lg-3	3204202	Mackinaw	735	3507	on	679	F	7
5/17/2003	MACK wap Lg-3	3204202	Mackinaw	765	5091	on	1030	F	7
5/17/2003	MACK wap Lg-3	3204202	Mackinaw	660	3400	on	564	F	6
5/17/2003	MACK wap Lg-3	3204202	Mackinaw	721	4117	on	844	F	8
5/17/2003	MACK wap Lg-3	3204202	Mackinaw	688	3261	on	502	F	9
3/14/2003	MACK wap med-1	3114053	Mackinaw	527	1412	on	324	U	5
5/17/2003	MACK wap med-1	3114053	Mackinaw	545	1352	on	212	M	6
5/17/2003	MACK wap med-1	3114053	Mackinaw	522	1392	on	205	F	7
5/17/2003	MACK wap med-1	3114053	Mackinaw	534	1362	on	310	U	ND
5/17/2003	MACK wap med-1	3114053	Mackinaw	567	1413	on	264	U	5
5/17/2003	MACK wap med-2	3204203	Mackinaw	541	1445	on	204	U	7
5/17/2003	MACK wap med-2	3204203	Mackinaw	565	1454	on	323	F	6
5/17/2003	MACK wap med-2	3204203	Mackinaw	562	1489	on	212	U	7
5/17/2003	MACK wap med-2	3204203	Mackinaw	583	1434	on	310	U	7
5/17/2003	MACK wap med-2	3204203	Mackinaw	590	1525	on	233	F	7
5/17/2003	MACK wap med-3	3204205	Mackinaw	602	1596	on	288	F	6
5/17/2003	MACK wap med-3	3204205	Mackinaw	552	1530	on	210	U	6
5/17/2003	MACK wap med-3	3204205	Mackinaw	555	1530	on	305	U	6
5/17/2003	MACK wap med-3	3204205	Mackinaw	550	1568	on	275	F	6
5/17/2003	MACK wap med-3	3204205	Mackinaw	580	1605	on	300	U	6
5/17/2003	MACK wap med-4	3154153	Mackinaw	615	1743	on	233	M	7
5/17/2003	MACK wap med-4	3154153	Mackinaw	581	1698	on	370	F	7
5/17/2003	MACK wap med-4	3154153	Mackinaw	544	1632	on	322	M	ND
5/17/2003	MACK wap med-4	3154153	Mackinaw	575	1689	on	266	U	6
4/11/2003	MACK wap med-4	3154153	Mackinaw	603	1713	on	315	F	8
5/17/2003	MACK wap sm-1	3204206	Mackinaw	412	714	on	128	M	5
5/17/2003	MACK wap sm-1	3204206	Mackinaw	400	565	on	115	U	5
5/17/2003	MACK wap sm-1	3204206	Mackinaw	330	801	on	121	U	5
5/17/2003	MACK wap sm-1	3204206	Mackinaw	487	807	on	160	F	6
5/17/2003	MACK wap sm-1	3204206	Mackinaw	342	371	on	84	U	4
5/17/2003	MACK wap sm-2	3204207	Mackinaw	476	1009	on	168	U	6
5/17/2003	MACK wap sm-2	3204207	Mackinaw	503	1037	on	232	F	6
5/17/2003	MACK wap sm-2	3204207	Mackinaw	537	1160	on	176	F	5
5/17/2003	MACK wap sm-2	3204207	Mackinaw	525	1149	on	284	M	5
5/17/2003	MACK wap sm-2	3204207	Mackinaw	484	1102	on	180	M	5

Table D1 cont'd. Biological data on Lake Chelan DDT/PCB TMDL fish samples.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)[1]	Total Weight (gm)	Fillet Type skin-on/off	Fillet Weight (gm)	Sex[2]	Age (yrs)
5/17/2003	MACK wap sm-3	3204208	Mackinaw	539	1306	on	224	F	5
5/17/2003	MACK wap sm-3	3204208	Mackinaw	528	1219	on	211	F	6
5/17/2003	MACK wap sm-3	3204208	Mackinaw	512	1247	on	227	M	5
5/17/2003	MACK wap sm-3	3204208	Mackinaw	545	1314	on	244	M	5
5/17/2003	MACK wap sm-3	3204208	Mackinaw	532	1246	on	195	U	6
5/23/2003	kok wap Lg-1	3214552	Kokanee	295	208	on	90	U	2
5/23/2003	kok wap Lg-1	3214552	Kokanee	280	170	on	72	M	2
5/23/2003	kok wap Lg-1	3214552	Kokanee	285	211	on	87	F	2
5/23/2003	kok wap Lg-1	3214552	Kokanee	290	209	on	70	M	2
5/23/2003	kok wap Lg-1	3214552	Kokanee	280	189	on	73	M	2
5/23/2003	kok wap Lg-2	3214553	Kokanee	285	211	on	89	F	2
5/23/2003	kok wap Lg-2	3214553	Kokanee	305	234	on	91	F	2
5/23/2003	kok wap Lg-2	3214553	Kokanee	290	226	on	91	M	3
5/23/2003	kok wap Lg-2	3214553	Kokanee	315	271	on	110	U	3
5/23/2003	kok wap Lg-2	3214553	Kokanee	315	267	on	96	U	3
5/23/2003	kok wap med-1	3214554	Kokanee	255	144	on	60	F	2
5/23/2003	kok wap med-1	3214554	Kokanee	260	143	on	59	M	2
5/23/2003	kok wap med-1	3214554	Kokanee	260	143	on	65	F	2
5/23/2003	kok wap med-1	3214554	Kokanee	255	144	on	60	M	2
5/23/2003	kok wap med-1	3214554	Kokanee	255	142	on	62	M	2
5/23/2003	kok wap med-2	3214555	Kokanee	260	156	on	65	U	3
5/23/2003	kok wap med-2	3214555	Kokanee	265	155	on	64	U	2
5/23/2003	kok wap med-2	3214555	Kokanee	260	149	on	55	U	2
5/23/2003	kok wap med-2	3214555	Kokanee	250	146	on	66	M	3
5/23/2003	kok wap med-2	3214555	Kokanee	255	151	on	56	M	2
5/23/2003	kok wap med-3	3214556	Kokanee	270	165	on	70	U	3
5/23/2003	kok wap med-3	3214556	Kokanee	270	157	on	65	F	2
5/23/2003	kok wap med-3	3214556	Kokanee	270	169	on	80	M	2
5/23/2003	kok wap med-3	3214556	Kokanee	265	165	on	72	U	2
5/23/2003	kok wap med-3	3214556	Kokanee	270	169	on	70	U	2
5/23/2003	Kok wap sm-1	3214557	Kokanee	240	121	on	51	M	2
5/23/2003	Kok wap sm-1	3214557	Kokanee	230	103	on	37	U	2
5/23/2003	Kok wap sm-1	3214557	Kokanee	245	125	on	59	F	2
5/23/2003	Kok wap sm-1	3214557	Kokanee	240	104	on	45	F	2
5/23/2003	Kok wap sm-1	3214557	Kokanee	235	111	on	50	U	2
5/23/2003	Kok wap sm-2	3214558	Kokanee	240	130	on	61	M	2
5/23/2003	Kok wap sm-2	3214558	Kokanee	255	134	on	65	F	2
5/23/2003	Kok wap sm-2	3214558	Kokanee	240	134	on	65	M	2
5/23/2003	Kok wap sm-2	3214558	Kokanee	260	132	on	72	M	2
5/23/2003	Kok wap sm-2	3214558	Kokanee	250	139	on	66	F	2
5/21/2003	Burb Luc-1	3214550	Burbot	535	786	off	118	F	7
5/21/2003	Burb Luc-1	3214550	Burbot	518	789	off	107	M	6
5/21/2003	Burb Luc-1	3214550	Burbot	524	714	off	116	M	10
6/3/2003	Burb Luc-1	3214550	Burbot	524	808	off	142	M	6
8/13/2003	Burb Luc-1	3214550	Burbot	460	589	off	104	F	5

Table D1 cont'd. Biological information on Lake Chelan DDT/PCB TMDL fish samples.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)[1]	Total Weight (gm)	Fillet Type skin-on/off	Fillet Weight (gm)	Sex[2]	Age (yrs)
5/21/2003	Burb Luc-2	3154154	Burbot	501	865	off	143	F	5
5/21/2003	Burb Luc-2	3154154	Burbot	531	877	off	124	F	6
7/29/2003	Burb Luc-2	3154154	Burbot	575	858	off	117	M	13
4/11/2003	Burb Luc-2	3154154	Burbot	526	893	off	96	F	7
4/11/2003	Burb Luc-2	3154154	Burbot	545	856	off	93	M	9
5/21/2003	Burb Luc-3	3214551	Burbot	571	1035	off	123	F	8
5/21/2003	Burb Luc-3	3214551	Burbot	572	1081	off	200	F	7
5/21/2003	Burb Luc-3	3214551	Burbot	586	1268	off	204	F	8
7/29/2003	Burb Luc-3	3214551	Burbot	540	907	off	178	F	9
6/3/2003	Burb Luc-3	3214551	Burbot	548	950	off	152	M	8
3/14/2003	Burb Wap-1	3114054	Burbot	550	743	off	101	M	10
3/14/2003	Burb Wap-1	3114054	Burbot	454	573	off	87	M	9
4/10/2003	Burb Wap-1	3114054	Burbot	484	718	off	72	F	7
8/13/2003	Burb Wap-1	3114054	Burbot	472	619	off	60	F	7
8/13/2003	Burb Wap-1	3114054	Burbot	495	677	off	111	M	7
3/13/2003	Burb Wap-2	3114050	Burbot	567	901	off	138	F	13
8/13/2003	Burb Wap-2	3114050	Burbot	532	789	off	122	F	12
8/13/2003	Burb Wap-2	3114050	Burbot	520	791	off	127	F	8
4/11/2003	Burb Wap-2	3114050	Burbot	483	756	off	122	M	7
7/29/2003	Burb Wap-2	3114050	Burbot	562	807	off	118	U	13
4/10/2003	Burb Wap-3	3114055	Burbot	557	944	off	105	M	11
3/14/2003	Burb Wap-3	3114055	Burbot	538	933	off	94	M	11
3/14/2003	Burb Wap-3	3114055	Burbot	550	903	off	120	M	8
4/11/2003	Burb Wap-3	3114055	Burbot	534	924	off	95	F	8
8/26/2003	Burb Wap-3	3114055	Burbot	547	902	off	133	F	ND
4/10/2003	Burb Wap-4	3154150	Burbot	585	1148	off	155	F	13
4/10/2003	Burb Wap-4	3154150	Burbot	543	979	off	106	F	9
4/10/2003	Burb Wap-4	3154150	Burbot	539	950	off	111	F	6
5/17/2003	Burb Wap-4	3154150	Burbot	544	1004	off	149	M	9
4/11/2003	Burb Wap-4	3154150	Burbot	524	1017	off	103	M	11
3/13/2003	Burb Wap-5	3114051	Burbot	605	1163	off	176	F	11
3/14/2003	Burb Wap-5	3114051	Burbot	552	1199	off	188	F	8
5/17/2003	Burb Wap-5	3114051	Burbot	636	1230	off	186	M	17
5/17/2003	Burb Wap-5	3114051	Burbot	582	1188	off	181	M	10
5/17/2003	Burb Wap-5	3114051	Burbot	590	1246	off	167	M	11
3/13/2003	Burb Wap-6	3114052	Burbot	635	1338	off	178	F	14
3/14/2003	Burb Wap-6	3114052	Burbot	598	1333	off	182	F	8
5/17/2003	Burb Wap-6	3114052	Burbot	595	1317	off	186	M	12
8/13/2003	Burb Wap-6	3114052	Burbot	608	1251	off	202	F	14
7/29/2003	Burb Wap-6	3114052	Burbot	607	1302	off	196	F	8
4/10/2003	Burb Wap-7	3154152	Burbot	625	1405	off	191	F	13
5/17/2003	Burb Wap-7	3154152	Burbot	651	1434	off	243	F	13
5/17/2003	Burb Wap-7	3154152	Burbot	721	2173	off	284	F	14
4/11/2003	Burb Wap-7	3154152	Burbot	608	1362	off	220	M	13
4/11/2003	Burb Wap-7	3154152	Burbot	618	1720	off	260	M	9

Table D1 cont'd. Biological information on Lake Chelan DDT/PCB TMDL fish samples.

