WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

TMDL Technical Assessment of DDT and PCBs in the Lower Okanogan River Basin

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TMDL Technical Assessment of DDT and PCBs in the Lower Okanogan River Basin

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by
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July 2003

Waterbody Numbers: see Table 1

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Abstract

The Washington State Department of Ecology (Ecology) Environmental Assessment Program prepared an assessment of total maximum daily loads (TMDLs) of DDT and PCBs in the lower Okanogan River basin, including Osoyoos Lake. Sampling conducted during 2001-2002 examined DDT and PCB concentrations in the water column of the mainstem Okanogan River, water in tributary streams, sewage treatment plant (STP) effluent and sludge, and cores of bottom sediments. Composite samples of three species of fish – carp (*Cyprinus carpio*), mountain whitefish (*Prosopium williamsoni*), and smallmouth bass (*Micropterus dolomieui*) – also were analyzed for DDT and PCBs. Data from these samples were used in conjunction with historical data to develop the TMDLs.

Results suggest that only small loads of DDT and PCBs are delivered to Osoyoos Lake and the lower Okanogan River through tributary streams and STPs. Combined, measurable DDT and PCB loads from tributaries and STPs averaged approximately 200 mg t-DDT/day and 3 mg t-PCB/day, respectively. This contrasts sharply with the measured loads in several reaches of the lower Okanogan River (1,500 – 4,300 mg t-DDT/day; no measurable PCBs), the assimilative capacities of the river (1,300 – 6,700 mg t-DDT/day; 230 – 1,100 mg t-PCB/day), and theoretical loads based on fish tissue concentrations (13,000 – 32,000 mg t-DDT/day; 0 – 6,500 mg t-PCB/day). The loading analysis showed that the bulk of loading was internal, presumably through bottom sediments. Load allocations and waste load allocations were developed for tributaries, STPs, and sediments.

Recommendations for further study are to expand the sampling effort around the Osoyoos Lake basin, including a re-assessment of DDT and PCB concentrations in Osoyoos Lake fish. Carp from the Monse reach of the Okanogan River also should be analyzed for DDT and PCBs. Investigation of DDT loading through erosional processes also is recommended, although it appears improbable that DDT loading can be substantially reduced through best management practices.

Acknowledgements

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Introduction

Problem Description

The Okanogan River flows from its headwaters in British Columbia (B.C.) through north-central Washington where it empties into the Columbia River near the town of Brewster. The Okanogan basin drains approximately 8,900 mi^2 of mostly forest and rangeland in the uplands, while the fertile valley bottom provides one of the most productive orchard regions in B.C. and Washington.

Beginning in the early 1970s, Canadian investigators began documenting high DDT levels in fish collected from B.C. lakes along the mainstem Okanogan River (Northcote et al., 1972). In 1983, the Washington State Department of Ecology (Ecology) collected data which revealed DDT and PCB contamination in fish from the lower Okanogan River below the Canada border (Hopkins et al., 1985). Since then, a number of Ecology surveys have verified DDT and PCB contamination in the basin (Johnson and Norton, 1990; Davis and Serdar, 1996; Johnson et al., 1997; Serdar et al., 1998).

Some of the fish tissue and water samples collected by Ecology fell short of state surface water quality standards established to provide beneficial uses of surface waters, such as fish consumption and aquatic habitat. Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that are not expected to improve within the next two years.

Waters placed on the 303(d) list require the preparation of Total Maximum Daily Loads (TMDLs), a key tool in the work to clean up polluted waters. TMDLs identify the maximum amount of a pollutant allowed to be released into a waterbody so as not to impair uses of the water, and allocate that amount among various sources.

Five separate waterbody segments in the lower Okanogan River basin are included on the 1998 303(d) list due to excessive DDT and/or PCB contamination (Table 1). Decision matrices for these listings have called for a TMDL as the action needed to address these listings (Appendix B), triggering a TMDL assessment which is the subject of the present report. This TMDL will be the basis for a plan to clean up DDT and PCBs in the lower Okanogan River basin.

Table 1. Basis for 303(d) listed segments in the lower Okanogan River basin.

Waterbody	Old Segment No.	New Segment No.	Basis for Listing
Okanogan R.	WA-49-1010	YN58LL	Exceeds NTR criteria for 4,4'-DDD, 4,4'-DDE, PCB-1254, and PCB-1260 in fish tissue[a]
Osoyoos Lk.	WA-49-9260	060VKD	Exceeds NTR criteria for 4,4'-DDD and 4,4'-DDE in fish tissue[b]
Tallant Cr.	WA-49-1017	LD33FC	Exceeds Washington State chronic criteria for DDT in water[c]
Elgin Cr.	WA-49-1022	KR66GR	"
Ninemile Cr.	WA-49-1049	IP09QF	"

NTR=National Toxics Rule
[a]Davis and Serdar, 1996
[b]Johnson and Norton, 1990
[c]Johnson et al., 1997

Watershed Description

Most of the Okanogan River basin lies above the Canada border where its flows are regulated by four lakes along the mainstem river, all lying above the U.S.-Canada border except the 14,150 acre Osoyoos Lake which straddles the border. The lower Okanogan River flows out of Osoyoos Lake (elevation 915' m.s.l.) at the city of Oroville 79 miles southward to its confluence with the Columbia River (779' m.s.l.). The Similkameen River joins the Okanogan just downstream of Oroville, increasing its flow by 400% on average. About 20 small tributary streams also drain the 2,600 mi^2 Washington portion of the basin (hereinafter referred to as the lower Okanogan River basin), most of which are small or intermittent, contributing little to the overall flow of the lower Okanogan (Figure 1). Table 2 shows average flows at U.S. Geological Survey (USGS) gaging stations along the lower Okanogan River and Similkameen River.

Table 2. Annual harmonic mean flows at USGS gaging stations in the lower Okanogan River basin.

USGS Station	Description	Period of Record	Flow (cfs)*	Flow (l/s)*
12442500	Similkameen River near Nighthawk, WA	1929-1999	2,113	59,840
12439500	Okanogan River at Oroville, WA	1943-1999	547	15,491
12445000	Okanogan River near Tonasket, WA	1912-1924, 1930-1999	2,670	75,614
12447200	Okanogan River at Malott, WA	1966-1999	2,729	77,285

*1 cfs = 28.32 l/s

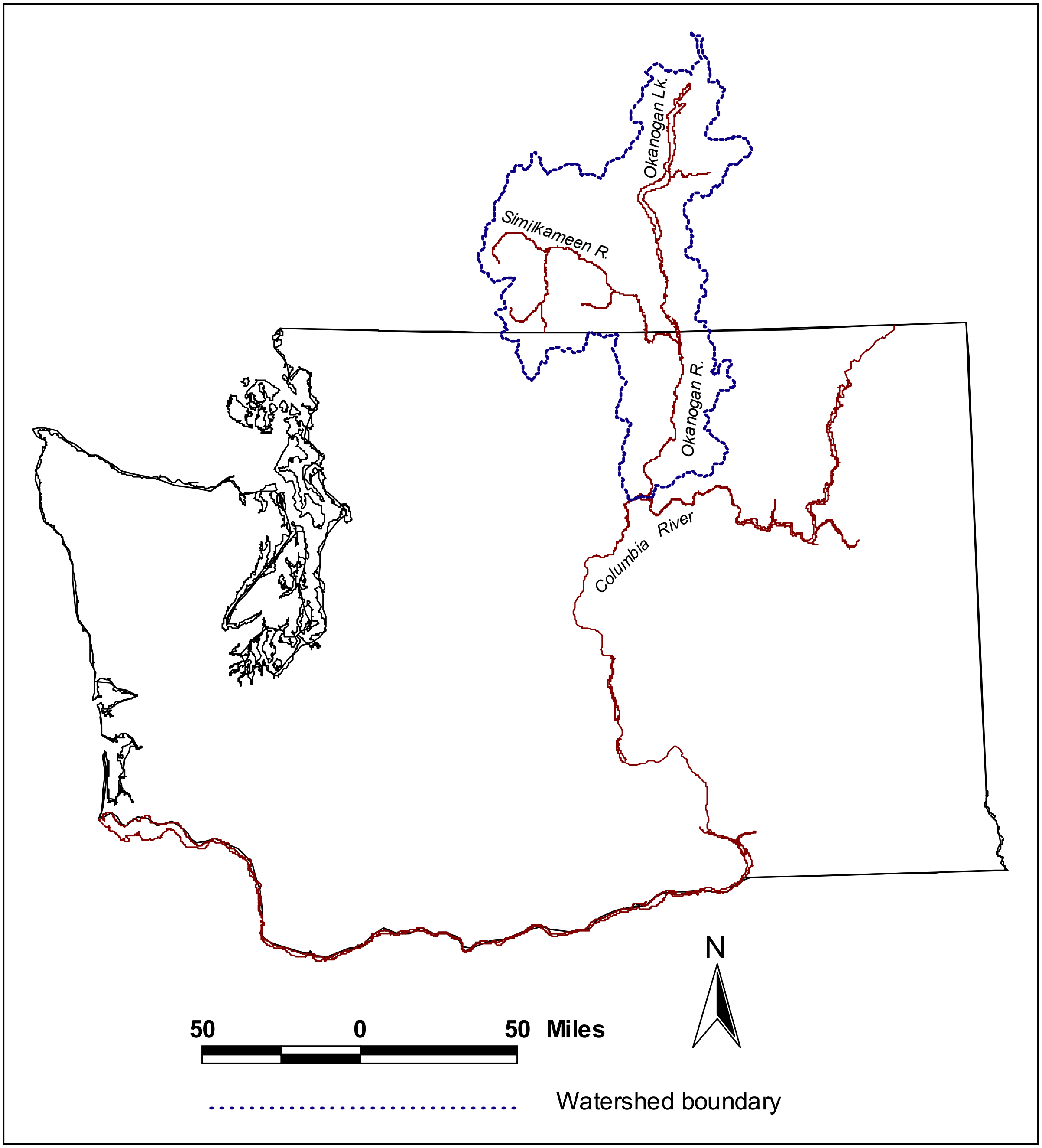

Figure 1. Okanogan River Watershed

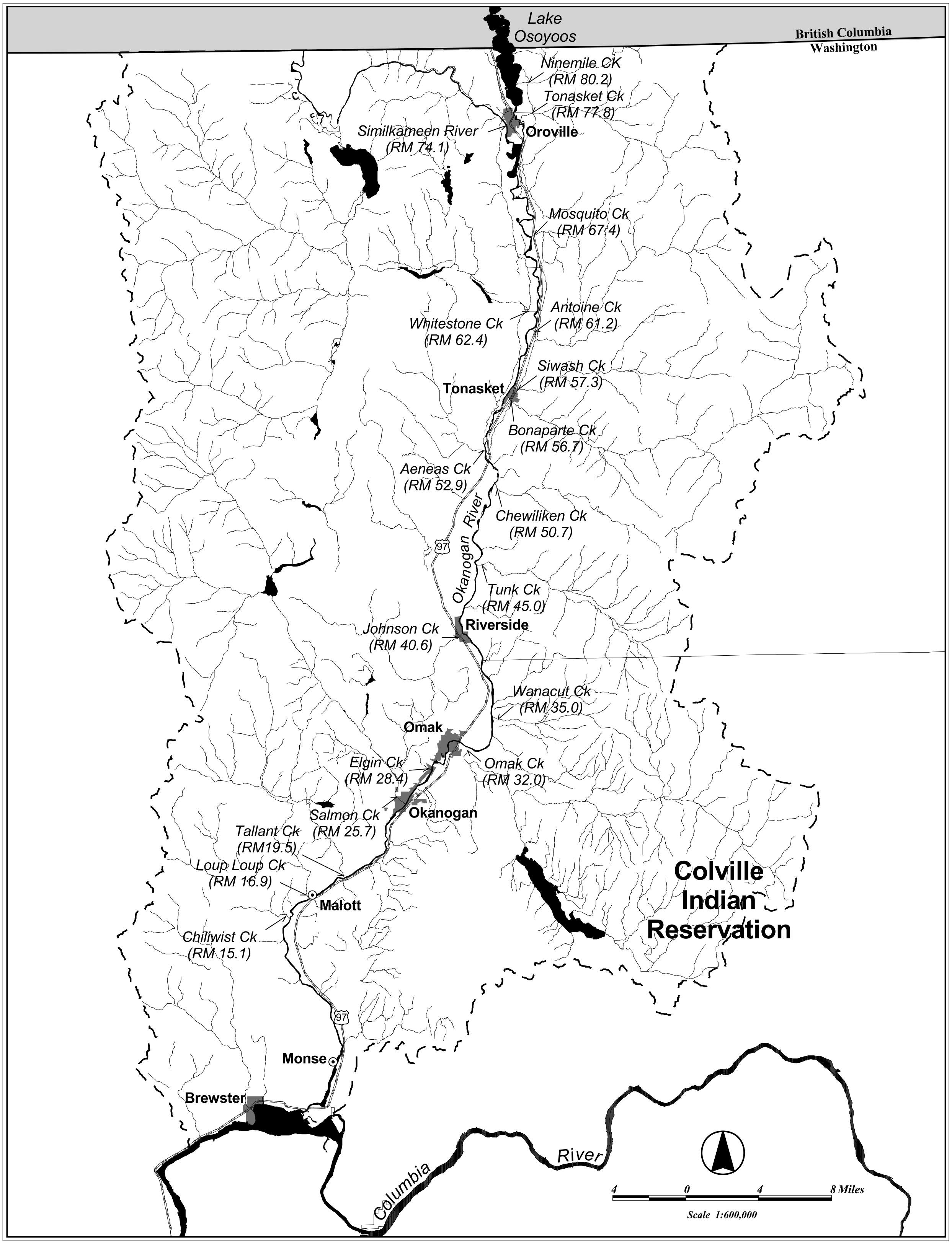

Figure 2. Location of lower Okanogan River and Osoyoos Lake tributary streams

The lower Okanogan River basin lies in a semi-arid region with annual precipitation of approximately 20 inches in the higher elevations of the basin fringes to as little as 10 inches near the valley bottom. Surface hydrology generally follows a snowmelt regime, with low flows occurring September-March. Several of the small streams are diverted for irrigation and flow only during releases from their storage reservoirs, but groundwater comprises the major source of irrigation water for the basin.

The basin is sparingly populated, with 39,564 residents in Okanogan County according to the 2000 census. The cities of Omak and Okanogan have a combined population of about 7,000. Other population centers include the cities of Oroville (≈ 1,600), and Tonasket (≈ 1,000). The southern portion of the lower Okanogan River provides the western boundary of the Colville Indian Reservation from river mile (RM) 38.6 to the mouth at the Columbia River.

Land cover is primarily forest and rangeland, especially in the uplands. Near the valley bottom, orchards and pasture/hay are the primary agricultural uses. Fruit orchards have a long history in the Okanogan valley, with the first orchards planted in 1857. By 1916 there were approximately 12,000 acres of irrigated orchards in the lower Okanogan River valley. Fruit orchards presently comprise about 2% or approximately 37,000 acres of the land arealands, providing over 99% of the tree fruit grown in British Columbia (Sinclair and Elliott, 1993). The upper Okanogan River basin (above the Canada border) has a similar composition of orchard.

Background on DDT and PCB Contamination

The insecticide DDT (1,1,1-trichloro-2,2-*bis*[*p*-chlorophenyl]ethane) was used widely to control orchard pests such as the codling moth (*Carpocaspa Pomonella*) beginning in the mid-1940s. Nationally, peak use of DDT occurred during 1959 when 80 million pounds (36 million kg) was produced (Sittig, 1980). In 1958, the U.S. Department of Agriculture (USDA) began a program to phase out DDT for its insect control programs due to concerns about its persistence in the environment and toxicity to non-target organisms. Domestic use declined steadily until 1972, when the U.S. Environmental Protection Agency (EPA) banned DDT for all uses except for emergencies. One of these emergencies occurred shortly afterward (1974) during an infestation of the Douglas fir tussock moth (*Hemerocampa pseudotsugata*) when the EPA approved a USDA application of 140,000 kg DDT to forests east of the Sanpoil River on the Colville Indian Reservation and the Huckleberry Mountain Range near Rice, WA (Orgil et al., 1976; Peakal, 1976).

DDT use in the lower Okanogan River basin probably followed national trends, although details of its use are essentially non-existent. A survey of pesticide use in B.C. suggests that peak use in the Okanogan River basin probably occurred during 1965 (B.C. Water Resources Service, 1973). Sales of DDT (50W formulation) from 1960 until 1970 were approximately 1.3 million kg in the Okanogan basin above the border (upper basin). Extrapolation of DDT usage derived from temporal use patterns and relative size of the upper and lower basins suggests that approximately 3.6 million kg of DDT was applied to the Okanogan River basin for agricultural use from the late 1940s until 1970, with 2.5 million kg applied in the upper basin and 1.1 million kg applied in the lower basin. These application rates are consistent with other orchard areas in Washington where cumulative use was sometimes equal to or greater than 400 kg/acre during the same period (Blus et al., 1987).

DDT can persist in the environment for decades along with its primary aerobic metabolite DDE (1,1-dichloro-2,2-*bis*[*p*-chlorophenyl]ethylene) and the anaerobic breakdown product DDD (1,1-dichloro-2,2-*bis*[*p*-chlorophenyl]ethane). Their persistence is due to low vapor pressure and resistance to degradation, including photoxidation. DDT[1] sorbs to sediments and particulate matter in the aquatic environment due to its low water solubility and high affinity for solids, especially solids with a high organic carbon content. Transport of DDT to streams and movement within aquatic environments is often associated with erosion of contaminated soils and elevated loads of suspended solids as a result of erosion or sediment re-suspension (e.g. Johnson et al., 1988; Joy and Patterson, 1997).

DDT and its derivatives also accumulate in fish tissues through direct uptake across gill or epithelial membranes, or through diet. Accumulation in edible muscle is usually highest where fat or lipid content is high, due to DDT's preferential solubility in non-polar solvents. Lipid content was found to be a positive determinant of DDT concentrations within and among species in Osoyoos Lake (Serdar et al., 1998), although Johnson et al. (1988) did not find this necessarily to be the case in the Yakima River.

A review of Ecology's historical statewide data indicates that the highest DDT concentrations are generally found in bottom-feeding species with high lipid content such as carp (*Cyprinus carpio*), largescale suckers (*Catostomus macrocheilus*), lake whitefish (*Coregonus clupeaformis*), and the insectivorous mountain whitefish (*Prosopium williamsoni*). There appears to be little biomagnification of DDT in lean-muscled predators inhabiting higher trophic positions such as smallmouth bass (*Micropterus dolomieui*) or yellow perch (*Perca flavescens*), yet some predator species with moderate-to-high lipid (e.g. northern pikeminnow [*Ptychocheilus oregonensis*) and lake trout [*Salvelinus namaycush*]) may accumulate substantial DDT concentrations.

The combination of DDT's wide usage and the bioaccumulative properties of DDT and its derivatives make them among the most prevalent pesticides in fish tissue. DDE was the most common chemical found in two U.S. surveys of pesticides and other bioaccumulative chemicals in fish tissues, with detection >98% of sites sampled (Schmitt et al., 1990; EPA, 1992). Ecology statewide screening-level data on contaminants in fish collected 1982-1995 showed DDT compounds to be the most common chemicals in fish, with a detection frequency of 95% (123 of 130 samples).

Unlike DDT, polychlorinated biphenyls (PCBs) were generally not intended to be dispersed in the environment, but their similar characteristics and mass production and use have led to parallel environmental fates. PCBs were first produced for commercial use in 1929 and continued until a 1979 ban on all PCB manufacturing, processing, and distribution due to concerns about possible human carcinogenicity (Sittig, 1980). They were produced almost exclusively as Aroclors, the trade name for PCB mixtures containing 21-68% chlorine by weight.

[1] Unless stated otherwise, DDT hereinafter refers to DDE, DDD, and DDT. The sum of these compounds is total DDT (t-DDT). The sum of PCB Aroclors is total PCB (t-PCB).

The names given to the different Aroclors reflect this composition; Aroclor[PCB]-1248, for instance, contains approximately 48% chlorine by weight. Principal uses were as heat transfer fluids, plasticizers, wax and pesticide extenders, lubricants, and fluids for hydraulic machinery, vacuum pumps, and compressors.

Much of the 600 million kg of PCBs used domestically has found its way into the environment through improper disposal or by leakage of sealed systems (Sittig, 1980), although loss to the environment through their use in open systems such as hydraulic fluids in die cast machinery, heat transfer systems, and specialty inks was not uncommon (EPA, 1995). Their primary uses are associated more with heavy industry or urban centers rather than agriculture (EPA, 1992), although direct application to the environment occurred on a lesser scale through use as pesticide extenders or as used oil mixtures applied to roads for dust control. Furthermore, many of the same properties that made PCBs commercially desirable – their stability and resistance to degradation – make them extremely persistent in the environment, and they have become one of the most ubiquitous of all environmental contaminants.

Like DDT, PCBs have low solubilities in water and a strong tendency to sorb to organic carbon-rich sediments and accumulate in fish tissue; lipid solubility increases with the degree of chlorination (Mabey et al., 1982). PCBs were detected in fish from 91% of U.S. sites nationally (EPA, 1992), although difficulty in obtaining adequately low quantitation limits suggests that their presence is probably under-reported. Ecology/EPA Manchester Environmental Laboratory's (MEL) recent success at obtaining PCB quantitation limits an order of magnitude lower than before has revealed PCBs in fish tissues where none previously would have been reported (e.g. Serdar, 1999; Serdar et al., 1999).

Little is known about sources of PCB contamination in the lower Okanogan River basin, except no major sources appear evident. Like other parts of the nation, PCB contamination in the Columbia River basin is generally more prevalent in urban and industrial lands than in agricultural or range lands (Munn and Gruber, 1997).

Table 3 lists available studies with data on DDT and/or PCBs in the lower Okanogan River basin. Ecology surveys conducted from 1983 through 1995 provide the bulk of this information, although the sediment survey done by the Colville Tribe in 2001 is quite extensive. Tables 4 and 5 summarize DDT and PCB data collected by Ecology prior to the initiation of the present study.

Table 3. Sources of data on DDT and PCBs in the lower Okanogan River basin.

Location	Year	Type of study	Agency/Reference
Okanogan R. near Okanogan and Malott	1983-1984	Statewide program to monitor contaminants in fish and sediment	Ecology Hopkins et al., 1985
Okanogan STP	1988	Class II inspection	Ecology Reif, 1990
Osoyoos Lk.	1989	One-time statewide survey of contaminants in fish and sediment	Ecology Johnson and Norton, 1990
Okanogan R. near Monse	1994	Statewide program to monitor pesticides in fish and sediment	Ecology Davis and Serdar, 1996
Lower Okanogan R. basin	1995	Intensive study of DDT sources to the Okanogan R.	Ecology Johnson et al., 1997
Osoyoos Lk.	1995	Intensive study of DDT in fish tissue	Ecology Serdar et al., 1998
Several Okanogan R. tributaries	2000-2001	Pesticide analyses done on a subset of routine water quality monitoring samples	Okanogan County Conservation District unpublished
Mainstem Okanogan and Similkameen rivers	2001	Intensive study of contaminants in bottom sediments	Colville Confederated Tribes (D. Hurst, written communication)

Table 4. Summary of lower Okanogan River basin DDT data collected by Ecology, 1984-1995.

	Water			Bottom Sediment			Edible Fish Tissue			Whole Fish	
Ecology Data (1984-1995)	**n**	**t-DDT (ng/l)**		**n**	**t-DDT (ng/g, dry)**		**n**	**t-DDT (ng/g, wet)**		**n**	**t-DDT (ng/g, wet)**
Okanogan River Mainstem	3	u(1)		2	18 – 56		3	1,700 – 3,200		4	800 – 1,800
Tributaries to the Okanogan River and Osoyoos Lake	17	u(1) – 500		na	--		na	--		na	--
Sewage treatment plants	2	u(8 – 60)		1	300[a]		na	--		na	--
Osoyoos Lake	na	--		na	--		19	40 – 1,200		2	60 – 1,000

u=undetected at practical quantitation limit in parentheses
na=not analyzed
[a]STP sludge
ng/l=parts per trillion
ng/g=parts per billion

Table 5. Summary of lower Okanogan River basin PCB data collected by Ecology, 1984-1995.

	Water			Bottom Sediment			Edible Fish Tissue			Whole Fish	
Ecology Data (1984-1995)	**n**	**t-PCB (ng/l)**		**n**	**t-PCB (ng/g, dry)**		**n**	**t-PCB (ng/g, wet)**		**n**	**t-PCB (ng/g, wet)**
Okanogan River Mainstem	na	--		2	u(47) – 21		3	u(10) – 45		4	56 – 600
Tributaries to the Okanogan River and Osoyoos Lake	na	--		na	--		na	--		na	--
Sewage treatment plants	1	u(300)		1	u(200)[a]		na	--		na	--
Osoyoos Lake	na	--		na	--		2	u(20 – 40)		2	24 – 66

t-PCB=total PCB
u=undetected at practical quantitation limit in parentheses
na=not analyzed
[a]STP sludge

Data from these surveys provided an initial snapshot of contamination indicating high concentrations of DDT and moderate-to-low PCBs were present in fish from the lower Okanogan River between the city of Okanogan and the mouth, and moderate DDT concentrations were present in Osoyoos Lake fish. Subsequent surveys (Johnson et al., 1997; Serdar et al., 1998) verified that Osoyoos Lake fish contain moderate-to-high DDT concentrations, depending on species, and that several tributaries emptying into the lower Okanogan River contain measurable DDT although overall loading of DDT is low. In addition, the 2001 survey by the Colville Tribe showed that sediments are not indicative of widespread contamination in the lower mainstem Okanogan River (D. Hurst, written communication).

Some of the samples from these surveys contained DDT and/or PCB concentrations above National Toxics Rule criteria for fish tissue or Washington State water quality criteria for water. The following section provides details about the scope of the TMDL conducted to address the 303(d) listings resulting from these data.

Applicable Water Quality Criteria

Applicable human health criteria for DDT and PCBs have been established by the federal government under the National Toxics Rule (40 CFR 131). Water quality criteria for DDT and PCBs have been established by Washington State to protect aquatic life and are promulgated in the Water Quality Standards (Ch. 173-201A WAC). These regulations are discussed separately below. The applicable numerical criteria are shown in Table 6.

Table 6. Water quality criteria for DDT and PCBs for the protection of human health and aquatic life.

Parameter	Human Health[a]– Water (ng/l)	Human Health[a]– Tissue (ng/g)	Aquatic Life[b]– Water (ng/l)
4,4'-DDE	0.59	32	1
4,4'-DDD	0.83	45	1
4,4'-DDT	0.59	32	1
t-DDT	ne	ne	1
PCB Aroclors	0.17	5.3	14
t-PCB	0.17	5.3	14

[a]NTR (40 CFR 131), for consumption of organisms and water
[b]Ch. 201-173A WAC, chronic criteria
ne=not established

National Toxics Rule

In 1992, EPA promulgated the National Toxics Rule (NTR) which established numeric, chemical-specific water quality criteria for all priority pollutants. The federal Clean Water Act requires adoption of the NTR criteria in all states which do not have sufficient criteria to protect designated uses of state waters. Some of the NTR criteria are applicable in Washington, which has not developed water quality standards to protect human health from exposure to toxicants.

NTR human health criteria for DDT and PCBs were derived primarily from acceptable fish tissue concentrations, since consumption of fish is considered to be the major exposure pathway for humans (exposure through water consumption is negligible, representing approximately 0.5% of total intake). The human health criteria (HHC) are calculated using the following equation:

$$HHC = \frac{RF \times BW \times (10^6\ ng/mg)}{q1^* \times [WC + (FC \times BCF)]}$$

Where:

- RF (risk factor) = the acceptable level of cancer risk. The risk level is decided by states where the NTR criteria apply. For Washington, Ecology has adopted an acceptable upper-bound excess cancer risk of one in a million (10^{-6}) for a lifetime exposure.

- BW (body weight) = the average body weight of the consumer. The NTR uses an average consumer body weight of 70 kg.

- q1* (cancer slope factor) = the cancer potency of each chemical. The NTR uses a q1* 0.34 mg/kg-day for 4,4'-DDE and 4,4'-DDT; the q1* for 4,4'-DDD is 0.24 mg/kg-d. For PCBs the q1* is 2 mg/kg-d.

- WC (water consumption) = the average daily consumption of water by a consumer. The NTR uses a water consumption rate of 2 l/d.

- FC (fish consumption) = the average fish tissue consumption by a consumer. The NTR uses a fish tissue consumption rate of 0.0065 kg/d.

- BCF (bioconcentration factor) = the concentration of a chemical in tissue from the water column. The NTR uses a BCF of 53,600 for DDT compounds and 31,200 for PCBs.

Fish bioconcentrate contaminants directly from the water column through uptake by gill or epithelial tissue. Concentrations in water (C_w) and fish tissue (C_t) are linked by bioconcentration factors (BCFs), expressed by the following formula:

$$BCF = C_t/C_w$$

Acceptable fish tissue concentrations may then be calculated by $C_t = BCF \times C_w$ (Table 6).

The values used by EPA to derive the NTR human health criteria are not necessarily used by public health agencies to establish fish consumption advisories in Washington. They are, however, used to assess water quality violations by Ecology. Agencies responsible for assessing the need for fish consumption advisories (e.g. Washington State Department of Health) often examine local conditions such as consumption rates and sub-populations at risk during site-specific evaluations. Public health agencies also may consider different contaminant potencies and health endpoints than those used by EPA for criteria development.

Washington State

Water quality standards for surface waters of Washington State are set in Chapter 173-201A of the Washington Administrative Code (WAC). The lower Okanogan River and its tributaries are designated as a Class A streams under Ch. 173-201A WAC. Osoyoos Lake is designated as Lake Class. Characteristic uses of Class A and Lake Class waters include, but are not limited to:

- Water supply (domestic, industrial, agricultural)
- Stock watering
- Fish and shellfish (migration, rearing, spawning, harvesting)
- Wildlife habitat
- Recreation (primary contact recreation, sport fishing, boating, aesthetic enjoyment)
- Commerce and navigation

Ch. 173-201A WAC includes a provision that "Toxic, radioactive, or deleterious material concentrations shall be below those which have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent on those waters, or adversely affect public health as determined by the department [Ecology]." The numeric criteria to protect aquatic life from DDT and PCB exposure spelled out in Ch. 173-201A-040 WAC were originally derived by EPA to protect the most sensitive aquatic species (EPA, 1980a and 1980b).

Scope of the TMDL

Geographic

This TMDL covers the lower Okanogan River and all of its tributaries from the Canadian border (RM 82.5) to the mouth near Brewster, including the southern portion of Osoyoos Lake (RM 79.0 – 82.5).

Pollutant Parameters

The TMDL covers 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, t-DDT, and PCBs as Aroclors or t-PCB.

