WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Lower Okanogan River Basin DDT and PCBs Total Maximum Daily Load

Submittal Report

October 2004
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Prepared by:

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Water Quality Program

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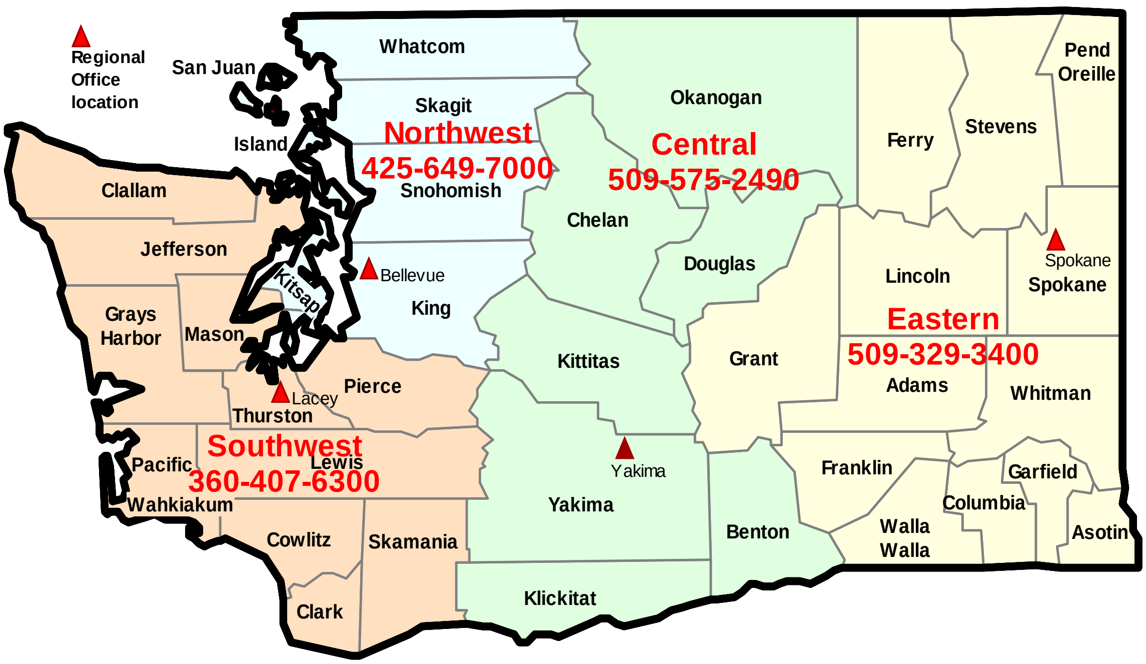

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Executive Summary

Basin:	Okanogan River (Washington)
Key Impaired	Resources: Water Quality
Uses Affected:	Water Supply (Domestic), Harvest of aquatic organisms
Type of Impairment:	Concentrations of DDT, 4,4'-DDD, 4,4'-DDE and PCBs in fish Tissue, DDT in Water
Pollutant:	DDT, 4,4'-DDD, 4,4'-DDE and PCBs
Contribution Factors:	Historic agricultural, industrial, commercial and residential practices.

The Okanogan River originates in the Cascade Mountains north of the international border between British Columbia and Washington State. The Okanogan River is characterized by a series of lakes north of international boundary and a free flowing river flowing out of lake Osoyoos, which straddles the boundary, 78 miles to it's confluence with the Columbia River. The Okanogan River's primary tributary is the Similkameen River, which enters 5 miles south of Lake Osoyoos. The Similkameen River normally contributes three quarters of the combined flow in the Okanogan River. The Similkameen River originates on the east slopes of the Cascade Mountains along the international boarder and meets the Okanogan River at Oroville, Washington. Agriculture, forestry, mining, and recreation are the major land-use activities in the Okanogan watershed.

Under Section 303(d) of the federal Clean Water Act, the Okanogan River and several tributaries have been listed by Washington State for non-attainment of the EPA human health criteria for DDT and PCBs in edible fish tissue and for non-attainment of Washington State chronic criteria for DDT in water. Therefore, a Total Maximum Daily Load (TMDL) project was conducted for the portion of the river that flows through Washington State, as required by the Clean Water Act. The source of these contaminants appears to be the legacy from historic agricultural and industrial activities common throughout the Okanogan River watershed.

The chemical characteristics of DDT and PCBs cause them to be classified as persistent, bioaccumulative toxins. These contaminants are a legacy of past activities as their use has been banned in both the United States and Canada for more than 25 years. Due to the legacy nature of the contamination, substantial mitigation of the DDT and PCB contamination, both directly and indirectly, has already occurred in the Okanogan Basin. Direct actions include the banning of these materials from use; while, indirect actions include irrigation improvements that have reduced the loss of agricultural topsoil that potentially could carry pesticide residues to the Okanogan River and associated waterbodies. The DDT and PCBs in the lower Okanogan River Basin TMDL continues to promote community actions that address DDT and PCB contamination, along with new actions of source identification and development of management strategies to address any sources of contamination subsequently revealed.

Introduction

Section 303(d) of the federal Clean Water Act mandates that the state of Washington establish Total Maximum Daily Loads (TMDLs) for surface waters that do not meet water quality standards, designed to protect, restore and preserve water quality, after application of technology-based pollution controls. The U.S. Environmental Protection Agency (EPA) has established regulations (40 CFR 130) and developed guidance (EPA, 1991) for setting TMDLs.

Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. The state's water quality standards consist of both (1) designated uses, such as supporting cold water biota and providing a drinking water supply, and (2) criteria, usually numeric, required to achieve those uses. When a lake, river or stream fails to meet the water quality standards after application of required technology-based controls, the Clean Water Act requires the state to place the water body on a list of "impaired" water bodies and to prepare an analysis called a Total Maximum Daily Load.

The goal of a TMDL is to ensure that the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the sources that cause them. The TMDL determines the amount of a given pollutant that can be discharged to and assimilated by the water body and still meet standards; this is called the loading capacity. The TMDL also allocates that load among the various sources, both point and non-point.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the cause of the water quality problem or its loading capacity. The sum of the individual allocations and the margin of safety must be equal to or less than the loading capacity.

In addition to the mandatory components of a TMDL, the general purposes of this document are to:

- Summarize data that document which stream segments exceeded standards for DDT and PCBs.
- Summarize the results of a technical assessment which identified probable sources of DDT and PCB contaminant loading that cause increases in contaminant concentrations in fish tissue and tributary waters.
- Summarize actions recommended for meeting water quality standards.
- Summarize monitoring that should be used to track TMDL implementation and determine progress toward attaining water quality standards.

A Detailed Implementation Plan (DIP) will be developed within a year of TMDL approval by EPA, to expand the initial implementation strategy into a working plan. Further public input will be sought to help prepare the DIP, which will identify how, when, and where voluntary restoration activities will be implemented. Details of a monitoring plan will be developed. The Washington State Department of Ecology (Ecology) and other entities will provide technical assistance and seek additional funding for these activities.

This TMDL addresses the 303(d) listed water quality impaired water bodies for the DDT and PCBs in the lower Okanogan River basin on the Okanogan River, Lake Osoyoos and the tributary streams Tallant Creek, Elgin Creek and Ninemile Creek, as well as the unlisted tributaries of Antoine Creek and Mosquito Creek. Antoine and Mosquito Creeks do not meet the state water quality standards based on the 2001-2002 sampling study. The specific water body identification numbers and impairments being addressed by this TMDL are: Okanogan River segment ID **YN58LL** for 4,4’-DDD, 4,4’-DDE, PCB-1254 and PCB-1260 in fish tissue**;** Lake Osoyoos ID **060VKD** for 4,4’-DDD, 4,4’-DDE in fish tissue; and all of the following water bodies for exceeding state chronic criteria for DDT: Tallant Creek ID **LD33FC**; Elgin Creek ID **KR66GR**; Ninemile Creek ID **IP09QF**; Antoine Creek ID **NN36KM**; and Mosquito Creek ID **QH83DF**.

Components of the TMDL

The five components of a TMDL, as required by the Clean Water Act and applied to this TMDL, are described below:

Loading Capacity

The loading capacity is the maximum amount of pollutant that a water body can receive without violating water quality standards. The loading capacity is allocated between waste load allocations, load allocations, natural background, and a margin of safety. No natural background value exists for DDT and PCB compounds, therefore no allocation is made for it in this TMDL.

Waste Load Allocations

A waste load allocation is that portion of a receiving water's loading capacity that is allocated to point sources of pollution. There are four permitted wastewater discharges to the Okanogan River and its primary tributary, the Similkameen River. These permitted discharges represent the municipal wastewater treatment plants in Oroville, Tonasket, Omak and Okanogan. allocations were calculated for these permitted discharges based on their respective design capacities and the water quality standards for DDT, DDE, DDD and PCBs.

Load Allocations

A load allocation is that portion of the receiving water's loading capacity that is allocated to non-point sources of pollution or to natural background sources. Load allocations for this TMDL are based on the concentration of contaminants in fish tissue in the mainstem Okanogan River and based on the Washington State chronic criteria for DDT in water for selected tributaries.

Margin of Safety

EPA requires that a TMDL include a margin of safety to account for any lack of knowledge concerning the relationship between loads and water quality. This TMDL relies on a margin of safety implicitly included in the conservative assumptions that were calculated into the regulatory numerical values contained in the National Toxics Rule and the Water Quality Standards for Surface Waters of the State of Washington.