Collection Date	Composite Identification	Sample Number	Species	Total Length (mm)[1]	Total Weight (gm)	Fillet Type skin-on/off	Fillet Weight (gm)	Sex[2]	Age (yrs)
8/12/2003	Rose BCRA-1	3334350	Black Crappie	278	314	on	70	U	4
8/12/2003	Rose BCRA-1	3334350	Black Crappie	280	328	on	74	U	6
8/12/2003	Rose BCRA-1	3334350	Black Crappie	272	317	on	71	U	5
8/12/2003	Rose BCRA-1	3334350	Black Crappie	203	143	on	63	U	2
8/12/2003	Rose BCRA-1	3334350	Black Crappie	192	116	on	51	U	2
9/23/2003	Rose BOWS-1	3394400	Rainbow	219	119	on	73	U	ND
9/30/2003	Rose BOWS-1	3394400	Rainbow	225	127	on	74	U	1
9/23/2003	Rose BOWS-1	3394400	Rainbow	227	139	on	72	U	1
9/23/2003	Rose BOWS-1	3394400	Rainbow	227	139	on	78	U	1
9/23/2003	Rose BOWS-1	3394400	Rainbow	240	145	on	84	U	1
10/11/2003	BOWS Wap lg	3394401	Rainbow	326	344	on	98	U	1
10/12/2003	BOWS Wap lg	3394401	Rainbow	321	342	on	105	F	1
10/12/2003	BOWS Wap lg	3394401	Rainbow	313	310	on	91	U	1
10/12/2003	BOWS Wap lg	3394401	Rainbow	309	308	on	85	F	1
9/30/2003	BOWS Wap lg	3394401	Rainbow	312	303	on	86	U	1
10/2/2003	BOWS Wap med	3394402	Rainbow	305	296	on	156	U	1
10/2/2003	BOWS Wap med	3394402	Rainbow	302	275	on	74	F	1
9/30/2003	BOWS Wap med	3394402	Rainbow	293	247	on	70	U	1
10/2/2003	BOWS Wap med	3394402	Rainbow	293	237	on	66	U	1
10/12/2003	BOWS Wap med	3394402	Rainbow	294	233	on	67	F	1
10/12/2003	BOWS Wap sm	3394403	Rainbow	283	228	on	122	U	1
9/30/2003	BOWS Wap sm	3394403	Rainbow	291	216	on	104	U	1
10/11/2003	BOWS Wap sm	3394403	Rainbow	290	214	on	115	U	1
9/30/2003	BOWS Wap sm	3394403	Rainbow	278	209	on	110	U	1
10/2/2003	BOWS Wap sm	3394403	Rainbow	265	173	on	90	U	1

Table D1 cont'd. Biological information on Lake Chelan DDT/PCB TMDL fish samples.

Collection Date	Individual Identification	Sample Number	Species	Total Length (mm)[1]	Total Weight (gm)	Fillet Type skin-on/off	Fillet Weight (gm)	Sex[2]	Age (yrs)
5/17/2003	WAP20	3214450	Mackinaw	476	1009	on	168	U	6
5/17/2003	WAP24	3214451	Mackinaw	541	1445	on	204	U	7
5/17/2003	WAP25	3214452	Mackinaw	545	1352	on	212	M	6
5/17/2003	WAP27	3214453	Mackinaw	522	1392	on	205	F	7
5/17/2003	WAP33	3214454	Mackinaw	667	2608	on	470	U	7
5/17/2003	WAP35	3214455	Mackinaw	613	2100	on	357	F	6
5/17/2003	WAP37	3214456	Mackinaw	765	5091	on	1030	F	7
5/17/2003	WAP43	3214457	Mackinaw	552	1530	on	210	U	6
5/17/2003	WAP46	3214458	Mackinaw	615	1743	on	233	M	7
5/17/2003	WAP48	3214459	Mackinaw	598	2342	on	410	U	5
5/17/2003	WAP49	3214460	Mackinaw	620	1947	on	309	F	8
5/17/2003	WAP52	3214461	Mackinaw	721	4117	on	844	F	ND
5/17/2003	WAP57	3214462	Mackinaw	550	1568	on	275	F	6
5/17/2003	WAP58	3214463	Mackinaw	400	565	on	115	U	5
5/17/2003	WAP60	3214464	Mackinaw	484	1102	on	180	M	6
5/17/2003	WAP61	3214465	Mackinaw	330	801	on	121	U	5
5/17/2003	WAP66	3214466	Mackinaw	688	3261	on	502	F	9
5/17/2003	WAP67	3214467	Mackinaw	575	1689	on	266	U	6
5/17/2003	WAP68	3214468	Mackinaw	580	1605	on	300	U	6
5/17/2003	WAP70	3214469	Mackinaw	532	1246	on	195	U	6
5/17/2003	WAP22	3214470	Mackinaw	412	714	on	128	M	5
5/17/2003	WAP23	3214471	Mackinaw	652	2759	on	472	U	6
5/17/2003	WAP26	3214472	Mackinaw	665	2545	on	450	F	7
5/17/2003	WAP30	3214473	Mackinaw	735	3507	on	679	F	7
5/17/2003	WAP34	3214474	Mackinaw	562	1489	on	212	U	7
5/17/2003	WAP41	3214475	Mackinaw	539	1306	on	224	F	5
5/17/2003	WAP47	3214476	Mackinaw	570	2242	on	335	U	6
5/17/2003	WAP50	3214477	Mackinaw	537	1160	on	176	F	5
5/17/2003	WAP64	3214478	Mackinaw	567	1413	on	264	U	5
5/17/2003	WAP65	3214479	Mackinaw	342	371	on	84	U	4
10/11/2003	CHELAN01	3394404	Rainbow	326	344	on	96	U	1
10/2/2003	CHERIV08	3394407	Rainbow	305	296	on	83	U	1
9/30/2003	CHERIV02	3394406	Rainbow	278	209	on	59	U	1
8/13/2003	BOWS01	3394405	Rainbow	249	127	on	67	U	1

1 Total fish length defined as measurement from tip of nose to tip of tail (forked tails center compressed).
2 M = male; F = female; U = unable to visually determine sex.
ND = No data.

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Appendix E

Sample Site Locations for the Lake Chelan DDT/PCB TMDL Study

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Table E1. Lake Chelan basin water sample locations (NAD 27).

Location	Site ID	Latitude	Longitude	Description
First Creek	SS01	47.874246	-120.199473	Just upstream of Highway 97 bridge
Knapp Coulee	SS02	47.843909	-120.101018	Just upstream of culvert under Highway 97
Chelan River	DT08	47.835282	-120.015195	Off the end of the boat launch dock
Culvert east of Crystal View	NS13	47.859403	-120.066621	At the culvert outlet under Highway 150
Purtteman Creek	NS15	47.863432	-120.086401	Just upstream of culvert under Highway 150
Culvert at Veroske's	NS16	47.864302	-120.092155	Outlet of culvert under Highway 150
Cooper Drainage	NS18	47.880429	-120.112628	Just upstream of culvert under Highway 150
Bennet Road	NS19	47.878404	-120.118159	At Bennet Road manhole on Highway 150
Keupkin Street	NS21	47.889331	-120.171870	At the Keupkin Street manhole in Manson
Buck Orchards	NS22	47.892453	-120.179734	Just above culvert under Lakeshore Drive
Wapato Lake + Joe Creek	NS23	47.924685	-120.176905	Upstrm of culvert at Wapato Lake Rd, Lower Joe Creek Rd, and Manson Blvd intersection
Stink Creek	NS24	47.930003	-120.192653	Just upstrm of discharge at Pickens Landing
Twentyfive Mile Creek	LU25	47.992922	-120.261006	Just upstream of discharge to Lake Chelan
Prince Creek	LU26	48.147492	-120.497094	Just upstream of discharge to Lake Chelan
Railroad Creek	LU27	48.201287	-120.593440	At the Wooden bridge ~ 200m upstream
Fish Creek	LU28	48.237487	-120.613903	Just upstream of discharge to Lake Chelan
Stehekin River	LU29	48.317922	-120.675571	Just upstream of discharge to Lake Chelan
Mill Bay boat ramp	NS30	47.878611	-120.126944	Just above discharge to Lake Chelan

* See Figure 2 for site locations within the basin.

Table E2. Lake Chelan transect sediment site locations (NAD 27).

Basin	Site ID	Latitude	Longitude	Sample Description
Wapato	W-0.69	47.840443	-120.022238	Sandy w/ silt; small organic chunks
Wapato	W-1.89	47.841593	-120.048057	Grey color; gritty/sandy w/ organic matter
Wapato	W-3.15	47.846405	-120.074159	Thin rusty top layer over grey; gritty
Wapato	W-4.41	47.853616	-120.099158	Thin rusty top layer over grey
Wapato	W-5.64	47.861656	-120.122601	Thin rusty top layer over grey
Wapato	W-6.86	47.865413	-120.147948	Thin rusty top layer over grey
Wapato	W-8.22	47.871646	-120.175585	Thin rusty top layer over grey; sulfur smell
Wapato	W-9.31	47.882031	-120.193206	Thin orange/black surface, above grey silt
Wapato	W-10.17	47.892558	-120.203148	Thin brown/orange surface; grey silt below
Wapato	W-11.08	47.905608	-120.205271	Thicker brown/orange surface layer
Lucerne	L-13.00	47.933787	-120.201857	Thick brown top layer, sand below
Lucerne	L-16.00	47.975482	-120.204583	Thick brown top layer; some wood debris
Lucerne	L-17.79	47.994116	-120.229851	Grey silt/clay w/ thin brown/orange surface
Lucerne	L-20.51	48.010646	-120.283215	Grey silt/clay w/ thin brown/orange surface
Lucerne	L-34.33	48.123951	-120.501987	Grey silt/clay w/ thin brown/orange surface
Lucerne	L-40.62	48.200185	-120.566757	Grey silt/clay w/ thin brown/orange surface
Lucerne	L-47.00	48.273448	-120.633751	Silty w/ rust brown organic surface

* See Figure 2 for site location within the basin.

Table E3. Lake Chelan tributary alluvium sediment site locations (NAD 27).

Tributary	Site ID	Latitude	Longitude	Sediment Description
First Creek	1st-Sed	47.885425	-120.192352	Dark brown sand w/ surface organic debris
Railroad Creek	RR-Sed	48.190782	-120.547175	Sandy w/ large amount of wood debris
Stehekin River	Ste-Sed	48.312599	-120.667561	Brown silty sand w/ macrophytes

* See Figure 2 for site location within the basin.

Table E4. Lake Chelan core sediment site locations (NAD 27).

Basin	Site ID	Latitude	Longitude	General Location/Depth of Core
Wapato	WB01	47.885425	-120.192352	Outer edge of Manson Bay / 122 meters
Lucerne	LB02	48.190782	-120.547175	2.25 miles downlake from Lucerne / 207 meters

* See Figure 2 for site location within the basin.

Appendix F

Data Quality Summary and Results for the Field and Laboratory Quality Assurance Sample Analysis

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Data Quality Summary

The complete set of field and laboratory duplicate sample pair results and their associated relative percent differences (RPDs) for the study can be found in Table F-2.

Fish Tissue

The EPA Manchester Environmental Laboratory (MEL) conducted the analysis of fish tissue for the study. Precision of fish tissue results were estimated by calculating the RPD of duplicate sample pairs. Overall, the precision of tissue analysis for DDT and metabolites was generally good with an average RPD of 15.6%.

Laboratory matrix spike/matrix spike duplicate analysis for tissue sample 03204203 had low recovery for DDD (*i.e.*, 29% and 16%) and a RPD of 58%. Because of these low recoveries and high RPD, results for sample 03204203 were qualified as estimated "J". Matrix spike/matrix spike duplicate results for sample 03214454 had an RPD of 148% for the DDT result, because one of the spiked samples had a 12% recovery for DDT. Due to the low recovery in one of the spikes and the high resulting RPD, results for tissue sample 03214454 were also qualified as estimated "J".