Ecology's 2001-2002 Study

Objectives and Strategy

During 2001 – 2002, Ecology collected data necessary to conduct a TMDL assessment for the geographic area and parameters covering the scope of the lower Okanogan TMDL. Objectives of this sampling were to assess DDT and PCB loads to the lower Okanogan River and Osoyoos Lake, assess DDT and PCB concentrations in edible fish tissue, and reconstruct historic DDT and PCB levels in sediments. This was considered necessary to achieve the goal of the lower Okanogan TMDL project: to determine if and where DDT/PCB loading may be reduced and how this may affect concentrations in fish tissue. Means to reduce DDT and PCB loading will be addressed in the TMDL implementation phase.

Early in the planning process it was recognized that this would not be a traditional TMDL. First, although DDT and PCBs have been banned for decades, they persist in the environment and generally have become nonpoint contaminants often dissipated and dispersed far from their original sources. Second, the listings in the lower Okanogan River and Osoyoos Lake are based on fish tissue, adding layers of complexity to calculating loads and load allocations, customary elements of a TMDL assessment.

The need to approach this TMDL assessment from a broad geographical perspective was also recognized early in the planning process. The distribution of agricultural lands and results of previous Ecology studies suggested DDT contamination existed throughout the lower Okanogan River valley. The geographical locations of PCB contamination were less certain, but the problem was addressed basin-wide rather than focusing on a single listed river reach.

Given these and other considerations, four sampling components were identified to carry out the TMDL assessment:

- Re-assessment of DDT and PCB loads transported to the lower Okanogan River and Osoyoos Lake through tributaries and municipal sewage treatment plants.
- Measurement of DDT and PCB concentrations in the water column of the lower Okanogan River.
- Analysis of DDT and PCB concentrations in edible fish tissue from the lower Okanogan River.
- Analysis of DDT and PCB concentrations in sediment cores from the lower Okanogan River and Osoyoos Lake.

The following sections describe methods for collecting data for these components of the study and sample results. A TMDL analysis is then performed to quantify loads to the lower Okanogan River and Osoyoos Lake. Also included is a quantitative analysis of DDT/PCB accumulation by lower Okanogan River and Osoyoos Lake fish. These analyses are performed using data collected during 2001-2002 as well as previous Ecology data and data collected by other agencies.

Methods

Sampling Strategy

Sample types, sample locations, and analyses were all conducted to best meet the project objectives. Table 7 summarizes samples collected during 2001-2002.

Table 7. Samples collected during Ecology's 2001-2002 assessment of DDT and PCBs in the lower Okanogan River basin.

Location	Whole Water[a]	Sediment/Sludge[b]	Fish Tissue[c]
Osoyoos Lake	--	Core – DDT/PCBs + chlorinated pesticides	--
Mainstem Okanogan River:			
Oroville reach	DDT/PCBs	--	DDT/PCBs
Riverside-Omak reach	DDT/PCBs	--	DDT/PCBs
Malott-Monse reach	DDT/PCBs	Core – DDT/PCBs + chlorinated pesticides	DDT/PCBs
Tributary Streams	DDT (DDT/PCBs in Similkameen R.)	--	--
Sewage Treatment Plants	DDT/PCBs	Sludge – DDT/PCBs	--

[a]ancillary analyses included TSS, TOC, and field parameters
[b]ancillary analyses included TOC and ^{210}Pb
[c]ancillary analysis included percent lipids

Lower Okanogan River and Osoyoos Lake tributaries were sampled for DDT in the present assessment during the high-flow season (April-May) when more streams contain water than other times of year. Previous sampling of tributary streams was conducted during low flows (July-August)(Johnson et al., 1997). PCBs were not analyzed in water from tributaries since they are extremely difficult to detect in water without expensive specialized methods. There is also little reason to suspect these streams contain measurable PCBs since they are primarily an industrial and urban contaminant.

Water from the three municipal sewage treatment plants (STPs) discharging to the lower Okanogan River or Similkameen River – Oroville, Omak, and Okanogan – were also sampled for DDT and PCBs (Tonasket STP began discharging to the Okanogan River after sampling for this project had been completed). STPs may act as funnels for DDT in urban areas (Reif, 1990) possibly due to improper disposal or storage and historic non-agricultural insecticidal uses such as mosquito control. Previous studies have not adequately investigated DDT in STP effluent. PCBs were also sampled in STP effluent since STPs represent the few places in the basin where PCBs may be present at detectable concentrations, due, for instance, to the high density of electrical transformers in the service area compared to other parts of the basin. The only known analysis of PCBs in a lower Okanogan River basin water sample was from Okanogan STP effluent analyzed in 1988 by Reif (1990). No PCBs were detected in this sample.

STP sludge was also examined for DDT and PCBs since it provides a more feasible media for detection of these chemicals due their tendency to sorb to organic-rich solids. In the absence of detectable concentrations in effluent, sludge may be used to calculate crude estimates of DDT and PCB loads via STPs.

High-flow data were collected to supplement previously reported low-flow data in order to address potential seasonal variation. Water column samples were collected at three locations in the lower mainstem Okanogan River in May during the rising limb of the season hydrograph (Figure 3), since rising flows are most likely to entrain DDT-containing particulate matter. Samples were also analyzed for PCBs. Sampling locations were at the Osoyoos Lake outlet to assess contaminant loads from across the border; at Riverside just upstream of the largest urban center in the lower Okanogan River basin; and at Malott below urban centers and near the Okanogan River mouth. Samples were also collected at the mouth of the Similkameen River.

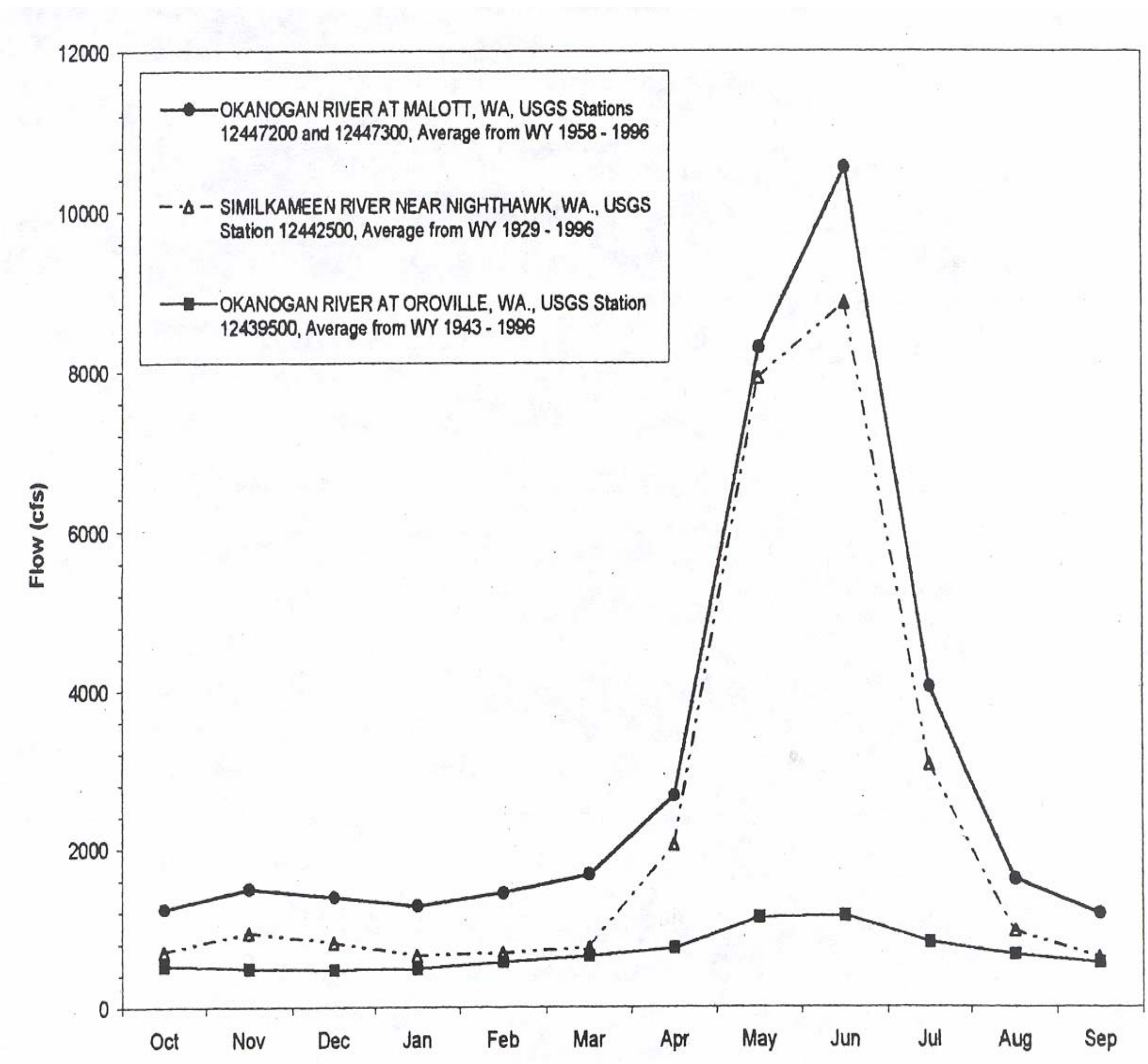

Figure 3. Lower Okanogan River and Similkameen River average monthly flows (figure adapted from WEST Consultants, Inc. and Hammond, Collier, & Wade-Livingstone, Inc., 1999)

To assess the geographical distribution of contaminants in lower Okanogan River fish, three species were sampled from the upper river (Oroville reach, RM 77.3 – 76.4), middle river (Riverside-Omak reach, RM 41.0 – 30.7), and lower river (Monse reach, RM 10.5 – 4.9). These three reaches also encompass the population centers and public boat launches along the river.

Species analyzed were common carp (*Cyprinus carpio*), mountain whitefish (*Prosopium williamsoni*), and smallmouth bass (*Micropterus dolomieui*). These are the three most common resident game species in the lower Okanogan River and represent different feeding behaviors and habitat uses. Edible tissue (fillet) was analyzed for DDT and PCBs. Results were provided to Washington State Department of Health (WDOH) for their assessment of any potential human health risks associated with consumption of each species.

Carp are bottom-feeding detritivores generally found in slow-moving shallow waters, although they are adaptable to a variety of habitat types. They are known to accumulate high concentrations of DDT, PCBs, and other chlorinated organic chemicals (e.g. Davis and Serdar, 1996; Serdar et al., 1998).

Mountain whitefish are more pelagic, preferring riffle areas and feeding primarily on zooplankton and insects. Mountain whitefish also can accumulate high concentrations of chlorinated organic chemicals due largely to their high lipid content (e.g. Johnson et al., 1988; Ecology, 1995).

Smallmouth bass prefer gravelly substrates along gradually sloped littoral areas. Initially planktivorous or insectivorous as juveniles, they become predators (piscivorous) and are a prized game fish. Due to their lean muscle, their tendency to accumulate DDT and PCBs is much less so than either carp or mountain whitefish.

Sediment cores were collected to reconstruct historical DDT and PCB concentrations from sediment deposits. Two to four decades have passed since DDT and PCBs were banned or their use peaked in the U.S. and Canada, and concentrations in the aquatic environment have since been declining. However, existing lower Okanogan River basin data are not sufficient to gauge trends over time. In the absence of previously established baselines, sediment coring is the best method to reconstruct historic contamination levels.

Due to the high laboratory costs associated with analyzing multiple sediment horizons, coring was limited to two sites: southern Osoyoos Lake and the mouth of the Okanogan River near Monse. These sites may represent the only locations in the basin with sediment deposits deep enough to reconstruct contamination levels going back several decades.

Field Procedures

Sample locations and descriptions are in Appendix C.

Each tributary stream was sampled once each during April and May to take advantage of high flows. Samples were collected as close to the creek mouths as feasible to make accurate estimates of contaminant delivery to the lower Okanogan River. Samples were collected using a hand-held bottle for water less than one foot deep or a U.S. Geological Survey (USGS) depth-integrating sampler for deeper water. The depth-integrating sampler consists of a DH-81 adapter with a D-77 cap and 1-liter jar assembled so that water contacts only Teflon or glass. Samples were collected by slowly lowering the sampler to the bottom then immediately raising the sampler at the same rate from three points (quarter-point transect) across each stream.

Mainstem Okanogan River water samples from Riverside and Malott were collected from bridges as quarter-point transects using a USGS DH-76 and 1-pint "milk bottles." The water sample at the Osoyoos Lake outlet was collected just below the dam structure on the right bank. The Similkameen water sample was a quarter-point transect collected from a boat near the mouth.

The depth-integrating samplers and jars were cleaned prior to sampling by scrubbing with Liquinox® detergent followed by sequential rinses with tap water, deionized water, pesticide-grade acetone, and spectro-grade hexane. Sample bottles, preservatives, and holding times are described in the quality assurance project plan (Serdar, 2002).

Stream flows were measured using USGS Stream Gaging Procedure (196) and a Swoffer Model 2100 TSR or a Marsh-McBirney, Inc. Model 201 flow meter. pH was measured using an Orion Model 250 temperature-compensating pH meter. Specific conductance was measured using a YSI Model 33 S-C-T meter. Temperature readings were done with both the pH and S-C-T meters. Sample location coordinates were recorded using a Magellan NAV 5000 global positioning receiver.

Sediment cores were collected using a Wildco stainless steel box corer fitted with a 14cm x 14cm x 50cm (i.d.) acrylic liner. Layers (horizons) were collected individually every 1-cm or 2-cm. Cores were dated using measured of ^{210}Pb activity in selected horizons. ^{210}Pb is created in the atmosphere from radioactive decay of ^{226}Ra and ^{222}Rn. Once deposited in sediments, it is no longer in equilibrium with its source elements and the age of deposition is estimated from its concentration, known half-life (22 years), and the ^{210}Pb concentration in deeper "background" sediments (loss of >95% of activity).

Fish were collected using a Smith-Root electrofishing boat. Weight and length measurements were collected in the field along with scale samples for subsequent age determination by Washington Department of Fish and Wildlife (WDFW). Individual fish were assigned a sample number with corresponding identification in a field log, double-wrapped in aluminum foil (dull side in), then sealed in a zip-lock bag. Samples were kept on ice until return from the field where they were frozen at –20°C at the Ecology headquarters building.

Composite fillet homogenates were prepared by scaling the fish then removing the entire fillet from the left side. Skin was removed from the carp specimens prior to filleting. The resulting sample contained the skin (except carp) and some of the belly flap and dorsal fat, consistent with EPA recommendations for assessing chemical contaminants in fish (EPA, 1995).

Three composite samples of each species (carp, mountain whitefish, and smallmouth bass) were analyzed from each of the three collection locations (Oroville, Riverside-Omak, and Monse reaches) except carp which could not be obtained from the Monse reach. Each composite sample consisted of five to ten individual fish except for smallmouth bass from the Oroville reach. Two of these specimens were analyzed individually due to the lack of available samples in the reach. Biological data on fish are in Appendix D.

Tissues were homogenized with three passes through a Kitchen-Aid® food processor. Ground tissue was thoroughly mixed following each pass through the grinder.

All equipment used for tissue preparation was thoroughly washed with Liquinox® detergent, rinsed in hot water, deionized water, pesticide-grade acetone, and finally, pesticide-grade hexane. This decontamination procedure was repeated between processing of each composite sample. Fully homogenized tissues were stored frozen (−20°C) in two 8-oz. glass jars with Teflon lid liners, certified for trace organics analysis; one container submitted for analysis and the other archived at -20 °C.

Laboratory Procedures

Analytical methods are shown in Table 8. All chemical analyses were conducted at MEL except ^{210}Pb which was performed by the Battelle Marine Sciences Laboratory in Sequim, WA.

Table 8. Analyses, reporting limits, and methods.

Analysis	Reporting Limits	Method
Water		
DDT analogs	0.06 - 1.7 ng/l	GC/ECD (mod. of EPA 8081, 8082, 3510, 3620, and 3665)
PCB (Aroclors)	0.6 ng/l	"
TOC	0.1 mg/l	combustion/NDIR (EPA 415.1)
TSS	1 mg/l	gravimetric (EPA 160.2)
Sediments/sludge		
Chlor. Pest.	0.4 - 11 ng/g[a,b]	GC/ECD (mod. of EPA 8081, 8082, 3540, 3550, 3620, 3665)
PCB (Aroclors)	2 - 5 ng/g[b]	"
TOC	0.1 µg/g	combustion/NDIR (PSEP)
^{210}Pb	ne	alpha spectroscopy
Fish Tissue		
DDT analogs	0.5 - 3 ng/g	GC/ECD (EPA 8081, 8082, 3540, 3620, 3665)
PCBs (Aroclors)	3 - 18 ng/g	"
Percent lipids	0.01%	Manchester

[a]toxaphene reporting limits were one to two orders of magnitude higher
[b]reporting limits for sludge samples were an order of magnitude higher than for bottom sediments
ne=not established

DDT and PCBs in water were extracted using one or more of EPA SW-846 Methods 3510, 3620, 3665 or modifications of these methods. Samples were extracted with methylene chloride, solvent-exchanged to hexane, and cleaned-up with Florisil to remove interferences. Analysis was done using gas chromatography (GC) with electron capture detection (ECD), EPA Methods 8081 and 8082. A large volume injection technique was used to lower practical quantitation limits by an order of magnitude in samples from the lower mainstem Okanogan River, Similkameen River, and STPs.

Bottom sediments, sludge, and tissue samples analyzed for chlorinated pesticides and PCBs were extracted with acetone using the Soxhlet extraction procedure, eluted through a Florisil column first with 100% hexane, then with a 50/50 mixture of hexane and diethyl ether. Sample extracts were analyzed using EPA 8081 and 8082 GC/ECD methods. Sludge samples had higher reporting limits due to low percent solids and interfering compounds.

Percent lipids in fish tissue were determined gravimetrically following extraction with a 50/50 mixture of hexane and methylene chloride. This method was developed at MEL.

Data Quality

Data quality for this project was generally good. Case narratives for each sample set are included in Appendix E. With few exceptions, measurement quality objectives for precision and bias met targets identified in the project plan (Serdar, 2002).

Precision as measured by relative percent difference of duplicate results was generally 10% or less (Appendix E, Table E-1). The few exceptions were possibly due to sample non-homogeneity or analyte concentrations near reporting limits. Precision of matrix spike duplicates was generally high.

Matrix spike recoveries were good for DDT and PCBs in water samples (79%-110%) and fish tissue (96%-122%). Most of the chlorinated pesticides spiked in sediment samples were recovered within the acceptable 50%-150% recovery window, although spike recoveries were low as 8% for endrin aldehyde, 31% for heptachlor, and 39% for 2,4'-DDT.

Analysis of laboratory control samples and standard reference materials generally showed results within control limits and provided further evidence of low bias for DDT compounds. Table 9 shows results of Standard Reference Materials analyzed with sediments and fish tissues.

Table 9. Results of Standard Reference Material (SRM) analysis.

Analyte	NIST SRM 1944[a] (ng/g, dry)	MEL (ng/g, dry)	NIST SRM 1974a[b] (ng/g, wet)	MEL (ng/g, wet)
4,4'-DDT	119 ± 11	**180**	0.445 ± 0.067	u(3.0)
4,4'-DDE	86 ± 12[c]	76	5.84 ± 0.63	5.8
4,4'-DDD	106 ± 18[c]	110	4.90 ± 0.72	**3.0**
2,4'-DDT	ne	3.3	0.96 ± 0.21[c]	u(1.0)
2,4'-DDE	19 ± 3[c]	21	0.599 ± 0.031[c]	u(3.8)
2,4'-DDD	38 ± 8[c]	35	1.56 ± 0.32[c]	u(1.9)
Cis-chlordane	16.51 ± 0.83	**19**	1.96 ± 0.32	na
Trans-chlordane	8 ± 2[c]	**20**	1.89 ± 0.19	na

[a]New York/New Jersey Waterway Sediment
[b]Organics in Mussel Tissue (*Mytilus edulis*)
[c]reference values (not certified)
bold values outside range of certified or reference values
ne=not established
u=undetected at practical quantitation limit in parentheses
na=not analyzed

No blank contamination was detected during tributary stream sampling. Other quality control elements such as holding times, blanks, instrument calibration, and surrogate recoveries were discussed in the MEL case narratives and all data are considered usable as qualified.

Results of 2001-2002 Sampling

Complete results of 2002-2002 sampling are in Appendix F.

DDT and PCBs in the Lower Okanogan River Mainstem Water Column

Table 10 shows results of water column sampling conducted in the lower Okanogan River during May 2002. Comparable concentrations of 4,4'-DDE and 4,4'-DDD (0.14 – 0.29 ng/l) were found at all three lower Okanogan River sites. None of the nine PCB Aroclors analyzed were detected at practical quantitation limits of 0.64 – 0.67 ng/l.

Table 10. DDT and PCB concentrations in lower Okanogan River water, May 2002.

Location	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE (ng/l)	4,4'-DDD (ng/l)	4,4'-DDT (ng/l)	t-DDT (ng/l)	PCBs[a] (ng/l)
Okanogan R. @ Zosel Dam	77.4	5/13/02	33,131	18	**0.23**	**0.29**	u(0.080)	**0.52**	u(0.66)
Okanogan R. @ Riverside	40.6	5/13/02	137,620	20	**0.22**	**0.14**	u(0.076)	**0.36**	u(0.66)
Okanogan R. @ Malott	17.0	5/14/02	146,681	26	**0.17**	**0.16**	u(0.10)	**0.33**	u(0.64)

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

These results represent the first time DDT compounds have been detected in the water column of the lower Okanogan River. Previous sampling during 1995 by Johnson et al. (1997) failed to detect DDT in the lower Okanogan River at a practical quantitation limit of 1 ng/l, therefore it is impossible to determine if the 2002 results represent a change from 1995 levels. The May 2002 concentrations probably would have gone undetected had MEL not used the large volume injection to achieve low quantitation limits (≤0.1 ng/l).

DDT in Osoyoos Lake Tributaries and Lower Okanogan River Tributaries

DDT concentrations in water collected near the mouths of Osoyoos Lake and lower Okanogan River tributaries are shown in Table 11. These represent all of the tributary streams found flowing during the April and May 2001 sampling events, except for the Similkameen River which was sampled during May 2002. In all, 18 streams were sampled and 13 were found flowing during both April and May sampling events. This is about twice the number of streams sampled during July-August 1995 even though the 2001 water year was extraordinarily dry.

Table 11. DDT concentrations in tributary streams of Osoyoos Lake and the lower Okanogan River, April-May 2001[a].

Location	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE (ng/l)	4,4'-DDD (ng/l)	4,4'-DDT (ng/l)	t-DDT (ng/l)
Nine Mile Cr.	80.2	4/17/01	99	12	**1.8**	**0.4**	**1.3**	**3.5**
"		5/16/01	32	u(1)	**1.4**	**0.6**	**1.5**	**3.5**
Tonasket Cr.	77.8	4/17/01	361	4	**1.5**	u(0.8)	**1**	**2.5**
"		5/16/01	26	9	**1.2**	u(1.7)	**1.1**	**2.3**
Similkameen R.	74.1	5/13/02	113,551	14	u(0.067)	u(0.067)	u(0.080)	nd
Mosquito Cr.	67.4	4/11/01	0.24	7	**0.8**	**0.7**	u(0.8)	**1.5**
"		5/16/01	0.5	2	**1.7**	**0.4**	**1.4**	**3.5**
Whitestone Cr.	62.4	4/11/01	114	10	**0.6**	u(0.8)	u(0.8)	**0.6**
"		5/16/01	85	5	**0.4**	u(1.6)	u(1.6)	**0.4**
Antoine Cr.	61.2	4/17/01	10	12	**5.2**	**1.1**	**1.7**	**8.0**
"		5/16/01	31	16	**1.8**	**0.5**	**1**	**3.3**
Siwash Cr.	57.3	4/16/01	24	1	**0.5**	u(0.8)	u(0.8)	**0.5**
"		5/16/01	0	--	--	--	--	--
Bonaparte Cr.	56.7	4/11/01	62	21	**0.4**	u(0.8)	u(0.8)	**0.4**
"		5/17/01	153	55	**0.4**	u(1.7)	u(1.7)	**0.4**
Aeneas Cr.	52.9	4/16/01	95	u(1)	**0.4**	u(0.8)	u(0.8)	**0.4**
"		5/17/01	78	2	**0.4**	u(1.6)	u(1.6)	**0.4**
Chewiliken Cr.	50.7	4/11/01	9	u(1)	u(0.8)	u(0.8)	u(0.8)	nd
"		5/17/01	0	--	--	--	--	--
Tunk Cr.	45.0	4/16/01	106	2	u(0.9)	u(0.9)	u(0.9)	nd
"		5/17/01	197	16	u(1.7)	u(1.7)	u(1.7)	nd
Johnson Cr.	40.6	4/16/01	79	11	u(0.8)	u(0.8)	u(0.8)	nd
"		5/17/01	29	12	u(1.7)	u(1.7)	u(1.7)	nd
Wanacut Cr.	35.0	4/12/01	29	1	u(0.8)	u(0.8)	u(0.8)	nd
"		5/17/01	14	1	u(1.7)	u(1.7)	u(1.7)	nd
Omak Cr.	32.0	4/12/01	382	5	u(0.8)	u(0.8)	u(0.8)	nd
"		5/15/01	596	35	u(1.7)	u(1.7)	u(1.7)	nd
Elgin Cr.	28.4	4/12/01	27	7	**3.7**	**0.4**	**1.8**	**5.9**
"		5/15/01	19	20	**5.8**	**0.9**	**2.5**	**9.2**
Salmon Cr.	25.7	4/17/01	284	1	**0.4**	u(0.9)	u(0.9)	**0.4**
"		5/15/01	0	--	--	--	--	--
Tallant Cr.	19.5	4/16/01	0	--	--	--	--	--
"		5/15/01	0	--	--	--	--	--
Loup Loup Cr.	16.9	4/16/01	0	--	--	--	--	--
"		5/15/01	3	u (1)	**0.7**	u(1.6)	**0.7**	**1.4**
Chiliwist Cr.	15.1	4/16/01	71	11	**0.4**	u(0.8)	u(0.8)	**0.4**
"		5/16/01	27	1	u(1.7)	u(1.7)	u(1.7)	nd

[a]Similkameen River samples May 2002
detected values in **bold**
u=undetected at practical quantitation limit in parentheses
nd=not detected

DDT was detected in water from 12 streams with t-DDT concentrations ranging from 0.4 – 9.2 ng/l. 4,4'-DDE was the primary metabolite detected, with 4,4'-DDT present at the second highest concentration, unlike lower mainstem Okanogan River samples which had no measurable 4,4'-DDT. Low concentrations of 2,4'-DDT (≤0.5 ng/l) were also detected in several creeks. Antoine Creek had 2,4'-DDD at 1.3 ng/l during April 2001 sampling.

Elgin Creek in the lower part of the basin (RM 28.4) had the highest t-DDT concentrations, followed by Antoine Creek and Nine Mile Creek which is an Osoyoos Lake tributary. This partially mirrors the 1995 study which found these streams to have some of the highest DDT concentrations and is indicative of a pattern showing streams with high DDT concentrations in the upper and lower parts of the basin (RM 61-80 and RM 15-28). Little or no DDT was found in the middle basin (RM 32-57), especially RM 32-51 where no DDT at all was detected.

Tallant Creek was not sampled in the present study because it was dry. This creek generally contains water only during late summer or early autumn due to releases from Leader Lake, its primary source. When Tallant Creek was sampled in 1995, t-DDT concentrations up to 500 ng/l were found and Tallant Creek contributed about 75% of the DDT load to the lower Okanogan River during that period.

No DDT was detected in the Similkameen River during May 2002 sampling even though the large volume injection method used for this sample provided quantitation limits an order of magnitude lower than in other tributaries. PCBs Aroclors were also analyzed in the Similkameen River water sample, but none were detected at a quantitation limit of 0.67 ng/l.

DDT and PCB Concentrations in STPs

Three municipal sewage treatment plants (STPs) were sampled for DDT and PCBs during 2001. The Omak STP and Okanogan STP discharge treated effluent directly to the Okanogan River while the Oroville STP effluent is discharged to the Similkameen River approximately four miles upstream of the formal confluence with the Okanogan River. Samples of final effluent were collected on three occasions and sludge was collected once.

Table 12 shows results of DDT and PCB analysis of STP effluent samples. Table 13 shows results of sludge samples analyzed for DDT and PCBs. DDT was detected in Oroville and Okanogan STP effluent on two occasions, with t-DDT concentrations (0.7 – 1.8 ng/l) comparable to those found in tributary streams. No evidence of PCBs were found in a scan of the April, 2001 and May 2001 samples. Samples collected during May 2002 were analyzed for PCBs only using a large volume injection method. A low concentration of PCB-1248 (0.39 ng/l) was found in Okanogan STP effluent, but no other PCBs were detected.

DDT and PCBs were detected in sludge from all three STPs, with the highest concentrations from the Oroville STP. t-PCBs were found at higher concentrations than t-DDT in sludge unlike effluent samples where DDT concentrations were higher. This may suggest that, while both DDT and PCBs are present in STPs, PCBs are more strongly sequestered in solids. The Omak STP consistently showed the lowest concentrations of DDT in both media and of PCBs in sludge, even where the TSS and TOC content – factors often correlated with higher concentrations of organochlorine compounds – was highest.

Table 12. DDT and PCB concentrations in lower Okanogan River basin STP effluent, 2001-2002.

Location	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE (ng/l)	4,4'-DDD (ng/l)	4,4'-DDT (ng/l)	t-DDT (ng/l)	PCBs[a] (ng/l)
Oroville STP	b	4/17/01	6	1	**0.5**	u(0.9)	**0.6**	**1.1**	nd*
		5/16/01	7	u(1)	u(1.7)	u(1.7)	**0.7**	**0.7**	nd*
		5/14/02	7	u(1)	na	na	na	na	u(0.63)[c]
Omak STP	29.9	4/17/01	24	2	u(0.8)	u(0.8)	u(0.8)	nd	nd*
		5/17/01	26	4	u(1.6)	u(1.6)	u(1.6)	nd	nd*
		5/13/02	26	3	na	na	na	na	u(0.66)
Okanogan STP	24.8	4/16/01	16	4	**0.7**	u(0.8)	**0.6**	**1.3**	nd*
		5/17/01	16	4	**0.4**	**0.4**	**1**	**1.8**	nd*
		5/14/02	11	5	na	na	na	na	**0.39**[d]

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
[b]Similkameen River mile 4.0
[c]Practical quantitation limit was 0.94 ng/l for PCB-1254
[d]Concentration of PCB-1248. Other Aroclors undetected at a practical quantitation limit of 0.65 ng/l
detected values in **bold**
u=undetected at practical quantitation limit in parentheses
nd=not detected
*no practical quantitation limit determined

Table 13. DDT and PCB concentrations in lower Okanogan River basin STP sludge, June 2001 (ng/g,dw).

