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DEPARTMENT OF
ECOLOGY

Upper Yakima River Basin Suspended Sediment and Organochlorine Pesticide Total Maximum Daily Load Evaluation

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by
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April 2002

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Abstract

An upper Yakima River basin suspended sediment and organochlorine pesticide total maximum daily load (TMDL) evaluation was conducted by the Washington State Department of Ecology as required by the federal Clean Water Act. This evaluation was an extension of the 1997 lower Yakima basin TMDL and addressed several organochlorine pesticide 303(d) listings of water column and fish tissue in the upper basin. Turbidity and suspended sediment were included as transport mechanisms for the pesticides and as pollutants themselves.

Historical data and data collected during the 1999 irrigation season (April to October) were used for this TMDL. The data evaluation for the upper Yakima River basin indicated that:

- In many tributaries and the mainstem, turbidity and suspended sediment (as total suspended solids) were too high for too long and could be harmful to salmon.
- Dieldrin and total DDT (DDT+DDE+DDD) had decreased in mainstem fish, but some fish samples still exceeded total DDT and dieldrin criteria for human health. Concentrations of the individual compounds, 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD, did not exceed fish tissue criteria.
- Water column 4,4'-DDE, total DDT, and dieldrin exceeded chronic aquatic toxicity and human health criteria at two sites in the Cherry Creek sub-basin. Unfortunately, organochlorine pesticide concentrations were not well correlated with suspended sediment, turbidity, or organic carbon.
- Upper basin water quality is improving (and is less severe than was reported for the lower basin in 1997), but nonpoint sources will require TMDL targets to protect aquatic communities and human health.

Turbidity targets were calculated for seven sub-basins to decrease suspended sediment loading. Meeting these targets will move the mainstem towards meeting a turbidity target of not more than a 5 turbidity unit increase from Nelson (river mile 191) to Harrison Bridge (river mile 121.7) by 2011. DDT and dieldrin targets were calculated so Cherry Creek will meet aquatic toxicity and human health criteria. A dieldrin target for the Cle Elum area, and DDT and dieldrin targets for the Yakima River at Umtanum, were calculated based on fish tissue concentrations. Reductions in the availability of organochlorine pesticides to fish are needed to meet human health criteria, especially to meet the dieldrin target at Umtanum.

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Introduction

Background

The Yakima River basin is located in south-central Washington State (Figure 1). The Yakima River flows 214.5 miles from the outlet of Keechelus Dam, southeasterly to its confluence with the Columbia River. The basin drains nearly half of Washington's eastern slope of the Cascade Mountains (6,155 square miles). Land uses in the basin vary from forestland, range, and intensively irrigated agriculture to urban and suburban areas. Past studies and monitoring data have shown that each of these uses contributes to suspended sediment loads to the Yakima River and many of its tributaries.

The Washington State Department of Ecology (Ecology) is responsible for protecting water quality and aquatic communities, and for managing water resources. Ecology recognizes that suspended sediments can deteriorate aquatic communities, and are a key transport mechanism for organochlorine pesticides, bacteria, nutrients, and several other potential pollutants.

In 1994-1995, Ecology initiated a total maximum daily load (TMDL) evaluation of the Yakima River basin suspended sediment and persistent organochlorine pesticide problem. After conducting preliminary sampling throughout the basin in 1994, Ecology decided to focus its efforts in 1995 on the more severe problems in the lower basin. The lower Yakima River basin TMDL was designed to examine both the suspended sediment and associated pesticides. Based on results from the technical evaluation, Ecology established TMDLs for the mainstem and for sub-basins in the lower basin to attain state water quality standards for turbidity, aquatic life criteria for pesticides, and to protect fish health and habitat (Joy and Patterson, 1997). In 15 years, TMDL targets will be modified to address human health issues from ingestion of organochlorine-contaminated fish in the lower basin. As a result of the TMDL efforts to date, coordinated sediment control activities in the lower basin have begun to improve water quality in the lower Yakima River and many of its tributaries (USGS, unpublished data; Roza-Sunnyside Joint Board of Control, unpublished data).

In 1999, Ecology continued its assessment of suspended sediment, organochlorine pesticides, bacteria, and metals in the upper Yakima River basin. Ecology's Environmental Assessment Program staff wrote three quality assurance project plans for TMDL-related projects (Johnson, 1999; Rogowski, 1999; and Dickes and Joy, 1999). Water quality and fish tissue monitoring following the project plans were conducted from March 1999 to January 2000.

1. Johnson (2000) collected metals samples and found no criteria violations. He recommended that copper, cadmium, silver, and mercury be removed from the 303(d) list for the upper Yakima River.

2. Rogowski (2000) tested fish tissue for persistent pesticides. He detected levels of some pesticides at or above human health criteria, and he recommended continued listing for total DDT (DDT+DDE+DDD) and dieldrin in the upper Yakima River.

3. The purpose of the suspended sediment and organochlorine pesticide TMDL project (this report) is to evaluate the effect of suspended sediment loads on water quality in the upper mainstem of the Yakima River during the irrigation season, and to document sources of suspended sediment and persistent organochlorine pesticides (Dickes and Joy, 1999). The TMDL recommends necessary reductions in these parameters to support aquatic resources, and to reduce their loading to the river and lower basin.

Suspended sediment associations with general land uses and with fecal coliform bacteria were also investigated in the Cherry/Wilson Creek sub-basin as part of the original project plan (Dickes and Joy, 1999), and will be discussed as separate documents.

Problem Description

Under Section 303(d) of the federal Clean Water Act, states must submit a list of impaired waters to the U.S. Environmental Protection Agency (USEPA) every two years. Impaired waters are those that are not meeting, or are not expected to meet, water quality standards with technology-based controls or other legally required pollution control mechanisms. For those waters, states are required to conduct TMDL evaluations which set water quality-based controls on sources.

The upper Yakima River and several of its tributaries listed in Table 1 are included in Washington's 303(d) list of impaired waters because of metals, persistent pesticides in water and fish tissue, fecal coliform bacteria, dissolved oxygen, and temperature water quality criteria violations (Ecology, 1998). Temperature listings are numerous in the upper basin and many are not included in the table. This TMDL project does not address them, because Ecology is using a specific modeling approach for temperature TMDLs. For example, the Teanaway River temperature TMDL technical evaluation was written (Stohr and Leskie, 2000), and after the public review process, the TMDL submittal was accepted by USEPA Region 10 in January 2002.

Although turbidity and suspended sediment data collected by Ecology and others had suggested water quality was impaired, these parameters were not included in the 1998 303(d) list for upper Yakima basin waters for the following reasons:

- State criteria for turbidity require comparisons of sample results to a background turbidity level, and are most readily applied to individual discharges. Most monitoring studies are not designed to provide a background value, or assess the cumulative effects of several sources of turbidity.
- The state has not adopted total suspended solids (TSS) or suspended sediment criteria to generally assess water quality conditions and to place a waterbody on the 303(d) list. A site-specific evaluation is necessary to determine if suspended sediment concentrations exceed levels harmful to aquatic communities, or if suspended sediment is a transport mechanism for other contaminants of concern.
- The lower Yakima River basin TMDL did not evaluate the sources of background turbidity delivered from the upper watershed. Preliminary data collected in1994 indicated some elevated nonpoint sources were present. During the lower Yakima TMDL review period, Ecology assured USEPA that "background" upper basin sources of sediment and total DDT and individual DDT compounds would be evaluated and controlled.

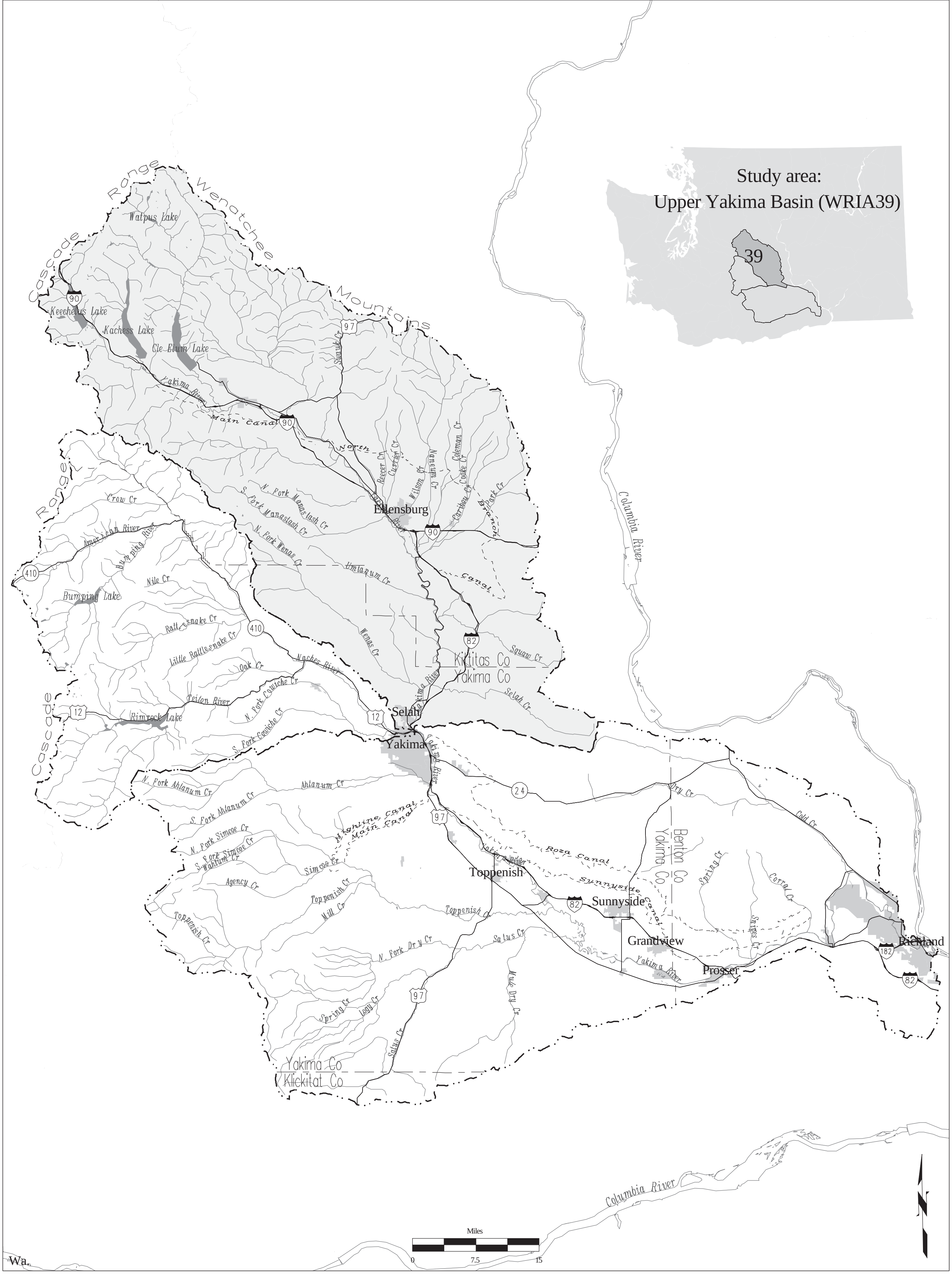


Figure 1. The Yakima River Basin and Upper Yakima Study Area.

Table 1. A partial list of water quality limited segments in the upper Yakima River basin, and waterbodies and parameters addressed in this TMDL report.

Old Waterbody Number	New Waterbody Number	Waterbody Name	Parameters on the 303(d) List or Requiring Assessment	
			Assessed	Not Assessed
WA-39-1032	FT68CJ	Cherry Creek	4,4'-DDE, DDT, dieldrin, turbidity*, suspended sediment*	Temperature
WA-39-1034	SZ58XV	Cooke Creek	Fecal coliform*, turbidity*, suspended sediment*	Dissolved oxygen., temperature
WA-39-1020	PY59BF	Wilson Creek	Fecal coliform*, turbidity, suspended sediment	Temperature
WA-39-1010	EB21AR	Yakima River (from Naches R. to Ellensburg)	4,4'-DDE, DDT, dieldrin, cadmium*, silver*, copper*, mercury*, turbidity, suspended sediment	
WA-39-1030	EB21AR	Yakima River (from Ellensburg to Cle Elum)	4,4'-DDE, DDT, cadmium*, copper*, mercury*, turbidity, suspended sediment	Dissolved oxygen., temperature
WA-39-3000	AT33DI	Manastash Creek	turbidity, suspended sediment	Instream flow
WA-39-1500	WF36AI	Taneum Creek	turbidity, suspended sediment	Instream flow, temperature
WA-39-2000	ZH39IA	Teanaway River	turbidity, suspended sediment	Instream flow, temperature
WA-39-1012	RJ61TR	Wenas Creek	turbidity, suspended sediment	Instream flow
		Sorenson Creek	turbidity, suspended sediment	
		Packwood Ditch	turbidity, suspended sediment	

* Addressed in a separate document from this report.
Underlined parameters were not in the 1998 303(d) list but are part of this TMDL evaluation.

An upper Yakima River suspended sediment TMDL evaluation was proposed as a priority action by Ecology's Central Regional Office after a 1995 Watershed Needs Assessment (Ecology, 1996a). The evaluation was proposed as an extension of the lower Yakima basin TMDL to address similar listings in the upper basin, and to finish TSS evaluation work started in 1994. The lower basin TMDL demonstrated that soil erosion and suspended sediment are primary transport mechanisms for DDT from land to the aquatic system (Joy and Patterson, 1997). Turbidity and TSS targets were determined that would reduce soil erosion practices and prevent suspended sediment and DDT from degrading aquatic life.

Likewise in 1995, the 303(d)-listed organochlorine pesticides, nutrients, dissolved oxygen, and bacteria problems throughout the upper Yakima basin were suspected of being associated with suspended sediment loading and transport. In addition, sediment is a potential aquatic habitat issue for salmon and the federal Endangered Species Act steelhead and bull trout listings in the upper Yakima basin (YVCOG, 1995; Haring, 2001; Northwest Power Planning Council, 2001). Monitoring data on activities implemented under the lower Yakima basin sediment TMDL, and for best management projects to control suspended sediment, are showing a broad range of water quality and aquatic habitat improvements.

Ecology, the US Geological Survey (USGS), the US Bureau of Reclamation (USBR), the Kittitas County Conservation District, and the Kittitas Reclamation District have all conducted water quality monitoring in the upper Yakima River basin. Since 1987, the USGS National Water-Quality Assessment (NAWQA) project in the Yakima basin has been the most comprehensive effort, providing a wealth of water quality and ecological data and analysis. Their data have been used for metals and organochlorine pesticide 303(d) listings, and were the basis for the suspended sediment to organochlorine pesticides relationship used in the lower basin TMDL. Their recent work has located several areas in the upper basin with impaired fish, invertebrate, and algal communities due to sediment and other contaminant effects (Morace et al., 1999).

Other monitoring programs have focused on one water quality parameter or a smaller geographical area. Ecology researchers and monitoring staff detected elevated levels of persistent pesticides in fish tissue in the upper watershed (Johnson et al., 1986), and fecal coliform and dissolved oxygen problems in the Wilson/Cherry sub-basin (Johnson and Prescott, 1980; Joy, 1988; Ecology, 2000). The Kittitas County Conservation District and the Kittitas Reclamation District have been using their data to effectively direct their technical outreach activities, observe water quality trends, and identify contaminant contributions from various sources (Bain, 1994, 1998; Lael, 2000; Satnik, 2000). Most of the data collected by these groups have shown erosion and suspended sediment problems in irrigated agricultural or rangeland areas, and some improvements in conditions since the 1970s and 1980s.

Most forested sub-basins in the upper Yakima River basin have not been intensively monitored for suspended sediment, but water quality and fish habitat problems from excessive sediment transport have been noted by several agencies. In the past, poor timber harvesting practices and poor management of recreational areas were reported as having contributed to suspended sediment and water quality problems in forested areas of the basin (USDA, 1978).

Partly because of the need to stop erosion and improve water quality and aquatic habitat, forested areas of the upper Yakima River basin have been undergoing management changes. The Timber, Fish and Wildlife agreement was signed in 1987, and the Yakima Resources Management Cooperative began addressing forestry and fishery resource conflicts in forestlands in 1989. Fisheries agencies have been active in assessing the impacts of sediment on fish habitat as well. These groups and others such as the Northwest Power Planning Council have sponsored research that has identified problem areas for channel and upland rehabilitation. Also, they have shown the effectiveness of best management practices (Confederated Tribes and Bands of the Yakama Nation, Washington Department of Fisheries, and Washington Department of Wildlife, 1990; Watson, 1991; Arango, Eitemiller, and Fraser, 1993).

A few studies have shown that municipal point sources have not been a significant source of metals, suspended sediment, and organochlorine pesticides in the upper Yakima basin (Johnson, 2000; Morace et al., 1999). Sand and gravel operations and urban stormwater systems under the state general discharge permit system have not been investigated.

This TMDL project will recommend suspended sediment and turbidity targets for the tributaries and mainstem upper Yakima River, as well as targets for organochlorine pesticides. The targets are intended to reduce the suspended sediment load in the upper and lower basins, and to reduce the likelihood of organochlorine pesticide transport in the aquatic environment. The TMDL builds on water quality improvement efforts already underway by local groups in the basin. The continued cooperation between landowners, land managers, local resource agencies, federal and state research programs, and regulatory agencies will promote further improvements in water quality and aquatic community in the Yakima River basin.

Water Quality Standards and Guidelines

The upper Yakima TMDL evaluation relies on state standards and criteria, federal guidelines, and data from scientific research. The data from this body of regulations and recommendations are compared to historical data and data collected from the project area during the 1999 TMDL monitoring period.

Washington State has water quality standards based on characteristic uses of a waterbody. Included in the standards are numeric and narrative criteria, as well as antidegradation criteria set to protect the characteristic uses in different classifications of water (Table 2).

- The upper Yakima River basin contains both Class A and Class AA waterbodies (WAC 173-201A-130) and is expected to have very high water quality that supports all or nearly all uses.
- The Yakima River from the mouth to the Cle Elum River (river mile 185.6) is Class A with a special condition placed on the temperature criteria.
- The Yakima River above the Cle Elum River is Class AA.
- All tributaries to the Class A portion of the upper Yakima River are Class A; tributaries to the Class AA portion are Class AA.
- All streams and rivers within the national forest boundaries are Class AA or Lake Class (WAC 173-201A-120(1)).

All sample sites for this project are located in Class A waterbody segments, except for the Cle Elum River and the uppermost Yakima River site (river mile 191) which are Class AA.

Ecology is currently revising its water quality standards to follow site-specific uses. The final details of these revisions and the date they will become effective are uncertain. When the changes occur, the TMDL findings may help to guide appropriate site-specific criteria for the basin.

Table 2. Class AA (extraordinary) and Class A (excellent) fresh water quality standards and characteristic uses (WAC 173-201A).

	Class AA	Class A
General Characteristic	Shall markedly and uniformly exceed the requirements for all, or substantially all uses.	Shall meet or exceed the requirements for all, or substantially all uses.
Characteristic Uses	Shall include, but not be limited to, the following: domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.	Same as AA.
	Water Quality Criteria	
Fecal Coliform	Shall not exceed a geometric mean value of 50 organisms/100 mL, with not more than 10% of samples exceeding 100 organisms/100 mL.	Shall not exceed a geometric mean value of 100 organisms/100 mL, with not more than 10% of samples exceeding 200 organisms/100 mL.
Dissolved Oxygen	Shall exceed 9.5 mg/L.	Shall exceed 8.0 mg/L.
Total Dissolved Gas	Shall not exceed 110% saturation.	Same as AA.
Temperature	Shall not exceed 16.0°C due to human activities. When conditions exceed 16.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Increases from nonpoint sources shall not exceed 2.8°C.	Temperature shall not exceed 18°C due to human activities. *Special condition – temperature shall not exceed 21ºC. When conditions exceed 21.0°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C, nor shall such temperature increase at any time exceed t=34/(T+9). Increases from nonpoint sources shall not exceed 2.8°C.
pH	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.2 units	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.5 units.
Turbidity	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background is more than 50 NTU.	Same as AA.
Toxic, Radioactive, or Deleterious Material (Narrative Criteria)	Shall be below concentrations which have the potential singularly or cumulatively to adversely affect characteristic uses, cause acute or chronic conditions to the most sensitive aquatic biota, or adversely affect public health.	Same as AA.
Aesthetic Values	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.	Same as AA.

* Special temperature condition for the Yakima River from the mouth to river mile 185.6.

NTU - turbidity units

Toxic contaminants are controlled by federal guidelines adopted by Washington State (WAC 173-201A). Concentrations for total DDT (4'4'-DDT + 4'4'-DDE + 4'4'-DDD) and dieldrin in the water column should be less than the chronic and acute toxicity criteria for the protection of aquatic life (Table 3).

Table 3. USEPA water quality criteria for DDT, DDE, DDD, and dieldrin.

Toxic	Human Health Criteria (1)	Chronic Criteria(2)	Acute Criteria (3)
4,4'-DDT	0.00059 ug/L	0.001 ug/L	1.1 ug/L
4,4'-DDE	0.00059 ug/L	0.001 ug/L	1.1 ug/L
4,4'-DDD	0.00083 ug/L	0.001 ug/L	
Dieldrin	0.00014 ug/L	0.0019 ug/L	2.5 ug/L

(1) National Toxics Rule (40 CFR 131.36).
(2) Not to be exceeded as a 24-hour average.
(3) Not to be exceeded at any time.
Human health criteria for pesticides in water are based on the health risk from consuming fish.
Aquatic life biota are protected by chronic and acute criteria.

Concentrations in water and tissue also should be less than the National Toxics Rule (40 CFR 131.36) human health criteria. The human health water quality criteria for DDT compounds and dieldrin are based on the carcinogenic risk from consuming fish and water contaminated with these pesticides. Edible tissue concentrations of 45 ug/Kg DDD, 32 ug/Kg DDE or DDT or total DDT, and 0.65 ug/Kg dieldrin are the criteria calculated for a lifetime carcinogenic risk of 1:1,000,000 according to the National Toxics Rule (40 CFR 131.36). These are basic human health criteria that do not consider more sensitive populations, higher fish consumption rates, or other factors that would go into a detailed risk analysis. The water column human health criteria are back calculated from the tissue carcinogenic risk criteria using average bioconcentration factors and tissue lipid content values (Table 3).

Turbidity is a surrogate measurement of suspended material in the water column. It is easier to perform in the laboratory, and has lower costs than the total suspended solids (TSS) analyses, another surrogate measurement for suspended sediment. Within the 1994 and 1995 irrigation seasons, suspended sediment, turbidity, and TSS were all highly correlated in samples collected from the lower Yakima River basin (Joy and Patterson, 1997). These empirical relationships were the basis for measuring turbidity and TSS to represent suspended sediment in the upper Yakima basin.

Washington State turbidity criteria do not contain a strict numeric measurement or duration element. Instead they are based on a relative change in turbidity units (NTU) above "background" (Table 2). Class A and AA criteria allow a 5 NTU gain; Class B and C allow a 10 NTU gain. The criteria have been primarily used to control point source and short-term water quality impacts from streamside construction activities. Taken with the narrative criteria, the turbidity criteria can be used as guidance to protect river reaches beyond an individual point source when turbidity from multiple sources would damage the ecosystem of the river reach (WAC 173-201A-100 (9)). But since the criteria are missing a duration element, this use of the criteria needs to be balanced with the knowledge that aquatic ecosystems have evolved with, and can recover from, short-duration events with relatively high turbidities.

The state of Idaho has more recently developed turbidity criteria with a duration element to protect cold water aquatic communities:

"Turbidity, below any applicable mixing zone set by the Department, shall not exceed background turbidity by more than 50 NTU instantaneously or more than 25 NTU for more than ten consecutive days." (IDAPA 58.01.02.250.02.d)

Joy and Patterson (1997) used both the Idaho and Washington turbidity criteria as guidance in the lower Yakima basin TMDL to limit the cumulative effect of elevated turbidity discharges on the river from irrigation project drains and tributaries. The close correlation between turbidity and suspended sediments, and between suspended sediments and DDT compounds, made turbidity an effective measure of water quality and aquatic health.

Lower Yakima River mainstem background turbidity was set as the 90th percentile turbidity value of combined Naches River and upper Yakima River sources. According to the lower Yakima TMDL, by 2002 the turbidity of the Yakima River between the confluence of the Yakima and Naches rivers (rm 116.3) and the Kiona gage (rm 30) is not to increase more than 5 NTU over the background of the irrigation season (April through October). In addition, Joy and Patterson (1997) used the narrative criteria (Table 2) and the Idaho example to set a 25 NTU 90th percentile turbidity target at the mouths of the irrigation return drains and tributaries to protect a moderately healthy aquatic community in the lower basin.