Results for tissue surrogate spikes were within acceptable limits. The DDT analogs and PCB Aroclor surrogate spike recoveries met measurement quality objectives (MQOs) proposed in the Quality Assurance Project Plan (Coots and Era-Miller, 2002) for accuracy with few exceptions.

All tissue samples were analyzed within holding times except two dilution samples analyzed for DDE (03154153DU1 and 03214464DU1), and one dilution sample analyzed for DDT and DDE (03214454DU1), which were analyzed 49 days from extraction, instead of the established 40. The associated duplicate results were qualified as estimates "J". No target analytes were detected in method blanks analyzed with each extraction batch.

Three tissue samples were used as laboratory splits. Samples with analyte concentrations greater than five times the reporting limit met RPD acceptance criteria, except duplicates for samples 03154153 and 03214464 analyzed for DDD with RPDs of 78% and 75%, respectively. The associated DDD results for these two samples were qualified as estimated "J".

PCB congener in tissue analysis was conducted by Pace Analytical Services, Inc. Minneapolis, Minnesota. All samples were extracted and analyzed within the established holding times. Calibration standards for all target analytes and labeled reference compounds were within acceptance criteria. Sample 03424000 was analyzed as a laboratory duplicate. RPDs for detected analytes were within method acceptance criteria with exception of congener 203 which had a RPD of 62.5%.

The tissue analysis of dioxins and furans was also conducted by Pace Analytical. All PCDD and PCDF samples were analyzed within established holding times. Results from the analyses were reviewed for qualitative and quantitative accuracy, validity, and usefulness, following National Functional Guidelines for Organic Data Review adapted for high resolution dioxin analysis. Recoveries of the isotopically-labeled PCDD/PCDF internal standards from sample extracts ranged from 65-107%. All labeled standard recoveries were within control ranges. Laboratory spike samples were prepared with the samples. The spiked native compounds were recovered at 87 to 106% and RPDs of 2.1 to 9.6%.

Water and SPMDs

Precision for DDT and metabolites were estimated by analysis of field duplicate sample pairs. Analysis of field duplicates estimates the overall variability of analysis (field + laboratory). Precision of DDT and metabolite analysis was generally good with an average RPD of 15.5%. All samples of DDT and metabolites were analyzed within holding times, except for sample 03444114, collected 10/28/04. Results from this sample exceeded the calibration curve. It was re-analyzed three days after the 40 days established for sample extracts using a higher calibration curve. Re-analysis confirmed the results from the first analysis so the data were not qualified.

Measurement quality objectives (MQOs) were established for target analytes in the study's Quality Assurance Project Plan (Coots and Era-Miller, 2002). Surrogate recoveries were also used as an indicator of the analytical quality. Surrogate compounds similar to target compounds were spiked into all samples, blanks, and quality assurance (QA) samples to determine accuracy based on their recovery.

Three surrogate compounds were used as spikes: 4,4-dibromooctafluorobiphenyl [DBOB], dibutylchlorendate [DBC], and decachlorobiphenyl [DCB]. MQOs were met with few exceptions. Due to a laboratory accident, most of the extract from sample 03254082 was lost, resulting in all three surrogate recoveries below MQOs. Results for this sample were reported as estimates "J".

Seven samples from the May sample survey had DBOB spike results reported below the MQO. This compound typically extracts poorly from clean water matrices. The recoveries for DCB and DBC were within MQOs so data were not qualified based on the low recovery for DBOB. No target analytes were detected in method blanks from project samples.

Quality assurance was assessed for TSS, TOC, and turbidity in water using duplicates, blanks, matrix spikes, and review of sample holding times until analysis. The RPDs for field duplicates were good for turbidity (1.1%), TSS (0%), and TOC (1.0%). All laboratory split samples were within established control limits. No target analytes were detected in any laboratory method blanks associated with study samples. All matrix spike recoveries associated with study samples were within laboratory acceptance limits. All TOC and TSS samples were analyzed within established holding times until analysis. Turbidity samples 03444105-03444110 and 03214080-03214082 were analyzed beyond the 48 hour required holding time. These samples were qualified as estimates "J".

The results from laboratory control samples, surrogate recoveries, and precision estimates for SPMD analysis were used to estimate data quality. Results for laboratory control samples and surrogate recoveries met MQOs established in the Quality Assurance Project Plan (Coots and Era-Miller, 2003). The average RPD for matrix spike blanks analyzed for DDT and metabolites was 10.0%. All matrix spike and surrogate recoveries associated with study samples were within laboratory acceptance limits. No target analytes were detected in laboratory blanks, and all analysis of SPMD samples met established holding times.

Samples for TOC and turbidity were collected for calculating SPMD estimates of target analyte concentrations in the water column. Data quality was assessed using method blanks, matrix spikes, and review of sample holding times until analysis. All holding times were met and no target analytes were detected in any method blanks for TOC or turbidity associated with SPMD samples. Matrix spike results were within acceptance criteria for all TOC analysis.

Sediments

Surface and core sediments were analyzed to meet project objectives. Precision for DDT and metabolites and PCBs were estimated by analysis of duplicate and triplicate samples. Precision of DDT and metabolites was acceptable with an average RPD of 19.1% for field replicates and an average relative standard deviation (RSD) of 36.1% for the field triplicate. These higher relative differences in sediments are likely attributed to non-homogeneous distribution of analytes in the samples. Sediments by nature tend to have higher variability for duplicate results than water.

All sample holding times were met for sediment analysis except for dilutions from core samples 03517067 – 03517069 and 03517075. Results for these samples were not qualified based on exceeding holding time because dilution results matched original results made before the holding time had expired. Table F2 shows all field and laboratory duplicate and triplicate analyses and their reported RPDs and RSDs for the study.

Surrogate analysis for transect and alluvium samples met MQOs established for target analytes in the Quality Assurance Project Plan (Coots and Era-Miller, 2003) with few exceptions. As a measure of analytical quality, compounds similar to target analytes were spiked into all samples, blanks, and QA samples for a determination of analytical accuracy based on the amount the spike recovered.

Four surrogate compounds were spiked into sediment samples: 4,4-dibromooctafluorobiphenyl [DBOB], dibutylchlorendate (DBC), and tetrachloro-m-xylene (TMX) for DDT and metabolite analysis; and decachlorobiphenyl (DCB) for PCB Aroclor analysis. Occasionally one of the surrogates was outside laboratory quality control (QC) limits (OBS4054A1-A2, OBS4055A2, OCS4054A2, OCS4055A2, and 03517063). The DBOB for two samples (03517054 and 033517057) were less than reporting limits due to dilutions for other analytes, which caused percent recoveries to be outside QC limits. In every case the percent recovery for other surrogates were within QC limits, so data were not qualified. No target analytes were detected in method blanks.

Results of matrix spikes for sediment core analysis met all established QC limits. The transect and alluvium sediments had a problem with one of the QC samples due to the native concentration in one of the matrix spikes with DDT levels greater than 10 times the concentration used for the matrix spike. The spike recovery from the sample was considered unreliable as an indicator of accuracy for the project. Results for PCB Aroclor matrix spikes were within established QC limits.

All laboratory control samples were within established QC limits. A standard reference material (SRM) 1941b was analyzed along with core sediments as an additional laboratory control sample. The NIST 1941b sample contained 4,4'-DDE and 4,4'-DDD at certified concentrations and 4,4'-DDT as a reference concentration. As shown below in Table F1, sample bias is fairly low for DDT compounds.

Table F1. Results for Standard Reference Materials (SRM) analysis, pesticides in sediment.

Analyte	NIST SRM 1941b (*u*g/Kg, dw)	MEL (*u*g/Kg, dw)[1]
4,4'-DDE	3.22 ± 0.28	4.06
4,4'-DDD	4.66 ± 0.46	4.90
4,4'-DDT	1.12 ± 0.42	1.30

1 = Results are means of duplicate analysis – OCS4054A1 and OCS4055A1.

When analytes were positively identified but below the reporting limit, results were qualified as estimates "J". This was the case for some of the sediment core results. All data were considered acceptable as qualified.

Quality assurance for the analysis of TOC in transect and core sediments was evaluated based on sample holding times and analysis of laboratory blanks, duplicates, and control samples. All TOC analysis was conducted within established holding times. No target analytes were detected in method blanks associated with study samples, and all laboratory duplicates and control samples were within acceptance limits.

Analysis of Pb^{210}, Cs^{137} and stable Pb (lead) in sediments was conducted for estimates of sediment age. Analysis of these analytes was performed within established holding times.

The analysis of stable Pb was performed at the MEL. No target analytes were detected in method blanks associated with project samples. Results for matrix spikes, laboratory duplicates, and laboratory control samples were within acceptance limits.

The analysis of Pb^{210} and Cs^{137} was performed at the STL Richland laboratory. Initial results reported for the Pb^{210} and Cs^{137} samples were received with higher than anticipated detection limits. The laboratory was subsequently asked to rerun the samples for longer periods on the activity detectors to allow for lower limits of detection. This resulted in lower limits of detection but some data were qualified as estimates. No activity was detected in method blanks. Laboratory control samples were within acceptance limits. Due to low volume of sediments available for the required analysis, precision was determined by recounting samples on a different detector. Quality assurance sample results were within acceptance limits. The data were considered usable and acceptable as qualified.

Table F2. Precision Estimates for Field and Laboratory Quality Assurance Samples.

Sample ID		Matrix	Analysis	QA Type	Results		RPD[1]
No. 1	No. 2				No. 1	No. 2	
03214288	03214288	Water (NTU)	Turbidity	lab dup.	6.1	6.1	0.0
03214287	03214287	Water (mg/L)	TSS	lab dup.	46	47	2.2
03214289	03214289	Water (mg/L)	TSS	lab dup.	17	17	0.0
03214294	03214294	Water (mg/L)	TOC	lab dup.	1.5	1.4	6.9
03214290	03214290	Water (mg/L)	TOC	lab dup.	4.1	4.0	2.5
03214281	03214281	Water (mg/L)	TOC	lab dup.	2.3	2.2	4.4
03254083	03254083	Water (NTU)	Turbidity	lab dup.	12	12	0.0
03254085	03254085	Water (mg/L)	TSS	lab dup.	21	22	4.7
03254081	03254081	Water (mg/L)	TOC	lab dup.	2.4	2.3	4.3
03254086	03254086	Water (mg/L)	TOC	lab dup.	2.0	1.6	22.2
03344117	03344117	Water (mg/L)	TSS	lab dup.	4	4	0.0
03344109	03344109	Water (NTU)	Turbidity	lab dup.	11	11	0.0
03344106	03344106	Water (mg/L)	TOC	lab dup.	2.7	2.6	3.8
03444117	03444117	Water (NTU)	Turbidity	lab dup.	0.9	0.9	0.0
03444106	03444106	Water (mg/L)	TSS	lab dup.	2	2	0.0
03444116	03444116	Water (mg/L)	TOC	lab dup.	2.8	2.8	0.0
03474975	03474975	Water (mg/L)	TSS	lab dup.	4.4	4.4	0.0
03474976	03474976	Water (mg/L)	TOC	lab dup.	1	2	66.7
03354080	03354080	Water (mg/L)	TOC	lab dup.	1.3	1.3	0.0
03214296	03214297	Water (ng/L)	4,4'-DDE	field rep.	0.93	1.20	25.4
03214296	03214297	Water (ng/L)	4,4'-DDT	field rep.	0.23	0.26	12.2
03214296	03214297	Water (ng/L)	4,4'-DDD	field rep.	0.23	0.30	26.4
03214296	03214297	Water (NTU)	Turbidity	field rep.	1.9	1.8	5.4
03214296	03214297	Water (mg/L)	TSS	field rep.	4	4	0.0
03214296	03214297	Water (mg/L)	TOC	field rep.	8.9	8.9	0.0
03254091	03254093	Water (ng/L)	4,4'-DDE	field rep.	0.89	0.92	3.3
03254091	03254093	Water (ng/L)	4,4'-DDT	field rep.	0.17	0.30	55.3
03254091	03254093	Water (ng/L)	4,4'-DDD	field rep.	0.29	0.28	3.5
03254091	03254093	Water (NTU)	Turbidity	field rep.	1.4	1.4	0.0
03254091	03254093	Water (mg/L)	TSS	field rep.	4	4	0.0
03254091	03254093	Water (mg/L)	TOC	field rep.	9.5	9.6	1.0
03344116	03344117	Water (ng/L)	4,4'-DDE	field rep.	1.3	1.4	7.4
03344116	03344117	Water (ng/L)	4,4'-DDT	field rep.	0.39	0.4	2.5
03344116	03344117	Water (ng/L)	4,4'-DDD	field rep.	0.27	0.26	3.8
03344116	03344117	Water (NTU)	Turbidity	field rep.	1.2	1.2	0.0
03344116	03344117	Water (mg/L)	TSS	field rep.	4	4	0.0
03344116	03344117	Water (mg/L)	TOC	field rep.	3.9	4.0	2.5
03444116	03444117	Water (NTU)	Turbidity	field rep.	0.9	0.9	0.0
03444116	03444117	Water (mg/L)	TSS	field rep.	2	2	0.0
03444116	03444117	Water (mg/L)	TOC	field rep.	11.2	11.3	0.9
03474977	03474983	Water (NTU)	Turbidity	field rep.	1.5	1.5	0.0
03474977	03474983	Water (mg/L)	TSS	field rep.	3	3	0.0
03474977	03474983	Water (mg/L)	TOC	field rep.	15.9	15.8	0.6

Table F2 cont'd. Precision Estimates for Field and Laboratory Quality Assurance Samples.