Seasonal Variation

Seasonal variation, or the changes in loading rates due to changing conditions associated with the annual change in seasons, has been accounted for by sampling during both high flow and low flow events. Additionally, the human health and chronic aquatic life criteria for DDT and PCBs are driven by long-term exposures. Since the accumulation of DDT and PCBs in fish is a time-integrative process, and the chronic aquatic life criteria are based on long-term exposures, seasonal variations in loads are not an important factor in determining load allocations for these parameters.

Background

The Okanogan River flows from its headwaters in British Columbia (B.C.) through north-central Washington, where it discharges into the Columbia River near the town of Brewster. The Okanogan River basin drains approximately 8,900 square miles of area. The uplands consist mostly of forests and rangelands, while the fertile valley bottom provides one of the most productive orchard regions in B.C. and Washington (Figure 1).

Most of the Okanogan River basin lies north of the Canadian border, where its flow is regulated by four lakes along the river’s mainstem. All of the lakes are located north of 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 and flows 79 miles southward to its confluence with the Columbia River (779’ m.s.l.). The Similkameen River joins the Okanogan River just downstream of Oroville, where its flow is increased by an average of 400 percent. About 20 small tributary streams also drain the 2,600 mi^2 of the Washington portion of the basin (hereinafter referred to as the lower Okanogan River basin). Most of the tributaries are small or intermittent, contributing little to the overall flow of the lower Okanogan River (Figure 2).

The lower Okanogan River basin is located within a semi-arid region that has an 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.

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 downstream to its confluence with 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 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 percent or approximately 37,000 acres of the land area. The upper Okanogan River basin (north of the Canadian border) has a similar composition of orchard lands, providing over 99 percent of the tree fruit grown in British Columbia (Sinclair and Elliott, 1993).

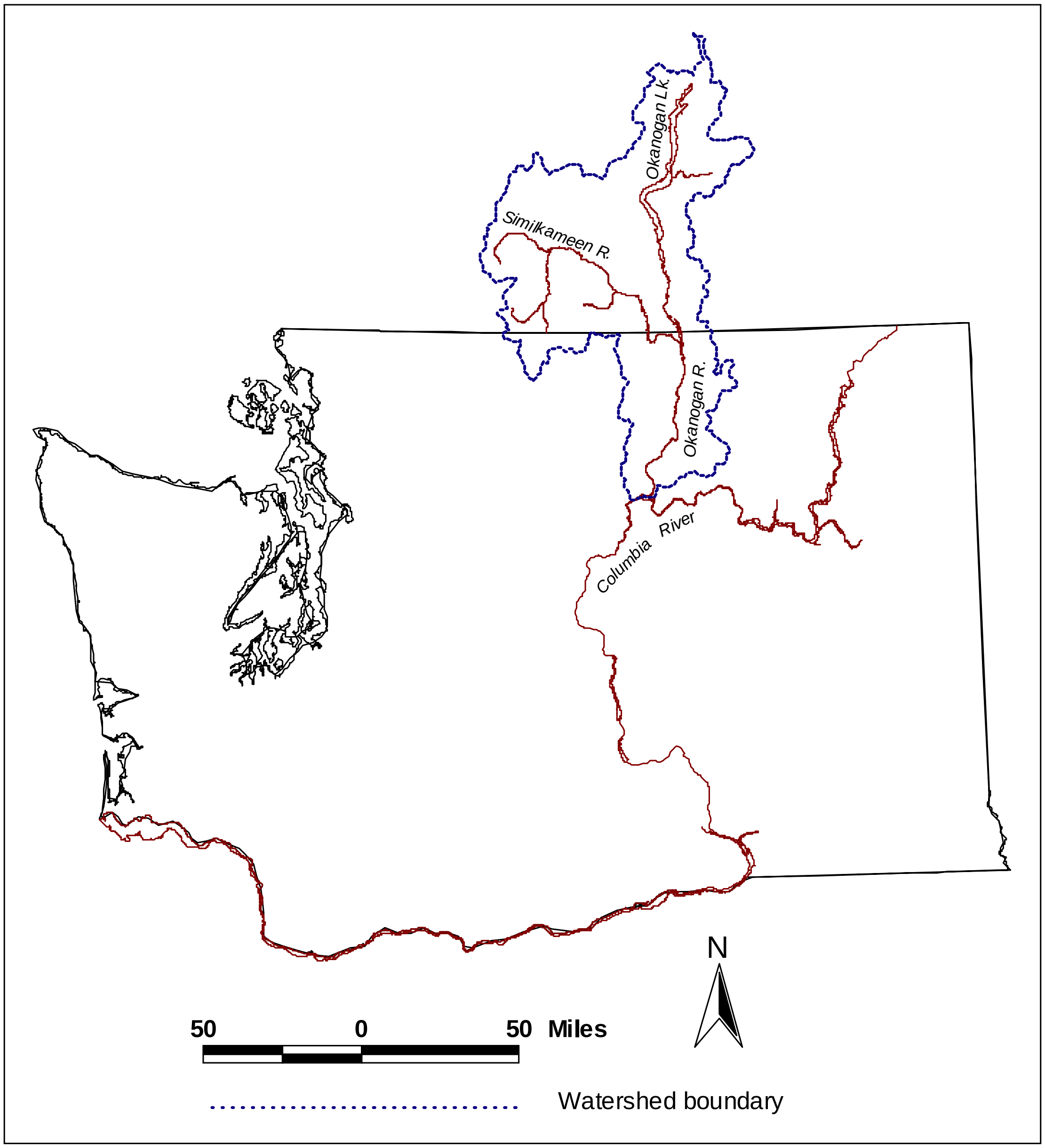

Figure 1: Okanogan River Watershed

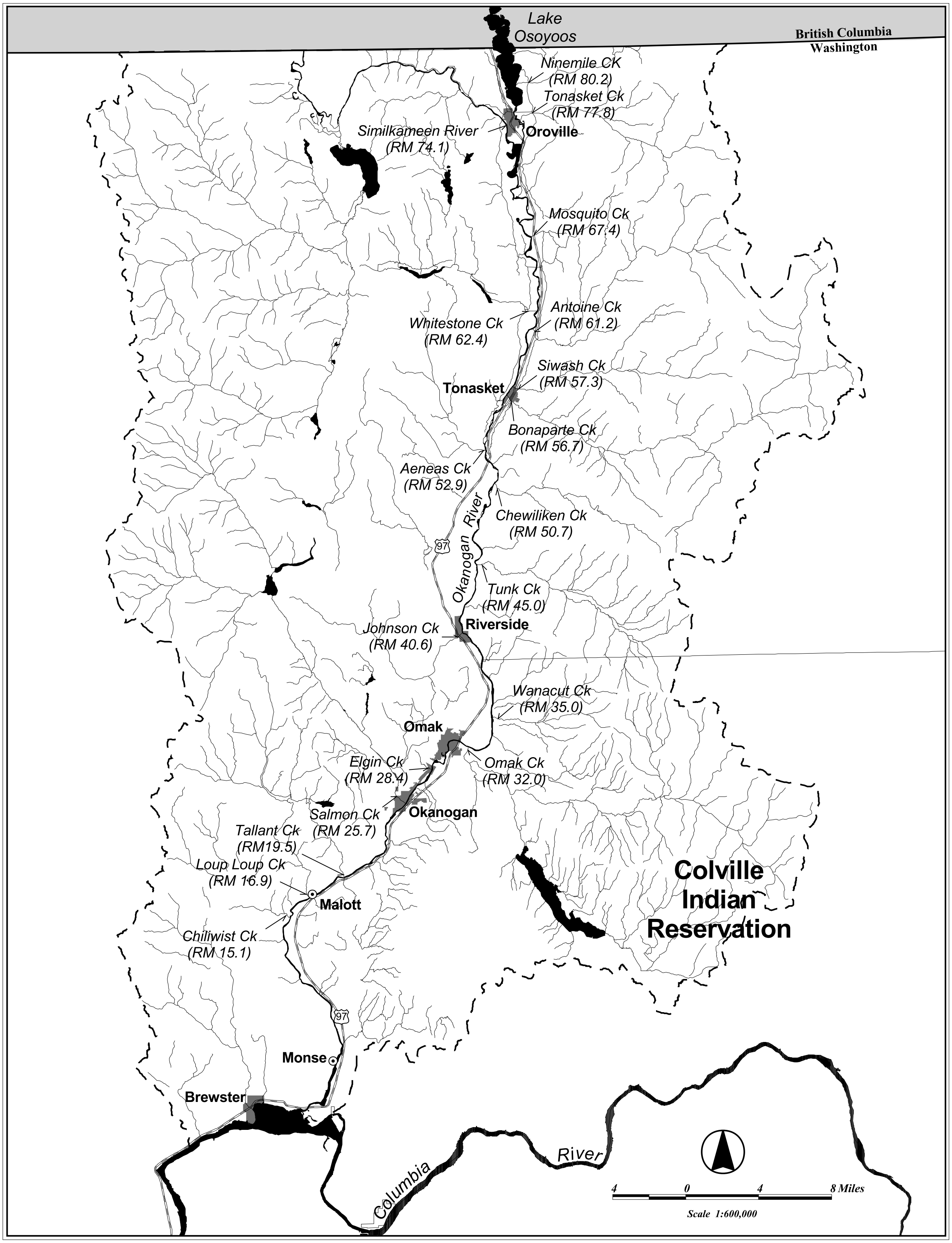

Figure 2: Location of Lower Okanogan River and Osoyoos Lake Tributary Streams

Applicable Criteria

Within the state of Washington, water quality standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). Authority to adopt such rules, regulations, and standards as are necessary to protect the environment is vested with the Department of Ecology. Under the federal Clean Water Act, the EPA Regional Administrator must approve the water quality standards adopted by the State (Section 303(c)(3)). Through adoption of these water quality standards, Washington has designated certain characteristic uses to be protected and the criteria necessary to protect these uses [Washington Administrative Code (WAC), Chapter 173-201A].