Other suspended sediment and turbidity criteria for the protection of aquatic communities have been offered and argued in the scientific literature. USEPA guidance documents roughly classify suspended sediment concentrations on their impairment of aquatic habitat or organisms as follows (Mills et al., 1985):

TSS Concentration	Impairment
< 10 mg/L	improbable
10 - 100 mg/L	potential
> 100 mg/L	probable

Studies summarized by Newcombe and McDonald (1991) have shown that suspended sediment and turbidity adversely affect all life-stages of salmon and other cold water fisheries (Table 4). The values in Table 4 show both the effects of high concentrations of short duration, and the effects of lower concentrations of longer duration. More recently, data collated by Newcombe (1996) suggest that suspended sediment concentrations between 7 and 20 mg/L for extended periods have been shown to detrimentally affect salmonids.

Table 4. A summary of TSS on selected salmonids commonly present in the Yakima basin, based on data collected by Newcombe and McDonald (1991).

Species	Concentration (mg/L)	Duration (hours or days)	Effect
Chinook Salmon	1400	36 hrs	10% mortality of juveniles
	488	4 days	50% mortality of smolts
	82,000	6 hrs	60% mortality of juveniles
	19,364	4 days	50% mortality of smolts
	1.5-2.0	60 days	Gill hyperplasia, poor condition of fry
	6	60 days	Reduction of growth rate
	75	7 days	Harm to quality of habitat
	84	14 days	Reduction of growth rate
	1,547	4 days	Histological damage to gills
	650	1 hr	Homing performance disrupted
Rainbow Trout	19,364	4 days	50% mortality of smolts
	157	72 days	100% egg mortality
	21	48 days	62% reduction in egg to fry survival
	37	60 days	46% reduction in egg to fry survival
	7	48 days	17% reduction in egg to fry survival
	90	19 days	5% mortality of sub-adults
	171	4 days	Histological damage to gills
	50	77 days	Reduction of growth rate
	100	1 hr	Avoidance response
Whitefish	16,613	4 days	50% mortality of juveniles
	0.7	1 hr	Abandon overhead cover
Salmon (general)	8	24 hrs	Sportfishing declines

Ecology's review of data did not find suspended sediment concentrations in the upper Yakima basin at some of the extreme concentrations in Table 4 (see *Historical Data Analysis*, below). However, of interest were concentrations above 100 mg/L in spring, or during peak storm or rain-on-snow events of an unknown duration, that could be potentially harmful. Also, the potential effects from weeks or months of suspended solids concentrations between 10 mg/L and 100 mg/L were thought to be a potential problem for aquatic communities in this basin.

As seen in the work compiled by Newcombe and McDonald (1991) and conducted by others, concern over turbidity and suspended sediments involves their behavioral and physical effects on fish, and the sedimentation of fish spawning areas and habitats for macroinvertebrates. Sigler et al. (1984) and Harvey (1989) presented data showing that prolonged exposure to turbidities of 25 NTU to 50 NTU reduced feeding and growth of coho and steelhead fingerlings, and caused them to emigrate. Berg (1982) and Bjornn and Reiser (1991) showed that turbidities between 10 and 60 NTU over two to four days could disrupt feeding and territorial behavior in juvenile salmon.

Researchers have found it difficult, at times, to pinpoint the most vulnerable life-stage on which to set guidelines. For example, Everest et al. (1987) suggest production of salmon species with longer residence times in freshwater (chinook, coho, and steelhead) is more limited by habitat and food availability than by spawning success. Therefore, suspended sediment effects on summer food availability and winter shelter could be a more serious problem than sedimentation of spawning areas. Sedimentation would have a more serious effect on invertebrate and algal communities on which some fish life-stages depend for food. Also, some research suggests that suspended sediment concentrations of 25-100 mg/L, while detrimental to smaller juvenile salmonids, enhance foraging by larger individuals (Gregory, Servizi, and Martens, 1993).

Study Area

The study area includes the upper Yakima River basin from river mile (rm) 121.7 to the headwaters, approximately 2,139 square miles (mi^2). The primary monitoring and assessment area consists of the mainstem Yakima River and its major tributaries from rm 121.7 (Harrison Bridge, near the town of Selah) upstream to rm 191 (4.5 miles northwest of Cle Elum on Interstate 90) (Figure 2).

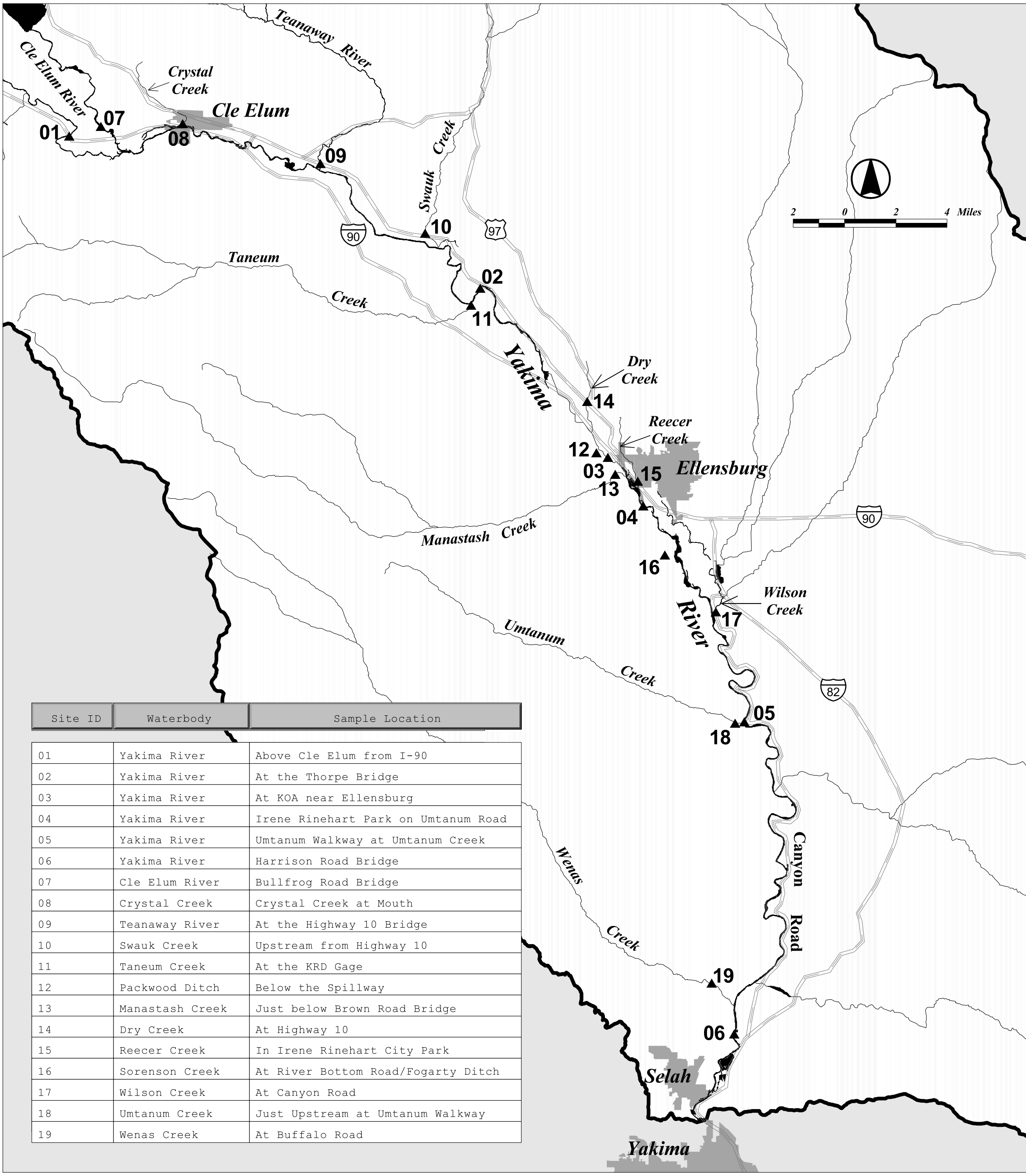
The Yakima River and its upper tributaries head at glaciers and snowfields near the 5,000 – 7,000-foot crest of the Cascade Mountains (Pearson, 1985). Three major lakes, Kachess, Keechelus, and Cle Elum, were converted to reservoirs between 1903 and 1933; they store much of the mountain runoff for managed flood control and irrigation releases. The Teanaway River runs without impoundments, but irrigation withdrawals are located in its lower valley.

A network of supply canals, diversions, and irrigation return drains are located all along the upper Yakima basin, but especially in the Kittitas Valley near Ellensburg. Water from the Yakima River and from mountain streams flowing through the valley is directed through the irrigation network. The Yakima River enters a narrow canyon at rm 147 and opens to the Wenas Valley at rm 123, and then to the lower Yakima Valley at Selah Gap at rm 116. In the lower part of the canyon during irrigation season, the Roza Dam can divert over half of the Yakima River to the Roza Canal to serve approximately 72,500 acres in the lower Yakima basin, and to operate the Roza Power Plant.

A related study area focused on tributaries in the Wilson-Cherry Creek sub-basin, referred to in this study as the Kittitas Valley (Figure 3). Wilson-Cherry is the largest sub-basin (394 mi^2) in the study area. The sub-basin has the greatest diversity of land use and the highest population density in the upper Yakima. One or more irrigation canals or diversions from the Yakima River intersect Naneum, Schnebly, Coleman, Cooke, Caribou, Parke, and Badger creeks that flow out of the surrounding hills to the north and east. From the 1870s to the 1990s, water from these creeks and irrigation supply water from the Yakima River were freely mixed and redistributed. Since the 1990s, less intermixing is present.

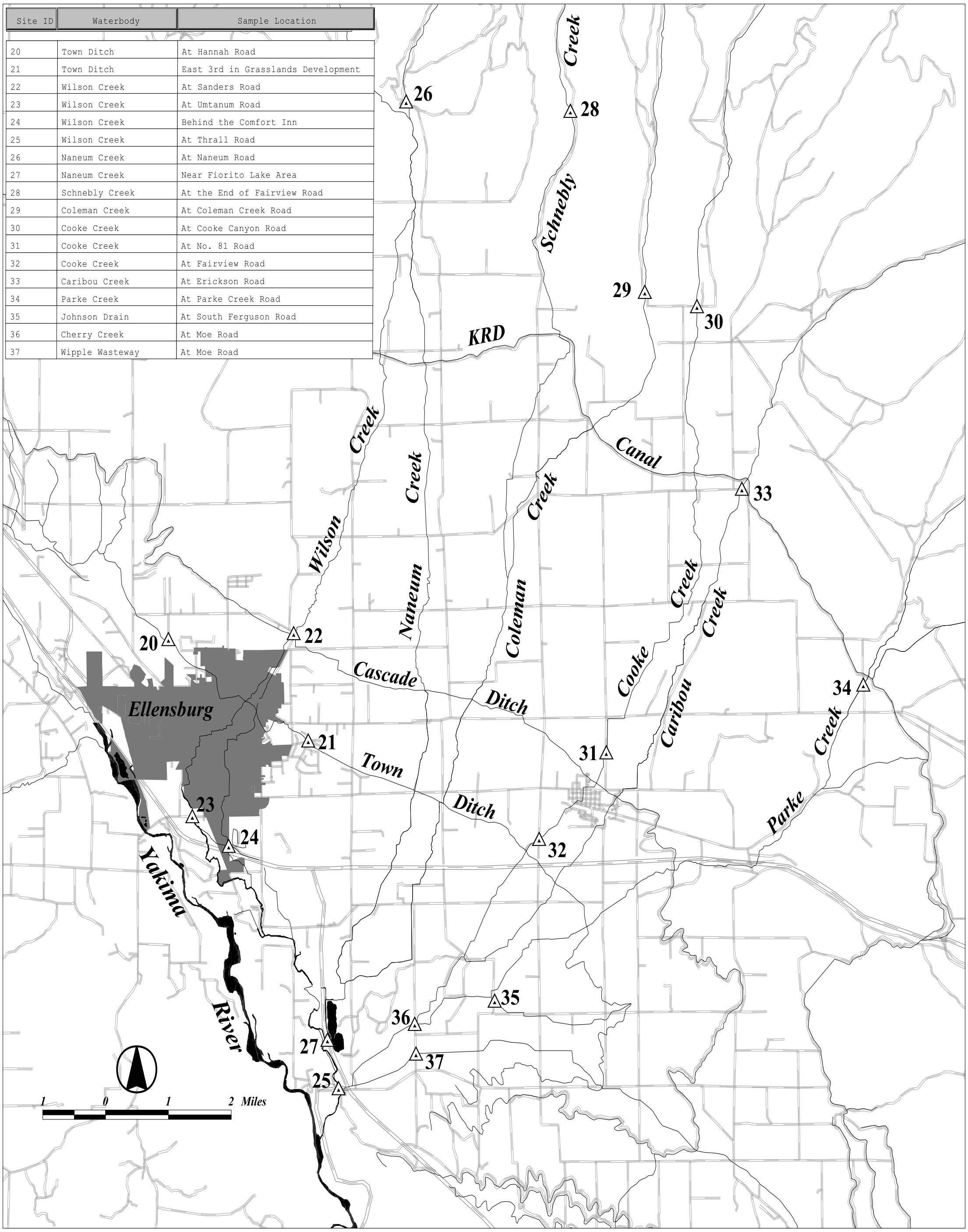
Land Use

Political, climatological, and geological features influence the pattern of land use in the 2139 mi^2 of the upper Yakima basin. The upper Yakima are ceded lands of the Confederated Tribes and Bands of the Yakama Indian Nation and are part of their usual and accustomed rights area. Most of the upper Yakima River basin is located in Kittitas County with only the Wenas sub-basin and



Site ID	Waterbody	Sample Location
01	Yakima River	Above Cle Elum from I-90
02	Yakima River	At the Thorpe Bridge
03	Yakima River	At KOA near Ellensburg
04	Yakima River	Irene Rinehart Park on Umtanum Road
05	Yakima River	Umtanum Walkway at Umtanum Creek
06	Yakima River	Harrison Road Bridge
07	Cle Elum River	Bullfrog Road Bridge
08	Crystal Creek	Crystal Creek at Mouth
09	Teanaway River	At the Highway 10 Bridge
10	Swauk Creek	Upstream from Highway 10
11	Taneum Creek	At the KRD Gage
12	Packwood Ditch	Below the Spillway
13	Manastash Creek	Just below Brown Road Bridge
14	Dry Creek	At Highway 10
15	Reecer Creek	In Irene Rinehart City Park
16	Sorenson Creek	At River Bottom Road/Fogarty Ditch
17	Wilson Creek	At Canyon Road
18	Umtanum Creek	Just Upstream at Umtanum Walkway
19	Wenas Creek	At Buffalo Road

Figure 2. Upper Yakima TMDL Sampling Locations for the Mainstem Yakima River and Major Tributaries.



Site ID	Waterbody	Sample Location
20	Town Ditch	At Hannah Road
21	Town Ditch	East 3rd in Grasslands Development
22	Wilson Creek	At Sanders Road
23	Wilson Creek	At Umtanum Road
24	Wilson Creek	Behind the Comfort Inn
25	Wilson Creek	At Thrall Road
26	Naneum Creek	At Naneum Road
27	Naneum Creek	Near Fiorito Lake Area
28	Schnebly Creek	At the End of Fairview Road
29	Coleman Creek	At Coleman Creek Road
30	Cooke Creek	At Cooke Canyon Road
31	Cooke Creek	At No. 81 Road
32	Cooke Creek	At Fairview Road
33	Caribou Creek	At Erickson Road
34	Parke Creek	At Parke Creek Road
35	Johnson Drain	At South Ferguson Road
36	Cherry Creek	At Moe Road
37	Wipple Wasteway	At Moe Road

Figure 3. Upper Yakima TMDL Sampling Locations in Kittitas Valley.

areas below rm 125 of the Yakima River located in Yakima County. Approximately 58% of the basin is under federal or state ownership. The U.S. Military controls access to 231 mi^2 of the southeastern portion of the basin. Most of the mountainous areas and headwater streams are located within the Wenatchee National Forest. Several irrigation districts serve the agricultural areas.

The higher elevations in the basin that receive the greatest rainfall are largely forested, giving way to rangeland and agricultural lands in the lower hillslopes and valley floors (Figure 4). Over half of the basin is classified as forested (54%) based on statistics from the geographical information system coverage from USGS (GIRAS). Rangeland occupies 31% of the basin, surrounding the largest blocks of agricultural lands in the Kittitas and Wenas valleys that occupy about 12% of the area. The urban/residential centers of Easton, Roslyn, Cle Elum, Ellensburg, Kittitas, and Selah are scattered along the valley floor and represent 2% of the land area. Water, wetlands, snowfields, glaciers, rocky outcrops, and transportation corridors take up less than 2% of the basin.

The 1153 mi^2 of forests in the basin are both publicly and privately owned. The Wenatchee National Forest administered by the US Forest Service controls about 52% of the forested lands. The rest is split between the Washington Department of Natural Resources (10%) and private companies (38%). Their forests are intermixed in the national forest or tend to be at lower elevations closer to the mainstem.

Range areas provide forage for beef cattle and sheep grown in the Yakima basin. In Washington State, Kittitas County ranked fifth in beef and sixth in sheep and lamb production in 2000 (Washington Agricultural Statistics Service, 2001). Rangeland is also a large part of the L.T. Murray Wildlife Area and the Yakima Firing Range.

With the assistance of irrigation, agricultural areas of the upper Yakima basin are primarily devoted to forage crop production. Kittitas County ranked third in the state in all hay production in 1999, and first in hay other than alfalfa, e.g., timothy hay (Washington Agricultural Statistics Service, 2001). Kittitas County also reports significant production of sweet corn, potatoes, spring wheat, oats, apples, and pears. Orchard crops are dominant agricultural commodities of the Wenas Valley and the area around Selah. Most Kittitas growers use rill irrigation, but more are beginning to use sprinklers and other alternatives. Just a few growers in the basin practice dryland farming.

The agricultural areas in the upper Yakima basin are served by several irrigation districts including the Kittitas Reclamation District, Cascade Irrigation District, Ellensburg Town Canal, West Side Irrigation Company, and portions of the Naches-Selah Irrigation District. In 1986, these districts provided water to over 85,830 acres with an annual diversion allotment of over 420,000 acre-feet (Perala, 1992). Several smaller irrigation companies and districts also serve areas in the basin.

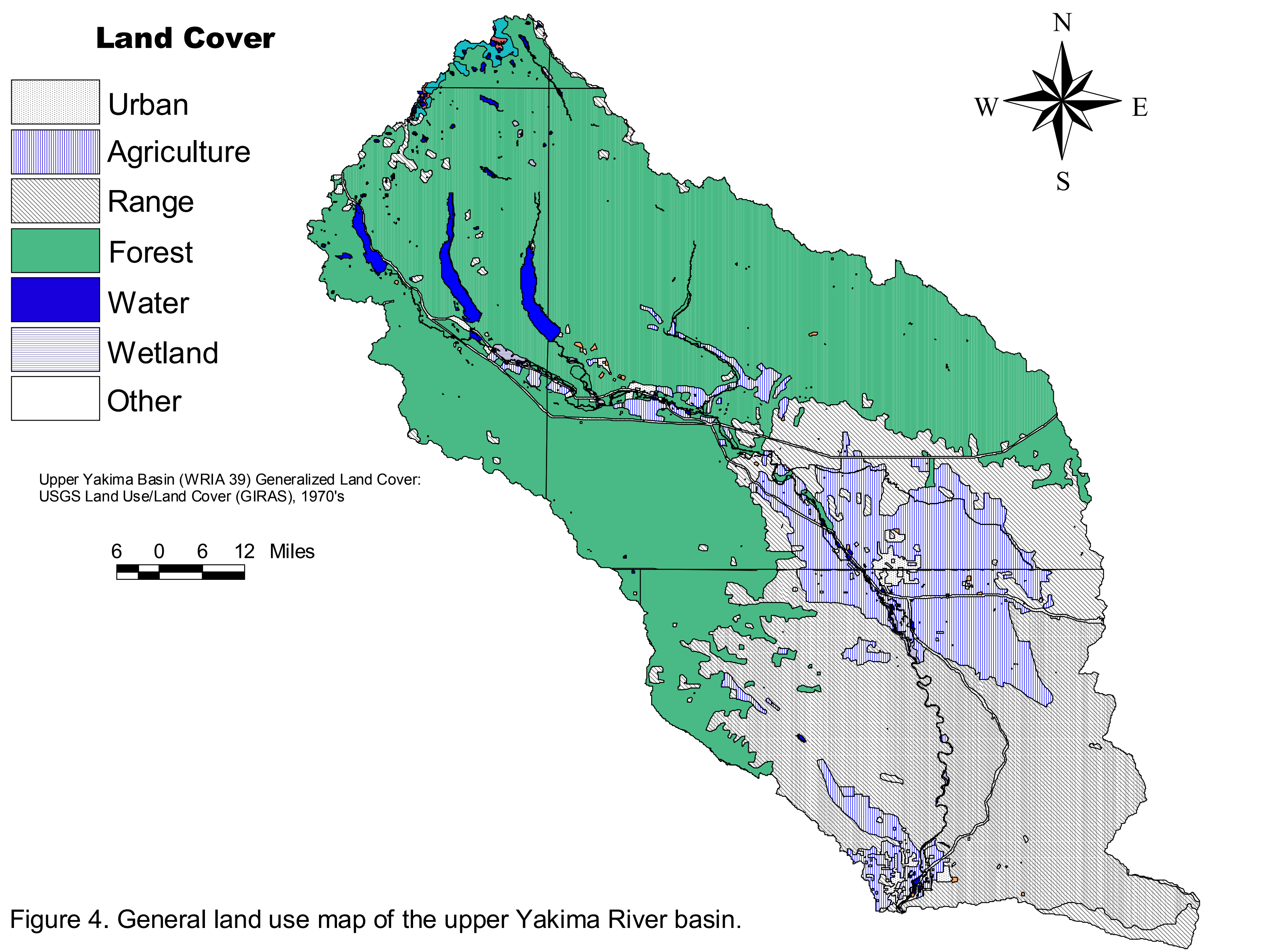


Figure 4. General land use map of the upper Yakima River basin.

Pollutant Sources

The quantity and distribution of historical DDT and other organochlorine pesticide uses in the upper Yakima River basin have not been well documented. Potentially, growers could have used them in orchards and on row crops. Cattlemen could have used them to reduce pests around the herds, and foresters could have used them to control tussock moth and other pests. Railroads and warehouses were commonly fumigated with DDT to eliminate a wide range of pests. Finally, local mosquito control districts commonly used DDT in fields, streets, and on waterways.

The USEPA banned all but emergency uses of DDT in 1972. For example, one permitted emergency use was the July 1974 Pacific Northwest tussock moth outbreak. The use of dieldrin was restricted in 1970, and U.S. production was restricted in 1974. All uses of products containing dieldrin were banned in 1983.

Yakima basin organochlorine pesticides are considered a legacy pollutant problem. It is unlikely that significant quantities of DDT and organochlorine pesticides have entered the basin since 1972. On the other hand, these pesticides have proven to be very persistent and pervasive. Recent monitoring studies in the upper Yakima basin by Ecology, US Geological Survey, and local agencies have detected DDT compounds and dieldrin in farm soils, water, bed sediments, and fish tissue. The data from these studies are discussed in more detail in the *Water Quality Evaluation* section below.

Data collected in the Yakima basin and other areas has documented that the organochlorine pesticides are highly associated with soil particles. The primary mechanism for the transport of these pesticides and other contaminants from the lands in the Yakima basin to the aquatic environment is soil erosion. Soil erosion can be driven by water or by wind, and both have a potential to widely disperse organochlorine pesticides along with the soil particles. Excessive turbidity and suspended sediment loading from soil and channel erosion have been documented in the basin from all land use types, but especially agricultural and forest lands. Much of the documentation points to historical practices. Recreational activities, mining, gravel operations, livestock grazing, and urban stormwater also have been mentioned as potential loading sources. Ecology has not documented total suspended solids problems at municipal wastewater treatment plants in the basin. The details of the historical suspended sediment, turbidity, and organochlorine pesticides data are summarized in the *Water Quality Evaluation* section below.

Study Objectives

The objectives for the upper Yakima TMDL evaluation were agreed to and described in a quality assurance (QA) project plan written in 1999 (Dickes and Joy, 1999). This evaluation report covers the following objectives listed in the project plan:

1. Characterize the upper Yakima River basin for TSS and turbidity, primarily during the irrigation season, and set TMDL targets.

- Evaluate the suspended sediment load in the upper Yakima River during the irrigation season.
- Evaluate contributions from major tributaries.
- Set suspended sediment TMDL targets for the upper river basin during the irrigation season.
- Evaluate the effect of the upper basin TMDL targets on the lower basin suspended sediment TMDL.