Location	%TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	PCB-1260	PCB-1254	PCB-1248	t-PCB[a]
Oroville STP	36.7	**180**	**26**	**36**	**242**	**48**	**130**	**95**	**273**
Omak STP	40.3	**68**	u(45)	**23**	**91**	**41**	**100**	**63**	**204**
Okanogan STP	32.0	**110**	**23**	**40**	**173**	**51**	**120**	**63**	**234**

[a]Aroclors 1242, 1232, 1221, and 1016 not detected at practical quantitation limits of 43 ng/g (Oroville STP), 45 ng/g (Omak STP), and 42 ng/g (Okanogan STP)
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Three of seven PCB Aroclors analyzed in sludge were detected; PCB-1260, -1254, and -1248. These are the most common Aroclors detected in Washington's freshwater aquatic environment both statewide (e.g. Hopkins et al., 1985; Davis et al., 1995; Davis and Serdar, 1996) and at sites with known PCB sources (e.g. Ecology, 1995). As mentioned previously, PCB-1248 was the only Aroclor detected of the nine analyzed in effluent samples.

DDT and PCB Concentrations in Sediment Cores

Sediment cores were collected to reconstruct the history of DDT and PCB deposition in Osoyoos Lake and the lower Okanogan River. A relatively deep core (approximately 45 cm) was obtained at the southern end of Osoyoos Lake (Table 14). Penetration was not as deep in the core collected near the Okanogan River mouth (Table 15). Deposition of fine sediments near the mouth may not have occurred until the formation of Lake Pateros (consequently backing-up the Okanogan River near the mouth) in 1967, and therefore bottom sediments pre-dating 1967 are probably absent at this site.

Table 14. DDT and PCB concentrations in Osoyoos Lake sediment core collected June 2001 (ng/g, dw).

Depth Interval (cm)	Year deposited	%TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	PCB-1260	PCB-1254	PCB-1248	t-PCB[a]
0-1	2001.0	4.37%	**35**	**43**	**3**	**81**	u(2.8)	u(2.8)	**1.1**	**1.1**
1-2	1999.0	3.78%	**32**	**42**	**0.79**	**75**	u(5.4)	u(5.4)	u(5.4)	nd
2-3	1998.8	4.25%	**75**	**77**	**96**	**248**	u(5.4)	u(5.4)	**2.2**	**2.2**
3-4	1998.5	4.03%	**34**	**39**	**13**	**86**	u(5.3)	u(5.3)	u(5.3)	nd
4-5	1998.3	4.47%	**39**	**44**	u(5.3)	**83**	u(2.6)	**0.79**	u(2.6)	**0.79**
6-7	1996.5	4.23%	**37**	**20**	**1**	**58**	u(2.5)	**0.74**	u(2.5)	**0.74**
8-9	1993.5	4.05%	**37**	**38**	**13**	**88**	u(2.3)	u(2.3)	**1.2**	**1.2**
10-11	1991	3.93%	**38**	**43**	**4**	**85**	u(2.2)	u(2.2)	**1.1**	**1.1**
13-14	1988	3.99%	**35**	**45**	**4.8**	**85**	u(2.0)	u(2.0)	**1.0**	**1.0**
16-17	1985	3.72%	**39**	**47**	**1.8**	**88**	u(1.9)	**0.75**	u(1.9)	**0.75**
19-20	1981	3.60%	**36**	**54**	**6.4**	**96**	u(1.7)	u(1.7)	**0.85**	**0.85**
23-24	1976	3.04%	**92**	**150**	**12**	**254**	u(3.3)	**2.7**	**2.0**	**4.7**
27-28	1967	2.43%	**42**	**92**	**1.6**	**136**	u(2.9)	**1.4**	u(2.9)	**1.4**
31-32	1957	2.12%	**21**	**48**	**3.5**	**72**	u(2.7)	u(2.7)	u(2.7)	nd
35-36	1945	1.93%	**3.7**	**8.6**	u(0.61)	**12**	u(2.5)	u(2.5)	u(2.5)	nd
39-40	1932	1.76%	**2.2**	**5.1**	u(0.56)	**7.3**	u(2.2)	u(2.2)	u(2.2)	nd
44-45	1917	1.76%	u(0.55)	**0.22**	u(0.55)	**0.22**	u(2.2)	u(2.2)	u(2.2)	nd

[a]Aroclors 1242, 1232, 1221, and 1016 not detected at practical quantitation limits of 1.7 – 5.4 ng/g
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table 15. DDT and PCB concentrations in lower Okanogan River sediment core collected September 2001 (ng/g, dw).

Depth Interval (cm)	Year deposited	%TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	PCB-1260	PCB-1254	PCB-1248	t-PCB[a]
0-2	2001	1.95%	**6.9**	**1.9**	u(0.63)	**8.8**	u(2.5)	**0.89**	u(2.5)	**0.89**
6-8	1998	1.72%	**7.1**	**2.2**	u(0.53)	**9.3**	u(2.1)	**0.74**	u(2.1)	**0.74**
12-14	1995	1.62%	**7.5**	**2.6**	u(0.49)	**10**	u(2.0)	**1.1**	u(2.0)	**1.1**
18-20	1992	1.48%	**6.8**	**2.5**	u(0.45)	**9.3**	u(1.8)	**0.88**	u(1.8)	**0.88**
24-26	1988	1.40%	**8.0**	**3.0**	u(0.44)	**11**	u(1.8)	**1.1**	u(1.8)	**1.1**
28-30	1984	1.41%	**9.9**	**4.4**	**0.65**	**15**	**0.44**	**1.5**	u(1.7)	**1.94**
30-32	1981	1.44%	**14**	**8.0**	**1.1**	**23**	**0.74**	**2.1**	u(1.7)	**2.84**

[a]Aroclors 1242, 1232, 1221, and 1016 not detected at practical quantitation limits of 1.7 – 2.5 ng/g
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Sediments in the core from Osoyoos Lake dated from 1917 whereas the oldest horizons from the river mouth were deposited circa 1981, although the lack of background ^{210}Pb from the mouth leaves some doubt about the accuracy of age estimates at this site. Sedimentation rates appear to be about three times higher near the mouth (1.6 cm/yr) compared to southern Osoyoos Lake (0.5 cm/yr).

DDT concentrations in the Osoyoos Lake core were an order of magnitude higher than sediments of approximately equal age from the Okanogan River mouth. Differences between these locations are probably due to dilution by relatively clean sediments from the Similkameen River which supplies the vast majority of sediments to the lower Okanogan River (Ehinger, 1994). Evidence indicating the Similkameen River provides a diluting influence comes from data showing low (≤2 ng/g) to undetectable DDT concentrations and other chlorinated organics in Similkameen River bottom sediments (D. Hurst, written communication; Johnson and Plotnikoff, 2000). Similkameen River sediments have also been shown to contain very little organic carbon content which probably accounts for the lower TOC in sediments from the Okanogan River mouth.

The reconstructed history of DDT contamination in Osoyoos Lake shows initial DDT concentrations barely detectable or very low from 1917 until 1945 (Figure 4), where its presence may be due to limited mixing by burrowing organisms. DDT concentrations rose sharply after 1945, peaked around 1976, then declined sharply between 1976 and 1981. DDT concentrations show little change during the subsequent two decades.

A large spike in DDT concentrations was seen in sediments deposited around late 1998 or early 1999. Concentrations of t-DDT (250 ng/g) were triple those seen during the 1980s and 1990s (60-100 ng/g). This sample had a remarkably high concentration of 4,4'-DDT relative to 4,4'-DDE and 4,4'-DDD, constituting 39% of t-DDT. Other horizons had 4'4-DDT making up a maximum of 15% t-DDT, but was generally 5% or less. The high proportion of 4,4'-DDT coupled with the anomalous concentration suggests the occurrence of a large disturbance and subsequent input of agricultural soils where DDT is degraded at a much slower rate than in the aquatic environment (Harris et al., 2000). The presence of high levels of undegraded DDT could possible have resulted from a spill or dumping during the late 1990s.

DDT concentrations at the Okanogan River mouth show a decreasing trend in the 1980s followed by steady concentrations during the last decade (Figure 5). The decline in DDT concentrations during the 1980s is most likely the tail end of a longer and steeper decline, but the limited core depth only permitted analysis back to 1981. The late 1990s spike seen in Osoyoos Lake DDT concentrations did not appear in the sediment core from the mouth. It is possible that it could have been missed if this spike was a singularly discreet episode. Alternatively, it may take several years for a contaminant pulse to travel from Osoyoos Lake sediments to the mouth of the Okanogan River.

PCB concentrations in core samples were low, with concentrations generally around 1 ng/g t-PCB (Figures 4 and 5). The pattern of PCB concentrations in both cores appeared to mirror DDT concentrations, including a late 1990s spike in the Osoyoos Lake core. The peak PCB concentration was found in the 1976 horizon in Osoyoos Lake sediments followed by a sharp decline 5 years later. No PCBs were detected in sediments deposited in 1957 or earlier.

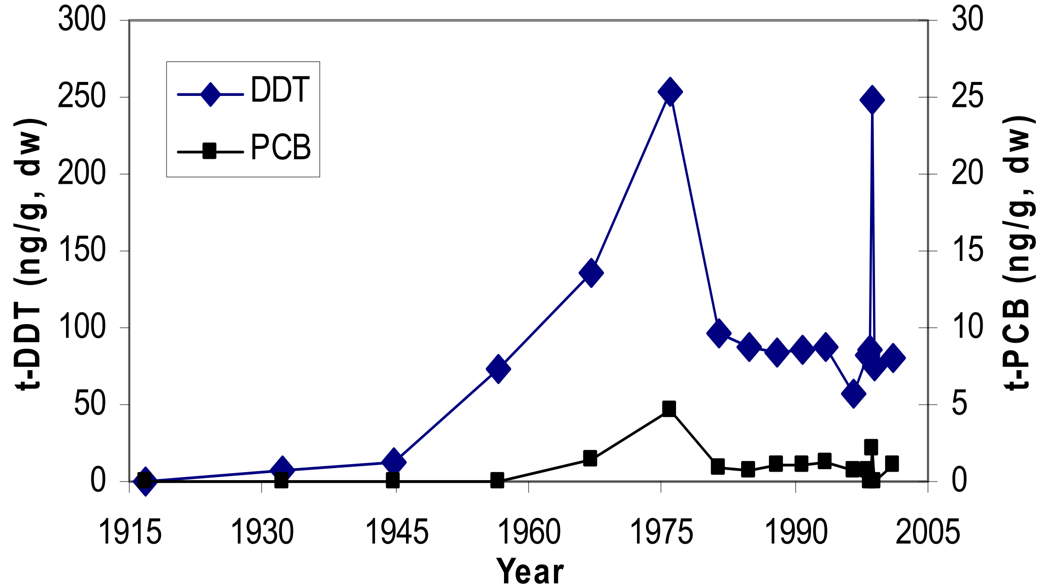

Figure 4. T-DDT and t-PCB concentrations in Osoyoos Lake sediment core

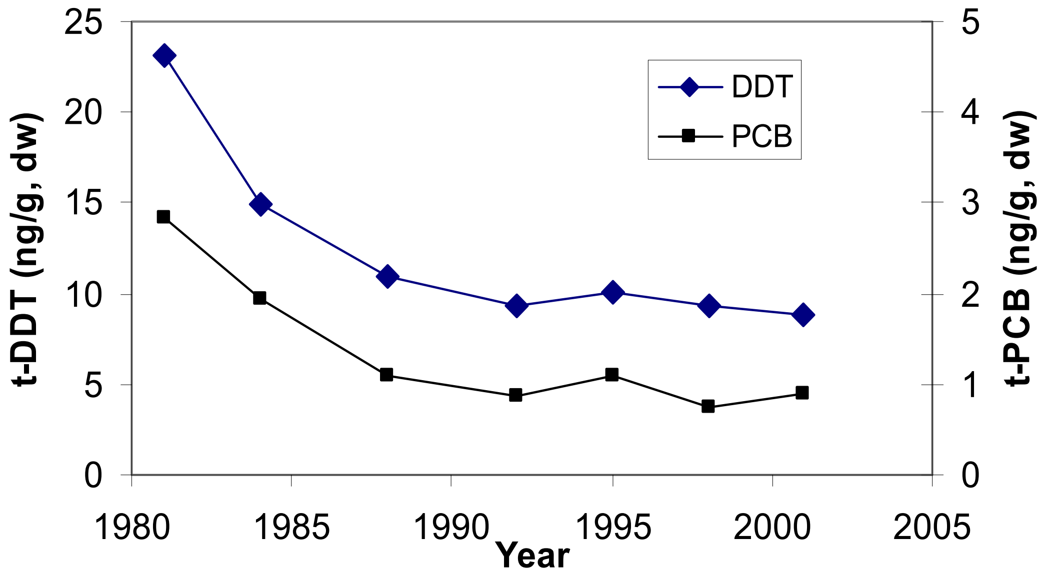

Figure 5. T-DDT and t-PCB concentrations in lower Okanogan River sediment core

Unlike DDT concentrations which were much higher in Osoyoos Lake sediments, PCB concentrations were similar in core samples from both locations. This may suggest that low-level PCB sources such as STPs between the lake and the river mouth keep depositional areas enriched with low levels of PCBs.

DDT and PCB Concentrations in Fish Tissue

Carp, mountain whitefish, and smallmouth bass were collected from three locations on the lower Okanogan River during 2001, except for carp which were not found at the Monse location. Samples at each location were sorted by size to assess this as a factor affecting contaminant accumulation. Samples were analyzed for DDT, PCBs, and lipid content in fillet. Table 16 shows the results.

Concentrations of t-DDT ranged from 30 to 600 ng/g, while t-PCB concentrations were much lower, ranging from 2 ng/g or less to 40 ng/g. Mountain whitefish and carp generally had much higher DDT and PCB concentrations than smallmouth bass.

4,4'-DDE was the primary DDT component, exceeding the NTR criterion of 32 ng/g in all samples except smallmouth bass from the Riverside-Omak location. 4,4'-DDD concentrations were much lower with only one sample – Riverside-Omak carp – exceeding the NTR criterion of 45 ng/g. None of the samples exceeded the 4,4'-DDT criterion.

PCB-1254 made up the highest proportion of t-PCB in most samples, followed by PCB-1260 and PCB-1248. PCB-1242 was not detected aside from a low concentration (4.0 ng/g) in one Riverside-Omak carp sample. All carp and mountain whitefish met or exceeded the NTR criterion for PCBs (5.3 ng/g). In contrast, only one of the nine smallmouth bass samples had t-PCB greater than the criterion.

Lipid content, size, and location all appear to be factors in DDT and PCB concentrations within each species. Figures 6 and 7 show lipid-normalized t-DDT and t-PCB concentrations grouped by species for each location. Carp and mountain whitefish collected at the Oroville location clearly had higher lipid-normalized t-DDT concentrations than from other sites. Smallmouth bass from Monse had lipid-normalized t-DDT concentrations slightly higher than those collected from the Oroville and Riverside-Omak locations.

Lipid-normalized t-PCB concentrations generally followed the same location pattern as with lipid-normalized t-DDT; the highest concentrations were at Oroville, followed in decreasing order by Riverside Omak and Monse. However, carp from Oroville and Riverside-Omak had similar concentrations, and the lipid-normalized t-PCB concentrations in the large-sized smallmouth bass from Monse were much higher than those from other locations.

In nearly all cases, the largest fish composites (greatest mean total length) had the highest t-DDT and t-PCB concentrations for each species at each site. This was generally the case in lipid-normalized concentrations as well. It should be noted that species were not sampled by size class in order to compare locations according to size. For instance, carp size classes are not

Table 16. DDT and PCB concentrations in fillet of fish from the lower Okanogan River, 2001 (ng/g, ww)

Sample No. (02-)	Species	Location	n per comp.	mean length (mm)	mean weight (g)	mean age (yr)	Lipid (%)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	PCB-1248	PCB-1254	PCB-1260	t-PCB[a]
128230	CARP	Oroville	8	552±25	2,135±432	nc	1.04	**290**	**37**	u(1.6)	**327**	**2.7**	**5.1**	**4.7**	**13**
128231	"	"	8	514±7	1,749±93	nc	0.84	**410**	**24**	u(1.5)	**434**	**1.7**	**3.9**	**3.1**	**9**
128232	"	"	7	463±37	1,348±354	nc	1.55	**210**	**38**	**0.6**	**249**	**3.6**	**4.2**	**2.2**	**10**
128233	"	Riv. - Omak	8	619±20	3,345±385	nc	3.43	**270**	**41**	u(1.5)	**311**	**6.8**	**9.2**	**10**	**26**
128234/35	"	"	8	584±12	2,740±481	nc	3.00	**220**	**29**	u(1.6)	**249**	**13**	**10**	**13**	**36**
128236	"	"	8	550±13	2,393±320	nc	3.09	**210**	**26**	u(1.6)	**236**	u(18)	**9.9**	**8.4**	**22**[b]
128237	MTWF	Oroville	8	363±21	315±76	5	0.79	**460**	**38**	**17**	**515**	**3.0**	**12**	**8.7**	**24**
128238	"	"	8	330±7	229±54	4	1.31	**330**	**21**	**9.8**	**361**	**2.9**	**9.8**	**7.3**	**20**
128245	"	"	8	290±14	167±21	2	1.17	**150**	**19**	**5.1**	**174**	**2.4**	**6.1**	**3.2**	**12**
128239/40	"	Riv. - Omak	10	365±19	453±87	6	4.26	**520**	**62**	**17**	**599**	**5.2**	**19**	**18**	**42**
128241	"	"	10	334±13	331±69	5	4.70	**330**	**39**	**13**	**382**	**3.0**	**10**	**7.3**	**20**
128249	"	"	10	284±20	209±48	3	4.58	**160**	**19**	**6.0**	**185**	**5.0**	**18**	**7.0**	**30**
128242	"	Monse	9	326±48	301±134	4	2.96	**110**	**14**	**3.2**	**127**	**3.5**	**9.8**	**6.2**	**20**
128243	"	"	9	246±7	127±18	2	3.07	**120**	**16**	**3.7**	**140**	**2.5**	**6.4**	**2.3**	**11**
128244	"	"	8	220±15	81±14	2	1.55	**73**	**4.9**	**2.8**	**81**	u(2.8)	**2.9**	**2.1**	**5**
128246	SMBS	Oroville	1	424	1,111	5	3.21	**230**	**44**	**14**	**288**	**3.9**	**8.1**	**2.6**	**15**
128247	"	"	4	316±28	472±138	nc	1.39	**64**	**11**	**2.3**	**77**	u(2.7)	**2.4**	u(2.7)	**2**
128248	"	"	1	248	206	1	1.60	**100**	**3.5**	**0.8**	**104**	u(2.8)	**2.2**	u(2.8)	**2**
128250	"	Riv. - Omak	7	350±56	685±377	4	1.17	**78**	**6.5**	**3.1**	**88**	u(2.7)	**2.7**	u(2.7)	**3**
128251	"	"	7	287±11	320±47	3	1.42	**55**	**2.9**	**1.6**	**60**	**5.6**	**2.1**	u(2.7)	**8**
128252	"	"	7	213±28	133±50	1	0.95	**25**	**1.7**	**0.8**	**28**	u(2.8)	u(2.8)	u(2.8)	nd
128253	"	Monse	5	327±12	496±41	3	1.35	**150**	**14**	**3.0**	**167**	**2.9**	**9.5**	**1.9**	**14**
128254	"	"	5	276±32	276±98	3	1.12	**89**	**11**	**1.6**	**102**	u(2.7)	**2.2**	u(2.7)	**2**
128255	"	"	5	200±10	98±18	1	0.70	**59**	**3.4**	**0.8**	**63**	u(2.8)	u(2.8)	u(2.8)	nd

[a]Aroclors 1268, 1262, 1242, 1232, 1221, and 1016 not detected at practical quantitation limits of 2.7 – 5.4 ng/g
[b]Includes 4.0 ng/g PCB-1242
MTWF=mountain whitefish
SMBS=smallmouth bass
nc=not calculated
detected values in **bold**
u=undetected at practical quantitation limit in parentheses
nd=not detected

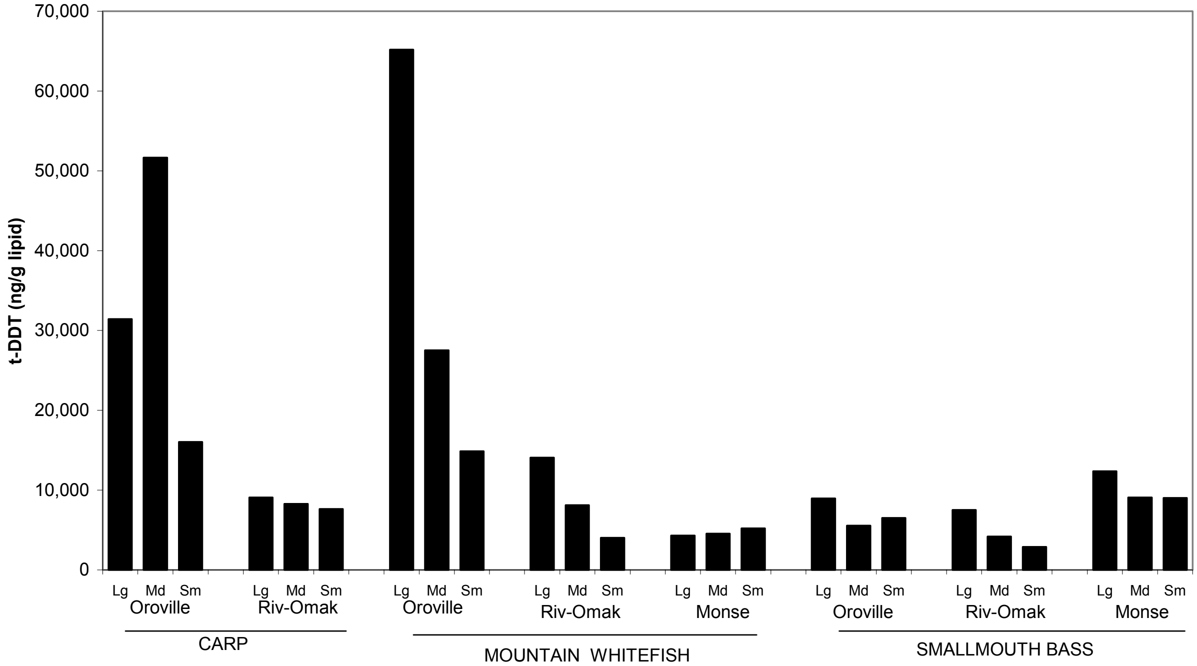

Figure 6. Lipid-normalized t-DDT concentrations in lower Okanogan River fish muscle ordered by mean length of fish in each composite (Lg=large, Md=medium, Sm=small) and location for each species.

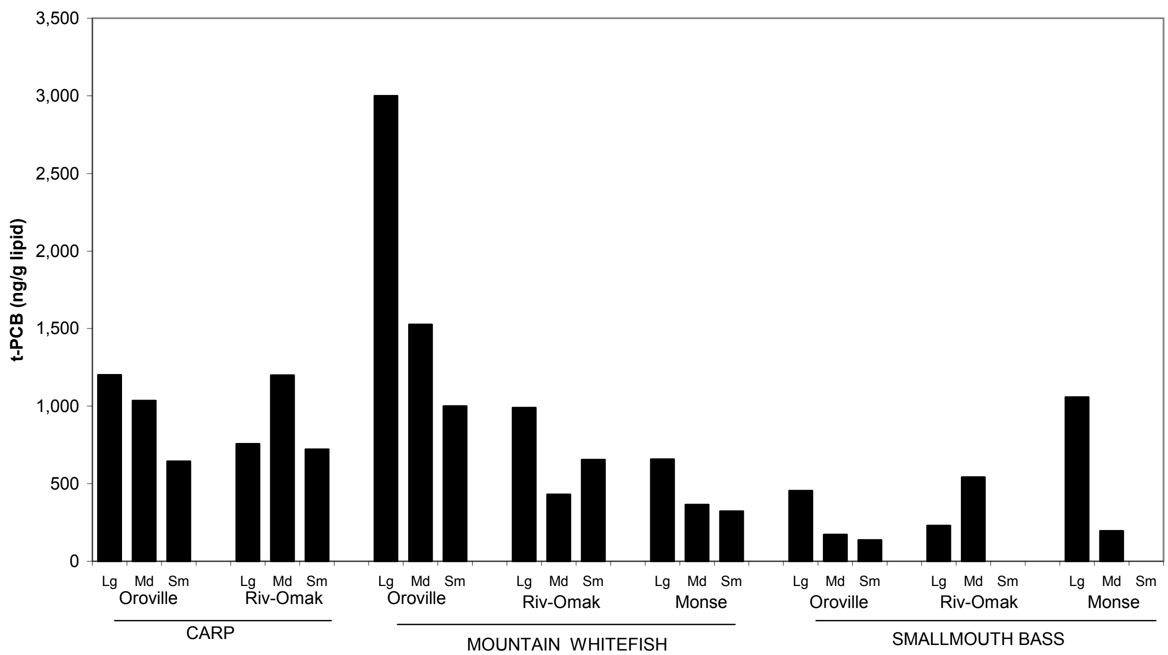

Figure 7. Lipid-normalized t-PCB concentrations in lower Okanogan River fish muscle ordered by mean length of fish in each composite (Lg=large, Md=medium, Sm=small) and location for each species.

necessarily a valid comparison between Oroville and Riverside-Omak, since all composites from Riverside-Omak had a larger or nearly equal average size than those from Omak. Grouping by size was done to assess the relationship with contaminant concentrations within each location.

TMDL Analysis

The following sections contain a TMDL analysis of DDT and PCBs in the lower Okanogan River basin using the data collected during 2001-2002, or in some cases historical data (Appendix F) to describe or quantify DDT and PCB loading to the lower Okanogan River and Osoyoos Lake.

Daily DDT and PCB Loads to the Lower Okanogan River and Osoyoos Lake

DDT Loads Delivered Through Tributary Streams

Loads were calculated using the following equation:

$Load\ (mg/day) = C_w \times (10^{-6}\ mg/ng) \times Q \times (86{,}400\ s/day)$

Where:

- C_w (concentration in water) = concentration of DDT or PCBs in water (ng/l)
- Q (discharge) = instantaneous flow, unless stated otherwise (l/s)

DDT loads in tributaries were measured during a total of four rounds of sampling conducted during 1995 and 2001 (Table 17). As mentioned previously, sampling during 1995 represented low-flow conditions, with many stream channels dry and others (e.g. Tallant Creek) flowing due only to release of stored irrigation water (T. Neslen, OCCD, personal communication). To account for the intermittent flow (and resultant loading) in some streams, weighted mean loads were calculated for each stream by multiplying the mean loads by the percentage of times the stream was found flowing during sampling visits. The following formula describes calculation of the weighted mean load for each tributary:

Weighted Mean Load = (sum of n loads/n) x (n/number of sample attempts)

The t-DDT load from all tributaries combined average 205 mg/day, with 4,4'-DDE and 4,4'-DDT comprising the bulk (93%) of the t-DDT load. Most of the DDT load delivered to the lower Okanogan River through tributary streams is from Tallant Creek (61% of t-DDT), even though this stream was found to be flowing during only two of four attempts to sample it. Flow in Tallant Creek is limited to a few months per year when water is released from Leader Lake for irrigation. Therefore, DDT loads from Tallant Creek are probably best described as comparatively large, episodic, and difficult to accurately quantify without intensive investigation.

Table 17. Weighted mean DDT loads in tributary streams of Osoyoos Lake and the lower Okanogan River based on water column samples collected 1995-2002 (mg/day).

Location	RM	Samples/ Attempts	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT
Okanogan R. @ Osoyoos, B.C.	91.2	1/1	0.0	0.0	0.0	0.0
Haynes Cr. (BC)	82.8	1/1	1.3	0.0	0.0	1.3
Nine Mile Cr.	80.2	4/4	6.6	2.1	4.9	13.6
Tonasket Cr.	77.8	2/4	12.4	0.0	8.4	20.8
Similkameen R.	74.1	2/2	0.0	0.0	0.0	0.0
Mosquito Cr.	67.4	3/4	1.0	1.0	0.0	2.0
Whitestone Cr.	62.4	4/4	6.7	0.0	0.0	6.7
Antoine Cr.	61.2	4/4	4.8	0.6	1.0	6.4
Siwash Cr.	57.3	1/4	0.3	0.0	0.0	0.3
Bonaparte Cr.	56.7	3/4	1.9	0.0	0.0	1.9
Aeneas Cr.	52.9	3/4	1.5	0.0	0.0	1.5
Chewiliken Cr.	50.7	1/2	0.0	0.0	0.0	0.0
Tunk Cr.	45.0	2/4	0.0	0.0	0.0	0.0
Johnson Cr.	40.6	2/4	0.0	0.0	0.0	0.0
Wanacut Cr.	35.0	2/4	0.0	0.0	0.0	0.0
Omak Cr.	32.0	3/4	0.0	0.0	0.0	0.0
Elgin Cr.	28.4	4/4	14.4	0.6	7.1	22.0
Salmon Cr.	25.7	1/4	2.5	0.0	0.0	2.5
Tallant Cr.	19.5	2/4	46.6	10.5	68.6	125.7
Loup Loup Cr.	16.9	2/4	trace	0.0	trace	0.1
Chiliwist Cr.	15.1	2/4	0.6	0.0	0.0	0.6
		Total =	**100.4**	**14.7**	**90.1**	**205.2**

trace = <0.05 mg/day

Nine Mile, Tonasket, and Elgin creeks together account for a large remainder of the DDT loads from tributaries (27% of t-DDT). Nine Mile and Elgin creeks were among the four streams to have measurable DDT loads during all 1995 and 2001 sampling events. Whitestone and Antoine creeks also had measurable DDT loads during all rounds of sampling.

Mean DDT loads were higher during 1995 compared to 2001 (307 mg t-DDT /day vs. 104 mg t-DDT/day, respectively) due primarily to the Tallant Creek samples collected during 1995. However, mean loads were similar between years when the contribution from Tallant Creek is removed (55 mg t-DDT /day in 1995; 104 mg t-DDT/day in 2001).

Notable is the absence of any DDT load from the Similkameen River, which has the potential to deliver large loads due to its high flow. For instance, had 4,4'-DDE been detected at the very low practical quantitation limit (0.07 ng/l) during 2002 sampling, the resulting daily load (660 mg/day) would have been an order of magnitude higher than the average daily loads of all other tributaries combined during 2001.

DDT and PCB Loads Delivered Through STPs

Daily DDT and PCB loads from the Oroville, Omak, and Okanogan STPs are shown in Table 18. Loads were calculated from effluent sampling conducted during April and May 2001, and in May 2002.

Table 18. Mean DDT and PCB loads in lower Okanogan River basin STPs based on whole effluent samples (DDT) and PCB concentrations in STP sludge collected 2001-2002 (mg/day).

