Quality Assurance Project Plan

TMDL Technical Assessment of DDT and PCBs in the Okanogan River

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303(d) listings addressed in this study:

Okanogan R. (YN58LL, formerly WA-49-1010) – 4,4'-DDD, 4,4'-DDE, PCB-1254 and PCB-1260 in fish tissue
Osoyoos Lake (060VKD, formerly WA-49-9260) – 4,4'-DDD, 4,4'-DDE in fish tissue
Tallant Creek (LD33FC, formerly WA-49-1017) – DDT in water
Elgin Creek (KR66GR, formerly WA-49-1022) – DDT in water
Ninemile Creek (IP09QF, formerly WA-49-1049) – DDT in water

Ecology EIM Number: DSER0009

Approvals

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Background/Problem Statement

The Okanogan River is a large Columbia River drainage with a basin covering a total area of approximately 8,900 mi^2 in north-central Washington and British Columbia. Approximately 2,600 mi^2 of the basin is in Washington (lower basin) where the mainstem Okanogan River flows out of Osoyoos Lake 79 miles southward to its confluence with the Columbia River (Figure 1).

The basin is sparingly populated, with a headcount of 39,564 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).

Land cover is primarily forest and rangeland, especially in the uplands. Orchards and pasture/hay are the primary agricultural uses. Orchards constitute about 2% of the land area, primarily in the vicinity of the mainstem Okanogan River valley bottom.

Historical DDT use in the Okanogan Basin, primarily on orchard 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 Okanogan River and Osoyoos Lake fish (Hopkins et al., 1985; Johnson and Norton, 1990; Davis and Serdar, 1996; Serdar et al., 1998).

Data from 1984 and 1994 have shown total DDT (t-DDT) concentrations in several fish species from the lower Okanogan River among the highest ever recorded in Washington State (1,700 – 3,200 ng/g). Concentrations in Osoyoos Lake fish, collected primarily during a 1995 survey, showed more moderate levels (40 – 1,200 ng/g t-DDT), but concentrations were generally elevated above the National Toxics Rule (NTR) criterion for DDT (32 ng/g for 4,4-DDT and 4,4'-DDE, 45 ng/g for 4,4'-DDD).

A study by Johnson et al (1997) also found DDT in several streams tributary to the Okanogan River and Osoyoos Lake. Three streams had t-DDT concentrations above the Washington State water quality standard to protect aquatic life from chronic exposure to DDT (0.001 µg/l). Tallant Creek, flowing into the lower Okanogan River, had t-DDT concentrations up to 500 times the standard. However, the daily loads of DDT to the Okanogan River from all of the sources combined was low, approximately 0.3 grams/day (Johnson et al., 1997).

PCBs have also been found in some Okanogan River and Osoyoos Lake fish (Hopkins et al., 1985; Davis and Serdar, 1996; Serdar et al., 1998). Concentrations of total PCBs (t-PCBs, sum of Aroclors) in muscle tissues were relatively low (20 – 40 ng/g) in fish from the lower reaches of the mainstem Okanogan River. Osoyoos Lake fish had no detectable PCBs in muscle tissues, but detectable concentrations in whole fish indicate that PCBs are present in the lake.

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*unless stated otherwise, DDT refers to DDT and its breakdown products, DDE and DDD. The sum of these compounds is total DDT (t-DDT).

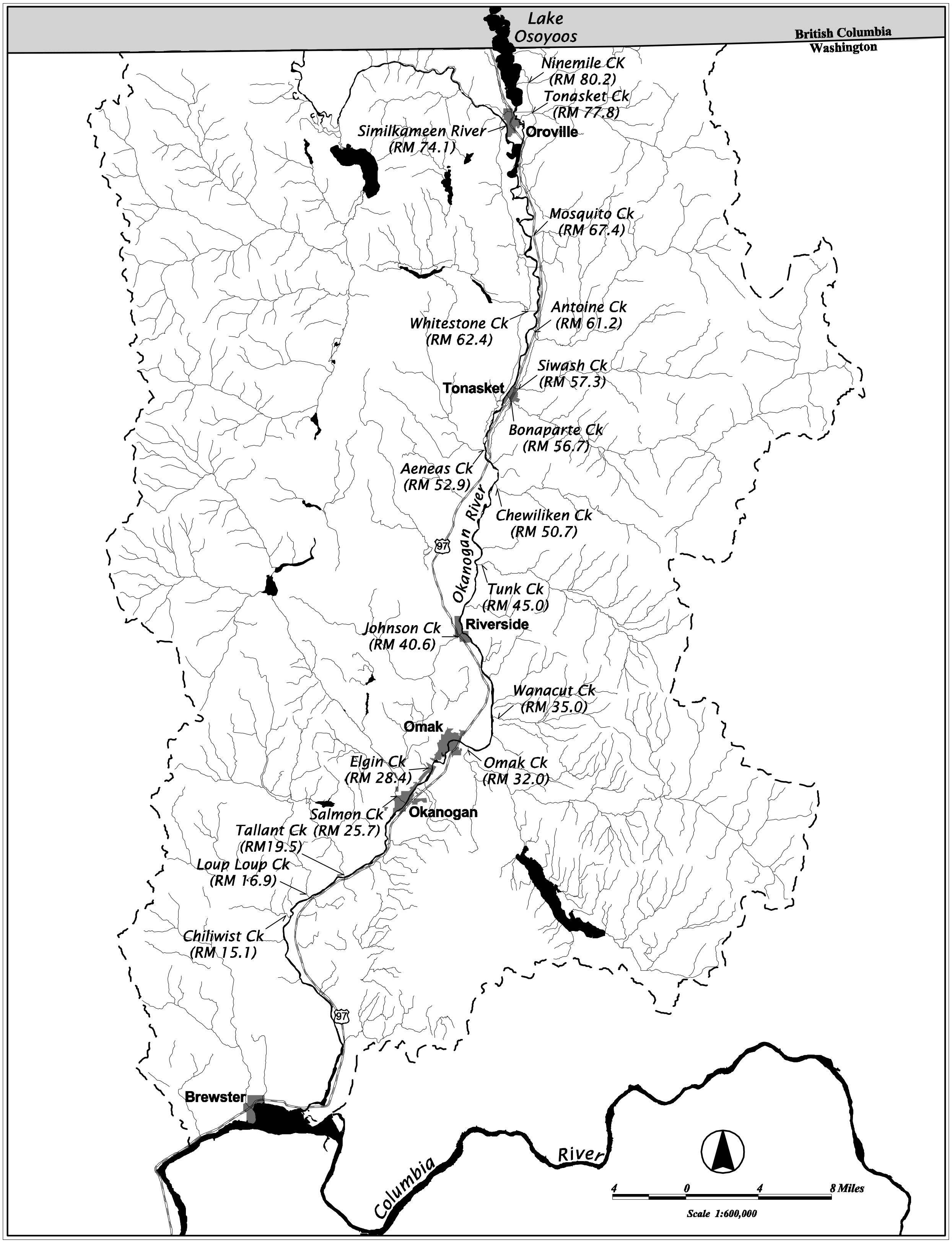

Figure 1. Location of Okanogan River and Osoyoos Lake Tributary Streams

PCBs are a ubiquitous environmental contaminant and like DDT, they persist in the aquatic environment for decades, accumulating in fish tissue. However, due to the difficulty in detecting PCBs in the water column, no effort had been made to track down the source(s) of PCBs in the Okanogan River system.

Table 1 summarizes Ecology's data on DDT in the Okanogan River basin prior to commencement of the present study. The complete data set is in Appendix A. There were no data available from other sources, except for Osoyoos Lake fish data collected above the Canada border. Needless to say, there are not sufficient data to accurately characterize DDT contamination of the aquatic environment of the Okanogan River system, with the possible exception of tributary water and Osoyoos Lake fish tissue. Mainstem river data are particularly lacking, especially data on fish tissue and sediments.

A summary of Ecology's Okanogan PCB data is shown in Table 2. There are so few data that it is impossible to assess whether there is a realistic PCB problem in the basin. All available data were from Ecology, about half of which are nearly two decades old.

As a result of these findings, one Okanogan River segment, Osoyoos Lake, and several tributaries have been included on the Clean Water Act Section 303(d) list due to the presence of DDT in fish and water samples. One Okanogan River segment is also listed for PCBs due to their presence in fish tissue. A total maximum daily load (TMDL) has been identified as the action initially needed to bring these waterbodies into compliance with state and federal water quality standards. This study plan identifies the data needed to assess loading of DDT and PCBs in the Okanogan River, Osoyoos Lake, and their tributaries.

Table 1. Summary of Existing Okanogan Basin DDT Data Collected by Ecology, 1984-1995 and Applicable Criteria.

	Water		**Bottom Sediment**		**Edible Fish Tissue**		**Whole Fish**	
	n	**t-DDT (ng/L)**	**n**	**t-DDT (ng/g, dry)**	**n**	**t-DDT (ng/g, wet)**	**n**	**t-DDT (ng/g, wet)**
Ecology Data (1984-1995)								
Okanogan River Mainstem	3	nd (1)	2	18 – 56	3	1,700 – 3,200	4	800 – 1,800
Tributaries to the Okanogan River and Osoyoos Lake	17	nd (1) – 500	na	--	na	--	na	--
STPs	2	nd (8 – 60)	1	300[a]	na	--	na	--
Osoyoos Lake	na	--	na	--	19	40 – 1,200	2	60 – 1,000
National Toxics Rule Criteria – Human Health		**0.59**[b]		**ne**		**32**[c]		**ne**
Chronic Water Quality Standard – Aquatic Life		**1**		**ne**		**ne**		**ne**

nd=not detected at practical quantitation limit in parentheses
na=not analyzed
ne=not established
a=STP sludge
b=Criteria for 4,4'-DDT and 4,4'-DDE. Criterion for 4,4'-DDD is 0.84 ng/L.
c=Criteria for 4,4'-DDT and 4,4'-DDE. Criterion for 4,4'-DDD is 45 ng/g.

Table 2. Summary of Existing Okanogan Basin PCB Data Collected by Ecology, 1984-1995 and Applicable Criteria.