2. Evaluate water column concentrations for pesticides in the Cherry Creek basin.
    - Evaluate the 303(d) listing for DDT, DDE, and dieldrin.
    - Evaluate the relationship between suspended sediment and pesticides, particularly total DDT (DDT+DDE+DDD) and dieldrin.
    - Screen for the presence of previously identified pesticides.

Pesticide data from fish tissue samples collected in the upper Yakima mainstem by Rogowski (2000) are also used to evaluate the current human health risk from DDT and dieldrin.

The QA project plan also included two other monitoring objectives. Some data collected from Wilson/Cherry sub-basin tributaries of the Kittitas Valley by Ecology, the Kittitas Conservation District (Lael, 2000), and Kittitas Reclamation District (Satnik, 2000) will be used in this report. However, separate evaluation reports discussing those data with the following objectives will be written later:

3. Evaluate suspended sediment in the Kittitas Valley and develop TMDL targets for the major drainages and land uses.
    - Evaluate the major sources of suspended sediment loading from the Kittitas Valley entering the Yakima River via Wilson Creek.
    - Coordinate with on-going data collection in the basin by the Kittitas Conservation District and the Kittitas Reclamation District.
    - Estimate suspended sediment transport from various land use types during the irrigation season.
    - Estimate suspended sediment transport from various land use types outside of the irrigation season through historic data analysis or, if resources allow, through continued field investigation.
    - Develop a suspended sediment TMDL for the major drainages and associated land uses in the Kittitas Valley.

4. Evaluate fecal coliform bacteria in the Kittitas Valley.
    - Evaluate fecal coliform 303(d) listings for Wilson Creek and Cooke Creek based on dominant land use.
    - Provide baseline fecal coliform data for other drainages in the Valley.

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Methods

Field and Laboratory Analyses

There were 19 sites for the upper Yakima River mainstem study area: six on the mainstem and 13 on tributaries (Figure 2, Table 5). The mainstem and major tributary sites were used to compare and characterize suspended sediment and turbidity loading through the upper Yakima River basin during the irrigation season. The terminal site at rm 121.7 of the mainstem is the uppermost site of the lower Yakima River TMDL area (Joy and Patterson, 1997). Background sites in the headwater areas of individual tributaries or above the two large reservoirs upstream of rm 191, Keechelus and Kachess, were not established in this phase of the TMDL. Data from sites at the mouth of tributaries were used to calculate seasonal loads to the mainstem and to compare to various criteria. Mainstem sites were used to check loading calculations and evaluate longitudinal changes in water quality.

Data from samples collected for the Wilson and Cherry creeks assessment were also used for this mainstem TMDL evaluation. The Kittitas Valley sampling area had 18 sites (Figure 3, Table 5). Wilson and Cherry Creek basin sites were located to assess the contribution of generalized land use types (forest, range, agriculture, residential) to TSS, turbidity, chloride, and fecal coliform loading. Sites were distributed in cooperation with existing Kittitas Reclamation District and Kittitas County Conservation District monitoring networks. In addition, water column pesticide samples were taken from Wipple Wasteway and Cherry Creek to verify the existing 303(d) listing in Cherry Creek for total DDT, DDE, and dieldrin as well as to document presence/ absence of DDD and other organochlorine pesticides (Table 1).

The sampling dates were selected to characterize the irrigation season as well as to coincide with the sampling being performed by the Kittitas County Conservation District (Olsen, 1999) and the Kittitas Reclamation District (Satnik, 2000). Water quality field surveys occurred over a three-day period. The upper mainstem Yakima River and its tributaries were sampled on the first day, the Kittitas Valley sites were sampled on the second day, and flows at the Kittitas Valley sites were measured on the third day. Sampling occurred every other week from April through mid-November 1999 for a total of 17 events.

Water quality data from municipal wastewater treatment plants at Cle Elum and Ellensburg were also included in the TMDL assessment. Discharge monitoring report data were reviewed for total suspended solids (TSS) and effluent discharge volumes.

Field measurements and samples for laboratory analyses were collected at each site. Air temperature, water temperature, and conductivity were measured, and stream discharge or gage height was recorded. TSS and turbidity samples were collected at all sites. Samples were depth integrated using a DH 76 sampler, except in very shallow streams or drains where hand dipping was necessary. For rivers, streams, and canals wider than two meters, a composite sample was taken. Sub-samples from multiple points on a cross-section were agitated and added to a single container for laboratory submittal. Standard Ecology protocols were used for sample collection, preservation, and shipping to the Manchester Environmental Laboratory (MEL, 1994).

Table 5. Sampling locations for the upper Yakima basin suspended sediment TMDL, April through November 1999.

Station name	Station location	Field ID	USBR Gaging Station	Ecology Gaging Station	Staff gage	Instan-taneous flow **	Field	TSS & Turbidity	DDT Metabolites & Dieldrin		FC
UPPER YAKIMA TMDL											
Yakima River above Cle Elum	from I-90 bridge	01-YKI					X	X			
Yakima River at Thorp bridge	bridge north of Thorp	02-YKTH					X	X			
Yakima River at KOA	bridge near Ellensburg KOA	03-YKKO	X				X	X			
Yakima River at Irene Rinehart Park	bridge just below Irene Rinehart Park	04-YKIR					X	X			
Yakima River at Umtanum Walkway	below mouth of Umtanum Creek	05-YKUM	X				X	X			
Yakima River at Harrison Road bridge	at Harrison Road bridge	06-YKHA					X	X			
Cle Elum River	Bullfrog Rd bridge	07-CLE	X				X	X			
Crystal Creek at mouth	just upstream of road bridge	08-CRY		X	X	X	X	X			
Teanaway River at Hwy 10	at Hwy 10 bridge	09-TEA	X				X	X			
Swauk Creek above Hwy 10	upstream near old gaging station	10-SWA		X	X	X	X	X			
Taneum Creek at KRD gage	below bridge	11-TAN	X				X	X			
Packwood Ditch at Thorpe Hwy	culvert at mouth below spillway	12-PAC		X	X	X	X	X			
Manastash Creek at Brown Rd	just downstream of bridge	13-MAN		X	X	X	X	X			
Dry creek at Hwy 10	at Hwy 10 bridge	14-DRY			X	X	X	X			
Reecer Creek in Irene Rinehart Park	below road bridge in park	15-REE				X	X	X			
Sorenson Creek below River Bottom Rd	below confluence with Fogerty Ditch	16-FOG		X	X	X	X	X			
Wilson Creek at Canyon Rd	at Canyon Road bridge	17-WIL					X	X			
Umtanum Creek at walkway	upstream of the RR bridge	18-UMT			X	X	X	X			
Wenas Creek via Buffalo Rd	near the old concrete dam	19-WEN		X	X	X	X	X			
KITTITAS VALLEY TMDL											
Town Ditch at Hannah Rd	at end of Hannah Rd	20-TWHN				X	X	X			X
Town Ditch at East 3rd	bridge in Grasslands development	21-TWE3				X	X	X			X
Wilson Creek at Sanders Rd	at Sanders Rd bridge	22-WLSN				X	X	X			X
Wilson Creek at Umtanum Rd	at Umtanum Rd bridge	23-WLUM				X	X	X			X
Wilson Creek behind the Comfort Inn	just off the freeway exit	24-WLCM				X	X	X			X
Wilson Creek at Thrall Rd	at Thrall Rd bridge	25-WLTH	X				X	X			X
Naneum Creek upper basin	Naneum Rd bridge	26-NN				X	X	X			X
Naneum Creek near Fiorito Ponds area	at the end of the access road	27-NNFR		X	X	X	X	X			X
Schnebly upper basin	above gate at end of Fairview Rd	28-SCH				X	X	X			X
Coleman Creek upper basin	first bridge on Coleman Canyon Rd	29-CL				X	X	X			X
Cooke Creek upper basin	first bridge at Cooke Creeke Rd "T"	30-CK				X	X	X			X
Cooke Creek at No 81 Rd	at N0 81 Rd bridge	31-CK81				X	X	X			X
Cooke Creek at Fairview Rd	at Fairview Rd bridge	32-CKFA				X	X	X			X
Caribou Creek upper basin	at Erickson Rd bridge	33-CR				X	X	X			X
Parke Creek upper basin	Parke Creek Rd at culvert	34-PR				X	X	X			X
Johnson Drain at So Ferguson Rd	at culvert on So Ferguson Rd	35-JNFR				X	X	X			X
Cherry Creek at Moe Rd	at Moe Rd bridge	36-CHMO				X	X	X	X		X
Wipple Wasteway at Moe Rd	at Moe Rd bridge	37-WPMO				X	X	X	X		X

** flows taken periodically to develop rating curve

Low-level organochlorine pesticides and other pesticide samples were collected in the Cherry Creek basin from Cherry Creek and Wipple Wasteway at Moe Road. Samples were depth and width integrated using pre-cleaned DH-81 Teflon-nozzle samplers, and pre-cleaned and certified glass containers. Additionally, total organic carbon and dissolved organic carbon (DOC) were sampled at these two sites.

Low levels of detection of DDT compounds and dieldrin were achieved using gas chromatograph electron capture detection techniques (modifications of USEPA SW-846 methods 3510, 8081, 3620, and 3665). All samples and blanks were spiked with surrogates prior to extraction to evaluate recoveries. A matrix spike and matrix spike duplicate were analyzed each run to measure accuracy and precision of the method. Each run included a duplicate field sample from one site as well.

Chlorophenoxy herbicides, organophosphorous pesticides, and nitrogen containing pesticides were analyzed using draft USEPA method 8085 with gas chromatography and atomic emission detection. Confirmation of herbicides was performed using gas chromatography and ion-trap mass spectrometry. Surrogate spikes were used, but matrix spikes were not.

Besides the instantaneous discharge measurements at some sites, Ecology, USBR, Kittitas Reclamation District, and several irrigation districts conducted continuous discharge monitoring. Ecology sites near the mouths of Crystal Creek, Swauk Creek, Reecer Creek, Naneum Creek, Packwood Ditch, Sorenson Ditch, and Umtanum Creek were monitored using standard protocols currently established by Ecology's Stream Hydrology Unit (Evans and Larson, 2000). Continuous discharge data also were obtained through the Internet for several USBR stations on the Yakima River mainstem.

Fish tissue pesticides analyses were also performed in this study area to investigate 303(d) listings (Rogowski, 2000). Rogowski collected fish from the mainstem above the Cle Elum River and at Wymer above Lmuma Creek. Fillets were analyzed for 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, and dieldrin.

Monitoring was accomplished with help and resources provided by the Kittitas Reclamation District and the Kittitas County Conservation District. Data collection was coordinated with these two districts, and data were freely exchanged. Side-by-side sampling was also performed to judge interagency quality assurance.

Quality Assurance and Quality Control

Collecting replicate samples at 10% of the sites assessed total variation for field sampling and analytical variability. Replicate sites were rotated throughout the season. Additionally, laboratory blanks, matrix spike, and matrix spike duplicate samples were collected for pesticide analyses. The conductivity meter was pre-and post-calibrated in the field using a 100 umhos/cm calibration standard. The lab followed standard operating quality control procedures described in MEL (1994). For example, laboratory duplicates and blanks were analyzed on 10% of the samples.

Replicate samples collected by Ecology are evaluated in Table 6. The average relative percent difference goals set in the QA project plan were met.

Table 6. Root mean square error (RMSE) of the coefficient of variation (c.v.) and average total relative percent difference (RPD) of field replicate samples collected by Ecology.

Parameter	No. of pairs*	RMSE of c.v. (%)	Average RPD (%)	RPD Goal (%)
Chloride	20	2.0	2.2	20
Total suspended solids	72	24.3	8.4	20
Turbidity	71	17.3	16.5	20
Total organic carbon	8	11.3	12.8	20
Total dissolved carbon	8	8.4	10	20
DDT	3 (8)	27.2	22.2	50
DDE	5 (8)	3.2	0.5	50
DDD	1 (8)	2.5	6	50
Dieldrin	6 (8)	15.1	15.8	50

* Eight pesticide duplicate samples were collected; calculations include only pairs with detections.

Pesticide blanks, surrogates, matrix spikes, and matrix spike duplicates were evaluated with each set of samples. No target analytes were detected in any of the procedural blanks. A few data were qualified when surrogate or matrix spike recoveries were out of laboratory control limits. Target analytes detected below the practical quantitation limit were qualified as estimates.

Water Quality Evaluation

Historical Data Analysis

Suspended Sediment and Turbidity

At the time this TMDL was initiated, a detailed evaluation of the total suspended sediment loading and turbidity had not been conducted, but loading estimates had been made to generally describe their seasonal and spatial characteristics in the upper Yakima River basin. Several agencies had collected water samples as parts of broader water quality programs, and other researchers had collected samples for short-term assessments. The historical data record was incomplete both spatially and temporally. The largest long-term data sets have been collected at a few sites in the upper basin from March through September. Data interpretations vary as to what the more significant source of suspended sediment loading during this period is: rain event and snowmelt or irrigation run-off. Fewer pesticide analyses of water and fish tissue have been collected in the upper Yakima basin than in the lower basin, so less is known about the relationship between pesticides and suspended sediment, and the trends in fish tissue pesticide burdens, in the upper basin.

USGS analysis of data from 1974 to 1981 (Rinella, McKenzie, and Fuhrer, 1992) suggested that Yakima River median annual suspended sediment concentrations and 75th percentile values did not show a significant difference among upper Yakima River sites until Harrison Bridge (rm 121), but that seasonal differences were apparent between Cle Elum, Ellensburg, and Umtanum reaches. Samples collected from higher elevation sites like upper Swauk Creek and Log Creek were noted to have occasionally high turbidity or total suspended solids (TSS) concentrations, but few samples were available to determine the significance of sediment contributions to runoff events. The USGS researchers had additional findings from reviewing upper Yakima TSS data:

- Median seasonal Yakima River suspended sediment concentrations from 1974 – 1981 were highest during spring snowmelt and high flows (April through June).
- The median suspended sediment concentrations at upper Yakima River sites for 1974 – 1981 were from 4 mg/L at Cle Elum to 10 mg/L at Harrison Bridge. The 90th percentile concentrations were from 16 mg/L at Cle Elum to 52 mg/L at Umtanum; maximums were from 52 mg/L at Cle Elum to 261 mg/L at Harrison Bridge.
- The few tributaries and irrigation return drains with significant numbers of samples had median suspended sediment concentrations from 12 to 30 mg/L, and 90th percentile concentrations from 38 to 82 mg/L.
- The greatest increase in median suspended sediment concentrations between mainstem sites at Ellensburg and Umtanum was observed during the irrigation season (July through September).

- The annual suspended sediment load analysis for high (1974), median (1980), and low (1977) flow years indicated fairly constant loads between Cle Elum and Ellensburg. However, a doubling of the load between Ellensburg and Umtanum, especially during the high flow year, was attributed to Wilson Creek and other irrigation returns.
- Significant decreasing trends in turbidity or suspended sediment from 1974 – 1981 were observed for the Yakima River at Cle Elum and Wipple Wasteway at Thrall.

Another USGS analysis of water year 1988-89 data (Bramblett and Fuhrer, 1999) indicated that 64% of the average annual suspended sediment load at Cle Elum, and 66% of the average annual load at Umtanum, passed during what they defined as the irrigation season (June through September). Another 24% of the annual average load at Umtanum occurred in the snowmelt months of April and May. So by difference, only 10% of the load was transported from October through March. The authors noted that seasonal changes in 1988-89 turbidity and suspended sediment data were small at the Yakima River at Cle Elum because of few upstream erodible sediment sources and sediment settling in reservoirs. They also concluded that the highest loading during the irrigation season was a result of high reservoir streamflows, coupled with agricultural activities of the Kittitas Valley near Ellensburg.

The Kittitas County Conservation District (Bain, 1998) assessment gave a similar annual suspended sediment load for Umtanum as Bramblett and Fuhrer (1999), but inferred a slightly different seasonal pattern. In Bain's calculation, the Teanaway River winter storm and spring snowmelt sediment loads accounted for 40% of the annual load at the Umtanum mainstem site. Bain asserted that since the Teanaway load is mainly delivered during "rainfall and snowmelt events", the majority of the load is not delivered to the mainstem at Umtanum from June through September.

The low numbers of samples, different monitoring strategies, and different calculation methods can explain some of the dissimilarities between Bramblett and Fuhrer (1999), and Bain (1998) sediment loading conclusions. This can be further illustrated in a third loading calculation conducted by Ecology on the 1988 and 1989 USGS data. The Beale's ratio estimator method (Dolan, Yui, and Geist, 1981) uses the ratio of the load to the flow on sampled days adjusted by the mean flow of the time period to estimate the mean load of the time period of interest. It works better than regression or simple loading equations when data are stratified by season or flow interval (Dolan, Yui, and Geist, 1981). The USGS uses the regression-based ESTIMATOR program that assumes a linear relationship between the natural logs of the flow and the natural log of the suspended sediment concentration, and is adjusted by the sine and cosine of an annual cycle (Morace et al., 1999). The two loading analysis results are presented in Table 7.

The annual loading results of the USGS and Ecology methods were within 15% of each other, but the seasonal loads calculated by Ecology were more like what Bain (1998) proposed. The Ecology and Bain calculations suggest a significant portion of the suspended sediment loading to the Yakima River at Umtanum occurs during the early part of the irrigation season, April and May, a period of snowmelt and runoff from higher elevations in the basin. The USGS called this the pre-irrigation season, even though irrigation canals and systems are in operation. The Teanaway River would be a significant source of this early suspended sediment loading to the mainstem based on the data presented by Bain (1998), and Rinella, McKenzie, and Fuhrer

(1992). The USGS method emphasized late irrigation season loading and de-emphasized early snowmelt season loading, perhaps because of poor correlations between discharge and suspended sediment in the early season. The few data used in the analysis also contribute to the variability in the results and conclusions.

Table 7. Comparison of seasonal and annual suspended sediment loads (tons) as calculated by USGS and by Ecology for the Yakima River at Umtanum.

			USGS ESTIMATOR Method		Ecology Beale's Ratio Method	
Water Year	Season*	n	Load	% of total	Load	% of total
1988	Non-irrigation	6	2,730	6.1	3,240	8.4
	Pre-irrigation	3	7,808	17.5	17,507	45.6
	Irrigation	6	34,160	76.4	17,641	46.0
	Annual		44,698		38,388	
1989	Non-irrigation	7	6,006	9.0	15,051	19.1
	Pre-irrigation	3	21,655	32.5	44,408	56.5
	Irrigation	5	39,040	58.5	19,154	24.4
	Annual		66,701		78,701	

USGS-defined seasons:

Non-irrigation – October through March
Pre-irrigation – April and May
Irrigation – June through September

Number of suspended sediment samples for each season denoted in "n" column.

Historical data characterizing background suspended sediment loading or turbidities are not readily available above the reservoirs or in forested areas of the upper sub-basins. Suspended sediment measurements collected by the USGS from the Cle Elum River above the reservoir were in the range of 0.5 to 3 mg/L (Morace et al., 1999). Cabin Creek and Big Creek TSS data collected in the late 1980s were less than 10 mg/L, usually 1 to 5 mg/L, except during a spring freshet event on Cabin Creek when one TSS concentration reached 91 mg/L (STORET, 2000). Bain (1998) also observed one high TSS value from Big Creek (40 mg/L) in spring, when the other three values collected were < 1 mg/L. Other sites below forested areas in the upper reaches of the Kittitas Valley creeks were monitored in 1992-93 by the Kittitas County Conservation District and reported by Bain (1998). Annual median TSS concentrations for sites in the upper reaches of Manastash, Naneum, and Caribou creeks were 6 mg/L, 7 mg/L, and 22 mg/L, respectively; maximum concentrations were 77 mg/L, 18 mg/L, and 59 mg/L, respectively.

Organochlorine Pesticides

Fish tissue and water column samples have been collected by Ecology for pesticide analyses in only a few areas of the upper Yakima basin since the 1980s. Johnson, Norton, and Yake (1986) collected fish and water samples in the upper Yakima:

- 4,4'-DDE was detected in edible fillets from fish collected near Cle Elum, Wymer, and Roza Dam. Concentrations ranged from less than 20 ug/Kg to 390 ug/Kg (parts per billion); six samples exceeded the 31.6 ug/Kg criterion for fish consumption to protect human health.

- Dieldrin was detected in one fish fillet at 20 ug/Kg at Roza Dam; it exceeded the 0.65 ug/Kg criterion to protect human health.
- Dieldrin was detected in Wilson Creek water on one of five occasions. The single detection had an estimated concentration of 0.006 ug/L, and an associated TSS concentration of 27 mg/L.
- DDT compounds were not detected in water above a detection limit from 0.005 to 0.01 ug/L (parts per billion) at either site.

Four water samples collected from Cherry Creek in 1995 (April, June, July, and September) were analyzed for pesticides including DDT compounds and dieldrin (Davis, Johnson, and Serdar, 1998). DDT compounds and dieldrin were not found in any of the samples at a quantitation limit of 0.05 ug/L. TSS concentrations were 129 mg/L in April, 52 mg/L in June, 77 mg/L in July, and 27 mg/L in October. Other pesticides detected were the following: chlorpyrifos, 2,4 – D, atrazine, bromacil, bromoxynil, dacthal, dicamba, 2-methyl-4-chlorophenoxyacetic acid (MCPA), and 2-(2-methyl-4-chlorophenoxy) propionic acid (MCPP).

USGS detected dieldrin and DDT compounds in whole water samples from several areas of the upper basin during sampling runs in 1988 and 1989 (Rinella et al., 1992):

- Dieldrin and DDT compounds were detected in Cherry Creek at Thrall on six of six occasions, with a range of 0.001 to 0.041 ug/L dieldrin, and 0.001 to 0.039 ug/L total DDT.
- Dieldrin was detected once at Wilson Creek and once at the Yakima River at Umtanum.
- DDT compounds and dieldrin were not detected in routine whole water samples from the Cle Elum River above or below Cle Elum Lake, or from the Yakima River at Cle Elum.
- Large volume water samples showed parts per trillion or nanogram/liter (ng/L) levels of DDT compounds or dieldrin in both the filtered water and associated sediment from the Cooper River, Yakima River at Cle Elum, Umtanum Creek, Wilson Creek above Cherry Creek, and Cherry Creek.

Bed sediments also were analyzed by USGS at several locations (Rinella et al., 1992):

- DDT compounds and dieldrin were not detected in the Cle Elum River above Cle Elum Lake, Jungle Creek, and the Teanaway River below the Forks.
- The North Fork of the Teanaway River, Taneum Creek, Naneum Creek, Umtanum Creek, and the South Fork of Manastash Creek contained detectable concentrations of DDT compounds (0.4 to 0.8 ug/Kg total DDT). Dieldrin was not detected in these same sediments.
- Cherry Creek at Thrall had elevated concentrations of DDT compounds (54.3 and 69 ug/Kg total DDT) and dieldrin (35 and 39 ug/Kg).
- Yakima River at Umtanum had 5 ug/Kg total DDT and 1 ug/Kg dieldrin.

Dieldrin and DDT compounds also were detected in fish tissue collected by USGS in 1989 and 1990 (Rinella et al., 1992). A total of 19 fish samples were collected from various parts of the upper Yakima basin; all samples were whole composites of five to ten fish. Several different native species were analyzed: rainbow trout, mountain whitefish, sculpin, largescale sucker, and bridgelip sucker. DDT and dieldrin results are summarized in Table 8. DDT compounds were detected in most of the fish samples collected except in sculpins.

Table 8. Total DDT and dieldrin results from 1989–1990 USGS fish tissue sampling in the upper Yakima River basin (extracted from Table 28 in Rinella et al., 1992).

Species/Location	Avg. wt. (g)	% Lipids	Total DDT (ug/Kg)	Dieldrin (ug/Kg)
Rainbow Trout				
Waptus R. near Roslyn	12	3.48	10	<10
Jungle Cr. near Cle Elum	8	1.8	10	<10
Teanaway R. below Forks	33	2.22	10	<10
Umtanum Cr.	67	1.68	30	<10
Yakima R. at Umtanum	21	4.1	50	10
Mountain Whitefish				
Yakima R. at Cle Elum	259	6.64	110	10
Yakima R. at Cle Elum	284	5.84	160	10
Yakima R. at Umtanum	236	5.92	210	20
Sculpin				
Yakima R. at Cle Elum	5	2.08	<10	<10
Jungle Cr. near Cle Elum	5	1.76	<10	<10
N. Fork Teanaway R.	8	1.49	<10	<10
Taneum Cr. near Thorp	14	1.4	<10	<10
S. Fork Manastash Cr.	9	1.95	<10	<10
Naneum Cr. below High Cr.	12	1.54	<10	<10
Umtanum Cr.	3	1.19	10	<10
Largescale Sucker				
Cherry Cr. at Thrall	94	5.94	50	20
Yakima R. at Umtanum	1357	6.64	310	10
Bridgelip Sucker				
Cherry Cr. above Wipple Wasteway	51	7.93	150	30
Yakima R. at Umtanum	553	7.03	350	10

Total DDT = DDT+DDE+DDD

The ability of fish or other aquatic organisms to bioconcentrate or bioaccumulate total DDT and dieldrin depends on several factors including: the concentrations of the pesticides in water, sediment, and food; age of the organism; lipid content of the organism; and the organism's position in the food chain. In the USGS study, the upper Yakima fish with the highest lipid contents had detectable levels of both DDT compounds and dieldrin. This was consistent with findings throughout the Yakima Valley and in other parts of the world. When results are normalized for the percent lipid content, upper Yakima valley fish had an order of magnitude lower total DDT and five times less dieldrin than fish collected by USGS from the Yakima River at Kiona.