Location	RM	n	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB[a]
Oroville STP	b	3	0.1	0.0	0.4	0.5	0.1
Omak STP	29.9	3	0.0	0.0	0.0	0.0	1.3
Okanogan STP	24.8	3	0.8	0.3	1.1	2.2	1.3

[a]Results shown are for PCB Aroclors 1260, 1254, 1248, 1242, 1232, 1221, and 1016
[b]Similkameen River mile 4.0. The Similkameen River enters at Okanogan River mile 74.1

Daily loads of DDT and PCBs were low at all three STPs sampled. Oroville and Okanogan STPs had daily DDT loads similar to the lowest measured loads in tributary streams. Daily loads in effluent were 2.7 mg t-DDT/day and 0.4 mg t-PCB/day from all three STPs combined.

As shown previously, PCBs were present at substantial concentrations in sludge from all three treatment plants (200-270 ng/g t-PCB, dw). Since PCBs were difficult to detect in water, estimates can be made of PCBs discharged from STPs in the form of suspended particulate matter in effluent. Assuming the suspended solids in effluent are composed primarily of sludge, the estimated t-PCB load from STPs combined is approximately 2.7 mg/day using the following formula:

$$mg\ PCB/day = mg\ PCB/kg\ sludge \times (mg\ sludge/l\ effluent \times [kg/10^6\ mg]) \times l\ effluent/day$$

Using sludge concentrations to estimate DDT loads yields an average combined t-DDT load of 1.7 mg/day, similar to the combined load measured from whole effluent samples (2.7 mg t-DDT/day).

Calculation of DDT and PCB Loads and Assimilative Capacities of Osoyoos Lake and the Lower Okanogan River

Loads measured and delivered to the lower mainstem Okanogan River, theoretical loads based on tissue concentrations, and the lower Okanogan River's capacity to assimilate DDT and PCBs are presented in this section and Table 19. The derivation of loads and assimilative capacities used for the lower Okanogan River TMDL basin assessment is illustrated in Figure 8.

Delivered loads are the weighted mean loads from tributary streams and STPs (Tables 17 and 18) and combined for each Okanogan River reach.

Table 19. Total load delivery, measured loads, theoretical loads, and assimilative capacities of DDT and PCBs at several Osoyoos Lake and lower Okanogan River reaches (mg/day).

Reach	RM	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB
Osoyoos Lake						
Total load delivered to reach (tribs.)	91.2 – 80.2	8	2	5	15	0
Theoretical Load	82.5 – 79.0	17,000	10,000	770	25,000	0
Assimilative cap. @ Osoy. Lk. outlet	79.0	800	1,100	800	1,400	230
Oroville						
Total load delivered to reach (tribs.)	77.8	12	0	8	21	0
Cumulative load	77.8	12	0	8	21	0
Measured load @ Oroville	77.4	660	830	0	1,500	0
Theoretical load	77.3 – 76.4	7,800	650	280	8,700	820[a]
Assimilative capacity @ Oroville	77.4	800	1,100	800	1,400	230
Near Tonasket						
Total load delivered to reach (tribs. and STPs)	74.1 – 52.9	16	2	1	19	trace[b]
Cumulative load	77.4 – 52.9	680	830	1	1,500	trace[b]
Measured load @ Riverside	40.6	2,600	1,700	0	4,300	0
Theoretical load	41.0 – 30.7	41,000	4,900	1,500	45,000	6,500[a]
Assimilative capacity nr. Tonasket	50.7	3,900	5,500	3,900	6,500	1,100
Malott						
Total load delivered to reach (tribs. and STPs)	50.7 – 19.5	64	11	77	152	3[b]
Cumulative load	50.7 – 19.5	2,700	1,700	77	4,500	3[b]
Measured load @ Malott	17.0	2,200	2,000	0	4,200	0
Theoretical load	10.5-4.9	13,000	1,500	400	13,000	2,600[a]
Assimilative capacity @ Malott	17.0	4,000	5,600	4,000	6,700	1,100
Mouth						
Total load delivered to reach (tribs.)	16.9 – 15.1	1	0	0	1	0
Cumulative load	17.0 – 15.1	2,200	2,000	0	4,200	0
Theoretical load	10.5-4.9	13,000	1,500	400	13,000	2,600[a]
Assimilative cap. @ Okan. R. mouth	0.0	4,000	5,600	4,000	6,700	1,100

trace = <0.5 mg/day

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016

[b]Results shown are for PCB Aroclors 1260, 1254, 1248, 1242, 1232, 1221, and 1016

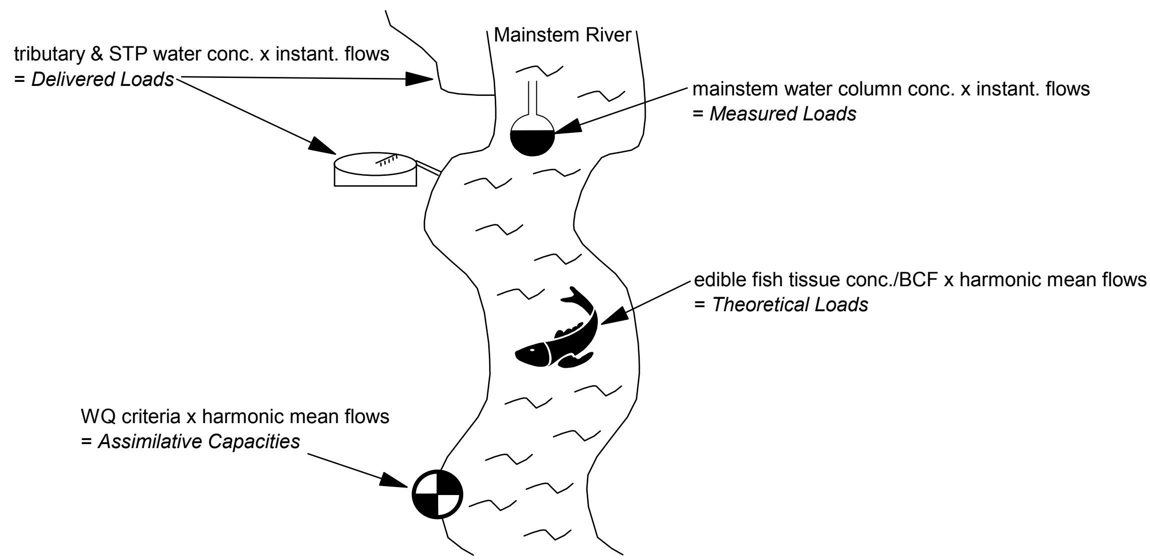

Figure 8. Schematic illustration showing derivation of loads and assimilative capacities used for TMDL assessment

Measured loads in the lower mainstem Okanogan River were calculated from DDT and PCB concentrations analyzed during May 2002 (Table 10) and daily flows recorded at USGS gaging stations at Oroville, near Tonasket, and at Malott.

Theoretical loads were determined using DDT and PCB concentrations in fish tissue back-calculated to water concentrations using BCFs for each chemical. The most contaminated species from each reach was used to calculate theoretical loads (mountain whitefish for lower Okanogan River reaches [Table 16], lake whitefish for Osoyoos Lake [Appendix F]).

Assimilative capacities were calculated using NTR human health criteria and Ch. 173-201A WAC chronic aquatic life criteria (Table 6). Flows used to calculate assimilative capacities were harmonic means recorded at USGS gaging stations (Table 2).

DDT loads delivered through tributaries and STPs were generally one to three orders of magnitude below the measured loads, theoretical loads, and the assimilative capacities of each reach indicating that exogenous DDT input accounts for only a minor amount of the load in the lower mainstem Okanogan River and Osoyoos Lake.

Since no PCBs were detected in lower Okanogan River water, it is not feasible to compare delivered loads to measured loads. Like DDT, however, delivered PCBs appear to be orders of magnitude below theoretical loads and assimilative capacities in all reaches except Osoyoos Lake where PCBs were undetectable in edible fish tissue.

PCBs loads consisted of a trace amount (0.1 mg t-PCB/day) from the Oroville STP, representing about 0.01% of the assimilative capacity of the Okanogan River near Tonasket based on the state criterion. The combined t-PCB loads from the Omak and Okanogan STPs (2.6 mg t-PCB/day) was about 0.3% of the assimilative capacity of the Okanogan River at Malott.

Using Washington State and NTR DDT criterion, the measured loads in the lower Okanogan River did not exceed assimilative capacities except for t-DDT in the Oroville reach where it was 15% above the assimilative capacity. Measured loads of 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were below the assimilative capacities at Oroville when the NTR criteria were used to calculate the assimilative capacities of these compounds.

Although measured loads of DDT shown in Table 19 represent the only instance when accurate, instantaneous load assessments have been available for the lower mainstem Okanogan River, these loads may actually overestimate annual average DDT loads in the water column. Measured loads were calculated during high-flow conditions in May when TSS concentrations are typically at or near their annual peak, suggesting that DDT (which sorbs to particulate matter) may also be at its highest concentration. A potentially more accurate measurement of average annual loads could be obtained from tissues in fish, which integrate concentrations over time and space.

Theoretical loads of DDT and PCBs were much higher than measured loads in all reaches of the lower Okanogan River, with the exception of 4,4'-DDD at Oroville where the theoretical and measured loads were similar. The comparatively high theoretical loads (derived from tissue concentrations) indicate that the relationship with measured loads (derived from water column concentrations) is inconsistent with the BCFs used to link tissue and water concentrations. The BCFs for both DDT and PCBs appear to overestimate the theoretical water concentrations that should lead to certain concentrations in tissue.

Source Assessment

Historical DDT use in the Okanogan Basin, primarily on orchard and other agricultural lands, has resulted in contamination of the aquatic environment. Although banned in the U.S. as a pesticide in 1972, DDT and its breakdown products have persisted, accumulating at high concentrations in lower Okanogan River and Osoyoos Lake fish as shown in this and other investigations (e.g. Johnson and Norton, 1990; Davis and Serdar, 1996; Serdar et al., 1998).

PCBs are a ubiquitous environmental contaminant and, like DDT, they have persisted in the aquatic environment and continue to accumulate in fish tissue even though production of PCBs was banned 25 years ago. However, due to the difficulty in detecting PCBs in the water column, little effort has been made to track down the source(s) of PCBs in the lower Okanogan River system.

It is notable that while PCBs in edible fish tissues may be a human health concern at the levels reported here (2 – 42 ng/g), it is not uncommon to find similar levels in other Washington waters where no discernible sources of PCB exist (Davis and Johnson, 1994; Davis et al., 1998). Conversely, waterbodies with known point sources of PCBs such as the Spokane River have

PCB concentrations in fish one to two orders of magnitude higher than those found in the lower Okanogan River (Ecology, 1995).

The source of DDT delivered to tributaries has not been examined. Presumably, DDT bound to agricultural soils makes its way to streams directly or through rivulets formed during rainstorms, snowmelt, or irrigation. Due to the low solubility of DDT compounds in water, the mechanism of delivery probably involves particle transport rather than leaching and dissolution of DDT.

Transport of agricultural soil particles to streams depends on a variety of factors. Within streams, increasing flows result in higher TSS concentrations. For streams where DDT was detected during all four rounds of sampling, flows were a major positive determinant of TSS concentrations in Ninemile Creek ($r^2 = 0.89$), Antoine Creek ($r^2 = 0.89$) and Elgin Creek ($r^2 = 0.94$) but less so in Whitestone Creek ($r^2 = 0.27$). However, higher concentrations of DDT compounds were not a function of higher TSS concentrations, and in some cases (Ninemile and Elgin) showed a negative relationship with TSS. Only Whitestone Creek showed DDT concentrations highly dependent on TSS (t-DDT; $r^2 = 0.97$).

Differences in TSS levels among tributaries account for about 25-40% of the variation in concentrations and loads of DDT based on an analysis of pooled tributary data. However, the regression used to explain this relationship is leveraged largely by data from Tallant Creek with high TSS (122 mg/l) and exceptionally high DDT (0.5 µg t-DDT/l). Absent the Tallant Creek data, TSS does little to explain DDT concentrations.

The lack of a strong functional relationship between TSS and DDT concentrations suggests suspended solids in the water columns of tributaries are largely composed of particles other than contaminated soils. In general, orchards and other agricultural lands in the lower Okanogan River basin are on shallow slopes, soils are well-drained, grass is maintained as ground cover in orchards, and irrigation is sprinkler or drip rather than rill and furrow. These conditions do not lend themselves to substantial erosion of agricultural soils as occurs, for instance, in the lower Yakima River basin where TSS and DDT are highly correlated in tributaries (Johnson et al., 1988; Joy and Patterson, 1997).

During the initial investigation of DDT in Okanogan basin streams, GIS covers were used to overlay DDT concentrations on the amount of steep slopes and percentage of orchard lands in each tributary basin. Although this was conducted only on a cursory basis, these factors appeared to correlate poorly with DDT concentrations in streams (A. Johnson, Ecology, personal communication).

In urban areas, STPs may serve as a funnel for waterborne contaminants. The wastewater system could potentially deliver contaminants such as DDT that were used historically for non-agricultural purposes such as mosquito control and carried off soil via stormwater to STPs. DDT and PCBs also could potentially end up in STPs as a result of improper storage and disposal.

Other possible DDT and PCB sources and delivery mechanisms that were not revealed by sampling may include groundwater, deposition of airborne material, illegal dumping, and erosion of contaminated bank material. It is also possible that the streams sampled deliver large DDT and PCB loads that were not captured during sampling, and therefore tributary sampling conducted during 1995 and 2001 was not representative. Another possibility is that small near-bank drainages went unnoticed during tributary sampling.

These sources and delivery mechanisms probably contribute unaccounted quantities of DDT and PCBs to some extent. However, if the continual delivery of significant DDT quantities to the lower Okanogan River and Osoyoos Lake through one or more of these mechanisms results in water column concentrations comparable to fish tissue concentrations (using a BCF conversion), then the water column concentrations should be present at higher concentrations.

In consideration of the factors previously mentioned, it is unlikely that significant exogenous sources of DDT and PCBs have gone unaccounted. There are essentially two scenarios to explain DDT and PCB accumulation in fish tissues.

The first explanation is that the BCF used to calculate the NTR water criteria for DDT and PCBs are inaccurate. These BCFs (53,600 for DDT and 31,200 for PCBs) were derived specifically for criteria development, not for site-specific assessment. It is possible that at least some species in the lower Okanogan River concentrate DDT and PCBs by factors one to two orders of magnitude higher than the criteria BCF.

A higher BCF for DDT in fish makes it possible to explain high tissue concentrations relative to water. For the present DDT listings in the lower Okanogan River and Osoyoos Lake, BCFs ranging from 66,000 to 2,800,000 would explain reported tissue concentrations at DDT concentrations in water. These BCFs are not unreasonable considering EPA cites seven examples of field-measured BCFs for DDT in freshwater fish (whole body) greater than one million (Ambient Water Quality Criteria for DDT; EPA, 1980a). BCFs are generally lower for muscle than whole body, but EPA (1980a) lists BCFs of 460,000 and 370,000 for lake trout (*Salvelinus namaycush*) and cisco (*Coregonus* sp.) muscle, respectively. EPA reports a narrower range freshwater fish BCFs for PCBs in their criteria development document for PCBs (EPA, 1980b), with a maximum whole body BCFs of 270,000 (*Pimephales promelas*; Aroclors 1242 and 1260) and muscle BCFs less than 10,000 (*Salvelinus fontinalis* and *Oncorhynchus mykiss* [formerly *Salmo gairdneri*]).

The second plausible explanation for high DDT and PCBs in fish relative to water column concentrations is that the exposure route is something other than water. Specifically, fish may be accumulating DDT and PCBs through contaminated sediments or diet. The lack of significant exogenous DDT sources combined with high fish tissue concentrations suggests that the bed sediments are the primary route of exposure in lower Okanogan River and Osoyoos Lake fish.

It is not unreasonable to assume that re-suspended Osoyoos Lake sediments account for nearly all of the measured DDT loads in the lower Okanogan River. Osoyoos Lake bed sediments re-suspended during high flows, spring turnover, or other perturbations may account for the disparity between DDT load delivery and measured loads in the water column of the lower mainstem Okanogan River. These differences can be explained by assuming suspended solids in the water column are composed of re-suspended surficial (top 2-cm) Osoyoos Lake bed sediments. Table 20 compares measured loads with loads calculated by assuming TSS at the Osoyoos Lake outlet is composed of the same material as the top 2-cm of the Osoyoos Lake sediment core. Loads from re-suspended Osoyoos Lake bed sediments match well with the measured DDT loads at Riverside and Malott, although measured loads at Oroville should be approximately 150% higher. Relative concentrations of DDT compounds in measured loads (i.e. 4,4'-DDE ≈ 4,4'-DDD >> 4,4'-DDT) are similar to concentrations in Osoyoos Lake bed sediment, further indicating that measured loads may originate from sediment re-suspension.

Table 20. Measured loads of DDT and PCBs at several lower Okanogan River reaches compared to loads estimated from re-suspension of surficial Osoyoos Lake bed sediments (mg/day).

Reach	RM	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB[a]
Measured load @ Oroville	77.4	660	830	0	1,500	0
Measured load @ Riverside	40.6	2,600	1,700	0	4,300	0
Measured load @ Malott	17.0	2,200	2,000	0	4,200	0
Loads calculated from re-suspension of surficial (top 2-cm) Osoyoos Lk. bed sediments		1,700	2,200	100	4,000	30

[a]Results shown are for PCB Aroclors 1260, 1254, 1248, 1242, 1232, 1221, and 1016

The Colville Confederated Tribes conducted a longitudinal transect of DDT in 40 lower Okanogan River sediments from the Osoyoos Lake outlet to the mouth during 2001 (Hurst and Stone, 2002; D. Hurst, written communication). Aside from two locations, little DDT was found. 60% of the sites had DDT (t-DDT) less than the detection limit (0.5 ng/g) and another 35% had concentration 1-10 ng/g (mostly less than 2 ng/g). The only significant DDT levels were found just below the Osoyoos Lake outlet (but upstream of Zoesel Dam) at 46 ng/g t-DDT and just downstream of Elgin Creek (260 ng/g t-DDT). The site upstream of Zoesel Dam probably collects much of the same settling particulate material as southern Osoyoos Lake since it is within the impounded reach of the river (although technically not part of Osoyoos Lake).

The reason for the high DDT in sediments downstream of Elgin Creek is not certain, although this stream has chronically high DDT concentrations and moderate TSS levels. The Elgin Creek site also may be one of the few locations in the lower mainstem Okanogan River where very fine material is able to accumulate. Visual inspection reveals only a few large areas of fine sediment deposits in the mainstem river, an observation shared by investigators conducting the Colville Confederated Tribes survey.

Load Allocations

DDT and PCB Load Allocations in Tributary Streams

DDT and PCB load allocations (LAs) for tributary streams are shown in Table 21. LAs were set at assimilative capacities. For tributaries with weighted mean loads below assimilative capacities, LAs were set at current loading levels. Since DDT and PCBs are persistent bioaccumulative chemicals and have not been found at acutely toxic concentrations in the present study, LAs for tributary streams may be set at monthly or even yearly averages, but are expressed as daily loads for consistency within this report.

Table 21. DDT and PCB load allocations for individual tributary streams (mg/day).

Stream/Reach	**RM**	**4,4'-DDE**	**4,4'-DDD**	**4,4'-DDT**	**t-DDT**	**t-PCB**
Osoyoos Lake						
Okanogan R. @ Osoyoos BC	91.2	800	1,100	800	1,400	230
Haynes Cr. BC	82.8	0.3	**0.0**	**0.0**	0.5	0.1
Nine Mile Cr.	80.2	2.0	**2.1**	2.0	3.4	0.6
Oroville						
Tonasket Cr.	77.8	4.9	**0.0**	4.9	8.4	1.4
Near Tonasket						
Similkameen R.	74.1	1,000	1,000	1,000	3,000	790
Mosquito Cr.	67.4	0.4	0.5	**0.0**	0.6	0.1
Whitestone Cr.	62.4	5.9	**0.0**	**0.0**	**6.7**	1.7
Antoine Cr.	61.2	1.9	**0.6**	**1.0**	3.3	0.6
Siwash Cr.	57.3	**0.3**	**0.0**	**0.0**	**0.3**	0.1
Bonaparte Cr.	56.7	**1.9**	**0.0**	**0.0**	**1.9**	0.8
Aeneas Cr.	52.9	**1.5**	**0.0**	**0.0**	**1.5**	0.8
Chewiliken Cr.	50.7	**0.0**	**0.0**	**0.0**	**0.0**	0.1
Malott						
Tunk Cr.	45.0	**0.0**	**0.0**	**0.0**	**0.0**	1.1
Johnson Cr.	40.6	**0.0**	**0.0**	**0.0**	**0.0**	0.4
Wanacut Cr.	35.0	**0.0**	**0.0**	**0.0**	**0.0**	0.2
Omak Cr.	32.0	**0.0**	**0.0**	**0.0**	**0.0**	4.3
Elgin Cr.	28.4	1.8	**0.6**	1.8	3.1	0.5
Salmon Cr.	25.7	**2.5**	**0.0**	**0.0**	**2.5**	1.0
Tallant Cr.	19.5	0.2	0.3	0.2	0.4	0.1
Mouth						
Loup Loup Cr.	16.9	**0.0**	**0.0**	**0.0**	**0.1**	0.1
Chiliwist Cr.	15.1	**0.6**	**0.0**	**0.0**	**0.6**	0.4

Bold values indicate load allocations are currently being met

Setting LAs for the Okanogan River at Osoyoos, B.C. and the Similkameen River was more difficult since no DDT or PCBs have been detected at either location, yet they potentially deliver substantial DDT/PCB loads even while concentrations remain undetectable. Major differences in laboratory quantitation limits between sampling conducted during 1995 and later in 2002 made a logical approach to LAs even more difficult.

LAs for the Okanogan River at Osoyoos, B.C. (where the river enters Osoyoos Lake) were set at assimilative capacities for this location. Setting LAs for the Okanogan River at Osoyoos, B.C. is more practical than setting LAs farther downstream in mid-lake at the Canada border.

For the Similkameen River, LAs were set at average loads calculated from flows and one-half the practical quantitation limits during sampling in 1995 and 2002. Although this may initially seem an arbitrary approach, LAs are well within the assimilative capacities of the Similkameen River and account reasonably well for the increased DDT loads measured in the lower Okanogan River downstream of the Similkameen River confluence (see Table 19).

The following streams would require load reductions in order to meet LAs:

- Haynes Creek (4,4'-DDE, t-DDT)
- Ninemile Creek (4,4'-DDE, 4,4'-DDT, t-DDT)
- Tonasket Creek (4,4'-DDE, 4,4'-DDT, t-DDT)
- Mosquito Creek (4,4'-DDE, 4,4'-DDD, t-DDT)
- Whitestone Creek (4,4'-DDE)
- Antoine Creek (4,4'-DDE, t-DDT)
- Elgin Creek (4,4'-DDE, 4,4'-DDT, t-DDT)
- Tallant Creek (4,4'-DDE, 4,4'-DDD, 4,4'-DDT, t-DDT).

DDT and PCB Waste Load Allocations in STPs

DDT and PCB waste load allocations (WLAs) for STPs are in Table 22. WLAs were determined from design criteria flows and criteria concentrations for DDT and PCBs. Like the LAs for tributaries, WLAs are expressed as daily loads for consistency but may be set as monthly or yearly averages.

Table 22. DDT and PCB waste load allocations for STPs (mg/day).

STP	RM	Design flow (l/s)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB
Oroville[a]	d	21.6	**1.1**	**1.6**	**1.1**	**1.9**	**0.3**
Omak[b]	29.9	82.8	**4.2**	**6.0**	**4.2**	**7.2**	1.2
Okanogan[c]	24.8	23.7	**1.2**	**1.7**	**1.2**	2.0	0.3
		Criteria (ng/l)	*0.59*	*0.83*	*0.59*	*1.0*	*0.17*

[a]NPDES permit WA-002239-0
[b]NPDES permit WA-002094-0
[c]NPDES permit WA-002236-0
[d]Similkameen River mile 4.0. The Similkameen River enters at Okanogan River mile 74.1
Bold values indicate waste load allocations are currently being met

Daily loads measured during 2001-2002 (Table 18) are generally consistent or lower than WLAs. Exceptions are small exceedances of t-PCB at Omak and Okanogan STPs, and t-DDT at the Okanogan STP.

DDT and PCB Load Allocations for Sediments

Table 23 shows DDT and PCB load allocations for exogenous sources (tributary streams and STPs), bottom sediments, and assimilative capacities of successive Osoyoos Lake and lower Okanogan River reaches. LAs for bottom sediments were calculated as the difference between the cumulative LAs/WLAs and the assimilative capacity of each reach.

Table 23. DDT and PCB load allocations for bottom sediments (mg/day).

Reach	RM	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB
Osoyoos Lake						
Cumulative LAs (tribs.)	91.2-80.2	800	1,100	800	1,400	230
Bottom sediments	82.5-79.0	0	0	0	0	0
Assimilative capacity	79.0	800	1,100	800	1,400	230
Oroville						
Cumulative LAs/WLAs (tribs.and STPs)	91.2-77.8	800	1,100	800	1,400	230
Bottom sediments	79.0-77.4	0	0	0	0	0
Assimilative capacity	77.4	800	1,100	800	1,400	230
Near Tonasket						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 52.9	1,800	2,100	1,800	4,400	1,000
Bottom sediments	77.4-50.7	2,100	3,400	2,100	2,100	100
Assimilative capacity	50.7	3,900	5,500	3,900	6,500	1,100
Malott						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 19.5	1,800	2,100	1,800	4,400	1,000
Bottom sediments	50.7-17.0	2,200	3,500	2,200	2,300	100
Assimilative capacity	17.0	4,000	5,600	4,000	6,700	1,100
Mouth						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 15.1	1,800	2,100	1,800	4,400	1,000
Bottom sediments		2,200	3,500	2,200	2,300	100
Assimilative capacity		4,000	5,600	4,000	6,700	1,100

LAs for the Okanogan River at Osoyoos, B.C. constitute all of the assimilative capacities at Osoyoos Lake and the Okanogan River at Oroville. The added assimilative capacity of the Similkameen River provides for bottom sediment DDT LAs of about one-half the assimilative capacities at reaches below Oroville. However, little capacity is available for bottom sediment PCB LAs at any of the reaches. This is due to the relative uncertainty regarding PCBs in the Similkameen River which in turn is a function of the relatively high practical quantitation limits for PCBs. A greater degree of certainty that PCBs were much lower in the Similkameen River would add capacity for a PCB LA in bottom sediments.

Seasonal Variation and Margin of Safety

Seasonal variation has been addressed through sampling during low-flow and high-flow events. Use of weighted mean loads also incorporates flows and contaminant concentrations measured at various times of the year.

Both the human health and chronic aquatic life criteria for DDT and PCBs are driven by long-term exposures to fish tissue. Acute toxicity is not considered to be a concern at concentrations in the lower Okanogan River basin (EPA, 1980a; EPA, 1980b). Since accumulation of DDT and PCBs by fish is a time-integrative process, and effects are based on long-term exposures, seasonal variations in loads are not an important factor in determining load allocations.

Margins of safety have not been incorporated into load and waste load allocations due to the nonpoint nature of DDT and PCBs and the relative inability to control their discharge to the water column of Osoyoos Lake and the lower Okanogan River.

Load Reductions

Load reductions required to meet DDT/PCB LAs are shown in Table 24. On a reach-by-reach basis, no load reductions are required to meet LAs through delivery from tributaries and STPs since substantial reserve capacity exists at all reaches. As mentioned previously, however, some load reductions are needed to meet assimilative capacities in certain tributary streams and STPs.

Table 24. Required DDT and PCB load reductions and reserve capacity (-) at Osoyoos Lake and lower Okanogan River reaches (mg/day).

Reach	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB[a]
Osoyoos Lake					
Tribs. and STPs	-790	1,100	-800	-1,400	-230
% reduction	0%	0%	0%	0%	0%
Sediments	17,000	10,000	760	13,000	0
% reduction	100%	100%	100%	100%	0%
Oroville					
Tribs. and STPs	-790	-1,100	-790	-1,400	-230
% reduction	0%	0%	0%	0%	0%
Sediments	7,800	650	270	24,000	820
% reduction	100%	100%	100%	100%	100%
Near Tonasket					
Tribs. and STPs	-1,800	-2,100	-1,800	-4,400	-1,000
% reduction	0%	0%	0%	0%	0%
Sediments	39,000	1,500	-620	30,000	6,400
% reduction	95%	31%	0%	93%	98%
Malott					
Tribs. and STPs	-1,700	-2,100	-1,700	-4,200	-1,000
% reduction	0%	0%	0%	0%	0%
Sediments	10,700	-2,000	-1,900	14,500	2,500
% reduction	83%	0%	0%	86%	96%
Mouth					
Tribs. and STPs	-1,800	-2,100	-1,800	-4,400	-1,000
% reduction	0%	0%	0%	0%	0%
Sediments	10,700	-2,000	-1,900	14,500	2,500
% reduction	83%	0%	0%	86%	96%

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016

Major load reductions from bottom sediments will be required to meet LAs for all reaches except where reserve capacities exist for 4,4'-DDD and 4,4'-DDT at Malott and the mouth, and 4,4'-DDT near Tonasket. No load reductions are required to meet t-PCB LAs in Osoyoos Lake since PCBs have not been detected in fish from this location.

Reductions in DDT and PCB Concentrations in Bottom Sediments

Accumulation of a contaminant through all components of the aquatic environment is often referred to as bioaccumulation, with the numerical relationship described by bioaccumulation factors (BAFs). For fish, BAFs are probably more appropriate than BCFs to describe the contaminant link with the aquatic environment because BCFs substantially underestimate the bioaccumulation potential for hydrophobic chemicals that are resistant to metabolism and degradation such as DDT and PCBs (EPA, 2000).

Biota-sediment accumulation factors (BSAFs) are the simplest model to explain the relationship between contamination of an organism and bottom sediments. BSAFs are essentially the ratio of contaminant concentrations in tissue to concentrations in sediment and may be used in situations where the concentration ratios do not change substantially over time, both the organism and food are exposed to the contaminant, and sediment concentrations are representative of those in the vicinity of the organism. For hydrophobic chemicals such as DDT and PCBs, this relationship is more accurately defined by factoring in tissue lipid and sediment organic carbon which strongly influence the uptake and retention of these chemicals. Site-specific BSAFs may then be calculated using the formula:

$$BSAF = (C_t/f_l)/(C_s/f_{oc})$$

where:

C_t = contaminant concentration in tissue
C_s = contaminant concentration in sediment
f_l = lipid fraction in tissue
f_{oc} = fraction of organic carbon in sediment

Current data on DDT and PCB in sediments and fish tissue were used to establish site-specific BSAFs at Osoyoos Lake and several lower Okanogan River reaches (Table 25). Data used were mean DDT, PCB, and TOC concentrations in the surficial layers (top 2-cm) of sediment cores collected from Osoyoos Lake (Osoyoos Lake and Oroville BSAFs) and from the Okanogan River mouth (Riverside-Omak and Monse BSAFs). Fish tissue data were the same as those used to calculate theoretical loads.