	Water		Bottom Sediment		Edible Fish Tissue		Whole Fish	
	n	t-PCB (ng/L)	n	t-PCB (ng/g, dry)	n	t-PCB (ng/g, wet)	n	t-PCB (ng/g, wet)
Ecology Data (1984-1995)								
Okanogan River Mainstem	na	--	2	nd (47) – 21	3	nd (10) – 45	4	56 – 600
Tributaries to the Okanogan River and Osoyoos Lake	na	--	na	--	na	--	na	--
STPs	1	nd (300)	1	nd (200)[a]	na	--	na	--
Osoyoos Lake	na	--	na	--	2	nd (20 – 40)	2	24 – 66
National Toxics Rule Criteria – Human Health		**0.17**[b]		**ne**		**5.3**[b]		**ne**
Chronic Water Quality Standard – Aquatic Life		**14**		**ne**		**ne**		**ne**

nd=not detected at practical quantitation limit in parentheses
na=not analyzed
ne=not established
a=STP sludge
b=Criteria for total PCBs (t-PCB)

Basis for 303(d) Listings

Mainstem Okanogan River and Osoyoos Lake

Table 3 shows data used as the basis for including one mainstem Okanogan River segment (segment YN58LL near Monse) and one Osoyoos Lake segment (060VKD) on the most recent (1998) 303(d) list. The 303(d) decision matrices have been included in Appendix B.

Each segment has been listed due to a single composite fish sample: Okanogan River segment YN58LL due to excessive 4,4'-DDD, 4,4'-DDE, PCB-1254 and PCB-1260 in a single carp fillet sample collected during 1994 as part of the Washington State Pesticide Monitoring Program (Davis and Serdar, 1996); Osoyoos Lake segment 060VKD due to excessive 4,4'-DDE and 4,4'-DDD in a single largemouth bass fillet sample collected during 1989 screening survey of lakes statewide (Johnson and Norton, 1990).

Table 3. Data Used as the Basis for Inclusion of Okanogan River Segment YN58LL and Osoyoos Lake Segment 060VKD on the 1998 303(d) List.

Matrix	**Waterbody**	**Ref.**	**4,4'-DDE (ng/g)**	**4,4'-DDD (ng/g)**	**PCB-1254 (ng/g)**	**PCB-1260 (ng/g)**	**t-PCB (ng/g)**
Carp muscle fillet (n=1)	Okanogan R. Segment YN58LL	a	1,650	1,050	25	20	45
Largemouth bass muscle fillet (n=1)	Osoyoos Lk. Segment 060VKD	b	150	55	nd (20)	nd (20)	nd (20)
NTR Criteria for edible fish tissue	**--**	**--**	**32**	**45**	**na**	**na**	**5.3**

a-Davis and Serdar, 1996
b- Johnson and Norton, 1990
nd=not detected at practical quantitation limit in parentheses
NTR=National Toxics Rule (40 CFR 131). Fish tissue criteria are translated from water criteria.
na=not applicable

Although fillet data from the Okanogan River are limited to a single composite sample of carp, whole body and other fish tissues analyzed from 1983 to 1994 also showed high levels of DDT accumulation in fish tissue (Hopkins et al., 1985; Davis and Serdar, 1996). Likewise, the limited Osoyoos Lake data used for listing are supported by 18 fillet samples analyzed from the lake in 1995 which showed excessive 4,4'-DDE in 16 samples and excessive 4, 4'-DDD in five of the 18 samples (Serdar et al., 1998).

The PCB listings for Okanogan River Segment YN58LL is more tenuous since it is based on a single sample with few data to support it. Two other samples collected a decade earlier had only 22 ng/g PCB-1260 in one sample and non-detectable PCB concentrations. However, the 1994 data meet the Water Quality Program's minimum requirements for assessing water quality for the 303(d) list (WQP Policy 1-11; Ecology, 1993).

Tributaries to the Okanogan River and Osoyoos Lake

Okanogan River tributaries Tallant Creek (Segment LD33FC) and Elgin Creek (Segment KR66GR), as well Osoyoos Lake tributary Ninemile Creek (Segment IP09QF), have been included on the 1998 303(d) list due to excessive t-DDT in whole water (Table 4). Two water samples collected near the mouth of each creek during 1995 had t-DDT above the Washington State chronic aquatic life standard of 1 ng/L (Johnson et al., 1997), meeting the minimum data requirements for the 303(d) list.

Table 4. Data Used as the Basis for Inclusion of Tallant Creek Segment LD33FC, Elgin Creek Segment KR66GR, and Ninemile Creek Segment IP09QF on the 1998 303(d) List.

Matrix	Waterbody	Ref.	t-DDT (ng/L)
Whole water (n=2)	Tallant Creek Segment LD33FC	a	190 – 500
Whole water (n=2)	Elgin Creek Segment KR66GR	a	6 – 8
Whole water (n=2)	Ninemile Creek Segment IP09QF	a	5 – 6
Washington State Standard for water[b]	**--**	**--**	**1**

a- Johnson et al., 1997
[b]Ch. 173-201 WAC

Both the fish tissue data and tributary stream listings might suggest that DDT contamination occurs at either end of the lower Okanogan River basin. All of the 303(d) listings are downstream of River Mile (RM) 20 and upstream of RM 79. However, this is due in part to a dearth of sampling in the intervening 60 mile reach. There had been no water, fish, or sediment samples collected from the mainstem Okanogan River between Okanogan and Osoyoos Lake.

Although little was known about possible contamination in the reach between Okanogan and Osoyoos Lake, the distribution of fruit orchards throughout the river valley strongly suggested that DDT contamination was similar to other parts of the basin where DDT had already been documented. This suspicion was partially supported by the study of Johnson et al (1997) which found at least some DDT in seven of the eleven tributary streams flowing into the Okanogan River during the study period.

It is noteworthy that although the listing was based on comparison (and exceedence) of the aquatic life standard for t-DDT, all samples from Tallant, Elgin, and Ninemile Creeks also exceeded the NTR criteria for human health; 0.59 ng/L for 4,4'DDE and 4,4'-DDT, and 0.84 ng/L for 4,4'-DDD. Had the NTR human health criteria been used for comparison in the 1998 303(d) listing decision, Antoine Creek would have been included on the list. Antoine Creek, an Okanogan River tributary, had 4,4'-DDE above the NTR criteria in two samples collected near the mouth during 1995 (Johnson et al., 1997).

It is also noteworthy that while many of the streams flowing into the Okanogan river during the 1995 sampling had some level of measurable DDT, the total amount of DDT calculated to be entering the Okanogan River from tributaries was small, approximately 0.3 g t-DDT/day. As a result, DDT concentrations in the water column of the Okanogan River, measured once upstream of Osoyoos Lake and twice at Malott, were below the quantitation limit of 1 ng/L. The Similkameen River, by far the largest tributary of the Okanogan River, providing an average of 75% of the Okanogan River flow, also had no detectable concentrations of DDT in the water column.

To summarize, data collected in the Okanogan River basin up until commencement of this project suggested the following:

1. DDT concentrations in fish are very high in the lower reaches of the Okanogan River (downstream of Okanogan).
2. PCBs are present in fish in the lower Okanogan River reaches, but there is not enough evidence to suggest they contain high concentrations.
3. Osoyoos Lake fish contain moderate to high concentrations of DDT, depending on the species.
4. There is some evidence that Osoyoos Lake fish may contain PCBs, although concentrations are probably low.
5. DDT is delivered to the Okanogan River in more than half of the dozen or so tributary streams flowing into the Okanogan River, but overall loading is low.
6. Due to the lack of sampling PCBs in water, there is no evidence that PCBs are being delivered to the Okanogan River through tributaries.
7. DDT concentrations in the water column of the Okanogan River are very low, which is consistent with the low loads delivered by tributaries.
8. No sampling has been conducted to determine PCB concentrations in the water column of the Okanogan River.

Project Description and Objectives

Objectives of this project are to assess DDT and PCB loads to the Okanogan River and Osoyoos Lake, assess DDT and PCB concentrations in edible fish tissue, and to reconstruct historic DDT and PCB and to the extent possible, predict future DDT and PCB concentrations in fish tissues. The ultimate goal of the project is to determine where (if any) DDT/PCB loading may be reduced (including loading from sediments) and how this may affect concentrations in fish tissue. Means to reduce DDT and PCB loading will be addressed in the TMDL implementation phase.

The following components of the study will be used to address the study objectives:

1. **Measure loads of DDT and PCBs transported to the Okanogan River and Osoyoos Lake through tributaries and municipal sewage treatment plants**.

This component of the project is essentially a re-assessment of the Ecology's 1995 study of DDT sources to the Okanogan River by Johnson et al., (1997). The 1995 study showed that numerous small streams entering the Okanogan River and Osoyoos Lake contained DDT but overall loading to these waterbodies was low (approximately 0.3 g t-DDT/day). The low rate of loading was due mainly to the small contribution these streams provide to the overall flow of the Okanogan River, approximately 1% of the historic mean harmonic Okanogan River flow at Malott as recorded at U.S. Geological Survey station 12447200. Combined, these loads are not enough to bring DDT levels in the water column of the Okanogan River up to detectable levels. Data collected by Johnson et al., (1997) also indicate that the mainstem Okanogan River entering the U.S. (via Osoyoos Lake) does not carry a measurable DDT load. The Similkameen River, which quadruples the Okanogan River flow just below the border, vastly increases the assimilative capacity of the river.

While these data appear to provide a comprehensive picture of DDT concentrations in waters of the lower Okanogan River basin, they were collected during low flows in late July and late August when many stream channels were dry and other streams were flowing due to active irrigation. To address potential seasonal variation, Okanogan River and Osoyoos Lake tributaries will be sampled during the high flow season (April-May) when more streams are likely to contain water.

PCBs will not be analyzed in water from tributaries since they are extremely difficult to detect in water without expensive specialized methods. There is no reason to suspect that tributary streams in the Okanogan River basin contain measurable concentrations of PCBs since they are primarily an industrial or urban contaminant.

Water from the three municipal sewage treatment plants (STPs) discharging to the Okanogan River – Oroville, Omak, and Okanogan – will also be sampled for DDT. STPs may act as funnels for DDT in urban areas possibly due to improper disposal or storage and historic non-agricultural insecticidal uses such as mosquito control. Reif (1990) found high levels of DDT in sludge from the Okanogan STP. Although Johnson et al., (1997) did not detect DDT in a single

Okanogan STP effluent sample collected during the 1995 study, they failed to investigate the Oroville and Omak STPs.

PCBs will be sampled in STP effluent since they are the few places in the basin where they may be present at detectable concentrations, due, for instance, to the high density of electrical transformers in these cities compared to other parts of the basin. The only known analysis of PCBs in lower Okanogan River basin water was a single Okanogan STP effluent sample collected in 1988 by Reif (1990), although no PCBs were detected.