Samples with larger, older fish also had higher concentrations than samples with smaller, younger fish. For example, the average weights of the two sucker composite samples collected from the Yakima River at Umtanum were far greater than the weights of the samples collected from Cherry Creek. Since bioaccumulation can be a function of the duration of exposure, the larger suckers from Umtanum had higher total DDT tissue burdens than the smaller Cherry Creek suckers. Dieldrin has less of a tendency to bioaccumulate, so that could partially explain why dieldrin was lower in Umtanum suckers than Cherry Creek suckers.

1999 Monitoring Results

Discharge, Suspended Sediment, and Turbidity

Discharge

The monitoring period for this TMDL was March through November 1999. The river was managed by USBR under the normal 'flip-flop' conditions, i.e., water released from storage to the lower Yakima basin during the irrigation season in April through August primarily came from the upper Yakima, and in September and October the supply of water to the lower basin was switched (flip-flopped) to Naches basin storage. The following peak flow events occurred at Umtanum in the water year (since October 1998) prior to the April through October 1999 irrigation season: 7657 cfs on December 30; 4621 cfs on January 15; and 4112 cfs on March 26 (Figure 5).

The average monthly discharges in the Yakima River at Umtanum in the 1999 irrigation season appeared to be higher than average earlier in the irrigation season, and lower than average after June, compared to records since 1980 when 'flip-flop' operational management began (Figure 6). May and June average monthly flows were at or above the 75th percentile discharge reported (but not the highest on record) despite lower than normal average precipitation. Releases from the reservoirs and snowmelt from the Teanaway River basin were the primary sources of water in the mainstem Yakima from April through June (Figure 5). The cooler temperatures may have influenced the higher than average discharges in June.

Monthly average temperatures in 1999 at Ellensburg (1980 – 1999) were below the 25th percentile for the months of April through July (Figure 7). Only August and November had higher than normal average monthly temperatures. Monthly average rainfall in 1999 at Ellensburg was also lower than average (1980 – 1999) from March through July, and September through November (Figure 7). Local growers commented that the lower temperatures and lack of rain in the spring of 1999 prevented rapid melting of the snowpack and caused a decreased number of peak flooding events in local creeks. This, Ecology was told, deposited less sediment on their fields and in their canals than would normally be carried from the upper watersheds.

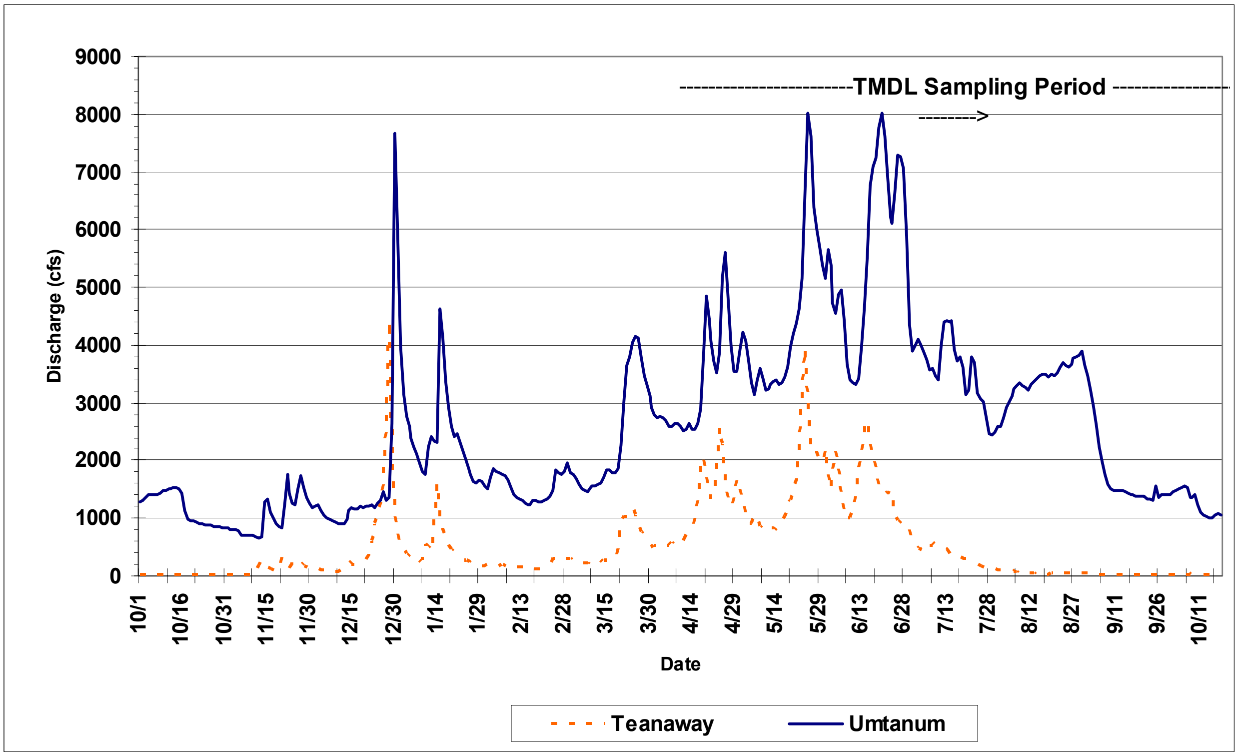


Figure 5. Average daily discharge for the upper Yakima River at Umtanum and the Teanaway River in water year 1999.

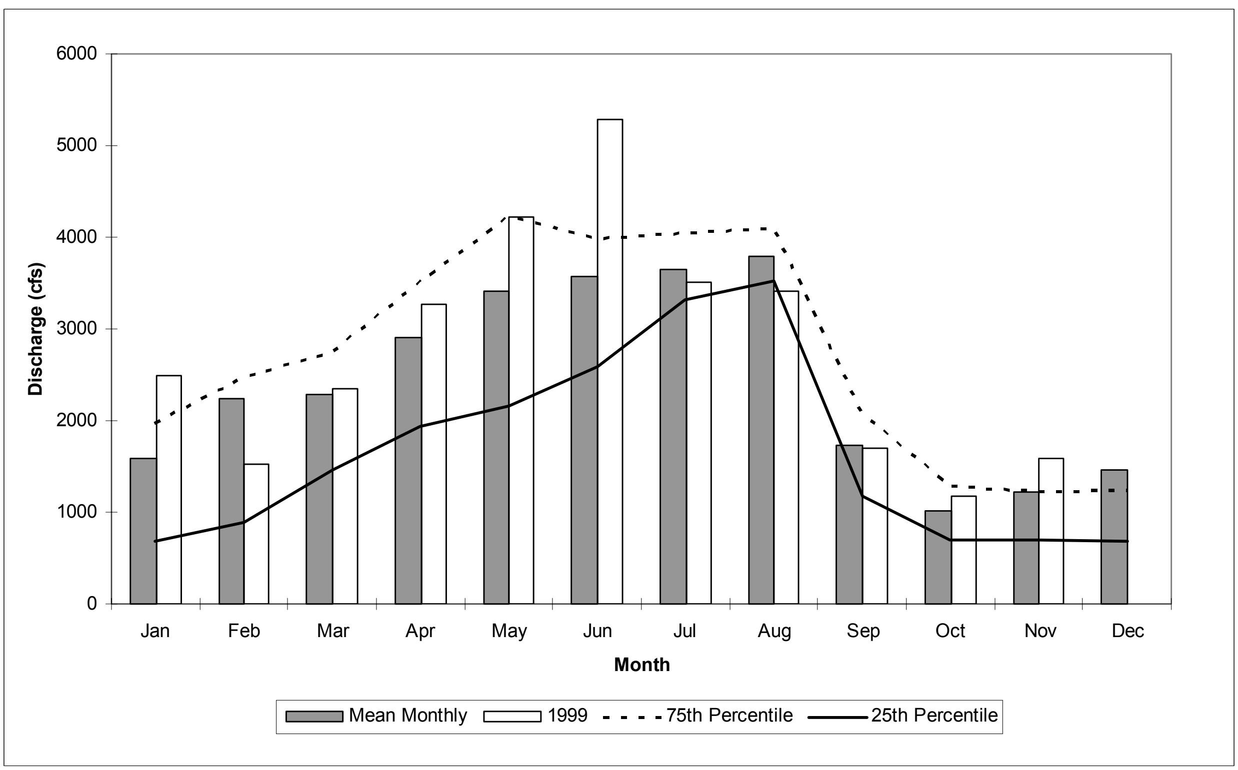
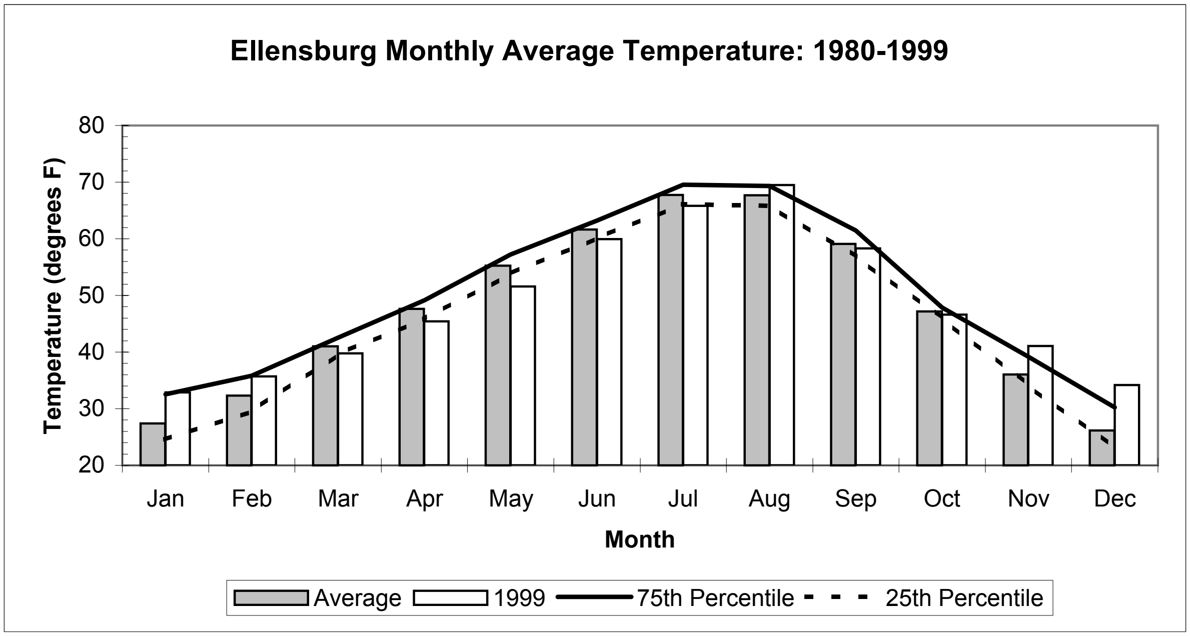


Figure 6. Discharge statistics for the Yakima River at Umtanum (1980-1999) compared to 1999 survey period.



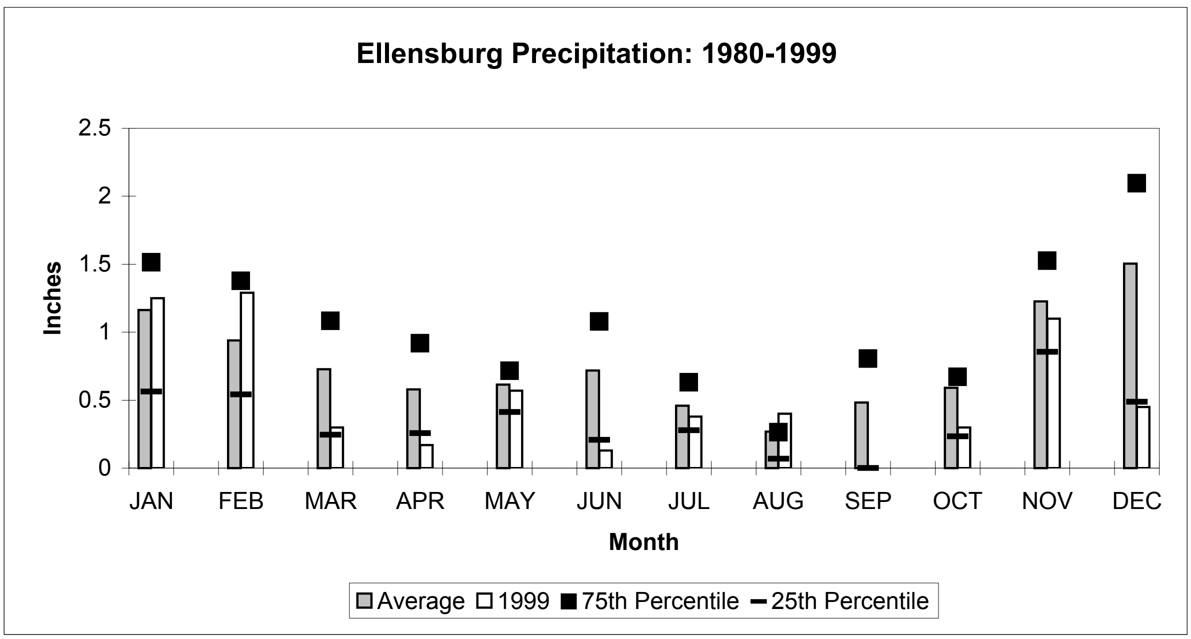


Figure 7. Climatological data comparing historical record to 1999 TMDL survey conditions at Ellensburg.

Suspended Sediment and Turbidity

The 1999 sediment rating curves for the Teanaway River, Wilson Creek, and Yakima River at Umtanum are compared to available historical data in Figure 8. The Teanaway River sediment curve appears to have undergone a shift that may indicate some reduction in sediment loading since the early 1980s. More data from the Teanaway River would be necessary to justify a more confident statement of improvement. Wilson Creek rates from the past ten years were similar to 1999. The 1999 suspended sediment loads for the Yakima River at Umtanum were better correlated to discharge volumes than the historical data (Figure 8).

In 1999 the concentrations of suspended sediment and the turbidity values in the upper Yakima River generally increased downstream from Nelson to Harrison Bridge. The median, range, and 90^{th} percentile statistics for the total suspended solids (TSS) and turbidity samples collected at each of the mainstem sites are shown in Table 9. Mainstem TSS concentrations followed turbidities closely, and the two were significantly correlated (Figure 9). The distinct pattern of the early and late irrigation season that was examined in the historical data (see *Historical Data Analysis*) was also present in 1999 (Figure 10). However, the colder spring weather in 1999 may have extended the influence of snowmelt-related concentrations later into June than usual.

Table 9. Summary of TSS and turbidity results from the 1999 TMDL survey along the upper Yakima River.

Site Description: Mainstem Yakima River and Major Tributaries	Total Suspended Solids (mg/L)				Turbidity (NTU)			
	Median	Min	Max	90th	Median	Min	Max	90th
Yakima R. near Nelson at I-90	3	<1	15	13	1.6	0.6	11	7.5
Yakima R. at Thorp Road bridge	6	<1	49	33	2.2	<0.5	26	17.0
Yakima R. above Ellensburg near KOA	5	2	52	31	2.6	0.8	26	17.7
Yakima R. near Irene Rinehart Park	8	2	49	29	2.7	0.9	24	18.7
Yakima R. at Umtanum Walkway	14	3	43	35	4.5	1.4	23	20.4
Yakima R. at Harrison Road	11	2	46	41	4.7	1.2	24	20.2
Cle Elum R. at Bullfrog Road	1	<1	3	3	0.9	<0.5	1.3	1.2
Crystal Cr. near mouth	3	<1	10	5	1.8	0.6	7.5	3.7
Teanaway R. at Hwy 10	2	<1	78	49	1.1	<0.5	33	26.0
Swauk Cr. at Hwy 10	2	<1	71 J	16	2.0	<0.5	40	9.5
Taneum Cr. at Kittitas Recl. District gage	5	<1	43	33	2.9	0.5	21	15.9
Packwood Ditch at mouth	8	1	49	13	8.9	5.2	20	13.0
Manastash Cr. at Brown Road	9	1	49	32	6.7	1.2	22	19.2
Dry Cr. at Hwy 10	2	<1	19	4	1.4	0.6	10	2.5
Reecer Cr. in Irene Rinehart Park	5	2	32	9	4.0	1.3	14	7.7
Fogarty Ditch/Sorenson Cr. below confluence	14.5	6	139	38	9.8	5.1	70	21.8
Wilson Cr. at Canyon Road	37	10	132	54	15.5	4.9	43	24.8
Umtanum Cr. above the railroad bridge	2	<1	6	5	1.2	0.7	17	3.4
Wenas Cr. at Buffalo Road access	7	3	98	39	3.5	2	24	13.4
Naneum, Coleman, Cooke, and Schnebly sites*	4	<1	55	16	2.6	<0.5	25	7.5

* See text (*TMDL Monitoring Results - Suspended Sediment and Turbidity*) for explanation of tributary background estimate
nd = no data collected
J = estimate
90th = 90th percentile during irrigation season
Median = median during irrigation season
Min, Max = minimum and maximum over monitoring period

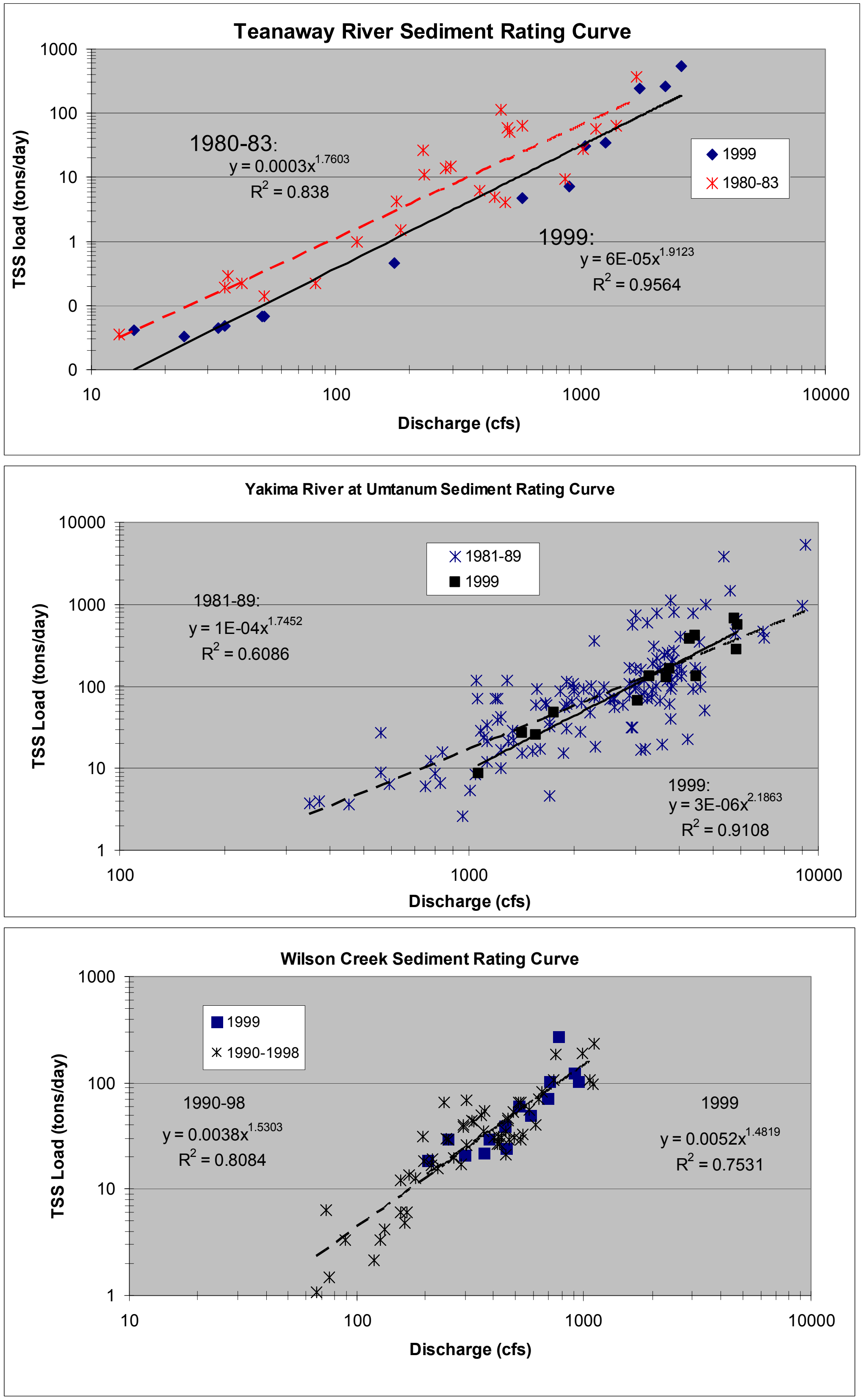


Figure 8. Sediment rating curves for three sites in the upper Yakima River basin, comparing historical data to 1999 TMDL survey data.

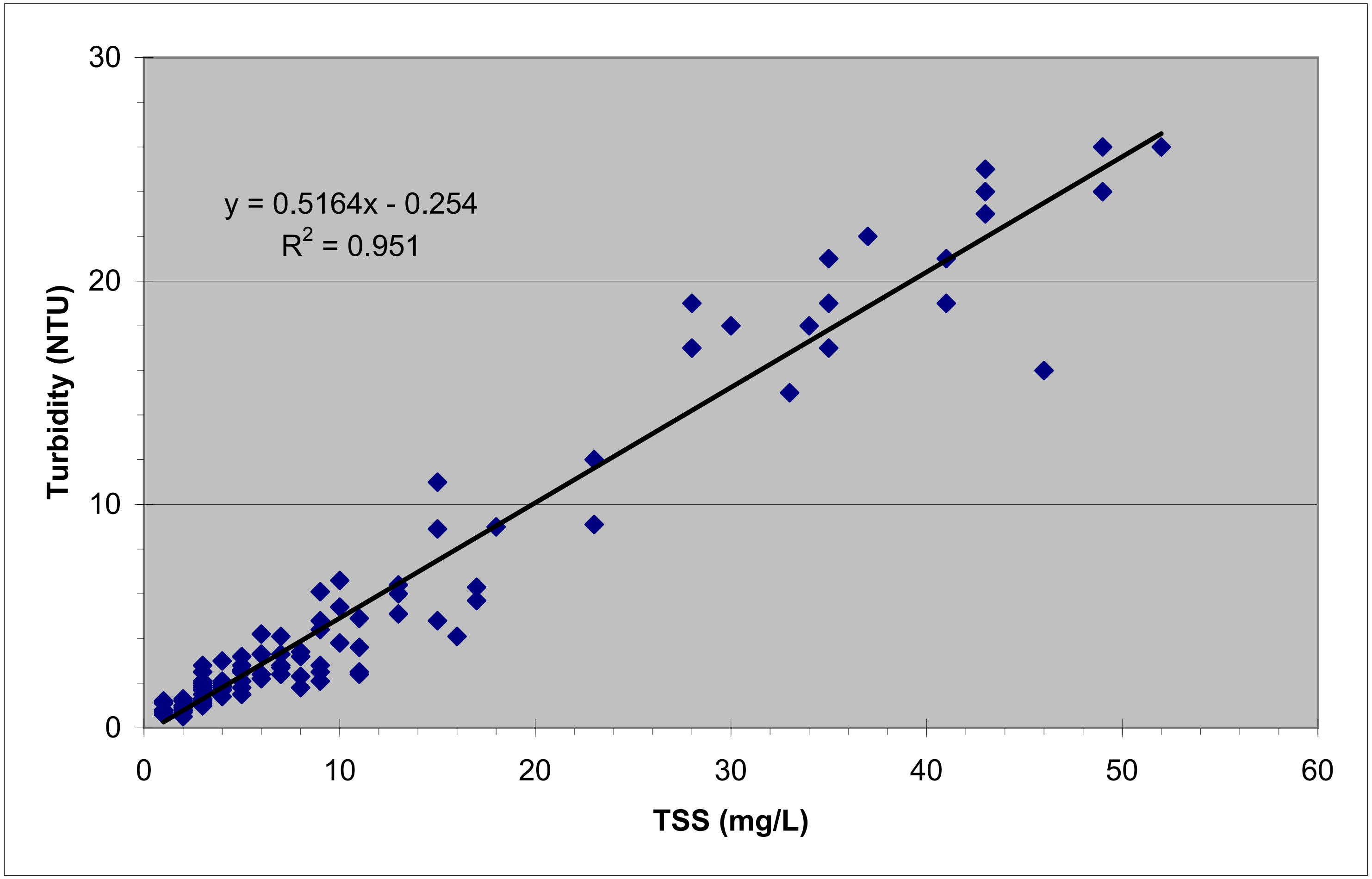


Figure 9. Relationship between TSS and turbidity in samples collected from six sites on the upper Yakima River mainstem from April to October of 1999 as part of the Ecology TMDL study.