BSAFs generally ranged by approximately an order of magnitude (2.3 – 34.9) demonstrating a fairly good correlation between DDT/PCB concentrations in sediment and tissue. The BSAF for PCB at Oroville was very high due to low lipid content of fish combined with low PCB level in sediments. High BSAFs for 4,4'-DDT at Riverside-Omak and Monse were driven by very low concentrations in sediment.

Table 25. BSAFs at Osoyoos Lake and several lower Okanogan River reaches.

Location	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t- PCB[a]
Osoyoos Lk	12.6	6.0	10.2	8.9	11.3[b]
Oroville	34.9	2.3	21.7	16.8	129.1
Riv-Omak	21.1	9.1	162.1[c]	19.0	15.1
Monse	11.3	4.9	77.1[c]	10.1	10.4

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
[b]One-half practical quantitation limit (10 ng/g) used as tissue concentration
[c]One-half practical quantitation limit (0.032 ng/g) used as sediment concentration

Reductions in sediment DDT/PCB concentrations required to meet LAs at several Osoyoos Lake and lower Okanogan River reaches were calculated by applying BSAFs to required reductions in tissue concentrations (Table 26). Except for PCBs in Osoyoos Lake, complete (100%) or near complete reductions are needed to meet LAs in the Osoyoos Lake and Oroville reaches, reflecting the LAs given to sediments in these reaches (0 mg/day). Large percent reductions are also needed for 4,4’-DDE, t-DDT, and PCBs in sediments in the lower reaches, but reserve capacities exist in most cases for 4,4-DDD and 4,4’-DDT.

Table 26. Reductions or reserve capacity (-) in sediment DDT and PCB concentrations (ng/g OC) required to meet load allocations.

Reach	4,4'-DDE	4,4’-DDD	4,4’-DDT	t-DDT	t-PCB[a]
Osoyoos Lake					
Current concentration	822	1,043	46.5	1,912	13.5
Reduction required to meet LA	822	1,030	48.0	1,905	0.0
Percent reduction	100%	99%	100%	100%	0%
Oroville					
Current concentration	822	1,043	46.5	1,912	13.5
Reduction required to meet LA	820	1,043	46.5	1,912	13.5
Percent reduction	100%	100%	100%	100%	100%
Near Tonasket					
Current concentration	354	97.4	1.6[b]	453	45.6
Reduction required to meet LA	336	37.8	-0.4	431	45.6
Percent reduction	95%	39%	0%	95%	100%
Malott					
Current concentration	354	97.4	1.6[b]	453	45.6
Reduction required to meet LA	308	-97.4	-6.7	398	45.6
Percent reduction	87%	0%	0%	88%	100%
Mouth					
Current concentration	353	97.4	1.6[b]	453	45.6
Reduction required to meet LA	308	-97.4	-6.7	398	45.6
Percent reduction	87%	0%	0%	88%	100%

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
[b]One-half practical quantitation limit (0.032 ng/g) used as sediment concentration

Trends in sediment DDT and PCB concentrations obtained from sediment cores suggest in most cases these required reductions will not be met in the near future. Concentrations have remained stable for the past two decades in the Osoyoos Lake sediments and for the past decade in sediments at the Okanogan River mouth.

Load Reductions in Individual Tributaries and STPs

Table 27 shows load reductions needed to bring individual tributaries and STP in line with Washington State and NTR criteria. In general, required load reductions are less than 10 mg/day. Tallant, Elgin, Tonasket, and Ninemile creeks will require the largest load reductions. Three of these – Tallant, Elgin, and Ninemile – are currently on the 303(d) list for t-DDT. The Okanogan STP was the only one of the three STPs requiring load reductions for DDT and PCBs.

Table 27. Load reductions required to meet criteria within individual tributaries and STPs (mg/day).

Location	RM	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	t-PCB[a]
Haynes Cr. BC	82.8	1.0	0	0	0.8	0
Nine Mile Cr.	80.2	4.6	0	2.8	10.2	0
Tonasket Cr.	77.8	7.4	0	3.5	12.4	0
Mosquito Cr.	67.4	0.6	0.5	0	1.4	0
Whitestone Cr.	62.4	0.8	0	0	0	0
Antoine Cr.	61.2	2.8	0	0	3.1	0
Elgin Cr.	28.4	12.5	0	5.3	19.0	0
Okanogan STP	24.8	0	0	0.3	0.8	0.2
Tallant Cr.	19.5	46.4	10.2	68.4	125	0

[a]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016

Conclusions

This project constitutes a total maximum daily load (TMDL) assessment of DDT and PCBs in the lower Okanogan River basin. The primary goal of the lower Okanogan River TMDL assessment project was to determine where DDT/PCB loading reductions are required in order to bring edible fish tissue concentrations in line with criteria concentrations. This was accomplished through analysis of DDT and PCB loads delivered to the lower Okanogan River and Osoyoos Lake through tributaries and municipal sewage treatment plants, DDT and PCB concentrations in the water column of the lower Okanogan River, DDT and PCB concentrations in edible fish tissue from the lower Okanogan River, and DDT and PCB concentrations in sediment cores from the lower Okanogan River and Osoyoos Lake. Most of the data supporting this effort were collected during 2001-2002, but historical data also were used.

Results of water sample data collected during 2001-2002 largely confirm a previous report (Johnson et al., 1997) showing that DDT loads delivered to the Okanogan River and Osoyoos Lake through tributaries are very low. Present data also demonstrate that DDT and PCB loads delivered to the Okanogan River through three STPs are very low. Combined (tributaries and STPs), measurable loads delivered to Osoyoos Lake and the lower Okanogan River are approximately 200 mg/day t-DDT on average, and less than 1 mg/day for t-PCB.

In contrast to previous findings, DDT concentrations in edible fish tissues from the Okanogan River appear to be much lower than in the 1980s and 1990s (Hopkins et al, 1985; Davis and Serdar, 1996). Maximum concentrations are 600 ng/g t-DDT compared with 3,200 ng/g reported in earlier studies. However, 4,4-DDE exceeded the criterion in 23 of the 24 samples analyzed. Only one sample exceeded the 4,4'-DDD criterion, and none of the samples exceeded the 4,4'-DDT criterion.

Maximum PCB concentrations appear to be similar to earlier findings, with a maximum concentration of 42 ng/g compared to 45 ng/g in a previous study. The PCB criterion was met or exceeded in 16 of 24 samples analyzed.

Although DDT concentrations appear to be declining in edible fish tissues, loads delivered to the river still do not account for measured loads in the mainstem Okanogan River or concentrations in fish tissues. This is especially true for the major DDT component in tissue, 4,4'-DDE, which follows the pattern:

delivered loads << measured loads ≈ assimilative capacities << theoretical loads

where delivered loads are from tributaries and STPs, measured loads are those measured in the water column of the mainstem Okanogan River, assimilative capacities are the loads matching the criteria at each reach, and theoretical loads are those back-calculated to water from fish tissue concentrations.

Since exogenous sources account for only a small fraction of the contaminant levels in Osoyoos Lake and lower Okanogan River fish tissue, it is assumed that the major source of DDT and

PCBs is from internal loading, particularly bottom sediments. It appears that the Okanogan River continues to be dosed with contaminated Osoyoos Lake sediments which are re-suspended and transported downstream, especially during high flows. Downstream of Oroville, DDT concentrations in sediments appear to be diluted from relatively clean Similkameen River sediments which are reflected in lower concentrations in fish and sediments. However, major reductions in sediment DDT and PCB concentrations will be needed in order to bring concentrations in fish tissue down to criteria levels.

There are few realistic options for obtaining meaningful reductions in DDT and PCB loading to Osoyoos Lake and the lower Okanogan River. It appears that most loading to fish occurs internally through direct or indirect exposure to sediments. Natural attenuation will eventually reduce levels through dilution and capping, especially downstream of the Similkameen River confluence.

Recommendations

In terms of further study, the following recommendations are made in order to enhance the understanding of DDT and PCBs dynamics in the aquatic ecosystem of the Okanogan River basin:

- More data are needed on DDT and PCBs in Osoyoos Lake. In particular, data should be collected to increase confidence that the Osoyoos Lake data used in the present study are representative of current conditions. This should include a re-assessment of DDT and PCB concentrations in Osoyoos Lake fish, collection of additional water samples from the Okanogan River at Osoyoos, B.C. (Osoyoos Lake inlet), and increasing sample coverage of DDT and PCBs in Osoyoos Lake bottom sediments.

- The occurrence and extent of episodic DDT loading through bank erosion, stream channel erosion, or other erosional processes should be investigated.

- Carp samples should be collected from the Monse reach for analysis of DDT and PCBs in edible tissue to compare to carp from other reaches and other species from Monse.

Most tributaries currently are delivering loads below their load allocations. Tributaries exceeding their assimilative capacities for one or more contaminants – Haynes, Ninemile, Tonasket, Mosquito, Whitestone, Antoine, Elgin, and Tallant creeks – should be closely examined to determine if better management at the riparian or watershed level can reduce inputs. Tallant Creek is a particularly good candidate for applying best management practices since flow is highly regulated and DDT concentrations are very high, as are concentrations of suspended solids, suggesting the occurrence of orchard soil erosion during water releases from Leader Lake, the source of Tallant Creek. Elgin Creek also may be a candidate since total suspended solids and DDT concentrations are consistently high, although flows are not as episodic as Tallant Creek.

The source of PCBs in the Okanogan sewage treatment plant should be investigated if levels in effluent remain above the assimilative capacity of the effluent.

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Appendices

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Appendix A

Glossary of Acronyms and Symbols

303(d) - Section 303(d) of the federal Clean Water Act

B.C. – British Columbia

BAF – bioaccumulation factor

BCF - bioconcentration factor

BSAF – biota-sediment accumulation factor

BW – body weight

C_s – concentration in sediment

C_t – concentration in tissue

C_w – concentration in water

DDD – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethane (a.k.a. 4,4'-DDD)

DDE – 1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene (a.k.a. 4,4'-DDE)

DDT – 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane (a.k.a. 4,4'-DDT and also used to refer to the DDD and DDE analogs)

Ecology – Washington State Department of Ecology

ECD – electron capture detector

EPA – U.S. Environmental Protection Agency

FC - fish consumption

GC – gas chromatography

GIS – Geographic Information System

HHC – human health criteria

LA – load allocation

MEL – Manchester Environmental Laboratory

MOS – margin of safety

m.s.l. – mean sea level

NDIR – nondispersive infrared

ng/g – nanograms per gram (parts per billion)

ng/l – nanograms per liter (parts per trillion)

NIST – National Institute of Standards and Technology

NPDES – National Pollutant Discharge Elimination System

NTR – National Toxics Rule

Q – discharge

q1* – cancer slope factor

Pb – lead

PCB – polychlorinated biphenyl

Ra – radium

RF – risk factor

RM – river mile

Rn – radon

SRM – standard reference material

STP – sewage treatment plant

t-DDT – total DDT (sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT in this report)

t-PCB – total PCB (sum of PCB Aroclors in this report)

TMDL – Total Maximum Daily Load

TOC – total organic carbon

TSS – total suspended solids

µg/l – microgram per liter (parts per billion)

USDA – U.S. Department of Agriculture

USGS – U.S. Geological Survey

WAC – Washington Administrative Code

WC – water consumption

WDFW – Washington Department of Fish and Wildlife

WLA – waste load allocation

Appendix B

Decision Matrices for the 1998 303(d) List

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Water Name	NINEMILE CREEK
Parameter	DDT
Mediu	Water
Place on 1998 List?	Yes
Listed in 1996	No
Action Needed	TMDL
New Segment ID #	IP09QF
Old Segment ID #	WA-49-1049
Stream Route #	0.365
Water Resource Inventory Area	49
Township	40N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	15
Grid Longitude	
Basis for Consideration of Listing	Johnson, et al. 1995. , 2 excursions beyond the chronic criterion collected on 7/24/95 and 8/31/95 at the mouth of Ninemile Creek to Osoyoos Lake.
Remarks	

Water Name	OKANOGAN RIVER
Parameter	4,4'-DDD
Mediu	Water
Place on 1998 List?	No
Listed in 1996	No
Action Needed	None
New Segment ID #	YN58LL
Old Segment ID #	WA-49-1020
Stream Route #	91.196
Water Resource Inventory Area	49
Township	37N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	16
Grid Longitude	
Basis for Consideration of Listing	1 excursion beyond National Toxics Rule (40 CFR Part 131) criterion at USEPA station 543022 (below Tonasket) on 5/6/71.
Remarks	A single excursion beyond the criterion does not meet the Water Quality Program Policy for listing.; The EPA data downloaded from STORET were challenged as not meeting the quality assurance criteria of the Water Quality Program policy on listing. The listed STORET contact (Ray Peterson) was asked to verify that these criteria were met for the data used as a basis for listing. EPA did not verify that these data meet the quality assurance criteria. Therefore, these data from STORET should not be used as a basis for listing.

Water Name	OKANOGAN RIVER
Parameter	4,4'-DDE
Mediu	Tissue
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	YN58LL
Old Segment ID #	WA-49-1010
Stream Route #	9.756
Water Resource Inventory Area	49
Township	31N
Waterbody Grid #	
Range	25E
Grid Latitude	
Section	27
Grid Longitude	
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible carp tissue during 1994.
Remarks	

Water Name	OKANOGAN RIVER
Parameter	PCB-1260
Mediu	Tissue
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	YN58LL
Old Segment ID #	WA-49-1010
Stream Route #	7.063
Water Resource Inventory Area	49
Township	31N
Waterbody Grid #	
Range	25E
Grid Latitude	
Section	34
Grid Longitude	
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible fish tissue of carp at RM 5 during 1994.
Remarks	

Water Name	OKANOGAN RIVER
Parameter	PCB-1254
Mediu	Tissue
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	YN58LL
Old Segment ID #	WA-49-1010
Stream Route #	9.756
Water Resource Inventory Area	49
Township	31N
Waterbody Grid #	
Range	25E
Grid Latitude	
Section	27
Grid Longitude	
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible carp tissue during 1994.
Remarks	

Water Name	OKANOGAN RIVER
Parameter	4,4'-DDD
Mediu	Tissue
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	YN58LL
Old Segment ID #	WA-49-1010
Stream Route #	9.756
Water Resource Inventory Area	49
Township	31N
Waterbody Grid #	
Range	25E
Grid Latitude	
Section	27
Grid Longitude	
Basis for Consideration of Listing	Davis and Serdar, 1996 , excursions beyond the criterion in edible carp tissue during 1994.
Remarks	

Water Name	OSOYOOS LAKE
Parameter	4,4'-DDE
Mediu	Water
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	060VKD
Old Segment ID #	WA-49-9260
Stream Route #	
Water Resource Inventory Area	49
Township	40N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	22
Grid Longitude	
Basis for Consideration of Listing	Johnson and Norton, 1990. excursion beyond the criterion in the edible tissue of a composite of Largemouth Bass collected in 1989.
Remarks	

Water Name	OSOYOOS LAKE
Parameter	DDT
Mediu	Water
Place on 1998 List?	No
Listed in 1996	No
Action Needed	None
New Segment ID #	060VKD
Old Segment ID #	WA-49-9260
Stream Route #	
Water Resource Inventory Area	49
Township	40N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	22
Grid Longitude	
Basis for Consideration of Listing	1 excursion beyond National Toxics Rule (40 CFR Part 131) criterion at USEPA station 543020 (at Ososyoos Lake outlet) on 5/6/71.
Remarks	A single excursion beyond the criterion does not meet the Water Quality Program Policy for listing.; The EPA data downloaded from STORET were challenged as not meeting the quality assurance criteria of the Water Quality Program policy on listing. The listed STORET contact (Ray Peterson) was asked to verify that these criteria were met for the data used as a basis for listing. EPA did not verify that these data meet the quality assurance criteria. Therefore, these data from STORET should not be used as a basis for listing.

Water Name	OSOYOOS LAKE
Parameter	4,4'-DDD
Mediu	Water
Place on 1998 List?	Yes
Listed in 1996	Yes
Action Needed	TMDL
New Segment ID #	060VKD
Old Segment ID #	WA-49-9260
Stream Route #	
Water Resource Inventory Area	49
Township	40N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	22
Grid Longitude	
Basis for Consideration of Listing	Johnson and Norton, 1990. excursion beyond the criterion in the edible tissue of a composite of Largemouth Bass collected in 1989.
Remarks	

Water Name	OSOYOOS LAKE
Parameter	4,4'-DDD
Mediu	Water
Place on 1998 List?	No
Listed in 1996	Yes
Action Needed	None
New Segment ID #	060VKD
Old Segment ID #	WA-49-9260
Stream Route #	
Water Resource Inventory Area	49
Township	40N
Waterbody Grid #	
Range	27E
Grid Latitude	
Section	22
Grid Longitude	
Basis for Consideration of Listing	1 excursion beyond National Toxics Rule (40 CFR Part 131) criterion at USEPA station 543020 (at Ososyoos Lake outlet) on 5/6/71.
Remarks	The EPA data downloaded from STORET were challenged as not meeting the quality assurance criteria of the Water Quality Program policy on listing. The listed STORET contact (Ray Peterson) was asked to verify that these criteria were met for the data used as a basis for listing. EPA did not verify that these data meet the quality assurance criteria. Therefore, these data from STORET should not be used as a basis for listing.

Water Name	TALLANT CREEK		
Parameter	DDT	Mediu	Water
Place on 1998 List?	Yes	Listed in 1996	No
Action Needed	TMDL		
New Segment ID #	LD33FC	Old Segment ID #	WA-49-1017
Stream Route #	0	Water Resource Inventory Area	49
Township	32N	Waterbody Grid #	
Range	25E	Grid Latitude	
Section	02	Grid Longitude	
Basis for Consideration of Listing	Johnson, et al. 1995. , 2 excursions beyond the chronic criterion collected on 7/24/95 and 8/31/95.		
Remarks			

Water Name	UNNAMED CREEK		
Parameter	DDT	Mediu	Water
Place on 1998 List?	Yes	Listed in 1996	No
Action Needed	TMDL		
New Segment ID #	KR66GR	Old Segment ID #	WA-49-1022
Stream Route #	0	Water Resource Inventory Area	49
Township	33N	Waterbody Grid #	
Range	26E	Grid Latitude	
Section	03	Grid Longitude	
Basis for Consideration of Listing	Johnson, et al. 1995. , 2 excursions beyond the chronic criterion collected on 7/25/95 and 8/31/95 at the mouth of an unnamed Creek at Okanogan RM 28.4..		
Remarks			

Appendix C

Sample Locations

Table C-1. Lower Okanogan River basin tributary sample locations (NAD 83).

		Latitude			Longitude			
Location	**RM**	**deg**	**min**	**sec**	**deg**	**min**	**sec**	**Description**
Haynes Cr.	82.8	49	00	18	119	26	12	at Brookdale campsite on corner of 16th and 45th
Nine Mile Cr.	80.2	48	58	14.1	119	25	17.82	at Thorndike Rd. X-ing
Tonasket Cr.	77.8	48	56	17.46	119	25	27.3	at mouth
Similkameen R. (7/24/95)	74.1 (SR 5.0)	48	56	7.2	119	26	24	at county road bridge to Oroville
Similkameen R. (5/13/02 sample)	74.1 (SR 3.7)	48	55	10.8	119	25	54	at mouth
Mosquito Cr.	67.4	48	50	24.6	119	24	34.8	at Hwy 97 X-ing
Whitestone Cr.	62.4	48	46	28.8	119	24	46.2	at River Loop Road
Antoine Cr.	61.2	48	45	32.88	119	24	32.28	at Hwy 97 X-ing
Siwash Cr.	57.3	48	42	42.24	119	26	12.54	in Tonasket between Hwy 97 and RR bridge
Bonaparte Cr.	56.7	48	42	13.8	119	26	40.8	near mouth at Chief Tonasket Apple Packing plant
Aeneas Cr.	52.9	48	39	34.14	119	28	46.56	at Tonasket-Oroville Westside Road X-ing
Chewiliken Cr.	50.7	48	37	48.6	119	27	46.8	Off McLaughlin Canyon Road 100 ft. downstream of USGS gage
Tunk Cr.	45.0	48	33	42.36	119	29	6.84	just upstream of mouth on Keystone Orchard land
Johnson Cr.	40.6	48	30	8.28	119	30	16.92	in Riverside at road X-ing near mouth
Wanacut Cr.	35.0	48	25	54.6	119	27	59.4	at Precision Pine 200 m upstream of mouth
Omak Cr.	32.0	48	24	19.8	119	30	6	at X-ing with road that tees off Omak-Riverside E. Rd.
Elgin Cr.	28.4	48	23	21	119	33	5.4	at Rt. 215 X-ing in Okanogan
Salmon Cr.	25.7	48	21	37.5	119	34	57.18	in Okanogan just upstream of mouth
Tallant Cr.	19.5	48	18	06	119	39	42	at Old Hwy 97 X-ing
Loup Loup Cr.	16.9	48	16	59.34	119	42	28.74	in Malott at Old Hwy 97 X-ing
Chiliwist Cr.	15.1	48	16	0.18	119	44	1.8	In orchard just downstream of Old Hwy 97 X-ing

Table C-2. Lower Okanogan River basin STP sample locations (NAD 83).

		Latitude			Longitude			
Location	**RM**	**deg**	**min**	**sec**	**deg**	**min**	**sec**	**Description**
Oroville STP	74.1 (SR 4.0)	48	55	32	119	26	29	final effluent at plant
Omak STP	29.9	48	24	2	119	32	1	final effluent at plant
Okanogan STP	24.8	48	21	10	119	35	39	final effluent at plant

Table C-3. Mainstem Okanogan River water sample locations (NAD 83).

		Latitude			Longitude			
Location	**RM**	**deg**	**min**	**sec**	**deg**	**min**	**sec**	**Description**
Okanogan R. @ Osoyoos, B.C.	91.2	49	05	24	119	32	06	above Osoyoos Lake at Rd. 22 bridge
Okanogan R. @ Zosel Dam	77.4	48	55	51	119	25	9	off right bank 50 ft downstream of dam spillway
Okanogan R. @ Riverside	40.6	48	30	12	119	30	15.6	off bridge @ Riverside
Okanogan R. @ Malott	17.0	48	16	42	119	24	6	off bridge @ Malott

Table C-4. Lower Okanogan River basin sediment core sample locations (NAD 83).

		Latitude			Longitude			
Location	**RM**	**deg**	**min**	**sec**	**deg**	**min**	**sec**	**Description**
Osoyoos Lake	79.4	48	57	26	119	25	50	approx. one-half mile north of State Park boat launch
Okanogan River mouth	2.3	48	6	18	119	41	21	at depositional area in right bend of river just north of Hwy 97

Table C-5. Mainstem Okanogan River fish sample locations.

Location	**RM**	**Description**
Osoyoos Lake	82.5 – 79.0	southern Osoyoos Lake between Canada border and outlet
Oroville	77.3 – 76.4	between Hwy 97 bridge at Oroville and ¼ upstream of Similkameen R. confluence
Riverside - Omak	41.0 – 30.7	between bridges in Omak, 1 mi. above boat launch at Riverside to ½ mi. below boat launch
Monse	10.5 – 4.9	between RR bridge above Monse to road X-ing at Monse

Appendix D

Biological Data on Okanogan River Fish Sampled during 2001

Table D-1. Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish no.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128230	Oroville	11/5/01	OR-22	CARP	587		2,868	558	R
	Oroville	11/5/01	OR-17	CARP	576		2,409	308	5
	Oroville	11/5/01	OR-10	CARP	575		2,502	500	R
	Oroville	11/5/01	OR-19	CARP	553		1,808	224	R
	Oroville	11/5/01	OR-9	CARP	545		2,037	362	5
	Oroville	11/5/01	OR-11	CARP	528		2,122	434	R
	Oroville	11/5/01	OR-14	CARP	527		1,634	340	6
	Oroville	11/5/01	OR-15	CARP	527		1,696	332	6
				n	**8**		**8**	**8**	**4**
				MEAN	**552**		**2135**	**382**	**nc**
				S.D.	**25**		**432**	**109**	**nc**
128231	Oroville	11/5/01	OR-2	CARP	525		1,685	336	R
	Oroville	11/5/01	OR-20	CARP	524		1,775	242	R
	Oroville	11/5/01	OR-1	CARP	515		1,865	320	8
	Oroville	11/5/01	OR-21	CARP	513		1,842	318	5
	Oroville	11/5/01	OR-13	CARP	511		1,608	336	R
	Oroville	11/5/01	OR-5	CARP	510		1,663	326	5
	Oroville	11/5/01	OR-23	CARP	509		1,827	320	R
	Oroville	11/5/01	OR-6	CARP	507		1,726	238	6
				n	**8**		**8**	**8**	**4**
				MEAN	**514**		**1749**	**305**	**nc**
				S.D.	**7**		**93**	**40**	**nc**
128232	Oroville	11/5/01	OR-3	CARP	505		1,672	272	3
	Oroville	11/5/01	OR-8	CARP	495		1,489	240	5
	Oroville	11/5/01	OR-18	CARP	484		1,681	356	R
	Oroville	11/5/01	OR-12	CARP	482		1,548	314	nm
	Oroville	11/5/01	OR-4	CARP	435		1,106	274	R
	Oroville	11/5/01	OR-16	CARP	432		1,229	330	4
	Oroville	11/5/01	OR-7	CARP	410		713	97	2
				n	**7**		**7**	**7**	**4**
				MEAN	**463**		**1348**	**269**	**nc**
				S.D.	**37**		**354**	**85**	**nc**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish no.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128233	Omak	9/17/01	OM-33	CARP	645		3,908	802	R
	Omak	9/17/01	OM-32	CARP	640		3,623	820	6
	Riverside	9/18/01	RV-16	CARP	635		3,637	872	R
	Riverside	9/18/01	RV-13	CARP	630		3,509	710	7
	Riverside	9/18/01	RV-9	CARP	605		2,854	678	7
	Riverside	9/18/01	RV-11	CARP	605		3,229	690	6
	Riverside	9/18/01	RV-8	CARP	600		3,134	606	7
	Riverside	9/18/01	RV-1	CARP	595		2,865	726	6
				n	**8**		**8**	**8**	**6**
				MEAN	**619**		**3345**	**738**	**nc**
				S.D.	**20**		**385**	**87**	**nc**
128234, 128235	Riverside	9/18/01	RV-6	CARP	595		3,057	726	R
	Omak	9/17/01	OM-34	CARP	595		3,552	770	6
	Omak	9/17/01	OM-36	CARP	595		2,835	644	R
	Riverside	9/18/01	RV-3	CARP	590		2,317	496	6
	Omak	9/17/01	OM-38	CARP	590		2,004	572	6
	Riverside	9/18/01	RV-12	CARP	575		2,736	610	R
	Riverside	9/18/01	RV-2	CARP	570		2,965	584	8
	Riverside	9/18/01	RV-5	CARP	565		2,454	648	8
				n	**8**		**8**	**8**	**5**
				MEAN	**584**		**2740**	**631**	**nc**
				S.D.	**12**		**481**	**87**	**nc**
128236	Riverside	9/18/01	RV-17	CARP	565		2,413	528	6
	Omak	9/17/01	OM-37	CARP	565		1,924	644	7
	Omak	9/17/01	OM-35	CARP	560		3,030	592	6
	Riverside	9/18/01	RV-15	CARP	555		2,530	558	5
	Riverside	9/18/01	RV-18	CARP	545		2,440	616	6
	Riverside	9/18/01	RV-10	CARP	539		2,391	380	R
	Riverside	9/18/01	RV-4	CARP	537		2,212	496	6
	Riverside	9/18/01	RV-7	CARP	535		2,206	426	R
				n	**8**		**8**	**8**	**6**
				MEAN	**550**		**2393**	**530**	**nc**
				S.D.	**13**		**320**	**92**	**nc**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128237	Oroville	11/5/01	OR-24	MTWF	407	378	419	144	6
	Oroville	5/9/01	1	MTWF	376	nm	418	135	6
	Oroville	11/5/01	OR-25	MTWF	362	333	285	132	3
	Oroville	5/9/01	4	MTWF	360	nm	363	131	4
	Oroville	11/5/01	OR-28	MTWF	360	331	239	75	4
	Oroville	11/5/01	OR-26	MTWF	351	320	245	98	5
	Oroville	11/5/01	OR-30	MTWF	345	321	313	nm	4
	Oroville	11/5/01	OR-31	MTWF	339	310	240	62	5
				n	**8**	**6**	**8**	**7**	**8**
				MEAN	**363**	**nc**	**315**	**nc**	**5**
				S.D.	**21**	**nc**	**76**	**nc**	**1**
128238	Oroville	5/9/01	2	MTWF	338	nm	331	111	3
	Oroville	5/9/01	7	MTWF	337	nm	292	106	5
	Oroville	11/5/01	OR-34	MTWF	336	309	178	49	3
	Oroville	11/5/01	OR-27	MTWF	334	309	225	80	2
	Oroville	11/5/01	OR-33	MTWF	329	305	186	40	5
	Oroville	11/5/01	OR-35	MTWF	325	298	201	72	4
	Oroville	11/5/01	OR-32	MTWF	320	294	210	71	3
	Oroville	11/5/01	OR-36	MTWF	320	295	210	80	3
				n	**8**	**6**	**8**	**8**	**8**
				MEAN	**330**	**nc**	**229**	**76**	**4**
				S.D.	**7**	**nc**	**54**	**25**	**1**
128245	Oroville	11/5/01	OR-39	MTWF	314	294	199	72	3
	Oroville	11/5/01	OR-29	MTWF	309	285	201	82	2
	Oroville	11/5/01	OR-42	MTWF	291	266	164	65	3
	Oroville	11/5/01	OR-38	MTWF	285	265	163	54	3
	Oroville	11/5/01	OR-44	MTWF	284	261	160	55	2
	Oroville	11/5/01	OR-37	MTWF	282	261	159	56	3
	Oroville	11/5/01	OR-43	MTWF	281	260	149	45	2
	Oroville	11/5/01	OR-40	MTWF	272	250	143	54	2
				n	**8**	**8**	**8**	**8**	**8**
				MEAN	**290**	**268**	**167**	**60**	**2**
				S.D.	**14**	**14**	**21**	**12**	**0.5**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128239, 128240	Omak	9/17/01	OM-21	MTWF	400	372	490	195	9
	Riverside	9/18/01	RV-24	MTWF	398	370	655	242	4
	Riverside	9/18/01	RV-22	MTWF	368	343	460	188	4
	Omak	9/17/01	OM-19	MTWF	365	336	455	140	10
	Omak	9/17/01	OM-17	MTWF	361	344	495	170	7
	Omak	9/17/01	OM-23	MTWF	361	336	385	148	6
	Omak	9/17/01	OM-15	MTWF	353	330	467	184	5
	Omak	9/17/01	OM-27	MTWF	350	326	349	120	10
	Riverside	9/18/01	RV-27	MTWF	347	323	394	166	4
	Riverside	9/18/01	RV-21	MTWF	346	306	382	138	4
				n	**10**	**10**	**10**	**10**	**10**
				MEAN	**365**	**339**	**453**	**169**	**6**
				S.D.	**19**	**20**	**87**	**35**	**2**
128241	Riverside	9/18/01	RV-25	MTWF	345	321	339	146	4
	Riverside	9/18/01	RV-28	MTWF	345	321	408	162	3
	Omak	9/17/01	OM-26	MTWF	344	319	325	134	4
	Omak	9/17/01	OM-18	MTWF	343	320	462	123	4
	Omak	9/17/01	OM-1	MTWF	341	317	296	102	6
	Riverside	9/18/01	RV-26	MTWF	339	318	379	154	6
	Omak	9/17/01	OM-22	MTWF	333	311	317	114	10
	Riverside	9/18/01	RV-23	MTWF	322	297	264	128	4
	Omak	9/17/01	OM-24	MTWF	314	392	277	97	4
	Omak	9/17/01	OM-7	MTWF	313	291	241	83	4
				n	**10**	**10**	**10**	**10**	**10**
				MEAN	**334**	**321**	**331**	**124**	**5**
				S.D.	**13**	**27**	**69**	**26**	**2**
128249	Omak	9/17/01	OM-5	MTWF	310	288	252	83	3
	Omak	9/17/01	OM-25	MTWF	307	282	239	80	4
	Omak	9/17/01	OM-4	MTWF	297	273	277	101	3
	Omak	9/17/01	OM-3	MTWF	294	269	238	93	3
	Omak	9/17/01	OM-16	MTWF	291	270	212	74	3
	Omak	9/17/01	OM-6	MTWF	286	265	227	82	3
	Omak	9/17/01	OM-2	MTWF	280	258	199	77	4
	Omak	9/17/01	OM-8	MTWF	265	241	171	67	1
	Omak	9/17/01	OM-14	MTWF	255	233	129	42	3
	Omak	9/17/01	OM-20	MTWF	253	235	145	45	2
				n	**10**	**10**	**10**	**10**	**10**
				MEAN	**284**	**261**	**209**	**74**	**3**
				S.D.	**20**	**19**	**48**	**19**	**1**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128242	Monse	11/6/01	MO-15	MTWF	397	366	510	196	6
	Monse	11/6/01	MO-16	MTWF	376	350	436	156	4
	Monse	11/21/01	MO-39	MTWF	362	335	411	174	4
	Monse	11/6/01	MO-17	MTWF	358	331	382	146	5
	Monse	11/21/01	MO-40	MTWF	310	285	227	114	4
	Monse	11/21/01	MO-38	MTWF	305	282	208	77	3
	Monse	11/6/01	MO-18	MTWF	291	264	217	84	1
	Monse	11/21/01	MO-37	MTWF	275	250	158	64	2
	Monse	11/21/01	MO-34	MTWF	261	244	157	62	3
				n	**9**	**9**	**9**	**9**	**9**
				MEAN	**326**	**301**	**301**	**119**	**4**
				S.D.	**48**	**45**	**134**	**50**	**2**
128243	Monse	11/6/01	MO-27	MTWF	259	235	164	63	1
	Monse	11/21/01	MO-42	MTWF	256	233	140	48	2
	Monse	9/18/01	MO-12	MTWF	245	225	116	36	1
	Monse	9/18/01	MO-14	MTWF	245	224	132	54	1
	Monse	11/21/01	MO-36	MTWF	244	224	103	36	1
	Monse	11/21/01	MO-41	MTWF	244	224	112	39	3
	Monse	11/6/01	MO-19	MTWF	242	226	128	47	3
	Monse	9/18/01	MO-11	MTWF	240	220	125	44	3
	Monse	9/18/01	MO-13	MTWF	240	219	120	43	1
				n	**9**	**9**	**9**	**9**	**9**
				MEAN	**246**	**226**	**127**	**46**	**2**
				S.D.	**7**	**5**	**18**	**9**	**1**
128244	Monse	11/6/01	MO-20	MTWF	240	218	96	35	2
	Monse	11/6/01	MO-24	MTWF	236	220	97	30	3
	Monse	11/6/01	MO-22	MTWF	225	208	88	nm	1
	Monse	11/6/01	MO-21	MTWF	221	205	83	nm	2
	Monse	11/6/01	MO-23	MTWF	220	201	86	28	1
	Monse	11/21/01	MO-35	MTWF	219	204	79	26	2
	Monse	11/6/01	MO-26	MTWF	202	186	65	20	2
	Monse	11/6/01	MO-25	MTWF	198	177	57	20	1
				n	**8**	**8**	**8**	**6**	**8**
				MEAN	**220**	**202**	**81**	**nc**	**2**
				S.D.	**15**	**15**	**14**	**nc**	**1**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128246	Oroville	5/9/01	11	SMBS	424		1,111	394	**5**
				n	**1**	**1**	**1**	**1**	**1**
				MEAN	**424**		**1,111**	**394**	**5**
				S.D.					
128247	Oroville	5/9/01	10	SMBS	347		630	174	**R**
	Oroville	5/9/01	9	SMBS	325		525	152	**3**
	Oroville	5/9/01	12	SMBS	310		422	124	**R**
	Oroville	5/9/01	13	SMBS	281		309	116	**R**
				n	**4**		**4**	**4**	**1**
				MEAN	**316**		**472**	**142**	**nc**
				S.D.	**28**		**138**	**27**	**nc**
128248	Oroville	11/5/01	OR-45	SMBS	248	237	206	65	**1**
				n	**1**	**1**	**1**	**1**	**1**
				MEAN	**248**	**237**	**206**	**65**	**1**
				S.D.					