Sludge will also be sampled for DDT and PCBs since it provides a more probable media for detection of these chemicals. In the absence of detectable concentrations in effluent, sludge may be used to calculate crude estimates of DDT and PCB loads via STPs.

2. **Measure DDT and PCB concentrations in the water column of the Okanogan River and Similkameen River**.

Existing data by Johnson et al., (1997) have shown that neither the Okanogan River nor the Similkameen River has detectable concentrations of DDT. However, these measurements were generally made on single occasions and at low flows. There are also no data on DDT in the Okanogan River at the Osoyoos Lake outlet or in the mid-reaches of the lower basin.

Water column samples will be collected at three locations in the mainstem Okanogan River: 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 mouth. Samples will also be conducted at the mouth of the Similkameen River.

All water column samples will be analyzed for DDT and PCBs. Sampling will be conducted in May during the rising limb of the season hydrograph since rising flows are most likely to entrain DDT-containing particulate matter.

Realistically, these data will likely confirm that the Okanogan River and Similkameen River have non-detectable concentrations of DDT and PCBs in the water column. However, a finding of significant DDT and/or PCBs concentrations will be useful in erasing the incongruity between water column concentrations and fish tissue concentrations. In other words, high concentrations of DDT and/or PCBs in the water column will help explain quantifiably how fish are accumulating these contaminants. The best current explanation is that sediments provide the primary exposure route for DDT and PCBs in fish.

3. **Measure DDT and PCB concentrations in edible fish tissue**.

Fish tissue is the driver for concerns about DDT and PCB contamination in the lower Okanogan River basin. Even though little can be done to remove DDT or PCB contamination in the Okanogan River basin, it is important to know concentrations in fish since they provide the exposure link to consumers potentially at risk (i.e. humans, piscivorous birds and mammals).

Sufficient data exist to assess DDT and PCBs in fish from Osoyoos Lake, but few data exist on the mainstem Okanogan River below Osoyoos Lake. As a result, a map of 303(d)-listed waters shows a mile-long reach of impaired waters among 78 miles of unimpaired waters as if Okanogan River segment YN58LL was a contamination hot-spot in an otherwise clean river. A more likely scenario is that fish in the entire reach of the river downstream of Osoyoos Lake contain appreciable DDT contamination; PCBs are less certain.

To assess the geographical distribution of contaminants in fish, three species from the upper river (Oroville reach), middle river (riverside-Omak reach), and lower river (Monse reach) will be analyzed for DDT and PCBs in edible muscle tissue. These three reaches also encompass the population centers and public boat launches along the river.

Species analyzed will be common carp (*Cyprinus carpio*), mountain whitefish (*Prosopium williamsoni*), and smallmouth bass (*Micropterus dolomieui*). These are the three most common resident game species in the Okanogan River and represent different feeding behaviors and habitat uses.

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

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

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

Edible muscle tissues will be analyzed for DDT and PCBs. Results will be provided to Washington State Department of Health (WDOH) for their assessment of any potential human health risks associated with consumption of each species.

4. **Measure DDT and PCB concentrations in sediment cores.**

DDT was banned in 1972, with the exception of limited emergency use by the U.S. Forest Service in the mid-1970s (Orgil et al., 1976; Peakal, 1976). Peak use of DDT nationally occurred during 1959 (Sittig, 1980) and probably during or before 1965 in the Okanogan River basin (B.C. Water Resources Service, 1973). PCB use in the U.S. was restricted to sealed systems in 1977 and further manufacture, distribution, and processing was banned in 1979 (Sittig, 1980).

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 Okanogan River basin data are nor sufficient to gauge trends over time. In the absence of previously established baselines, sediment coring is the best method of reconstructing historic contamination levels.

Concentration gradients in sediment layers may be used to predict concentrations in future sediment deposits. This in turn may be useful in predicting future contaminant levels in fish tissues since sediments appear to be the primary route of DDT and PCB.

Due to the high laboratory costs associated with analyzing multiple sediment horizons, coring will be 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.

To summarize, the four different sampling components of the project will be used to re-assess DDT loading from tributaries and STPs (PCB loading will also be determined at STPs). Valuable data on DDT and PCB concentrations in fish tissues will be produced which will be reviewed by WDOH to assess human health implications. Water column DDT/PCB concentrations in the Okanogan River water column will be assessed to determine their suitability in explaining the concentrations in fish tissue. If river water DDT/PCB concentrations are very low as expected, sediment concentrations will be used to establish an exposure link, and concentration gradients in sediments may then be used to predict future tissue concentrations.

Data from other agencies may also be used to fill in data gaps. For instance, The Colville Confederated Tribes have recently completed a survey to assess the longitudinal gradient in DDT concentrations in Okanogan River sediments from the Osoyoos Lake outlet to the mouth of the river (Don Hurst, Fulcrum Environmental, written communication). Environment Canada has also recently completed collecting data on DDT and PCBs in fish from northern Osoyoos Lake (Bev McNaughton, Environment Canada, written communication). These data will be included in the final technical report.

Project Organization

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Project Schedule

Sample Collection – April, 2001 – May, 2002
Draft Technical Report – June 2002
Final Technical Report – September 2002

Data Quality Objectives

Data quality objectives for this project mirror measurement quality objectives and are shown in Table 5. Precision and bias estimates from successful studies (Johnson et al., 1997; Serdar et al., 1998) are used as objectives for the present study. Accuracy objectives were calculated as the sum of bias + (2 x precision). Accuracy and bias are expressed as deviation from the true value and precision is expressed as relative standard deviation standard deviation of multiple results divided by the mean).

Measurement quality objectives may be difficult to achieve at results at or near the reporting limits because the relative accuracy decreases rapidly near the reporting limit concentrations.

Except for PCBs in water, the required reporting limits in Table 5 are sufficiently low to measure analyte concentrations at the applicable criteria listed in Tables 1 and 2.

Table 5. Measurement Quality Objectives.

Variable	Accuracy	Precision	Bias	Required Reporting Limits
Water				
DDT analogs	30%	5%	20%	0.6 ng/l
PCBs (Aroclors)	30%	5%	20%	0.6 ng/l
TOC	15%	5%	5%	0.1 mg/l
TSS	15%	5%	5%	1 mg/l
Sediment/Sludge				
DDT analogs	50%	15%	20%	5 ng/g
PCBs (Aroclors)	50%	15%	20%	5 ng/g
TOC	25%	10%	5%	0.1 μg/g
^{210}PCB				
Fish Tissue				
DDT analogs	40%	10%	20%	5 ng/g
PCBs (Aroclors)	40%	10%	20%	5 ng/g
Percent lipids	20%	5%	10%	0.1%

Field Procedures

Tributary sampling will be conducted twice during April-May to take advantage of peak flows. Samples will be collected as near the creek mouths as feasible to make accurate estimates of contaminant delivery to the Okanogan River. River water samples from Riverside and Malott will be collected from bridges as quarter point transects. The Similkameen water sample will be a quarter point transect collected from a boat near the mouth. The water sample at the Osoyoos lake outlet will be collected just below the dam structure on the right bank. Sample locations will be recorded with a global positioning receiver. Samples will be composited in 1-gallon glass jars using 1-liter priority pollutant cleaned jars to collect sub-samples (Table 6). sub-samples will be collected using a depth-integrating device (ACOE D-77 Teflon cap with DH-81 adapter) fitted to the 1-liter collection jars so that the water samples only contact glass or Teflon.

Sediment cores will be collected using a Wildco box corer fitted with a 15cm x 15cm x 50cm acrylic liner. Layers or horizons will be collected individually every centimeter resulting in a maximum of 50 sub-samples per core. Sub-samples for analysis will then be selected to represent; 1) current conditions (top layer); 2) background conditions to calibrate ^{210}Pb; and 3) equal intervals representing sediments deposited since about 1945 to the present. Deposition rates will be difficult to estimate in the field in the absence of visual clues such as a Mt. St. Helens ash layer. To avoid analyzing samples with little relevance to DDT and PCB contamination (i.e. before their use), results of ^{210}Pb analysis will be reviewed prior to chemical analysis in order to estimate the age of each horizon.

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

Composite fillet homogenates will be prepared by removing the scales then removing the entire fillet from the left side of each fish. The resulting sample will contain the skin and some of the belly flap and dorsal fat, consistent with EPA recommendations for assessing chemical contaminants in fish (EPA, 1995).

Three composite samples of each species (carp, mountain whitefish, and smallmouth bass) will be analyzed from each of the three collection locations (upper, middle, and lower Okanogan River). Each composite sample will consist of five to eight fish, depending on availability.

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

All equipment used for tissue preparation will be thoroughly washed with Liquinox® detergent, rinsed in hot water, deionized water, pesticide-grade acetone, and finally, pesticide-grade hexane. This decontamination procedure will be repeated between processing of each composite sample.

Fully homogenized tissues will be stored frozen (−20°C) in two 8-oz. glass jars with Teflon lid liners certified for trace organics analysis; one container submitted for analysis and the other archived at -20 °C.

Table 6. Sample Containers, Preservation, and Holding Times

Analysis	Container	Preservation	Holding Time
DDT, PCBs in water	1-gallon glass jar w/certificate of analysis, Teflon lid liner	cool to 4° C	7-d extraction 14-d analysis
TOC in water	60 ml n/m poly	cool to 4° C, H2SO4 to pH<2	7-d
TSS in water	1-liter w/m poly	cool to 4° C	28-d
DDT, PCBs in sediment	4-oz glass jar w/certificate of analysis, Teflon lid liner	cool to 4° C	7-d extraction 14-d analysis (1-yr if frozen)
TOC in sediment	2-oz glass jar	cool to 4° C	
^{210}Pb in sediment	2-oz glass jar	cool to 4° C	NA
DDT, PCBs, percent lipids in fish	8-oz glass jar w/certificate of analysis, Teflon lid liner	cool to 4° C	7-d extraction 14-d analysis (1-yr if frozen)

NA=Not Applicable

Laboratory Procedures

Analytical methods are shown in Table 7. All chemical analysis will be conducted at the Manchester Environmental Laboratory (MEL) except low-level PCBs. Costs to conduct chemical analyses are shown in Appendix C.