Streams in the lower Okanogan Basin watershed have the following designated uses assigned in Chapter 173-201A WAC, Table 602. The designated uses are:

- Aquatic Life Uses
  - Non-Core Salmon/Trout: **Salmon and trout spawning, non-core rearing, and migration.** For the protection of spawning, non-core rearing, and migration of salmon and trout, and other associated aquatic life.
- Recreational Uses
  - Primary Contact
- Water Supply Uses
  - Domestic Water
  - Industrial Water
  - Agricultural Water
  - Stock Water
- Miscellaneous Uses
  - Wildlife Habitat
  - Harvesting
  - Commerce/Navigation
  - Boating
  - Aesthetics

This TMDL is designed to address impairments of designated uses caused by DDT and PCB concentrations in fish tissues and surface waters.

Chapter 173-201A WAC contains DDT and PCB criteria to protect aquatic life (Table 1). Because this criteria does not include a human health component and does not protect all designated uses (i.e. use of water as a domestic supply and harvesting of organisms), the Clean Water Act requires the additional use of the water quality criteria set in National Toxics Rule, Chapter 40 of the Code of Federal Regulation part 141.36 (40CFR131.36). The National Toxics Rule (NTR) defines the criteria for DDT, DDD, DDE and PCBs for the protection of human health. The numeric criteria are given in Table 2.

Table 1: Criteria from Chapter 173-201A WAC

Toxics Substances Criteria (µg/L)		
	Freshwater	
Substance	Acute	Chronic
DDT (and metabolites)	1.1a	0.001b
Polychlorinated Biphenyls (PCBs)	2.0b	0.014b

Notes to Table 1:

a. An instantaneous concentration not to be exceeded at any time.

b. A 24-hour average not to be exceeded.

Table 2: Human Health Criteria from 40CFR131.36 (July 1, 2000 edition)

		Human Health (10^{-6} risk for carcinogens) for the consumption of:	
	CAS	Water & Organisms	Organisms Only
(#) Compound	Number	(µg/L)	(µg/L)
(108) 4,4'-DDT	50293	0.00059	0.00059
(109) 4,4'-DDE	72559	0.00059	0.00059
(110) 4,4'-DDD	72548	0.00083	0.00083

Water Quality and Resource Impairments

The lower Okanogan River, Osoyoos Lake and their Washington State tributaries of Ninemile Creek, Similkameen River, Tallant Creek, and unnamed (Elgin) creek were included in Washington's 1998 list of impaired waters compiled under Section 303(d) of the Clean Water Act due to water quality impairments by DDT, 4-4'-DDD, 4,4'-DDE, PCB-1254, PCB-1260, Dissolved Oxygen, Fecal Coliform, Arsenic, and Temperature. In addition to the 303(d) listed impaired waters the lower Okanogan River tributaries Antoine Creek and Mosquito Creek were found to be impaired by DDT (Serdar 2003). This TMDL addresses the water quality impairments from DDT, 4,4'-DDD, 4,4'-DDE, PCB-1254, PCB-1260 included in Table 3.

Table 3: Impaired Waterbodies Addressed in this TMDL

Waterbody	Old Segment No.	New Segment No.	Township, Range & Section	Impairment(s)	Years listed on the 303(d) List:
Okanogan River	WA-49-1010	YN58LL	31N, 25E, Section 27	Exceeds NTR criteria for 4,4'-DDD, 4,4'-DDE, and PCB-1254 in fish tissue[a]	1996 1998
Okanogan River	WA-49-1010	YN58LL	31N, 25E, Section 34	Exceeds NTR criteria for PCB-1260 in fish tissue[a]	1996 1998
Osoyoos Lk.	WA-49-9260	060VKD	40N, 27E, Section 22	Exceeds NTR criteria for 4,4'-DDD, 4,4'-DDE in fish tissue[b]	1996 1998
Tallant Creek	WA-49-1017	LD33FC	32N, 25E, Section 02	Exceeds Washington State chronic criteria for DDT in water[c]	1998
Elgin Creek (listed as Unnamed Creek)	WA-49-1022	KR66GR	33N, 26E, Section 03	Exceeds Washington State chronic criteria for DDT in water[c]	1998
Ninemile Creek	WA-49-1049	IP09QF	40N, 27E, Section 15	Exceeds Washington State chronic criteria for DDT in water[c]	1998
Antoine Creek		NN36KM	38N, 27E Section 27	Exceeds Washington State chronic criteria for DDT in water[d]	Unlisted but impaired
Mosquito Creek		QH83Df	38N, 27E Section 27	Exceeds Washington State chronic criteria for DDT in water[d]	Unlisted but impaired

NTR=National Toxics Rule

[a] Davis and Serdar, 1996

[b] Johnson and Norton, 1990

[c] Johnson et al., 1997

[d] Serdar, 2003

Technical Approach and Results

An approach of mass balancing was used in the **Lower Okanogan River Basin DDT and PCBs Total Maximum Daily Load** TMDL evaluation for DDT and PCB compounds in the lower Okanogan River basin. The mass balancing was used to evaluate the sources of contaminant loading and their potential impacts to the water quality in the basin. This study approach used several techniques for the collection of surface water data, sediment data, fish tissue data and discharge information from the NPDES permitted dischargers. Data collected was used to assess potential DDT and PCB sources and to compare data from the current study to other data sources. (Serdar 2003)

Technical Assessment Objectives and Strategy

During 2001 – 2002, Ecology collected data necessary to conduct a TMDL assessment for the geographic area and parameters covering the lower Okanogan River and all of its tributaries from the Canadian border (RM 82.5) to its mouth near Brewster, including the southern portion of Osoyoos Lake (RM 79.0 – 82.5). The TMDL concerns 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, t-DDT, and PCBs (as Aroclors or t-PCB). Objectives of the 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 their concentrations in fish tissue.

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 non-point 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 as a potential difficulty 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 discharged by 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 study components 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 fish in the lower Okanogan River and Osoyoos Lake. These analyses were 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 4 summarizes samples collected during 2001-2002.

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.

Table 4: 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.)	--	--
STPs	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

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 was 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.

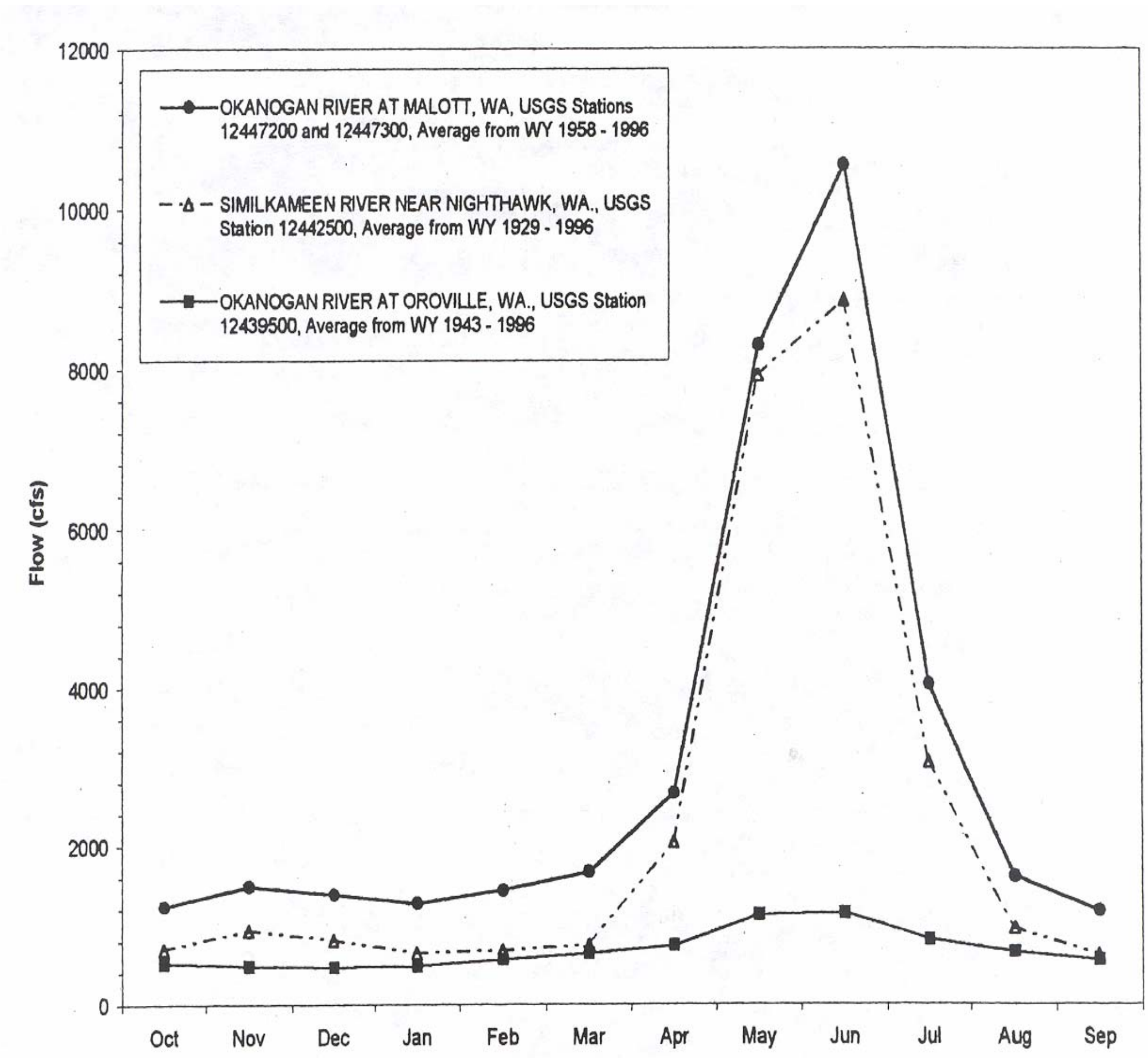

Figure 3: Lower Okanogan River and Similkameen River Average Monthly Flows (figure adapted from WEST Consultants, Inc. and Hammond, Collier, & Wade-Livingstone, Inc., 1999)

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 three of 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.

