Upper Yakima River Basin

Suspended Sediment, Turbidity, and Organochlorine Pesticide

Total Maximum Daily Load Study

Water Quality Effectiveness Monitoring Report

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Water Quality
Effectiveness Monitoring Report

by
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Water Body Number(s):

WRIA 39
Upper Yakima River Watershed

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Abstract

The upper Yakima River watershed is an important water resource in the state of Washington. In 2002, the Washington State Department of Ecology (Ecology) set a total maximum daily load (TMDL) for suspended sediment, turbidity and organochlorine pesticides in the watershed. In 2006, Ecology, the Kittitas County Conservation District (KCCD), and the Kittitas County Water Purveyors (KCWP) collected samples for total suspended solids (TSS) and turbidity analyses from sites throughout the watershed. The resulting data was used to evaluate if TMDL targets were met as a result of the completion of implementation activities in the watershed.

This report describes the first five years of activities following implementation of the TMDL. It also evaluates the data collected by the Washington Department of Ecology, Kittitas County Conservation District, and Kittitas County Water Purveyors to determine if the 2006 TMDL targets are being met. The 90^{th} percentile turbidity values of tributary and main-stem monitoring sites collected in 2006 are compared to 1999 values and to values collected at background monitoring stations in the watershed.

This report shows that implementation of the TMDL is successful so far. The analysis shows that TSS loading and turbidity values were lower in 2006 compared to 1999, but that assigned TMDL targets for turbidity were not met at all sites. TSS values were lower in 2006 compared to 1999, and were lower than the predicted loads required to meet interim turbidity targets. Turbidity targets were met on three out of four tributaries and at all main-stem sites. In order to maintain the success rate of water quality improvement, this study recommends continued implementation of suspended sediment-reducing activities and continued monitoring throughout the Upper Yakima River watershed.

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What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of water bodies – lakes, rivers, streams or marine waters – that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. To develop the list, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data submitted by local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

TMDL process overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the water bodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. Then the local community works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the water body and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete source (referred to as a point source) such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If it comes from a set of diffuse sources (referred to as a nonpoint source) such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation.*

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Water quality assessment/Categories 1-5

The 303d list identifies polluted waters in Washington. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides water bodies into five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – No data available, or insufficient data available.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
    - 4a – Has a TMDL approved and it is being implemented.
    - 4b – Has a pollution control project in place that should solve the problem.
    - 4c – Is impaired by a non-pollutant such as low water flow, dams, culverts.
- Category 5 – Polluted waters that require a TMDL – the 303d list.

Background

The Yakima River is a 5th order stream that runs 215 miles from the outlet of Lake Keechelus in the Cascade Mountains to the Columbia River near Richland, Washington (Snyder and Stanford 2001). The Yakima River watershed is located in south central Washington State (Figure 1) and drains an area of 6,155 square miles. This watershed contains 500,000 acres of some of the most intensively irrigated lands in the United States (Cuffney et al. 2000). The Yakima River watershed is divided into three separate water resource inventory areas (WRIAs).

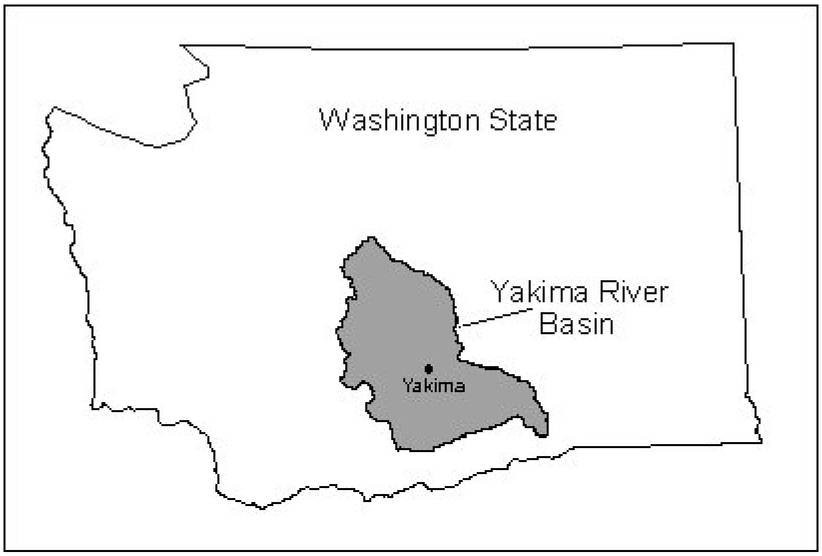


Figure 1. Location of Yakima River Watershed in Washington State[1]

The project area for the TMDL is the upper Yakima River watershed, part of the greater Yakima River watershed. The upper Yakima River watershed is designated WRIA 39. Figure 2 shows a map of the upper Yakima River watershed. This watershed drains an area 2,139 square miles. Elevations range from about 7,000 feet above sea level at the crest of the Cascade Mountains to about 1,000 feet above sea level at the confluence of the Yakima and Naches Rivers. This confluence also forms the upper boundary of the lower Yakima River watershed.

[1] From http://www.ecy.wa.gov/programs/wq/tmdl/yakima_wq/intro.html 10 November 2007

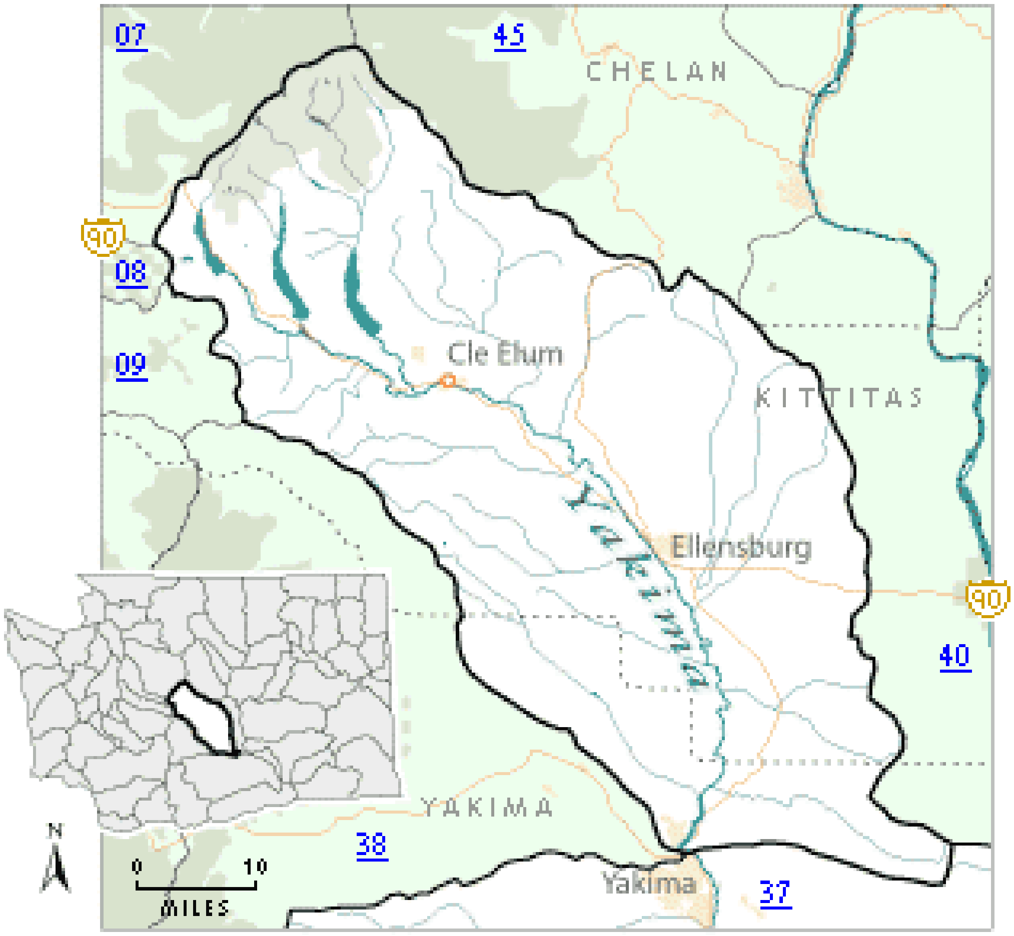


Figure 2. Map of the Upper Yakima River Watershed (WRIA 39)[2]

Land uses in the upper Yakima River watershed vary from wilderness, forestland, livestock range, and intensively irrigated agriculture to urban and suburban areas (Joy 2002). The upper Yakima River watershed is predominately forested (1,153 square miles) in its higher elevations and it contains 85,000 acres of irrigated agriculture in its lower elevations. The majority of irrigated acreage drains to the tributaries of Wilson Creek, Manastash Creek, and Sorenson Creek. Most of the irrigated acreage in the watershed produces forage crops such as alfalfa and timothy hay in addition to sweet corn, potatoes, spring wheat, oats, apples and pears (Joy 2002). Although some irrigation systems on some fields have been converted to sprinklers, most of these crops are irrigated with flood and furrow irrigation.

[2] http://www.ecy.wa.gov/programs/wq/tmdl/tmdls_by_wria/tmdl-wria39.html 10 November 2007

Below the outlet of the Lake Keechelus dam, the main tributaries to the upper Yakima River are the Kachess River, Cle Elum River, and Teanaway River. There are many other smaller tributaries to the upper Yakima River. Of significance to this report are the following tributaries: Wilson Creek, Manastash Creek, Sorenson Creek, and the Teanaway River. Creech and Joy (2002) set targets for these tributaries to be reached by the year 2006.

The United States Department of the Interior's Bureau of Reclamation (USBR) operation of the Yakima Project greatly influences stream discharge volumes in the Yakima River and some of its tributaries. The USBR delivers water to meet downstream demands, such as irrigation, power production, and instream flow for fish protection. To meet these demands, the USBR releases water from three storage reservoirs in the upper Yakima River watershed: Lake Keechelus, Lake Kachess and Lake Cle Elum (Figure 2). All are located in the watershed above the stream gage on the Yakima River at Cle Elum (USBR 2002). Some of the water released from the reservoirs meets irrigation demand in the upper Yakima River watershed. However, much of the released water flows down the Yakima River through the project area to meet irrigation demands in the lower Yakima River watershed.

Irrigation water diversions and snowpack runoff also have a significant influence on stream discharge in the project area. Factors affecting stream discharge levels include:

- Amount of snowpack in the mountains above and below reservoirs
- Time of year
- Demand for water from irrigation and power production projects

The Kittitas Reclamation District (KRD) is the only irrigation district in the upper Yakima River watershed that receives and delivers a contracted amount of water from USBR operations. The non-USBR contracted irrigation districts in the project area include the Ellensburg Water Company, Cascade Irrigation District, and the West Side Irrigation Company. Additionally, several water rights holders divert water from tributaries such as the Teanaway River, Manastash Creek, and Taneum Creek (Joy 2002). The Roza Irrigation District (RID) diverts water from the Yakima River in the upper Yakima River watershed, but does not use the water until 11 miles downstream in the Roza Canal, in the lower Yakima River watershed (USBR 2002).

Many operational objectives of the USBR Yakima Project cause the Yakima River to sustain predictable discharge volumes during the irrigation season. However, these discharge volumes are often outside of a normative hydrograph for the Yakima River. For example, as a result of a 1980 Federal District Court order, named the Quackenbush Decision, the USBR adopted the "Flip-Flop" operations scenario to improve salmon spawning habitat. The Flip-Flop regime reduces discharges from upper Yakima River reservoirs in September and October by as much as 3,000 cubic feet per second (cfs). Increased reservoir releases in the Naches River watershed then make up for the reduced releases from the upper Yakima River reservoirs.

The USBR interim operating plan (USBR 2002) states, "the mission of the Yakima Project operations has primarily been to supply water for irrigation in the Yakima Basin. This activity often results in low water levels in the lower main stem of the Yakima River in the summer and fall and abnormally high flows in reaches of the upper main stem." The higher discharge volumes in the upper Yakima River during July and August generally have a lower turbidity because of dilution from reservoirs, but carry higher loads of suspended sediment because of the larger flow volume.

Water quantity for consumptive uses is considered a valuable resource in the Yakima River watershed. However, designated in-stream uses such as salmonid rearing, spawning, and migration are also valuable. Snyder and Stanford (2001) noted that "the Yakima River Basin, Washington, historically sustained diverse and abundant salmon and steelhead runs". Salmon and steelhead returns to the Yakima River watershed have declined from an estimated several hundred thousand in the 1800s to 3,330 in 1995. Snyder and Stanford (2001) identified five roadblocks to salmon recovery in the Yakima River watershed, two of which are water quality impairments. One water quality impairment identified by Snyder and Stanford (2001) is the alteration of the natural temperature regime. The other impairment is linked to increased nutrient levels, and increased levels of suspended sediment carrying pesticides to Yakima River tributaries.

In 1999, Ecology conducted an assessment of suspended sediment, organochlorine pesticides, bacteria, and metals in the upper Yakima River basin. In 2002, the *Upper Yakima River Basin Suspended Sediment and Organochlorine Pesticide TMDL Evaluation* (*TMDL Evaluation*) (Joy, 2002) was completed by Ecology and the *Upper Yakima River Basin Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL: Submittal Report (TMDL)* (Creech and Joy, 2002) was approved by the US Environmental Protection Agency. A detailed implementation plan for this TMDL was completed in 2003.

Water Quality Standards and Beneficial Uses

A state's 303(d) list is an inventory of water bodies that do not meet state water-quality standards. Ecology completes TMDL projects that set pollutant reduction targets for each 303(d) listing. The 303(d) listings that prompted the *TMDL Evaluation* (Joy 2002) were for the organochlorine pesticides DDT, its metabolites 4,4'-DDE and 4,4'-DDD, and dieldrin in water and in fish tissue.

The State of Washington water quality standards (WAC 173-201A) uses the National Toxic Rule (NTR) (40CFR 131.36) as water-quality criteria for DDT, 4,4'-DDE, 4,4'-DDD and dieldrin. For DDT, the NTR limit in water is 0.59 ng/L, for 4,4'-DDE it is also 0.59 ng/L, while 4,4'-DDD has a limit of 0.83 ng/L and dieldrin has a limit of 0.014 ng/L.

Rogowski (2000) provided fish tissue monitoring results from the Yakima River that showed dieldrin, DDT, and DDT breakdown products were lower in 1999, compared to sample results from the 1980s. Nonetheless, fish tissue analysis showed that the dieldrin, DDT and DDT breakdown products still violated standards.

Historical data were used to place several water bodies on the 1998 303(d) list for violations of state water-quality standards for these organochlorine pesticides. Included in the historical data are findings by the United States Geological Survey (USGS) National Water Quality Assessment (NAWQA) program and by Johnson, Norton, and Yake (1986), The 1998 303(d) listings investigated by the *TMDL Evaluation* (Joy 2002) are presented in Table 1.