Table 7. Analytical Methods, Reporting Limits, and Laboratories

Analysis	Required Reporting Limit	Method	Laboratory
Water			
DDT analogs	0.6 ng/l	GC/ECD (mod. of EPA 8081, 3510, 3620, and 3665)	MEL
PCB (Aroclors)	0.6 ng/l	GC/ECD (mod. of EPA 8081, 3510, 3620, and 3665)	MEL
TOC	0.1 mg/l	combustion/NDIR (EPA 415.1)	MEL
TSS	1 mg/l	gravimetric (EPA 160.2)	MEL
Sediments			
DDT analogs	5 ng/g	GC/ECD (EPA 8081)	MEL
PCB (Aroclors)	5 ng/g	GC/ECD (EPA 8081)	MEL
TOC	0.1 µg/g	combustion/NDIR (PSEP)	MEL
^{210}Pb	NA	alpha spectroscopy	Battelle
Fish Tissue			
DDT analogs	5 ng/g	GC/ECD (EPA 8081)	MEL
PCBs (Aroclors)	2 ng/g	GC/ECD (EPA 8081)	MEL
Percent lipids	0.1%	gravimetric EPA 608.5	MEL

Quality Control Procedures

Field Quality Control

All sampling will be done in a manner to prevent cross-contamination of samples. Nitrile gloves will be worn during sampling. All sampling equipment will be cleaned prior to use (see section on Field Procedures).

Replicate samples of water will be collected to provide an estimate of overall variability. Fish sampling will consist of numerous replicates that will also provide an estimate of overall variability. Table 8 summarizes quality control samples collected in the field.

Lab Quality Control

The QC procedures routinely followed by Manchester Laboratory for the chemical analyses requested will be satisfactory for purposes of this project. Laboratories will conduct analyses within recommended holding times. QC sample results will be reported for at least one method blank, one matrix spike, and one matrix spike duplicate per DDT/PCB analytical batch (Table 8). Surrogate compound recoveries will also be analyzed along with each sample for DDT and PCB analysis. The project lead will identify the sample to be used for the matrix spikes. QC samples for TOC will include a laboratory duplicate and a laboratory control sample.

Table 8 shows the quality control results needed to meet measurement quality objectives for the project. It is virtually impossible to quantify the maximum error in each QC element to avoid exceeding the maximum error stipulated in the measurement quality objectives. However, the target QC requirements in Table 8 should suffice based on results of QC sample analyses from previous studies (Johnson et al., 1997; Serdar et al., 1998). There are no requirements for the field replicates because environmental variability is incorporated into the results of replicate analyses. Matrix spikes may provide an indication of bias due to interference from the sample matrix. However, matrix spike data may be difficult to interpret at concentrations near the quantitation limits. Surrogate recoveries should provide a useful estimate of overall accuracy at the concentrations used. TOC laboratory control sample recoveries will provide an estimate of accuracy for the entire analytical procedure.

Table 8. Quality Control Sample and Analysis Requirements.

Variable	Method Blanks	Matrix Spikes	Matrix Spike Duplicates	Surrogates	Lab Duplicates	Lab Control Samples	Standard Reference Material
Water							
DDT analogs	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	85%-115% recov.	NA
PCBs (Aroclors)	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	85%-115% recov.	NA
TOC	NA	75%-125% recov.	≤20% RPD	NA	≤20% RPD	within control limits	NA
TSS	NA	NA	NA	NA	≤20% RPD	NA	NA
Sediment/ Sludge							
DDT analogs	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	NA	NA
PCBs (Aroclors)	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	NA	NA
TOC	NA	75%-125% recov.	≤20% RPD	NA	≤20% RPD	within control limits	NA
^{210}Pb	NA	NA	NA	NA	NA	NA	NA
Fish Tissue							
DDT analogs	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	NA	w/in cert. values
PCBs (Aroclors)	<20% of result	50%-150% recov.	≤25% RPD	50%-150% recov.	NA	NA	w/in cert. values
Percent lipids	NA	NA	NA	NA	≤20% RPD	NA	NA

NA=Not Applicable
RPD=Relative Percent Difference

Data Review and Validation

Station data and field data will be written in field notebooks and will then be entered into the Environmental Information System (EIM). After laboratory data is reviewed, it will also be entered into EIM. All of the data will be entered in EIM before the final report is complete.

Manchester's SOP for reduction, review, and reporting of the chemical data will meet the needs of this project. Each laboratory unit assembles data packages consisting of raw data from the analyses of the samples, copies of the pertinent logbook sheets, QA/QC data, and final reports of data entered into LIMS. These data packages are subjected to a data verification and quality assurance review by another analyst familiar with the procedure. Reviewers use *US EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* February, 1994 and *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review*, October, 1999.

On receipt of the chemistry data, the project lead will review the results for completeness, reasonableness, and usability. Data and case narratives will also be reviewed to assure that quality control procedures meet frequency requirements and control limits. After data review is completed and following any corrective actions required, the complete biological and chemical data will be forwarded to the client.

The project lead will provide a draft report of the study results to the clients in June, 2002. At a minimum, the final report will contain the following:

- A map of the study area showing sampling sites
- Latitude/longitude and other location information for each sampling site
- Descriptions of field and laboratory methods used in the study
- A discussion of data quality and the significance of any problems encountered in the analyses
- Summary tables of the chemistry data
- An evaluation of contaminant sources and loads, addressing seasonal variations if feasible
- Calculations of assimilative capacities for all receiving waters
- Where feasible, a discussion of possible load allocations for pollutants of concern
- Recommendations for follow-up work

A final report will be prepared after receiving comments from the Water Quality Program's Central Regional Office and any other reviewers they have selected. The goal is to have the revised final report completed by September 2002.

Data Quality Assessment

The data will be reviewed to make sure the data satisfactorily meets the data quality objectives (DQOs) established in this project plan.

Preliminary Assessment of Data Collected for the Okanogan River TMDL

The following sections contain a preliminary assessment of data on DDT and PCBs collected on tributaries and STPs as part of the Okanogan River TMDL. Data used for this assessment were collected during April-May 2001 as described in component #1 of the *Project Description and Objectives* section in the project plan. These data are used in conjunction with historical data to describe DDT and PCB loading to the Okanogan River and Osoyoos Lake.

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

Mainstem Okanogan River

Table 9 shows contaminant load capacity, measured loads, and theoretical loads in the Okanogan River Segment YN58LL near Monse. All load calculations are based on the harmonic mean of annual flows 1966-1999 measured approximately 5 river miles upstream at Malott (USGS Station 12447200). Criteria and theoretical contaminant concentrations in water are based on tissue concentrations divided by the bioconcentration factors (BCFs) for 4,4'-DDE and 4,4'-DDD (BCF=53,600), and PCBs (BCF=31,200). For instance, the NTR human health water criteria for 4,4'-DDE is derived from the acceptable tissue concentration of 31.6 ng/g divided by the BCF (53,600[L water/1000g tissue]).

Whole water concentrations of 4,4'-DDE and 4,4'-DDD at Malott measured by Johnson et al., (1997) are probably slightly above or below the NTR criteria. However, based on the theoretical relationship between water concentrations and tissue concentrations (i.e. the BCF), 4,4'-DDE and 4,4'-DDD concentrations in water should be higher by factors of 30 and 20, respectively. Conversely, tissue concentrations should be lower by these factors if the measured water concentrations (<1 ng/L) are representative of river conditions. These disparities assume that the BCFs are accurate representations of tissue accumulation through water. However, BCFs do not account for accumulation through diet and interactions with sediment.

Maximum loads for 4,4'-DDE and 4,4'-DDD calculated from water column samples at Malott in 1995 (Johnson et al., 1997) are more realistic than theoretical loads calculated from tissue concentrations. This conclusion is supported by DDT concentrations sampled in tributaries coincidentally with mainstem river samples in 1995. DDT in tributaries (except Similkameen River.) was also measured on two occasions during 2001. For all tributaries combined, the measured rate of 4,4'-DDE and 4,4'-DDD delivery to the mainstem Okanogan River averaged 100 and 15 mg/day, respectively. The maximum possible delivery rate was approximately 3,500 mg/day for both 4,4'-DDE and 4,4'-DDD, values similar to the load capacities in the mainstem Okanogan River at Segment YN58LL.

Table 9. DDT and PCB Load Capacity, Measured Load, and Theoretical Load for the Okanogan River Segment YN58LL.

	4,4'-DDE	4,4'-DDD	PCB-1254	PCB-1260	t-PCB
NTR Human Health Water Criteria (ng/L)	0.59	0.84	na	na	0.17
Measured Water Conc. (ng/L)	<1	<1	nm	nm	nm
Theoretical Water Conc. (ng/L)[a]	31	20	0.80	0.64	1.4
Load Capacity (mg/day)[b]	3,900	5,600	na	na	1,100
Measured Load (mg/day)[b]	<6,700	<6,700	nm	nm	nm
Theoretical Load (mg/day)[a,b]	206,000	131,000	5,400	4,300	9,600

NTR=National Toxics Rule
na=not applicable
nm=not measured
[a]Theoretical water concentration based on tissue concentrations reported in Table 3 and a BCF of 53,600 for 4,4'-DDE and 4,4'-DDD, and a BCF of 31,200 for PCBs
[b]Load capacity based on harmonic mean flow of 77,285 L/s at Malott

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*BCFs were developed by EPA for the Ambient Water Quality Criteria documents (EPA, 1980a; EPA, 1980b)

The range of possible PCB loads in the Okanogan River is more difficult to assess due to the lack of any direct measurements of PCBs in the water column of the mainstem river or tributary streams. The theoretical load is 9,600 mg/day based on tissue concentrations shown in Table 3 and a BCF of 31,200. The disparity between the theoretical load and the load capacity is a factor of nine, much lower than for DDT.

Measurements of PCB delivery to the Okanogan River has not been undertaken due to the difficulty associated with detecting PCBs in whole water. Quantitation limits typically obtained in the laboratory are 1 – 2 orders of magnitude higher than the NTR criteria of 0.17 ng/L. However, water samples from thirteen tributaries were qualitatively examined for PCBs, but there was no evidence that PCBs were present.

Effluent samples from the three sewage treatment plants (STPs) discharging to the mainstem Okanogan River were also qualitatively examined for PCBs but, like tributary samples, there was no evidence that PCBs were present. However, PCBs were present at substantial concentrations in sludge from all three treatment plants. Sludge from the Oroville, Omak, and Okanogan treatment plants had t-PCB concentrations of 270, 200, and 230 ng/g, respectively. From these concentrations, the estimated t-PCB load from STPs combined is approximately 3 mg/day, assuming suspended solids in STP effluent and sludge have identical PCB concentrations. This load represents approximately 0.3% of the Okanogan River's assimilative capacity for t-PCB at Malott.