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, sampling locations, laboratory procedures and data quality assurance procedures are contained in the Okanogan Technical Assessment Report (Appendix B, Serdar 2003).

Results of 2001-2002 Sampling

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

<u>DDT and PCBs in the Lower Okanogan River Mainstem Water Column</u>

Table 5 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.

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 Metro Environmental Laboratory (MEL) not used the large volume injection to achieve low quantitation limits (≤0.1 ng/l).

Table 5: 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
u=undetected at practical quantitation limit in parentheses

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.

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.

Table 6: 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 Creek	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 Creek	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 River	74.1	5/13/02	113,551	14	u(0.067)	u(0.067)	u(0.080)	nd
Mosquito Creek	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 Creek	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 Creek	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 Creek	57.3	4/16/01	24	1	0.5	u(0.8)	u(0.8)	0.5
"		5/16/01	0	--	--	--	--	--
Bonaparte Creek	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 Creek	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 Creek	50.7	4/11/01	9	u(1)	u(0.8)	u(0.8)	u(0.8)	nd
"		5/17/01	0	--	--	--	--	--
Tunk Creek	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 Creek	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 Creek	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 Creek	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 Creek	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 Creek	25.7	4/17/01	284	1	0.4	u(0.9)	u(0.9)	0.4
"		5/15/01	0	--	--	--	--	--
Tallant Creek	19.5	4/16/01	0	--	--	--	--	--
"		5/15/01	0	--	--	--	--	--
Loup Loup Creek	16.9	4/16/01	0	--	--	--	--	--
"		5/15/01	3	u (1)	0.7	u(1.6)	0.7	1.4
Chiliwist Creek	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
u=undetected at practical quantitation limit in parentheses
nd=not detected

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 7 shows results of DDT and PCB analysis of STP effluent samples. Table 8 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. The 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.

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.

Table 7: 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
u=undetected at practical quantitation limit in parentheses
nd=not detected
*no practical quantitation limit determined

Table 8: 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)

u=undetected at practical quantitation limit in parentheses

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 9). Penetration was not as deep in the core collected near the Okanogan River mouth (Table 10). Deposition of fine sediments near the mouth of the Okanogan River 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 9: DDT & 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

u=undetected at practical quantitation limit in parentheses

Table 10: 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
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 Polotnikoff, 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 possibly have resulted from a spill or illegal 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 4). 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 3 and 4). 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.

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.

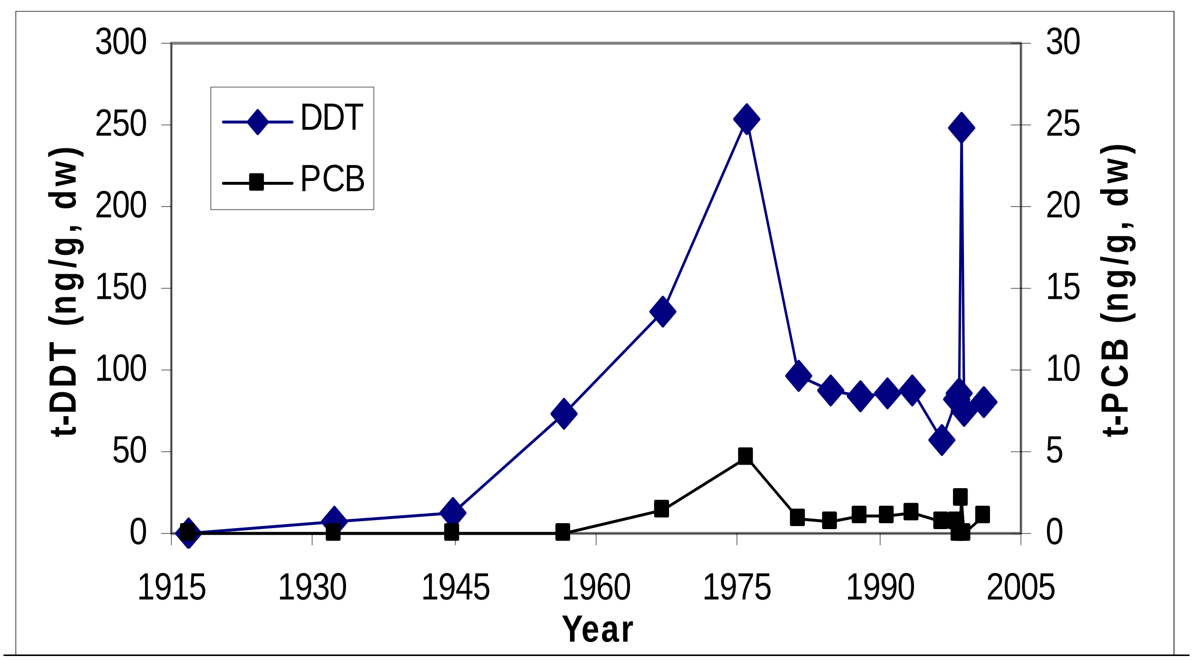

Figure 4: T-DDT and t-PCB Concentrations in Osoyoos Lake Sediment Core

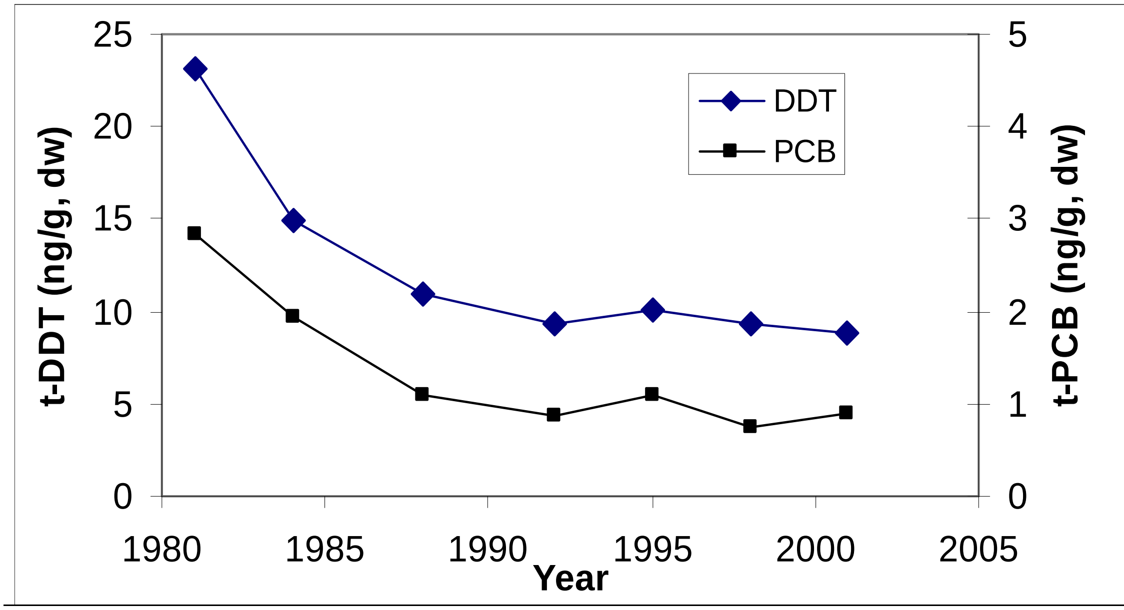

Figure 5: T-DDT and t-PCB concentrations in lower Okanogan River sediment core

<u>DDT and PCB Concentrations in Fish Tissue</u>

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 11 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 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.