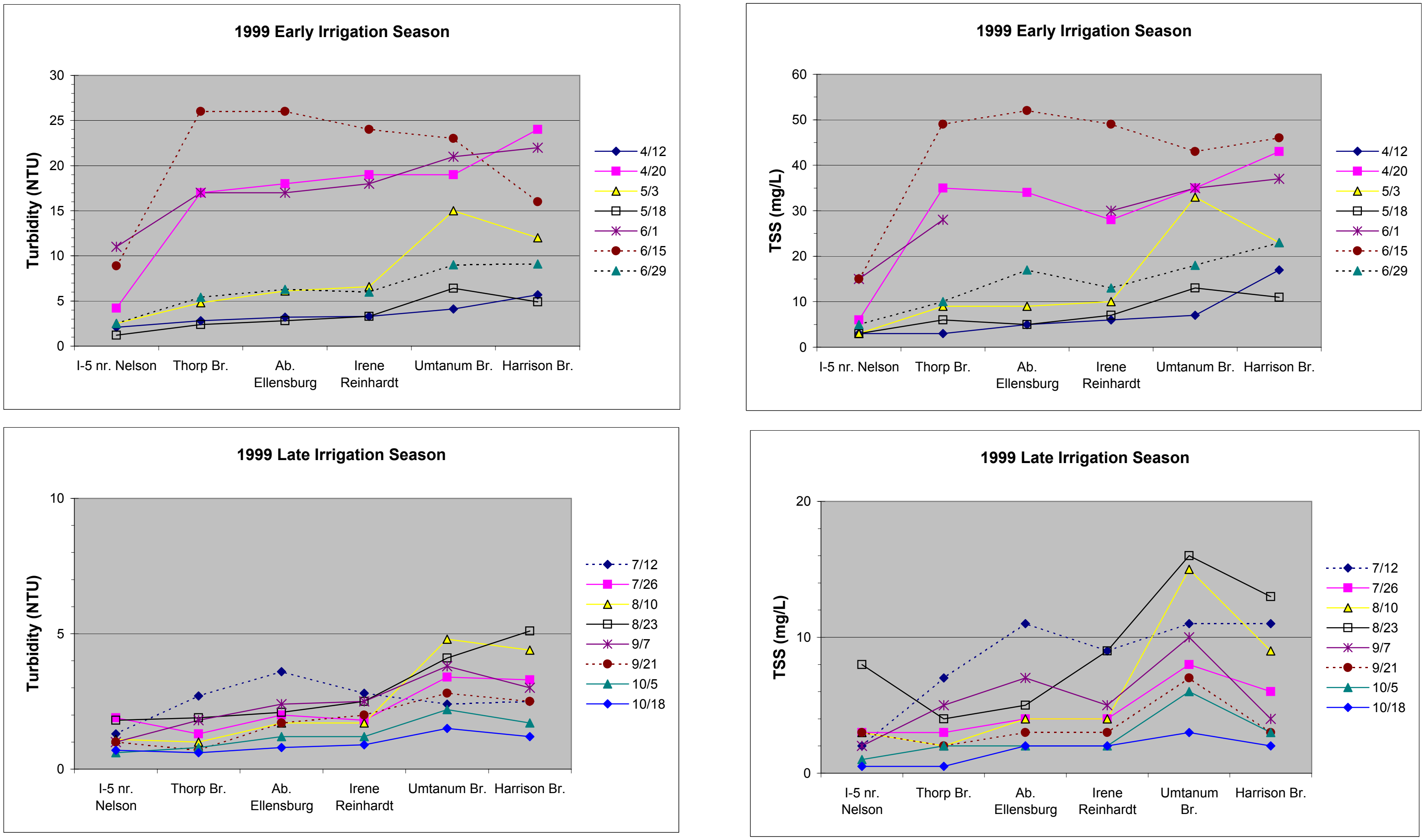


Figure 10. Comparisons of turbidity and TSS values for individual survey runs at six sites on the mainstem upper Yakima River. Early (April - June) and late (July - October) irrigation season data are contrasted.

The highest TSS and turbidity measurements were observed from late-April to mid-June at various sites from Thorp Road Bridge downstream to Harrison Bridge (Figure 9). Some of these data appear to be strongly influenced by snowmelt and runoff from the Teanaway River basin as recorded at Thorp Road Bridge. The largest increase in the turbidity and TSS 90^{th} percentile statistics occurred between Nelson and the Thorp Road Bridge, below the influence of the Cle Elum River, Teanaway River, and Swauk Creek.

Although TSS and turbidity continued to increase in the downstream direction, mainstem turbidities throughout the study area dropped below 5 NTU from July through October. This later period is influenced by reservoir releases and irrigation operations. The greatest increase of median TSS and turbidity statistics from the entire irrigation season occurred between the Irene Rinehart Park site and the Umtanum Bridge crossing, the reach where Wilson Creek and Sorenson Creek discharge (Table 9).

The Yakima River near Nelson was chosen to represent the background condition of the mainstem. The background is used in evaluating water quality relative to the turbidity criterion of not more than 5 NTU over background conditions as it was used in the lower Yakima River TMDL (Joy and Patterson, 1997). Lake Easton and the Kachess and Keechelus reservoirs upstream influence the initial suspended sediment of the site. The reservoirs act as settling basins for upper watershed sediment loads, and reduce sediment transported to the river below the reservoirs. Big Creek and Little Creek watersheds are located between these reservoirs and Nelson, and may influence suspended sediment loads and turbidity at the Nelson site. TSS concentrations and turbidities from these watersheds may be more visible since the Yakima River near Nelson is located above the Cle Elum River, the outlet to another significant reservoir. Monitoring data above the reservoirs may better characterize background conditions in the future.

As shown in Table 9, the median TSS concentration at Nelson during the 1999 survey was 3 mg/L, with a range of less than 1 to 15 mg/L. The turbidity samples had 0.6 to 11 NTU, and a median of 1.6 NTU. The higher concentrations and values occurred early in the irrigation season (April through June). Ecology data collected from the site for several years have indicated only five TSS measurements above 12 mg/L; all of these were collected outside the irrigation season (Ecology, 2000).

The 90^{th} percentile turbidities at all mainstem sites downstream of Nelson were more than 5 NTU over the 90^{th} percentile background condition. The Yakima sites at Irene Rinehart Park, Umtanum, and Harrison Bridge were more than 10 NTU over background (Table 9). All mainstem sites increased 7 to 17 NTU over the Nelson turbidity on April 20, June 1, and June 15 (Figure 9). The mainstem reach with the Cle Elum River, Teanaway River, and Swauk Creek inputs caused the greatest increases on each of these dates. During three additional surveys turbidities at Umtanum and Harrison Bridge sites below Ellensburg increased 5 NTU over the background at Nelson. None of the mainstem turbidities observed in surveys after June 29 increased to values of 5 NTU over the Nelson background value.

The tributaries monitored during the 1999 irrigation season had a wide range of suspended sediment concentrations and turbidities that influenced the mainstem (Table 9). The highest values of turbidity (70 NTU) and TSS (139 mg/L) were observed in Sorenson Creek below the confluence with Fogerty Ditch. The highest median values were calculated for Wilson Creek at Canyon Road, 15.5 NTU and 37 mg/L, respectively.

The only data available to judge background turbidity and TSS for the tributaries in 1999 were collected from streams in the upper reaches of the Wilson/Cherry sub-basin. Sites were established along the forest-range margin on upper reaches of Naneum, Coleman, Cooke, and Schnebly creeks (Figure 3 and Table 5). Until better background sites can be established for individual tributaries, the numerical distribution of sample results from these sites were assumed to be adequate for estimating the turbidity and suspended sediment increases in study area tributaries.

The individual median values for these sites were less than 2 NTU turbidity, and 2 to 3 mg/L TSS. Maximum turbidities of 11 to 25 NTU with TSS concentrations of 20 to 55 mg/L occurred early in the irrigation season. Statistics based on combining their data as a background condition are shown in Table 9. When the median and 90th percentile turbidities and TSS concentrations are compared to similar statistics derived from samples collected in the lower reaches of the tributaries, it is evident that there are large increases in many tributaries. Some of these increases may be of natural origin, but others are the result of preventable soil and channel erosion. The Teanaway River, Taneum Creek, Packwood Ditch, Manastash Creek, Sorenson Creek, Wilson Creek, and Wenas Creek were identified as having potential suspended sediment problems, because turbidities increased more than 5 or 10 NTU over the estimated background condition.

The average TSS concentration from Cle Elum Wastewater Treatment Plant (WWTP) effluent during the irrigation season was 52 mg/L. Ellensburg WWTP had an average TSS concentration of 3.6 mg/L. The averages of the WWTPs are quite different, because Cle Elum is a lagoon system and Ellensburg provides more conventional treatment. The relatively elevated TSS concentrations from lagoons are often related to algal blooms in the treatment cells, and discharges under 2 million gallons per day are allowed an average monthly concentration of 75 mg/L. The Cle Elum WWTP is on schedule to be converted to another type of process in the near future, and permit limits will be more stringent (e.g., a monthly average not to exceed 30 mg/L TSS).

Aquatic Effects

The median and 90th percentile TSS and turbidity values for each of the tributary and mainstem sites are compared to some aquatic health guidelines in Figure 11. The USEPA TSS aquatic resource impairment guidelines and the turbidity threshold values suggested by Harvey (1989) for Idaho's cold water fishery turbidity criteria are used. The same guidelines were used for comparisons to sites monitored in the lower Yakima basin in 1994 and 1995 (Joy and Patterson, 1997). The upper Yakima sites meet these criteria to a much greater degree than the lower Yakima basin sites did. Some potential water quality problems for fish and aquatic communities are indicated by these guidelines. Median turbidities greater than 10 NTU are considered a concern for territorial and feeding behavior (Berg, 1982; Bjornn and Reiser, 1991). Median TSS concentrations at the lower mainstem sites are at levels shown in Table 4 that could affect salmon growth rates or egg to fry survivability. Both sets of TSS and turbidity statistics for Wilson and Sorenson creeks, and the 90th percentile statistics for the Teanaway River, pose similar concerns for the health of the aquatic community.

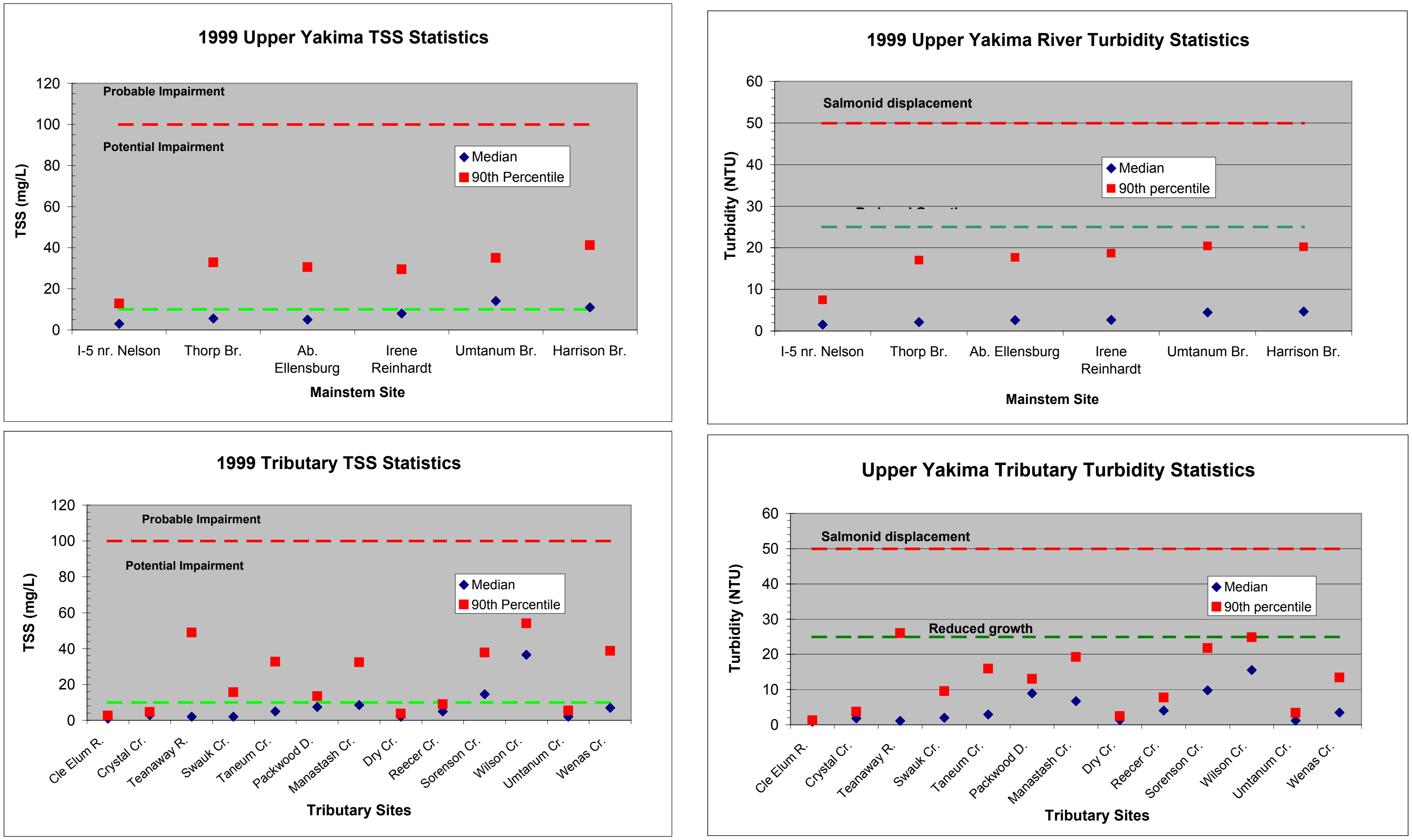


Figure 11. TSS and turbidity data collected from upper Yakima River TMDL sites compared to threshold effects on aquatic communities and organisms.

As mentioned earlier, work by Newcombe and MacDonald (1991) and Newcombe (1996) suggests some sub-lethal effects may occur to juvenile and adult salmonids at concentrations between 7 and 20 mg/L over prolonged periods of exposure. Since continuously monitored data was not collected; the duration of exposure was estimated by generating daily data from the observed data. One or more regression equations were developed relating observed TSS concentrations to recorded discharges at each site. The result was an estimate of daily suspended sediment concentrations over the course of the irrigation season at each site. Examples of the daily TSS estimates are shown for the Teanaway River, Yakima River at Irene Rinehart Park, Yakima River at Umtanum, and Wilson Creek sites (Figure 12).

The observed field data and regression-based estimates match well on the Teanaway and Yakima mainstem sites, but match only fair with Wilson Creek. Observed and estimated values were paired and the root mean square of the coefficient of variation (RMSE-cv) and Nash-Sutcliffe coefficient were calculated for each generated data set (see Appendix).

With reference to the concentrations in Table 4, the daily TSS estimates in 1999 indicate that the pulses of suspended sediment over 75 mg/L were probably of very short duration and not significantly harmful to salmonids. However, emergent fry and juvenile salmon in Wilson Creek could be subject to sub-lethal effects from exposure to 7 to 40 mg/L suspended sediment for more than 60 days (Figure 12). Similar conditions were estimated for most of the return drain and tributary sites, although only until late June or early July. Spawning area productivity could also be reduced in the Teanaway River or in the mainstem Yakima River downstream because of concentrations of 7 to 20 mg/L TSS over more than 30 days. The Yakima River at Umtanum could be affected for longer periods. The risk to salmonids appeared to be slight at sites above the Teanaway River.

Considering these potential impacts on the fish populations, the period of highest risk from suspended sediment and turbidity in the mainstem upper Yakima basin appears to be early in the irrigation season (April through June) when chinook fry are emerging and steelhead adults are spawning. Some effects on the aquatic communities may be present for longer in Wilson Creek and mainstem sites below Wilson Creek.

Water and Sediment Balances

Gaging data collected by several agencies were used to estimate a water balance for the upper Yakima River from Nelson to Harrison Bridge (Table 10). The observed discharge volumes at key mainstem sites closely matched the water balance gaged inputs and diversions for the irrigation season. Errors in the water balance were higher for the early period (April through June) than for the later period (July through October).

Loading from the tributaries and other sources affects the mainstem concentrations. Two methods of creating a suspended sediment loading balance were used: the Beales ratio estimator, (introduced in the *Historical Data Analysis* section) and a regression analysis using the best fit of suspended sediment loads as a function of discharge. Results from both methods were applied to a mass balance equation for the upper basin. The results for the two methods are shown in Table 10. The Beales estimator suspended sediment balance had less error between estimated

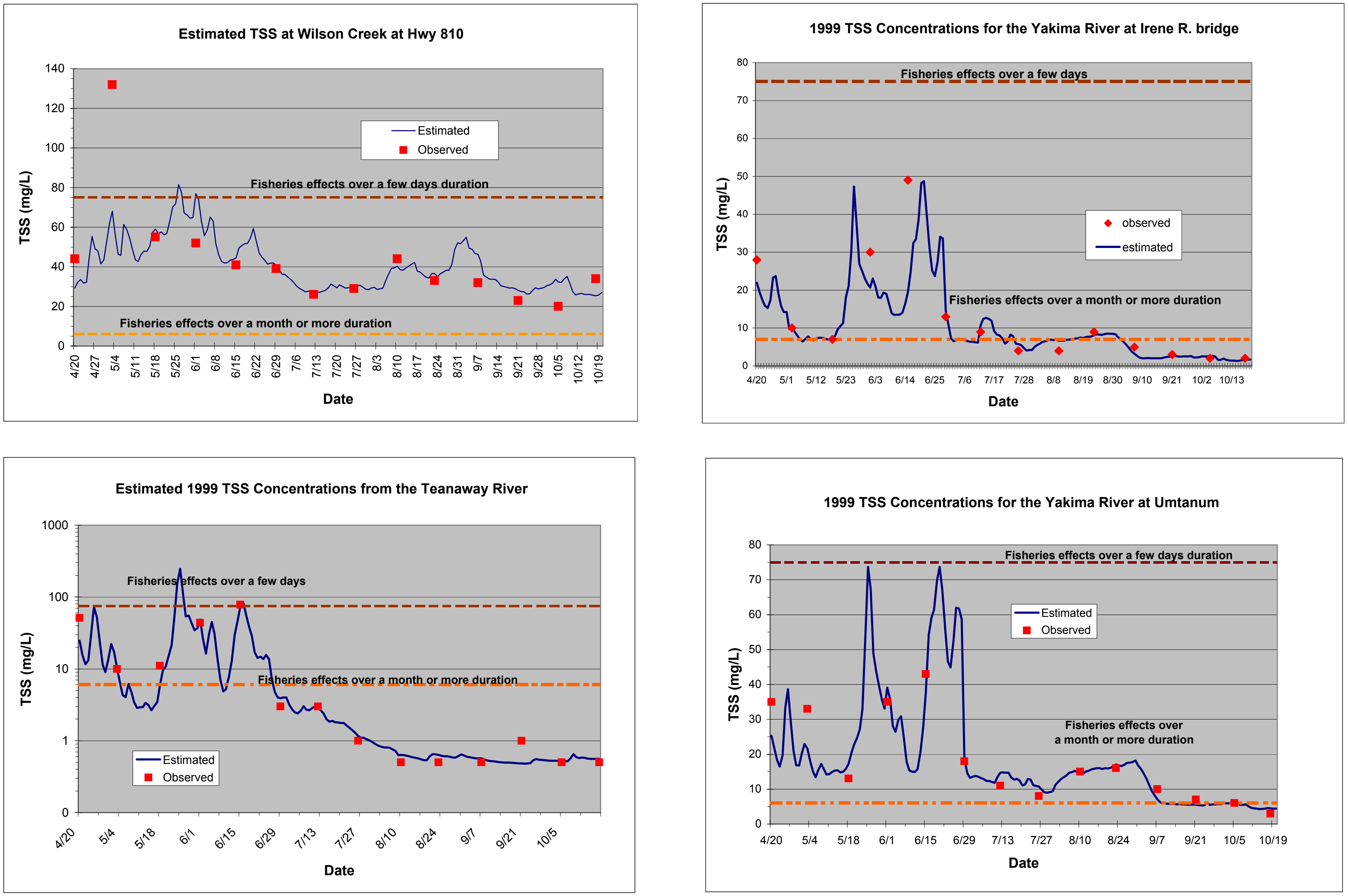


Figure 12. Estimated TSS concentrations from regression equations compared to field data collected at three sites in the upper Yakima River. Results are compared to fisheries effect threshold concentrations suggested by Newcombe (1996).

Table 10. 1999 water balance and TSS load balances for the upper Yakima River study area.

Relative percent difference is between calculated water volume or load at the mainstem site and sum of the upstream inputs and diversions.

1999 Water Balance

Site	Q 4/20-10/18 cfs season	Q 4/20-6/30 cfs early	Q 7/1-10/18 cfs late	Sum of Inputs and Diversion Relative % Difference		
Yakima at Nelson Rd	**752**	**1235**	**441**			
Cle Elum River	1453	1357	1522			
Crystal Creek	2.2	4.8	1.3			
Cle Elum WWTP	0.8					
Teanaway River	706	1573	144			
Swauk Creek	70.5	156	15			
Westside Canal	-85	-91	-82			
Taneum Creek	64	136	17			
Yakima River at Thorp	**2909**	**4013**	**2194**	2964	4371	2058
Town Canal	-111	-115	-108	-1.9%	-8.5%	6.4%
Cascade Canal	-84	-77	-89			
Dry Creek	20					
Packwood Ditch	50	51	50			
Yakima River at KOA	**3056**	**4448**	**2145**	2784	3872	2047
Manastash Creek	56	119	15	9.3%	13.8%	4.7%
Ellensburg WWTP	5.5					
Reecer Creek	30	29	31			
Yakima River at Irene R.	**3131**	**4522**	**2240**	3148	4596	2191
Fogerty/Sorenson	44	51	39	-0.5%	-1.6%	2.2%
Wilson/Cherry	537	788	380			
Yakima at Umtanum	**3500**	**4877**	**2636**	3712	5361	2659
Roza Canal	-1615	-1830	-1475	-5.9%	-9.5%	-0.9%
Wenas Creek	25	60	3.3			
Yakima at Harrison Bridge	**1900**	3100	1134	1910	3107	1164
				-0.5%	-0.2%	-2.6%

1999 TSS Load Balance Using Beales Estimator Values

Site	TSS 4/20-10/20 Tons/day season	TSS 4/20-6/29 Tons/day early	TSS 7/1-10/20 Tons/day late	Sum of Inputs and Diversion Relative % Difference		
Yakima at Nelson Rd	**14**	**28**	**3**			
Cle Elum River	5.8	7.5	4.8			
Crystal Creek	0.03	0.06	0.04			
Cle Elum WWTP	0.12					
Teanaway River	77	188	0.9			
Swauk Creek	6.4	15	0.07			
Westside Canal	-2.7	-5.9	-0.8			
Taneum Creek	4	10	0.2			
Yakima River at Thorp	**132**	**278**	**24**	105	243	8
Town Canal	-3.6	-7.1	-1.1	23%	14%	98%
Cascade Canal	-2.7	-5	-0.9			
Dry Creek	0.11					
Packwood Ditch	1.2	1	1.2			
Yakima River at KOA	**164**	**340**	**35**	127	267	23
Manastash Creek	4.4	10	0.4	25%	24%	41%
Ellensburg WWTP	0.05					
Reecer Creek	0.5	0.7	0.3			
Yakima River at Irene R.	**145**	**288**	**37**	169	351	36
Fogerty/Sorenson	3.2	6	1.1	-15%	-20%	4%
Wilson/Cherry	71	132	31			
Yakima at Umtanum	**215**	**399**	**79**	219	426	69
Roza Canal	-88	-160	-47	-1.9%	-6.5%	13.4%
Wenas Creek	3.9	10	0.05			
Yakima at Harrison Bridge	**131**	**271**	**27**	131	249	32
				0.1%	8.5%	-17.1%

1999 TSS Load Balance Using Average Regression Values

Site	TSS 4/20-10/20 Tons/day season	TSS 4/20-6/29 Tons/day early	TSS 7/1-10/20 Tons/day late	Sum of Inputs and Diversion Relative % Difference		
Yakima at Nelson Rd	**20**	**47**	**2.2**			
Cle Elum River	4.9	6.3	3.9			
Crystal Creek	0.021	0.048	0.003			
Cle Elum WWTP	0.12					
Teanaway River	69	173	0.8			
Swauk Creek	4.9	12	0.1			
Westside Canal	-2.8	-6.0	-0.7			
Taneum Creek	5.5	14	0.2			
Yakima River at Thorp	**157**	**370**	**21**	101	247	7
Town Canal	-3.8	-8.3	-0.9	43%	40%	103%
Cascade Canal	-2.5	-5.2	-0.7			
Dry Creek	0.1	0.1	0.1			
Packwood Ditch	1.2	1.2	1.2			
Yakima River at KOA	**209**	**478**	**34**	152	358	20
Manastash Creek	3.5	8.4	0.4	31%	29%	51%
Ellensburg WWTP	0.05					
Reecer Creek	0.5	0.7	0.3			
Yakima River at Irene R.	**134**	**281**	**40**	213	487	35
Fogerty/Sorenson	2.7	4.1	1.6	-46%	-54%	14%
Wilson/Cherry	68	117	37			
Yakima at Umtanum	**240**	**486**	**89**	205	402	78
Roza Canal	-90	-160	-48	15.9%	19.0%	12.8%
Wenas Creek	2.8	7.5	0.05			
Yakima at Harrison Bridge	**120**	**261**	**29**	153	334	41
				-24.0%	-24.4%	-34.4%

key mainstem sites and estimated input and diverted loads than the regression derived balance. The estimated loads for the Yakima River at Umtanum matched upstream inputs and diverted loads especially well using the Beales estimator. Data from the water and Beales sediment load balances are shown as sets of pie charts in Figure 13.