Osoyoos Lake

Table 10 shows contaminant load capacity and theoretical loads for Southern Osoyoos Lake Segment 060VKD. All load calculations are based on the Okanogan River harmonic mean annual flows 1943-1999 near the lake outlet (USGS Station 12439500). Theoretical contaminant concentrations in water are based on tissue concentrations divided by BCFs. No measured loads are shown since DDT has not been measured in the Osoyoos Lake water column.

Theoretical concentrations of 4,4'-DDE and 4,4'-DDD in the water column derived from tissue concentrations and BCFs are reported in Table 10 as a possible range of values since different fish species have varying amounts of 4,4'-DDE and 4,4'-DDD. The lowest estimates for 4,4'-DDE and 4,4'-DDD were derived from average concentrations in Osoyoos Lake yellow perch and smallmouth bass, respectively, and are below or only slightly above the NTR criteria. However, the high end of the ranges for both 4,4'-DDE and 4,4'-DDD in Table 10 have concentrations an order of magnitude above the NTR criteria.

DDT loads to Osoyoos Lake through ongoing delivery routes are primarily from Ninemile Creek and Haines Creek (B.C.). Tonasket Creek, while not discharging to the Osoyoos Lake proper, has its mouth located above the Zoesel Dam and delivered an average of 0.025 mg/day 4,4'-DDE and 17 mg/day 4,4'-DDT during monitoring in 2001. In April 2001, Tonasket Creek contributed 50% of the total measurable DDT loads to the Okanogan River and Osoyoos Lake. In addition to being a significant route of DDT delivery, a major debris torrent occurred in Tonasket Creek in July 2001. This mass wasting event mobilized an enormous quantity of material, possibly including some DDT-contaminated soils. However, it's not clear if contaminated soils reached the Okanogan River during this event.

Table 10. DDT Load Capacity and Theoretical Loads for Osoyoos Lake Segment 060VKD.

	4,4'-DDE	4,4'-DDD
NTR Human Health Water Criteria (ng/L)	0.59	0.84
Measured Water Conc. (ng/L)	nm	nm
Theoretical Water Conc. (ng/L)[a]	0.80 – 12.6	0.22 – 7.6
Load Capacity (mg/day)[b]	790	1,100
Measured Load (mg/day)	nm	nm
Theoretical Load (mg/day)[a,b]	1,000 – 17,000	290 – 10,000

NTR=National Toxics Rule
nm=not measured
[a]Theoretical water concentration based on tissue concentrations reported in Serdar et al (1998) and a BCF of 53,600 for 4,4'-DDE and 4,4'-DDD
[b]Load capacity based on Okanogan R. at Oroville harmonic mean flow of 15,491 L/s

Tributaries to the Okanogan River and Osoyoos Lake

Table 11 shows contaminant load capacity and theoretical loads for Tallant Creek (Segment LD33FC), Elgin Creek (Segment KR66GR), and Ninemile Creek (Segment IP09QF).

Table 11. DDT Load Capacity and Measured Loads for Tallant Creek (Segment LD33FC), Elgin Creek (Segment KR66GR), and Ninemile Creek (Segment IP09QF).

	t-DDT
Washington Chronic Water Quality Standard for Aquatic Life (ng/L)	1.0
Measured Water Conc. (ng/L)	
Tallant Creek Segment LD33FC	340 (±160)[a]
Elgin Creek Segment KR66GR	7.2 (±1.7)[b]
Ninemile Creek Segment IP09QF	4.7 (±1.4)[b]
Load Capacity (mg/day)	
Tallant Creek Segment LD33FC	0.73 (±0)[a]
Elgin Creek Segment KR66GR	3.1 (±1.6)[b]
Ninemile Creek Segment IP09QF	3.5 (±3.6)[b]
Measured Load (mg/day)	
Tallant Creek Segment LD33FC	250 (±110)[a]
Elgin Creek Segment KR66GR	22 (±14)[b]
Ninemile Creek Segment IP09QF	14 (±11)[b]

[a] range
[b] standard deviation

Although the listing was based on comparison (and exceedence) of the aquatic life standard for t-DDT, all samples from Tallant, Elgin, and Ninemile Creeks exceeded the National Toxics Rule (NTR) criteria for human health. The NTR criteria for 4,4'-DDE and 4,4'-DDT is 0.59 ng/L, and 0.84 ng/L for 4,4'-DDD. Had the NTR human health criteria been used for comparison in the 1998 303(d) listing decision, Antoine Creek would have been included on the list. Antoine Creek, an Okanogan River tributary, had 4,4'-DDE above the NTR criteria in two samples collected near the mouth during 1995 (Johnson et al., 1997).

t-DDT concentrations above the Washington chronic standard were verified in Elgin and Ninemile Creeks during 2001. Tallant Creek results could not be verified because it was dry during the 2001 sampling.

Additional Okanogan River and Osoyoos Lake tributaries twice-sampled near their mouths during 2001 also showed t-DDT in excess of the Washington chronic standard. These were Tonasket Creek, Mosquito Creek, and Antoine Creek. Two whole water effluent samples from the Okanogan Sewage Treatment Plant (STP) also had t-DDT above the Washington chronic standard. Whole effluent from the Oroville STP had 4,4'-DDT above the NTR human health criterion during two rounds of sampling in 2001.

Source Assessment

Osoyoos Lake and Mainstem Okanogan River

DDT source assessment conducted to date consists primarily of tributary sampling. Complete results of tributary sampling are in Appendix A. In 1995, all tributaries to Osoyoos Lake and the Okanogan River containing discernible flow were sampled for DDT compounds during July and August (Johnson et al., 1997). Effluent from the Okanogan sewage treatment plant (STP) was also sampled due to DDT previously detected in sludge (Reif, 1990). 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). Delivery of 4,4'-DDE and 4,4-DDD from all sources combined averaged 130 and 25 mg/day, respectively, with Tallant Creek accounting for 50-90% of the combined total.

Tributary sampling was repeated during April and May 2001 to represent high-flow conditions without influence of irrigation. Many more streams were flowing compared to the 1995 sampling event, even though the region was experiencing an exceptionally dry winter and spring. Effluent from all three STPs (Oroville, Omak, and Okanogan) discharging to the mainstem Okanogan River were also sampled. Delivery of 4,4'-DDE and 4,4-DDD from all sources combined averaged 67 and 5 mg/day, respectively, with Nine Mile, Tonasket, Antoine, and Elgin Creeks accounting for the bulk of the loads. Tallant Creek was not flowing during the 2001 sampling events and the absence of this source results in the lower combined loads. In fact, total loads measured during 1995 and 2001 were remarkably similar when Tallant Creek is removed from the equation.

Table 12 shows 4,4'-DDE and 4,4-DDD loads delivered to Osoyoos Lake and the mainstem Okanogan River through tributaries and STPs. Measured loads were calculated as the means of all samples collected during the four rounds of sampling in 1995 and 2001. Delivered DDT makes up only a small fraction of the load capacity for each corresponding river segment; <5% for 4,4'-DDE and <1% for 4,4'-DDD.

The relatively small loads delivered through tributaries and STPs further the gap in explaining fish tissue concentrations. For Osoyoos Lake and the lower Okanogan River where fish tissue data are available, DDT loads are best represented by the following pattern:

delivered loads << *load capacities* << *theoretical loads*

where *delivered loads* are the combined DDT loads from tributaries to the mainstem Okanogan River, *load capacities* are the assimilative capacities of the mainstem Okanogan River, and *theoretical loads* are loads calculated from concentrations of DDT in fish tissue (shown in Tables 9 and 10). Osoyoos Lake has some exceptions to this pattern where load capacities and theoretical loads may not substantially differ when considering DDT concentrations in tissues of certain species.

Table 12. Measured DDT Loads and Load Capacity at Three Okanogan River Reaches from the Osoyoos Lake Outlet to the Vicinity of Malott (mg/day).

RM	Tributary or STP	4,4'-DDE	4,4'-DDE	4,4'-DDD	4,4'-DDD
		Measured	Capacity	Measured	Capacity
91.2	Okanogan R. @ Osoyoos BC	0.0		0.0	
82.8	Haynes Cr. BC	1.3		0.0	
80.2	Nine Mile Cr.	6.6		2.1	
	TOTAL FOR SEGMENT	**7.9**		**2.1**	
79.0	**Osoyoos Lake Outlet**		**790**		**1,100**
77.8	Tonasket Cr.	24.7		0.0	
	TOTAL FOR SEGMENT	**32.6**		**2.1**	
77.4	**Okanogan R. @ Oroville**		**790**		**1,100**
74.1	Similkameen R.	0.0		0.0	
	Oroville STP	0.2		0.0	
67.4	Mosquito Cr.	1.3		1.3	
62.4	Whitestone Cr.	6.7		0.0	
61.2	Antoine Cr.	4.8		1.1	
57.3	Siwash Cr.	1.1		0.0	
56.7	Bonaparte Cr.	3.7		0.0	
52.9	Aeneas Cr.	3.0		0.0	
	TOTAL FOR SEGMENT	**53.5**		**4.5**	
50.7	**Okanogan R. nr. Tonasket**		**3,900**		**5,500**
50.7	Chewiliken Cr.	0.0		0.0	
45.0	Tunk Cr.	0.0		0.0	
40.6	Johnson Cr.	0.0		0.0	
35.0	Wanacut Cr.	0.0		0.0	
32.0	Omak Cr.	0.0		0.0	
	Omak STP	0.0		0.0	
28.4	Elgin Cr.	14.4		1.2	
25.7	Salmon Cr.	9.8		0.0	
	Okanogan STP	0.8		0.6	
19.5	Tallant Cr.	93.2		20.9	
	TOTAL FOR SEGMENT	**172**		**27.3**	
17.0	**Okanogan R. @ Malott**		**3,900**		**5,600**
16.9	Loup Loup Cr.	0.2		0.0	
15.1	Chiliwist Cr.	2.4		0.0	
	Okanogan River TOTAL	**174**	**3,900**	**27.3**	**5,600**

Tributaries to the Okanogan River and Osoyoos Lake

The source of DDT delivered to tributaries has not been examined. Presumably, DDT bound to orchard 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 orchard soil particles to streams depends on a variety of factors. Within streams, increasing flows result in higher TSS concentrations. For streams examined during four rounds of sampling, flows were a major positive determinant of TSS concentrations for Ninemile Cr. ($r^2 = 0.89$), Antoine Cr. ($r^2 = 0.89$) and Elgin Cr. ($r^2 = 0.94$) but less so in Whitestone Cr. ($r^2 = 0.27$). 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 originating somewhere other than orchards. In general, orchards in the Okanogan River Basin are on shallow slopes, soils are well-drained, grass ground cover is maintained in orchards, and irrigation is sprinkler or drip rather than rill and furrow. These conditions do not lend themselves to substantial erosion of orchard soils as occurs for instance in the lower Yakima River Basin (Johnson et al., 1988).