Table 11: 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
u=undetected at practical quantitation limit in parentheses
nd=not detected

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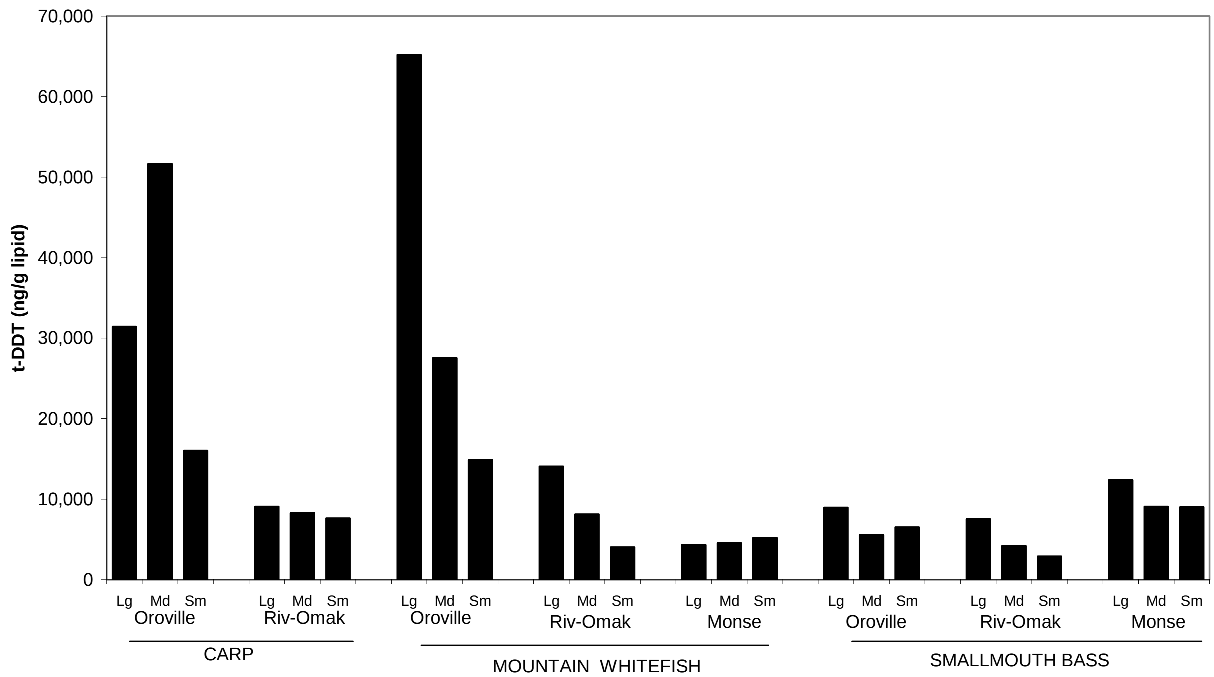

Figure 6: Lipid-Normalized t-DDT Concentrations in Lower Okanogan River Fish Muscle Ordered by Mean Length of Fish in each Composite (Lg=large, Md=medium, Sm=small) and Location for each Species

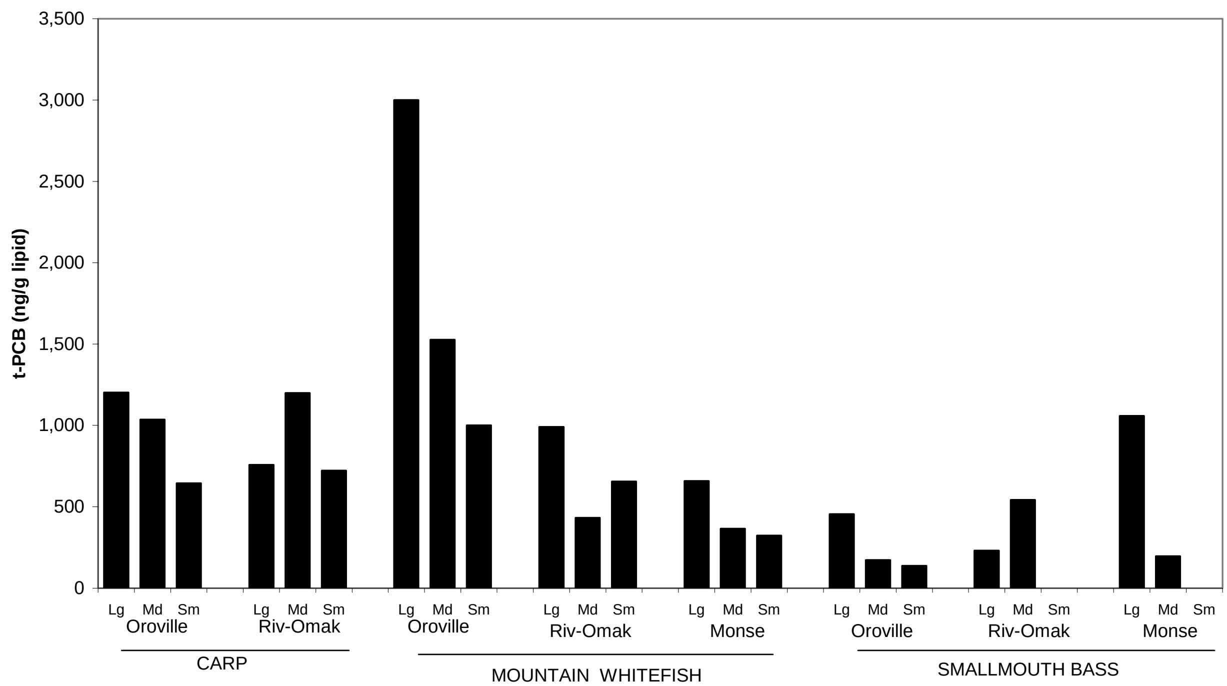

Figure 7: Lipid-Normalized t-PCB Concentrations in Lower Okanogan River Fish Muscle Ordered by Mean Length of Fish in Each Composite (Lg=large, Md=medium, Sm=small) and Location for each Species

Loading Capacity

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 A) 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

<u>DDT Loads Delivered Through Tributary Streams</u>

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 12). 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:

$$Weighted\ Mean\ Load = (sum\ of\ n\ loads/n) \times (n/number\ of\ sample\ attempts)$$

Table 12: 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, BC	91.2	1/1	0.0	0.0	0.0	0.0
Haynes Creek (BC)	82.8	1/1	1.3	0.0	0.0	1.3
Nine Mile Creek	80.2	4/4	6.6	2.1	4.9	13.6
Tonasket Creek	77.8	2/4	12.4	0.0	8.4	20.8
Similkameen River	74.1	2/2	0.0	0.0	0.0	0.0
Mosquito Creek	67.4	3/4	1.0	1.0	0.0	2.0
Whitestone Creek	62.4	4/4	6.7	0.0	0.0	6.7
Antoine Creek	61.2	4/4	4.8	0.6	1.0	6.4
Siwash Creek	57.3	1/4	0.3	0.0	0.0	0.3
Bonaparte Creek	56.7	3/4	1.9	0.0	0.0	1.9
Aeneas Creek	52.9	3/4	1.5	0.0	0.0	1.5
Chewiliken Creek	50.7	1/2	0.0	0.0	0.0	0.0
Tunk Creek	45.0	2/4	0.0	0.0	0.0	0.0
Johnson Creek	40.6	2/4	0.0	0.0	0.0	0.0
Wanacut Creek	35.0	2/4	0.0	0.0	0.0	0.0
Omak Creek	32.0	3/4	0.0	0.0	0.0	0.0
Elgin Creek	28.4	4/4	14.4	0.6	7.1	22.0
Salmon Creek	25.7	1/4	2.5	0.0	0.0	2.5
Tallant Creek	19.5	2/4	46.6	10.5	68.6	125.7
Loup Loup Creek	16.9	2/4	trace	0.0	trace	0.1
Chiliwist Creek	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

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.

Ninemile, Tonasket, and Elgin Creeks together account for a large remainder of the DDT loads from tributaries (27% of t-DDT). Ninemile 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 13. Loads were calculated from effluent sampling conducted during April and May 2001, and in May, 2002.

Table 13: 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 Loading 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 14.

Delivered loads are the weighted mean loads from tributary streams and STPs (12 and 13) and combined for each Okanogan River reach.

Measured loads in the lower mainstem Okanogan River were calculated from DDT and PCB concentrations analyzed during May, 2002 (Table 5) and daily flows recorded at USGS gaging stations at Oroville, near Tonasket, and at Malott.

Theoretical loads in this report represent the all the aquatic environmental impacts on fish tissue contaminant levels. This aquatic environment impact includes contaminant exposures from water, sediments and the food chain in the Okanogan River as a water contamination concentration that would reasonably be expected to result in fish tissue contamination that has been observed in the most recent Okanogan River fish tissue samples. 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 11], lake whitefish for Osoyoos Lake [Appendix A]).

Loading capacities were calculated using NTR human health criteria and Ch. 173-201A WAC chronic aquatic life criteria (Table 1). Flows used to calculate loading 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 loading 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 loading 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 loading 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 loading capacity of the Okanogan River at Malott.

Table 14: Total Load Delivery, Measured Loads, Theoretical Loads, and Loading 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; RM 91.2- 79.0						
Total load delivered to reach (tribs.)	91.2 – 80.2	8	2	5	15	0
Theoretical Load (US Waters)	82.5 – 79.0	17,000	10,000	770	25,000	0
Loading cap. @ Osoy. Lk. outlet	79.0	800	1,100	800	1,400	230
Near Oroville; RM 79-77.4						
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]
Loading capacity @ near Oroville	74.1	800	1,100	800	1,400	230
Near Tonasket; RM 77.4-50.7						
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]
Loading capacity near. Tonasket	50.7	3,900	5,500	3,900	6,500	1,100
Near Malott; RM 50.7-17.0						
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]
Loading capacity @ Malott	17.0	4,000	5,600	4,000	6,700	1,100
Mouth; RM 16.0-0.0						
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]
Loading 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

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

Although measured loads of DDT shown in Table 14 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 could also 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 15 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.

CCT 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. Sixty percent 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 may also 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 CCT survey.

Table 15: 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

Load and Wasteload Allocations

<u>DDT and PCB Load Allocations in Tributary Streams</u>

DDT and PCB load allocations (LAs) for tributary streams are shown in Table 16. LAs were set at loading capacities. For tributaries with weighted mean loads below loading 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.

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 loading 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 Canadian 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 loading 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 14).

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), and Tallant Creek (4,4'-DDE, 4,4'-DDD, 4,4'-DDT, t-DDT).