Table 1. The 1998 303(d) Listings Prompting the Upper Yakima River Basin Suspended Sediment, Turbidity and Organochlorine Pesticide TMDL

Water body Name	Parameter	Medium (Fish Tissue or Water)
Yakima River	4,4'-DDE	Tissue
Yakima River	4,4'-DDE	Tissue
Yakima River	DDT	Tissue
Yakima River	DDT	Tissue
Yakima River	Dieldrin	Tissue
Cherry Creek	4,4'-DDE	Water
Cherry Creek	DDT	Water
Cherry Creek	Dieldrin	Water

Joy and Patterson (1997) observed a strong correlation between suspended sediment concentration (measured as total suspended solids or TSS) and total DDT concentration in surface water samples from the lower Yakima River watershed, where the primary land and water use is irrigated agriculture. Joy and Patterson (1997) also showed that turbidity and suspended sediment were correlated across a large range of TSS concentrations in the lower Yakima River watershed. Joy and Patterson (1997) predicted TSS and DDT concentrations for a series of turbidity targets.

Although the 1998 303(d) list did not include turbidity in the upper Yakima River watershed, turbidity and TSS were investigated as part of the TMDL study (Joy 2002) because of their relationship to the organochlorine pesticide DDT in the lower Yakima River watershed (Joy and Patterson 1997). The USGS NAWQA reports correlated organochlorine pesticide sources with irrigated agricultural activities (Rinella et al. 1992; Morace et al. 1999). Joy (2002) recorded violations of the state numeric turbidity criteria and documented TSS concentrations that occurred at durations that could harm aquatic communities, specifically salmonids.

Washington State water-quality standards are set for the protection of beneficial uses in waters of the state. The standards designate beneficial uses and apply numeric criteria that protect those beneficial uses. The state standards set a limit of no more than 5 NTU increase in turbidity over background conditions in the upper Yakima River and its tributaries in order to protect the beneficial uses provided in Table 2 (WAC 173-201A 2006).

Table 2. State Water-quality Standards Use Designations and Water Bodies Where They Apply in the Upper Yakima River Watershed

Beneficial Use	Water Bodies
Core Summer Habitat for Salmonids	Yakima River above the Cle Elum River Teanaway River main stem Manastash Creek
Salmonid Spawning and Rearing	Yakima River below Cle Elum River and its tributaries

Turbidity

Turbidity is a measure of light refraction in the water, and is related to the amount of sediment and suspended solids in the water. Fish and other aquatic life are affected by suspended solids in the water column and sediment that has settled out on the bottom of the water body. Effects are similar for both fresh and marine waters.

The effects of suspended solids on fish and other aquatic life can be divided into four categories:

1. Acting directly on the fish swimming in the water and either killing them or reducing their growth rate, resistance to disease, and the like.
2. Preventing the successful development of fish eggs and larvae
3. Modifying natural movements and migrations
4. Reducing the supply of available food

Suspended solids may also carry chemical and biological contaminants to water bodies, where these pollutants can be taken up in the tissue of fish. Humans or wildlife that eat the contaminated fish can become sick as a result.

Turbid waters also interfere with the treatment and use of water as potable water supplies. High turbidity can also interfere with the recreational use and aesthetic enjoyment of the water.

The turbidity criteria in the state water quality standards are primarily established to protect aquatic life. Two different turbidity criteria are established to protect six different categories of aquatic communities (WAC 173-201A-200):

1. To protect the designated aquatic life uses of “Char,” “Salmon and Trout Spawning, Core Rearing, and Migration,” “Salmon and Trout Spawning and Noncore Rearing,” and “Non-anadromous Interior Redband Trout,” turbidity must not exceed: A) 5 NTU over background when the background is 50 NTU or less; or B) a 10% increase in turbidity when the background turbidity is more than 50 NTU.

2. To protect the designated aquatic life uses of “Salmon and Trout Rearing and Migration Only” and “Indigenous Warm Water Species” turbidity must not exceed: A) 10 NTU over background when the background is 50 NTU or less; or B) a 20% increase in turbidity when the background turbidity is more than 50 NTU.

TMDL Summary

TMDL evaluation: 1999 conditions

The TMDL Evaluation (Joy 2002) assessed historical TSS, turbidity, organochlorine pesticide and discharge data collected in the upper Yakima River watershed. In addition, Joy (2002) performed monitoring of these parameters in the project area during April through October 1999. Joy concluded that, if applied to the main stem of the Yakima River at each tributary, the Washington State turbidity criteria are inadequate for basin-wide control of suspended sediment loading. That is to say, the cumulative impact of a 5 NTU turbidity increase from each tributary would fail to protect aquatic organisms in the Yakima River. In other words, setting a background condition for turbidity above each tributary of the main stem Yakima River would not adequately control suspended sediment on a basin-wide scale. In addition, the long "duration of elevated suspended sediment concentrations in the lowest main stem 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 [United States Environmental Protection Agency (USEPA)] guidance levels and scientific literature"(Joy 2002).

The historical data evaluation presented by Joy (2002) suggested that TSS and turbidity came from different areas on a seasonal basis. From November through March, there is little excess loading of suspended sediment to the Yakima River from its tributaries. During the early irrigation season, i.e. April through June, a large percentage of suspended sediment measured at the Yakima River at Umtanum station is a result of suspended sediment loading from the Teanaway River snowmelt season. During the period from July through October, the primary sources of suspended sediment are high volume reservoir releases and erosion from irrigated fields in tributary watersheds such as Wilson Creek (Joy 2002). Sediment loads from irrigated agricultural return flows, such as from Wilson Creek, Sorenson Creek, and Manastash Creek were high during most of the irrigation season, but made up a smaller portion of the total sediment load during the April through June run-off period.

Joy (2002) evaluated turbidity, TSS, and discharge data collected from six main-stem sites in 1999. The most upstream sampling site was named the Yakima River at Nelson. Samples were taken out of the Yakima River from the Interstate-90 bridge at river mile (RM) 191.1. The next downstream site was the Yakima River at Thorp Road Bridge, then the Yakima River at Kampgrounds of America (RM 155), the Yakima River at Irene Rinehart Park (RM 153.1), Yakima River at Umtanum (RM 139.8) and Yakima River at Harrison Road Bridge (River Mile 121.7). The Yakima River at Harrison Road Bridge was the most downstream sampling site on the Yakima River main stem.

The average monthly discharge in the Yakima River at Umtanum during the TMDL evaluation in 1999 was higher than average during the early irrigation season and lower than average from July through October. This was based on records collected since 1980, when the USBR began operating the Yakima Project according to the "Flip-Flop" operational scenario.

Joy (2002) showed that TSS and turbidity values in the upper Yakima River generally increased downstream from the Yakima River at Nelson to the Yakima River at Harrison Road. Table 3 shows the median, range, and 90th percentile values for TSS and turbidity samples collected from the main stem Yakima River during April through October 1999.

These results indicate that, in general, the historical pattern of seasonal sediment release still prevailed. However, in 1999 an increased suspended sediment load was observed coming from the Teanaway River well into the month of June. This may have been due to a larger than average Teanaway snowpack that took longer than average to melt.

Table 3. Median, Minimum, Maximum and 90th Percentile Values for Total Suspended Solids and Turbidity in the Main Stem Upper Yakima River During the 1999 Irrigation Season (from Joy 2002)

Site Name	Total Suspended Solids Measured in mg/L*				Turbidity Measured in NTU**			
	Median	Min	Max	90th percentile	Median	Min	Max	90th percentile
Yakima River @ Nelson	3	<1	15	13	1.6	0.6	11	7.5
Yakima River a@ Thorp Road Bridge	6	<1	49	33	2.2	<0.5	26	17.0
Yakima River @ KOA	5	2	52	31	2.6	.8	26	17.7
Yakima River at Irene Rinehart Park	8	2	49	29	2.7	0.9	24	18.7
Yakima River at Umtanum	14	3	43	35	4.5	1.4	23	20.4
Yakima River at Harrison Road Bridge	11	2	46	41	4.7	1.2	24	20.2

*mg/L = milligrams per liter
** NTU = nephelometric turbidity units, a measure of waters cloudiness

Joy (2002) showed that the largest increase in the turbidity and TSS 90th percentile statistics occurred between the Yakima River at Nelson and the Yakima River at the Thorp Road Bridge. This site is below the influence of the Cle Elum River, Teanaway River, and Swauk Creek. The largest overall increase in median TSS values occurred between the Yakima River at Irene Rinehart Park and the Yakima River at Umtanum. This portion of the river receives irrigation return flows from the Wilson Creek watershed and from Sorenson Creek. Turbidity values dropped below 5 NTU at all of the main stem sampling sites during the July through October sampling period, but still showed an increase in turbidity in a downstream direction (Joy 2002).

The tributary monitoring results from Joy (2002) are presented in Table 4. Three sites located upstream of the influence of irrigated agriculture in the Wilson Creek watershed were sampled to estimate the background turbidity value of the tributaries. They were located on Naneum Creek, Cooke Creek, Coleman Creek, and Schnebly Creek. A summary of sampling results for these sites is displayed in Table 5.

Joy (2002) showed that the upper Yakima River main stem was in violation of state turbidity standards on many occasions from April through June 1999. "The Yakima River sites at Irene Rinehart Park, Umtanum and Harrison Road all had 90th percentile values higher than 10 NTU over the background 90th percentile value for the Yakima River at Nelson." All main stem Yakima River sites increased 7 to 17 NTUs over background turbidity on 20 April, 1 June and 15 June 1999. Three other exceedences of 5 NTU over background occurred at the Yakima River at Umtanum and the Yakima River at Harrison Road sites during the 1999 sampling. However, no state turbidity standard violations in the Yakima River main stem occurred during the sampling period after June 1999 (Joy 2002).

Table 4. Results From 1999 Tributary Sampling of Median, Minimum, Maximum and 90th Percentile TSS and Turbidity (from Joy 2002)

Site Name	TSS Measured in mg/L				Turbidity Measured in NTU			
	Median	Min	Max	90th percentile	Median	Min	Max	90th percentile
Cle Elum River at Bullfrog Road	1	<1	3	3	0.9	<0.5	1.3	1.2
Crystal Creek near mouth	3	<1	10	5	1.8	0.6	7.5	3.7
Teanaway River at Hwy 10[1]	2	<1	78	49	1.1	<0.5	33	26.0
Swauk Creek at Hwy 10	2	<1	71J	16	2.0	<0.5	40	9.5
Taneum Creek 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 Creek at Brown Road[1]	9	1	49	32	6.7	1.2	22	19.2
Dry Creek at Hwy 10	2	<1	19	4	1.4	0.6	10	2.5
Reecer Creek in Irene Rinehart Park	5	2	32	9	4.0	1.3	14	7.7
Fogarty Ditch/Sorenson Creek below confluence[1]	14.5	6	139	38	9.8	5.1	70	21.8
Wilson Creek at Canyon Road[1]	37	10	132	54	15.5	4.9	43	24.8
Umtanum Creek above Railroad Bridge	2	<1	6	5	1.2	0.7	17	3.4
Wenas Creek at Buffalo Road	7	3	98	39	3.5	2	24	13.4
[1]Tributaries with targets set by the *TMDL* for the year 2006								

Table 5. Statistics for the Results Combined from Background Sites, Naneum Creek, Cooke Creek, Coleman Creek, and Schnebly Creek

Site Name	TSS Measured in mg/L				Turbidity Measured in NTU			
	Median	Min	Max	90^{th} percentile	Median	Min	Max	90^{th} percentile
Combined result of background sites	4	<1	55	16	2.6	<0.5	25	7.5

April through October is the critical season for turbidity and suspended sediment in the upper Yakima River watershed. Irrigation season usually begins in mid-April and ends in mid-October. Snowmelt runoff usually begins in lower elevations in April and runs through June in higher elevations. Increased discharge results throughout the watershed. Creech and Joy (2002) stated that "analysis performed on data from the upper Yakima basin indicates the months of greatest concern for human-caused turbidity, suspended sediment loading, and pesticide transport is April through October. Turbidity and suspended sediment loads are usually lower outside of this period except during storm events …. Therefore, the critical season for TMDL evaluation and compliance is the period of April through October." April through October is also when several beneficial uses are potentially impaired by increased turbidity, TSS, and organochlorine pesticide loading in the Yakima River. Particularly high levels of turbidity and TSS are found April through June when Chinook salmon fry emerge and steelhead eggs incubate (Joy 2002).

Joy (2002) developed several mathematical relationships to evaluate the TMDL data and to set load allocations that would achieve water-quality standards for turbidity. For this TMDL, Ecology relied on the USEPA-approved method used in the Lower Yakima River TSS and DDT TMDL documentation (Joy and Patterson 1997). This method allows a 90^{th} percentile background turbidity value at a selected control point for the main stem Yakima River, and 90^{th} percentile compliance of a specified NTU increase at all downstream points.

A tributary-based control methodology was selected to be utilized by Joy (2002) for two main reasons:

1. The actual amount of control regarding turbidity at each tributary may be quite variable
2. Setting a background limit in the main stem based above and below each tributary would not be protective of aquatic life,

Joy showed that:

> IF tributaries met state turbidity standards by meeting 90^{th} percentile turbidity values equal to or less than 5 NTU over their background values,
>
> THEN the main stem Yakima River would not increase more than 5 NTUs over its background value established on the Yakima River at Nelson.

The 90th percentile value was chosen as the target for turbidity to limit the duration of turbidity events, and to be consistent with targets set for turbidity in the *Lower Yakima TSS TMDL* by Joy and Patterson in 1997 (Joy 2002).

Joy (2002) used the Beales Ratio Estimator to estimate daily loads in tons per day of TSS from each tributary and at each main stem monitoring location. The concentrations of TSS and turbidity were highly correlated during the critical season. The statistical theory of roll-back (STR) (Ott 1995) was used to estimate the turbidity reductions required to meet the TMDL targets at the mouths of some tributaries for the *TMDL Evaluation* (Joy 2002). Using STR allowed for calculating a statistical estimate of future turbidity results after the targets were met. In this case, the estimates of future results were based on a 10 NTU increase from background conditions in 2006 and a 5 NTU increase from background conditions in 2011. Then, Joy used the regression equations to convert turbidity values to TSS values. Finally, he used the TSS values to estimate the tons per day that would result from the reductions in TSS and turbidity. These tons per day estimates, as well as the TSS relationship with turbidity in the Yakima River, were used to verify that the Yakima River sites would meet turbidity targets.

To meet the 2006 targets, Joy (2002) predicted that landowners in the tributary watersheds would need to accomplish the load reductions presented in Table 6. These loading limits were presented as the loading capacity in the *TMDL* by Creech and Joy (2002).