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 do little to explain DDT concentrations in corresponding streams (A. Johnson, Ecology, personal communication).

Sewage Treatment Plants

STPs may serve as a funnel for waterborne contaminants in urban areas. 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. DDT has previously been detected at a high concentration in sludge from the Okanogan wastewater treatment plant (Reif, 1990).

Discussion of DDT and PCB Data Collected from Tributaries and STPs as a Component of the Okanogan River TMDL

There are several possible explanations to account for the apparent disjunction between measured DDT/PCB loads and fish tissue concentrations. One possible explanation is that a large quantity of unaccounted DDT is being delivered to the Okanogan River and Osoyoos Lake. Possible delivery mechanisms include groundwater, deposition of airborne material, illegal dumping, and erosion of contaminated bank material. There also exists the possibility that the streams sampled deliver large DDT quantities 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 delivery mechanisms probably contribute unaccounted quantities of DDT to some extent. However, if the continual delivery of significant DDT quantities to the Okanogan River and Osoyoos Lake through one or more of these mechanisms results in water column concentrations comparable to fish tissue concentrations (as a function of BCF), then the water column concentrations should be at easily detectable concentrations. For example, 4,4'-DDE concentrations in the Okanogan River should be 31 ng/L, well above the typical quantitation limit of 1 ng/L (Table 9). As it stands, DDT has not been detected in Okanogan River water, although samples have only been collected on three occasions (Appendix A).

In consideration of the factors previously mentioned, it is unlikely that significant exogenous sources of DDT have gone unaccounted. Yet the perplexing questions remains: How are fish accumulating the bulk of their DDT burdens if water column concentrations are relatively low?

There are essentially two scenarios to explain DDT accumulation in fish tissues. The first explanation is that the BCF used to calculate the NTR water criteria for DDT is inaccurate. This BCF (53,600) was derived specifically for criteria development, not for site-specific assessment. It is possible that at least some species in the Okanogan River concentrate DDT 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 Okanogan River and Osoyoos Lake, BCFs ranging from 66,000 to 2,800,000 would explain reported tissue concentrations at DDT quantitation limits 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 (1980) lists BCFs of 460,000 and 370,000 for lake trout (*Salvelinus namaycush*) and cisco (*Coregonus* sp.), respectively.

The second plausible explanation for high DDT in fish relative to water column concentrations is that the exposure route is something other than water. Specifically, fish may be accumulating DDT through contaminated sediments or diet. 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). BAFs may be calculated for sediments (chemical conc. in tissue divided by conc. in sediment) or for water (chemical conc. in tissue divided by conc. in water). 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).

Future Direction of Okangan River TMDL Technical Assessment

As shown in the preliminary assessment, loading of DDT and PCB from tributaries and STPs does little to explain the concentrations of these contaminants in fish tissues. Therefore, the remaining analysis will focus primarily on sediments as a source of DDT and PCBs in fish.

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 Okanogan River and Osoyoos Lake fish. BSAFs used in conjuction with fish tissue concentrations and sediment core data can be used to assess historic and future trends in DDT and PCB concentrations in fish tissue.

The simplest used to explain the relationship between contamination of an organism and sediments is the biota-sediment accumulation factor (BSAF). 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 anionic 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:

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

where:

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

Current data on DDT and PCB in sediments may be used to establish BSAFs with current data on DDT and PCBs in fish tissue. Reconstructed historical DDT and PCB concentrations in sediment cores may be used to project future concentration gradients in sediments. Projected future DDT/PCB concentrations in fish tissue can then be derived by applying site-specific BSAFs to projected concentrations in sediments.

Sediment core and fish tissue data have been collected for this project (components #3 and #4 in the *Project Description and Objectives* section of the project plan). Analysis of the BSAF method is presently being conducted, but not developed far enough to discuss here in detail.

It should be noted that although all sampling described in the *Project Description and Objectives* section of the project plan has been completed with one exception. Carp from the lower (Monse) reach of the Okanogan River were unobtainable during several attempts to collect them. While the TMDL can be produced without these samples, the data they will provide will increase the robustness of the analysis. It is therefore recommended that another attempt be made to collect these samples. The effort and cost associated with obtaining them should be relatively minor (approximately 40 hours and $1,000 in laboratory costs). Data obtained from these samples would not be available for the draft technical report (June, 2002) but should be available for incorporation into the final report (September, 2002).

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Appendix A

DDT Concentrations in Okanogan Tributaries, July 1995.

Location	RM	Date	Flow l/s	TSS mg/l	4,4'-DDE ug/l	4,4'-DDD ug/l	4,4'-DDT ug/l	t-DDT ug/l	t-DDT mg/d
Nine Mile Cr.	80.2	7/24/95	20	2	**0.0031**	**0.0014**	**0.0019**	**0.0064**	10.96
Similkameen R.	74.1	7/24/95	38515	3	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Whitestone Cr.	62.4	7/24/95	122	27	**0.001**	nd(0.001)	nd(0.001)	**0.001**	10.52
Antoine Cr.	61.2	7/24/95	45	25	**0.0015**	nd(0.001)	nd(0.001)	**0.0015**	5.87
Bonaparte Cr.	56.7	7/25/95	11	4	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Omak Cr.	32.0	7/24/95	193	3	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Elgin Cr.	28.4	7/25/95	34	41	**0.0031**	nd(0.001)	**0.0024**	**0.0055**	16.15
Okanogan STP		7/25/95	na		nd(0.008)	nd(0.008)	nd(0.008)	nd	nd
Tallant Cr.	19.5	7/24/95	8	122	**0.18**	**0.037**	**0.28**	**0.497**	364.83
Loup Loup Cr.	16.9	7/24/95	31	6	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
TOTAL =			38980						408

DDT Concentrations in Mainstem Okanogan R. and Similkameen R., July 1995

Location	RM	Date	Flow l/s	TSS mg/l	4,4'-DDE ug/l	4,4'-DDD ug/l	4,4'-DDT ug/l	t-DDT ug/l	t-DDT mg/d
Similkameen R.	74.1	7/24/95	38515	3	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Okanogan R. @ Malott	17.0	7/25/95	49277	5	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
TOTAL =									0.00

DDT Concentrations in Okanogan Tributaries, August 1995.

Location	RM	Date	Flow l/s	TSS mg/l	4,4'-DDE ug/l	4,4'-DDD ug/l	4,4'-DDT ug/l	t-DDT ug/l	t-DDT mg/d
Haynes Cr. BC	82.8	8/30/95	6	2	**0.0026**	nd(0.001)	nd(0.001)	**0.0026**	1.27
Nine Mile Cr.	80.2	8/31/95	8	1	**0.0025**	**0.0015**	**0.0014**	**0.0054**	3.96
Misquito Cr.	67.4	8/31/95	28	11	**0.0016**	**0.0016**	nd(0.001)	**0.0032**	7.83
Whitestone Cr.	62.4	8/31/95	144	14	**0.0006**	nd(0.001)	nd(0.001)	**0.0006**	7.49
Antoine Cr.	61.2	8/31/95	65	26	**0.0007**	nd(0.001)	nd(0.001)	**0.0007**	3.94
Aeneas Cr.	52.9	8/31/95	57	1	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Elgin Cr.	28.4	8/31/95	62	156	**0.0056**	nd(0.001)	**0.0024**	**0.008**	43.06
Tallant Cr.	19.5	8/31/95	8	28	**0.074**	**0.02**	**0.094**	**0.188**	138.00
TOTAL =			379						205.56

DDT Concentrations in Mainstem Okanogan R., August 1995

Location	RM	Date	Flow l/s	TSS mg/l	4,4'-DDE ug/l	4,4'-DDD ug/l	4,4'-DDT ug/l	t-DDT ug/l	t-DDT mg/d
Okanogan R. @ Osoyoos BC	91.2	8/30/95	na	3	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
Okanogan R. @ Malott	17.0	8/31/95	42763	2	nd(0.001)	nd(0.001)	nd(0.001)	nd	nd
TOTAL =									0.00

DDT Concentrations in Okanogan Tributaries, April 2001.

Location	RM	Date	Flow l/s	TOC mg/l	TSS mg/l	4,4'-DDE ug/L	4,4'-DDD ug/L	4,4'-DDT ug/L	t-DDT ug/L	t-DDT mg/d
Nine Mile Cr.	80.2	4/17/01	99	5.4	12	**0.0018**	**0.0004**	**0.0013**	**0.0035**	29.80
Tonasket Cr.	77.8	4/17/01	361	5.3	4	**0.0015**	nd(0.0008)	**0.001**	**0.0025**	77.87
Oroville STP		4/17/01	6	8.9	1	**0.0005**	nd(0.0009)	**0.0006**	**0.0011**	0.52
Mosquito Cr.	67.4	4/11/01	0.24	4.0	7	**0.0008**	**0.0007**	nd(0.0008)	**0.0015**	0.03
Whitestone Cr.	62.4	4/11/01	114	4.0	10	**0.0006**	nd(0.0008)	nd(0.0008)	**0.0006**	5.93
Antoine Cr.	61.2	4/17/01	10	3.2	12	**0.0052**	**0.0011**	**0.0017**	**0.008**	6.79
Siwash Cr.	57.3	4/16/01	24	5.7	1	**0.0005**	nd(0.0008)	nd(0.0008)	**0.0005**	1.05
Bonaparte Cr.	56.7	4/11/01	62	6.4	21	**0.0004**	nd(0.0008)	nd(0.0008)	**0.0004**	2.13
Aeneas Cr.	52.9	4/16/01	95	1.4	nd(1)	**0.0004**	nd(0.0008)	nd(0.0008)	**0.0004**	3.30
Chewiliken Cr.	50.7	4/11/01	9	4.1	nd(1)	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd	0.00
Tunk Cr.	45.0	4/16/01	106	4.6	2	nd(0.0009)	nd(0.0009)	nd(0.0009)	nd	0.00
Johnson Cr.	40.6	4/16/01	79	2.1	11	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd	0.00
Wanacut Cr.	35.0	4/12/01	29	4.3	1	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd	0.00
Omak Cr.	32.0	4/12/01	382	5.0	5	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd	0.00
Omak STP		4/17/01	24	4.8	2	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd	0.00
Elgin Cr.	28.4	4/12/01	27	2.5	7	**0.0037**	**0.0004**	**0.0018**	**0.0059**	13.57
Salmon Cr.	25.7	4/17/01	284	2.6	1	**0.0004**	nd(0.0009)	nd(0.0009)	**0.0004**	9.81
Okanogan STP		4/16/01	16	8.6	4	**0.0007**	nd(0.0008)	**0.0006**	**0.0013**	1.81
Tallant Cr.	19.5	4/16/01	0							
Loup Loup Cr.	16.9	4/16/01	0							
Chiliwist Cr.	15.1	4/16/01	71	2.8	11	**0.0004**	nd(0.0008)	nd(0.0008)	**0.0004**	2.45
TOTAL=			1798							155.07

DDT Concentrations in Okanogan Tributaries, May 2001.