Sample ID		Matrix	Analysis	QA Type	Results		RPD[1]
No. 1	No. 2				No. 1	No. 2	
03154153	03154153	Tissue (*u*g/Kg, ww)	4,4'-DDE	lab dup.	910	1400	42.4
03154153	03154153	Tissue (*u*g/Kg, ww)	4,4'-DDT	lab dup.	26	19	31.1
03154153	03154153	Tissue (*u*g/Kg, ww)	4,4'-DDD	lab dup.	14	32	78.3
03214454	03214454	Tissue (*u*g/Kg, ww)	4,4'-DDE	lab dup.	1600	1900	17.1
03214454	03214454	Tissue (*u*g/Kg, ww)	4,4'-DDT	lab dup.	52	55	5.6
03214454	03214454	Tissue (*u*g/Kg, ww)	4,4'-DDD	lab dup.	36	42	15.4
03214464	03214464	Tissue (*u*g/Kg, ww)	4,4'-DDE	lab dup.	950	980	3.1
03214464	03214464	Tissue (*u*g/Kg, ww)	4,4'-DDT	lab dup.	27	27	0.0
03214464	03214464	Tissue (*u*g/Kg, ww)	4,4'-DDD	lab dup.	8.6	19	75.4
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	PCB 070	lab dup.	7.1	7.2	1.4
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	PCB 110	lab dup.	14.0	14.0	0.0
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	PCB 180	lab dup.	54	47	13.9
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	4,4'-DDE	lab dup.	190	170	11.1
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	4,4'-DDT	lab dup.	59	51	14.5
SRM 1946	SRM 1946	Tissue (*u*g/Kg, ww)	4,4'-DDD	lab dup.	5.7	4.4	25.7
03154150	03154151	Tissue (*u*g/Kg, ww)	PCB-1254	field rep.	5.4	5.4	0
03154150	03154151	Tissue (*u*g/Kg, ww)	4,4'-DDE	field rep.	390	360	8
03154150	03154151	Tissue (*u*g/Kg, ww)	4,4'-DDT	field rep.	10	9.2	8.3
03154150	03154151	Tissue (*u*g/Kg, ww)	4,4'-DDD	field rep.	5.0	4.4	12.8
03214454	03214480	Tissue (*u*g/Kg, ww)	4,4'-DDE	field rep.	1600	1600	0.0
03214454	03214480	Tissue (*u*g/Kg, ww)	4,4'-DDT	field rep.	52	44	16.7
03214454	03214480	Tissue (*u*g/Kg, ww)	4,4'-DDD	field rep.	36	33	8.7
03204203	03204204	Tissue (*u*g/Kg, ww)	4,4'-DDE	field rep.	850	1100	25.6
03204203	03204204	Tissue (*u*g/Kg, ww)	4,4'-DDT	field rep.	26	29	10.9
03204203	03204204	Tissue (*u*g/Kg, ww)	4,4'-DDD	field rep.	17	21	21.1
03214469	03214481	Tissue (*u*g/Kg, ww)	4,4'-DDE	field rep.	610	670	9.4
03214469	03214481	Tissue (*u*g/Kg, ww)	4,4'-DDT	field rep.	15	17	12.5
03214469	03214481	Tissue (*u*g/Kg, ww)	4,4'-DDD	field rep.	9.8	20	68.5
03424003	03424003	Tissue (*u*g/Kg, ww)	Tetra-PCBs	field rep.	201	215	6.7
03424003	03424003	Tissue (*u*g/Kg, ww)	Penta-PCBs	field rep.	2280	2105	8.0
03424003	03424003	Tissue (*u*g/Kg, ww)	Hexa-PCBs	field rep.	2604	2389	8.6
03424003	03424003	Tissue (*u*g/Kg, ww)	Hepta-PCBs	field rep.	1099	998	9.6
03424003	03424003	Tissue (*u*g/Kg, ww)	Octa-PCBs	field rep.	137	77	56.1
03424003	03424003	Tissue (*u*g/Kg, ww)	Total PCBs	field rep.	6321	5784	8.9
03218248	03218247	Tissue (*u*g/Kg, ww)	2,3,7,8-TCDD	field rep.	0.45	0.47	4.3
03218248	03218247	Tissue (*u*g/Kg, ww)	2,3,7,8-TCDF	field rep.	1.70	1.30	26.7
03218248	03218247	Tissue (*u*g/Kg, ww)	Total PeCDF	field rep.	2.70	1.50	57.1
03218248	03218247	Tissue (*u*g/Kg, ww)	Total HxCDD	field rep.	2.50	2.50	0.0
03218248	03218247	Tissue (*u*g/Kg, ww)	Total HxCDF	field rep.	0.49	0.40	20.2
03218248	03218247	Tissue (*u*g/Kg, ww)	Total HpCDD	field rep.	1.30	1.40	7.4
03218248	03218247	Tissue (*u*g/Kg, ww)	OCDD	field rep.	2.90	4.10	34.3
03218248	03218247	Tissue (*u*g/Kg, ww)	OCDF	field rep.	0.32	0.33	3.1

Table F2 cont'd. Precision Estimates for Field and Laboratory Quality Assurance Samples.

Sample ID No. 1	Sample ID No. 2	Sample ID No. 3	Matrix	Analysis	QA Type	Results No. 1	Results No. 2	Results No. 3	RPD[1]
04054985	04054986		Lipids (ng)	PCB-1016	lab dup.	134	118		12.7
04054985	04054986		Lipids (ng)	PCB-1260	lab dup.	178	168		5.8
04054985	04054986		Lipids (ng)	Congener 4	lab dup.	130	130		0.0
04054985	04054986		Lipids (ng)	Congener 29	lab dup.	160	150		6.5
04054985	04054986		Lipids (ng)	4,4'-DDE	lab dup.	33.8	30.9		9.0
04054985	04054986		Lipids (ng)	4,4'-DDT	lab dup.	33.1	30.4		8.5
04054985	04054986		Lipids (ng)	4,4'-DDD	lab dup.	28.9	26.7		7.9
03263007	03263008		Lipids (ng)	PCB-1016	lab dup.	113	150		28.1
03263007	03263008		Lipids (ng)	PCB-1260	lab dup.	170	166		2.4
03263007	03263008		Lipids (ng)	Congener 4	lab dup.	124	120.6		2.7
03263007	03263008		Lipids (ng)	Congener 29	lab dup.	167	181.3		8.2
03263007	03263008		Lipids (ng)	4,4'-DDE	lab dup.	33.19	34.34		3.4
03263007	03263008		Lipids (ng)	4,4'-DDT	lab dup.	34.94	27.86		22.5
03263007	03263008		Lipids (ng)	4,4'-DDD	lab dup.	32.9	23.35		34.0
03434089	03434090		Lipids (ng)	PCB-1016	lab dup.	172	159		7.9
03434089	03434090		Lipids (ng)	PCB-1260	lab dup.	167	168		0.6
03434089	03434090		Lipids (ng)	4,4'-DDE	lab dup.	35.67	34.87		2.3
03434089	03434090		Lipids (ng)	4,4'-DDT	lab dup.	31.06	30.64		1.4
03434089	03434090		Lipids (ng)	4,4'-DDD	lab dup.	31.3	31.52		0.7
03238172	03238172	03238172	Sediment (%)	TOC	lab trip.	3.10	3.02	2.86	4.01[2]
03238184	03238184	03238184	Sediment (%)	TOC	lab trip.	3.00	3.02	2.97	0.83[2]
03238181	03238221		Sediment (%)	TOC	lab dup.	1.28	1.26		1.6
03238177	03238222	03238223	Sediment (%)	TOC	lab trip.	1.68	1.73	1.68	1.7[2]
03517052	03517052		Sediment (pCI/g)	Pb^{210}	lab dup.	4.17	4.70		12.0
FQJ0A2AA	FQJ0A2AD		Sediment (pCI/g)	Cs^{137}	lab dup.	2.02	2.19		8.1
FQJ0A2AC	FQJ0A2AE		Sediment (pCI/g)	Pb^{210}	lab dup.	1.17	1.18		0.9
03517070	03517070	03517070	Sediment (%)	TOC	lab trip.	2.50	2.31	2.19	6.7[2]
03238181	03238221		Sediment (%)	TOC	field rep.	1.28	1.26		1.6
03238177	03238222	03238223	Sediment (%)	TOC	field trip.	1.68	1.73	1.68	1.7[2]
03238181	03238221		Sediment (*u*g/Kg,dw)	4,4'-DDE	field rep.	370	570		42.6
03238181	03238221		Sediment (*u*g/Kg,dw)	4,4'-DDT	field rep.	170	190		11.1
03238181	03238221		Sediment (*u*g/Kg,dw)	4,4'-DDD	field rep.	2.7	2.8		3.6
03238177	03238222	03238223	Sediment (*u*g/Kg,dw)	4,4'-DDE	field trip.	190	240	230	12.0[2]
03238177	03238222	03238223	Sediment (*u*g/Kg,dw)	4,4'-DDT	field trip.	41	18	46	42.6[2]
03238177	03238222	03238223	Sediment (*u*g/Kg,dw)	4,4'-DDD	field trip.	180	410	610	53.8[2]

1 = relative percent difference [(difference between replicate pair concentration / mean concentration of replicate pair)*100].
2 = for triplicate analysis, relative standard deviation is used [(standard deviation of sample concentrations/mean of sample concentrations)*100].
lab dup. = laboratory duplicate (split)
lab trip. = laboratory triplicate
field rep. = field replicate
field trip. = field triplicate

Table F3. Precision Estimates for PCB congeners in fish - Kokanee (ng/Kg, ww)

Duplicate Sample No. 03424003		Homolog group	Results		RPD[1]
IUPAC	Co-elute		No. 1	No. 2	
40	40/41/71	Tetrachloro	22.1	25.7	15.1
49	49/69	Tetrachloro	38.8	39.9	2.8
56		Tetrachloro	19.5	18.2	6.9
60		Tetrachloro	19.1	22.3	15.5
64		Tetrachloro	31.1	32.3	3.8
66		Tetrachloro	70.2	76.5	8.6
82		Pentachloro	24.0	20.6	15.2
83		Pentachloro	18.5	18.5	0.0
84		Pentachloro	40.4	35.6	12.6
85	85/116/117	Pentachloro	94.7	92.5	2.4
86	86/87/97/108/119/125	Pentachloro	135	147	8.5
88	88/91	Pentachloro	27.7	24.9	10.6
90	90/101/113	Pentachloro	306	284	7.5
92		Pentachloro	77	64.1	18.3
95		Pentachloro	105	127	19.0
99		Pentachloro	288	268	7.2
105		Pentachloro	200	181	10.0
107	107/124	Pentachloro	21.2	ND	NC
109		Pentachloro	59.4	53.1	11.2
110	110/115	Pentachloro	361	311	14.9
118		Pentachloro	522	478	8.8
128	128/166	Hexachloro	107	99.6	7.2
129	129/138/163	Hexachloro	754	743	1.5
130		Hexachloro	63.2	57.0	10.3
132		Hexachloro	87.4	78.4	10.9
133		Hexachloro	18	ND	NC
135	135/151	Hexachloro	122	109	11.3
136		Hexachloro	26.6	25.1	5.8
137		Hexachloro	34.5	30.4	12.6
141		Hexachloro	44.6	44.1	1.1
146		Hexachloro	131	127	3.1
147	147/149	Hexachloro	216	201	7.2
153	153/168	Hexachloro	806	694	14.9
156	156/157	Hexachloro	73.2	71.9	1.8
158		Hexachloro	54.2	47.5	13.2
164		Hexachloro	32.5	28.0	14.9
167		Hexachloro	33.9	33.0	2.7