Table 16: 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; RM 91.2-80.2						
Okanogan River @ Osoyoos BC	91.2	796.3	1133.8	796.3	1349.7	229.5
Haynes Creek BC	82.8	0.3	0.0	0.0	0.5	0.1
Ninemile Creek	80.2	2.0	2.1	2.0	3.4	0.6
Sum =		798.6	1135.9	798.3	1353.6	230.2
Near Oroville; RM79-77.4						
Tonasket Creek	77.8	4.9	0.0	4.9	8.4	1.4
Sum =		4.9	0.0	4.9	8.4	1.4
Near Tonasket; RM 77.4-50.7						
Similkameen River	74.1	998.7	998.7	1028.1	3025.6	791.0
Mosquito Creek	67.4	0.4	0.5	0.0	0.6	0.1
Whitestone Creek	62.4	5.9	0.0	0.0	6.7	1.7
Antoine Creek	61.2	1.9	0.6	1.0	3.3	0.6
Siwash Creek	57.3	0.3	0.0	0.0	0.3	0.1
Bonaparte Creek	56.7	1.9	0.0	0.0	1.9	0.8
Aeneas Creek	52.9	1.5	0.0	0.0	1.5	0.8
Chewiliken Creek	50.7	0.0	0.0	0.0	0.0	0.1
Sum =		1010.6	999.8	1029.1	3039.9	795.2
Near Malott; RM 50.7-17.0						
Tunk Creek	45.0	0.0	0.0	0.0	0.0	1.1
Johnson Creek	40.6	0.0	0.0	0.0	0.0	0.4
Wanacut Creek	35.0	0.0	0.0	0.0	0.0	0.2
Omak Creek	32.0	0.0	0.0	0.0	0.0	4.3
Elgin Creek	28.4	1.8	0.6	1.8	3.1	0.5
Salmon Creek	25.7	2.5	0.0	0.0	2.5	1.0
Tallant Creek	19.5	0.2	0.3	0.2	0.4	0.1
Sum =		4.5	0.9	2.0	6.0	7.6
Mouth; RM 17.0-0.0						
Loup Loup Creek	16.9	0.0	0.0	0.0	0.1	0.1
Chiliwist Creek	15.1	0.6	0.0	0.0	0.6	0.4
Sum =		0.6	0.0	0.0	.07	.05

DDT and PCB Waste Load Allocations in STPs

DDT and PCB waste load allocations (WLAs) for STPs are in Table 17. 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 17: 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]	e	21.6	1.1	1.6	1.1	1.9	0.3
Tonasket[d]	56.4	17.5	0.9	1.3	0.9	1.5	0.5
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]NPDES permit WA-005233-7
[e]Similkameen River mile 4.0. The Similkameen River enters at Okanogan River mile 74.1

Daily loads measured during 2001-2002 (Table 13) 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. It is not known if the potential discharge of contaminants is within the Tonasket WLA. The current discharge for the city of Tonasket has not been sampled due to the Tonasket WWTP beginning its discharge to the river after the samples were taken for the current TMDL assessment report.

DDT and PCB Load Allocations for Sediments

Table 18 shows DDT and PCB load allocations for exogenous sources (tributary streams and STPs), bottom sediments, and loading 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 loading capacity of each reach.

LAs for the Okanogan River at Osoyoos, B.C. constitute all of the loading capacities at Osoyoos Lake and the Okanogan River at Oroville. The added loading capacity of the Similkameen River provides for bottom sediment DDT LAs of about one-half the loading 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.

Table 18: 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	798.6	1135.9	798.3	1353.6	230.2
Bottom sediments	82.5-79.0	0	-12.4	0.3	0	0
Loading capacity	79.0	798.6	1123.5	798.6	1353.6	230.1
Near Oroville						
Cumulative LAs/WLAs (tribs.and STPs)	91.2-77.8	803.5	1135.9	803.2	1362.0	231.6
Bottom sediments	79.0-77.4	0.2	-5.3	0.4	0.2	0.0
Loading capacity	77.4	803.7	1130.6	803.7	1362.2	231.6
Near Tonasket						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 52.9	1816.1	2138.6	1834.3	4405.3	1027.6
Bottom sediments	77.4-50.7	2038.4	3283.9	2020.2	2127.8	83.1
Loading capacity	50.7	3854.5	5422.5	3854.5	6533.1	1110.6
Near Malott						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 19.5	1826.0	2147.2	1841.7	4420.5	1036.7
Bottom sediments	50.7-17.0	2113.7	3395.1	2097.9	2256.9	98.5
Loading capacity	17.0	3939.7	5542.3	3939.7	6677.4	1135.2
Mouth						
Cumulative LAs/WLAs (tribs.and STPs)	91.2 – 15.1	1826.6	2147.2	1841.7	4421.2	1037.2
Bottom sediments		2113.1	3395.1	2097.9	2256.2	98.0
Loading capacity		3939.7	5542.3	3939.7	6677.4	1135.2

Load Reductions

Load reductions required to meet DDT/PCB LAs are shown in Table 19. 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 loading capacities in certain tributary streams and STPs.

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.

Table 19: Required DDT and PCB Load Reductions and Reserve Capacity (-) at 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						
Tribs. (reduction)	91.2-80.3	-790.7	-1133.8	-793.4	-1338.7	-230.2
% reduction		0%	0%	0%	0%	0%
Sediments (reduction)	82.5-79.2	17114.1	10238.0	777.7	28117.7	0.0
% reduction		100%	100%	100%	100%	0%
Oroville						
Tribs. (reduction)	91.2-77.8	-783.2	-1133.8	-789.9	-1326.3	-231.6
% reduction		0%	0%	0%	0%	0%
Sediments (reduction)	79.0-77.4	7933.9	664.0	265.8	8858.8	829.5
% reduction		100%	100%	100%	100%	100%
Reach	**RM**	**4,4'-DDE**	**4,4'-DDD**	**4,4'-DDT**	**t-DDT**	**t-PCB**
Near Tonasket						
Tribs. and STPs (reduction)	91.2 – 52.9	-1779.5	-2134.9	-1819.6	-4350.3	-1027.5
% reduction		0%	0%	0%	0%	0%
Sediments (reduction)	77.4-50.7	39000.5	1587.9	-572.2	45230.8	6408.0
% reduction		95%	33%	0%	96%	99%
Malott						
Tribs. and STPs (reduction)	91.2 – 19.5	-1725.1	-2132.1	-1750.2	-4213.1	-1034.0
% reduction		0%	0%	0%	0%	0%
Sediments (reduction)	50.7-17.0	10367.9	-1915.2	-1790.8	11986.8	2467.0
% reduction		83%	0%	0%	84%	96%
Mouth						
Tribs. and STPs (reduction)	91.2 – 15.1	-1725.1	-2132.1	-1750.2	-4213.1	-1034.5
% reduction		0%	0%	0%	0%	0%
Sediments (reduction)	17.0-0.0	10367.9	-1915.2	-1790.8	11986.8	2467.5
% reduction		83%	0%	0%	84%	96%

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

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 (Riv-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.

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.

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.

Table 20: BSAFs at Osoyoos Lake and Several Lower Okanogan River Reaches

Location	4,4'-DDE	4,4'-DDD	4,4'-DDT	t-4,4'-DDT	t- PCB[a]
Osoyoos Lake	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

Table 21: 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 conc.	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 conc.	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 conc.	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 conc.	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 conc.	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

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 streams – Tallant Creek, Elgin Creek, and Ninemile Creek – 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 22: 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 Creek BC	82.8	1.0	0	0	0.8	0
Nine Mile Creek	80.2	4.6	0	2.8	10.2	0
Tonasket Creek	77.8	7.4	0	3.5	12.4	0
Mosquito Creek	67.4	0.6	0.5	0	1.4	0
Whitestone Creek	62.4	0.8	0	0	0	0
Antoine Creek	61.2	2.8	0	0	3.1	0
Elgin Creek	28.4	12.5	0	5.3	19.0	0
Okanogan STP	24.8	0	0	0.3	0.8	0.2
Tallant Creek	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

Seasonal Variation

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

Margin of Safety

The federal Clean Water Act requires that a margin of safety be identified to account for uncertainty when establishing a TMDL. The margin of safety can be explicit in the form of an allocation, or implicit in the use of conservative assumptions in the analysis.

A large portion of the Margin of safety in this TMDL is the long standing bans on use of these persistent compounds in the environment. As the reduction of contaminants in the system is observed, no new sources will occur. The non-point nature of DDT and PCBs and the difficulty to directly control their discharge to the water have abated over time and the improvements to land and water management within the valley assures improving long term control of non-point contaminant migration pathways. This TMDL also relies on the conservative means by which the criteria have been set for the DDT and PCB related contaminants for the margin of safety. Additionally; this margin of safety is enhanced by the legacy nature of the contaminants addressed in this TMDL, the concentrations of contaminants should continue to decline even after the regulatory criteria have been met.

Summary Implementation Strategy

Introduction

Pursuant to the 1997 Memorandum of Agreement between Ecology and the EPA, a Summary Implementation Strategy (SIS) is included in this submittal report for the *Okanogan River DDT and PCB Total Maximum Daily Load Project*. This goal of this SIS is to present a clear, concise and sequential concept of how suspended DDT and PCB pollution will be reduced within the Lower Okanogan basin in order to meet the fish tissue and surface water criteria for DDT and PCBs. It is anticipated that implementation of the TMDL will return this water body to conditions that meet the targets and criteria noted above by July and 2054. The SIS complies with the federal mandate of the Clean Water Act, State laws to control point and non-point source pollution, and the 1997 Memorandum of Agreement between EPA and Ecology.