Location	RM	Date	Flow l/s	TOC mg/l	TSS mg/l	4,4'-DDE ug/L	4,4'-DDD ug/L	4,4'-DDT ug/L	t-DDT ug/L	t-DDT mg/d
Nine Mile Cr.	80.2	5/16/01	32	3.8	nd(1)	**0.0014**	**0.0006**	**0.0015**	**0.0035**	9.59
Tonasket Cr.	77.8	5/16/01	26	6.1	9	**0.0012**	nd(0.0017)	**0.0011**	**0.0023**	5.23
Oroville STP		5/16/01	7	7.1	nd(1)	nd(0.0017)	nd(0.0017)	**0.0007**	**0.0007**	0.42
Mosquito Cr.	67.4	5/16/01	0.5	4.0	2	**0.0017**	**0.0004**	**0.0014**	**0.0035**	0.14
Whitestone Cr.	62.4	5/16/01	85	4.5	5	**0.0004**	nd(0.0016)	nd(0.0016)	**0.0004**	2.94
Antoine Cr.	61.2	5/16/01	31	3.7	16	**0.0018**	**0.0005**	**0.001**	**0.0033**	8.88
Siwash Cr.	57.3	5/16/01	0							
Bonaparte Cr.	56.7	5/17/01	153	5.8	55	**0.0004**	nd(0.0017)	nd(0.0017)	**0.0004**	5.30
Aeneas Cr.	52.9	5/17/01	78	1.5	2	**0.0004**	nd(0.0016)	nd(0.0016)	**0.0004**	2.69
Chewiliken Cr.	50.7	5/17/01	0							
Tunk Cr.	45.0	5/17/01	197	6.6	16	nd(0.0017)	nd(0.0017)	nd(0.0017)	nd	0.00
Johnson Cr.	40.6	5/17/01	29	2.4	12	nd(0.0017)	nd(0.0017)	nd(0.0017)	nd	0.00
Wanacut Cr.	35.0	5/17/01	14	4.7	1	nd(0.0017)	nd(0.0017)	nd(0.0017)	nd	0.00
Omak Cr.	32.0	5/15/01	596	4.5	35	nd(0.0017)	nd(0.0017)	nd(0.0017)	nd	0.00
Omak STP		5/17/01	26	4.2	4	nd(0.0016)	nd(0.0016)	nd(0.0016)	nd	0.00
Elgin Cr.	28.4	5/15/01	19	2.5	20	**0.0058**	**0.0009**	**0.0025**	**0.0092**	15.31
Salmon Cr.	25.7	5/15/01	0							
Okanogan STP		5/17/01	16	10.8	4	**0.0004**	**0.0004**	**0.001**	**0.0018**	2.56
Tallant Cr.	19.5	5/15/01	0							
Loup Loup Cr.	16.9	5/15/01	3	3.6	nd(1)	**0.0007**	nd(0.0016)	**0.0007**	**0.0014**	0.34
Chiliwist Cr.	15.1	5/16/01	27	2.6	1	nd(0.0017)	nd(0.0017)	nd(0.0017)	nd	0.00
TOTAL=			1341							53.41

DDT Concentrations in Okanogan Basin STP Water, 1988-2001.

Location	Ref.	RM	Date	Flow (l/s)	TSS (mg/l)	4,4'-DDE ug/L	4,4'-DDD ug/L	4,4'-DDT ug/L	t-DDT ug/L
Okanogan STP influent	a	25	10/18/88	17.6	260	nd(0.06)	nd(0.06)	nd(0.06)	nd
Okanogan STP effluent	a	25	10/18/88	17.6	8	nd(0.06)	nd(0.06)	nd(0.06)	nd
Okanogan STP effluent	b	25	7/25/95	nr	nr	nd(0.008)	nd(0.008)	nd(0.008)	nd
Oroville STP	c		4/17/01	6	1	**0.0005**	nd(0.0009)	**0.0006**	**0.0011**
Omak STP	c		4/17/01	24	2	nd(0.0008)	nd(0.0008)	nd(0.0008)	nd
Okanogan STP	c	25	4/16/01	16	4	**0.0007**	nd(0.0008)	**0.0006**	**0.0013**
Oroville STP	c		5/16/01	7	nd(1)	nd(0.0017)	nd(0.0017)	**0.0007**	**0.0007**
Omak STP	c		5/17/01	26	4	nd(0.0016)	nd(0.0016)	nd(0.0016)	nd
Okanogan STP	c	25	5/17/01	16		**0.0004**	**0.0004**	**0.001**	**0.0018**

PCB Concentrations in Okanogan Basin STP Water, 1988-2001.

Location	Ref.	RM	Date	Flow (l/s)	TSS (mg/l)	PCB-1260 (ug/l)	PCB-1254 (ug/l)	PCB-1248 (ug/l)	PCB-1242 (ug/l)	PCB-1232 (ug/l)	PCB-1221 (ug/l)	PCB-1016 (ug/l)	t-PCB (ug/l)
Okanogan STP influent	a	25	10/18/88	17.6	260	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd
Okanogan STP effluent	a	25	10/18/88	17.6	8	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd(0.3)	nd
Oroville STP	c		4/17/01	6	1	nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*
Omak STP	c		4/17/01	24	2	nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*
Okanogan STP	c	25	4/16/01	16	4	nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*
Oroville STP	c		5/16/01	7	nd(1)	nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*
Omak STP	c		5/17/01	26	4	nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*
Okanogan STP	c	25	5/17/01	16		nd*	nd*	nd*	nd*	nd*	nd*	nd*	nd*

* no practical quantitation limit determined

a Ecology Okanogan STP Class II Inspection - Reif, 1990

b Ecology "DDT source study" - Johnson et al., 1997

DDT Concentrations in Okanogan Basin STP Sludge, 1988-2001.

Location	Ref.	RM	Date	% TOC	% Fines	4,4'-DDE (ng/g, dry)	4,4'-DDD (ng/g, dry)	4,4'-DDT (ng/g, dry)	t-DDT (ng/g, dry)	2,4'-DDE (ng/g, dry)	2,4'-DDD (ng/g, dry)	2,4'-DDT (ng/g, dry)
Okanogan STP	a	25	10/18/88	na	na	**130**	**57**	**110**	**297**	na	na	na
Oroville STP	b		6/15/01	36.7	na	**180**	**26**	**36**	**242**	**9.1**	nd(22)	nd(22)
Omak STP	b		6/15/01	40.3	na	**68**	nd(45)	**23**	**91**	nd(23)	nd(45)	nd(23)
Okanogan STP	b	25	6/15/01	32.0	na	**110**	**23**	**40**	**173**	**4.2**	**6.3**	**5.5**

PCB Concentrations in Okanogan Basin STP Sludge, 1988-2001.

Location	Ref.	RM	Date	% TOC	% Fines	PCB-1260 (ng/g, dry)	PCB-1254 (ng/g, dry)	PCB-1248 (ng/g, dry)	PCB-1242 (ng/g, dry)	PCB-1232 (ng/g, dry)	PCB-1221 (ng/g, dry)	PCB-1016 (ng/g, dry)	t-PCB (ng/g, dry)
Okanogan STP	a	25	10/18/88	na	na	nd(200)	nd(200)	nd(200)	nd(200)	nd(200)	nd(200)	nd(200)	nd
Oroville STP	b		6/15/01	36.7	na	**48**	**130**	**95**	nd(43)	nd(43)	nd(43)	nd(43)	**273**
Omak STP	b		6/15/01	40.3	na	**41**	**100**	**63**	nd(45)	nd(45)	nd(45)	nd(45)	**204**
Okanogan STP	b	25	6/15/01	32.0	na	**51**	**120**	**63**	nd(42)	nd(42)	nd(42)	nd(42)	**234**

a Ecology Okanogan STP Class II Inspection - Reif, 1990

b present study

DDT Concentrations in Okanogan River Sediments, 1984-1994.

Location	Ref.	RM	Date	% TOC	% Fines	4,4'-DDE (ng/g, dry)	4,4'-DDD (ng/g, dry)	4,4'-DDT (ng/g, dry)	t-DDT (ng/g, dry)	2,4'-DDE (ng/g, dry)	2,4'-DDD (ng/g, dry)	2,4'-DDT (ng/g, dry)
Okanogan R. blw. Malott	a	12	1984	1	62	**21**	**18**	**17**	**56**	na	na	na
Okanogan River above Brewster	b	7	9/13/94	2	73	**6.4**	**12**	nd (12)	**18**	nd(12)	nd(12)	nd(12)

a Ecology BWMP-Hopkins et al, 1985

b Ecology WSPMP-Davis and Serdar, 1996

PCB Concentrations in Okanogan River Sediments, 1984-1994.

Location	Ref.	RM	Date	% TOC	% Fines	PCB-1260 (ng/g, dry)	PCB-1254 (ng/g, dry)	PCB-1248 (ng/g, dry)	PCB-1242 (ng/g, dry)	PCB-1232 (ng/g,wet)	PCB-1221 (ng/g,wet)	PCB-1016 (ng/g,wet)	Tot PCB (ng/g,wet)
Okanogan R. blw. Malott	a	12	1984	1	62	**21**	na	na	na	na	na	na	**21**
Okanogan River above Brewster	c	7	9/13/94	2	73	nd(47)	nd(47)	nd(47)	nd(47)	na	na	na	nd

a Ecology BWMP-Hopkins et al, 1985

b Ecology WSPMP-Davis and Serdar, 1996

DDT Concentrations in Okanogan River/Osoyoos Lake Fish Muscle, 1983-1995.