RPD[1] = relative percent difference

Table F3 cont’d. Precision Estimates for PCB congeners - Kokanee (ng/Kg, ww)

Duplicate Sample No. 03424003		Homolog group	Results		
IUPAC	Co-elute		No. 1	No. 2	RPD[1]
170		Heptachloro	67.9	50.8	28.8
171	171/173	Heptachloro	37.3	36.0	3.5
172		Heptachloro	27.3	23.7	14.1
174		Heptachloro	82.3	68.3	18.6
177		Heptachloro	84.8	76.2	10.7
178		Heptachloro	69.4	57.1	19.4
179		Heptachloro	30.7	27.2	12.1
180	180/193	Heptachloro	223	226	1.3
183	183/185	Heptachloro	123	110	11.2
187		Heptachloro	353	323	8.9
196		Octachloro	23.1	ND	NC
198	198/199	Octachloro	60.8	57.8	5.1
202		Octachloro	16.5	ND	NC
203		Octachloro	36.3	19.0	62.6
		Total PCB Congeners	6320	5784	8.9

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Appendix G

DDT/PCB and Ancillary Results for the Lake Chelan TMDL Study

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Table G1. DDT concentrations (ng/L) in tributary streams and Lake Chelan, May - November 2003.

Location (Site ID)	Date	Flow (cfs)	TSS (mg/L)	TOC (mg/L)	Turbidity (NTU)	4,4'-DDD	4,4'-DDE	4,4'-DDT	t-DDT
First Creek (SS01)	5/19/03	25.3	**5**	1.0 U	**1.6 J**	0.32 U	0.32 U	0.44 U	ND
	6/16/03	10.2	**3**	1.0 U	**1.0**	0.33 U	**0.08 J**	**0.12 J**	**0.20**
	8/19/03	3.18	**2**	1.0 U	0.5 U	0.34 U	0.34 U	0.47 U	ND
	10/27/03	3.73	**1**	**1.7**	**0.5 J**	0.31 U	0.31 U	0.43 U	ND
	11/18/03	3.32	**1**	**1.8**	0.5 U	0.32 U	0.32 UJ	0.45 U	ND
Knapp Coulee (SS02)	5/19/03	0.11	**19**	**2.3**	**4.4 J**	**1.5**	**3.1**	**1.4**	**6.0**
	6/16/03	0.14	**13**	**2.4**	**4.2**	**1.4**	**3.2**	**1.6**	**6.2**
	8/19/03	0.18	**29**	**2.7**	**5.3**	**1.5**	**5.2**	**2.0**	**8.7**
	10/27/03	0.21	**12**	**2.8**	**5.6 J**	**1.2**	**3.2**	**1.1**	**5.5**
	11/18/03	0.20	**4**	**2.8**	**1.6**	**1.1**	**2.6**	**0.89**	**4.6**
Chelan River (DT08)	5/19/03	-	NA	1.0 U	0.5 UJ	**0.072J**	0.33 U	0.46 U	**0.072**[1]
	6/16/03	-	NA	1.0 U	0.5 U	0.33 UJ	0.33 UJ	0.46 UJ	ND
	8/19/03	-	NA	1.0 U	0.5 U	0.34 UJ	0.34 UJ	0.47 UJ	ND
	10/27/03	-	NA	1.0 U	0.5 UJ	0.32 U	0.32 U	0.45 U	ND
	11/18/03	-	NA	1.0 U	0.5 U	0.34 U	0.34 U	0.47 U	ND
Culvert near Crystal View (NS13)	5/21/03	0.016	**47**	**3.4**	**14**	**0.18 J**	**2.8**	**0.69**	**3.7**
	6/16/03	0.011	**40**	**3.1**	**12**	0.63 U	**2.7**	**0.66**	**3.4**
	8/19/03	NS	NS	NS	NS	NS	NS	NS	NS
	10/27/03	0.016	**59**	**2.9**	**12 J**	**0.17 J**	**2.2**	**2.2**	**4.6**
	11/18/03	0.019	**30**	**3.7**	**7.7**	0.32 U	**3.1**	**0.58**	**3.7**
Purtteman Creek (NS15)	5/21/03	0.97	**27**	**1.8**	**6.1**	**0.20 J**	**0.74**	**0.63**	**1.6**
	6/16/03	0.95	**24**	**1.6**	**6.5**	**0.16 J**	**1.0**	**0.58**	**1.7**
	8/19/03	0.75	**52**	**1.6**	**11**	**0.28 J**	**1.5**	**1.7**	**3.5**
	10/27/03	1.09	**50**	**2.2**	**11 J**	**0.23 J**	**2.2**	**1.5**	**3.9**
	11/18/03	0.98	**20**	**2.1**	**6.2**	**0.17 J**	**1.1 J**	**0.82**	**2.1**
Culvert at Veroske's (NS16)	5/21/03	0.10	**17**	**3.2**	**5.2**	**1.8**	**8.8**	**7.6**	**18**
	6/16/03	0.05	**21**	**3.4**	**5.3**	**1.5**	**7.0**	**3.5**	**12**
	8/19/03	NS	NS	NS	NS	NS	NS	NS	NS
	10/27/03	0.11	**33**	**3.5**	**8.2 J**	**2.1**	**9.8**	**4.4**	**16**
	11/19/03	0.14	**14**	**3.4**	**4.1**	**1.4**	**6.3**	**3.1**	**11**
Cooper drainage (NS18)	5/21/03	0.05	**4**	**1.5**	**0.6**	**0.42 J**	**4.0**	**6.5**	**11**
	6/17/03	0.017	**9**	**2.0**	**0.6**	**0.50 J**	**5.5 J**	**19J**	**25**
	8/19/03	NS	NS	NS	NS	NS	NS	NS	NS
	10/28/03	0.09	**9**	**1.9**	**3.6**	**0.49**	**6.7**	**4.9**	**12**
	11/19/03	0.12	**5**	**1.9**	**1.8**	**0.42**	**3.8**	**7.0**	**11**

Table G1 cont'd. DDT concentrations (ng/L) in tributary streams and Lake Chelan, May - November 2003.

Location (Site ID)	Date	Flow (cfs)	TSS (mg/L)	TOC (mg/L)	Turbidity (NTU)	4,4'-DDD	4,4'-DDE	4,4'-DDT	t-DDT
Bennet Road (NS19)	5/21/03	0.20	**5**	**1.5**	0.5 U	**0.34**	**1.9**	**1.1**	**3.3**
	6/17/03	0.076	1 U	**1.4**	0.5 U	**0.17 J**	**1.1**	**0.66**	**1.9**
	8/19/03	0.021	**2**	**1.7**	0.5 U	**0.29 J**	**0.83**	**0.59**	**1.7**
	10/28/03	0.076	1 U	**1.5**	0.5 U	**0.20 J**	**1.2**	**0.70**	**2.1**
	11/19/03	0.076	**1**	**1.4**	0.5 U	**0.19 J**	**1.2**	**0.65**	**2.0**
Keupkin Street (NS21)	5/21/03	0.91	**2**	**4.1**	**1.2**	**7.1**	**20**	**8.7**	**36**
	6/17/03	0.54	**3**	**2.7**	**0.7**	**4.9**	**13**	**5.4**	**23**
	8/20/03	0.50	**2**	**2.8**	0.5 U	**4.9**	**15**	**7.4**	**27**
	10/28/03	0.54	1 U	**2.7**	0.5 U	**5.6**	**18**	**8.3**	**32**
	11/19/03	0.76	**1**	**2.5**	0.5 U	**4.0**	**13**	**5.4**	**22**
Buck Orchards (NS22)	5/21/03	0.20	1 U	**5.0**	0.5 U	**5.6**	**5.5**	**2.1**	**13**
	6/17/03	0.13	1 U	**3.9**	0.5 U	**1.6**	**4.2**	**1.9**	**7.7**
	8/20/03	0.23	1 U	**4.6**	0.5 U	**3.8**	**6.7**	**3.0**	**14**
	10/28/03	0.20	1 U	**4.6**	0.5 U	**7.1**	**6.7**	**3.4**	**17**
	11/19/03	0.21	1 U	**4.4**	0.5 U	**5.2**	**5.5**	**2.8**	**14**
Wapato Lake + Joe Creek (NS23)	5/21/03	2.08	**2**	**6.0**	**1.0**	0.32 U	**0.26 J**	0.45 U	**0.26**
	6/17/03	1.05	**1**	**5.7**	**0.5**	0.31 UJ	**0.13 J**	0.44 UJ	**0.13**
	8/20/03	0.020	**2**	**8.3**	**0.6**	0.33 U	0.33 U	0.46 U	ND
	10/28/03	0.50	1 U	**7.3**	**0.6**	0.33 U	0.33 U	0.46 U	ND
	11/19/03	1.85	**1**	**7.0**	**0.6**	0.33 U	0.33 U	0.47 U	ND
Stink Creek (NS24)	5/21/03	0.99	**4**	**8.9**	**1.9**	**0.23 J**	**0.93 J**	**0.23 J**	**1.4**
	6/17/03	0.62	**4**	**9.5**	**1.4**	**0.29 J**	**0.89 J**	**0.17 J**	**1.4**
	8/20/03	0.19	**4**	**3.9**	**1.2**	**0.27 J**	**1.3**	**0.39 J**	**2.0**
	10/28/03	0.55	**2**	**11.2**	**0.9**	**0.28 J**	**1.5**	**0.28 J**	**2.1**
	11/19/03	0.65	**3**	**15.9**	**1.5**	**0.28 J**	**1.6**	0.45 U	**1.9**
Mill Bay boat ramp (NS30)	5/21/03	0.020	**1**	**1.8**	**0.6**	**0.15 J**	**0.19 J**	**0.14 J**	**0.48**
Twentyfive Mile Creek (LU25)	5/20/03	79.6	**4**	**1.1**	**1.1**	0.33 U	0.33 U	0.46 U	ND
Prince Creek (LU26)	5/20/03	74.0	**2**	**1.3**	**0.9**	0.32 U	0.32 U	0.45 U	ND
Railroad Creek (LU27)	5/20/03	158	**1**	1.0 U	**1.4**	0.32 U	0.32 U	0.45 U	ND
Fish Creek (LU28)	5/20/03	54.1	**8**	**1.6**	**1.8**	0.32 U	0.32 U	0.44 U	ND
Stehekin River (LU29)	6/2/03	4,460	**7**	1.0 U	**2.4 J**	0.33 U	0.33 U	0.52 U	ND

NA = Not analyzed.
NS = Not sampled; not enough flow.
UJ = Not detected above estimated detection limit.
U = Not detected at the value shown.
J = Analyte positively identified, value is estimated.
ND = Not detected.
1 = Concentration reported likely a result of sediment disturbance at the boat launch site.

Table G2. Lake Chelan SPMD Results, May to November, 2003 (total ng per 5 membranes).