A citizen's workgroup that was formed as the Implementation Committee under the Okanogan Watershed Water Quality Management Plan served as citizen representatives in the development of this TMDL and implementation strategy. Groups represented in the TMDL workgroup include irrigated agriculture, ranchers, conservation districts and natural resource agencies, recreational interests, as well as numerous other interested parties or stakeholders, agencies and organizations. There is a high level of cooperation and communication between project participants, and their continued active pursuit of the goals TMDL's and watershed management plan, many of which are shared by both the TMDL and the Okanogan Watershed Water Quality Management Plan, will ultimately ensure the success of this TMDL.

The strategy to implement the TMDL is based upon actions already taken to address contaminant sources, the continuation of the many existing efforts, and the implementation of new actions. The non-point sources (load allocations) will be addressed by the use of best management practices (BMPs). Point sources (NPDES dischargers) are already working to understand the source of contaminants in their discharges and will continue to work under the NPDES program to reduce their contaminant loading to the Okanogan River. The principal focus of this TMDL implementation strategy will be to continue the removal of potential sources of contamination from the watershed and the implementation of seasonal and year-round BMPs to prevent the entry of persistent residues of DDT and PCBs into area waterbodies. Additionally, continued monitoring of implementation activities and fish tissue contaminant levels and water quality are essential in assessing the natural attenuation of contaminants.

This SIS will serve as guidance for developing a Detailed Implementation Plan (DIP) during the one-year period after the TMDL has been approved. The DIP will describe specific implementation activities that need to be performed to achieve the TMDL targets. The DIP will also present a thorough plan for monitoring implementation of this TMDL. It is anticipated that implementation of this TMDL will document long-term reductions in the DDT and PCBs in fish from the Lower Okanogan River Basin.

The technical assessment report identified the sediments within the Okanogan River as the primary load of contaminants. The restoration timeframe for this TMDL is primarily dependent on the natural breakdown of these persistent chemicals in the environment. Limited early data on fish tissue concentrations suggest a downward (improving water quality) trend in fish tissue concentrations when compared to data reported from the latest TMDL study. Data collection and analysis for fish tissue prior to the TMDL Technical Assessment report is insufficient for the establishment of baseline data. The downward trend cannot be determined due to the limited amount of the early data. The current TMDL assessment report does provide sufficient data for reference by future fish tissue studies

Implementation Activities

This TMDL is addressing water quality impairment from legacy loading. The primary actions for reducing DDT and PCB in the environment was the regulatory ban on DDT use in 1972 and the 1979 ban on PCB production, and the subsequent phase-out and control of PCB products.

A downward trend in DDT and PCB concentrations following the above bans is evident in the sediment cores from the south basin of Lake Osoyoos and the lowest segment of the Okanogan River. This downward trend, however, is not continuous in the Lake Osoyoos coring and exhibits an anomalous spike of high concentration in the past decade. This trending data suggests two courses of actions are needed to address continuing inputs of DDT to the watershed; continued implementation of BMPs to reduce pesticide residues reaching the affected surface waters and efforts to remove DDT containing products for the watershed.

Implementation Activities for Non-Point Sources

Several tributary streams within the Okanogan Basin were identified as carrying DDT contamination. Specific source areas of non-point contamination were not apparent and not identified by the technical assessment.

Lands that were in agricultural production during the time period that DDT was in common usage are considered potential sources of DDT due to the residues of DDT that persist in the soils. Erosion of these lands can be the source of contaminated river systems as shown in the report: *A Suspended Sediment and DDT Total Maximum Daily Load Evaluation Report for the Yakima River*. In that report DDT loading to the Yakima River was found to correlate strongly with the amount of sediment derived from agricultural runoff. Irrigation practices in the lower Okanogan River basin do not produce the amounts of sediment loading to the river that were seen in the Yakima example, even though pesticide application practices were similar in both basins at the time, which suggests that agricultural soil losses in the Okanogan are not as great a source of DDT as in the Yakima River area surface waters.

Historical improvements in irrigation delivery systems in the lower Okanogan River basin have resulted in the current irrigation systems efficiently providing water to the lands. According to the Okanogan Conservation District, irrigation practices that result in significant soil loss, such as open rill irrigation, are no longer practiced in the lower Okanogan Basin. Investigations in the lower Okanogan River basin by Ecology and the Colville Confederated Tribes did not document the discharge of irrigation drains in the Okanogan valley.

Experience in other irrigated river basins, like the lower Yakima River Basin, has shown that a movement to enclosed irrigation systems, like sprinklers or drip systems, effectively reduces the amount of pesticide residues carried from agricultural lands into nearby surface waters.

Continuing improvements to irrigation efficiency and water delivery systems may continue to decrease the soil that migrates directly from the agricultural lands. Therefore, working with irrigation water management to produce efficient irrigation practices will also reduce the transport of DDT residues from the agricultural lands.

BMPs that work directly with the riparian lands located between the current and former agricultural lands to reduce losses of soils that potentially contain pesticide residues are actively promoted through programs including: EQUIP, CREP, CRP, and Ecology administered grants of Centennial Clean Water funds, 319 funds and Salmon Recovery Funds. These funding sources are not dedicated only for projects that reduce DDT in surface waters, but are directed toward reducing a variety of pollutants. Many of the projects, such as exclusion fencing to restrict cattle from riparian areas that are promoted for environmental restoration and preservation can have the side benefit of DDT reduction through the prevention of erosion.

Potential sources of DDT contamination, other than agricultural soil erosion, have been suggested for the tributary streams. An example of this is a complaint that has been filed with the Ecology that an old orchard dump in the vicinity of Highway 20 crossing Talent Creek may be a continuing source of DDT contamination. Such complaints regarding inappropriate disposal will be investigated though the Washington State Model Toxics Control Act and other State regulations as appropriate.

Removing potential sources of DDT in the watershed is an important step in reducing the contamination in the Okanogan watershed. Programs for the collection of banned pesticides, including DDT, have been successfully implemented in both Washington and British Columbia, removing many stored pesticides from the watershed. The waste pesticide pickup programs, such as the one conducted by the Washington Department of Agriculture, reduces the potential of inappropriate disposal or accidental loss of DDT, or any other waste pesticide, in the watershed. Losses of DDT-containing materials could result from catastrophic losses from storage facilities through flood, fire, or inappropriate disposal activities. Such a disposal or catastrophic loss of stored materials could account for the spike in concentrations found in the sediment core from southern Lake Osoyoos.

Addressing PCB contamination in the lower Okanogan River Basin is more problematic than addressing the DDT pesticide. The primary uses of PCB were not intended for dispersal into the environment, but its environmental persistence is similar to that of DDT. Efforts to reduce PCB releases to the environment will include education efforts for disposal of potential PCB-containing materials common to industry, small businesses and households. Proper disposal of items and materials that potentially contain PCBs may be achieved through the existing moderate risk waste facility operated by Okanogan County. An experimental effort to collect and test sediment from storm drains in municipal areas has been proposed for the municipalities of Tonasket and Okanogan. This effort has the potential to collect PCBs from the urban environment and analytically test collected materials to determine the success of the project and its potential future applications in the valley.

Implementation Activities for Point Sources (NPDES)

The NPDES permitted dischargers in the Lower Okanogan Basin are the municipal wastewater treatment plants in Oroville, Tonasket, Omak and Okanogan. These facilities are the only potential point sources in the TMDL study area.

The NPDES discharge permits for the cities of Oroville Omak and Okanogan have recently been renewed. Coordination between the NPDES permit development and the ongoing development of this TMDL has resulted in each of these permits containing requirements to investigate the wastewater collection systems for the sources of DDT and PCBs in their effluent. An effort is being made to undertake a coordinated investigation of wastewater collection systems of these municipalities and the wastewater collection and treatment system for the city of Tonasket. The purpose of investigating the wastewater collection systems is to determine if there is a discreet or concentrated source of contaminants entering the systems that may be addressed efficiently before the contaminants enter the wastewater treatment plants.

The city of Tonasket was not included in the sampling for the technical assessment study as it was not discharging to the river at the time of the study. The city of Tonasket has since completed construction on an upgraded wastewater treatment system and is now discharging to the river. The NPDES permit was not conditioned with a requirement for investigating potential sources of DDT. However, the city of Tonasket has expressed a willingness to participate in DDT studies in anticipation of their next permit cycle.

Monitoring Strategy

The persistent natures of DDT and PCBs in the environment truly make them a legacy of past practices. While these toxic compounds continue to persist in the environment their effective levels are reduced over time through degradation and by natural attenuation through dilution and capping. The natural processes resulting in the lower exposure of aquatic life to the contaminants will play a major role in the success of this TMDL. Monitoring fish tissue concentrations of these contaminants will be the most effective means to judge the progress of environmental improvement.

Analytical testing results for fish tissue sampling for the 2003 TMDL Technical Assessment report show DDT and PCB values that appear to be substantially lower than the fish tissue samples that were taken in the period of 1984 – 1995. Unfortunately, there is insufficient data from 1985-1995 to determine if this apparent reduction of contamination in fish tissue is truly significant. The fish tissue data from the 2003 Technical Assessment report will serve as the baseline data to judge progress of environmental improvement. Repeating the fish tissue sampling efforts on a regular cycle of 5 years is recommended for the tracking of effective water quality improvements.