Location	ref.	RM	Date	Species	Lipid (%)	4,4'-DDT (ng/g,wet)	4,4'-DDD (ng/g,wet)	4,4'-DDE (ng/g,wet)	t-DDT (ng/g,wet)	2,4'-DDT (ng/g,wet)	2,4'-DDD (ng/g,wet)	2,4'-DDE (ng/g,wet)
Okanogan R. blw. Malott	a	12	9/13/84	Bridgelip sucker	2.7	**64**	**780**	**2,400**	**3,244**	**11**	nd(1)	**6**
Okanogan R. blw. Malott	a	12	9/15/84	Largemouth bass	4.2	**62**	**270**	**1,400**	**1,732**	**15**	nd(1)	**38**
Osoyoos Lake	b		7/25/89	Largemouth bass	1.1	**6**	**55**	**150**	**211**	na	na	na
Okanogan River above Brewster	c	7	9/13/94	Carp	9.1	**6**	**1,050**	**1,650**	**2,706**	nd(10)	**135**	**12**
Osoyoos Lake	d		8/30/95	Yellow perch	0.85	**4**	**12**	**37**	**53**	na	na	na
Osoyoos Lake	d		8/30/95	Yellow perch	1.1	**4**	**12**	**35**	**51**	na	na	na
Osoyoos Lake	d		8/30/95	Yellow perch	0.97	**4**	**14**	**43**	**61**	na	na	na
Osoyoos Lake	d		8/29/95	Yellow perch	1.12	**5**	**15**	**48**	**68**	na	na	na
Osoyoos Lake	d		8/29/95	Yellow perch	0.6	**4**	**8**	**30**	**42**	na	na	na
Osoyoos Lake	d		8/30/95	Yellow perch	0.99	**4**	**16**	**50**	**70**	na	na	na
Osoyoos Lake	d		8/29/95	Yellow perch	0.99	**4**	**16**	**50**	**70**	na	na	na
Osoyoos Lake	d		8/30/95	Yellow perch	0.87	**4**	**13**	**47**	**64**	na	na	na
Osoyoos Lake	d		8/29/95	Smallmouth bass	1.04	**2**	**6**	**35**	**43**	na	na	na
Osoyoos Lake	d		8/30/95	Smallmouth bass	1.11	**5**	**13**	**65**	**83**	na	na	na
Osoyoos Lake	d		8/29/95	Smallmouth bass	0.97	**5**	**16**	**72**	**93**	nd(4)	nd(4)	nd(4)
Osoyoos Lake	d		8/29/95	Mountain whitefish	4.06	**6**	**31**	**68**	**105**	na	na	na
Osoyoos Lake	d		8/29/95	Carp	1.41	**1**	**42**	**180**	**223**	na	na	na
Osoyoos Lake	d		8/28/95	Carp	2.78	U(8)	**103**	**550**	**653**	na	na	na
Osoyoos Lake	d		8/29/95	Carp	2.8	**2**	**130**	**420**	**552**	na	na	na
Osoyoos Lake	d		8/28/95	Carp	1.58	**1**	**60**	**260**	**321**	na	na	na
Osoyoos Lake	d		8/30/95	Lake Whitefish	7.51	**37**	**350**	**600**	**987**	na	na	na
Osoyoos Lake	d		8/30/95	Lake Whitefish	5.53	**25**	**460**	**755**	**1,240**	na	na	na

DDT Concentrations in Okanogan River/Osoyoos Lake Whole Fish, 1983-1995.

Location	ref.	RM	Date	Species	Lipid (%)	4,4'-DDT (ng/g,wet)	4,4'-DDD (ng/g,wet)	4,4'-DDE (ng/g,wet)	t-DDT (ng/g,wet)	2,4'-DDT (ng/g,wet)	2,4'-DDD (ng/g,wet)	2,4'-DDE (ng/g,wet)
Okanogan R. @ Okanogan	a	26	8/29/83	Bridgelip sucker	2.1	**144**	**241**	**1,399**	**1,784**	nd(1)	nd(1)	nd(1)
Okanogan R. @ Okanogan	a	26	8/29/83	Mountain whitefish	8.3	**54**	**115**	**642**	**811**	nd(1)	nd(1)	nd(1)
Okanogan River above Brewster	c	7	9/13/94	Largescale sucker	8.4	**21**	**120**	**760**	**901**	nd(10)	**13**	**1.4**
Okanogan River above Brewster	c	7	9/13/94	Largescale sucker	6.1	**39**	**180**	**1,100**	**1,319**	**1.2**	**18**	**2.2**
Osoyoos Lake	d		8/28/95	Largescale sucker	5.08	**40**	**190**	**810**	**1,040**	nd(3.7)	**3.5**	nd(3.7)
Osoyoos Lake	d		8/29/95	Largescale sucker	5.82	**17**	**120**	**440**	**577**	nd(3.6)	**2.3**	nd(3.6)

a Ecology BWMP-Hopkins et al, 1985
b Ecology "Ten Lakes Survey"-Johnson and Norton, 1990
c Ecology WSPMP-Davis and Serdar, 1996
d Ecology "Osoyoos Study" - Serdar, et al., 1998

DDT Concentrations in Okanogan River/Osoyoos Lake Fish Liver, 1984.

Location	ref.	RM	Date	Species	Lipid (%)	4,4'-DDT (ng/g,wet)	4,4'-DDD (ng/g,wet)	4,4'-DDE (ng/g,wet)	t-DDT (ng/g,wet)	2,4'-DDT (ng/g,wet)	2,4'-DDD (ng/g,wet)	2,4'-DDE (ng/g,wet)
Okanogan R. blw. Malott	a	12	9/14/84	Bridgelip sucker	23.1	**200**	**3,500**	**10,600**	**14,300**	nd(1)	**500**	**360**
Okanogan R. blw. Malott	a	12	9/16/84	Largemouth bass	na	**200**	**540**	**2,100**	**2,840**	nd(1)	**89**	**130**

PCB Concentrations in Okanogan River/Osoyoos Lake Fish Muscle, 1984-1995.

Location	ref.	RM	Date	Species	Lipid (%)	PCB-1260 (ng/g,wet)	PCB-1254 (ng/g,wet)	PCB-1248 (ng/g,wet)	PCB-1242 (ng/g,wet)	PCB-1232 (ng/g,wet)	PCB-1221 (ng/g,wet)	PCB-1016 (ng/g,wet)	Tot PCB (ng/g,wet)
Okanogan R. blw. Malott	a	12	9/13/84	Bridgelip sucker	2.7	nd(10)	na	na	na	na	na	na	nd
Okanogan R. blw. Malott	a	12	9/15/84	Largemouth bass	4.2	**22**	na	na	na	na	na	na	**22**
Osoyoos Lake	b		7/25/89	Largemouth bass	1.1	nd(20)	nd(20)	nd(20)	nd(20)	na	na	na	nd
Okanogan River abv. Brewster	c	7	9/13/94	Carp	9.1	**20**	**25**	nd(50)	nd(50)	nd(50)	nd(50)	nd(50)	**45**
Osoyoos Lake	d		8/29/95	Smallmouth bass	0.97	nd(40)	nd(40)	nd(40)	nd(40)	na	na	na	nd

PCB Concentrations in Okanogan River/Osoyoos Lake Whole Fish, 1983-1995.

Location	ref.	RM	Date	Species	Lipid (%)	PCB-1260 (ng/g,wet)	PCB-1254 (ng/g,wet)	PCB-1248 (ng/g,wet)	PCB-1242 (ng/g,wet)	PCB-1232 (ng/g,wet)	PCB-1221 (ng/g,wet)	PCB-1016 (ng/g,wet)	Tot PCB (ng/g,wet)
Okanogan R. @ Okanogan	a	26	8/29/83	Bridgelip sucker	2.1	nd(10)	**583**	na	na	na	na	na	**583**
Okanogan R. @ Okanogan	a	26	8/29/83	Mountain whitefish	8.3	nd(10)	**122**	na	na	na	na	na	**122**
Okanogan River abv. Brewster	b	7	9/13/94	Largescale sucker	8.4	**34**	**22**	nd(50)	nd(50)	nd(50)	nd(50)	nd(50)	**56**
Okanogan River abv. Brewster	b	7	9/13/94	Largescale sucker	6.1	**48**	**24**	nd(50)	nd(50)	nd(50)	nd(50)	nd(50)	**72**
Osoyoos Lake	d		8/28/95	Largescale sucker	5.08	**18**	**48**	nd(37)	nd(37)	na	na	na	**66**
Osoyoos Lake	d		8/29/95	Largescale sucker	5.82	nd(36)	**24**	nd(36)	nd(36)	na	na	na	**24**

PCB Concentrations in Okanogan River/Osoyoos Lake Fish Liver, 1984.

Location	ref.	RM	Date	Species	Lipid (%)	PCB-1260 (ng/g,wet)	PCB-1254 (ng/g,wet)	PCB-1248 (ng/g,wet)	PCB-1242 (ng/g,wet)	PCB-1232 (ng/g,wet)	PCB-1221 (ng/g,wet)	PCB-1016 (ng/g,wet)	Tot PCB (ng/g,wet)
Okanogan R. blw. Malott	a	12	9/14/84	Bridgelip sucker	23.1	**210**	na	na	na	na	na	na	**210**
Okanogan R. blw. Malott	a	12	9/16/84	Largemouth bass	na	nd(10)	na	na	na	na	na	na	nd

a Ecology BWMP-Hopkins et al, 1985
b Ecology "Ten Lakes Survey"-Johnson and Norton, 1990
c Ecology WSPMP-Davis and Serdar, 1996
d Ecology "Osoyoos Study" - Serdar, et al., 1998

Appendix B

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

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

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

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

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

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

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

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

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

Appendix C

Estimated Laboratory Costs to Conduct Okanogan TMDL Assessment

Variable	No. Field Samples	QA Samples	Total Samples	Unit Price	Total Price	Laboratory
Water						
DDT analogs	32	2	34	$159	$5,406	MEL
DDT analogs, PCBs (Aroclors)	7	1	8	$287	$2,296	MEL
TOC	38	NC	38	$29	$1,102	MEL
TSS	38	NC	38	$10	$380	MEL
Sediments						
DDT analogs, PCBs (Aroclors)	24	NC	24	$203	$4,872	MEL
TOC	24	NC	24	$33	$792	MEL
^{210}Pb	18	NC	18	$225	$4,050	Battelle
Fish Tissue						
DDT analogs, PCBs (Aroclors)	27	7	34	$287	$9,758	MEL
Percent Lipids	27	6	33	$31	$1,023	MEL
				TOTAL=	**$29,679**	

NC=no charge