Chemical	May - June 2003			July - August 2003			October - November 2003		
	Air Blank 263003	Lucerne 263000	Wapato* 263001/2	Air Blank 434085	Lucerne No Sample	Wapato* 434083/4	Air Blank 054983	Lucerne 054982	Wapato* 054978/9
4,4'-DDE	**8.1**	**14**	**680**	**4.5 J**	NS	**1050**	**2.9 J**	**35**	**730**
4,4'-DDD	5.0 U	**5.2**	**250**	5.0 U	NS	**445**	5.0 U	**18**	**200**
4,4'-DDT	**5.2**	**9.4**	**64**	**3.3 J**	NS	**38**	5.0 U	**10**	**38**
PCB -1016	50 U	50 U	50 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1221	50 U	50 U	50 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1232	50 U	50 U	50 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1242	50 U	50 UJ	50 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1248	**32 NJ**	**31 NJ**	**34 NJ**	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1254	25 U	25 UJ	25 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1260	25 U	25 U	25 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1262	25 U	25 U	25 U	50 U	NS	50 U	50 U	50 U	50 U
PCB - 1268	25 U	25 U	25 U	50 U	NS	50 U	50 U	50 U	50 U
PCB congener 4	**400**	**370**	**470**	**550**	NS	**410**	**540**	**340**	**370**
PCB congener 29	**690**	**790**	**880**	**621**	NS	**665**	**730**	**720**	**645**

* = Wapato results represent an average for a sample pair.
J = The analyte was positively identified; the associated numerical results is an estimate.
NS = No sample; SPMD was lost during deployment.
U = The analyte was not detected at or above the reported result.
NJ = There was evidence the analyte is present; the associated numerical result is an estimate.
Bold = The analyte is present in the sample. (Visual aid to locate detected compounds)

Table G3. Mean Temperature and Exposure Times for Lake Chelan SPMDs.

	May - June 2003		July - August 2003		October - November 2003	
	Temp (^oC)	Time (Days)	Temp (^oC)	Time (Days)	Temp (^oC)	Time (Days)
Wapato Basin	6.4	29.9	6.9	27.3	6.7	27.7
Lucerne Basin	8.3	29.2	*	*	8.5	26.2

* = SPMD and temperature sensor lost during deployment.

Table G4. TOC, Turbidity, and Temperature Results from Lake Chelan SPMD Deployments, May - November 2003.

Sample No. (03-)	Sample ID	Location	Collection Date	Collection Time	TOC (mg/L)	Turbidity (NTU)	Temp (°C)
198243	SPMD01W	Wapato Point	5/5/2003	1955	1.0 U	0.5 U	6.4
198244	SPMD02L	25-Mile Creek	5/6/2003	1130	1.0 U	0.5 U	8.1
234015	WAPSPMD	Wapato Point	6/4/2003	1720	1.0 U	0.5 U	6.6
234016	LUCSPMD	25-Mile Creek	6/4/2003	1625	1.0 U	0.5 U	7.5
314000	WAPATO	Wapato Point	7/29/2003	0924	1.0 U	0.5 U	7.0
314001	LUCERNE	25-Mile Creek	7/29/2003	1219	1.0 U	0.5 U	11.2
354080	WAPATO	Wapato Point	8/25/2003	1820	**1.3**	0.5 U	6.7
NA*	LUCERNE	25-Mile Creek	ND	ND	ND	ND	ND
434010	WAPATO	Wapato Point	10/21/2003	1645	1.0 U	0.5 U	8.3
434011	LUCERNE	25-Mile Creek	10/22/2003	1115	1.0 U	0.5 U	8.2
474980	WAPSPMD	Wapato Point	11/18/2003	0900	1.0 U	0.5 UJ	6.9
474981	LUCSPMD	25-Mile Creek	11/17/2003	1640	1.0 U	0.5 UJ	9.7

NA* = Not analyzed; SPMD lost during deployment -- no ancillary samples collected during retrieval.
ND = No data.

Table G5. Summary of Lake Chelan Transect and Alluvium Surface Sediments DDT and PCB Results, June 2003.

Site ID[1]	Laboratory No. (03-)	Collection		TOC @ 104 °C (%)	PCB Aroclors (*ug*/Kg dw)							Total PCB	DDT Analogs (*ug*/Kg dw)			Total DDT
		Date	Time		1016	1221	1232	1242	1248	1254	1260		4,4'-DDE	4,4'-DDD	4,4'-DDT	
Transect																
W-0.69	238171	6/4/03	1425	0.42	2.3 U	2.3 U	2.3 U	2.3 U	2.3 U	0.46 U	2.3 U	ND	**0.98**	**1.4**	0.45 U	**2.4**
W-1.89	238172	6/4/03	1400	3.10	4.9 U	4.9 U	4.9 U	4.9 U	4.9 U	0.98 U	4.9 U	ND	**7.1**	**12**	0.99 U	**19**
W-3.15	238173	6/4/03	1350	1.74	4.8 U	4.8 U	4.8 U	4.8 U	4.8 U	**1.6 J**	4.8 U	**1.6**	**330**	**350**	**31**	**710**
W-4.41	238174	6/4/03	1330	1.77	3.9 U	3.9 U	3.9 U	3.9 U	3.9 U	**1.2 J**	3.9 U	**1.2**	**110**	**250**	**20**	**380**
W-5.64	238175	6/4/03	1315	1.71	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	**1.7 J**	5.0 U	**1.7**	**390**	**540**	**46**	**980**
W-6.86	238176	6/4/03	1255	2.01	5.8 U	5.8 U	5.8 U	5.8 U	5.8 U	1.2 U	5.8 U	ND	**520**	**220**	**65**	**800**
W-8.22	238177	6/4/03	1225	1.68	4.3 U	4.3 U	4.3 U	4.3 U	4.3 U	**1.8**	4.3 U	**1.8**	**190**	**180**	**41**	**410**
W-9.31	238178	6/4/03	1150	2.07	6.9 U	6.9 U	6.9 U	6.9 U	6.9 U	**2.7 J**	6.9 U	**2.7**	**170**	**130**	**28**	**330**
W-10.17	238179	6/4/03	1520	1.75	4.6 U	4.6 U	4.6 U	4.6 U	4.6 U	**2.1**	4.6 U	**2.1**	**210**	**590**	**33**	**830**
W-11.08	238180	6/4/03	1535	1.72	5.4 U	5.4 U	5.4 U	5.4 U	5.4 U	1.1 U	5.4 U	ND	**260**	**820**	**23**	**1100**
					Mean Wapato basin concentrations							**1.9**	**220**	**310**	**36**	**560**
L-13.00	238181	6/3/03	2020	1.28	4.5 U	4.5 U	4.5 U	4.5 U	4.5 U	0.89 U	4.5 U	ND	**370**	**2.7**	**170**	**540**
L-16.00	238189	6/3/03	2000	1.59	4.4 U	4.4 U	4.4 U	4.4 U	4.4 U	**1.4 J**	4.4 U	**1.4**	**21**	**3.9**	**31**	**56**
L-17.79	238182	6/3/03	1900	2.44	6.0 U	6.0 U	6.0 U	6.0 U	6.0 U	1.2 U	6.0 U	ND	**22**	**8.4**	**1.8**	**32**
L-20.51	238183	6/3/03	1745	2.62	3.9 U	3.9 U	3.9 U	3.9 U	3.9 U	0.78 U	3.9 U	ND	**71**	**87**	**4.0**	**160**
L-34.33	238187	6/3/03	1620	2.28	4.2 U	4.2 U	4.2 U	4.2 U	4.2 U	0.84 U	4.2 U	ND	**23**	**31**	**3.5**	**58**
L-40.62	238184	6/3/03	1130	3.00	5.0 U	5.0 U	5.0 U	5.0 U	5.0 U	1.0 U	5.0 U	ND	**8.2**	**8.0**	0.89 U	**16**
L-47.00	238185	6/2/03	1410	3.17	4.4 U	4.4 U	4.4 U	4.4 U	4.4 U	0.88 U	4.4 U	ND	**2.0**	**1.2**	0.79 U	**3.2**
					Mean Lucerne basin concentrations							**1.4**	**74**	**20**	**42**	**120**
Alluvium																
First Creek	238186	6/4/03	1500	4.88	2.8 U	2.8 U	2.8 U	2.8 U	2.8 U	0.56 U	2.8 U	ND	**6.3**	**2.6**	**1.8**	**11**
Railroad Creek	238188	6/2/03	1500	5.06	4.4 U	4.4 U	4.4 U	4.4 U	4.4 U	1.7 U	4.4 U	ND	0.80 U	0.80 UJ	0.80 UJ	ND
Stehekin River	238190	6/2/03	1320	4.07	3.3 U	3.3 U	3.3 U	3.3 U	3.3 U	0.67 U	3.3 U	ND	0.67 U	0.67 UJ	0.67 UJ	ND

1 = Refer to Figure 2 for station locations.

Table G6. Grain Size Distribution for Transect and Alluvium Surface Sediments (Percent Retained in Each Size Fraction).

Site ID	Laboratory No. (03-)	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[b]
	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	
Transect[a]															
W-0.69	23-8171	1.0	0.9	2.8	41.5	40.7	7.5	1.8	1.3	1.0	0.9	0.3	0.2	0.1	5.6
W-1.89	23-8172	0.1	0.2	0.4	15.6	41.1	17.3	12.2	6.6	2.9	2.4	0.6	0.4	0.3	25.4
W-3.15[c]	23-8173	0.0	0.2	0.1	0.5	16.1	16.0	7.6	14.5	16.3	14.5	8.0	3.9	2.4	67.1
W-4.41	23-8174	0.0	0.1	0.1	0.1	0.2	1.6	17.5	17.8	24.9	21.0	8.5	4.3	3.9	97.9
W-5.64	23-8175	0.2	0.1	0.3	0.2	0.4	0.9	7.4	22.0	22.6	25.5	11.8	5.3	3.5	98.1
W-6.86	23-8176	0.1	0.2	0.9	0.6	1.4	3.1	5.4	21.6	22.7	23.8	11.8	4.7	3.8	93.8
W-8.22[d]	23-8177/8222	0.0	0.85	0.85	0.40	0.35	0.95	4.8	17.8	22.5	26.5	11.9	6.0	7.2	96.6
W-9.31	23-8178	0.0	0.1	0.1	0.1	0.3	0.8	4.2	20.1	21.4	35.4	9.4	5.2	3.0	98.7
W-10.17	23-8179	0.0	0.1	0.1	0.1	0.3	1.0	3.4	17.7	18.9	33.6	12.6	6.1	6.2	98.5
W-11.08	23-8180	0.0	0.1	0.1	0.1	0.4	1.1	5.8	21.8	19.0	27.2	16.3	5.3	2.9	98.3
L-13.00[d]	23-8181/8221	2.6	2.6	3.9	8.2	13.0	11.0	4.5	11.5	9.8	11.6	9.6	6.7	5.4	59.1
L-16.00	23-8189	2.1	2.3	1.8	2.0	6.4	17.6	15.0	15.8	9.8	9.4	7.9	3.7	6.1	67.7
L-17.79	23-8182	4.1	7.4	2.4	1.8	2.9	9.2	12.8	16.9	14.1	14.7	6.1	1.0	6.7	72.3
L-20.51	23-8183	0.0	1.3	2.3	2.7	4.2	9.8	7.2	18.8	13.2	16.6	10.8	4.9	8.3	79.8
L-34.33	23-8187	0.0	1.5	2.0	2.1	6.2	13.6	9.4	13.8	10.1	15.7	11.5	5.4	8.7	74.6
L-40.62	23-8184	0.0	0.8	3.9	3.9	5.2	9.9	6.8	15.5	14.9	20.1	7.0	3.9	8.2	76.4
L-47.00	23-8185	0.0	1.5	2.2	2.8	8.7	9.2	9.1	21.4	20.2	14.9	1.3	2.5	6.2	75.6
Alluvium[a]															
First Creek	23-8186	1.9	3.5	6.9	16.7	40.5	22.1	2.2	2.2	1.3	1.0	0.5	0.2	1.1	8.5
Railroad Crk	23-8188[e]	3.2	7.0	6.1	10.8	37.0	23.2	2.2	2.6	1.7	1.5	0.8	0.2	3.6	12.6
Stehekin R.	23-8190	0.1	1.5	2.6	3.7	5.7	20.4	29.0	20.6	8.5	3.2	1.5	0.8	2.5	66.1

[a] = Refer to Figure 2 for station locations.
[b] = Fines are defined as the total of silts and clays.
[c] = Result represents the mean of laboratory triplicate analysis.
[d] = Results represent the mean of a replicate pair.
[e] = Sample contained mostly sand and did not meet the 5-gram minimum for fines; results should be considered estimates.