The upper Yakima River basin water balance and load analyses demonstrate some key points for this study:

- Teanaway River and Wilson Creek are important sources of water and suspended sediment loading to the river during the irrigation season. The Teanaway is the predominant suspended sediment source early in the irrigation season, and Wilson Creek becomes dominant in the latter part of the season.
- Cle Elum River, below the lake, is a large source of water but a low source of suspended sediment.
- The combined TSS load of the Cle Elum and Ellensburg WWTPs contribute less than 0.1% of the cumulative river load, although the Cle Elum WWTP reported relatively high TSS values.
- The basin above the control point at Nelson is a more significant source of water and sediment load early in the season than later.
- The maximum load of 215 tons/day carried by the river occurs at the Umtanum gage, upstream of the Roza Canal diversion and below the Kittitas Valley irrigation returns.
- Approximately 42% of the water and 39% of the suspended sediment load is diverted to the Roza Canal system in 1999. A substantial portion of the water and suspended sediment diverted to the Roza Canal is returned to the Yakima River just downstream of the confluence with the Naches through the Roza Power Return (Joy and Patterson, 1997)
- Harrison Bridge receives the remainder over the dam, and a minor input and suspended sediment load from Wenas Creek, for an estimated load of 131 tons/day.

The water balance appeared to account for most of the water running through the upper Yakima basin, but the Beales suspended sediment balance had unaccounted loads entering the mainstem between some mainstem sites (Figure 13). These estimated loads, represented as some of the relative percent deviation in Table 10, are substantial – possibly 16% of the seasonal load. The unidentified source of sediment could be a combination of factors: 1) sampling error, 2) load estimation error, 3) channel erosion, 4) resuspension of sediment deposited during winter and early spring events, 5) in-channel activities such as gravel operations, wing-dam construction, and channel modification, 6) algal or other biotic growth, and 7) unmonitored irrigation returns.

Errors based on monitoring and calculating methods are possible at several steps. Sampling error is a possible source, because only three depth-integrated samples were collected over the width of the river (200-300’). Although mainstem TSS sample replicates matched fairly well (RMSE = 16.4%), it is possible that a significant part of the river channel carrying sediment was missed at one or more sites. Also, the Ecology TSS laboratory method has a known low bias at high concentrations compared to the USGS suspended sediment method, because larger particles are not easily obtained in the aliquot measured (the USGS method measures the entire sample).

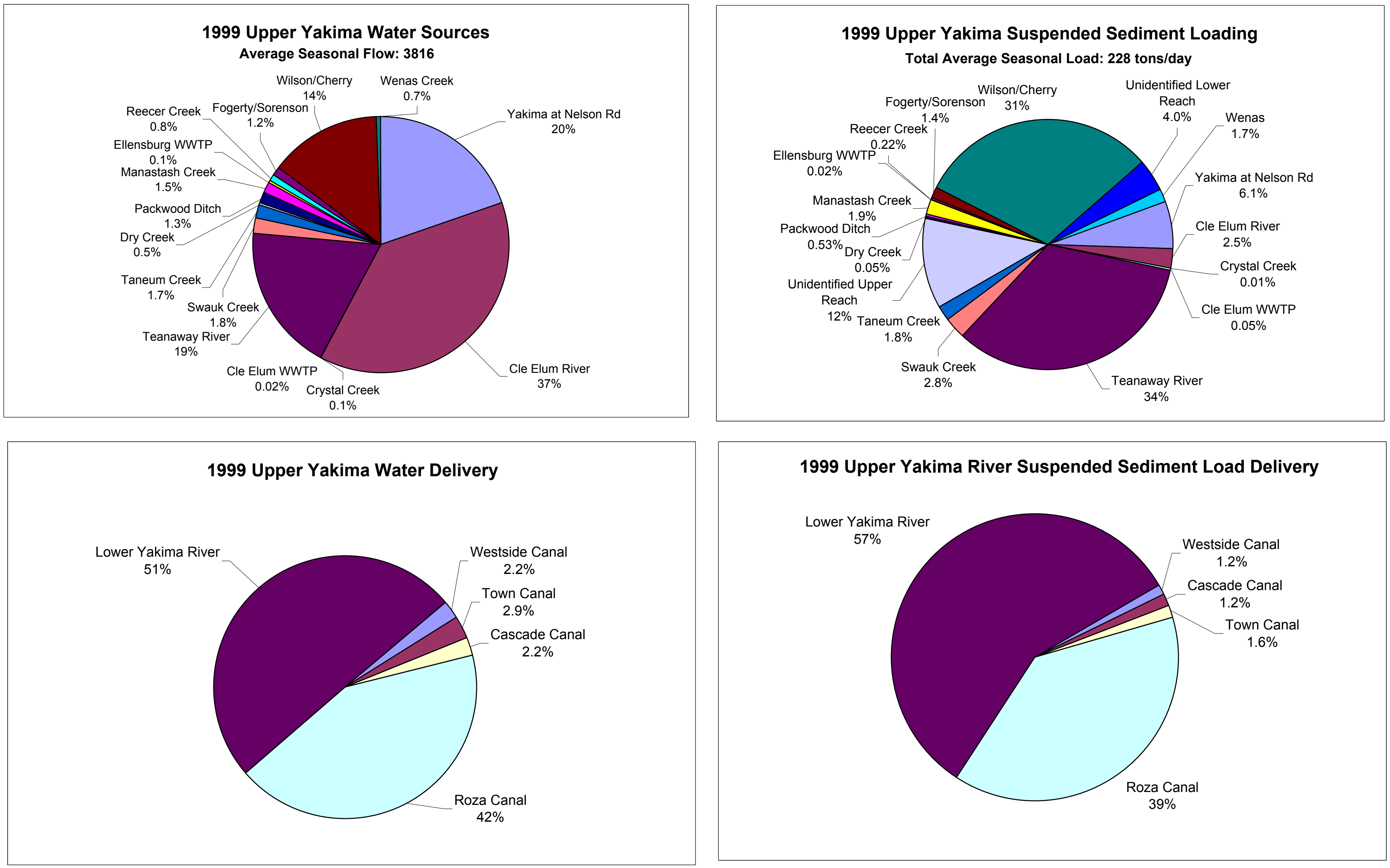


Figure 13. Water and TSS balances for the upper Yakima River during the 1999 irrigation season (April - October) based on data collected during the Ecology TMDL study.

Differences between current velocities and particle sizes at a given site could play a role in the analytical results of a sub-sample. On the other hand, the cumulative error in load calculation between Ecology and USGS techniques may be less than 15% based on research by USGS on Yakima at Kiona data (Glysson, Gray, and Schwartz, 2001). Finally, the load calculations have another source of error from using the average daily discharge. Differences between instantaneous discharges and average daily discharges can vary significantly between sites because of water management operations. However, these errors are reflected in the water balance (Table 10), and they are not large enough to account for the unidentified load.

Significant channel or other unidentified sources of sediment and turbidity are possible as the mass balance suggests. Two main areas were consistently contributing suspended sediment to downstream mainstem sites: the upper reach between the Yakima River at Nelson Siding and Thorp Bridge, and the lower reach from Thorp Bridge to the Umtanum gage. A third area showed both sediment gains and losses: the canyon and Roza pool reach to Harrison Bridge.

Based on observations in the study area, some possible sources have been suggested:

- Severe bank sloughing has been noted in several areas between Wilson Creek and Taneum Creek (Confederated Tribes and Bands of the Yakama Nation, Washington Department of Fisheries, and Washington Department of Wildlife, 1990).
- Some side-channel and instream activities using heavy equipment were observed by Ecology monitoring staff during some of the 1999 surveys.
- The pool behind Roza Dam could be an area for settling or for release of settled sediments under various hydraulic conditions.
- Algal growth could occur in the shallow reach below the dam and Roza diversion. Algae could be a component of the turbidity and TSS monitored at times at Harrison Bridge.

Identifying the sources and their magnitude will be a task for the post-TMDL effectiveness monitoring plan.

Organochlorine Pesticides

As discussed earlier and unlike the lower Yakima basin, few organochlorine pesticides have been detected in water samples from sites in the upper basin over the past ten years except when large volume techniques were used. The persistence of DDT and dieldrin in the upper basin had been demonstrated in bed sediment samples in several tributaries and fish tissue samples in the mainstem. Organochlorine pesticides had been most frequently detected in all media collected from sites in the Cherry/Wilson sub-basin. The results have been 303(d) listings for organochlorine pesticides in fish tissue in the mainstem and in water in Cherry Creek (Table 1).

Few other potential pesticide source areas for sampling were evident after a review of USGS, Ecology, and other available data. Therefore, monthly organochlorine pesticide monitoring (April to November) focused on water from Cherry Creek and Wipple Wasteway, the primary branches above the USGS monitoring site for Cherry Creek's original 303(d) listing (Table 1). In addition, Ecology collected and analyzed fish from the Cle Elum area and the area below Ellensburg at Wymer to determine current levels of these pesticides (Rogowski, 2000).

Organochlorine data collected by the Kittitas County Conservation District from soils in three fields in the Cherry Creek sub-basin also were used as part of the assessment (Lael, 2000).

Cherry Creek and Wipple Wasteway

Both DDT compounds and dieldrin were detected in most water samples at both sites during Ecology's 1999 effort (Table 11). Many of these reported organochlorine concentrations were detected at concentrations below the practical quantification limit, so they were qualified as estimates. Seasonal and spatial differences were recorded at the two sites:

- Organochlorine pesticides were not detected at either site during the September or November sampling run, and only dieldrin was detected in October.
- Wipple Wasteway 4,4'-DDE concentrations in April (0.0014 ug/L) and August (0.0012 ug/L) exceeded the chronic toxicity aquatic life criteria. When estimated concentrations are included, total DDT concentrations exceeded the chronic aquatic toxicity criterion in April, June, July, and August.
- Wipple Wasteway dieldrin concentrations were all below the chronic aquatic toxicity criterion.
- Cherry Creek total DDT concentrations only exceeded the chronic toxicity criterion in July, but none of the individual metabolite concentrations were greater than 0.001 ug/L.
- Cherry Creek dieldrin concentrations were at or exceed the chronic toxicity criterion in May and July.
- Two or more of the 4,4'-DDE results and six of the dieldrin results from both sites exceeded the human health criteria listed in Table 3.
- Cherry Creek sub-basin requires TMDLs to control dieldrin, 4,4'-DDE, and total DDT.

Table 11. Results of water samples collected by Ecology. All values microgram per liter (ug/L), whole water.

Date	Flow	4,4'-DDD		4,4'-DDE		4,4'-DDT		Total DDT		Dieldrin	
Cherry at Moe											
4/21/99	125	0.00064	U	0.00072	J	0.00064	U	0.00072	J	0.00083	
5/19/99	164	0.0006	U	0.0005	J	0.0002	NJ	0.0007	J	**0.0019**	
6/14/99	220	0.0006	U	0.0004	NJ	0.0002	NJ	0.0006	NJ	0.0015	J
7/14/99	66	0.0005	J	0.0008		0.0009		**0.0022**	J	**0.005**	
8/9/99	112	0.0007	U	0.0004	J	0.0005	J	0.0009	J	0.001	
9/8/99	95	0.0006	U	0.0006	U	0.0006	U			0.0016	U
10/4/99	95	0.0006	U	0.0006	U	0.0006	U			0.0017	
11/3/99	35	0.0006	U	0.0006	U	0.0006	U			0.0006	U
Wipple at Moe											
4/21/99	50	0.00062	U	**0.0014**		0.00036	J	**0.00176**	J	0.00038	J
5/19/99	167	0.0006	U	0.0007	J	0.0002	NJ	0.0009	NJ	0.0009	J
6/14/99	80	0.0006	U	0.0007	J	0.0004	NJ	**0.0011**	NJ	0.0012	J
7/14/99	82	0.0004	J	0.0007		0.0006	U	**0.0011**	J	0.0008	
8/9/99	170	0.0004	J	**0.0012**		0.0009		**0.0025**	J	0.001	J
9/8/99	202	0.0007	U	0.0007	U	0.0007	U			0.0017	U
10/4/99	189	0.0006	U	0.0006	U	0.0006	U			0.001	
11/3/99	33	0.0006	U	0.0006	U	0.0006	U			0.0006	U

Shading = Human health criteria for consumption of organism only: DDT - 0.00059 ug/L
DDE - 0.00059 ug/L
DDD - 0.00084 ug/L
Dieldrin - 0.00014 ug/L

Bold = Chronic toxicity criteria for aquatic organisms are: 0.001 ug/L DDD, DDE, DDT, or total DDT
0.0019 ug/L dieldrin

U = not detected at or above reported result.
J = the analyte is positively present and the result is an estimate.
NJ = there is evidence the analyte is present and the result is an estimate.

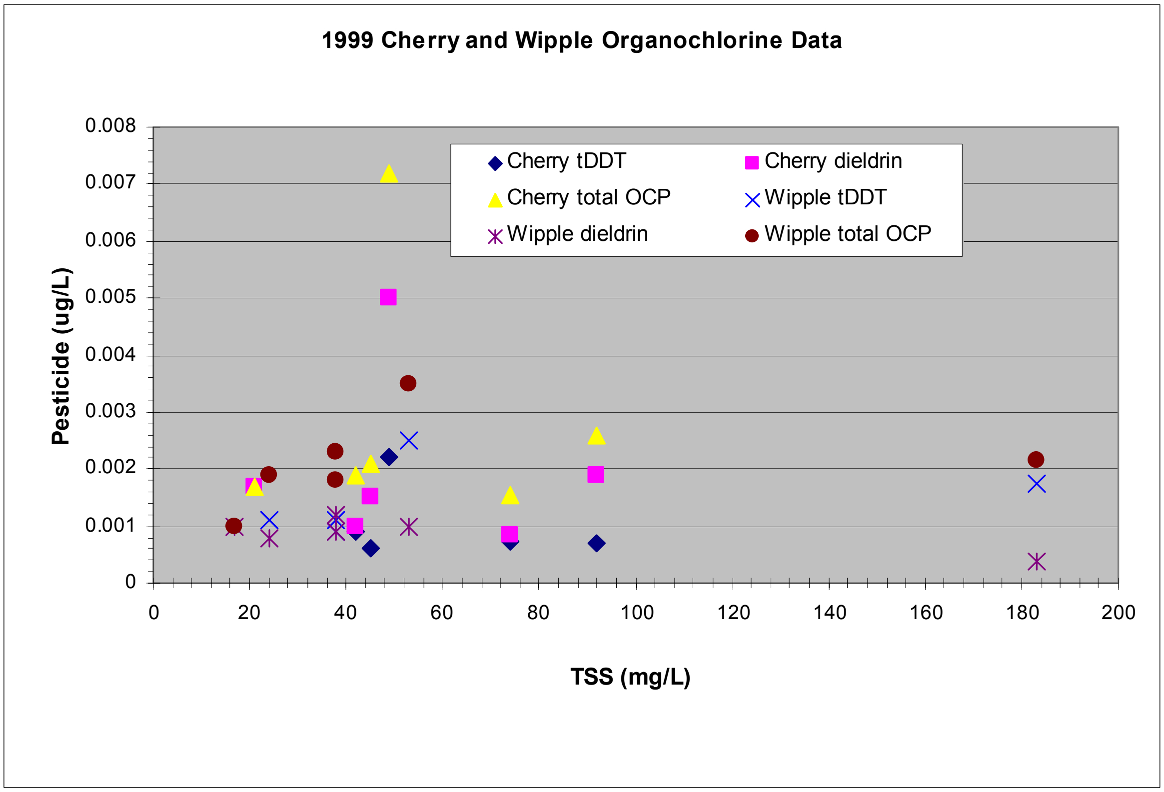
Kittitas County Conservation District collected water samples from Wipple Wasteway and Cherry Creek at the same locations in July 1999 (Lael, 2000). They did not detect DDT compounds or dieldrin in their samples. Kittitas County Conservation District's contract laboratory's detection limits were two orders of magnitude higher (0.042 to 0.121 ug/L) than the limits Ecology's laboratory was able to reach (0.0004 to 0.0016 ug/L).

Even though they are not directly comparable because of differences in location, the water column organochlorine pesticide concentrations collected by Ecology from Cherry Creek and Wipple Wasteway in 1999 were lower than those reported by USGS in 1988 (Rinella et al., 1992). The Ecology sites were located approximately one mile upstream of the USGS site that was situated below the confluence of Wipple Wasteway and Cherry Creek. Ecology obtained lower detection limits than USGS. Average concentrations of total DDT, individual DDT compounds, and dieldrin at each site were 40% to 80% lower than USGS results. Using the Beales estimator loading calculation, the 1999 total DDT combined load from both sites was lower by 48% and the dieldrin load lower by 61%. The average combined total suspended solids (TSS) load during Ecology's 1999 survey was 10% lower than during the 1988 USGS survey. In both of these comparisons, data collected during a storm event in 1989 were excluded from the USGS statistics; inclusion of the data would have made the differences even greater.

The organochlorine concentrations were not well correlated with TSS or total organic carbon concentrations at either site (Figure 14). This is contrary to the experience of past USGS and Ecology work with lower Yakima basin organochlorine problems, but consistent with USGS data collected ten years ago from Cherry Creek (Rinella et al., 1992). The following observations were made on the relationships between organochlorine pesticide, turbidity, TSS, and total organic carbon results collected in 1999 samples:

- The best correlation was found between the Wipple Wasteway total DDT results and turbidity - adjusted coefficient of determination (r^2) was 0.56 with a significance level of alpha = 0.09. Using the linear regression equation, a total DDT concentration of 0.001 ug/L would occur at 11.5 NTU (approximately 27 mg/L TSS).
- Total DDT was not detected in Cherry Creek samples when TSS concentrations were below 35 mg/L. Dieldrin was not detected when total organic carbon concentrations were below 4 mg/L or when TSS concentrations were below 20 mg/L.
- Dieldrin and total DDT were not detected in Wipple Wasteway samples when TSS concentrations were below 20 mg/L.
- A threshold for total DDT and dieldrin appearance in Cherry Creek and Wipple Wasteway samples appeared to occur at TSS concentrations between 20 and 35 mg/L.

In the lower basin, USGS and Ecology have had more predictable suspended sediment and organic carbon relationships even as pesticide concentrations have declined over time. For example, preliminary analysis of 1999 data collected by USGS indicates decreasing amounts of DDT continue to correlate to decreasing amounts of suspended sediment concentrations (USGS, unpublished data). The lack of such a strong association for the organochlorine pesticide concentration in the Cherry Creek sub-basin may be the result of several factors.



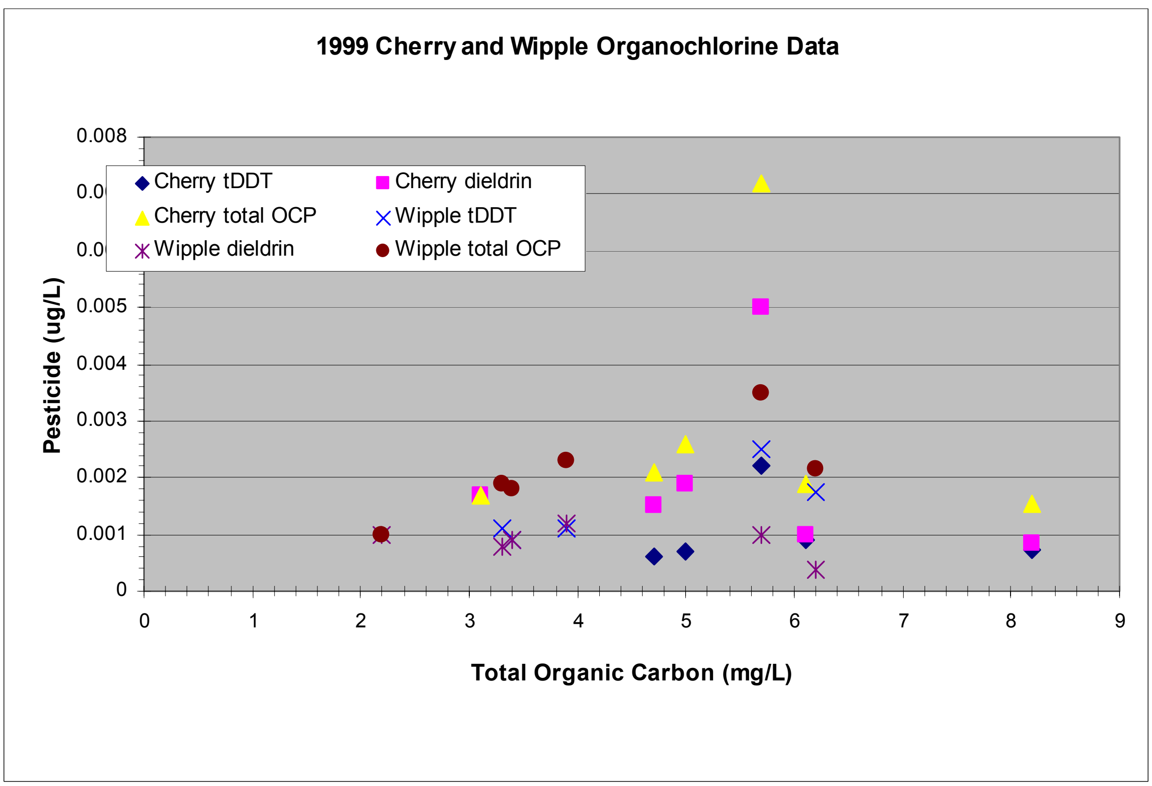


Figure 14. DDT and dieldrin concentrations compared to TSS and total organic carbon at two sites in the Cherry Creek sub-basin near Ellensburg, based on samples collected during the 1999 Ecology TMDL study.

One factor may be that a particular upstream set of fields or drains with organochlorine pesticides may contribute disproportionately less TSS and turbidity than the cumulative monitored downstream. Organochlorine pesticide contamination of field soils is not uniform throughout the valley (Lael, 2000). Kittitas County Conservation District pesticide analyses in 1999 suggest that sediment pesticide concentrations varied greatly even when areas of historical pesticide use were sampled.

The Kittitas County Conservation District took composite soil samples from three sites in the Cherry Creek/Wipple Wasteway sub-basin. Only one of three sites sampled had a confirmed concentration of DDT compounds (96 ug/Kg total DDT). One other site reported DDE at an estimated concentration of less than 5 ug/Kg, the method's practical quantification limit. The same two of the three District sites had detectable concentrations of dieldrin (22 and 51 ug/Kg).

Since the samples were composites, these numbers are field averages rather than maximum concentrations. And, as was reported by Lael (2000), the concentrations are far lower than USGS found in lower Yakima Valley soils in 1988 - 1989. However, some of the soils have enough pesticide residue to contaminate drains and creeks.