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128250	Omak	9/17/01	OM-28	SMBS	433	415	1,330	420	6
	Omak	11/6/01	OM-39	SMBS	421	385	1,102	292	7
	Omak	11/6/01	OM-40	SMBS	360	343	641	190	4
	Omak	9/18/01	RV-19	SMBS	316	292	469	164	3
	Omak	9/17/01	OM-29	SMBS	315	302	412	146	3
	Omak	11/6/01	OM-41	SMBS	308	293	388	144	3
	Riverside	9/18/01	RV-20	SMBS	300	286	455	162	3
				n	**7**	**7**	**7**	**7**	**7**
				MEAN	**350**	**331**	**685**	**217**	**4**
				S.D.	**56**	**52**	**377**	**103**	**2**
128251	Riverside	11/5/01	RV-29	SMBS	300	285	405	136	3
	Omak	9/17/01	OM-30	SMBS	296	285	332	122	3
	Omak	11/6/01	OM-43	SMBS	291	278	347	98	3
	Omak	11/6/01	OM-44	SMBS	290	275	309	98	3
	Omak	11/6/01	OM-42	SMBS	288	265	303	82	3
	Omak	11/6/01	OM-45	SMBS	274	260	270	71	3
	Omak	11/6/01	OM-46	SMBS	270	257	273	94	3
				n	**7**	**7**	**7**	**7**	**7**
				MEAN	**287**	**272**	**320**	**100**	**3**
				S.D.	**11**	**12**	**47**	**22**	**0**
128252	Omak	11/6/01	OM-48	SMBS	260	243	218	80	2
	Riverside	11/5/01	RV-30	SMBS	223	212	148	47	1
	Omak	11/6/01	OM-47	SMBS	223	212	145	nm	1
	Omak	9/17/01	OM-31	SMBS	220	211	154	54	1
	Omak	11/6/01	OM-49	SMBS	203	195	112	28	1
	Omak	11/6/01	OM-51	SMBS	181	171	82	nm	1
	Omak	11/6/01	OM-50	SMBS	179	170	69	20	1
				n	**7**	**7**	**7**	**5**	**7**
				MEAN	**213**	**202**	**133**	**nc**	**1**
				S.D.	**28**	**26**	**50**	**nc**	**0.4**

Table D-1 (continued). Sample biological data on Okanogan River fish collected for DDT/PCB analysis.

Samp. No.	Location	Date	Fish No.	Species	Total Length (mm)	Fork Length (mm)	Weight (g)	Total Fillet Weight (g)	Age (yrs)
128253	Monse	9/18/01	MO-3	SMBS	343	325	518	158	2
	Monse	9/18/01	MO-6	SMBS	332	319	521	196	3
	Monse	9/18/01	MO-7	SMBS	326	314	498	180	3
	Monse	9/18/01	MO-2	SMBS	325	311	518	202	3
	Monse	9/18/01	MO-4	SMBS	309	295	424	158	3
				n	**5**	**5**	**5**	**5**	**5**
				MEAN	**327**	**313**	**496**	**179**	**3**
				S.D.	**12**	**11**	**41**	**21**	**0.4**
128254	Monse	9/18/01	MO-5	SMBS	305	294	380	121	3
	Monse	9/18/01	MO-1	SMBS	300	287	360	138	3
	Monse	9/18/01	MO-10	SMBS	283	271	271	97	3
	Monse	9/18/01	MO-8	SMBS	265	253	228	74	3
	Monse	11/6/01	MO-32	SMBS	225	216	140	43	2
				n	**5**	**5**	**5**	**5**	**5**
				MEAN	**276**	**264**	**276**	**95**	**3**
				S.D.	**32**	**31**	**98**	**38**	**0.4**
128255	Monse	9/18/01	MO-9	SMBS	209	201	110	32	1
	Monse	11/6/01	MO-31	SMBS	209	199	116	40	1
	Monse	11/6/01	MO-28	SMBS	199	191	98	30	1
	Monse	11/6/01	MO-33	SMBS	196	189	94	31	1
	Monse	11/6/01	MO-29	SMBS	186	175	70	nm	1
				n	**5**	**5**	**5**	**4**	**5**
				MEAN	**200**	**191**	**98**	**nc**	**1**
				S.D.	**10**	**10**	**18**	**nc**	**0**

R=regenerated scales, cannot determine age
nm=not measured
nc=not calculated due to missing data

Appendix E

Sample Precision and
Manchester Environmental Laboratory Case Narratives

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Table E-1. Precision of laboratory and field replicate samples.

Sample No.1	Sample No.2	Sample No.3	Matrix	Analysis	QA Type	Result 1	Result 2	Result 3	RPD*
01158026	01158026		water (mg/l)	TSS	lab dup.	5	5		0%
01158026	01158028		water (mg/l)	TSS	field rep.	5	5		0%
01158026	01158026		water (mg/l)	TOC	lab dup.	5.0	5.0		0%
01158026	01158028		water (mg/l)	TOC	field rep.	5.0	5.0		0%
01208184	01208185		water (ng/l)	4,4'-DDE	field rep.	1.0	2.5		21%
01208184	01208185		water (ng/l)	2,4'-DDE	field rep.	u(1.6)	u(1.7)		nc
01208184	01208185		water (ng/l)	4,4'-DDD	field rep.	0.4	0.6		10%
01208184	01208185		water (ng/l)	2,4'-DDD	field rep.	u(1.6)	u(1.7)		nc
01208184	01208185		water (ng/l)	4,4'-DDT	field rep.	0.8	1.1		8%
01208184	01208185		water (ng/l)	2,4'-DDT	field rep.	u(1.6)	u(1.7)		nc
01208184	01208185		water (mg/l)	TSS	field rep.	16	17		2%
01208190	01208190		water (mg/l)	TSS	lab dup.	22	23		1%
01208198	01208198		water (mg/l)	TSS	lab dup.	4	4		0%
01168034	01168034		water (mg/l)	TSS	lab dup.	4	4		0%
01168032	01168032		water (mg/l)	TOC	lab dup.	4.6	4.6		0%
02208036	02208036		water (mg/l)	TSS	lab dup.	26	26		0%
02208036	02208036		water (mg/l)	TOC	lab dup.	4.7	4.9		1%
02208030	02208030		water (mg/l)	TOC	lab dup.	4.2	4.1		1%
01248213	01248213		sediment (ng/g,dw)	TOC104	lab dup.	4.06	3.80		2%
01248222	01248222		sludge (ng/g,dw)	TOC104	lab dup.	41.3	41.1		0%
01248223	01248223	01248223	sludge (ng/g,dw)	TOC104	lab trip.	32.5	33.8	32.6	2%
01248211	01248212		sediment (ng/g,dw)	2,4'-DDE	lab dup.	1.1	1.2		2%
01248211	01248211		sediment (ng/g,dw)	4,4'-DDE	lab dup.	36	38		1%
01248211	01248211		sediment (ng/g,dw)	2,4'-DDD	lab dup.	4.9	4.7		1%
01248211	01248211		sediment (ng/g,dw)	4,4'-DDD	lab dup.	39	38		1%
01248211	01248211		sediment (ng/g,dw)	2,4'-DDT	lab dup.	u(1.2)	1.4		nc
01248211	01248212		sediment (ng/g,dw)	4,4'-DDT	lab dup.	1.8	24		43%
01248211	01248211		sediment (ng/g,dw)	PCB-1248	lab dup.	1.2	u(2.3)		nc
01248211	01248212		sediment (ng/g,dw)	DDMU	lab dup.	6.1	6.5		2%
01378105	01378105	01378105	sediment (ng/g,dw)	TOC104	lab trip.	1.91	1.92	2.03	3%
01378121	01378121		sediment (ng/g,dw)	TOC104	lab dup.	1.71	1.81		1%
01378120	01378120		sediment (ng/g,dw)	4,4'-DDE	lab dup.	2.2	2.3		1%
01378120	01378120		sediment (ng/g,dw)	2,4'-DDD	lab dup.	4.8	5.4		3%
01378120	01378120		sediment (ng/g,dw)	4,4'-DDD	lab dup.	0.60	0.68		3%
01378120	01378120		sediment (ng/g,dw)	DDMU	lab dup.	0.72	0.92		6%
02128249	02128249		tissue (ng/g,ww)	lipids	lab dup.	4.85	4.31		3%
02128249	02128249		tissue (ng/g,ww)	4,4'-DDE	lab dup.	180	140		6%
02128249	02128249		tissue (ng/g,ww)	4,4'-DDD	lab dup.	20	18		3%
02128249	02128249		tissue (ng/g,ww)	4,4'-DDT	lab dup.	6.3	5.7		3%
02128249	02128249		tissue (ng/g,ww)	2,4'-DDD	lab dup.	2.3	2.2		1%
02128249	02128249		tissue (ng/g,ww)	2,4'-DDT	lab dup.	1.4	1.0		8%
02128249	02128249		tissue (ng/g,ww)	PCB-1248	lab dup.	5.2	4.9		1%
02128249	02128249		tissue (ng/g,ww)	PCB-1254	lab dup.	19	16		4%
02128249	02128249		tissue (ng/g,ww)	PCB-1260	lab dup.	7.9	6.2		6%

RPD=relative percent difference
*relative standard deviation for triplicate results
nc=not calculated due to non-detects

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Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

May 14, 2001

TO: Dave Serdar

FROM: Meredith Jones, Chemist

SUBJECT: **General Chemistry Quality Assurance Memo for Okanogan River TMDL week 15**

SUMMARY

The data generated by the analysis of these samples can be used without qualification. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Okanogan River TMDL week 15 project were received by Manchester Environmental Laboratory on 04/13/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

<u>Instrument Calibration</u>

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

<u>Procedural Blanks</u>

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Spiked Sample Analysis

Spiked sample analyses were performed where applicable with all spike recoveries within acceptance limits of ± 25%. Spiked sample analysis is performed at a frequency of at least 5%.

Precision Data

Spiked sample results and duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%. Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the method detection limit.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Jim Ross at (360) 871-8808 or Meredith Jones at (360) 871-8833 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

May 21, 2001

TO: Dave Serdar

FROM: Meredith Jones, Chemist

SUBJECT: **General Chemistry Quality Assurance Memo for Okanogan River TMDL week 16**

SUMMARY

The data generated by the analysis of these samples can be used without qualification. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Okanogan River TMDL week 16 project were received by Manchester Environmental Laboratory on 04/18/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

Procedural Blanks

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Spiked Sample Analysis

Spiked sample analyses were performed where applicable with all spike recoveries within acceptance limits of ± 25%. Spiked sample analysis is performed at a frequency of at least 5%.

Precision Data

Spiked sample results and duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%. Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the method detection limit.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Jim Ross at (360) 871-8808 or Meredith Jones at (360) 871-8833 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

June 20, 2001

TO: Dave Serdar

FROM: Kamilee Ginder, Chemist

SUBJECT: **General Chemistry Quality Assurance Memo for Okanogan TMDL-20**

SUMMARY

The data generated by the analysis of these samples can be used noting the qualifications discussed in this memo. Total Organic Carbon samples 01208182 and 01208193 are qualified as estimates due to the spiked sample analyzed with them had possible matrix interference causing spike recovery to be slightly higher than the acceptance limit of ±25%. Total Suspended Solids samples 01208180, 01208188, and 01208189 were under the 1 mg/L reporting limit and were therefore qualified. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Okanogan TMDL-20 project were received by Manchester Environmental Laboratory on 05/18/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

Procedural Blanks

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Spiked Sample Analysis

Spiked sample analyses were performed where applicable with all spike recoveries within acceptance limits of ± 25% except as noted in the summary. The spiked sample analyzed with Total Organic Carbon samples 01208182 and 01208193 had a slightly higher recovery than acceptance limits of ± 25%. This indicates the spiked sample has possible matrix interference. All samples associated with this analysis were qualified as estimates. Spiked sample analysis is performed at a frequency of at least 5%.

Precision Data

Spiked sample results and duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%. Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the method detection limit.

Laboratory Control Sample (LCS) Analyses

LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

The "J" qualification signifies the result is an estimate (see SUMMARY).

Please call Jim Ross at (360) 871-8808 or Kamilee Ginder at (360) 871-8826 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

August 21, 2001

TO: Dave Serdar

FROM: Michelle Lee, Chemist

SUBJECT: **General Chemistry Quality Assurance Memo for Okanogan TMDL Project Week 24**

SUMMARY

The data generated by the analysis of these samples can be used without qualification. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Okanogan TMDL Project Week 24 were received by Manchester Environmental Laboratory on 06/22/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

Instrument Calibration

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is monitored continually to ensure control.

Procedural Blanks

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Spiked Sample Analysis

Spiked sample analysis was not performed on this sample set.

Precision Data

Duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within the acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%.

Precision and accuracy specifications are based on sample concentrations greater than four times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than ± the method detection limit.

Laboratory Control Sample (LCS) Analyses

Accuracy is evaluated through the use of a known laboratory control standard. LCS analyses were within the windows established for each parameter.

Please call Michelle Lee at (360) 871-8812 or Jim Ross at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

October 15, 2001

TO: Dave Serdar

FROM: Kamilee Ginder, Chemist

SUBJECT: **General Chemistry Quality Assurance Memo for Okanogan TMDL - 37**

SUMMARY

The data generated by the analysis of these samples can be used without qualification. All analyses requested were evaluated by established regulatory quality assurance guidelines.

SAMPLE INFORMATION

Samples for Okanogan TMDL - 37 project were received by Manchester Environmental Laboratory on 9/14/01 in good condition.

HOLDING TIMES

All analyses were performed within established EPA holding times.

ANALYSIS PERFORMANCE

<u>Instrument Calibration</u>

Instrument calibration was checked by initial calibration verification standards and blanks. All initial and continuing calibration verification standards were within control limits. A correlation coefficient of 0.995 or greater was met. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperature is recorded before and after each analysis batch.

<u>Procedural Blanks</u>

The procedural blanks associated with these samples showed no significant analytical levels of analytes.

Spiked Sample Analysis

Spiked sample analyses were performed to see if the sample matrix contributes bias to the sample results. Spiked sample analysis were performed where applicable with all spike recoveries within acceptance limits of ± 25%. Spiked sample analysis is performed at a frequency of at least 5%.

Precision Data

Duplicate sample results were used to evaluate precision on this sample set. Relative Percent Differences (RPD) for general chemistry parameters were within acceptance limits of ± 20% for duplicate analysis. Laboratory duplication is performed at a frequency of at least 10%.

Precision and accuracy specifications are based on sample concentrations greater than five times the reporting limit. For results near the reporting limit, the criteria are not guaranteed to be better than +/- the reporting limit.

Laboratory Control Sample (LCS) Analyses

Accuracy is evaluated through the use of a known laboratory control standard. LCS analyses were within the windows established for each parameter.

Other Quality Assurance Measures and Issues

The "U" qualification indicates that the analyte was not detected at or above the reporting limit.

Please call Jim Ross at (360) 871-8808 or Kamilee Ginder at (360) 871-8826 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

June 6, 2002

Subject: **General Chemistry Quality Assurance Memo for Okanogan TMDL - 20**

Officer: Dave Serdar

By: Dean Momohara

Summary

The data generated by the analysis of these samples can be used without qualification.

All analyses requested were evaluated by established regulatory quality assurance guidelines.

Sample Information

Samples were received by Manchester Environmental Laboratory on 05/15/02 in good condition.

Holding Times

All analyses were performed within established EPA holding times.

Calibration

The instrument was calibrated in accordance with the appropriate method. Calibration and blank verifications were analyzed directly after the calibration, after every ten samples and at the end of the run. All checks were within control limits. The calibration correlation coefficients was ≥ 0.995. Balances are professionally calibrated yearly and calibrated in-house daily. Oven temperatures are recorded before and after each analysis batch.

Blanks

No analytically significant levels of analyte were detected in the method blanks associated with these samples.

Matrix Spikes

All matrix spike recoveries were within the acceptance limits of ± 25%.

Replicates

All duplicate relative percent differences were within acceptance limits of < 20%.

Laboratory Control Samples

All laboratory control sample recoveries were within acceptance limits.

Please call Dean Momohara at (360) 871-8808 to further discuss this project.

cc: Project File

Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

April 9, 2002

Subject: Okanogan TMDL

Samples: 02128230-02128255

Officer: Dave Serdar

By: Jessica Daiker, Cherlyn Milne, Kelly Donegan
Organic Extractions Unit

Lipids

Analytical Method(s)

These samples were prepared and analyzed following Manchester Laboratory's standard operating procedure for the extraction of percent lipids in tissue using a 50:50 mixture of hexane and methylene chloride. Prior to tare weight, 30 ml beakers were placed into a drying oven for 30 minutes and then placed into a desiccator until completely cooled. The extracts were transferred to a calibrated centrifuge tube and brought to a volume of 10ml. One ml of sample was transferred to a pre-weighed beaker. Solvent was allowed to evaporate off in a hood overnight. Beakers were placed in a drying oven for four hours and then placed into a desiccator until completely cooled. Beaker and residue were weighed.

Holding Times

The method has no sample preservations or holding times.

Blanks

The "U" qualifier included in the result indicates no mass gains from solvent were detected in the laboratory method blanks.

Laboratory Duplicates

Sample 02128249 was analyzed in duplicate. The relative percent difference between the duplicates is 11.9.

Comments

The procedure was modified to reduce weight errors due to moisture collecting on to beakers during storage. Prior to tare weight, the 30 ml beakers were placed in a drying oven for 30 minutes and then into a desiccator until completely cooled. The data are useable as reported.

Manchester Environmental Laboratory
7411 Beach DR E, Port Orchard Washington 98366

CASE NARRATIVE

April 27, 2001

Subject: Okanogan River TMDL - 16
Samples: 01168030 - 01168041
Case No. 1401-01
Officer: Dave Serdar
By: M. Mandjikov

Chlorinated Pesticide Results from the Okanogan River, week 16 – TMDL Study

SUMMARY:
Results reported below the PQL must be considered estimates due to the higher variability of the data in this region. All data reported below the PQL are qualified as estimates, "J".

METHODS:
Each sample was extracted into methylene chloride and solvent exchanged into hexane. Each extract was eluted through a macro Florisil® column with a 6 % preserved diethyl ether / 94 % hexane solution. The samples were split. One split was treated with sulfuric acid and analyzed for the DDT analogs. The other split was held in reserve.
These methods are modifications of EPA SW- 846 methods 3510, 8081, 3620, and 3665 .

BLANKS:
No analytes of interest were detected in the blanks.

SURROGATES:
All samples and blanks were spiked with decachlorobiphenyl (DCB) prior to extraction. All recoveries were within the acceptable range of 50 % - 150%.

Spiked and Duplicate Spikes Samples
Triplicate field samples of 01158024 were provided to the laboratory for analysis. Two of the replicates were spiked with the pesticide analytes to provide a measure of accuracy and precision of this method.

All spike recoveries were within the laboratory control limits of 50% - 150% of the reference value.

The relative percent differences (RPD) between the spiked samples are as follows:

p,p' DDE	%	o,p' DDE	%
p,p' DDD	%	o,p' DDD	%
p,p' DDT	%	o,p' DDT	%

HOLDING TIMES:
The samples were analyzed within the recommended holding times.

DATA QUALIFIERS:

Code	Definition
E	Reported result is an estimate because it exceeds the calibration.
J	The analyte was positively identified. The associated numerical result is an estimate.
N	There is evidence the analyte is present in this sample.
NJ	There is evidence that the analyte is present. The associated numerical result is an estimate.
NAF	Not analyzed for.
REJ	The data are unusable for all purposes.
U	The analyte was not detected at or above the reported result.
UJ	The analyte was not detected at or above the reported estimated result.
Bold Type	The analyte was present in the sample. Used as a visual aid to locate detected compounds on the report sheet.

Manchester Environmental Laboratory
7411 Beach DR E, Port Orchard Washington 98366

CASE NARRATIVE

June 12, 2001

Subject:	Okanogan TMDL - 20
Samples:	01208180 -- 01208199
Case No.	1529-01
Officer:	Dave Serdar
By:	M. Mandjikov

Chlorinated Pesticide Results from the Okanogan River, week 20 – TMDL Study

SUMMARY:
Results reported below the practical quantitation limit (PQL) must be considered estimates due to the higher variability of the data in this region. All data reported below the PQL are qualified as estimates, "J".
During the analysis, the system sensitivity for p,p' DDT increased resulting in an elevation of the control standards above the acceptable recovery limits of 115%. The recoveries of these control standards are 110% - 120%. The results for p,p' DDT may have a high bias and are qualified as estimates, "NJ".
The PQL for some of the o,p' congener results is estimated due to a control standard below the laboratory limits of 85% recovery (~ 75 %).
PCB Aroclors were not detected in any of the samples. Lindane was detected in three samples. The approximate concentrations are as follows:

01208189	.001 ug/L
01208198	.030 ug/L
01208199	.003 ug/L

METHODS:
Each sample was extracted into methylene chloride and solvent exchanged into hexane. Each extract was eluted through a macro Florisil® column with a 6 % preserved diethyl ether / 94 % hexane solution. The samples were split. One split was treated with sulfuric acid and analyzed for the DDT analogs. The other split was held in reserve.
These methods are modifications of EPA SW- 846 methods 3510, 8081, 3620, and 3665 .

BLANKS:
No analytes of interest were detected in the blanks.

SURROGATES:
All samples and blanks were spiked with decachlorobiphenyl (DCB) prior to extraction. All recoveries were within the acceptable range of 50 % - 150%, except 01208191 and 01208199. All results for these samples are qualified as estimates.

SPIKED AND DUPLICATE SPIKED SAMPLES:
Triplicate field samples of 01208194 were provided to the laboratory for analysis. Two of the replicates were spiked with the pesticide analytes to provide a measure of accuracy and precision of this method.

All spike recoveries were within the laboratory control limits of 50% - 150% of the reference value.

The relative percent differences (RPD) between the spiked samples are as follows:

p,p' DDE	4 %	o,p' DDE	2 %
p,p' DDD	7 %	o,p' DDD	6 %
p,p' DDT	5 %	o,p' DDT	4 %

HOLDING TIMES:
The samples were analyzed within the recommended holding times.

DATA QUALIFIERS:

Code	Definition
E	Reported result is an estimate because it exceeds the calibration.
J	The analyte was positively identified. The associated numerical result is an estimate.
N	There is evidence the analyte is present in this sample.
NJ	There is evidence that the analyte is present. The associated numerical result is an estimate.
NAF	Not analyzed for.
REJ	The data are unusable for all purposes.
U	The analyte was not detected at or above the reported result.
UJ	The analyte was not detected at or above the reported estimated result.
Bold Type	The analyte was present in the sample. Used as a visual aid to locate detected compounds on the report sheet.

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Manchester Environmental Laboratory
7411 Beach DR E, Port Orchard Washington 98366

CASE NARRATIVE

October 10, 2001

Subject: Okanogan TMDL, Week 37
Samples: 01378105 – 013781011, 01378115 - 01378121
Case No. 1945-01
Officer: Dave Serdar
By: M. Mandjikov

Polychlorinated Biphenyl and Chlorinated Pesticide Results from the Okanogan River Sediments, Week 37 – TMDL Study

SUMMARY:
Most samples contain traces of PCB Aroclor 1254 below the laboratory practical quantitation limit (PQL). Results reported below the PQL but above the instrument detection limit are qualified as estimates, “J”.

In this method, the target analytes must be identified by both columns within 40% relative percent difference between the results. In several cases, analytes are identified on one column but interference is present on the second column, obscuring the confirmation peak. When there is other evidence that the analytes are present, the lowest value of the two results is reported and qualified, NJ. This result is only reported if the retention time of the reported peak matches the retention time of the standard for that analyte.

All Heptachlor and o,p’ DDT results are qualified as estimates due to low matrix spike recoveries. All Endrin results are qualified as estimates due to a possible low bias.

P,p’ DDMU, a product of the metabolic breakdown of DDT, is identified in these samples and an estimate is reported.

METHODS:

The sediment samples were extracted with acetone using the Soxhlet extraction procedure. Each extract was eluted through a Florisil® column first with 100 % hexane (identified as the 0% diethyl ether fraction) and then with a 50% hexane / 50% preserved diethyl ether fraction. The extracts were solvent exchanged to iso-octane and the volume was adjusted to 1mL..

The 0% fraction extracts were treated with elemental mercury to remove sulfur and then treated with concentrated sulfuric acid. The 50% fraction extracts were treated with mercury and then split. One split was treated with concentrated sulfuric acid and the other analyzed without treatment.
These extracts were then analyzed by GC-ECD.

These methods are modifications of EPA SW- 846 methods 3540, 3550, 3620, 3665, 8081 and 8082.

BLANKS:
No analytes of interest were detected in the blanks.

SURROGATES:
All samples and blanks were spiked with tetrachloro-m-xylene (TMX), dibutylchlorendate (DBC), and decachlorobiphenyl (DCB) prior to extraction. All recoveries were within the acceptable range of 50 % - 150%.

DUPLICATE SAMPLES:
Sample 01378120 was prepared and analyzed in duplicate. The precision between the duplicates as relative percent difference (RPD) is as follows:

Analyte	%RPD	Analyte	%RPD
p,p' DDE	4 %	p,p' DDD	24 %
o,p' DDD	12 %	DDMU	13 %

SPIKED AND DUPLICATE SPIKED SAMPLES:
Triplicate samples of 01378108 were prepared for extraction. Two of the replicates were spiked with chlorinated pesticides and PCB Aroclors 1016 and 1260 to provide a measure of accuracy and precision of this method.