Table G7. DDT and PCBs as Aroclors in fish tissue from Lake Chelan, 2003 (*u*g/Kg, ww). Composites of five fish except where noted.

Sample No. (03-)	Species	Location (basin)	Mean length (mm)	Mean weight (g)	Mean age (years)	Lipid (%)	4,4'-DDE	4,4'-DDD	4,4'-DDT	Total DDT	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCB
114050	Burbot	Wapato	533±34	809±55	10.6	0.2	**140**	**1.2**	**4.9**	**146**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
114051	Burbot	Wapato	593±31	1205±33	11.4	0.3	**380**	**5.0**	**7.7**	**393**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	3.9 U	3.9 U	nd
114052	Burbot	Wapato	609±16	1308±35	11.2	0.3	**220**	**3.1**	**4.8**	**228**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
114054	Burbot	Wapato	491±36	666±70	8.0	0.2	**280**	**2.0**	**7.3**	**289**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
114055	Burbot	Wapato	545±9	921±18	9.5	0.2	**250**	**1.5**	**6.0**	**258**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
154150	Burbot	Wapato	547±23	1020±76	9.6	0.3	**375**	**4.7**	**9.6**	**389**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	**5.4**	1.9 U	**5.4**
154152	Burbot	Wapato	645±46	1619±340	12.4	0.2	**490**	**3.5**	**5.8**	**499**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
154154	Burbot	Lucerne	536±27	870±15	8.0	1.5	**7.4**	0.98U	**2.5**	**9.9**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214550	Burbot	Lucerne	512±30	737±90	6.8	0.3	**24**	0.98U	**0.73J**	**25**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214551	Burbot	Lucerne	563±19	1048±141	8.0	0.2	**30**	0.96U	**0.78J**	**31**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214552	Kokanee	Wapato	286±7	197±18	2.0	2.7	**99**	**5.9**	**6.4**	**111**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214553	Kokanee	Wapato	302±14	242±26	2.6	2.4	**69**	**2.1**	**3.3**	**74**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214554	Kokanee	Wapato	257±3	143±1	2.0	0.8	**23**	**2.2**	**1.7**	**27**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214555	Kokanee	Wapato	258±6	152±4	2.4	1.4	**26**	**1.8**	**1.8**	**30**	1.9 U	1.9 U	3.7 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214556	Kokanee	Wapato	269±2	165±5	2.2	2.0	**67**	**2.3**	**3.0**	**72**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214557	Kokanee	Wapato	238±6	113±10	2.0	1.5	**34**	**2.9**	**3.2**	**40**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214558	Kokanee	Wapato	249±9	134±3	2.0	2.2	**37**	**2.8**	**2.7**	**43**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
394401	Rainbow	Wapato	316±7	321±20	1	0.1	**24**	**0.83J**	**0.96**	**26**	1.9 U	1.9 U	3.7 U	1.9 U	1.9 U	**8.8**	1.9 U	**8.8**
394402	Rainbow	Wapato	297±6	258±27	1	0.1	**9.8**	0.87U	0.87U	**9.8**	1.7 U	1.7 U	3.5 U	1.7 U	1.7 U	**4.1J**	1.7 U	**4.1**
394403	Rainbow	Wapato	281±11	208±21	1	0.1 U	**16**	0.98U	0.98U	**16**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	**3.8**	2.0 U	**3.8**
394404	Rainbow	Wapato[1]	326	344	1	0.1 U	**10**	0.94U	0.94U	**10**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	**2.1**	1.9 U	**2.1**
394405	Rainbow	Wapato[1]	249	127	1	0.1 U	**5.6**	0.94U	0.94U	**5.6**	1.9 U	1.9 U	3.7 U	1.9 U	1.9 U	**3.1**	1.9 U	**3.1**
394406	Rainbow	Wapato[1]	278	209	1	0.1	**16**	0.94U	**0.40J**	**17**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	**3.7**	1.9 U	**3.7**
394407	Rainbow	Wapato[1]	305	296	1	0.1	**14**	0.82U	0.82U	**14**	1.6 U	1.6 U	3.3 U	1.6 U	1.6 U	**2.3**	1.6 U	**2.3**
204200	Mackinaw	Wapato	612±27	2101±118	6.6	2.4	**1500**	**15**	**23**	**1538**	1.8 U	1.8 U	3.6 U	1.8 U	1.8 U	3.6 U	3.6 U	nd
204201	Mackinaw	Wapato	650±30	2581±155	6.0	2.8	**1400**	**23**	**37**	**1460**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	3.9 U	3.9 U	nd
204202	Mackinaw	Wapato	714±41	3875±754	7.4	2.9	**580**	**20**	**17**	**617**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	**7.0**	3.9 U	**7.0**
114053	Mackinaw	Wapato	539±18	1386±28	5.8	1.5	**770**	**14**	**22**	**806**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
204203	Mackinaw	Wapato	568±19	1469±37	6.8	1.8	**975**	**19**	**28**	**1022**	1.8 U	1.8 U	3.7 U	1.8 U	1.8 U	3.7 U	3.7 U	nd
204205	Mackinaw	Wapato	568±23	1566±35	6.0	1.5	**620**	**13**	**15**	**648**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	3.9 U	3.9 U	nd
154153	Mackinaw	Wapato	584±27	1695±41	7.0	0.9	**1155J**	**23J**	**23**	**1201**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	**2.9**	**2.9**	**5.8**
204206	Mackinaw	Wapato	394±63	652±185	5.0	2.1	**750**	**15**	**21**	**786**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
204207	Mackinaw	Wapato	505±26	1091±67	5.4	1.4	**700**	**12**	**19**	**731**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
204208	Mackinaw	Wapato	531±13	1266±42	5.4	1.9	**790**	**16**	**18**	**824**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	3.8 U	3.8 U	nd

1 = Individual fish sample. U = not detected at the detection limit shown. nd = not detected.

Table G7 cont'd. DDT and PCBs as Aroclors in fish tissue from Lake Chelan and Roses Lake, 2003 (*u*g/Kg, ww).

Sample No. (03-)	Species	Location (basin)	Length (mm)	Weight (g)	Age (years)	Lipid (%)	4,4'-DDE	4,4'-DDD	4,4'-DDT	Total DDT	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	Total PCBs
214450	Mackinaw	Wapato	476	1009	6	1.7	**800**	**19**	**26**	**845**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	3.9 U	2.0 U	nd
214451	Mackinaw	Wapato	541	1445	7	7.7	**2100**	**44**	**64**	**2208**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	**6.5J**	3.8 UJ	**6.5**
214452	Mackinaw	Wapato	545	1352	6	5.2	**1300**	**36**	**39**	**1375**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	**5.0J**	3.9 U	**5.0**
214453	Mackinaw	Wapato	522	1392	7	1.1	**1100**	**20**	**31**	**1151**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214454	Mackinaw	Wapato	667	2608	7	3.0	**1700J**	**37**	**50**	**1787**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	3.8 U	3.8 U	nd
214455	Mackinaw	Wapato	613	2100	6	1.6	**410**	**9.2**	**18**	**437**	1.9 U	1.9 U	3.7 U	1.9 U	1.9 U	3.7 U	1.9 U	nd
214456	Mackinaw	Wapato	765	5091	7	4.5	**280**	**6.1**	**12**	**298**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	3.8 U	3.8 U	nd
214457	Mackinaw	Wapato	552	1530	6	4.1	**300**	**2.5**	**9.9**	**312**	1.8 U	1.8 U	3.6 U	1.8 U	1.8 U	1.8 U	1.8 U	nd
214458	Mackinaw	Wapato	615	1743	7	1.2	**1700**	**22**	**50**	**1772**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	3.9 U	3.9 U	nd
214459	Mackinaw	Wapato	598	2342	5	2.3	**210**	**1.6**	**6.3**	**218**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214460	Mackinaw	Wapato	620	1947	8	3.9	**1000**	**18**	**32**	**1050**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	**7.1J**	**5.4J**	**13**
214461	Mackinaw	Wapato	721	4117	NA	7.1	**520**	**17**	**12**	**549**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	**6.6J**	**6.0J**	**13**
214462	Mackinaw	Wapato	550	1568	6	2.1	**650**	**11**	**18**	**679**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214463	Mackinaw	Wapato	400	565	5	4.0	**920**	**15**	**27**	**962**	1.7 U	1.7 U	3.5 U	1.7 U	1.7 U	1.7 U	1.7 U	nd
214464	Mackinaw	Wapato	484	1102	6	2.9	**965J**	**14 J**	**27**	**1006**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214465	Mackinaw	Wapato	330	801	5	2.8	**690**	**8.4**	**22**	**720**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214466	Mackinaw	Wapato	688	3261	9	3.3	**1100**	**24**	**39**	**1163**	1.9 U	1.9 U	3.7 U	3.7 U	3.7 U	5.6 U	5.6 U	nd
214467	Mackinaw	Wapato	575	1689	6	1.1	**1400**	**16**	**32**	**1448**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	3.9 U	nd
214468	Mackinaw	Wapato	580	1605	6	1.3	**630**	**11**	**17**	**658**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214469	Mackinaw	Wapato	532	1246	6	2.1	**640**	**15**	**16**	**671**	2.0 U	2.0 U	4.0 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214470	Mackinaw	Wapato	412	714	5	5.0	**1100**	**18**	**37**	**1155**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	3.9 U	nd
214471	Mackinaw	Wapato	652	2759	6	2.8	**2300**	**20**	**42**	**2362**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	**8.9J**	**6.6J**	**16**
214472	Mackinaw	Wapato	665	2545	7	1.8	**510**	**6.0**	**13**	**529**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	**12 J**	2.0 U	**12**
214473	Mackinaw	Wapato	735	3507	7	2.0	**440**	**18**	**20**	**478**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	**15**	**7.6**	**23**
214474	Mackinaw	Wapato	562	1489	7	1.8	**1200**	**25**	**36**	**1261**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	3.9 U	3.9 U	nd
214475	Mackinaw	Wapato	539	1306	5	3.3	**870**	**20**	**26**	**916**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	3.9 U	1.9 U	nd
214476	Mackinaw	Wapato	570	2242	6	6.0	**400**	**4.9**	**14**	**419**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
214477	Mackinaw	Wapato	537	1160	5	0.6	**280**	**9.5**	**17**	**307**	1.9 U	1.9 U	3.9 U	1.9 U	1.9 U	1.9 U	1.9 U	nd
214478	Mackinaw	Wapato	567	1413	5	0.2	**640**	**14**	**13**	**667**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	**2.8**	2.0 U	**2.8**
214479	Mackinaw	Wapato	342	371	4	2.8	**660**	**13**	**19**	**692**	1.8 U	1.8 U	3.6 U	1.8 U	1.8 U	1.8 U	1.8 U	nd
394400	Rainbow	Roses Lk	228+8	134+10	1	0.5	**60**	**18**	**18**	**96**	2.0 U	2.0 U	3.9 U	2.0 U	2.0 U	2.0 U	2.0 U	nd
334350	Blk Crappie	Roses Lk	245+44	244+105	3.8	0.1	**27**	**4.3**	**0.65J**	**32**	1.9 U	1.9 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U	nd

U = not detected at the detection limit shown. nd = not detected

Table G8. PCB Congener TEQs in Fish Tissue from Lake Chelan, 2003 (ng/Kg)

PCBs (IUPAC #, structure)	TEF[1]	Mack. 214330[3]	Mack. 214331	Mack. 214332	Mack. 214333	Mack. 214334	Mack. 214335	Mack. 214336	Mack. 214337	Mack. 214338	Mack. 214339	Mack. 214340	Mack. 214341
PCB 77 - 3,3',4,4'-TCB	0.0005	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 105 - 2,3,3',4,4'-PeCB	0.0001	730	1300	1000	950	1200	600	640	600	1700	440	970	790
PCB 114 - 2,3,4,4',5-PeCB	0.0005	ND	75	69	63	77	ND	ND	ND	120	ND	53	59
PCB 118 - 2,3',4,4',5-PeCB	0.0001	1850	3100	2500	2400	3000	1500	1600	1400	4200	1200	2400	2100
PCB 123 - 2',3,4,4',5-PeCB	0.0001	ND	ND	ND	ND	53	ND	ND	ND	75	ND	ND	ND
PCB 126 - 3,3',4,4',5-PeCB	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 156 - 2,3,3',4,4',5-HxCB[2]													
PCB 157 - 2,3,3',4,4',5'-HxCB	0.0005	250	420	390	330	390	210	270	230	550	170	380	310
PCB 167 - 2,3',4,4',5,5'-HxCB	0.00001	125	210	170	160	170	99	110	110	260	88	160	160
PCB 169 - 3,3',4,4',5,5'-HxCB	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 170 - 2,2',3,3',4,4',5-HpCB	0.0001	155	210	250	200	ND	150	180	150	390	110	170	320
PCB 180 - 2,2',3,4,4',5,5'-HpCB[2]													
PCB 193 - 2,3,3',4,4',5,6-HpCB	0.00001	665	1100	1000	940	1200	640	800	600	1600	480	850	990
PCB 189 - 2,3,3',4,4',5,5'-HpCB	0.0001	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	PCB TEQs	0.4064	0.7216	0.6162	0.5625	0.6725	0.3374	0.3861	0.3371	0.9901	0.2657	0.5806	0.5170

Mack. = Mackinaw
[1] EPA 89
[2] Co-eluting congeners.
[3] Mean of replicate pair.