Table 6. The 1999 Total Suspended Solids Loads and Reductions in Tons Per Day Estimated in Order to Meet 2006 Targets (from Joy 2002)

Site	1999 Load (tons day^{-1})	Mainstem only + 5 NTU	Tributary-based 2006 target
Yakima River at Nelson	14	14	14
Teanaway River	77		43
Manastash Creek	4.4		4.2
Sorenson Creek	3.2		2.7
Wilson Creek	71		47
Yakima River at Umtanum	215	140	159
Yakima River at Harrison Bridge	131	87	98
Estimated % Reduction Needed from 1999 Conditions		35	26

The targets presented below are the interim (2006) targets for turbidity on the main stem Yakima River and in certain tributaries. Tributaries monitored for this project to evaluate the tributary goal were Wilson Creek, Sorenson Creek at Fogarty Ditch, Manastash Creek, and the Teanaway River.

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

- The 90th percentile turbidity values collected at the Yakima River at Umtanum (RM 139.8) and the Yakima River at Harrison Bridge (RM121.7) will not exceed 10 NTU over the 90th percentile turbidity value of samples collected from the Yakima River at Nelson (RM 191).

Creech and Joy (2002) identified turbidity as a water-quality impairment that is also a result of increased TSS concentrations in the upper Yakima River and some of its tributaries. As stated earlier, the original purpose of the TMDL report was to address 303(d) listings for organochlorine pesticides. Below are observations presented by Joy (2002) regarding organochlorine pesticide results compared to TSS concentrations and total organic carbon content of samples:

- The strongest correlation between DDT and turbidity occurred in the Wipple Wasteway. The Wipple Wasteway is a tributary to Wilson Creek via Cherry Creek. It carries mostly operational spill water from irrigation delivery ditches and return flows from irrigated fields. The adjusted coefficient of determination (r-squared value) was 0.56 with a significance level of alpha = 0.9.

- 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 below20 mg/L.

- Dieldrin and total DDT were not detected in the Wipple Wasteway when TSS concentrations were below 20 mg/L.

- A threshold for total DDT and dieldrin appearance in Cherry Creek and Wipple Wasteway samples appear to occur at TSS concentrations between 20 and 35 mg/L.

- By reducing TSS concentrations in Cherry Creek and Wipple Wasteway, which are tributaries to Wilson Creek, Joy (2002) reasoned that the concentrations of organochlorine pesticides should be below detection.

Watershed implementation or restoration activities

To reach the 2006 targets set in the *TMDL* (Creech and Joy 2002), suspended sediment loading from a variety of sources needed to be reduced. Joy (2002) and Creech and Joy (2002) identified several ongoing and potential sources of suspended sediment and turbidity to the upper Yakima River and its tributaries. These sources included forest roads, timber harvest activities, recreational use, and livestock grazing. In addition, suspended sediment loading can increase as a result of surface irrigation (Joy 2002). This has been observed in many fields in and out of the Yakima River watershed. Urban and construction storm water are other possible sources of suspended sediment to the Yakima River and its tributaries.

Creech (2003) prepared the detailed implementation plan (DIP) for the TMDL which outlined a strategy for meeting the 2006 interim targets and for meeting the 2012 final targets. The DIP outlined voluntary measures necessary to control the wide range of potential sediment sources in the watershed. It presented existing laws and legal agreements that, if enforced, would help prevent suspended sediment from entering the upper Yakima River and its tributaries. The DIP also presented a monitoring strategy for tracking implementation and for tracking the resulting water quality expected from implementation activities.

Many agencies and individual landowners have supported implementation of the DIP in various ways. Ecology staff provided technical assistance to project participants and sponsored annual meetings in the Kittitas Valley and the Teanaway River watershed to coordinate and track implementation. In addition, Ecology maintained a Memorandum of Agreement (MOA) with the USDA-Forest Service (USFS) to reduce pollutant loading to streams in the state of Washington from USFS-related activities. Ecology staff supported grant applications for projects in the Teanaway River watershed and in lower Kittitas County irrigated lands. As a result of this support, Ecology's Centennial Clean Water Fund and 319 Grant Program was utilized for three projects completed by local partners in the watershed (KCCD 2004; KCWP 2005; KCCD 2007). Also, Ecology staff wrote the Quality Assurance Project Plan (QAPP) for this effectiveness monitoring project (Creech 2006) and led the sampling effort to collect data for this report.

The KCCD has a long history of providing technical assistance to farmers who want to reduce erosion from their land. They have assisted with various implementation projects in the upper Yakima River watershed. They have provided irrigation planning assistance, cost share for implementation of best management practices (BMPs), and have conducted water-quality monitoring in the lower portion of the project area. They have also conducted extensive monitoring and provided technical and financial assistance to conduct implementation of BMP use in the Teanaway River watershed. The KCCD works in partnership with the United States Department of Agriculture's Natural Resource Conservation Service (NRCS) and Farm Service Agency (FSA) to provide technical, financial, and monitoring assistance for water quality protection.

Joy (2002) identified the Teanaway River watershed as the primary source of suspended sediment loading to the Yakima River during the first half of the April through October irrigation season. The KCCD (2004) reported that suspended sediment and turbidity in the Teanaway River could be attributed to serious soil erosion that occurs in the West, Middle, and North Fork of the Teanaway River. The high rates of erosion in the Teanaway River watershed are a result of forest roads, timber harvest, cattle grazing, unstable stream banks, and channel downcutting (KCCD 2004; KCCD 2007). Creech (2003) recommended the following activities occur to reduce soil erosion in the Teanaway River watershed and similar areas throughout the upper Yakima River watershed:

- Protect Riparian Vegetation and where possible, restore native riparian vegetation.
- Conduct outreach and education to riparian land owners regarding prevention of stream bank erosion.
- Avoid actions that will cause streambank erosion.
- Continue to monitor water quality in the area.
- Maintain roads and roadside ditches in order to prevent sediment from entering area water bodies.
- Implement livestock management BMP that prevent stream bank erosion.
- For the USFS and the Washington Department of Natural Resources (WDNR), implement appropriate working agreements with Ecology. For the USFS this is a MOA between the USFS and Ecology. For the WDNR this is the Forest and Fish Rules.

The KCCD has completed two grant-funded projects in the Teanaway River watershed that included stream bank stabilization and sediment-loading-reduction components. The KCCD (2004) reported planting 2,000 trees in the riparian zone of two different properties on the main stem Teanaway River. Also, KCCD (2004) completed the installation of two center pivot irrigation systems on approximately 100 acres of agricultural land formerly irrigated with furrow irrigation. In addition, this project replaced approximately 2.5 miles of earthen irrigation delivery ditch with pressurized irrigation delivery systems to approximately 200 acres of land near the main stem Teanaway River. By replacing the earthen ditch, the project was able to leave approximately 3.5 cfs in the river and eliminate one in-stream diversion structure.

In 2007, the KCCD reported completing more projects in the Teanaway River watershed. They completed three riparian vegetation planting projects on the North Fork of the Teanaway River, two riparian planting projects on the Middle Fork of the Teanaway River and one riparian planting project on an un-named tributary to the main stem Teanaway River. In addition, the KCCD assisted with the installation of root wads to protect a section of the bank of the North Fork Teanaway River from eroding.

The KCCD completed outreach and education in the Teanaway River watershed by sending newsletters to all of the residents in the Teanaway River watershed. Ecology also conducted outreach programs by conducting stream surveys in the watershed with landowners. In addition, Ecology installed information signs in the watershed encouraging visitors to the area to take care when in riparian zones (KCCD 2007).

Joy (2002) identified Wilson Creek as the primary source of suspended sediment to the Yakima River during the second half of the April through October irrigation season. Wilson Creek's flow volume is almost 100% irrigation return flow in the latter half of the irrigation season. Therefore, much of the suspended sediment load in Wilson Creek can be attributed to irrigation practices during this period (KCWP 2005). Sorenson Creek and Manastash Creek can also experience high levels of turbidity and contribute suspended sediment to the Yakima River throughout the irrigation season (Joy 2002; KCWP 2005).

Creech 2003 identified the following activities required to be completed in areas with irrigated agriculture to lower suspended sediment and turbidity levels in the lower Teanaway River, Wilson Creek, Sorenson Creek, and Manastash Creek.

- Avoid actions that will cause streambank destabilization and add sediment to area waterways.
- Implement appropriate BMP to prevent entry of TSS-laden irrigation return flows into area waterways.
- Administer public education programs for Kittitas Valley Irrigators, other land owners and resource users.
- Fund cost-assistance programs for irrigation BMP installation and use.
- Implement Livestock Management BMP use to prevent streambank erosion.

The KCCD has also completed several projects in the heavily irrigated areas that are drained by Wilson Creek, Manastash Creek, and Sorenson Creek. These include a cost-share program for polyacrylamide (PAM) use. The PAM is added to irrigation water and causes suspended sediment to flocculate out of suspension. In addition, it creates larger pores between soil particles and allows irrigators to more evenly soak their fields with less flow volume in each furrow. The PAM is used by many irrigators in the upper Yakima River watershed to reduce soil erosion from irrigated cropland. Table 7 presents participation information for the PAM Cost Share Program.

Table 7. Acres Per Year Enrolled in KCCD's PAM Cost Share Program and Estimated Tons of Soil Saved Per Year

Year	Acres Enrolled	KCCD's Estimate of Tons of Soil Saved Per Year by PAM Cost Share Program
1999	933	1314
2000	1566	7562
2001	2737	12418
2002	1928	9774
2003	1702	8190
2004	1787	8599
2005	2145	7353
2006	3358	11180

The KCCD provided Ecology staff with a list of all of the individual projects that KCCD and NRCS completed in order to implement recommendations of the TMDL. In total, they have assisted with the conversion of approximately 3,550 acres of rill irrigated cropland to sprinkler irrigated cropland. In addition, they have helped install gated pipe irrigation systems to 2,653 acres of cropland. Gated pipe allows an irrigator to better control the flow volume of irrigation water delivered to a field. KCCD reported assisting with the installation of buried pipe as a replacement to earthen ditches for 1,095 acres of irrigated cropland, which allows growers to receive water in a more controllable delivery mechanism. Some of the acreage reported includes acreage of BMPs used in the Teanaway River watershed, the Wilson Creek watershed, and the Manastash and Sorenson Creek watersheds. Table 8 outlines work completed by the KCCD using acres per year to track progress.

Table 8. Summation of BMP Application to Irrigated Agriculture for 2003 Through 2006 Estimated by the KCCD

	Acres				
Year	2003	2004	2005	2006	Total Acres
Buried Pipe Installed	647	82	237	127	1095
Gated Pipe Installed	1786	371	0	496	2653
Sprinklers Installed	1825	227	767	729	3549
PAM Cost Shared	1702	1787	2145	3358	8992
				TOTAL	16289

The KCWP also conducted projects in the Wilson Creek, Manastash Creek, and Sorenson Creek watersheds between March of 2002 and November of 2004. The KCWP performed various outreach activities, and presented information on irrigation BMP use to various audiences. They completed one erosion control project at People's Pond in the Yakima River floodplain near Ellensburg. They also completed a riparian fencing project at the downstream end of one of the Kittitas Reclamation District's delivery ditches. This project reduces bank erosion from cattle grazing near this water body.

Irrigation districts and companies within the service area of the KCWP adopted a water quality policy intended to help increase awareness of turbidity and suspended sediment problems generated by individual fields. The KCWP policy provides specific steps for an irrigator with a discharge of 300 NTU or more to follow to avoid being reported to Ecology.

The KCWP also conducted extensive water quality monitoring in irrigation canals and tributaries that return irrigation water to the Yakima River. These data are useful for tracking year-to-year changes in turbidity and TSS concentrations in project waterways at temporal and spatial scales that are more refined than the five-year effectiveness monitoring conducted by Ecology.

The USFS improved riparian areas and stream habitats in the Teanaway River watershed between 2000 and 2004. They improved 40 acres of riparian areas by placing boulders in areas that would prevent motorized vehicles from accessing floodplains and de-compacted soils that had been hardened by vehicle access. They placed large woody debris in riparian areas to increase bank stability and planted native riparian vegetation. The USFS also decommissioned 0.4 miles of roads in the Teanaway River watershed[3]. In addition, the USFS posted educational signs and provided a roving educator through the Respect the River program that educated people recreating in the Teanaway River watershed of the importance of protecting stream corridors.

The Yakima Training Center, a military training center in the southeast portion of the project area, and the Washington Department of Transportation (WDOT) continued implementation of erosion control programs, but Ecology did not have any specific information regarding the programs.

Table 9 summarizes the implementation actions completed for the TMDL. Policies were changed, and education and outreach were used to increase the public's awareness of the problems causing elevated turbidity. Various entities provided money to assist with demonstration and installation of BMPs adopted by irrigators. Funding sources included government agencies, as well as individuals and land management agencies taking responsibility to improve water quality in the upper Yakima River watershed.

1 Electronic mail message from R. D. G. Wassell, USFS Fish Biologist, Cle Elum, WA, 14 December 2007

Table 9. Summary of Implementation Activities for the Upper Yakima River Basin Suspended Sediment, Turbidity and Organochlorine Pesticide TMDL (from various sources reported above)

Public Education Programs	
2002	Public Involvement by Ecology for TMDL Submittal
2003	Public Involvement by Ecology for TMDL Detailed Implementation Plan Ecology installed informational signs in Teanaway River watershed
2004	KCWP Public outreach and education
2005	USFS Respect the River Program
2006	KCCD outreach program in Teanaway River watershed
Implementation of Sediment Reduction Best Management Practices	
2002	
2003	7963.9 acres
2004	4471.3 acres
2005	5155.2 acres
2006	6716.8 acres
Road Improvements By Large Acreage Forest Owners and Managers	
2002	
2003	USFS Respect the River Program
2004	
2005	
2006	USFS Removed and restored a section of road on Standup Creek, replaced culvert with bridge
Re-vegetation of Stream Banks and Stream Bank Stabilization	
2002	
2003	KCCD planted 2000 riparian plants on two properties in the Teanaway River watershed KCWP- completed Eaton Project and People's Pond Project
2004	
2005	KCCD completed riparian planting projects on 6 properties throughout the Teanaway River watershed
2006	

Goals and Objectives

Project goals

Determine the effectiveness of TMDL implementation actions between 2002 and 2006 to meeting the 2006 TMDL targets for turbidity.