Another related factor is that the organochlorine pesticides were detected in water somewhat seasonally (fewer in September through November). Persistent pesticides may be associated with a particular irrigation or cultivation task upstream of the Cherry Creek and Wipple Wasteway sites, a particular historical use, or soil type. Although they had very similar sample results, the Wipple Wasteway site tended to have slightly higher concentrations of DDT compounds than the Cherry Creek site, while the Cherry Creek site had slightly higher dieldrin concentrations.

The Kittitas County Conservation District field soil site with the DDT compounds was located on the steeper irrigated lands in the Wipple Wasteway part of the basin. USGS field and drain sediment samples collected in the Yakima basin in 1989 from orchard areas tended to have the highest concentrations of DDT compounds, while drain sediment downstream of potato-growing areas had high dieldrin concentrations (Rinella et al., 1999). Areas of the upper Yakima basin, and Wilson/Cherry sub-basin in particular, where these crops were historically grown may still be the greatest potential source of organochlorine pesticides. However, much is still unknown about how the transport and transformation of archived organochlorine pesticides in various soil types may have a role in upper Yakima basin monitoring results.

Mainstem Fish Tissue

Rogowski (2000) collected resident whitefish and rainbow trout above Cle Elum (rm 187), and suckers and rainbow trout below Ellensburg near Wymer (rm 136) in 1999. The four to nine fish of each species were individually filleted and homogenized. Then sub-samples of each fish were mixed together by species and analyzed for DDT compounds and dieldrin. The fish samples then represented average concentrations.

Trace levels of DDT compounds and dieldrin were detected in all fish composite samples from both locations (Table 12). The Washington State human health screening level for dieldrin

(0.65 ug/Kg) was exceeded in three of the five samples: one whitefish sample above Cle Elum and both samples from Wymer. The rainbow trout sample from Wymer was at the total DDT screening level (32 ug/Kg). None of the samples had DDT compounds that exceeded their individual screening levels; e.g., 4,4'-DDE did not exceed 32 ug/Kg in any sample. Rogowski (2000) recommended that a 303(d) listing for dieldrin is appropriate. Since the composite tissue sample represents an average concentration and the total DDT concentration was at the screening level, listing for total DDT was recommended for the upper Yakima River, but a listing for 4, 4'-DDE alone was not.

Table 12. Fish tissue concentrations of total DDT and dieldrin collected by Ecology at two sites in the upper Yakima basin in 1999 (Rogowski, 2000).

Location/Species	Avg. wt. (g)	% lipids	Total DDT (ug/Kg)	Dieldrin (ug/Kg)	Lipid Total DDT (ug/Kg)	Lipid Dieldrin (ug/Kg)
Cle Elum (rm 187)						
Whitefish	190	3.9	3.7	0.24 J	90	10
Whitefish	277	4.5	21	**1.3**	500	30
Rainbow Trout	542	1.8	1.6	0.38	90	20
Wymer (rm 136)						
Bridgelip Sucker	937	2.7	21	**1.5**	800	60
Rainbow Trout	478	2.7	**32**	**2.1**	1,200	80

Fish tissue = fillet
Total DDT = DDT+DDE+DDD
Wet weight (ug/Kg) and calculated lipid-normalized (ug/g) concentrations are shown.
Bold values exceed human health screening level guidelines: 0.65 ug/Kg dieldrin and 32 ug/Kg total DDT.

The concentrations of total DDT and dieldrin were quite different in the two whitefish samples from the Cle Elum site, and the Cle Elum fish tissue burdens were generally lower than those at Wymer. Rogowski (2000) surmised that the differences in DDT and dieldrin tissue burdens at Cle Elum were probably a result of fish size and age differences between the two samples (Table 12). Fish in Wymer had higher concentrations of total DDT and dieldrin. This becomes especially evident when the data are lipid-normalized (Table 12). The relative increase of organochlorine pesticide tissue burdens from headwaters to downstream in the Yakima River system has been documented in previous investigations (Johnson, Norton, and Yake, 1986; Rinella et al., 1999). The source of these pesticides in fish in the upper basin near Cle Elum remains uncertain. Undocumented historical sources, contaminated wind-blown dust, general atmospheric fallout, and tissue burdens in decaying fish that have migrated through more contaminated areas are possible sources.

All fillet tissue 4,4'-DDE burdens in 1999 were much lower than in fillets analyzed in 1985 by Ecology, except total DDT in the rainbow trout collected at Wymer (Johnson, Norton, and Yake, 1986). Larger trout were collected in 1999, and this may be the reason for the apparent lack in difference over the 14 years. Otherwise, lipid-normalized DDE and total DDT fillet tissue burdens decreased by 70% to 80% at Cle Elum and Wymer over the 14 years in similar species (whitefish and bridgelip suckers).

Pesticide Loading Analysis

The data are not available to do a complete loading and modeling analysis of the organochlorine problem in the upper Yakima basin. A rough load estimate was calculated from the 1999 water column and fish tissue data (Table 13). According to Beale's loading estimates of water column sample results, Cherry Creek and Wipple Wasteway combined roughly deliver 0.52 g/day of total DDT and 0.76 g/day of dieldrin, approximately half of the estimated loads delivered in 1988 according to USGS data. Following examples presented by USGS (Rinella, et al., 1999), Ecology used bioconcentration factors for total DDT and dieldrin as well as 1999 fish tissue burdens at Cle Elum and Wymer to estimate water column concentrations. The method assumes the fish tissue burdens are primarily dependent on the attraction of organochlorine pesticides in the water column for lipids in the fish. The average discharge volumes for the 1999 irrigation season were used to calculate the Yakima River water column estimates to loads.

The results suggest that the current loading of these pesticides from Cherry Creek and Wipple Wasteway account for 10% of the total DDT and 19% of the dieldrin available to fish downstream at Wymer. Organochlorine pesticide loads at Cle Elum estimated from the fish tissue burdens could account for as much as 40% of the load to Wymer. The Cle Elum, Cherry Creek, and Wipple Wasteway loads could not account for the estimated total DDT (5.1 g/day) and dieldrin (4 g/day) load at Wymer. The residual, or unidentified, loads of total DDT (2.5 g/day) and dieldrin (1.7 g/day) would be 49% and 43% of the totals, respectively.

The relatively large unidentified loads include an error factor in estimating the water concentration from fish tissue. The use of a bioconcentration factor ignores bioaccumulation which is uptake of the pesticides through food that may have also selectively bioaccumulated the pesticides. Resuspended bed sediments and trace levels of total DDT and dieldrin from other drainages may also be part of the unidentified load.

Although fish tissue is probably the best media for evaluating organochlorine pesticide compliance with criteria, using the fish tissue burdens of organochlorine pesticides to estimate water column loads through the upper Yakima basin is problematic. Besides the error factor mentioned above, the sediment compartment is ignored as a reservoir of pesticides, and the fish may not have spent their whole lives in the same spot along the river. The loading exercise demonstrates that the sources of a large portion of the dieldrin and DDT compounds in the upper Yakima cannot be easily identified. Ecology would concur with the statements by USGS (Rinella, Hamilton, and McKenzie, 1993) that, "it is difficult to quantify when total DDT contamination in the streams and fish in the Yakima River Basin will subside or end," and, "…contaminated agricultural soils could, therefore, provide a large and long-term reservoir of total DDT to streams and fish in the Yakima River for decades to come."

Table 13. Total DDT and dieldrin loading evaluation and loading capacities for the upper Yakima River.

	1999 Estimated Conditions					Water Criteria		1999 Loads		Loading Capacity/Targets	
	Fish tissue ug/Kg ww*	Bioconcentration Factor	Discharge cfs	Obser. Max. ng/L	Avg. water ng/L	Chronic Aquatic	Human Health	Est. Load g/day	Percent of Umtanum	Chronic toxicity g/day	Human health g/day
Cle Elum Area											
Total DDT	21	36,200	2200	--	0.39	1.0	0.59	2.08	41%	2.08	2.08
Dieldrin	1.3	3,100	2200	--	**0.28**	1.9	0.14	1.51	38%	1.51	**0.75 (50%)**
Cherry Creek and Wipple Wasteway										Target Loads	
Total DDT	--	--	265	**2.5**	0.08	1	0.59	0.52	10.2%	**0.4 (23%)**	**0.38 (27%)**
Dieldrin	--	--	265	**5**	0.12	1.9	0.14	0.76	19%	**0.68 (11%)**	**0.09 (88%)**
Unidentified Sources as Water column load by difference**											
Total DDT	--	--	1035	--	0.98			2.5	49%	2.5	2.5
Dieldrin	--	--	1035	--	0.68			1.7	43%	1.7	1.7
Sum of Sources above Wymer										Cumulative Upstream Loads	
Total DDT			3500					5.08		4.96 (2%)	4.94 (3%)
Dieldrin			3500					4.00		3.92 (2%)	2.57 (36%)
Yakima River at Wymer										Target Loads	
Total DDT	32	60,000	3500		**0.59**	1	0.59	5.08		**8.6**	**5.08**
Dieldrin	2.1	5,000	3500		**0.47**	1.9	0.14	4.0		**16.3**	**1.24 (69%)**

* wet weight

** Difference between Umtanum and estimated or measured inputs from upstream.

Total DDT = DDT+DDE+DDD metabolites

Parentheses = Reductions to estimated 1999 loads required to meet loading capacities.

Shading = Concentrations exceed one or more water quality criterion.

Bold = Loading capacity estimates of total DDT and dieldrin.

Borders = Dieldrin target loads that need more reduction to meet estimated load capacity.

In summary:

- Organochlorine pesticides continue to be detectable in the Cherry Creek sub-basin in all media tested and in fish tissue in the mainstem Yakima River.
- Despite the poor correlations of suspended sediment to water column pesticide concentrations, the tenacious presence of organochlorine pesticides in some Kittitas Valley field and bed sediments is well documented. A threshold for total DDT and dieldrin appearance in Cherry Creek and Wipple Wasteway occurs at 20 to 35 mg/L TSS.
- Water column concentrations in Cherry Creek and Wipple Wasteway continue to occasionally exceed DDE, total DDT, or dieldrin chronic aquatic toxicity criteria, and more often exceed human health criteria.
- The organochlorine concentrations and resultant loads are half of what they were 10 years ago.
- Dieldrin and DDT compounds are widely dispersed through the basin, but are at high enough concentrations to pose a human health risk from bioaccumulation in fish.
- Fish tissue burdens of DDT compounds and dieldrin continue to be higher in the mainstem below the Kittitas Valley area than in the upper basin near Cle Elum.
- Dieldrin tissue burdens exceeded screening guidelines at both sites, and total DDT tissue burdens exceeded guidelines below the Kittitas Valley.
- The fish tissue concentrations appear to be dropping compared to 14 years ago.

Since historical treatment of agricultural land with DDT and dieldrin are the most significant source of these pesticides today. Continuing to limit soil erosion and reducing suspended sediment loading to tributaries and to the Yakima River will be necessary to reduce organochlorine contamination. Reducing the transport and contamination of the water column and bed sediments should reduce the fish tissue burdens of these persistent and biomagnifying contaminants and accelerate progress to criteria compliance.

Total Maximum Daily Load Analysis

Applicable Water Quality Criteria and Appropriate Measures

The review of 1999 TMDL survey results and other data demonstrate that suspended sediment and turbidity in some waterbodies in the upper Yakima River basin may potentially affect aquatic communities, and that organochlorine pesticide contamination continues in water and fish. The analyses presented in the previous sections of this report indicate these problems are much less severe than found in the TMDL evaluation of the lower Yakima River basin, and the problems are less serious than data indicated for the upper Yakima basin a decade ago.

Suspended sediment and turbidity conditions, and dieldrin and DDT compound concentrations, were measured against several criteria and guidelines detailed in a prior section (see *Water Quality Standards and Guidelines*). Washington and Idaho turbidity criteria were used to compare longitudinal gains along the mainstem and in tributaries. USEPA recommendations were used to measure potential impairment to aquatic habitat from total suspended solids (TSS). Data from scientific literature were used to assess the potential harm to various life stages of salmonids from extended exposures to suspended sediments in the waterbodies. State criteria adopted from USEPA were used to evaluate concentrations of dieldrin and DDT compounds in water and fish tissue samples. The primary water quality issues from applying these criteria and measures to data in this TMDL evaluation conclude:

- Relative to Washington State turbidity criteria, turbidity levels in the upper Yakima River often increase more than 5 or 10 NTU between Nelson (rm 191) and Harrison Bridge (rm 121.7) during the months of April through June because of excessive suspended sediment loading from forested, range, and agricultural lands, and from unspecified sources.
- Relative to the Washington State turbidity criteria, the turbidity levels at the mouths of some tributaries increase more than 5 or 10 NTU over estimated background levels for one or more months of the irrigation season (April through October) due to forestry, livestock, urban runoff, recreation access, mining, and agricultural practices that do not prevent soil and channel erosion.
- The duration of the elevated suspended sediment loads and concentrations in the lowest mainstem sites of the study area, Wilson Creek, Sorenson Creek, and the Teanaway River, could potentially harm salmon eggs and emergent fry, and degrade aquatic habitat according to values in USEPA guidance levels and scientific literature. The concentrations of concern are generally between 7 and 100 mg/L suspended sediment (as TSS), or between 10 and 50 NTU turbidity, for more than 30 days.
- Dieldrin and DDT are present in some Cherry Creek basin soils and bed sediments. Erosion of some agricultural field soils continues to contaminate water with these pesticides in the Cherry Creek sub-basin to levels above the state and federal aquatic toxicity and human health criteria.

- Fish collected from the upper Yakima River continue to have dieldrin tissue burdens at or exceeding Washington Pesticide Screening levels. Composite fish samples collected below Ellensburg continue to have total DDT at the screening levels (but not 4,4'-DDE, 4,4'-DDT, or 4,4'-DDD individually).

When used alone, Washington State turbidity criteria are inadequate for basin-wide control of suspended sediment loading. This was the case for turbidity conditions in the lower Yakima River Suspended Sediment and DDT TMDL (Joy and Patterson, 1997). Establishing background turbidity in the mainstem above the confluence of each tributary or return drain will not adequately protect water quality and beneficial uses of the river from the cumulative effects of multiple sources. However, Idaho and Washington turbidity criteria can be used as general guidance to reduce extended periods of excessive suspended sediment loading. The USEPA-approved procedure used for the lower Yakima River TMDL will be used for the upper Yakima River TMDL: i.e., a 90th percentile background turbidity value at a selected control point for the mainstem river with 90th percentile compliance of a specified NTU increase at all downstream points.

Seasonal Variation and Impaired Uses

As described earlier in this report, water in the upper Yakima River basin is managed for irrigation and flood control. Analyses performed on data from the upper Yakima basin indicated the months of greatest concern for human-caused turbidity, suspended sediment loading, and pesticide transport are April through October, the irrigation season. Turbidity and suspended sediment loads are usually lower outside the irrigation season except during storm events described below. Therefore, the critical season for TMDL evaluation and compliance is the irrigation season.

Data show that elevated suspended sediment loads are also delivered during short-duration storm or rain-on-snow events within and outside of the irrigation season. The early part of the irrigation season (April to June) usually includes elevated background suspended sediment loading from rain-on-snow or snowmelt events. The natural contribution of these sources to the total seasonal load, and the ability of TMDL implementation activities to influence loading from these types of events, has not been quantified. As post-TMDL activities are conducted, the background suspended sediment and turbidities for tributaries and the mainstem river need to be better characterized in areas where all best management practices are functioning. The seasonal characteristics of the snowmelt and storm events in response to these practices will guide interpretation of TMDL targets and turbidity criteria. Most activities implemented to halt soil and channel erosion as part of the TMDL can function the whole year, and sediment and pesticide loading also should experience reductions other times of the year.

The irrigation season (April through October) also is a critical time when several beneficial uses are potentially impaired by suspended sediment and pesticide transport in the upper Yakima basin. Various life-stages of several salmonid species are migrating upstream or downstream, holding in side-channel and tributary rearing areas, or spawning in mainstem and tributaries of the upper Yakima between March and October. The period of highest risk from exposure to suspended sediment and turbidity appears to be early in the irrigation season (April through June) when the suspended sediment concentrations are high enough and for a long enough duration to potentially affect emerging chinook fry and incubating steelhead eggs. Potential risks from long-term exposure to suspended sediment and organochlorine pesticides also may occur in Wilson/Cherry creeks and in the mainstem Yakima below Ellensburg into August. The highest organochlorine pesticide concentrations were also recorded from water samples collected from Cherry Creek and Wipple Wasteway in April through August.

The lower basin TMDL targets are keyed to upper Yakima River water quality during the same irrigation season. Low turbidity and suspended sediment concentrations are required so that water quality-related beneficial uses can be met in the lower basin: e.g., fishery resource protection, elimination of organochlorine pesticide transport, spray or drip irrigation uses, and recreational enjoyment. The upper Yakima water quality conditions must be adequate to ensure water quality standards are met within the entire Yakima River.

Loading Capacity

Suspended Sediment and Turbidity

Water and suspended sediment load balances for the mainstem and tributaries during the 1999 irrigation season were previously presented (Table 10, Figure 13). A combination of concentration and duration terms is necessary to estimate the suspended sediment load capacity of the upper Yakima River during the irrigation season. The load capacity of each tributary also has a cumulative effect on the suspended sediment load capacity of the river. Since the effects of suspended sediment and turbidity on aquatic organisms are concentration-based rather than load-based, allowable concentration increases over a background value and over an acceptable exposure period were used to estimate 1999 load capacities.

The following steps were taken to include both terms in the load capacity estimates, and to determine the effects of load capacities of tributaries on the mainstem load capacity:

- The numerical distribution statistics of turbidities and TSS concentrations during the 1999 irrigation season (Table 9) were compared to the Nelson mainstem background site or the tributary background estimate. The state turbidity criteria of 10 NTU and 5 NTU over background were used as guidance (Table 14). The 10 NTU criterion normally used for Class B waters was used as an interim guideline, because natural background turbidity and non-anthropogenic generation and transport of turbidity along the waterbodies are not well defined yet. The median and 90th percentile background turbidity statistics were compared to background instead of maximum values to be consistent with the lower Yakima River TMDL and to allow for variation from natural short-term peak turbidity events. The 90th percentile value supports full beneficial use protection under USEPA policy (USEPA, 1995), and it is adequate for background definition under Ecology policy (Ecology, 1994, 1996a).

- The statistical rollback method (Ott, 1995) was applied to the median and 90th percentile statistics of some tributaries to calculate the turbidity reductions required to meet the 10 and 5 NTU guidelines at their mouths. The statistical rollback method proposed by Ott (1995) is a way to estimate the distribution characteristics of future set of samples after abatement processes are applied to the sources. The method assumes dispersion and dilution characteristics are consistent upstream of the monitoring point, and that only the mean and standard deviation of the chemical of interest population changes as abatement processes are applied.

- Estimated reductions were calculated for the Teanaway River, Manastash Creek, Sorenson Creek, and Wilson Creek to meet the 10 NTU over background guidance (Table 15). The reductions calculated for these tributaries and Taneum Creek, Packwood Ditch, and Wenas Creek to meet the 5 NTU over background guidance are also shown in Table 15. The reduction values are based on the 1999 estimated tributary background turbidity (Table 14).

- The estimated reductions were applied to the 1999 tributary suspended sediment loads from Table 10 after converting tributary turbidity values to suspended sediment concentrations. The 1999 suspended sediment load balance was then recalculated. Meeting the 10 NTU (interim reduction) and the 5 NTU guidance levels in the tributaries would have a significant impact on the upper Yakima River suspended sediment load (Figure 15). The net mainstem load reduction measured at Umtanum or Harrison Bridge would be 59 tons/day (26%) for the interim condition, and 99 tons/day (44%) for the 5 NTU condition (Table 16).

Table 14. Turbidity control site values for the upper Yakima tributaries and mainstem in 1999, and estimates of 10 NTU and 5 NTU increases.

Data Set	1999 Irrigation Season		+10 NTU		+5 NTU	
	Median	90th Percentile	Median	90th Percentile	Median	90th Percentile
Tributary background estimate* (Naneum, Caribou, Coleman, and Schnebly creeks)	2.6	7.5	13.4	18.6	8.2	13.2
Mainstem estimate for the Yakima River at Nelson	1.6	7.5	11.6	17.5	6.6	12.5

* Tributary median and 90th percentile calculated on the z statistical distribution (Zar, 1984).
All values are in NTU.

Table 15. Estimated turbidity reductions in upper Yakima River tributaries to meet the interim target of 10 NTU over background and the final 5 NTU over background.

Tributary	Median (NTU)	90th Percentile (NTU)	Interim Target			Final Target		
			Median (NTU)	90th Percentile (NTU)	Estimated Reduction (%)	Median (NTU)	90th Percentile (NTU)	Estimated Reduction (%)
Cle Elum R.	0.9	1.2						
Crystal Cr.	1.8	3.7						
Teanaway R.	**1.1**	**26.0**	**0.8**	**18.6**	**28.5**	**0.6**	**13.2**	**49.2**
Swauk Cr.	2.0	9.5						
Taneum Cr.	2.9	15.9				**2.4**	**13.2**	**17.0**
Packwood D.	8.9	13.0				**8.2**	**12**	**7.9**
Manastash Cr.	**6.7**	**19.2**	**6.5**	**18.6**	**3.1**	**4.6**	**13.2**	**31.3**
Dry Cr.	1.4	2.5						
Reecer Cr.	4.0	7.7						
Sorenson Cr.	**9.8**	**21.8**	**8.3**	**18.6**	**14.7**	**5.9**	**13.2**	**39.4**
Wilson Cr.	**15.5**	**24.8**	**11.6**	**18.6**	**25.0**	**8.2**	**13.2**	**46.8**
Umtanum Cr.	1.2	3.4						
Wenas Cr.	3.5	13.4				**3.3**	**13.2**	**1.5**

The estimated tributary background turbidity in Table 14 was used to calculate reductions.
Bold = Calculated statistics and reduction estimates.
Underline = Tributaries needing reductions to meet the final turbidity criterion.

Table 16. TSS (tons/day) during the April to October irrigation season for key mainstem sites and tributaries along the upper Yakima River, compared to 1999 loads.

Site	1999 Load (tons/day)	Mainstem only + 5 NTU	Tributary-based Interim	Tributary-based Final
Yakima R. at Nelson	14	14	14	14
Teanaway R.	77		43	28
Taneum Cr.	4.1		4.1	2.6
Packwood Ditch	1.2		1.2	1
Manastash Cr.	4.4		4.2	2.7
Sorenson Cr.	3.2		2.7	1.8
Wilson Cr.	71		47	26
Yakima R. at Umtanum	215	140	159	120
Yakima R. at Harrison Br.	131	87	98	75
Estimated Reductions (%)		35	26	44

All loads expressed as tons/day. See text for load calculation descriptions. Reductions use 1999 load estimates as base condition.

- When the statistical rollback method is applied to mainstem sites so that the 90th percentile turbidities were not more than 5 NTU over the background at Nelson, the turbidities at Umtanum and Harrison Bridge would require about a 35% reduction (Table 16). The estimate is based on statistics in Table 9 and the background values for a maximum 5 NTU increase from 1999 Nelson values in Table 14.

- The duration term was checked by comparing scientific literature values on salmonid effects to the daily estimates of turbidity and suspended sediment limited by 5 and 10 NTU over background. The daily suspended sediment estimates developed for mainstem and tributary sites (see *Aquatic Effects* section and Figure 12) were reduced by the percentages calculated from the previous load balance step (Tables 15 and 16). The regression equations for site TSS to discharge and TSS to turbidity were used to generate the new daily estimates. Figure 16 shows examples for the Teanaway River, Wilson Creek, and the Yakima River at Umtanum.

- If the suspended sediment load were reduced by 44%, TSS and turbidity concentrations would be cut by half in many places. The duration of elevated turbidity and suspended sediment would be brought within more tolerable periods for aquatic biota. For example, the peak TSS concentration at the Yakima River at Umtanum would drop from 74 to 41 mg/L. Exposure to the two early pulses of suspended sediment concentrations above 20 mg/L for 20 and 16 days would drop to 10 and 14 days. Teanaway River peak concentrations would drop below 75 mg/L and exposure to pulses greater than 20 mg/L for 16 and 7 days would drop to 5 and 3 days. Wilson Creek suspended sediments would drop below 50 mg/L all irrigation season during the interim condition, and would be lower than 20 mg/L if the 5 NTU target were met.

- Wilson Creek suspended sediment concentrations just mentioned could also significantly reduce the transport of DDT compounds and dieldrin. Twenty to 35 mg/L were considered threshold concentrations for the appearance of the pesticides in water samples (see *Cherry Creek and Wipple Wasteway* in *TMDL Monitoring Results*).

Tributary-based suspended sediment load capacities in Table 16 would yield mainstem loads as protective as the load calculated from the mainstem statistical rollback procedure. Because of the large margin of error in estimating any of these load capacities, the tributary-based final load capacity estimates will be used. These should allow the most protection to aquatic life from peak and longer-term exposure to suspended sediments, and the Wilson Creek load capacity should best limit transport of dieldrin and DDT compounds.