Table G8 cont'd. PCB Congener TEQs in Fish Tissue from Lake Chelan, 2003 (ng/Kg)

PCBs (IUPAC #, structure)	Mack. TEF[1]	Mack. 214342	Mack. 214343	Mack. 214344	Mack. 214345	Mack. 214346	Mack. 214347	Mack. 214348	Mack. 214349	Mack. 424001[4]	Mack. 424002[4]	Burbot 424000[4]	Kokanee 424003[3/4]
PCB 77 - 3,3',4,4'-TCB	0.0005	ND	ND	ND	ND	ND	ND	ND	ND	52.2	37.7	ND	ND
PCB 105 - 2,3,3',4,4'-PeCB	0.0001	620	670	810	540	1100	1500	710	640	1370	975	204	190
PCB 114 - 2,3,4,4',5-PeCB	0.0005	ND	ND	ND	ND	81	100	51	ND	96.2	72.3	ND	ND
PCB 118 - 2,3',4,4',5-PeCB	0.0001	1500	1700	2100	1400	2700	3900	1800	1600	3450	2610	483	500
PCB 123 - 2',3,4,4',5-PeCB	0.0001	ND	ND	ND	ND	ND	61	ND	ND	64.1	47.5	ND	ND
PCB 126 - 3,3',4,4',5-PeCB	0.1	ND	ND	ND	ND	ND	ND	ND	ND	24.1	18.8	ND	ND
PCB 156 - 2,3,3',4,4',5-HxCB[2] **PCB 157** - 2,3,3',4,4',5'-HxCB	0.0005	210	270	320	200	450	640	270	240	525	378	87.6	73
PCB 167 - 2,3',4,4',5,5'-HxCB	0.00001	110	120	140	95	190	290	110	100	213	168	ND	33
PCB 169 - 3,3',4,4',5,5'-HxCB	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB 170 - 2,2',3,3',4,4',5-HpCB	0.0001	130	170	200	140	360	390	180	140	266	431	66	59
PCB 180 - 2,2',3,4,4',5,5'-HpCB[2] **PCB 193** - 2,3,3',4,4',5,6-HpCB	0.00001	590	700	770	520	1200	1500	640	600	1200	1310	211	225
PCB 189 - 2,3,3',4,4',5,5'-HpCB	0.0001	ND	ND	ND	ND	ND	ND	ND	ND	ND	16.8	ND	ND
	PCB TEQs	0.3370	0.3972	0.4801	0.3142	0.6954	0.9730	0.4370	0.3650	3.2758	2.5468	0.1212	0.1140

Mack. = Mackinaw
[1] EPA 89
[2] Co-eluting congeners.
[3] Mean of replicate pair.
[4] Composite of five fish.

Table G9. Dioxins and Furans in Mackinaw Tissue from Lake Chelan, 2003 (ng/Kg, ww)

Compound	TEF[1]	Collection Basin, Lab ID Number, Fish Species, and Feeding Habit					
		Wapato 03218245 Mackinaw skin-on fillet Predator		Wapato 03218246 Mackinaw skin-on fillet Predator		Wapato * 03218247/8 Mackinaw skin-on fillet Predator	
% Lipids:		4.82 %		2.82 %		4.29 %	
2,3,7,8-TCDD	1	**0.32**	**J**	**0.34**	**J**	**0.46**	**J**
1,2,3,7,8-PeCDD	1	0.170	UJ	0.170	UJ	0.210	UJ
1,2,3,4,7,8-HxCDD	0.1	**0.35**	**J**	**0.36**	**J**	**0.42**	**J**
1,2,3,6,7,8-HxCDD	0.1	**0.80**	**J**	**0.86**	**J**	**1.12**	**J**
1,2,3,7,8,9-HxCDD	0.1	**0.19**	**J**	**0.34**	**J**	**0.37**	**J**
1,2,3,4,6,7,8-HpCDD	0.01	**0.90**	**BJ**	**0.73**	**BJ**	**0.84**	**BJ**
OCDD	0.0001	**4.80**	**BJ**	**3.60**	**BJ**	**3.50**	**BJ**
2,3,7,8-TCDF	0.1	**1.20**	**C**	**1.30**	**C**	**1.50**	**C**
1,2,3,7,8-PeCDF	0.05	0.270	UJ	0.180	UJ	0.120	UJ
2,3,4,7,8-PeCDF	0.5	0.210	UJ	0.095	UJ	0.135	UJ
1,2,3,4,7,8-HxCDF	0.1	**0.18**	**J**	**0.62**	**J**	**0.24**	**J**
1,2,3,6,7,8-HxCDF	0.1	**0.20**	**J**	**0.38**	**J**	**0.21**	**J**
2,3,4,6,7,8-HxCDF	0.1	0.130	UJ	0.130	UJ	0.093	UJ
1,2,3,7,8,9-HxCDF	0.1	0.170	UJ	0.290	UJ	0.135	UJ
1,2,3,4,6,7,8-HpCDF	0.01	**0.42**	**BJ**	**0.31**	**BJ**	0.210	UJ
1,2,3,4,7,8,9-HpCDF	0.01	0.150	UJ	0.130	UJ	0.180	UJ
OCDF	0.0001	**0.41**	**BJ**	**0.43**	**BJ**	**0.33**	**BJ**
TEQ		**0.63**		**0.74**		**0.85**	
% 2,3,7,8-TCDD		51 %		46 %		54 %	
% PCDDs		74 %		68 %		77 %	
% PCDFs		26 %		32 %		23 %	

[1] WHO/97
* = Mean of duplicate (split) samples 03218247 and 03218248; the most conservative qualifier is reported.
J = Estimated concentration; analyte was positively identified but concentration is below calibration range.
UJ = Analyte was not found at the estimated detection limit shown.
BJ = Analyte was positively identified but concentration is less than 10 times the method blank level.
C = Value obtained using confirmation analysis.

Table G10. Dioxins and Furans in Burbot Tissue from Lake Chelan, 2003 (ng/Kg, ww)

		Collection Basin, Lab ID Number, Fish Species, and Feeding Habit							
Compound	TEF[1]	Lucerne 03218249 Burbot skin-off fillet Bottom Predator		Wapato 03218250 Burbot skin-off fillet Bottom Predator		Wapato 03218251 Burbot skin-off fillet Bottom Predator		Lab Blank No.3437 Tissue	
% Lipids:		0.05 %		0.10 %		0.21 %			
2,3,7,8-TCDD	1	0.210	UJ	0.120	UJ	0.150	UJ	0.24	UJ
1,2,3,7,8-PeCDD	1	0.240	UJ	0.210	UJ	0.230	UJ	0.22	UJ
1,2,3,4,7,8-HxCDD	0.1	0.160	UJ	0.120	UJ	0.180	UJ	0.17	UJ
1,2,3,6,7,8-HxCDD	0.1	0.210	UJ	0.210	UJ	**0.35**	**J**	0.17	UJ
1,2,3,7,8,9-HxCDD	0.1	0.170	UJ	0.240	UJ	0.210	UJ	0.18	UJ
1,2,3,4,6,7,8-HpCDD	0.01	**0.66**	**BJ**	**0.38**	**BJ**	**1.80**	**BJ**	**0.54**	**J**
OCDD	0.0001	**4.70**	**BJ**	**2.00**	**BJ**	**15.00**	**B**	**2.80**	**J**
2,3,7,8-TCDF	0.1	0.220	UJ	**0.19**	**J**	**0.18**	**J**	0.19	UJ
1,2,3,7,8-PeCDF	0.05	0.270	UJ	0.190	UJ	0.270	UJ	0.19	UJ
2,3,4,7,8-PeCDF	0.5	0.170	UJ	0.140	UJ	0.058	UJ	0.15	UJ
1,2,3,4,7,8-HxCDF	0.1	**0.26**	**J**	0.097	UJ	0.140	UJ	0.18	UJ
1,2,3,6,7,8-HxCDF	0.1	**0.22**	**J**	0.070	UJ	0.140	UJ	0.16	UJ
2,3,4,6,7,8-HxCDF	0.1	**0.23**	**J**	**0.25**	**J**	0.066	UJ	0.17	UJ
1,2,3,7,8,9-HxCDF	0.1	0.170	UJ	0.110	UJ	0.160	UJ	0.13	UJ
1,2,3,4,6,7,8-HpCDF	0.01	**0.66**	**BJ**	**0.22**	**BJ**	**0.39**	**BJ**	**0.16**	**J**
1,2,3,4,7,8,9-HpCDF	0.01	0.150	UJ	0.097	UJ	0.190	UJ	0.16	UJ
OCDF	0.0001	**0.47**	**BJ**	**0.39**	**BJ**	**1.10**	**BJ**	**0.38**	**J**
TEQ		**0.085**		**0.050**		**0.077**			
% 2,3,7,8-TCDD		0 %		0 %		0 %			
% PCDDs		8 %		8 %		71 %			
% PCDFs		92 %		92 %		29 %			

[1] WHO/97.
UJ = Analyte was not found at the estimated detection limit shown.
J = Estimated concentration; analyte was positively identified but concentration is below calibration range.
BJ = Analyte was positively identified but concentration is less than 10 times the method blank level.
B = Analyte concentration is less than 10 times the method blank level.

Table G11. DDT and Flow Data from the Orchard Drain (ST11) Entering Roses Lake (data from Burgoon and Cross, 2004).

Date	Flow (cfs)	4,4'-DDD	4,4'-DDE	4,4'-DDT	t-DDT
		ng/L (pptr)			
3/19/02	0.06	5.02	10.2	8.63	24
4/17/02	0.036	ND	14.4	17.0	31
5/22/02	0.035	ND	ND	ND	ND
6/19/02	0.027	ND	9.69	10.2	20
7/23/02	0.028	ND	11.6	12.3	24
8/23/02	0.071	ND[1]	12.4[1]	10.3[1]	23[1]
9/17/02	0.074	ND	15.2	11.1	26
10/8/02	0.078	ND	11.5	10.2	22
11/20/02	0.046	2.89	9.65	7.46	20
12/17/02	0.22	7.16	19.8	17.5	44
2/25/03	0.30	ND	2.10	1.30	3.4
3/24/03	0.21	ND	9.80	2.60	12.4
4/15/03	0.12	ND	10.8	ND	10.8
5/20/03	0.11	ND[1]	12.2[1]	13.8[1]	26[1]
6/17/03	0.092	ND[1]	15.3[1]	ND[1]	15[1]
7/16/03	0.071	3.1[1]	6.10[1]	8.50[1]	18[1]
8/19/03	0.13	25.3	21.2	8.50	55
9/16/03	0.078	2.60[1]	10.7[1]	13.8[1]	27[1]
10/21/03	0.095	3.00	12.0	16.2	31
11/18/03	0.049	2.50	9.70	7.40	20
12/16/03	0.042	NS	NS	NS	NS
1/14/04	0.042	2.90	8.50	3.70	15.1

ND = Not detected at or above the detection limit.
[1] Mean of duplicate pair reported.