All spike recoveries were within the laboratory control limits of 50% - 150% of the reference value with the following exceptions:

Heptachlor and o,p' DDT had recoveries between 39 – 55 %. All results for these analytes have been qualified as estimates.

All relative percent differences (RPD) between the spiked samples are less than 40% with the exception of Endrin Aldehyde (46%). No Endrin Aldehyde was found native to any of the samples and therefore no data qualification is necessary for this analyte. The average RPD between the spikes is 19%.

LABORATORY CONTROL SAMPLE (LCS)
National Institute of Standards and Technology (NIST) SRM 1944 was used for the preparation of the laboratory control sample (LCS) for this analysis. All target analytes in the reference material with concentrations above the laboratory PQL recovered within 80% - 120% of the certified value with the exception of trans-Chlordane and p,p' DDT. It is suspected that there is interference in this reference material that co-elutes with the peaks of these two analytes.

There are no certified values available for the PCBs as Aroclors in this reference material.

HOLDING TIMES:
The samples were analyzed within the recommended holding times.

DATA QUALIFIERS:

Code	Definition
E	Reported result is an estimate because it exceeds the calibration.
J	The analyte was positively identified. The associated numerical result is an estimate.
N	There is evidence the analyte is present in this sample.
NJ	There is evidence that the analyte is present. The associated numerical result is an estimate.
NAF	Not analyzed for.
REJ	The data are unusable for all purposes.
U	The analyte was not detected at or above the reported result.
UJ	The analyte was not detected at or above the reported estimated result.
Bold Type	The analyte was present in the sample. Used as a visual aid to locate detected compounds on the report sheet.

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Manchester Environmental Laboratory
7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative

June 25, 2003

Subject: Okanogan TMDL, Week 20

Samples: 02208030 - 02208036

Officer: Dave Serdar

By: M. Mandjikov

PCB Aroclor and Chlorinated Pesticide Analysis

Analytical Method(s)

Prior to analysis all glassware was specially cleaned for ultra low level analysis. Each water sample was extracted with methylene chloride following EPA SW-846 Method 3510 then solvent exchanged into hexane. Interferences were removed from the extracts by performing a micro-Florisil cleanup procedure. All extracts were treated with sulfuric acid prior to analysis.

The large volume (LVI) technique employing a 30uL injection was used to concentrate the extract prior to analysis by GC-ECD using methods 8081 and 8082.

Holding Times

All samples were prepared and analyzed within the method holding times.

Calibration

All calibration curves used to quantify results were acceptable and within established QC limits with exception of the closing control for p,p' DDT (4,4' DDT) and the surrogate dibutylchlorendate (DBC) which had low recoveries (~ 79%). All p,p' DDT results are qualified as estimates, either with "NJ" or with "J". No further action was taken as a result of the low DBC recovery as all other QC affecting analytes eluting in the 50% fraction is within control.

Instrument degradation of Endrin and DDT

All analyses of the degradation check standard are within the established QC limits with the exception of the closing degradation check for Endrin. Only analytes eluting in the 50% Florisil fraction could possibly be affected and they are already qualified due to low closing controls.

Blanks

Either co-eluting interferences or congeners of PCB Aroclor 1254 were present at approximately the same concentration in both procedural blanks. The analyte p,p' DDT was also detected in both procedural blanks. The reporting limit for these analytes has been raised to 5 times the amount found in the highest blank.

Surrogates

Each sample, blank and QA sample were spiked with Tetrachloro-m-xylene (TMX), Dibutylchlorendate (DBC) and Decachlorobiphenyl (DCB).

The recoveries of TMX range between 23% and 153 % with the majority recovering below the control limit of 50%. All sample and blank results with TMX recovery are qualified as estimates; "UJ", "J" or "NJ" depending on other QC criteria present. The high recovery for TMX appears to be due to a co-eluting interferent and should be considered an anomaly.

For many of the samples, there was a late eluting "hump" present on the chromatogram indicating the presence of a heavy oil compound in the sample. The presence of oil in a sample is known to affect the recovery of DCB and PCB Aroclors during GC-ECD analysis. Sample 02208034 has the largest visible oil "hump" on the chromatogram and also the lowest recovery of DCB (~ 27%). All results for this sample are qualified as estimates, "UJ" or "NJ".

Laboratory Control Samples

Two blank samples were fortified with the target analytes. The analyte p,p' DDT and Aroclor 1016 recovered above the acceptable laboratory QC limits. All data for p,p' DDT have been qualified as estimates, "NJ" or "J". Aroclor 1016 was not detected in any sample and therefore no qualification is necessary. One of the fortified blanks had a high recovery for o,p' DDE and the other had a very high recovery for TMX. No action is taken on the basis of these recoveries.

The relative percent differences between the replicate laboratory control samples are less than 40% for all analytes with the exception of Aroclor 1016, and the surrogates TMX and DBC. No action is taken on the basis of poor precision.

Comments

There appears to be either low level p,p' DDT and Aroclor 1254 congener contamination or interference present eluting with these analytes that limits the ability to reduce the laboratory reporting limit of this method at this time. There also appears to be interference/contamination of p,p' DDT affecting the recoveries of the spikes and laboratory control samples. The results for these analytes may contain bias and should be considered a high estimate of the amount of the analyte native to these samples.

Data Qualifier Codes

U	-	The analyte was not detected at or above the reported result.
J	-	The analyte was positively identified. The associated numerical result is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
NC	-	Not Calculated
E	-	The concentration exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

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Manchester Environmental Laboratory

7411 Beach DR E, Port Orchard Washington 98366

CASE NARRATIVE

April 26, 2001

Subject:	Okanogan River TMDL - 15
Samples:	01158020 - 01158027
Case No.	1401-01
Officer:	Dave Serdar
By:	M. Mandjikov

Chlorinated Pesticide Results from the Okanogan River, week 15 – TMDL Study

SUMMARY:

Results reported below the PQL must be considered estimates due to the higher variability of the data in this region. All data reported below the PQL are qualified as estimates, "J".

METHODS:

Each sample was extracted into methylene chloride and solvent exchanged into hexane. Each extract was eluted through a macro Florisil® column with a 6 % preserved diethyl ether / 94 % hexane solution. The samples were split. One split was treated with sulfuric acid and analyzed for the DDT analogs. The other split was held in reserve.

These methods are modifications of EPA SW- 846 methods 3510, 8081, 3620, and 3665 .

BLANKS:

No analytes of interest were detected in the blanks.

SURROGATES:

All samples and blanks were spiked with decachlorobiphenyl (DCB) prior to extraction. All recoveries were within the acceptable range of 50 % - 150%.

Spiked and Duplicate Spikes Samples

Triplicate field samples of 01158024 were provided to the laboratory for analysis. Two of the replicates were spiked with the pesticide analytes to provide a measure of accuracy and precision of this method.

All spike recoveries were within the laboratory control limits of 50% - 150% of the reference value.

The relative percent differences (RPD) between the spiked samples are as follows:

p,p' DDE	2 %	o,p' DDE	2 %
p,p' DDD	1 %	o,p' DDD	2 %
p,p' DDT	.5 %	o,p' DDT	2 %

HOLDING TIMES:

The samples were analyzed within the recommended holding times.

DATA QUALIFIERS:

Code	Definition
E	Reported result is an estimate because it exceeds the calibration.
J	The analyte was positively identified. The associated numerical result is an estimate.
N	There is evidence the analyte is present in this sample.
NJ	There is evidence that the analyte is present. The associated numerical result is an estimate.
NAF	Not analyzed for.
REJ	The data are unusable for all purposes.
U	The analyte was not detected at or above the reported result.
UJ	The analyte was not detected at or above the reported estimated result.
Bold Type	The analyte was present in the sample. Used as a visual aid to locate detected compounds on the report sheet.

Manchester Environmental Laboratory

7411 Beach Dr E
Port Orchard Washington 98366
August 9, 2001

Project: **Okanogan TMDL**

Samples: 01248205, 01248207 through 01248208, 012482010 through 01248211, 01248213 through 01248214, 01248216 through 01248217, 01248219, 01248222 through 01248224

Project ID: 166001

To: Dave Serdar

By: Karin Feddersen for Myrna Mandjikov

Polychlorinated Biphenyl and Chlorinated Pesticides

Summary

Low percent solids and interfering compounds affected the reporting limits for these samples.

Significant levels of some non-target analytes were detected in these samples.

DDMU – A product of the metabolic breakdown of DDT. This compound was found in the sediment samples and an estimated value is reported.

Hexachlorobenzene – was present in sample 01248223 at a much higher concentration than in any of the other samples.

Polybrominated diphenyl ethers – Sample 01248223 was analyzed by AED to identify a series of late eluting unknown peaks. The peaks were identified as Bromkal 70 at a level of 1250 ug/Kg. These peaks were also found in samples 01248222 (~2200 ug/Kg) and 01248224 (~1300 ug/Kg).

If a PCB Arochlor pattern was detected below the reporting limit, an estimated value was reported for it. Results reported below the reporting limit but above the instrument detection limit are qualified as estimates, "J". If either the percent difference between the confirming columns or the standard deviation between the congener peaks chosen for quantitation are greater than 40%, then the result is qualified "NJ".

Other analyte values were too low to provide meaningful precision values. Possilbe non-homogeneity may be an explanation for the abnormal variability of p,p'DDT data. The data for

this analyte have not been qualified since the precision result for the spiked samples is acceptable.

Holding Times

These samples were extracted and analyzed within the recommended holding times.

Method Blanks:

No analytes of interest were detected in the method blanks.

Matrix Spikes (MS and MSD):

Triplicate aliquots of sample 01248219 were prepared for extraction. Two of the replicates were spiked with chlorinated pesticide and PCB Arochlors 1016 and 1260 to provide a measure of the accuracy of this method. All spike recoveries are within QC limits of 50% to 150% with several exceptions.

Heptachlor and Aldrin had recoveries between 31% and 52% These analytes generally have similar recoveries in most sediment samples using this method. All results for these analytes have been qualified as estimates.

Very little Endrin aldehyde was recovered from the spiked samples. Endrin aldehyde is a breakdown product of Endrin. There is no evidence of Endrin or any other Endrin breakdown products in the extracts. These analytes would be present if Endrin aldehyde was actually present. All Endrin aldehyde data is qualified "UJ".

There is a significant amount of 4,4'-DDE and 4,4'DDD native to sample 01248219. Thus, accurate quantitation of these analytes in the MS and MSD was not possible. The recoveries for 4,4'DDD are not reported, "NC". The results for these analytes are not qualified.

All relative percent differences (RPD) between the spiked samples are less than 40% with the exceptions of Heptachlor (45%) and o,p-DDT (42%).

Laboratory Control Sample (LCS)

Environmental Resource Associates' "PCBs in Soil" was used for the preparation of the LCS for this analysis. The recovery was 60% of the certified value. This recovery is consistent with recoveries from previous PCB analyses. We are currently evaluating this reference material.

The certified value provided by the vendor is 12.6 mg/Kg with acceptance recovery limits of 31% to 129% recovery.

Manchester Environmental Laboratory

7411 Beach Dr E, Port Orchard, Washington 98366

Case Narrative
5/28/2002

Subject: Okanogan TMDL, Spring Fish Study

Sample: 02128230 - 02128255

Officer: Dave Serdar

By: M. Mandjikov

DDT Analogs and PCB Aroclor Analysis

Analytical Method(s)

The tissue samples were extracted underwent clean up procedures and were analyzed using modifications of EPA SW- 846 methods 3540, 3620, 3665, and 8081/8082.

Holding Times

All samples with the exception of sample 02128240 were prepared and analyzed within the method holding times. The sample was initially analyzed within the holding time, however, 4, 4' DDD was found to be above the calibration range. The sample was diluted and re-analyzed after the holding time had been exceeded. This result is reported as an estimate,"J".

Calibration

All initial calibration for the reported pesticides and PCBs are acceptable and within the established QC limits. All bracketing continuing calibration control standards are within the established QC limits on at least one column.

Instrument degradation of Endrin and DDT

All analyses of the degradation check standard are within the established QC limits.

Blanks

There are no target analytes detected in any of the blanks.

Surrogates

Each sample, blank and QA sample was spiked with Tetrachloro-m-xylene (TMX), Dibutylchlorendate (DBC) and Decachlorobiphenyl (DCB). All TMX and DCB recoveries are reasonably acceptable within established QC limits with the exception of DBC.

All DBC recoveries with the exception of samples 02128231, OBT2092A2 and OCT2092A2 were below 50%. This appears to be related to the fish matrix in the 50% Florisil fraction. All of the 50% fractions were acid treated and re-analyzed. However, the recoveries did not improve. Analytes collected in the 50% fraction (4, 4' DDD, 4, 4' DDT) that had acceptable LCS and matrix spike recoveries are not qualified as recovery of the analyte in this matrix has been demonstrated.

2, 4' DDD was not included in the matrix spike or LCS and recovery was not demonstrated. Therefore, all results for this analyte that have low DBC recoveries have been qualified as estimates, "J" or "UJ".

Duplicates

Sample 02128249 was prepared in duplicate to assess the precision of this method. The relative percent differences (RPD) of all target analytes detected are within established QC limits.

Spiked Samples

Sample 02128251 was prepared in triplicate. Two of the replicates were spiked with Aroclors 1016, 1260 and the chlorinated pesticides. The spike recoveries and RPDs of all spiked analytes are within established QC limits.

Laboratory Control Sample

The percent recoveries of all spiked analytes were within established QC limits.

Standard Reference Material (SRM)

Approximately 5 grams of NIST SRM 1974a, Organics in Mussel Tissue (Mytilus edulis) was prepared and analyzed with this project. Only the certified values for p, p' DDE and p, p' DDD are at appropriate concentration for this method. The percent recoveries of these analytes are 99% and 61% respectively.

Comments

There is evidence that most of the samples in this project contain a mixture of the PCB Aroclors 1248, 1254, and 1260. In addition, weathering due to metabolic processes as well as interference from other Aroclors present in the samples affect the congener ratios and have distorted the individual Aroclor patterns. Consequently, several of the Aroclor results are qualified as estimates, "NJ".

All data can be used as qualified.

Data Qualifier Codes

U	-	The analyte was not detected at or above the reported result.
J	-	The analyte was positively identified. The associated numerical result is an estimate.
UJ	-	The analyte was not detected at or above the reported estimated result.
REJ	-	The data are unusable for all purposes.
NAF	-	Not analyzed for.
N	-	For organic analytes there is evidence the analyte is present in this sample.
NJ	-	There is evidence that the analyte is present. The associated numerical result is an estimate.
NC	-	Not Calculated
E	-	The concentration exceeds the known calibration range.
bold	-	The analyte was present in the sample. (Visual Aid to locate detected compounds on report sheet.)

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Appendix F

Sample Results

Table F-1. DDT concentrations (ng/l) in lower Okanogan River tributaries, July 1995 (Johnson et al, 1997).

Location	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
Nine Mile Cr.	80.2	7/24/95	20	2	**3.1**	**1.4**	**1.9**	**6.4**	nd	nd	nd
Similkameen R.	74.1	7/24/95	38,515	3	u(1)	u(1)	u(1)	nd	nd	nd	nd
Whitestone Cr.	62.4	7/24/95	122	27	**1**	u(1)	u(1)	**1**	nd	nd	nd
Antoine Cr.	61.2	7/24/95	45	25	**1.5**	u(1)	u(1)	**1.5**	nd	nd	nd
Bonaparte Cr.	56.7	7/25/95	11	4	u(1)	u(1)	u(1)	nd	nd	nd	nd
Omak Cr.	32.0	7/24/95	193	3	u(1)	u(1)	u(1)	nd	nd	nd	nd
Elgin Cr.	28.4	7/25/95	34	41	**3.1**	u(1)	**2.4**	**5.5**	nd	nd	nd
Tallant Cr.	19.5	7/24/95	8	122	**180**	**37**	**280**	**497**	**3**	**11**	**29**
Loup Loup Cr.	16.9	7/24/95	31	6	u(1)	u(1)	u(1)	nd	nd	nd	nd

detected values in **bold**
u=undetected at practical quantitation limits in parentheses

Table F-2. DDT concentrations (ng/l) in lower Okanogan River tributaries, August 1995 (Johnson et al, 1997).

Location	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
Haynes Cr. BC	82.8	8/30/95	6	2	**2.6**	u(1)	u(1)	**2.6**	nd	nd	nd
Nine Mile Cr.	80.2	8/31/95	8	1	**2.5**	**1.5**	**1.4**	**5.4**	nd	nd	nd
Mosquito Cr.	67.4	8/31/95	28	11	**1.6**	**1.6**	u(1)	**3.2**	nd	nd	nd
Whitestone Cr.	62.4	8/31/95	144	14	**0.6**	u(1)	u(1)	**0.6**	nd	nd	nd
Antoine Cr.	61.2	8/31/95	65	26	**0.7**	u(1)	u(1)	**0.7**	nd	nd	nd
Aeneas Cr.	52.9	8/31/95	57	1	u(1)	u(1)	u(1)	nd	nd	nd	nd
Elgin Cr.	28.4	8/31/95	62	156	**5.6**	u(1)	**2.4**	**8**	nd	nd	nd
Tallant Cr.	19.5	8/31/95	8	28	**74**	**20**	**94**	**188**	**1.2**	**5.6**	**10.4**

detected values in **bold**
u=undetected at practical quantitation limits in parentheses

Table F-3. DDT concentrations (ng/l) in lower Okanogan River tributaries, April 2001 (present study).

Sample No. (01-)	**Location**	**RM**	**Date**	**Flow (l/s)**	**TOC (mg/l)**	**TSS (mg/l)**	**4,4'-DDE**	**4,4'-DDD**	**4,4'-DDT**	**t-DDT**	**2,4'-DDE**	**2,4'-DDD**	**2,4'-DDT**
168039	Nine Mile Cr.	80.2	4/17/01	99	5.4	12	**1.8**	**0.4**	**1.3**	**3.5**	u(0.8)	u(0.8)	**0.4**
168038	Tonasket Cr.	77.8	4/17/01	361	5.3	4	**1.5**	u(0.8)	**1**	**2.5**	u(0.8)	u(0.8)	**0.4**
158020	Mosquito Cr.	67.4	4/11/01	0.24	4.0	7	**0.8**	**0.7**	u(0.8)	**1.5**	u(0.8)	u(0.8)	u(0.8)
158021	Whitestone Cr.	62.4	4/11/01	114	4.0	10	**0.6**	u(0.8)	u(0.8)	**0.6**	u(0.8)	u(0.8)	u(0.8)
168037	Antoine Cr.	61.2	4/17/01	10	3.2	12	**5.2**	**1.1**	**1.7**	**8**	u(0.8)	**1.3**	**0.5**
168030	Siwash Cr.	57.3	4/16/01	24	5.7	1	**0.5**	u(0.8)	u(0.8)	**0.5**	u(0.8)	u(0.8)	u(0.8)
158022	Bonaparte Cr.	56.7	4/11/01	62	6.4	21	**0.4**	u(0.8)	u(0.8)	**0.4**	u(0.8)	u(0.8)	u(0.8)
168031	Aeneas Cr.	52.9	4/16/01	95	1.4	u(1)	**0.4**	u(0.8)	u(0.8)	**0.4**	u(0.8)	u(0.8)	u(0.8)
159023	Chewiliken Cr.	50.7	4/11/01	9	4.1	u(1)	u(0.8)	u(0.8)	u(0.8)	nd	u(0.8)	u(0.8)	u(0.8)
168032	Tunk Cr.	45.0	4/16/01	106	4.6	2	u(0.9)	u(0.9)	u(0.9)	nd	u(0.9)	u(0.9)	u(0.9)
168033	Johnson Cr.	40.6	4/16/01	79	2.1	11	u(0.8)	u(0.8)	u(0.8)	nd	u(0.8)	u(0.8)	u(0.8)
158025	Wanacut Cr.	35.0	4/12/01	29	4.3	1	u(0.8)	u(0.8)	u(0.8)	nd	u(0.8)	u(0.8)	u(0.8)
158026	Omak Cr.	32.0	4/12/01	382	5.0	5	u(0.8)	u(0.8)	u(0.8)	nd	u(0.8)	u(0.8)	u(0.8)
158027	Elgin Cr.	28.4	4/12/01	27	2.5	7	**3.7**	**0.4**	**1.8**	**5.9**	u(0.8)	u(0.8)	**0.4**
168041	Salmon Cr.	25.7	4/17/01	284	2.6	1	**0.4**	u(0.9)	u(0.9)	**0.4**	u(0.9)	u(0.9)	u(0.9)
	Tallant Cr.	19.5	4/16/01	0									
	Loup Loup Cr.	16.9	4/16/01	0									
168035	Chiliwist Cr.	15.1	4/16/01	71	2.8	11	**0.4**	u(0.8)	u(0.8)	0.4	u(0.8)	u(0.8)	u(0.8)

detected values in **bold**
u=undetected at practical quantitation limits in parentheses

Table F-4. DDT concentrations (ng/l) in lower Okanogan River tributaries, May 2001 (present study).

Sample No. (01-)	Location	RM	Date	Flow (l/s)	TOC (mg/l)	TSS (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
208188	Nine Mile Cr.	80.2	5/16/01	32	3.8	u(1)	**1.4**	**0.6**	**1.5**	**3.5**	u(1.7)	u(1.7)	u(1.7)
208187	Tonasket Cr.	77.8	5/16/01	26	6.1	9	**1.2**	u(1.7)	**1.1**	**2.3**	u(1.7)	u(1.7)	u(1.7)
208186	Mosquito Cr.	67.4	5/16/01	0.5	4.0	2	**1.7**	**0.4**	**1.4**	**3.5**	u(1.7)	u(1.7)	u(1.7)
208191	Whitestone Cr.	62.4	5/16/01	85	4.5	5	**0.4**	u(1.6)	u(1.6)	**0.4**	u(1.6)	u(1.6)	u(1.6)
208184/208185	Antoine Cr.	61.2	5/16/01	31	3.7	16	**1.8**	**0.5**	**1**	**3.3**	u(1.6)	u(1.6)	u(1.6)
	Siwash Cr.	57.3	5/16/01	0									
208193	Bonaparte Cr.	56.7	5/17/01	153	5.8	55	**0.4**	u(1.7)	u(1.7)	**0.4**	u(1.7)	u(1.7)	u(1.7)
208194	Aeneas Cr.	52.9	5/17/01	78	1.5	2	**0.4**	u(1.6)	u(1.6)	**0.4**	u(1.6)	u(1.6)	u(1.6)
	Chewiliken Cr.	50.7	5/17/01	0									
208195	Tunk Cr.	45.0	5/17/01	197	6.6	16	u(1.7)	u(1.7)	u(1.7)	nd	u(1.7)	u(1.7)	u(1.7)
208196	Johnson Cr.	40.6	5/17/01	29	2.4	12	u(1.7)	u(1.7)	u(1.7)	nd	u(1.7)	u(1.7)	u(1.7)
208197	Wanacut Cr.	35.0	5/17/01	14	4.7	1	u(1.7)	u(1.7)	u(1.7)	nd	u(1.7)	u(1.7)	u(1.7)
208182	Omak Cr.	32.0	5/15/01	596	4.5	35	u(1.7)	u(1.7)	u(1.7)	nd	u(1.7)	u(1.7)	u(1.7)
208181	Elgin Cr.	28.4	5/15/01	19	2.5	20	**5.8**	**0.9**	**2.5**	**9.2**	u(1.6)	u(1.6)	u(1.6)
	Salmon Cr.	25.7	5/15/01	0									
	Tallant Cr.	19.5	5/15/01	0									
208180	Loup Loup Cr.	16.9	5/15/01	3	3.6	u(1)	**0.7**	u(1.6)	**0.7**	**1.4**	u(1.6)	u(1.6)	u(1.6)
208183	Chiliwist Cr.	15.1	5/16/01	27	2.6	1	u(1.7)	u(1.7)	u(1.7)	nd	u(1.7)	u(1.7)	u(1.7)

detected values in **bold**
u=undetected at practical quantitation limits in parentheses

Table F-5. DDT and PCB concentrations (ng/l) in the Similkameen River, May 2002 (present study).

Sample No.	Location	RM	Date	Flow (l/s)	TOC (mg/l)	TSS (mg/l)	DDT[a]	PCB[b]
02208032	Similkameen R.	3.7	5/13/02	113,551	5	14	u(0.067)	u(0.67)

[a]Results for 4,4-DDE, 4,4'-DDD, 2,4'-DDE, 2,4'-DDD, and 2,4'-DDT. Practical quantitation limit for 4,4-DDT was 0.08 ng/l.
[b]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
u=undetected at practical quantitation limits in parentheses

Table F-6. DDT concentrations (ng/l) in the Okanogan River, July-August 1995 (Johnson et al, 1997).

Location	RM	Date	Flow (l/s)	TSS (mg/l)	DDT[a]
Okanogan R. @ Osoyoos BC	91.2	8/30/95	24,975	3	u(1)
Okanogan R. @ Malott	17	7/25/95	49,277	5	u(1)

[a]Results for 4,4-DDE, 4,4'-DDD, and 4,4'-DDT. Practical quantitation limits for 2,4'-DDE, 2,4'-DDD, and 2,4'-DDT were not determined.
u=undetected at practical quantitation limits in parentheses

Table F-7. DDT and PCB concentrations (ng/l) in the Okanogan River, May 2002 (present study).

Sample No. (02-)	Location	RM	Date	Flow (l/s)	TOC (mg/l)	TSS (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDT[a]	PCB[b]
208031	Okanogan R. @ Zosel Dam	77.4	5/13/02	33,131	4.7	18	**0.23**	**0.29**	u(0.080)	**0.52**	u(0.066)	u(0.66)
208033	Okanogan R. @ Riverside	40.6	5/13/02	137,620	4.2	20	**0.22**	**0.14**	u(0.076)	**0.36**	u(0.066)	u(0.66)
208036	Okanogan R. @ Malott	17	5/14/02	146,681	4.8	26	**0.17**	**0.16**	u(0.10)	**0.33**	u(0.064)	u(0.64)

[a]Results for 2,4'-DDT, 2,4'-DDE, and 2,4'-DDD
[b]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016
u=undetected at practical quantitation limits in parentheses

Table F-8. DDT and PCB concentrations (ng/l) in Okanogan River basin STP water, 1988-1995.

Location	Ref.	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	PCB[a]
Okanogan STP influent	b	24.8	10/18/88	17.6	260	u(60)	u(60)	u(60)	u(300)
Okanogan STP effluent	b	24.8	10/18/88	17.6	8	u(60)	u(60)	u(60)	u(300)
Okanogan STP effluent	c	24.8	7/25/95			u(8)	u(8)	u(8)	

[a]Results shown are for PCB Aroclors 1260, 1254, 1248, 1242, 1232, 1221, and 1016
[b]Reif, 1990
[c]Johnson et al., 1997
u=undetected at practical quantitation limits in parentheses

Table F-9. DDT and PCB concentrations (ng/l) in Okanogan River basin STP effluent, 2001-2002.

Sample No.	Location	RM	Date	Flow (l/s)	TSS (mg/l)	TOC (mg/l)	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDT[a]	PCB[b]
01168040	Oroville STP	c	4/17/01	6	1	8.9	**0.5**	u(0.9)	**0.6**	**1.1**	u(0.9)	nd*
01208189	"	"	5/16/01	7	u(1)	7.1	u(1.7)	u(1.7)	**0.7**	**0.7**	u(1.7)	nd*
02208035	"	"	5/14/02	7	u(1)	6.4						u(0.63)[d]
01168036	Omak STP	29.8	4/17/01	24	2	4.8	u(0.8)	u(0.8)	u(0.8)	nd	u(0.8)	nd*
01208198	"	"	5/17/01	26	4	4.2	u(1.6)	u(1.6)	u(1.6)	nd	u(1.6)	nd*
02208030	"	"	5/13/02	26	3	4.2						u(0.66)
01168034	Okanogan STP	24.8	4/16/01	16	4	8.6	**0.7**	u(0.8)	**0.6**	**1.3**	u(0.8)	nd*
01208199	"	"	5/17/01	16	4	10.8	**0.4**	**0.4**	**1**	**1.8**	u(1.7)	nd*
02208034	"	"	5/14/02	11	5	9.9						**0.39**[e]

[a]Results for 2,4'-DDT, 2,4'-DDE, and 2,4'-DDD

[b]Results shown are for PCB Aroclors 1268, 1262, 1260, 1254, 1248, 1242, 1232, 1221, and 1016

[c]Similkameen River mile 4.2

[d]Practical quantitation limit was 0.94 ng/l for PCB-1254

[e]Concentration of PCB-1248. Other Aroclors undetected at a practical quantitation limit of 0.65 ng/l

detected values in **bold**

u=undetected at practical quantitation limit in parentheses

*no practical quantitation limit determined

Table F-10. DDT and PCB concentrations (ng/g, dw) in Okanogan STP sludge, 1988 (Reif, 1990).

Location	RM	Date	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	PCB[a]
Okanogan STP	24.8	10/18/88	**130**	**57**	**110**	**297**	u(200)

[a]Results shown are for PCB Aroclors 1260, 1254, 1248, 1242, 1232, 1221, and 1016
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-11. DDT concentrations (ng/g, dw) in Okanogan River basin STP sludge, 2001.

Sample No. (01-)	Location	RM	Date	% TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
248224	Oroville STP	a	6/15/01	36.7	**180**	**26**	**36**	**242**	**9.1**	u(22)	u(22)
248222	Omak STP	29.8	6/15/01	40.3	**68**	u(45)	**23**	**91**	u(23)	u(45)	u(23)
248223	Okanogan STP	24.8	6/15/01	32.0	**110**	**23**	**40**	**173**	**4.2**	**6.3**	**5.5**

[a]Similkameen River mile 4.2
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-12. PCB concentrations (ng/g, dw) in Okanogan River basin STP sludge, 2001.

Sample No. (01-)	Location	RM	Date	% TOC	PCB-1260	PCB-1254	PCB-1248	PCB-1242	PCB-1232	PCB-1221	PCB-1016	t-PCB
248224	Oroville STP	a	6/15/01	36.7	**48**	**130**	**95**	u(43)	u(43)	u(43)	u(43)	**273**
248222	Omak STP	29.8	6/15/01	40.3	**41**	**100**	**63**	u(45)	u(45)	u(45)	u(45)	**204**
248223	Okanogan STP	24.8	6/15/01	32.0	**51**	**120**	**63**	u(42)	u(42)	u(42)	u(42)	**234**

[a]Similkameen River mile 4.2
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-13. PCB concentrations (ng/g, dw) in Okanogan River sediments, 1984-1994.