Study objectives

The following tasks were undertaken in order to meet the projects goals:

1. Review the objectives of the *Upper Yakima River Basin Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL* and supporting documents:
    a. *Upper Yakima River Basin Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL Evaluation* (Joy 2002)
    b. *Upper Yakima River Basin Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL Submittal Report* (Creech and Joy 2002)
    c. *Upper Yakima River Basin Suspended Sediment, Turbidity, and Organochlorine Pesticide TMDL Detailed Implementation Plan* (Creech 2003)

2. Review and describe the implementation activities completed for the TMDL.

3. Use data collected by Ecology, KCCD, and KCWP in 2006 to calculate 90^{th} percentile turbidity values for tributaries and main-stem sites and determine whether or not the 2006 tributary and main stem targets for turbidity were met.

4. Provide recommendations that will help the upper Yakima River watershed meet 2012 TMDL targets.

Methods

During April through October of 2006, Ecology, KCWP and KCCD all collected water samples for turbidity and TSS at fixed sites according to the *Quality Assurance Project Plan for Suspended Sediment and Turbidity Total Maximum Daily Load Effectiveness-Monitoring Project in the Upper Yakima River Basin (QAPP)* prepared by Creech (2006) and, according the each organization's individual plan.

The QAPP was designed to use sampling methods, site locations, and data analysis techniques similar to those used in the initial TMDL evaluation by Joy (2002). The monitoring sites for this study were chosen based on recommendations of Joy (2002) and Creech and Joy (2002). Some sampling sites were located at slightly different locations than in 1999 to improve safety of the sampling staff (Creech 2006).

To characterize turbidity and TSS in the upper Yakima River, Ecology collected turbidity and TSS samples from four different main stem sites. The study used the Yakima River site at Nelson (RM 191.0) as the main stem Yakima River background site. For this study, samples were taken from the John Wayne Trail Bridge, 0.1 miles downstream of the Interstate-90 Bridge. The Interstate-90 Bridge was used in the 1999 data collection, but not in this study's data collection for safety reasons. Ecology also collected samples from the Yakima River at Irene Rinehart Park (RM 153.1), Yakima River at the Umtanum Walkway (RM 139.8), and Yakima River at Harrison Road Bridge (RM 121.7). Sample collection from the Yakima River at Irene Rinehart Park did not begin until 16 May 2006. However, Ecology collected samples at all the rest of their sites at least every other week from 4 April 2006 until 31 October 2006.

The TMDL evaluation (Joy 2002) determined tributary background turbidity values by compiling results from three upstream tributary sites in the Wilson Creek drainage. The 2006 effectiveness monitoring study used three different sampling sites to better represent background turbidity values of each tributary monitored. One background station was sampled in the Teanaway River watershed (Teanaway River at North Fork). A second background station was sampled on the upper Manastash Creek (Manastash Creek at Manastash Road) to determine background conditions for Manastash Creek at Brown Road and Sorenson Creek at Fogarty Ditch. One background site from the original study was sampled again in 2006; this site is located at Naneum Creek at Naneum Road. Naneum Creek at Naneum Road is the background site for Wilson Creek (Creech 2006).

Ecology generally followed the same schedule as the two other organizations for sampling main stem sites and tributary background sites as directed in the QAPP. They collected samples on the dates described in Table 10 under the column tributary and background sites.

The KCWP collected samples at three compliance monitoring sites identified in the TMDL. These sites were named Wilson Creek at Canyon Road, Sorenson Creek at Fogarty Ditch, and Manastash Creek at Brown Road. The KCWP collected samples from these sites once per week as part of their routine monitoring. This project uses KCWP results from weekly sampling to broaden its data set to include field replicates for a wider range of conditions. The KCWP sampling dates used in this project are presented in Table 10.

The KCCD collected data from the Teanaway River at Lambert Road and the background site of Teanaway River at North Fork. The Teanaway River at Lambert Road is comparable to the Teanaway River at HWY 10 site used for the *TMDL Evaluation* (Joy 2002), but was moved upstream 0.5 miles in order to increase the safety of sampling staff.

Table 10. Monitoring Site Types, Organizations, and Dates of Sampling in 2006 (adapted from Creech 2006)

Tributary Compliance Sites KCWP	Main Stem and Background Sites Ecology	Teanaway River Sites KCCD
4 April	4 April	4 April
11 April		
18 April	18 April	18 April
25 April		25 April
2 May	2 May	2 May
9 May		9 May
16 May	16 May	16 May
23 May		23 May
30 May	30 May	30 May
6 June		6 June
13 June	13 June	13 June
20 June		
27 June	27 June	27 June
5 July		
11 July	11 July	11 July
18 Jul		
25 July		
1 August		
	3 August	
8 August	8August	8 August
15 August		
22 August	22 August	
29 August		
5 September	5 September	5 September
12 September		
19 September	19 September	
26 September		
3 October	3 October	3 October
10 October		
17 October	17 October	17 October
24 October		
31 October	31 October	31 October

The KCCD staff collected samples weekly from the Teanaway River sites until the end of snowmelt runoff when the turbidity values were consistently less than 5 NTU. The TMDL Evaluation (Joy 2002) concluded that most suspended sediment loading to the Teanaway River occurs in the spring as a result of snow melt. Additionally, a more recent study by KCCD established that turbidity levels in the Teanaway generally drop to very low levels following spring snowmelt (KCCD 2004). Therefore, the QAPP recommended that the KCCD sample the Teanaway River sites weekly from mid-April through mid-June, and then monthly July through October (Creech 2006). Table 10 presents the dates when samples were collected from the Teanaway River sites.

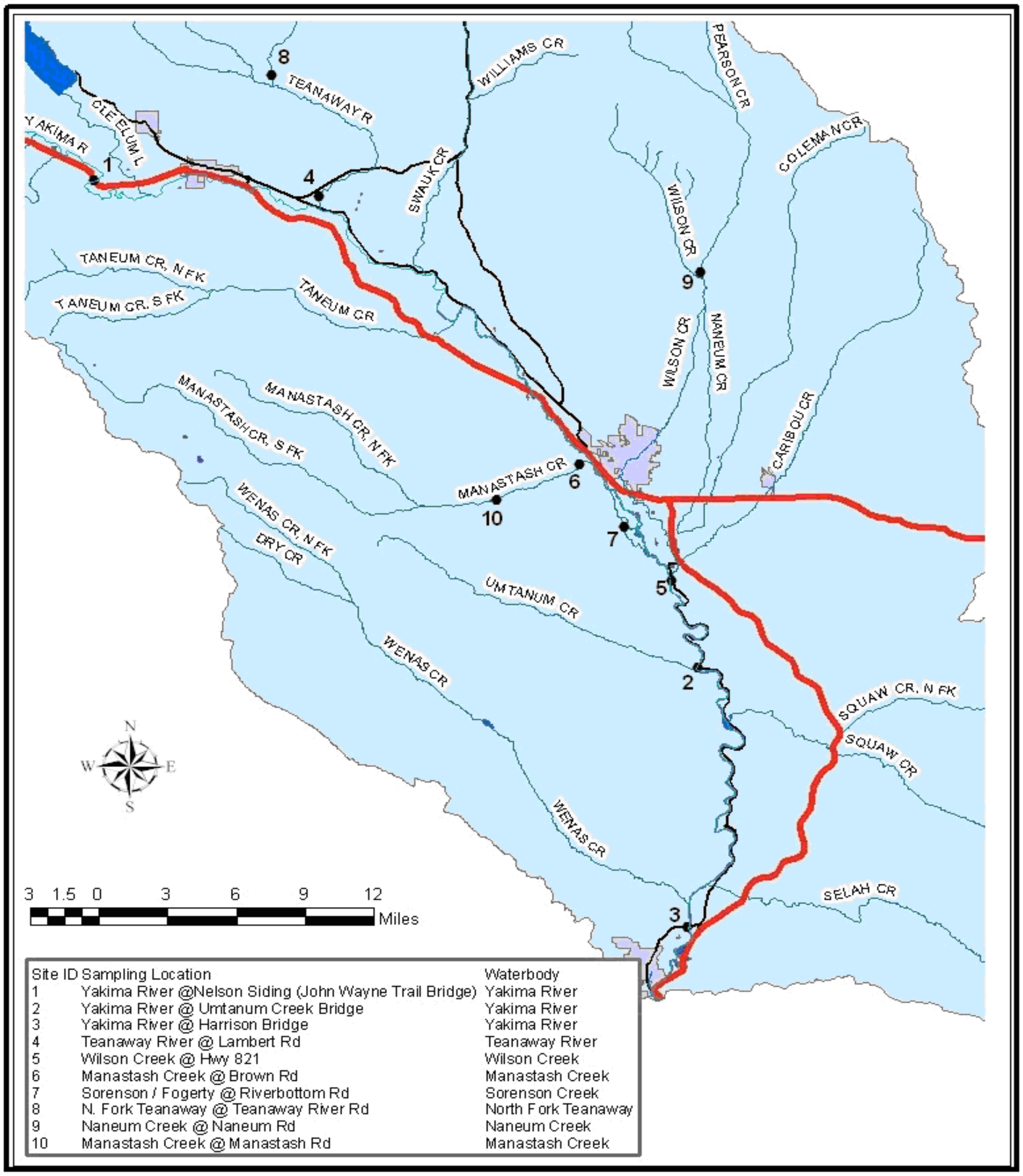


Figure 3. Map of Upper Yakima River Watershed Effectiveness Monitoring Locations (from Creech 2006)

Each group collected water samples for turbidity and TSS analyses using Federal Interagency Sedimentation Project (FISP) designed suspended-sediment samplers that permit the retrieval of depth-integrated samples. Sampling teams collected equal-width-increment (EWI) integrated samples by collecting a depth integrated sample from several stations along cross sections of the stream at each sampling site. Most often, 10 stations for one cross section were used. The sub-sample from each station along the cross section was poured into one large polypropylene bottle labeled for each site.

At bridge and walk-plank sites, staff collected samples using DH-76 or DH-59 suspended sediment samplers. The DH-59 and DH-76 are weighted samplers lowered into the current while attached to a tether to collect a depth-integrated, isokinetic sample. At sites where wading was a safe option, samples were collected using DH-81 suspended sediment samplers. The DH-81 sampler was used in the same manner as the others but is not weighted and was controlled using a hand held rod instead of a tether. The DH-81 is better suited for use on smaller creeks and drains where there is direct access to water of wading depth. If needed, nozzles of the samplers were changed depending on the depth and velocity of the water.

All monitoring sites on the main stem of the upper Yakima River were located at bridges. Most tributary sites were also located at bridges, except for one walk-plank site. Depth- and width-integrated samples were collected at all sites, with three exceptions that were described in the QAPP:

1. Wilson Creek at Hwy 821 – samples at this site were collected using grab sampling techniques, as the KCWP has documented that grab samples have a high correlation with integrated samples at this site (Creech 2006). These grab samples were depth integrated from the bank using a DH-81.

2. When the turbidity levels in the Teanaway dropped below ~5 NTU (in June), the KCCD used grab samples at the Teanaway sites.

3. During high flow events on Manastash Creek, the KCWP collected grab samples using a hand-held integrated sampler on a long rod, with the sampler held out as far as safely possible toward the thalweg of the creek. During high flow events, this portion of the Manastash Creek is well mixed, so these grab samples should be representative of stream conditions.

Laboratory analysis

The project used two different laboratories; Cascade Analytical Laboratory in Yakima, Washington and the KCWP water-quality laboratory in Ellensburg, Washington. Both laboratories are accredited by Ecology for measuring turbidity and TSS. Samples collected by Ecology and the KCCD were sent to Cascade Analytical Lab in Yakima, Washington. Samples collected by the KCWP were analyzed at the KCWP water-quality lab. The quality assurance project plan required that 10% of samples in the lab be duplicated for turbidity and TSS analysis. Both laboratories used EPA method 180.1 (USEPA 1983) for turbidity and Standard Methods 2540D (APHA 1992) for TSS. Both labs used ratio turbidimeters, based on recommendations by Joy and Patterson (1997). Lab information is presented in Table 11.

Table 11. Laboratory Procedures (from Creech 2006)

Parameter	Sample Matrix	Number of Samples per daily event	Expected Range of results	Reporting limit	Sample prep method	Analytical Method
Turbidity	Whole water	4 to 21, depending on day	1 to 1000 NTU	0.05 NTU	Hold @ 4C up to 48 hours	EPA 180.1
Total suspended solids	Whole water	4 to 21 depending on day	2 to 1000 mg/L	1 mg/L	Hold @ 4 C up to 7 days	SM 2540D

Discharge

The main stem Yakima River has discharge gages at various locations that are maintained by either the USGS or the USBR. Some tributaries have USBR stream gages. Average daily discharge data were downloaded from each organization's web sites.

Because there is no flow gage at the Yakima River at Nelson site, discharge at this location was estimated. To do this, the average daily discharge from the USBR's Cle Elum River gage was subtracted from the average daily discharge measured at the USBR's Yakima River at Cle Elum gage.

At tributary and background sites, various sources of stream-discharge data can be used. To estimate discharge at Wilson Creek at Canyon Road, the discharge records for Cherry Creek and Wilson Creek at Thorp Road were added. The USBR maintains a stream gage at the Teanaway River at Lambert Road, but it does not function during high discharge volumes. The USBR also maintains a stream gage on the Teanaway River below the confluence of the North, Middle and West Forks of the Teanaway River. Named the Teanaway River below the Forks, this gage provided an estimate for average daily discharge at the Teanaway River at Lambert Road.

Data analysis

The 90^{th} percentile values for turbidity and TSS were calculated at each site. Results were first converted to log base 10 values to normalize the data. The mean of the log-transformed data and the standard deviation of the log-transformed data were applied in the following equation from Zar (1984):

$$90^{th} \text{ percentile} = 10^{(\mu\log + 1.28 * \sigma\log)} \quad (1)$$

where: $\mu\log$ = mean of the log transformed data

$\sigma\log$ = standard deviation of the log transformed data

The 90^{th} percentile value derived using this formula assumes the data follow a log-normal distribution (Zar 1984). The variability in the data is expressed by the standard deviation. With some datasets, it is possible to calculate a 90^{th} percentile greater than any of the measured data.

An estimate of the loading of TSS in tons per day for certain sites was calculated using the Beale's ratio estimator formula (Thomann and Mueller 1987), where TSS samples and continuous stream discharge data were available. This is a method similar to that used to calculate loading for the *TMDL* (Joy 2002). This method uses the mean flow for the period ($\overline{Q}_p$), the mean daily loading on days when concentrations were measured (W_c), the mean daily flows on days when the concentrations were measured (Q_c), and the number of samples (n) to calculate mean load as:

$$\overline{W} = \overline{Q}_p \frac{\overline{W}_c}{\overline{Q}_c} \left[\frac{1 + \frac{1}{n}\left(\frac{S_{QW}}{\overline{Q}_c \overline{W}_c} \right)}{1 + \frac{1}{n}\left(\frac{S_Q^2}{\overline{Q}_c^2} \right)} \right] \qquad (2)$$

where

$$S_{QW} = \left(\frac{1}{n-1} \right) \left[\left(\sum_{i=1}^{n} Q_{ci} W_{ci} \right) - n \overline{Q}_c \overline{W}_c \right] \qquad (2.1)$$

and

$$S_Q^2 = \left(\frac{1}{n-1} \right) \left[\left(\sum_{i=1}^{n} Q_{ci} \right) - n \overline{Q}_c^2 \right] \qquad (2.2)$$

In Equations 2.1 and 2.2, Q_{ci} and W_{ci} are respectively the individually measured flows and loading for each sampling day.