Responsible Entities and Actions

The Okanogan Conservation District administers most of the incentive based or grant funded programs for the restoration and preservation of riparian lands, and the reductions of soil losses on agricultural lands. It is important that the Okanogan Conservation District continue to serve this role of coordinating grant funded projects in the watershed as they have the local knowledge and community contacts that are essential to the success of these programs.

The municipalities of Oroville, Tonasket, Omak and Okanogan are responsible for the compliance of their municipal wastewater treatment plants with their NPDES permits. The linkage between the NPDES and TMDL programs through the US Clean Water Act assures that the goals of the TMDL will be reflected in their NPDES permits.

Ecology will be responsible for the periodic monitoring of DDT and PCBs in fish tissues. Maintaining this responsibility within the state agency should provide consistent data quality.

Ecology is the responsible entity for determining compliance of interim and final targets, and conducting Effectiveness Monitoring in the future.

Adaptive Management

These implementation activities are centered on the maintenance and improvement of long term activities that have reduced water contaminant levels since the banning of DDT and PCBs. The inclusion long-term data collection and monitoring of fish tissue in the implementation activities is necessary due to the persistent nature of these legacy contaminants. The monitoring activities will serve to better define the rate that the water quality in the basin is improving. Re-evaluation of the long-term trends with additional data will allow the restoration timeframe to be determined with greater precession. If the water quality monitoring activities show unexpected long-term rises of contaminants in fish tissues, an examination of any potential new sources of DDT or sediments should also be undertaken. Additionally, intensive surveys and watershed investigation should be sought to identify significant events in the watershed that could re-suspend sediments.

Persistent elevated values of DDT or PCB contamination, or data that does not show the expected gradual declines over time, will trigger additional investigation under adaptive management. This should include, but not be limited to, further the investigations of tributary streams and potential groundwater transport of DDT.

Potential Funding Sources

Funding sources will be more fully explored in the development of the DIP.

At this time funding for the periodic (repeating every five years) monitoring of the lower Okanogan basin fish tissue is expected be accomplished with project funding through the normal operations of Ecology. Opportunities for external funding sources and adjustment to the frequency of study events will be considered as the body of data and time related trends are accumulated.

Funding for the Washington Department of Agriculture's waste pesticide pickup program is currently sustained through the Department of Agriculture. The benefits of such a program to water quality are direct but difficult to quantify as it is a preventive program. At this time the program appears to be well supported and will continue to be available in the Okanogan Valley.

The communities of Tonasket and Okanogan are seeking grant funding for the experimental effort to collect and test sediment from storm drains in municipal areas. This independent work by the cities may be facilitated through the efforts of the Okanogan Conservation District.

Detailed Implementation Plan

A DIP will be prepared within a year following approval by EPA of this document. Further public input will be sought to help prepare the plan. The plan will identify in more detail how, when, and where monitoring activities will be implemented. Ecology and other entities will provide technical assistance and seek additional funding for these monitoring activities and any restoration activities that may be identified as the body of data grows. It is the goal of this TMDL to meet the water quality standards for DDT in surface waters and 4,4'-DDD, 4,4'-DDE and PCBs in fish tissues by 2054.

Activities that Support this TMDL

Implementation Strategy

The implementation strategy for the Okanogan DDT and PCB TMDL is designed to address legacy loading of DDT and PCBs in the watershed from historic agricultural, industrial, commercial and domestic practices in the watershed. Implementation activities include continued implementation of activities that have reduced or controlled releases of contaminants to the surface waters and the continued investigation of potential contaminant sources in the Okanogan River Tributaries.

Supporting Regulations and Land Management Plans

Routine implementation of Washington's State Environmental Policy Act, the Okanogan County Comprehensive Plan and the Okanogan County Shoreline Master Program will assure the review of projects proposed in the vicinity of the Okanogan River and tributaries for potential environmental impacts due to erosion. This review process should ensure best management practices are used for new projects and that permitted activities will not impact the implementation of this TMDL. Continued implementation of Washington's Model Toxics Control Act should provide continued support for the investigation of potential contaminated sites that are uncovered over time, such as dump sites that include DDT and PCB containing materials.

Reasonable Assurance

During the development of the DDT and PCB TMDL for the lower Okanogan River basin, available data for water quality throughout the watershed was collected and evaluated. The mass balance approach to the TMDL and the quantity of data has shown that the loading of these legacy contaminants are far reduced from the time that they were in active use. Without new sources of contaminant entering the watershed, the downward trend should continue though at a much declined rate from what has been seen in recent years as indicated by the sediment core samples and dating conducted as part of the TMDL technical assessment. The rate of natural attenuation due to degradation, dilution and sequestering of materials in the deep sediments can only be estimated with the current set in data. Documentation of the attenuation will take long-term monitoring of fish tissue in the river system. The conservative assumptions used in setting the regulatory criteria, and the work by the NPDES permitted facilities should provide sufficient assurance that, with time, water quality is improving.

Each of these conservative measures will assure that the Okanogan Watershed will be monitored and protected from activities that would threaten the water quality while the legacy loading is mitigated through time and nature.

Public Participation

Public involvement is a required part of the TMDL process. The public participation activities performed to date for this TMDL are included in appendix A "Summary of Public Involvement". Additional public involvement activities will be included in preparation of the Detailed Implementation Plan.

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Definitions and Acronyms

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
CCT	Colville Confederated Tribes
CFR	Code of Federal Regulations, usually preceded by chapter number and followed by a section number (i.e. 40CFR131.36)
cfs	cubic feet per second
CWA	Clean Water Act
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)
DIP	Detailed Implementation Plan
Ecology	Washington State Department of Ecology
ECD	electron capture detector
EPA	U.S. Environmental Protection Agency
FC	fish consumption
g/day	grams per day
GC	gas chromatography
HHC	human health criteria
LA	load allocation
MEL	Manchester Environmental Laboratory
mg/l	milligrams per liter (parts per billion)
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 (40CFR131.36)
Q	discharge
q1*	cancer slope factor
Pb	lead
PCB	polychlorinated biphenyl
Ra	radium
RCW	Revised Code of Washington
RF	risk factor
RM	river mile
Rn	radon
SIS	Summary Implementation Plan
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)
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
WWTP	Wastewater Treatment Plant
µg/L	micrograms per liter

Appendix A

Summary of Public Involvement

Summary of Public Involvement

September 12, 2000	Met with the Okanogan Health District Board to present introductory information on the Okanogan DDT/PCB and Similkameen arsenic TMDLs.
November 7, 2000	Presentation on the Okanogan and Similkameen TMDLs made to the environmental science class at Wenatchee Community College class at the Omak branch campus.
September 7, 2000	Presentation to the Okanogan Conservation District Supervisor's meeting to introduce the Similkameen arsenic and Okanogan DDT/PCB TMDLs.
February 22, 2001	Public meeting at Okanogan PUD to kick -off Okanogan DDT/PCB and Similkameen Arsenic TMDLs.
July 26, 2001	Presentation on the Okanogan DDT/PCB and Similkameen arsenic TMDLs to the Okanogan Watershed Implementation committee.
August 9, 2001	Presentation to the Oroville-Tonasket irrigation District on the Okanogan DDT/PCB and Similkameen arsenic TMDLs.
October 25, 2002	Meeting with the Okanogan Watershed Implementation Committee to discuss the Similkameen River arsenic TMDL and the Okanogan River DDT/PCB TMDL.
February 24, 2003	Meeting with the Okanogan Watershed Implementation Committee to discuss the Similkameen River arsenic TMDL and the Okanogan River DDT/PCB TMDL.
June 24 2003	Meeting with Tonasket City Council to discuss the Okanogan DDT TMDL and the implications for the newly permitted municipal waste water discharge.
July 24, 2003	Meeting with the Okanogan Watershed Implementation Committee to discuss the Similkameen River arsenic TMDL and the Okanogan River DDT/PCB TMDL.
September 2003	Okanogan DDT/PCB Technical Assessment Report was posted to the Washington Department of Ecology Web Page. Notifications of report availability were sent to implementation committee inviting them to contact Ecology for a report copy(s) suited to their needs, downloaded from the internet/e-mail, mailed digital copy on disk or printed hard copy.
June 8, 2004	Notification of public comment period and public meetings placed on the Washington Department of Ecology's internet public involvement calendar.

June 11 through July 12, 2004	Public Comment Period for the Lower Okanogan Rive DDT/PCB TMDL Submittal report. Advertisements for the public comment period and public meetings were placed in the larges local newspapers Okanogan Chomical and the Okanogan Valley Gazette Tribune June 7 to 11 and again on the week of June 14 to 18.
June 16, 2004	Public meeting held in the evening at the Okanogan Public Utility District #1 Office in Okanogan. Meeting provided a forum to discuss the TMDL Submittal Report.
June 29, 2004	Public meeting held in the evening at the Oroville City Hall. Meeting provided a forum to discuss the TMDL Submittal Report.

Responses to Public Comments on the Lower Okanogan River Basin DDT and PCB Submittal Report Draft

No public comments were received on the Lower Okanogan River Basin DDT and PCB Submittal Report Draft. Changes to the document were made as a result of comments received from the United States Environmental Protection Agency in regards to required contents and clarification. Adjustments to the load allocation were made due to the inclusion of a Waste Load Allocation for the recently permitted discharge for the Tonasket Waste Water Treatment Plant.

Appendix B

Technical Report

TMDL Technical Assessment of
DDT and PCBs in the Lower Okanogan River Basin
July 2003

Ecology Publication Number 03-03-013

This publication may be viewed at the following website:
http://www.ecy.wa.gov/pubs/0303013.pdf

Paper copy may be obtained upon request.