Organochlorine Pesticides

The loading capacity for organochlorine pesticides in the upper Yakima basin is best set on human-health criteria for safe consumption of aquatic organisms. This especially makes sense since these pesticides are highly bioaccumulative, and human health criteria based on fish consumption are available. Water column concentrations in many places in the basin are at or below analytical detection limits but may exceed criteria. Fish and other aquatic organisms

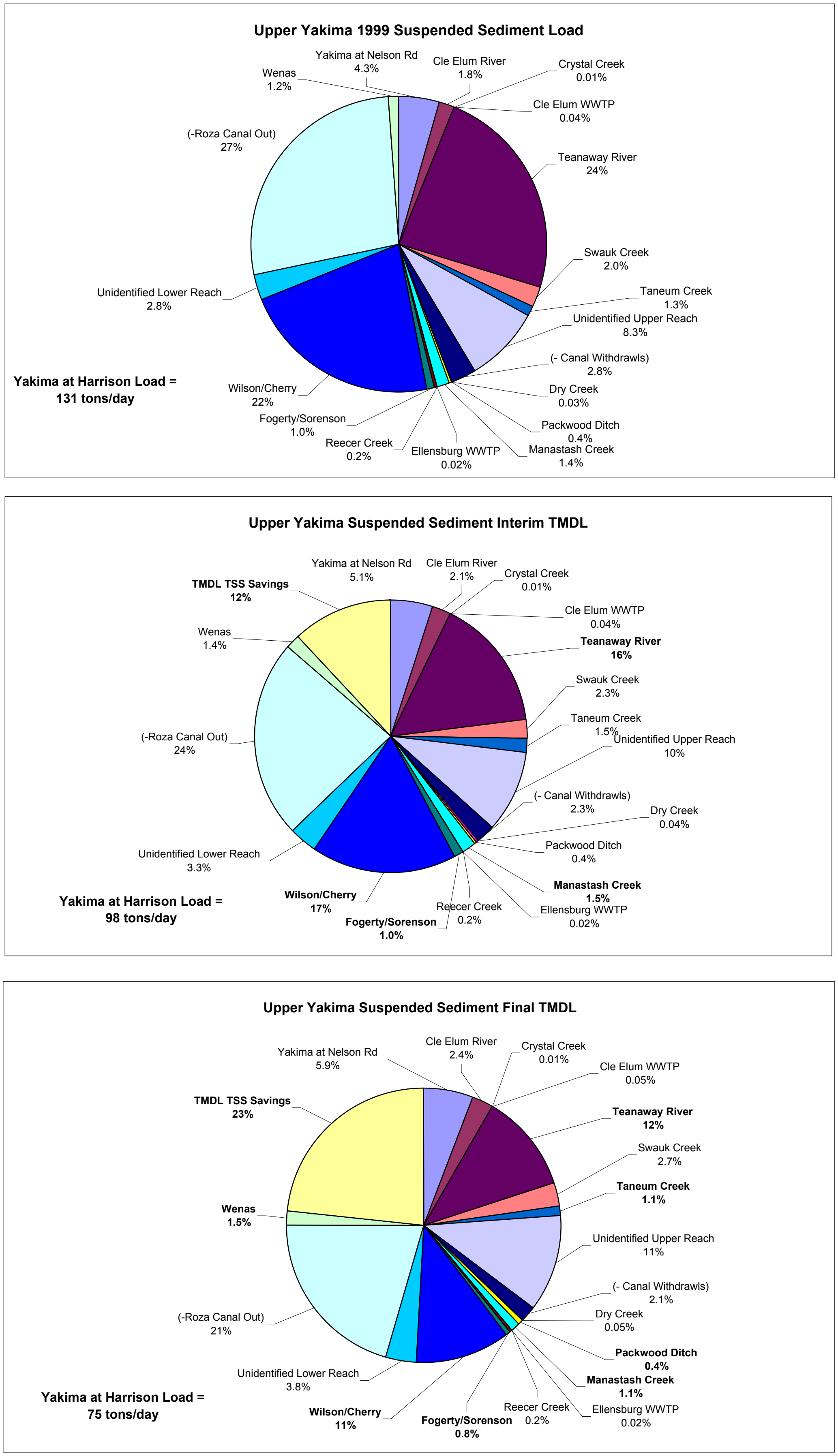


Figure 15. Suspended sediment loading (measured as TSS) to the upper Yakima River for the 1999 irrigation season (April - October), and compared to interim and final TMDL conditions in 2006 and 2011, respectively

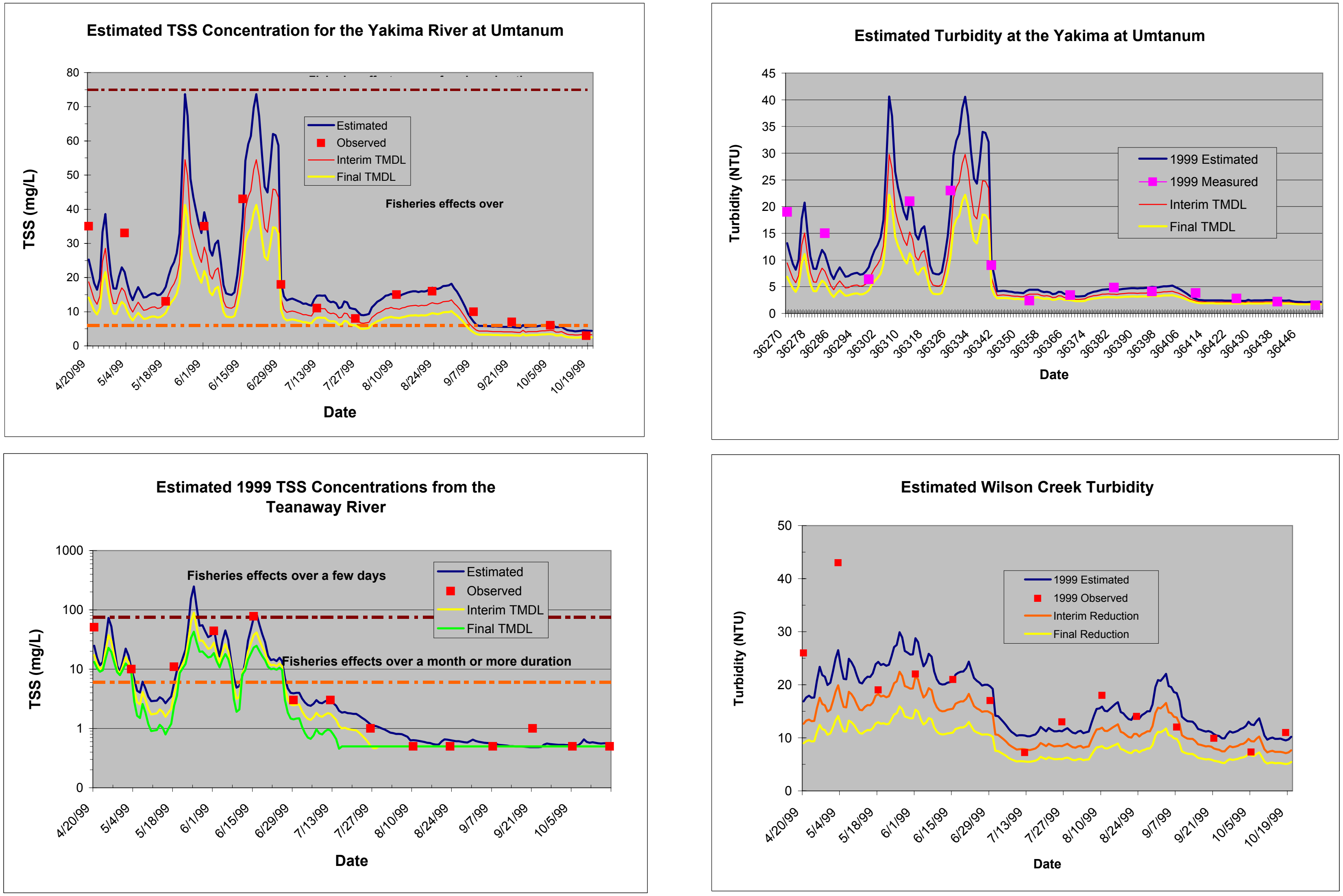


Figure 16. 1999 data and estimated levels of TSS and turbidity at two sites in the upper Yakima River relative to fisheries threshold effects levels. Estimated TMDL load reduction effects are also shown.

integrate organochlorine pesticide contamination from all compartments (sediment, water, and food organisms) in the river's aquatic ecosystem. Spatial and temporal monitoring of fish in the Yakima River are efficient tools to measure pesticide contamination trends.

Based on 1999 TMDL data results, the upper and lower Yakima River basins have no additional capacity for organochlorine pesticide loading. These pesticides are no longer used, but legacy residuals remain in soils and bed sediments, are widely dispersed through the basin, and continue to contaminate water and biota. Dieldrin, 4,4'-DDE, and total DDT in many water samples from Cherry Creek and Wipple Wasteway did not meet chronic toxicity criteria for aquatic organisms or human-health criteria (Table 11). Some upper Yakima River basin fish had tissue burdens of dieldrin and total DDT beyond Washington State screening-level human-health criteria (Table 12).

A basic organochlorine pesticide load balance for the upper Yakima was presented earlier (see *Pesticide Loading Analysis*). The load balance (Table 13) used Cherry Creek sub-basin water results and Yakima River mainstem fish tissue samples collected at Cle Elum (rm 187) and Wymer (rm 136). As described earlier, mainstem water concentrations were translated from tissue data, and loading estimates were based on average 1999 irrigation season discharge conditions. A large portion of the load was unidentified, but some of the load may have represented errors inherent in the estimating methods.

Also included in Table 13 is an estimate of dieldrin and total DDT load capacities of the Yakima River and Cherry Creek sub-basin, assuming the chronic aquatic toxicity and human health criteria are met in water and the human health criteria are met at Cle Elum and Wymer (near Umtanum). The water column human health criteria at Cle Elum and Wymer are calculated from using lipid content in the 1999 fish samples. However, these load capacities do not consider more stringent human health criteria based on elevated fish consumption rates or protection of special populations that could influence establishing regulatory-level criteria: e.g., a health advisory for infants and mothers or daily intake limits for subsistence fishers.

The estimated total DDT and dieldrin load capacities of Cherry Creek and Wipple Wasteway combined to meet chronic aquatic toxicity criteria compliance is 0.4 g/day total DDT and 0.68 g/day dieldrin (Table 13). To protect humans from adverse health risks, loads would need to drop to 0.38 g/day total DDT and 0.09 g/day dieldrin (Table 13). The estimated 1999 total DDT and dieldrin loads would need to be reduced by 27% and 88%, respectively, to meet the human health criteria.

According to the loading capacity estimate, the total DDT and dieldrin reductions in Cherry Creek and Wipple Wasteway loads will help meet the target capacities at Wymer, but other reductions are also needed. The estimated 1999 dieldrin load at Cle Elum (1.51 g/day) needs to be reduced by 50% to meet the human health criterion. Total DDT loads reductions are not necessary at Cle Elum since the fish met the human health criterion in 1999. The calculated load reductions at Cle Elum, Cherry Creek, and Wipple Wasteway are just adequate for the cumulative total DDT load (4.94 g/day) to meet the total DDT human health criterion load capacity at Wymer (5.08 g/day). The cumulative dieldrin load (2.57 g/day) does not meet the human health criterion load capacity at Wymer (1.24 g/day). An addition 50% dieldrin load reduction would be necessary to meet this load capacity target.

Load and Wasteload Allocations

A primary objective of the upper Yakima basin TMDL evaluation is to set suspended sediment targets as necessary for improvement of water quality, and to reduce cumulative loading of suspended sediment and organochlorine pesticides to the lower Yakima River basin. In 1999 the upper Yakima River tributaries and mainstem required a cumulative 44% reduction to meet the suspended sediment loading capacity in terms of limiting the river to not more than 5 NTU turbidity increase over the median and 90th percentile background value. Data evaluations presented earlier in this report show seven tributaries may need suspended sediment reductions to meet the 5 NTU turbidity increase limits at their mouths. Two of these tributaries, Teanaway River and Wilson/Cherry Creek, contributed over two-thirds of the seasonal load to the upper basin in 1999. The latter is also a source of organochlorine pesticide loads to the river.

The suspended sediment load and wasteload allocations for the upper Yakima River study area during the April to October irrigation season are shown in Table 17. The load allocations for total DDT and dieldrin during the same period are shown in Table 13. The suspended sediment loads in Table 17 are relative allocations based on 1999 data, and they reflect estimated suspended sediment reductions calculated for the mainstem (Table 14) and several tributaries (Table 15) from turbidity control targets. The load allocations for the tributaries and river will vary each year, because they are based on water supply, runoff, and other factors. The suspended sediment reduction numbers are more important for attaining water quality goals of the TMDL than the load numbers in the tables.

The total DDT and dieldrin load allocations are subject to the same variability, but the load capacity for the pesticides is ultimately measured by fish tissue burdens in the river. The final TMDL allocations for total DDT and dieldrin in the upper Yakima basin during the same period are taken from Table 13:

- 2.08 g/day total DDT and 0.75 g/day dieldrin in the Cle Elum area (measured as fish tissue meeting human health criteria).
- 0.38 g/day total DDT and 0.09 g/day dieldrin from Cherry Creek and Wipple Wasteway combined (measured as water column samples meeting human health criteria.
- 1.33 g/day reduction in dieldrin from other sources above the Yakima River at Umtanum (measured as fish tissue in the Yakima River at Wymer meeting the human health criterion).

The interim load allocations in Table 13 are only based on meeting aquatic toxicity criteria for total DDT and dieldrin in Cherry Creek and Wipple Wasteway.

Table 17. Load and wasteload allocations of suspended sediment for the mainstem and tributaries of the upper Yakima River basin for the April to October irrigation season.

Site	1999 Loads	Interim LA and WLA	Final LA and WLA
Yakima River at Nelson	14	14	14
Cle Elum River	5.8	5.8	5.8
Crystal Creek	0.03	0.03	0.03
Cle Elum WWTP	0.12	0.16*	0.16*
Teanaway River	77	43	28
Swauk Creek	6.4	6.4	6.4
Taneum Creek	4.1	4.1	2.6
Dry Creek	0.11	0.11	0.11
Packwood Ditch	1.2	1.2	1
Manastash Creek	4.4	4.2	2.7
Ellensburg WWTP	0.05	0.44*	0.44*
Reecer Creek	0.5	0.5	0.5
Sorenson Creek at Fogerty	3.2	2.7	1.8
Wilson Creek	71	47	26
Wenas Creek	3.9	3.9	3.7

LA = load allocations
WLA = wasteload allocations
* Loads based on current NPDES permit limits.
All loads are in units of average tons/day.

Two sets of allocations and turbidity targets are recommended and are shown in Tables 16 and 17. The interim loads are based on meeting the 10 NTU turbidity criterion targets in Tables 14 and 15. The final loads are based on meeting the 5 NTU turbidity criterion targets. Two load allocations for organochlorines based on meeting the aquatic toxicity criteria and meeting the human health criteria are shown in Table 13. The suspended sediment and organochlorine pesticide loads in the study area are nonpoint source problems, and an iterative approach is recommended. There are several reasons for proposing this approach:

- The greatest increases in turbidity over background conditions in April through June, and the degree to which snowmelt and high background contributes to increases in the mainstem and tributaries, has not been determined.
- Adequate background turbidity and suspended sediment data from areas without "anthropogenic sources" should be collected in many tributaries.
- Effectiveness of nonpoint source controls on the wide variety of land uses cannot yet be quantified: e.g., the time necessary to stabilize stream banks with riparian vegetation.
- Organochlorine pesticides controls may not respond directly to soil and channel erosion controls, if they are not applied to specific sites with high pesticide residues.
- Unidentified loads of total DDT, dieldrin, and suspended sediment are significant portions of the total loads.

Several sites for measuring target compliance are suggested in Tables 13 - 17. The primary compliance sites for suspended sediment in the mainstem are the Yakima River at Umtanum (rm 139.8) and the Yakima River at Harrison Bridge (rm 121.7) because the Roza pool and diversion and the Wenas Creek input between these sites make two compliance points necessary. Suspended sediment target compliance needs to be monitored near the mouths of the tributaries and at the point source outfalls as well. The Cle Elum area and Wymer (near Umtanum) area fish should continue to be used to measure compliance with the total DDT and dieldrin targets. Cherry Creek and Wipple Wasteway are target compliance points for these pesticides in the water column.

The contributions from Cle Elum and Ellensburg wastewater treatment plants (WWTPs), the point sources, to the suspended sediment load are less than 0.1% of the load. Adjustments to the WWTP NPDES permits are not necessary at this time, and allocations should be consistent with permit load limits. The Cle Elum WWTP should reduce loads by keeping TSS concentrations below 75 mg/L as much as possible. When a new WWTP is built in Cle Elum, NPDES permit limits for TSS should take the TMDL loads into account.

Margin of Safety

The suspended sediment, turbidity, and organochlorine pesticide data have several gaps that require conservative assumptions to create the TMDL targets. Most of these assumptions are considered implicit margin of safety factors, since no load allocation is explicitly assigned to them. The exceptions are the load allocations attributed to unidentified sources along the mainstem, portions of which could be errors in calculation or analytical measurement.

The following assumptions were used that are implicit margins of safety in the data evaluation:

- Background conditions were set only at a single control site on the Yakima River to evaluate turbidity criteria. By using the 90^{th} percentile statistic, approximately 90% of suspended sediment loading and turbidity levels gained downstream of the control site were considered human-caused and, therefore, remediable. As yet, only 10% of the load was implicitly allocated for natural generation of turbidity or suspended sediment.
- Load allocations to the tributaries to meet their turbidity targets will reduce the total suspended sediment loading by more than necessary to meet the estimated mainstem capacity. The final TMDL targets will reduce the loading to the mainstem by an estimated 44%, when only an estimated 35% is needed to meet the loading capacity.
- Compliance with the chronic aquatic toxicity criteria for DDT compounds and dieldrin is measured against a single sample rather than a 24-hour average. This is a conservative approach that assumes the 24-hour average is as high, or higher, than the single sample.
- Maximum organochlorine pesticide concentrations in fish samples were used to set loading capacities and TMDL targets in the mainstem Yakima River, and exposure of fish to pesticides was assumed to be through water contact rather than sediment and food routes.

Compliance Schedule and Monitoring Recommendations

In the TMDL process, a flexible schedule is allowed for compliance with load allocation targets since nonpoint source implementation is not an exact science. Interim targets are compared to monitoring data at regular intervals after best management practices, education programs, and other parts of the implementation strategy have been initiated. As the targets and data are compared, the progress toward improved water quality conditions is assessed, and adjustments or changes in the TMDL strategy are publicly discussed. The goal is to find practical and effective solutions to eliminate the water pollution problems addressed in the TMDL.

The following schedule of target compliance and TMDL-related activities is recommended:

October 2006

- Cherry Creek and Wipple Wasteway water column concentrations of individual DDT compounds, total DDT, and dieldrin will not exceed aquatic toxicity criteria (0.001 ug/L DDT compounds, or total DDT, and 0.0019 ug/L dieldrin).

- Concentrations of total DDT or individual DDT compounds will not exceed 32 ug/Kg wet weight in fish fillet samples collected from the upper Yakima River.

- Dieldrin concentrations in fish fillet samples will be monitored for progress toward meeting a compliance target of 0.65 ug/Kg wet weight. If progress has not been made relative to samples collected in 1999, studies will be undertaken to determine additional sources, transport, mechanisms, and uptake of dieldrin in the basin.

- The 90^{th} percentile of the turbidity values collected at the mouths of the Teanaway River, Manastash Creek, Sorenson Creek at Fogerty Ditch, and Wilson Creek below Cherry Creek will not exceed 10 NTU over the 90^{th} percentile background value established for the site.

- The 90^{th} percentile of the turbidity values collected at the Yakima River at Umtanum (rm 139.8) and the Yakima River at Harrison Bridge (rm 121.7) will not exceed 10 NTU over the 90^{th} percentile turbidity value of samples collected from the Yakima River at Nelson (rm 191).

October 2011

- Cherry Creek and Wipple Wasteway water column concentrations of individual DDT compounds, total DDT, and dieldrin will not exceed human health criteria (0.00059 ug/L DDT or DDE compounds, or total DDT, 0.00083 ug/L DDD, and 0.00014 ug/L dieldrin). If progress has not been made relative to samples collected in 1999 and 2006, additional studies will be undertaken to determine the best ways to prevent transport of dieldrin from the basin soils.

- Dieldrin concentrations in fish fillet samples will make substantial progress toward meeting a compliance target of 0.65 ug/Kg wet weight in the upper Yakima basin.

- The 90th percentile of the turbidity values collected at the mouths of the Teanaway River, Manastash Creek, Sorenson Creek at Fogerty Ditch, Wilson Creek below Cherry Creek, Taneum Creek, and Wenas Creek will not exceed 5 NTU over the 90th percentile background value. The geometric mean turbidity at the mouth of Packwood Ditch will not exceed 5 NTU over the geometric mean turbidity of the background site.

- The 90th percentile of the turbidity values collected at the Yakima River at Umtanum (rm 139.8) and the Yakima River at Harrison Bridge (rm 121.7) will not exceed 5 NTU over the 90th percentile turbidity value of samples collected from the Yakima River at Nelson (rm 191).

The compliance schedule for the upper Yakima TMDL should be synchronized with the lower Yakima and Teanaway TMDLs for coordination of monitoring and evaluation. It is important that all parties in the basin are given a set of compliance dates that are not conflicting or confusing. However, the availability of grant funds for implementation and monitoring activities could complicate coordination efforts.

Kittitas County Conservation District and Kittitas Water Purveyor monitoring and studies in the Cherry and Wilson Creek sub-basin have been helpful for identifying water quality problem areas. These two groups should continue to work together and may want to become the core of a monitoring clearinghouse in the basin. The clearinghouse would encourage close coordination with USBR, Ecology, USGS, and other monitoring performed by government or private groups. The clearinghouse should especially try to include groups working in the Teanaway and other headwater areas. Staff from Central Washington University should also be encouraged to participate. Ties to lower Yakima or basin-wide monitoring efforts may be more efficient through such a clearinghouse.

The following are monitoring needs identified during the course of this TMDL evaluation and recommended for inclusion into the final TMDL monitoring plan:

- Siting background stations in each of the sub-basins with TMDL targets, and monitoring turbidity, total suspended solids, and discharge over two irrigation seasons; or selecting representative basins for monitoring based on land use, geology, or other analytical factors.

- Intensive site placement and monitoring between the Yakima River at Nelson and the USBR Yakima River at Ellensburg gage to identify sources of suspended sediment.

- Tracking and documenting obvious sources of excessive suspended sediment and turbidity in the Cherry and Wilson Creek sub-basin, and in the Sorenson Creek sub-basin.

- Periodic monitoring of organochlorine pesticides from sites in the Cherry Creek sub-basin, and monitoring fish tissue at historical mainstem sites and between Cle Elum and Wymer.

- Designing a monitoring project to better understand uptake rates of organochlorine pesticides by fish in the Yakima basin from various environmental compartments (e.g., food, water, and sediment).

- Designing a monitoring project to track dieldrin transport from contaminated field soils to nearby drains or creeks, in order to better understand the chemodynamics involved.
- Collecting necessary data to construct a spatial model that simulates erosion, sediment, and pesticide transport in irrigated and non-irrigated areas of the basin.

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Appendix A

Goodness-of-fit measures for daily estimates of suspended sediment and turbidity based on discharge to TSS correlations and TSS to turbidity correlations.

Site	Total Suspended Solids		Turbidity	
	RMSE - cv	Nash – Sutcliffe R^2	RMSE - cv	Nash – Sutcliffe R^2
Yakima River at Nelson	43%	0.57	27%	0.7
Teanaway River	24%	0.90	21%	0.95
Yakima River at Thorp	37%	0.73	31%	0.75
Taneum Creek	36%	0.88	--	--
Manastash Creek	34%	0.83	24%	0.73
Yakima River at Irene Rinehart Park	24%	0.59	--	--
Sorenson Creek	45%	0.17	44%	0.07
Wilson Creek	21%	0.45	21%	0.53
Yakima River at Umtanum	18%	0.85	19%	0.87
Yakima River at Harrison Bridge	13%	0.95	25%	0.75

TMDL survey data from 1999 were used to develop the correlations.

Continuously recorded discharge data were used to generate estimated daily concentrations or turbidity values.

Observed and estimated values were paired (n = 14) and the root mean square of the coefficient of variation (RMSE-cv) and Nash-Sutcliffe coefficient were calculated for each generated data set.