Results

Quality assurance results

In total, 33 field replicates were collected out of the 217 samples for turbidity and TSS. Sixteen of the field replicates were taken from the Teanaway River, 7 from sites on the Yakima River main stem, and three at either the Manastash Creek at Manastash Road or Naneum Creek at Naneum Road sites. The KCWP collected 7 field replicates out of 92 samples on tributary sites. The mean Relative Standard Deviations (RSD) for each group's replicates and mean RSD of all replicates are presented in Table 12.

Table 12. RSD Values for Field Replicates

	Goal and Resulting RSD for Field Replicates		
Group	Goal for RSD	Turbidity	TSS
KCCD (Teanaway River sites)	7%	12.5 %	9.1 %
Ecology (Yakima River and tributary background)	7%	7.6 %	12.5
KCWP (tributary sites)	7%	9.0 %	10.3 %
Mean for Project	7%	11.4 %	10.5 %

The mean RSD for turbidity of project field replicates was 11.4%. The goal was 7%. The mean RSD value from field replicates for TSS was 10.5%. The field replicate samples with the highest RSD values for turbidity and TSS were generally collected when turbidity and TSS levels were very low. Greve (2002) noted that field replicates ". . . are used to estimate variability in sampling, processing, transport and analysis." The variability seen in the field replicates for this data set could be a result of all of these as well a result of slight variation in stream conditions between replicate samplings.

Quality assurance samples comparing results between sampling groups had a goal of 10% for the RSD. The RSD for all replicates collected by the groups at the Manastash at Brown site were 15.3% for turbidity and 35.8% for TSS. These results did not meet the goal of the project listed in Table 13. The results are acceptable for comparing results from the different sampling groups, although this variability should be recognized when comparing results among organizations. Greve (2002) noted that there are common sources of potential error when using multiple sampling crews. These could be as obvious as the use of different sampling methods and equipment. Different environmental sources of error such as changing stream conditions between replicates could be potential sources. The higher RSD for turbidity and TSS may be due to several factors ranging from different laboratories, different times of day that QA replicates were taken, and the slight variations in sampling techniques used by the three different organizations completing the sampling. Most likely, it is a result of all of these.

During 10 of the sampling events, a sample collected from the Manastash Creek at Brown road site was split and sent to each laboratory for turbidity and TSS analysis. The RSD for this split sample was 12.6% for turbidity and 18.9% for TSS. The goal for the RSD among laboratories was 10%. Results between laboratories can be compared, albeit with the notation that this goal was not met. Individual laboratory performance was acceptable for both laboratories used in the project. The KCWP laboratory completed its monitoring with an in lab RSD of 3.36% average for four turbidity lab duplicates. They duplicated three TSS samples that resulted in an RSD of 5.09%. Cascade Analytical Laboratory provided data from 54 duplicate results from the turbidity samples analyzed for Ecology and KCCD. Their RSD was 5.3 percent. Cascade Analytical Laboratory duplicated 58 of the TSS samples that were analyzed for Ecology and KCCD with the result of 6.7% RSD. Cascade Analytical Laboratory employed check standards to verify the accuracy of their equipment and this resulted in a 99.1 % recovery for turbidity check standards and a 97.5 % recovery for TSS standards.

With both labs meeting performance requirements, it seems possible that the method of splitting the samples may have caused the high RSDs. This may be a result of heavier particles settling in a recently mixed sample and not being transferred during the split. The sample container that receives the poured amount of the split may have received less TSS because of settling.

The results of all field blanks sent to the KCWP lab were less than 0.1 NTU for turbidity and all blank TSS samples sent to the KCWP lab were less than 1 mg/L. All of the blank samples sent to Cascade Analytical Laboratory by Ecology and KCCD returned results less than 0.2 NTU and all of the TSS blanks returned results less than 1 mg/L. The one blank that did not result under 1 mg/L was collected on 4 April 2006 and returned the result of 2 mg/L. The results of the quality assurance procedures for this project are presented in Table 13.

Table 13. Summary of Quality Assurance Results for the 2006 Data Set(goals from Creech 2006)

	Goal for % of Samples Replicated or Blanks	Actual % of Samples Replicated or Blanks	Turbidity RSD, or Percent Recovery		TSS RSD or Percent Recovery	
			Goal	Measured	Goal	Measured
Field Replicates	10 %	16.7%	7%	11.4%	7%	10.5%
QA replicates at Manastash Creek at Brown	7 QA replicates	12 completed, 2 were splits and 10 were triplicate	10%	15.3%	10%	35.8%
Split samples between two labs	10 splits		10%	12.6%	10%	18.9%
Field Blanks	One per sampling event per team	One per sampling event per team	0.2 NTU	0.2 NTU	<1 mg/L	<1 mg/L
Lab Blanks			<.2	<.2	<1 mg/L	<1 mg/L
Lab Duplicates	Cascade Analytical		10%	5.3 %	10%	6.7 %

The quality assurance goals set by the QAPP for the project (Creech 2006) were not fully achieved. Enough samples were taken over a broad range of conditions throughout the sampling period but higher than expected RSDs occurred for the QA replicates among groups and for lab splits between groups. Most of the very high values for individual RSD between replicates, quality assurance replicates or splits occurred at low turbidities and low concentrations for TSS. High numbers for turbidity and TSS concentrations had lower RSD values for replicates and splits. When this occurs, Ecology usually accepts the data set but states that the lower numbers caused the data-quality results to exceed the goals.

Turbidity results
Table 14 presents the main stem Yakima River sites' 90th percentile, median and increase in 90th percentile values over background for April through October 2006. The Yakima River at Nelson was the main stem Yakima River background site for this project. The Yakima River at Nelson had low turbidities throughout the sampling period compared to downstream sites. The 90th percentile turbidity value during the study period for the site was 4.1 NTU. The maximum value at the site during the study period was 6.3 NTU on 16 May 2006. The median value for the site was 1.7 NTU.

Table 14. The 2006 90th Percentile and Median Turbidity in NTU Results for Main Stem Upper Yakima River

Site Name	90th Percentile Turbidity in NTU	Median Turbidity in NTU	Difference from Background site (90th percentile)
Yakima River at Nelson	4.1	1.7	
Yakima River at Irene Rinehart park[1]	8.5	1.7	4.4
Yakima River at Umtanum	10.6	4	6.5
Yakima River at Harrison Road Bridge	11.8	4.1	7.7
[1]Data collection for this site did not start until 16 May 2006.			

No Yakima River main stem sites had 90th percentile turbidity values that were 10 NTU or more over the background 90th percentile turbidity value. So, the Yakima River met the 2006 turbidity reduction target. Each site downstream of the Yakima River at Nelson did increase more than 10 NTU on 2 days that it was sampled, but this was not enough to exceed the target 90th percentile value. Figure 4 compares the 90th percentile and median turbidity values for main stem upper Yakima River monitoring sites for the years 1999 and 2006.

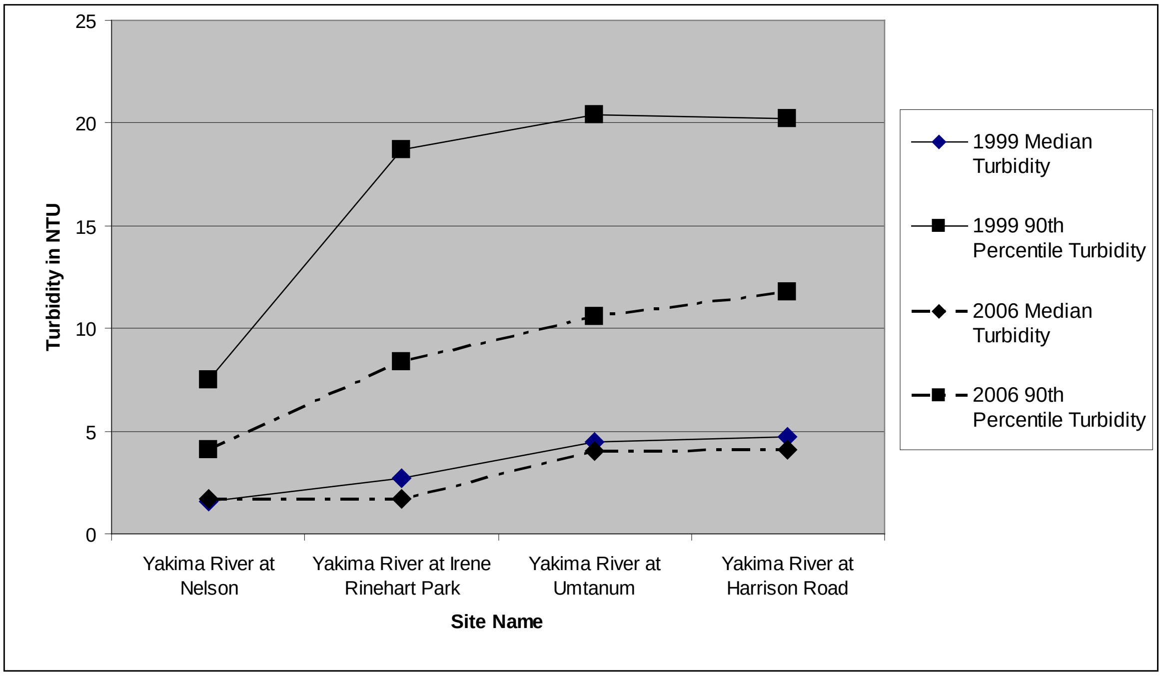


Figure 4. The Increase in 90th Percentile and Median Turbidity Results on the Yakima River Moving Downstream from the Background Station of Yakima River at Nelson

Neither the Yakima River at Umtanum nor the Yakima River at Harrison Bridge met the year 2012 water-quality standards based goal. This goal requires no more than a 5 NTU increase in 90th percentile values for turbidity over the background 90th percentile value. The Yakima River at Umtanum results showed a 6.5 NTU increase in turbidity over the background 90th percentile value. The Yakima River at Harrison Road Bridge had a 7.7 increase in turbidity 90th percentile value over background.

The 90th percentile turbidity values at all Yakima River sites were lower in 2006 than in 1999. However, the Yakima River showed the same seasonality for turbidity increases above standard during the initial 1999 study and historical data analysis conducted by Joy (2002). No increases over 5 NTU occurred after 13 June 2006. The 90th percentile turbidity values at the Yakima River at Nelson, Umtanum, and Harrison Bridge were all lower in 2006 compared to 1999. Table 15 compares turbidity values on the main stem between the two years. Differences in discharge volume and timing may partly explain why median turbidities were similar between years while 90th percentile values were lower in 2006.

Table 15. Comparison of 1999 and 2006 Median and 90th Percentile Turbidity Results on the Main Stem Yakima River

Site Description	Turbidity in NTU			
	1999		2006	
	Median	90th percentile	Median	90th percentile
Yakima River at Nelson	1.6	7.5	1.7	4.1
Yakima River at Irene Rinehart Park	2.7	18.7	1.7	8.5
Yakima River at Umtanum	4.5	20.4	4	10.6
Yakima River at Harrison Road	4.7	20.2	4.1	11.8

Three sites were used to determine the background turbidity conditions for this project:

- The Teanaway River at North Fork was the background site for the Teanaway River at Lambert Road.
- Naneum Creek at Naneum Road was the background site for Wilson Creek at Canyon Road.
- Manastash Creek at Manastash Road was the background site for both Manastash Creek at Brown Road and Sorenson Creek at Fogarty Ditch.

The Teanaway River at North Fork had a 90th percentile turbidity value of 12.4 NTU with a median turbidity value of 4.5. Manastash Creek at Manastash Road had a 90th percentile turbidity of 8.4 NTU, with a median turbidity value of 1.5NTU. The 90th percentile value for Naneum Creek at Naneum Road was 5.5 NTU. Its median value was 1.3 NTU. These results are presented in Table 19.

Table 16. The 90th Percentile Turbidity Values and Median Turbidity Values from Background Sites of Tributaries to the Upper Yakima River in 2006

Site name	90th percentile turbidity value	Median turbidity
Teanaway River at North Fork	12.4	4.5
Manastash Creek at Manastash Road	8.4	1.5
Naneum Creek at Naneum Road	5.5	1.3

In 2006, three tributary sites out of four had less than 10 NTU increases in their 90th percentile turbidity values. The 90th percentile turbidity value for the Teanaway River at Lambert Road was 22.2 NTU. The Teanaway River 90th percentile turbidity value was 9.8 NTU higher than the background 90th percentile value, so it met the 2006 turbidity target. The 90th percentile turbidity value of Manastash Creek at Brown Road was 10.0 NTU, with a median turbidity of 4.8 NTU. Manastash Creek had a 1.6 NTU increase in 90th percentile turbidity value above the background condition. Manastash Creek met the 2006 target. Sorenson Creek at Fogarty Ditch showed a 4.4 NTU increase in 90th percentile turbidity results over background. Sorenson Creek met the 2006 turbidity target. Wilson Creek did not meet the 2006 turbidity target. Wilson Creek's 90th percentile turbidity value of 24.3 NTU was 18.8 NTU over the background 90th percentile. In 2006 the median turbidity value of Wilson Creek was 10.5 NTU compared to 15.5 NTU in 1999.

Turbidity results from the 2006 tributary sampling are presented in Table 17. Figure 5 compares the 90th percentile and median turbidity values at tributary sites between 1999 and 2006. Figure 6 shows the 90th percentile turbidity value at each tributary background site, the 90th percentile turbidity value for the tributary compliance site, and the increase in turbidity from background.

Table 17. The 2006 90th Percentile and Median Results for Turbidity in NTU at Background and TMDL Target Sites

Site Name	90th Percentile Turbidity in NTU	Median Turbidity in NTU	Difference from Background Site (90th percentile)
Teanaway River at Background	12.4	4.5	
Teanaway River at Lambert Road[1]	22.2	2.6	9.8
Manastash Creek at Background	8.4	1.5	
Manastash Creek at Brown Road[1]	10.0	4.8	1.6
Sorenson Creek at Fogarty Ditch[1]	12.8	5.9	4.4
Naneum Creek at Background	5.5	1.3	
Wilson Creek at Canyon Road	24.3	10.5	18.8

[1]Sites that met the turbidity target.