Location	Ref.	RM	Date	% TOC	% Fines	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDT	PCB-1260
Okanogan R. blw. Malott	a	12	1984	1	62	**21**	**18**	**17**	**56**		**21**
Okanogan R. above Brewster	b	7	9/13/94	2	73	**6.4**	**12**	nd (12)	**18**	u(12)[c]	u(47)[d]

[a]Hopkins et al, 1985
[b]Davis and Serdar, 1996
[c]Results for 2,4'-DDT, 2,4'-DDE, and 2,4'-DDD
[d]Same result obtained for PCB-1254, PCB-1248, and PCB-1242
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-14. DDT concentrations (ng/g, dw) in Osoyoos Lake sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	Year	%TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
248205	0-1	2001.0	4.37%	**35**	**43**	**3.0**	**81**	**1.1**	**5.8**	u(1.4)
378115	1-2	1999.0	3.78%	**32**	**42**	**0.79**	**75**	**0.89**	**5.1**	u(1.4)
248207	2-3	1998.8	4.25%	**75**	**77**	**96**	**248**	**2.3**	**8.9**	u(2.7)
378116	3-4	1998.5	4.03%	**34**	**39**	**13**	**86**	**0.91**	**4.5**	u(1.3)
248208	4-5	1998.3	4.47%	**39**	**44**	u(5.3)	**83**	**1.2**	**5.8**	u(1.3)
248210	6-7	1996.5	4.23%	**37**	**20**	**1.0**	**58**	**1.1**	**5.6**	u(1.2)
248211	8-9	1993.5	4.05%	**37**	**38**	**13**	**88**	**1.2**	**4.8**	**1.0**
248213	10-11	1991.0	3.93%	**38**	**43**	**4.0**	**85**	u(1.1)	**4.7**	u(1.1)
248214	13-14	1988.0	3.99%	**35**	**45**	**4.8**	**84.8**	u(1.0)	**6.0**	u(1.0)
248216	16-17	1984.8	3.72%	**39**	**47**	**1.8**	**87.8**	**1.4**	**6.0**	u(0.94)
248217	19-20	1981.4	3.60%	**36**	**54**	**6.4**	**96.4**	**1.5**	**7.5**	u(0.85)
248219	23-24	1975.8	3.04%	**92**	**150**	**12**	**254**	**4.2**	**21**	u(1.7)
378117	27-28	1967.2	2.43%	**42**	**92**	**1.6**	**135.6**	**1.6**	**11**	u(0.72)
378118	31-32	1956.6	2.12%	**21**	**48**	**3.5**	**72.5**	**0.91**	**6.0**	u(0.67)
378119	35-36	1944.8	1.93%	**3.7**	**8.6**	u(0.61)	**12.3**	u(0.61)	**1.0**	u(0.61)
378120	39-40	1932.4	1.76%	**2.2**	**5.1**	u(0.56)	**7.3**	u(0.56)	**0.64**	u(0.56)
378121	44-45	1916.9	1.76%	u(0.55)	**0.22**	u(0.55)	**0.22**	u(0.55)	u(0.55)	u(0.55)

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-15. PCB concentrations (ng/g, dw) in Osoyoos Lake sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	PCB-1260	PCB-1254	PCB-1248	PCB-1242	PCB-1232	PCB-1221	PCB-1016	t-PCB
248205	0-1	u(2.8)	u(2.8)	**1.1**	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**1.1**
378115	1-2	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	nd
248207	2-3	u(5.4)	u(5.4)	**2.2**	u(5.4)	u(5.4)	u(5.4)	u(5.4)	**2.2**
378116	3-4	u(5.3)	u(5.3)	u(5.3)	u(5.3)	u(5.3)	u(5.3)	u(5.3)	nd
248208	4-5	u(2.6)	**0.79**	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(2.6)	**0.79**
248210	6-7	u(2.5)	**0.74**	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	**0.74**
248211	8-9	u(2.3)	u(2.3)	**1.2**	u(2.3)	u(2.3)	u(2.3)	u(2.3)	**1.2**
248213	10-11	u(2.2)	u(2.2)	**1.1**	u(2.2)	u(2.2)	u(2.2)	u(2.2)	**1.1**
248214	13-14	u(2.0)	u(2.0)	**1.0**	u(2.0)	u(2.0)	u(2.0)	u(2.0)	**1.0**
248216	16-17	u(1.9)	**0.75**	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(1.9)	**0.75**
248217	19-20	u(1.7)	u(1.7)	**0.85**	u(1.7)	u(1.7)	u(1.7)	u(1.7)	**0.85**
248219	23-24	u(3.3)	**2.7**	**2.0**	u(3.3)	u(3.3)	u(3.3)	u(3.3)	**4.7**
378117	27-28	u(2.9)	**1.4**	u(2.9)	u(2.9)	u(2.9)	u(2.9)	u(2.9)	**1.4**
378118	31-32	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	nd
378119	35-36	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	nd
378120	39-40	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	nd
378121	44-45	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	nd

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-16a. Miscellaneous pesticide concentrations (ng/g, dw) in Osoyoos Lake sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	DDMU	cis-Chlordane	trans-Chlordane	alpha-BHC	beta-BHC	gamma-BHC	delta-BHC	Heptachlor	Aldrin	Heptachlor epoxide
248205	0-1	**5.9**	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(1.4)	u(1.4)	u(2.8)
378115	1-2	**3.5**	u(1.4)	u(1.4)	u(1.4)	u(1.4)	u(1.4)	u(1.4)	u(1.4)	u(1.4)	u(1.4)
248207	2-3	**14**	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(11)	u(11)	u(2.7)	u(2.7)	u(5.4)
378116	3-4	**3.5**	u(1.3)	u(1.3)	u(1.3)	u(1.3)	u(1.3)	u(1.3)	u(1.3)	u(1.3)	u(1.3)
248208	4-5	**7.1**	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(6.6)	u(6.6)	u(1.3)	u(1.3)	u(2.6)
248210	6-7	**6.9**	**1.2**	**1.2**	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(1.2)	u(1.2)	u(2.5)
248211	8-9	**6.3**	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(2.4)	u(2.3)	u(1.2)	u(1.2)	u(2.3)
248213	10-11	**7.0**	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(1.1)	u(1.1)	u(2.2)
248214	13-14	**7.7**	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(4.0)	u(2.0)	u(1.0)	u(1.0)	u(2.0)
248216	16-17	**7.9**	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(3.8)	u(3.8)	u(1.9)	u(1.9)	u(1.9)
248217	19-20	**9.0**	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(3.4)	u(3.4)	u(0.85)	u(0.85)	u(1.7)
248219	23-24	**27**	u(3.3)	u(3.3)	u(3.3)	u(3.3)	u(8.4)	u(6.7)	u(1.7)	u(1.7)	u(3.3)
378117	27-28	**9.0**	u(0.72)	u(0.72)	u(0.72)	u(0.72)	u(0.72)	u(0.72)	u(0.72)	u(0.72)	u(0.72)
378118	31-32	**5.7**	u(0.67)	u(0.67)	u(0.67)	u(0.67)	u(0.67)	u(0.67)	u(0.67)	u(0.67)	u(0.67)
378119	35-36	**1.4**	u(0.61)	u(0.61)	u(0.61)	u(0.61)	u(0.61)	u(0.61)	u(0.61)	u(0.61)	u(0.61)
378120	39-40	**0.82**	u(0.56)	u(0.56)	u(0.56)	u(0.56)	u(0.56)	u(0.56)	u(0.56)	u(0.56)	u(0.56)
378121	44-45	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)	u(0.55)

detected values in **bold**

u=undetected at practical quantitation limit in parentheses

Table F-16b. Miscellaneous pesticide concentrations (ng/g, dw) in Osoyoos Lake sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	Endosulfan I	Dieldrin	Endrin	Endosulfan II	Endrin aldehyde	Endosulfan sulfate	Endrin ketone	Methoxychlor	Toxaphene
248205	0-1	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(140)
378115	1-2	u(6.8)	u(2.7)	u(5.4)	u(6.8)	u(6.8)	u(2.7)	u(6.8)	u(2.7)	u(140)
248207	2-3	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(5.4)	u(270)
378116	3-4	u(6.7)	u(2.7)	u(2.7)	u(6.7)	u(6.7)	u(2.7)	u(6.7)	u(6.7)	u(130)
248208	4-5	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(2.6)	u(130)
248210	6-7	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(120)
248211	8-9	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(2.3)	u(120)
248213	10-11	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(2.2)	u(110)
248214	13-14	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(100)
248216	16-17	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(1.9)	u(94)
248217	19-20	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(85)
248219	23-24	u(3.3)	u(1.7)	u(1.7)	u(1.7)	u(3.3)	u(3.3)	u(3.3)	u(3.3)	u(170)
378117	27-28	u(3.6)	u(1.4)	u(2.9)	u(3.6)	u(3.6)	u(1.4)	u(3.6)	u(1.4)	u(72)
378118	31-32	u(3.3)	u(1.3)	u(1.3)	u(3.3)	u(3.3)	u(1.3)	u(3.3)	u(1.3)	u(67)
378119	35-36	u(3.1)	u(1.2)	u(1.2)	u(3.1)	u(3.1)	u(1.2)	u(3.1)	u(1.2)	u(61)
378120	39-40	u(2.8)	u(1.1)	u(1.1)	u(2.8)	u(2.8)	u(1.1)	u(2.8)	u(1.1)	u(56)
378121	44-45	u(2.7)	u(1.1)	u(1.1)	u(2.7)	u(2.7)	u(1.1)	u(2.7)	u(1.1)	u(55)

u=undetected at practical quantitation limit in parentheses

Table F-17. DDT concentrations (ng/g, dw) in Okanogan River mouth sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	Year	%TOC	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-DDT	2,4'-DDE	2,4'-DDD	2,4'-DDT
378105	0-2	2001	1.95%	**6.9**	**1.9**	u(0.63)	**8.8**	u(0.63)	u(0.63)	u(0.63)
378106	6-8	1998	1.72%	**7.1**	**2.2**	u(0.53)	**9.3**	u(0.53)	u(0.53)	u(0.53)
378107	12-14	1995	1.62%	**7.5**	**2.6**	u(0.49)	**10.1**	u(0.49)	**0.49**	u(0.49)
378108	18-20	1992	1.48%	**6.8**	**2.5**	u(0.45)	**9.3**	u(0.45)	**0.44**	u(0.45)
378109	24-26	1988	1.40%	**8.0**	**3.0**	u(0.44)	**11.0**	u(0.44)	**0.52**	u(0.44)
378110	28-30	1984	1.41%	**9.9**	**4.4**	**0.65**	**15.0**	**0.18**	**0.65**	u(0.44)
378111	30-32	1981	1.44%	**14**	**8.0**	**1.1**	**23.1**	**0.38**	**1.0**	u(0.41)

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-18. PCB concentrations (ng/g, dw) in Okanogan River mouth sediment core, 2001.

Sample No. (01-)	Depth Interval (cm)	PCB-1268	PCB-1260	PCB-1254	PCB-1248	PCB-1242	PCB-1232	PCB-1221	PCB-1016	t-PCB
378105	0-2	u(2.5)	u(2.5)	**0.89**	u(2.5)	u(2.5)	u(2.5)	u(2.5)	u(2.5)	**0.89**
378106	6-8	u(2.1)	u(2.1)	**0.74**	u(2.1)	u(2.1)	u(2.1)	u(2.1)	u(2.1)	**0.74**
378107	12-14	u(2.0)	u(2.0)	**1.1**	u(2.0)	u(2.0)	u(2.0)	u(2.0)	u(2.0)	**1.1**
378108	18-20	u(1.8)	u(1.8)	**0.88**	u(1.8)	u(1.8)	u(1.8)	u(1.8)	u(1.8)	**0.88**
378109	24-26	u(1.8)	u(1.8)	**1.1**	u(1.8)	u(1.8)	u(1.8)	u(1.8)	u(1.8)	**1.1**
378110	28-30	u(1.7)	**0.44**	**1.5**	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	**1.5**
378111	30-32	u(1.7)	**0.74**	**2.1**	u(1.7)	u(1.7)	u(1.7)	u(1.7)	u(1.7)	**2.1**

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-19a. Miscellaneous pesticide concentrations (ng/g, dw) in Okanogan River mouth sediment core, 2001.

Sample No. (01-)	**Depth Interval (cm)**	**DDMU**	**cis-Chlordane**	**trans-Chlordane**	**alpha-BHC**	**beta-BHC**	**gamma-BHC**	**delta-BHC**	**Heptachlor**	**Aldrin**	**Heptachlor epoxide**
378105	0-2	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)	u(0.63)
378106	6-8	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)	u(0.53)
378107	12-14	**0.44**	u(0.49)	u(0.49)	u(0.49)	u(0.49)	u(0.49)	u(0.49)	u(0.49)	u(0.49)	u(0.49)
378108	18-20	**0.42**	u(0.45)	u(0.45)	u(0.45)	u(0.45)	u(0.45)	u(0.45)	u(0.45)	u(0.45)	u(0.45)
378109	24-26	**0.47**	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)
378110	28-30	u(0.52)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)	u(0.44)
378111	30-32	**0.87**	u(0.41)	u(0.41)	u(0.41)	u(0.41)	u(0.41)	u(0.41)	u(0.41)	u(0.41)	u(0.41)

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-19b. Miscellaneous pesticide concentrations (ng/g, dw) in Okanogan River mouth sediment core, 2001.

Sample No. (01-)	**Depth Interval (cm)**	**Endosulfan I**	**Dieldrin**	**Endrin**	**Endosulfan II**	**Endrin aldehyde**	**Endosulfan sulfate**	**Endrin ketone**	**Methoxychlor**	**Toxaphene**
378105	0-2	u(3.2)	u(1.3)	u(1.3)	u(3.2)	u(3.2)	u(1.3)	u(3.2)	u(1.3)	u(63)
378106	6-8	u(2.7)	u(1.1)	u(1.1)	u(2.7)	u(2.7)	u(1.1)	u(2.7)	u(1.1)	u(53)
378107	12-14	u(2.5)	u(0.98)	u(0.98)	u(2.5)	u(2.5)	u(0.98)	u(2.5)	u(0.98)	u(49)
378108	18-20	u(2.3)	u(0.90)	u(0.90)	u(2.3)	u(2.3)	u(0.90)	u(2.3)	u(0.90)	u(45)
378109	24-26	u(2.2)	u(0.88)	u(0.88)	u(2.2)	u(2.2)	u(0.88)	u(2.2)	u(2.2)	u(44)
378110	28-30	u(2.2)	u(0.87)	u(0.87)	u(2.2)	u(2.2)	u(0.87)	u(2.2)	u(0.87)	u(41)
378111	30-32	u(2.1)	u(0.83)	u(0.83)	u(2.1)	u(2.1)	u(0.83)	u(2.1)	u(0.83)	u(44)

u=undetected at practical quantitation limit in parentheses

Table F-20. DDT concentrations (ng/g, wet) in fillet tissue of fish from Osoyoos Lake and the lower Okanogan River, 1984-1995.

Location	Ref.	RM	Date	Species	Length (mm)	Weight (g)	% Lipid	4,4'-DDT	4,4'-DDD	4,4'-DDE	t-DDT	2,4'-DDT	2,4'-DDD	2,4'-DDE
Okanogan R. blw. Malott	a	12	9/13/84	Bridgelip sucker			2.7	**64**	**780**	**2,400**	**3,244**	**11**	u(1)	**6**
Okanogan R. blw. Malott	a	12	9/15/84	Largemouth bass			4.2	**62**	**270**	**1,400**	**1,732**	**15**	u(1)	**38**
Osoyoos Lake	b		7/25/89	Largemouth bass			1.1	**6**	**55**	**150**	**211**			
Okanogan River above Brewster	c	7	9/13/94	Carp	602	3,766	9.1	**6**	**1,050**	**1,650**	**2,706**	u(10)	**135**	**12**
Osoyoos Lake	d		8/30/95	Yellow perch	185	71	0.85	**4**	**12**	**37**	**53**			
Osoyoos Lake	d		8/30/95	Yellow perch	199	91	1.1	**4**	**12**	**35**	**51**			
Osoyoos Lake	d		8/30/95	Yellow perch	206	104	0.97	**4**	**14**	**43**	**61**			
Osoyoos Lake	d		8/29/95	Yellow perch	212	113	1.12	**5**	**15**	**48**	**68**			
Osoyoos Lake	d		8/29/95	Yellow perch	220	122	0.6	**4**	**8**	**30**	**42**			
Osoyoos Lake	d		8/30/95	Yellow perch	223	131	0.99	**4**	**16**	**50**	**70**			
Osoyoos Lake	d		8/29/95	Yellow perch	228	133	0.99	**4**	**16**	**50**	**70**			
Osoyoos Lake	d		8/30/95	Yellow perch	245	175	0.87	**4**	**13**	**47**	**64**			
Osoyoos Lake	d		8/29/95	Smallmouth bass	222	164	1.04	**2**	**6**	**35**	**43**			
Osoyoos Lake	d		8/30/95	Smallmouth bass	252	234	1.11	**5**	**13**	**65**	**83**			
Osoyoos Lake	d		8/29/95	Smallmouth bass	358	724	0.97	**5**	**16**	**72**	**93**	u(4)	u(4)	u(4)
Osoyoos Lake	d		8/29/95	Mountain whitefish	313	306	4.06	**6**	**31**	**68**	**105**			
Osoyoos Lake	d		8/29/95	Carp	438	1,170	1.41	**1**	**42**	**180**	**223**			
Osoyoos Lake	d		8/28/95	Carp	478	1,515	2.78	U(8)	**103**	**550**	**653**			
Osoyoos Lake	d		8/29/95	Carp	495	1,638	2.8	**2**	**130**	**420**	**552**			
Osoyoos Lake	d		8/28/95	Carp	539	2,219	1.58	**1**	**60**	**260**	**321**			
Osoyoos Lake	d		8/30/95	Lake Whitefish	510	1,245	7.51	**37**	**350**	**600**	**987**			
Osoyoos Lake	d		8/30/95	Lake Whitefish	555	1,508	5.53	**25**	**460**	**755**	**1,240**			

[a]Hopkins et al, 1985

[b]Johnson and Norton, 1990

[c]Davis and Serdar, 1996

[d]Serdar et al., 1998

detected values in **bold**

u=undetected at practical quantitation limit in parentheses

Table F-21. DDT concentrations (ng/g, wet) in liver tissue and whole fish from Osoyoos Lake and the lower Okanogan River, 1983-1995.

Location	Ref.	RM	Date	Species	Length (mm)	Weight (g)	Tissue	% Lipid	4,4'-DDT	4,4'-DDD	4,4'-DDE	t-DDT	2,4'-DDT	2,4'-DDD	2,4'-DDE
Okanogan R. @ Okanogan	a	26	8/29/83	Bridgelip sucker			whole body	2.1	**144**	**241**	**1,399**	**1,784**	u(1)	u(1)	u(1)
Okanogan R. @ Okanogan	a	26	8/29/83	Mountain whitefish			whole body	8.3	**54**	**115**	**642**	**811**	u(1)	u(1)	u(1)
Okanogan River above Brewster	b	7	9/13/94	Largescale sucker	478	1,141	whole body	8.4	**21**	**120**	**760**	**901**	u(10)	**13**	**1.4**
Okanogan River above Brewster	b	7	9/13/94	Largescale sucker	486	1,129	whole body	6.1	**39**	**180**	**1,100**	**1,319**	**1.2**	**18**	**2.2**
Osoyoos Lake	c		8/28/95	Largescale sucker	493	1,209	whole body	5.08	**40**	**190**	**810**	**1,040**	u(3.7)	**3.5**	u(3.7)
Osoyoos Lake	c		8/29/95	Largescale sucker	478	1,214	whole body	5.82	**17**	**120**	**440**	**577**	u(3.6)	**2.3**	u(3.6)
Okanogan R. blw. Malott	a	12	9/14/84	Bridgelip sucker			liver	23.1	**200**	**3,500**	**10,600**	**14,300**	u(1)	**500**	**360**
Okanogan R. blw. Malott	a	12	9/16/84	Largemouth bass			liver	na	**200**	**540**	**2,100**	**2,840**	u(1)	**89**	**130**

[a] Hopkins et al, 1985

[b] Davis and Serdar, 1996

[c] Serdar et al., 1998

detected values in **bold**

u=undetected at practical quantitation limit in parentheses

Table F-22. PCB concentrations (ng/g, wet) in fillet, liver, and whole fish from Osoyoos Lake and the lower Okanogan River, 1984-1995.

Location	Ref.	RM	Date	Species	Length (mm)	Weight (g)	Tissue	% Lipid	PCB-1260	PCB-1254	PCB-1248	PCB-1242	PCB-1232	PCB-1221	PCB-1016	t- PCB
Okanogan R. blw. Malott	a	12	9/13/84	Bridgelip sucker			fillet	2.7	u(10)							nd
Okanogan R. blw. Malott	a	12	9/15/84	Largemouth bass			fillet	4.2	**22**							**22**
Osoyoos Lake	b		7/25/89	Largemouth bass			fillet	1.1	u(20)	u(20)	u(20)	u(20)				nd
Okanogan R. abv. Brewster	c	7	9/13/94	Carp	602	3,766	fillet	9.1	**20**	**25**	u(50)	u(50)	u(50)	u(50)	u(50)	**45**
Osoyoos Lake	d		8/29/95	Smallmouth bass	358	724	fillet	0.97	u(40)	u(40)	u(40)	u(40)				nd
Okanogan R. @ Okanogan	a	26	8/29/83	Bridgelip sucker			whole body	2.1	u(10)	**583**						**583**
Okanogan R. @ Okanogan	a	26	8/29/83	Mountain whitefish			whole body	8.3	u(10)	**122**						**122**
Okanogan R. abv. Brewster	c	7	9/13/94	Largescale sucker	478	1,141	whole body	8.4	**34**	**22**	u(50)	u(50)	u(50)	u(50)	u(50)	**56**
Okanogan R. abv. Brewster	c	7	9/13/94	Largescale sucker	486	1,129	whole body	6.1	**48**	**24**	u(50)	u(50)	u(50)	u(50)	u(50)	**72**
Osoyoos Lake	d		8/28/95	Largescale sucker	493	1,209	whole body	5.08	**18**	**48**	u(37)	u(37)				**66**
Osoyoos Lake	d		8/29/95	Largescale sucker	478	1,214	whole body	5.82	u(36)	**24**	u(36)	u(36)				**24**
Okanogan R. blw. Malott	a	12	9/14/84	Bridgelip sucker			liver	23.1	**210**							**210**
Okanogan R. blw. Malott	a	12	9/16/84	Largemouth bass			liver	na	u(10)							nd

[a]Hopkins et al, 1985
[b]Johnson and Norton, 1990
[c]Davis and Serdar, 1996
[d]Serdar et al., 1998
detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-23. DDT concentrations (ng/g, wet) in fillet tissue of fish from the lower Okanogan River, 2001.

Sample No. (02-)	**Location**	**Species**	**# per comp.**	**Mean Length (mm)**	**Mean Weight (g)**	**% Lipid**	**4,4'-DDE**	**4,4'-DDD**	**4,4'-DDT**	**t-DDT**	**2,4'-DDE**	**2,4'-DDD**	**2,4'-DDT**
128230	Oroville	CARP	8	552	2,135	1.04	**290**	**37**	u(1.6)	**327**	u(0.7)	**2.4**	u(0.6)
128231	Oroville	CARP	8	514	1,749	0.84	**410**	**24**	u(1.5)	**434**	u(0.5)	**1.7**	u(0.5)
128232	Oroville	CARP	7	463	1,348	1.55	**210**	**38**	**0.6**	**249**	u(0.6)	**3.6**	u(0.54)
128233	Riv. - Omak	CARP	8	619	3,345	3.43	**270**	**41**	u(1.5)	**311**	u(1.1)	**3.8**	**0.6**
128234, 128235	Riv. - Omak	CARP	8	584	2,740	3.00	**220**	**29**	u(1.6)	**249**	u(1.0)	**2.9**	**0.5**
128236	Riv. - Omak	CARP	8	550	2,393	3.09	**210**	**26**	u(1.6)	**236**	u(1.0)	**2.5**	u(0.5)
128237	Oroville	MTWF	8	363	315	0.79	**460**	**38**	**17**	**515**	u(2.2)	**2.5**	**2.8**
128238	Oroville	MTWF	8	330	229	1.31	**330**	**21**	**9.8**	**361**	u(1.8)	**1.6**	**2.0**
128245	Oroville	MTWF	8	290	167	1.17	**150**	**19**	**5.1**	**174**	u(1.1)	**1.2**	**0.8**
128239, 128240	Riv. - Omak	MTWF	10	365	453	4.26	**520**	**62**	**17**	**599**	u(2.7)	**5.2**	**2.3**
128241	Riv. - Omak	MTWF	10	334	331	4.70	**330**	**39**	**13**	**382**	u(0.8)	**5.0**	u(0.5)
128249	Riv. - Omak	MTWF	10	284	209	4.58	**160**	**19**	**6.0**	**185**	u(16)	**2.2**	**1.2**
128242	Monse	MTWF	9	326	301	2.96	**110**	**14**	**3.2**	**127**	u(1.2)	**1.4**	**0.8**
128243	Monse	MTWF	9	246	127	3.07	**120**	**16**	**3.7**	**140**	u(0.5)	**2.2**	**0.8**
128244	Monse	MTWF	8	220	81	1.55	**73**	**4.9**	**2.8**	**81**	u(0.6)	**0.6**	**0.8**
128246	Oroville	SMBS	1	424	1,111	3.21	**230**	**44**	**14**	**288**	u(1.8)	**3.1**	**1.8**
128247	Oroville	SMBS	4	316	472	1.39	**64**	**11**	**2.3**	**77**	u(0.5)	**1.1**	u(0.5)
128248	Oroville	SMBS	1	248	206	1.60	**100**	**3.5**	**0.8**	**104**	u(0.6)	u(1.0)	**0.6**
128250	Riv. - Omak	SMBS	7	350	685	1.17	**78**	**6.5**	**3.1**	**88**	u(0.5)	**0.8**	**0.6**
128251	Riv. - Omak	SMBS	7	287	320	1.42	**55**	**2.9**	**1.6**	**60**	u(0.5)	u(1.0)	u(0.5)
128252	Riv. - Omak	SMBS	7	213	133	0.95	**25**	**1.7**	**0.8**	**28**	u(0.6)	u(1.0)	u(0.6)
128253	Monse	SMBS	5	327	496	1.35	**150**	**14**	**3.0**	**167**	u(1.1)	**2.2**	u(0.5)
128254	Monse	SMBS	5	276	276	1.12	**89**	**11**	**1.6**	**102**	u(0.6)	**1.6**	u(0.5)
128255	Monse	SMBS	5	200	98	0.70	**59**	**3.4**	**0.8**	**63**	u(0.5)	**0.7**	u(0.5)

detected values in **bold**
u=undetected at practical quantitation limit in parentheses

Table F-24. PCB concentrations (ng/g, wet) in fillet tissue of fish from the lower Okanogan River, 2001.

Sample No. (02-)	Location	Species	# per comp	Mean Length (mm)	Mean Weight (g)	% Lipid	PCB-1016	PCB-1221	PCB-1232	PCB-1242	PCB-1248	PCB-1254	PCB-1260	PCB-1262	PCB-1268	t-PCB
128230	Oroville	CARP	8	552	2,135	1.04%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**2.7**	**5.1**	**4.7**	u(2.8)	u(2.8)	**13**
128231	Oroville	CARP	8	514	1,749	0.84%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**1.7**	**3.9**	**3.1**	u(2.7)	u(2.7)	**9**
128232	Oroville	CARP	7	463	1,348	1.55%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**3.6**	**4.2**	**2.2**	u(2.7)	u(2.7)	**10**
128233	Riv. - Omak	CARP	8	619	3,345	3.43%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**6.8**	**9.2**	**10**	u(2.7)	u(2.7)	**26**
128234, 128235	Riv. - Omak	CARP	8	584	2,740	3.00%	u(2.6)	u(2.6)	u(2.6)	u(2.6)	**13**	**10**	**13**	u(2.6)	u(2.6)	**36**
128236	Riv. - Omak	CARP	8	550	2,393	3.09%	u(5.4)	u(2.7)	u(2.7)	**4.0**	u(18)	**9.9**	**8.4**	u(2.7)	u(2.7)	**22**
128237	Oroville	MTWF	8	363	315	0.79%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**3.0**	**12**	**8.7**	u(2.8)	u(2.8)	**24**
128238	Oroville	MTWF	8	330	229	1.31%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**2.9**	**9.8**	**7.3**	u(2.7)	u(2.7)	**20**
128245	Oroville	MTWF	8	290	167	1.17%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**2.4**	**6.1**	**3.2**	u(2.7)	u(2.7)	**12**
128239, 128240	Riv. - Omak	MTWF	10	365	453	4.26%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**5.2**	**19**	**18**	u(2.7)	u(2.7)	**42**
128241	Riv. - Omak	MTWF	10	334	331	4.70%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**3.0**	**10**	**7.3**	u(2.7)	u(2.7)	**20**
128249	Riv. - Omak	MTWF	10	284	209	4.58%	u(2.6)	u(2.6)	u(2.6)	u(2.6)	**5.0**	**18**	**7.0**	u(2.6)	u(2.6)	**30**
128242	Monse	MTWF	9	326	301	2.96%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**3.5**	**9.8**	**6.2**	u(2.7)	u(2.7)	**20**
128243	Monse	MTWF	9	246	127	3.07%	u(2.6)	u(2.6)	u(2.6)	u(2.6)	**2.5**	**6.4**	**2.3**	u(2.6)	u(2.6)	**11**
128244	Monse	MTWF	8	220	81	1.55%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**2.9**	**2.1**	u(2.8)	u(2.8)	**5**
128246	Oroville	SMBS	1	424	1,111	3.21%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**3.9**	**8.1**	**2.6**	u(2.7)	u(2.7)	**15**
128247	Oroville	SMBS	4	316	472	1.39%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**2.4**	u(2.7)	u(2.7)	u(2.7)	**2**
128248	Oroville	SMBS	1	248	206	1.60%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**2.2**	u(2.8)	u(2.8)	u(2.8)	**2**
128250	Riv. - Omak	SMBS	7	350	685	1.17%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**2.7**	u(2.7)	u(2.7)	u(2.7)	**3**
128251	Riv. - Omak	SMBS	7	287	320	1.42%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**5.6**	**2.1**	u(2.7)	u(2.7)	u(2.7)	**8**
128252	Riv. - Omak	SMBS	7	213	133	0.95%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	nd
128253	Monse	SMBS	5	327	496	1.35%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	**2.9**	**9.5**	**1.9**	u(2.8)	u(2.8)	**14**
128254	Monse	SMBS	5	276	276	1.12%	u(2.7)	u(2.7)	u(2.7)	u(2.7)	u(2.7)	**2.2**	u(2.7)	u(2.7)	u(2.7)	**2**
128255	Monse	SMBS	5	200	98	0.70%	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	u(2.8)	nd

detected values in **bold**

u=undetected at practical quantitation limit in parentheses