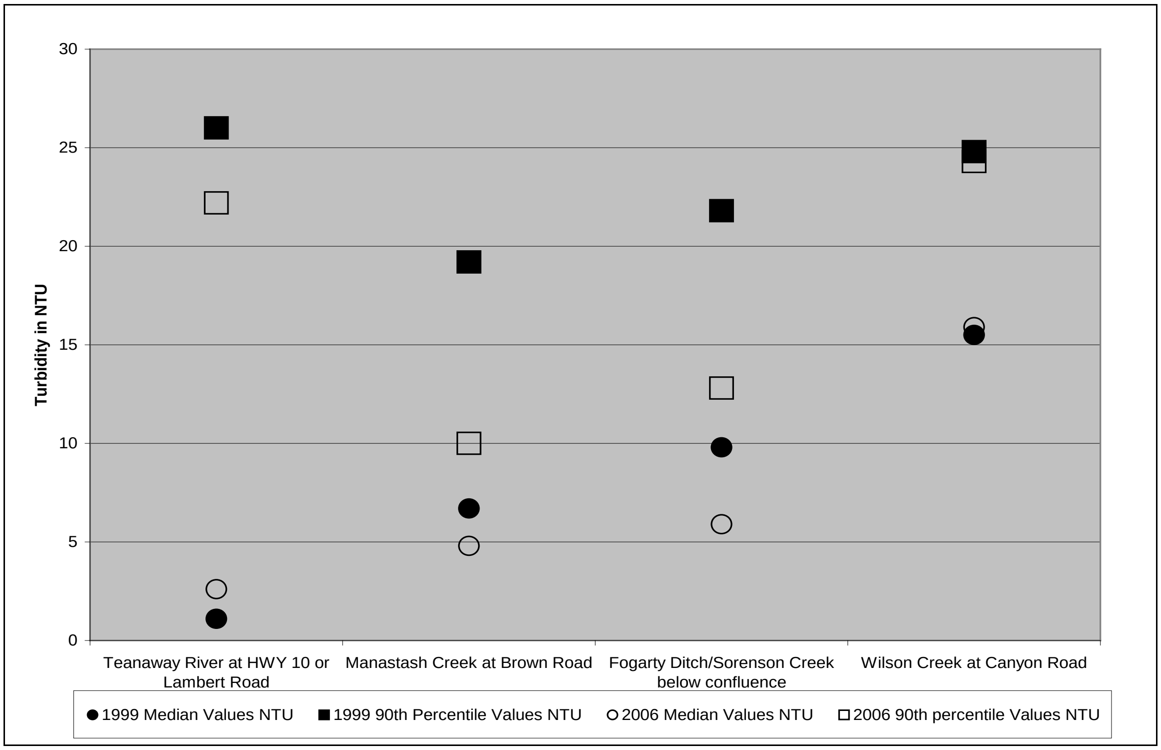


Figure 5. The 1999 and 2006 Median and 90th Percentile Turbidity Value for Tributaries Monitored in This Project

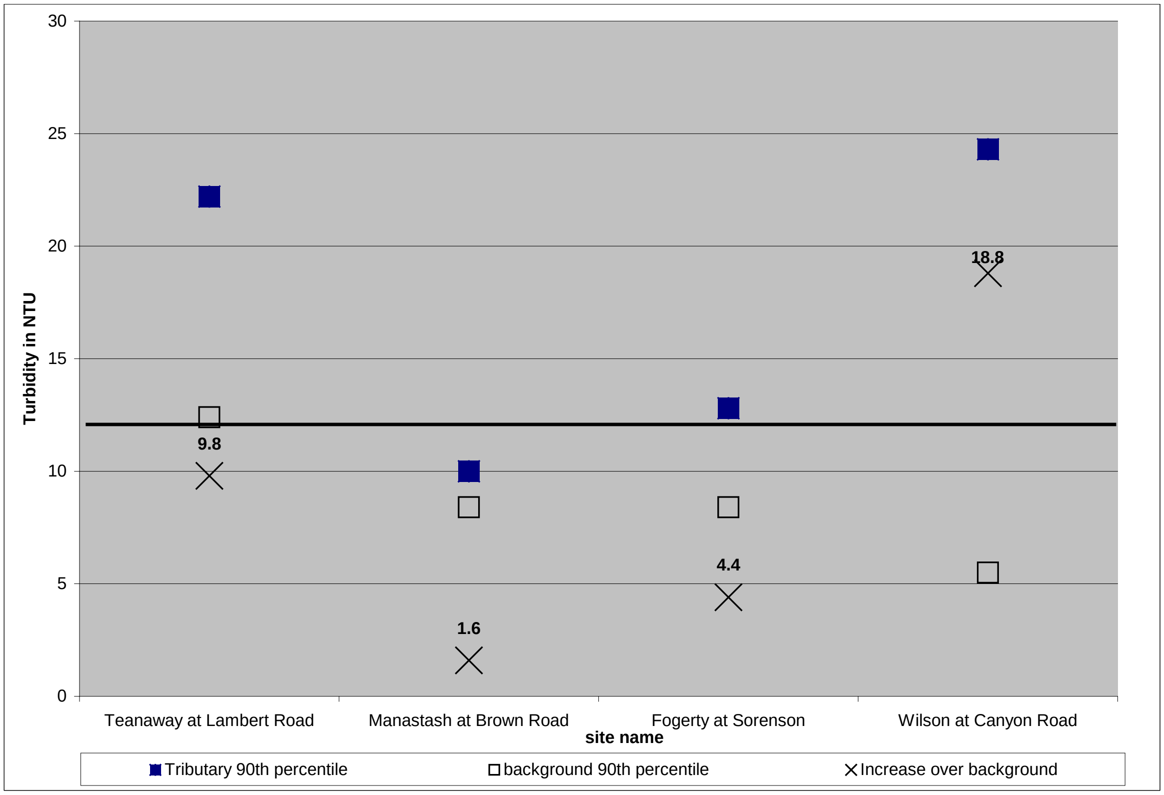


Figure 6. The 2006 90th Percentile Turbidity Value at Each Tributary Background Site, the 90th Percentile Turbidity Value for the Tributary Compliance Site, and the Increase in Turbidity from Background

TSS

Median and 90th percentile values for TSS were lower on the main stem Yakima River in 2006 than in 1999. The background 90th percentile value for TSS at the Yakima River at Nelson was 8.3 mg/L in 2006 and 13 mg/L in 1999. The median value for the Yakima River at Nelson was 3 mg/L in both 1999 and 2006. Moving down the river to the Yakima River at Umtanum, the 90th percentile value for TSS (24.6 mg/L) was lower in 2006 than in 1999 (35 mg/L). At the Yakima River at Harrison Bridge, the 2006 90th percentile and median TSS values were lower than they were in 1999. Figure 7 compares the 1999 and 2006 median and 90th percentile values for TSS concentration at Yakima River monitoring sites.

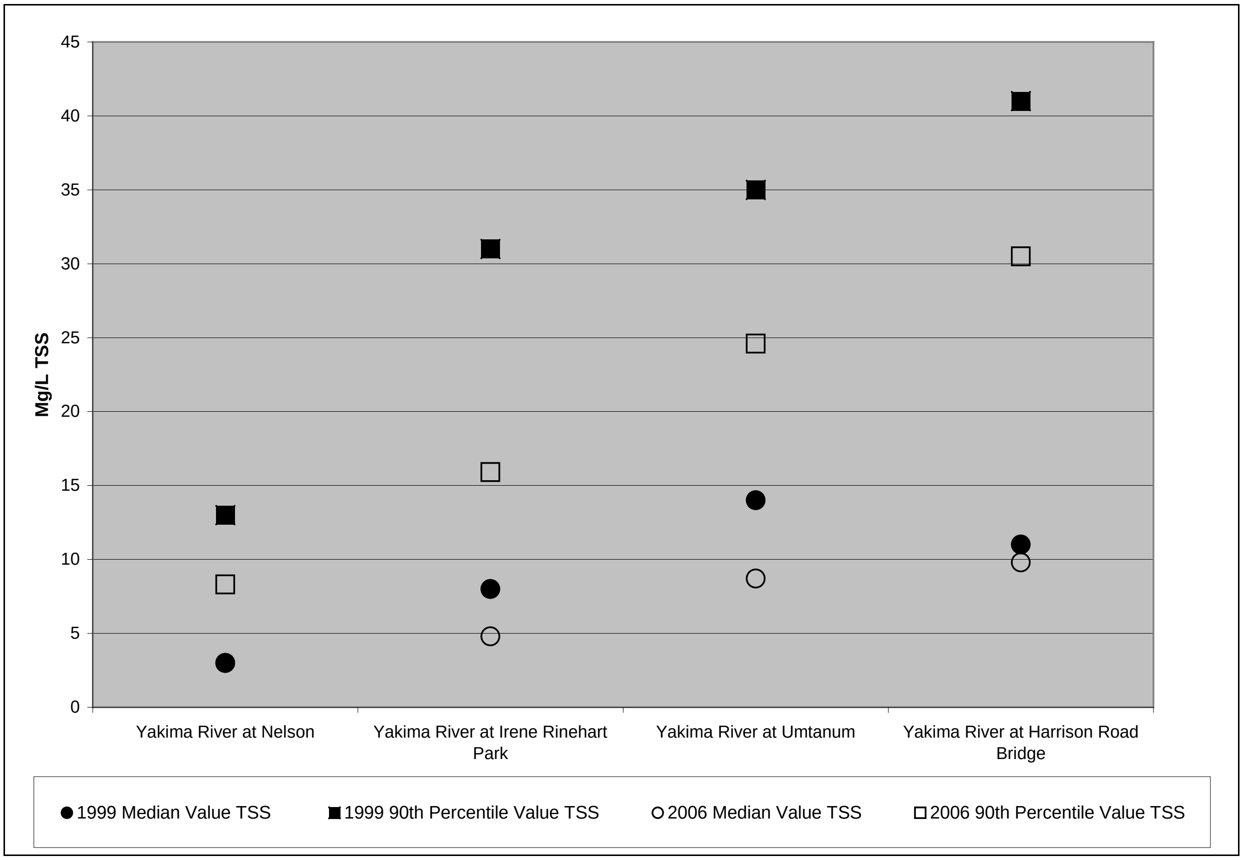


Figure 7. Comparison of Median and 90th Percentile TSS Concentrations between 1999 and 2006 at Yakima River Sites

The TSS concentrations from the tributaries were generally lower in the 2006 study than in 1999. The 90th percentile of TSS results for Wilson Creek at Canyon Road were higher in 2006. The median TSS values for the Teanaway River at Lambert Road were higher in 2006 than in 1999. Otherwise, the median and 90th percentile TSS values were lower in 2006 than in 1999. Figure 8 compares the 1999 and 2006 median and 90th percentile values for TSS concentration at tributary monitoring sites.

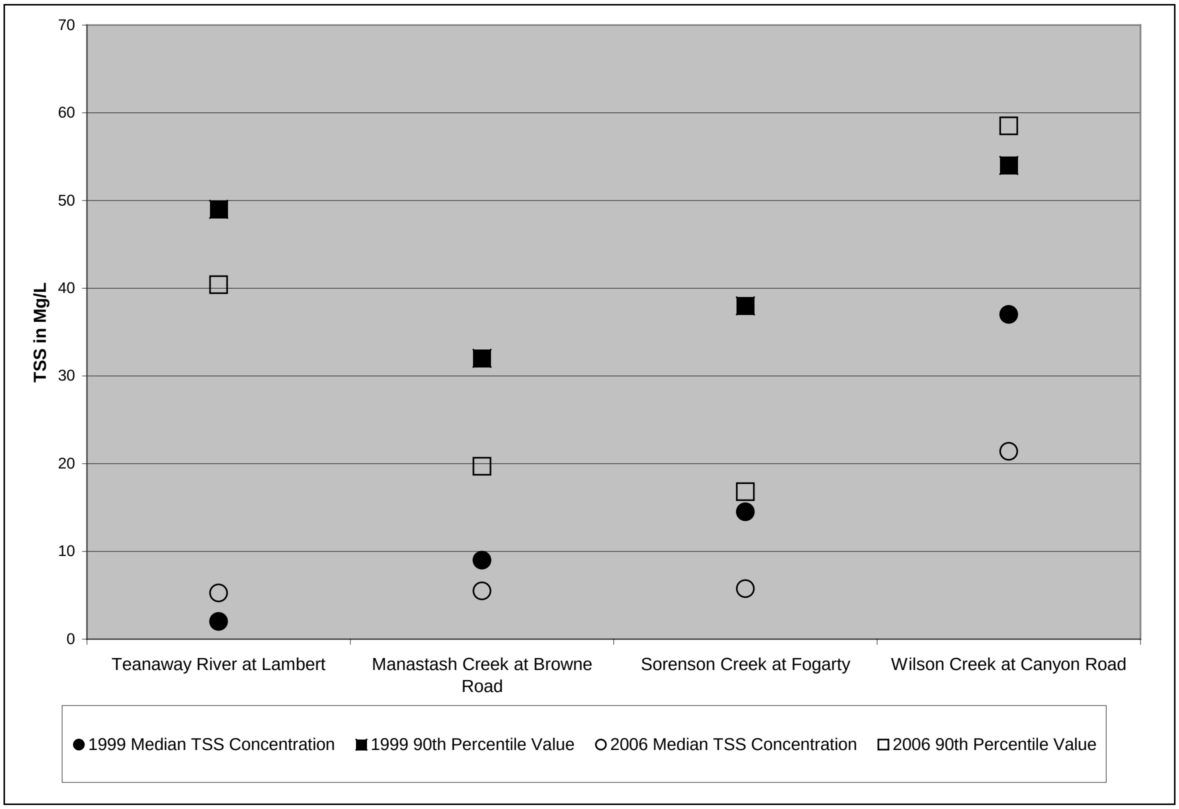


Figure 8. A Comparison of Median and 90th Percentile TSS Concentration Results from Tributary Monitoring Site

Discharge

Figure 9 presents the average monthly stream discharge values measured in the Yakima River at Umtanum in 1999 and 2006 relative to the 25th percentile monthly averages and the 75th percentile monthly averages. Stream discharges in the Yakima River were different in 2006 than in 1999. In 1999, the average monthly discharge of the Yakima River measured at Umtanum during April, May, and June was greater than the 75th percentile average monthly discharge for these months during the period of 1980 through 2006. However, August and September monthly average discharges for 1999 were near the 25th percentile discharges of average monthly discharge.

Stream discharge measured at the Yakima River at Umtanum during the 2006 monitoring project stayed lower than the 75th percentile and higher than the 25th percentile of average monthly flows between 1980 and 2006, with one exception. The average monthly stream flow during August 2006 was slightly higher than the 75th percentile for the 1980 through 2006 period of record.

During both irrigation seasons, there occurred no pro-rating of irrigation districts during the study period, and the river was operated according to a normal storage control, and the “flip-flop” regimen. The biggest difference in the two years is the available snowpack in 1999 and cooler temperatures in the spring of 1999 that could have provided for a longer snowmelt and run-off period. This would especially be evident in the Teanaway River, which has no reservoir storage control capacity.

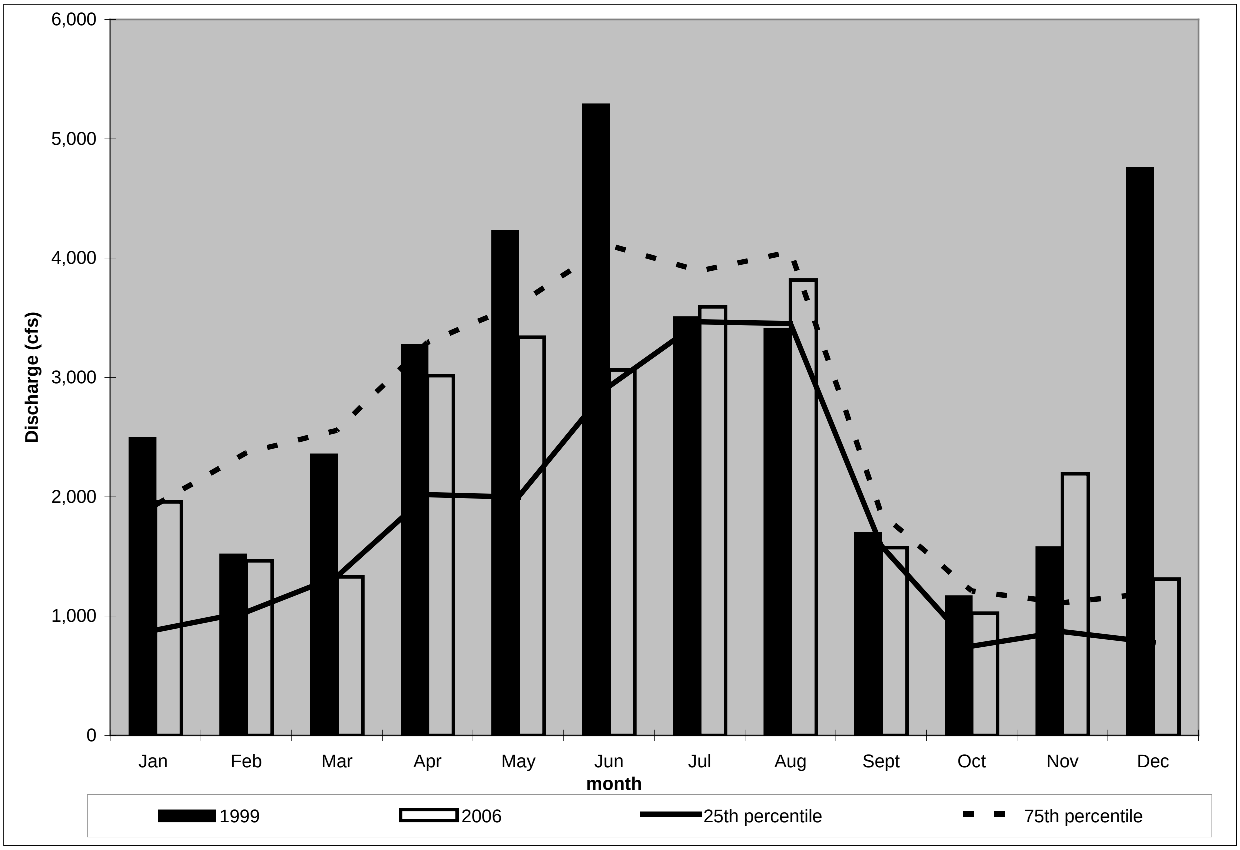


Figure 9. Comparison of Average Monthly Discharge in the Yakima River at Umtanum during 2006, 1999, 75th Percentile Months and 25th Percentile Month

The daily average discharge of Wilson Creek was lower in the 2006 sampling season than in 1999. Figure 10 shows the hydrograph for these two years. Interestingly, a period in September of 2006 had higher daily average discharges than in September of 1999.

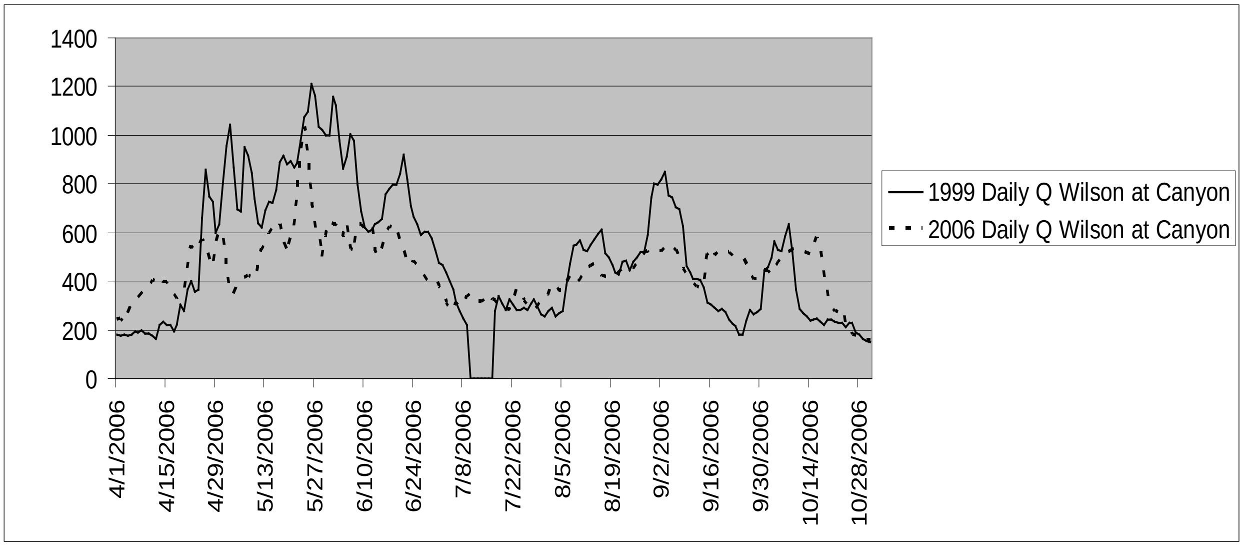


Figure 10. Comparison of Daily Average Discharge in Wilson Creek at Canyon Road in 1999 and 2006

The Teanaway River, as measured at Teanaway River below the Forks, had lower daily average discharge measured during the 2006 sampling season than in 1999. By examining the hydrograph in Figure 11, it can be seen that peak run off in the Teanaway River watershed came earlier in 2006 and with less volume than in 1999.

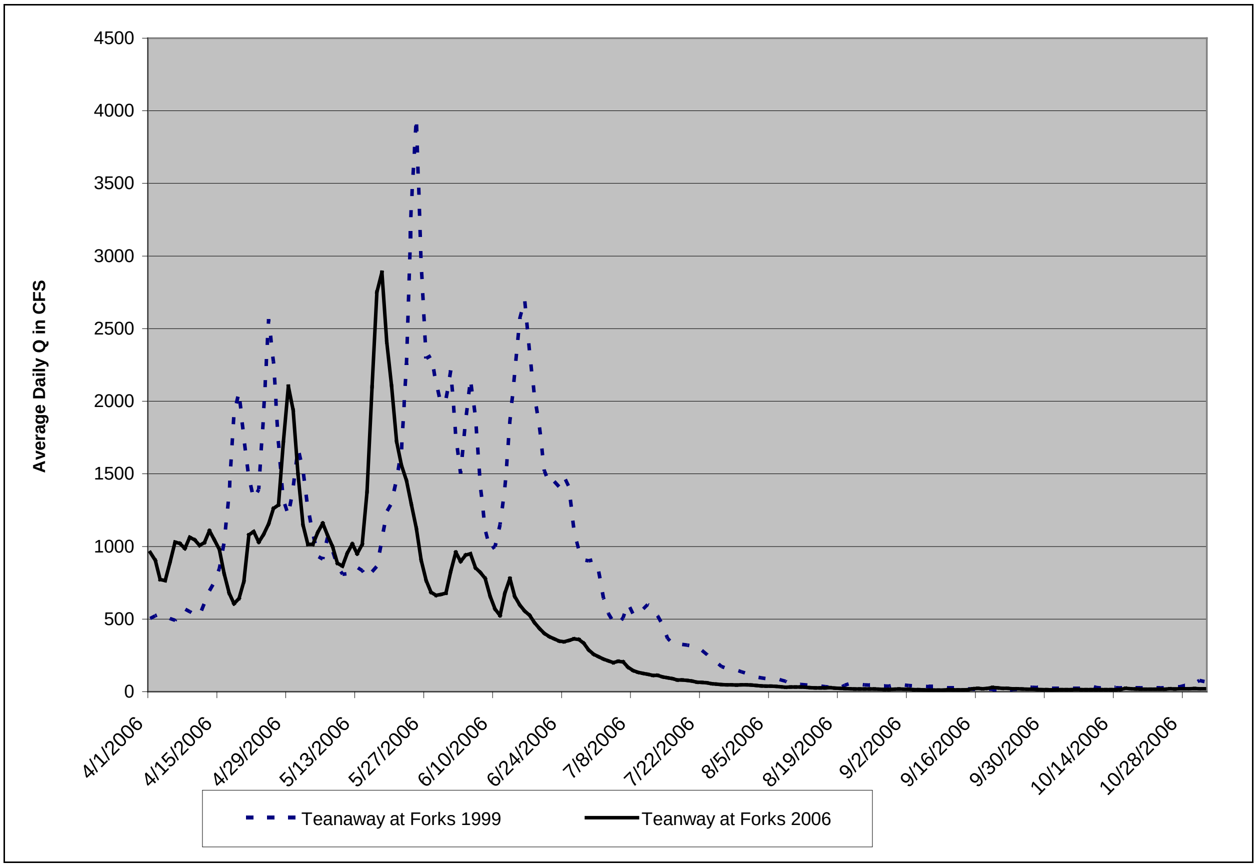


Figure 11. Comparison of Daily Average Discharge in the Teanaway River below the Forks in 1999 and 2006

TSS loading analysis

Joy (2002) estimated the 2006 reduction target in suspended sediment loading in the four study tributaries by making these assumptions:

- Each tributary experienced a 10 NTU increase in 90^{th} percentile turbidity values over background.
- Discharge volumes in 2006 and 1999 from tributaries were similar.

If such a reduction in turbidity was met, it was estimated that the main stem Yakima River would meet the target set for 2006. The Beale's Ratio Estimator was used to quantify the loading of suspended sediment at the Wilson Creek at Canyon Road site, the Yakima River at Nelson site, and the Yakima River at Umtanum site. An estimate of the average daily discharge was made for the Teanaway River at Lambert by using the average daily discharge value for the Teanaway River below the Forks gage.

During the study period, Wilson Creek contributed an average of 34 tons per day of suspended sediment to the Yakima River. The early season, measured from 18 April 2006 to 27 June 2006 accounted for an average of 55 tons per day. The later season, July through October, accounted for an average of 26.3 tons per day. The seasonal average in 1999 was 71 tons per day, with an early season average of 132 tons per day and a late season average of 31 tons per day.

In 1999, the Teanaway River near Lambert Road carried an average of 77 tons per day of suspended sediment to the Yakima River. The Teanaway River's early season average was 188 tons per day (measured between 20 April 2006 and 29 June 2006). The corresponding late season average, measured between June 30 and October 20, was 0.9 tons per day. The loading from the Teanaway River in 2006 was lower, but so was the average seasonal flow.

Table 18 summarizes the contributions in tons per day of suspended sediment from the Teanaway River and Wilson Creek in 1999 and 2006. Overall, both tributaries contributed considerably less suspended sediment in 2006.

Table 18. Summary of Loading in Tons Per Day from Wilson Creek and the Teanaway River During the Early, Late and Complete Irrigation Season

	Early irrigation season average daily load		Late irrigation season average daily load		Complete irrigation season average daily load	
Year / Site Name	1999	2006	1999	2006	1999	2006
Teanaway River	188	129	0.9	0.2	77	33
Wilson Creek	132	55	31	26.3	71	34

Suspended sediment loading at the Yakima River at Umtanum is presented in Table 19. Suspended sediment loading measured in metric tons per day was lower in 2006 than in 1999. The daily average load of TSS in the Yakima River at Umtanum during the 2006 irrigation season was 103 tons per day. The early season load was 177 tons per day and the later season load was 50.8 tons per day. During the 1999 irrigation season the loading in the Yakima River at Umtanum was 215 tons per day for the entire irrigation season, 399 tons per day during the early irrigation season and 78 tons per day during the later part of the irrigation season.

Table 19. Sediment Loading in Tons Per Day in the Yakima River at Umtanum in 1999 and 2006

	Early irrigation season average daily load		Late irrigation season average daily load		Complete irrigation season average load	
Year / Site Name	1999	2006	1999	2006	1999	2006
Yakima River at Nelson	28	12	3	0.9	14	6
Yakima River at Umtanum	399	177	78	50.8	215	103
Yakima River at Harrison Road	271	85	27	19.6	131	46

Wilson Creek joins the Yakima River upstream from the Yakima River at Umtanum site. Therefore, it is useful to compare the estimated loads from Wilson Creek to loads from the Yakima River at Umtanum. During both the 1999 and 2006 sampling periods, Wilson Creek contributed 33.0% of the average total suspended load at the Yakima River at Umtanum. In the early sampling period (April through June) of 1999, Wilson Creek contributed 33.1 % of the average load in the river at Umtanum, and 31.1 % of the average load during the same period of 2006. For the entire sampling period in 2006, Wilson Creek contributed 51.8 % of the average load to the Yakima River. However, during the same period in 1999 it only contributed 39.7 percent of the average load.

The apparent 2006 increase in the contribution from Wilson Creek could be the result of a longer period of snowmelt in 1999, which increased the daily load of TSS from tributaries such as the Teanaway River. It could also be a result of increased irrigation BMP use since 1999 in other tributary watersheds upstream of Wilson Creek. Manastash Creek and Sorenson Creek drain areas smaller than Wilson Creek. Implementation of BMPs in these watersheds may be easier to detect in the short time period since the TMDL was set. The KCWP (2005) notes that tributaries to Wilson Creek are nearly 100% irrigation return flow in the latter half of the irrigation season. These loading results may indicate that a larger percentage of suspended sediment in the Yakima River at Umtanum is a more influenced by irrigated agriculture in the Wilson Creek watershed in 2006 compared to 1999.

Discussion

The main purpose for conducting TMDL effectiveness monitoring is to determine if TMDL implementation is resulting in improved water quality, and ultimately, to provide information for continued protection of all beneficial uses of the watershed. Evaluation of interim targets, such as those evaluated in this report, also provides the opportunity to evaluate the validity of targets of the TMDL. In addition to evaluating the effectiveness of TMDL implementation and the appropriateness of TMDL targets, this monitoring project established more representative background monitoring sites for evaluating TMDL effectiveness.

Evaluation of TMDL effectiveness

The 90th percentile values for turbidity in the upper Yakima River were lower in 2006 than in 1999. The upper Yakima River main stem met the 2006 interim target for having no more than a 10 NTU increase in 90th percentile turbidity values above background conditions. To meet turbidity targets for 2012, more implementation activities that decrease suspended sediment loading to the river are necessary. The biggest increase in turbidity in the main-stem Yakima River occurred during the early portion of the April through October monitoring period. It is important for implementation efforts to focus on reducing sediment loading to tributaries and the Yakima River during the entire critical season (April through October), especially in Wilson Creek. However, controlling suspended-sediment runoff during the early part (April through June) of the monitoring season is a critical component of meeting water-quality standards in the upper Yakima River.

On 13 out of 14 sampling days in 2006, Wilson Creek at Canyon Road was more than 5 NTU over the background condition. During the early part of the irrigation season the increase in turbidity over background was greater than 10 NTU on five out of six of these sampling days. The Teanaway River, in contrast, only violated the state water-quality standard on two out of 16 days sampled, and these two violations occurred during the early portion of the monitoring season. Sorenson Creek violated the state turbidity standard on three of 15 days and Manastash Creek did not violate the state turbidity standard on any day that it was sampled for this study.

The upper Yakima River watershed drains three eco-regions: 1) The Cascades Ecoregion, 2) the Eastern Cascades Ecoregion and 3) the Columbia Basin Ecoregion (Omernick et al. 1987). Cuffney et al. (2000) utilized land uses, stream size, and eco-region to describe three different general types of streams that apply to the upper Yakima River watershed; divided them into:

1. Small streams of the Cascades (Cascades Ecoregion and Eastern Cascades Slope and Foothills Ecoregion) where grazing and forestry are the dominant land uses such as the Teanaway River and upper Manastash Creek.

2. Small streams of the Columbia Basin Ecoregion where irrigated agriculture is the dominant land use such as Wilson Creek, Sorenson Creek and lower Manastash Creek.

3. Large-river sites such as the Yakima River that are influenced directly and indirectly by forestry, grazing, urbanization, and agriculture.

The seasonal nature of the TSS loading and turbidity violations seem to correspond to these stream types. The results from this study show that a large amount of TSS loading and turbidity loading to the main stem Yakima River comes from the small streams of the Cascades on a seasonal basis during snowmelt. Also, the small streams of the Columbia Basin Ecoregion, such as Wilson Creek, are influenced by their background sites during snowmelt. As a result, these streams contribute elevated TSS loads and experience higher turbidity during the entire irrigation season. The upper Yakima River main stem receives TSS from both sources during the earlier portion of the irrigation season. Therefore, the main stem Yakima River violates water-quality standards because both stream types contribute TSS.

Implementation actions in the Teanaway River watershed focused much effort on riparian protection and water conservation (KCCD 2004 and KCCD 2007). This helps reduce erosion from stream banks. One source of suspended sediment in the Teanaway River could be forest roads. A study by Shi et al. (2008) demonstrated that soil erosion rates decreased with increasing buffer strip distance separating roads from waterways. In addition, Sheridan and Noske (2007) showed that different types of forest roads contribute eroded sediment for the same duration as rainfall occurred during their experiment. They reported that different types of forest roads contribute suspended sediment at different rates under similar precipitation conditions. They demonstrated that increasing truck traffic and decreasing surfacing material increased sediment delivery rates from roads. The forest managers in the upper portions of the upper Yakima River watershed, such as the Teanaway River watershed, should evaluate and implement road management practices that limit suspended sediment delivery to streams.

Implementation actions in the irrigated agricultural areas of the upper Yakima River watershed focused on a variety of activities from policy changes, educational efforts, irrigation BMP use, and riparian protection. Although much work was done and total suspended solid loading decreased substantially, turbidity improvements were not observed in Wilson Creek. Wilson Creek is the largest irrigated agricultural drainage in the upper Yakima River watershed. The lack of turbidity reduction in Wilson Creek may not be due to implementing the wrong types of actions. It may be a measure of not implementing enough BMPs. Walker (1994) examined three separate watersheds where BMP implementation occurred. He found that a large amount of BMP implementation was necessary to establish conditions that would show improving water quality monitoring trends. Other variables such as climatic and seasonal variability can influence water quality improvement trends unless enough BMP use is in place to overwhelm the other sources of variability (Walker 1994). Continued implementation and continued monitoring should eventually establish an improving trend in Wilson Creek.

Data and information from the KCWP (2005), KCCD (2004) and KCCD (2007) reports are valuable contributions to helping resource managers understand water quality in the upper Yakima River watershed. The KCWP (2005) reported an improving trend in much of the project area between the years 1999 and 2004. Although, they report an improving trend in three tributaries to Wilson Creek in those years, they were unable to detect an improving trend in Wilson Creek itself.

High turbidity from one tributary may increase Wilson Creek's turbidity on days when the other two tributary creeks are relatively clean.

The grant report by KCWP (2005) indicated that water-short (drought) years can negatively influence water quality in the following irrigation season. This reduction in water quality may be due to the effect of interrupting junior water right deliveries on planting and tilling practices in the upper Yakima River watershed. Junior water rights holders in the upper Yakima River watershed received interrupted supplies of water in the years 2001 and 2005. The KCWP (2005) observed an increased number of timothy hay fields that were plowed and seeded in the beginning of the 2002 and 2006 irrigation seasons. They could attribute this to the previous years' drought conditions and the related damage to the perennial hay crops, requiring an unusually high percentage of these crops to be replanted the following year. Indeed, KCWP (2005) reported that 2002 turbidities were generally higher than 2001 and 2006 turbidity results were higher than 2005 results. The higher turbidities following drought years could be attributed to a large percentage of newly-planted timothy hay fields with loose soil being irrigated with furrow irrigation methods.

Wilson Creek (figure 12) receives irrigation return flow in several of its tributaries. The KCWP (2005) tracked turbidity conditions at several fixed stations in 2002 through 2004. Cherry Creek and the Wipple Wasteway as well as the terminal ends (called tailends in the report) all contributed turbid water to Wilson Creek on various occasions. The KCWP (2005) attributed many of the events to the first irrigation of corn, the charge up of the irrigation system, and to

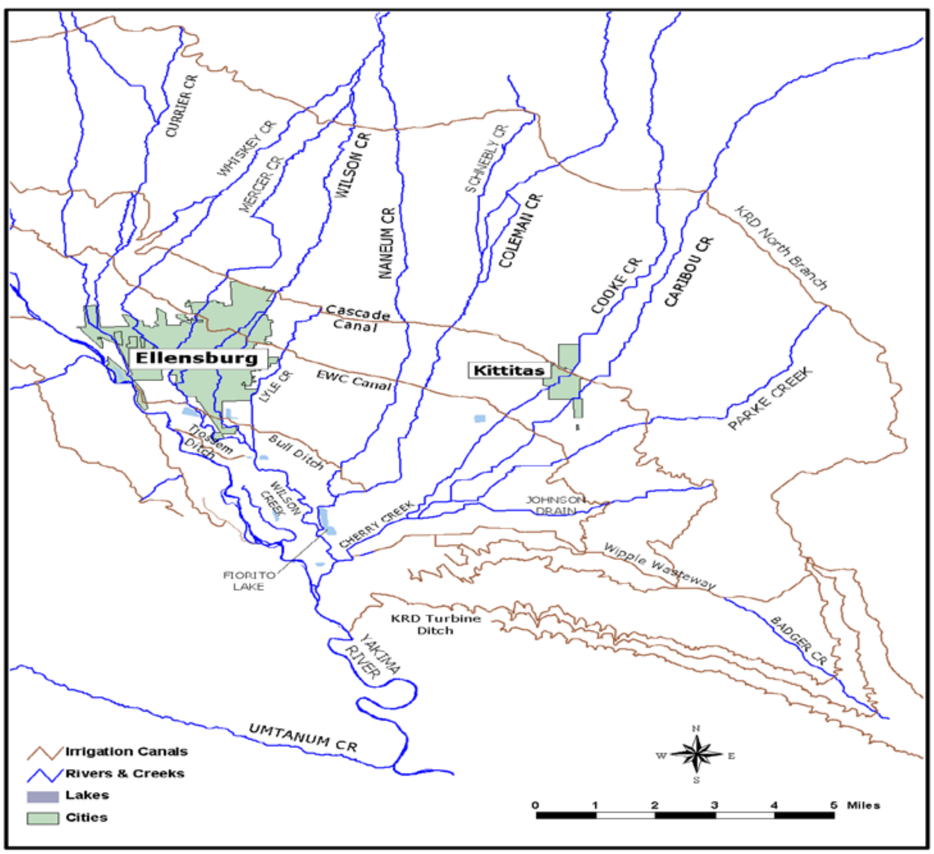


Figure 12. Map of Wilson Creek Watershed (courtesy of Kittitas Reclamation District)

weather events. Nonetheless, turbidity in Wilson Creek above its confluence with Cherry Creek generally remained below 10 NTU. Unpublished data from the KCWP show that this is also the case for the 2006 sampling season. In that case, much of the suspended sediment causing turbidity in Wilson Creek most likely resulted from irrigation in the Cherry Creek and Wipple Wasteway drainages.

Unpublished data from the KCWP show that water quality in Wilson Creek was in better condition in 2005 and in 2007 than this study presents. In 2005, the 90th percentile value of weekly turbidity results collected at Wilson Creek was 17 NTU. In 2007, the 90th percentile turbidity value of weekly sampling results collected by KCWP staff in Wilson Creek at Canyon Road was 15.1 NTU. An unpublished seasonal Kendall Test on 90th percentile turbidity results for Wilson Creek at Canyon Road between 1999 and 2007 suggested a slightly improving trend in turbidity since 1999. This could be a result of implementation of sediment control BMP use in the Wilson Creek watershed. At the same time, the trend could be a result of abnormally high turbidities in 1999 compared to abnormally low turbidities during drought years.

Most likely, BMP use, crop rotation, water timing and water availability, collectively play a role in the trend of turbidity in Wilson Creek. Additional analysis of existing data sets, crop rotation data and water use timing is recommended to understand the trend. Natural resource agencies that provide service to timothy growers should develop BMPs to limit soil loss from replanted timothy fields.

Evaluation of TMDL targets

Creech and Joy (2003) set the final TMDL targets to be met by the year 2012. If the turbidity targets are met, then the upper Yakima River and its tributaries will meet state water-quality standards (WAC 173-201A, 2006) for turbidity. While the criteria for turbidity provided in the state water-quality standards are set primarily for the protection of salmon and trout, the standards also protect a wide range of aquatic organisms.

Joy (2002) reported that TSS concentrations between 7 and 20 mg/L could harm early life stages of salmonids. He also reported that USEPA guidance (Mills et al 1985) shows that TSS levels between 10 and 100 mg/L had potential to harm aquatic organisms. Figure 13 shows that Wilson Creek was above 10 mg/L TSS for all but one day of the 2006 irrigation season. Joy (2002) also reported that turbidity as low as 10 NTU could have an adverse effect on salmonids. Wilson Creek at Canyon Road experienced turbidity higher than 10 NTU for the first four months of monitoring in 2006 (Figure 14).

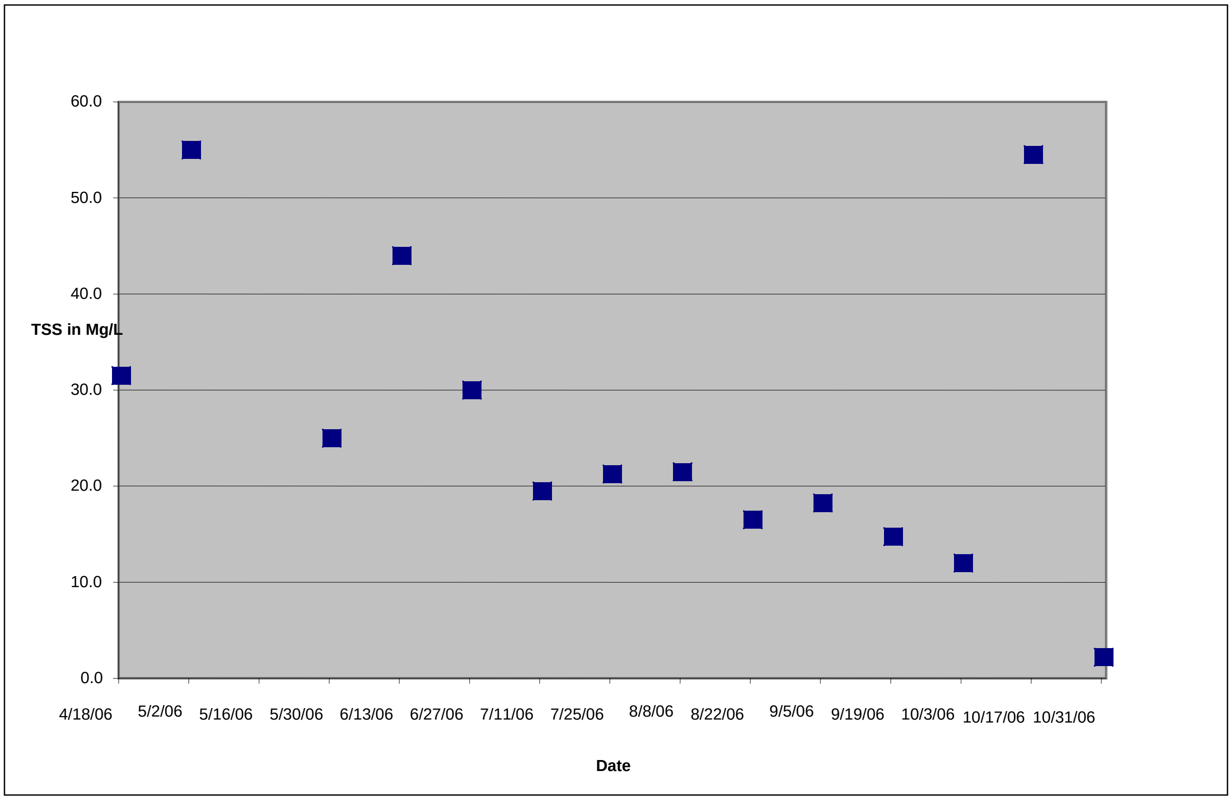


Figure 13. 2006 TSS Concentrations from Wilson Creek at Canyon Road

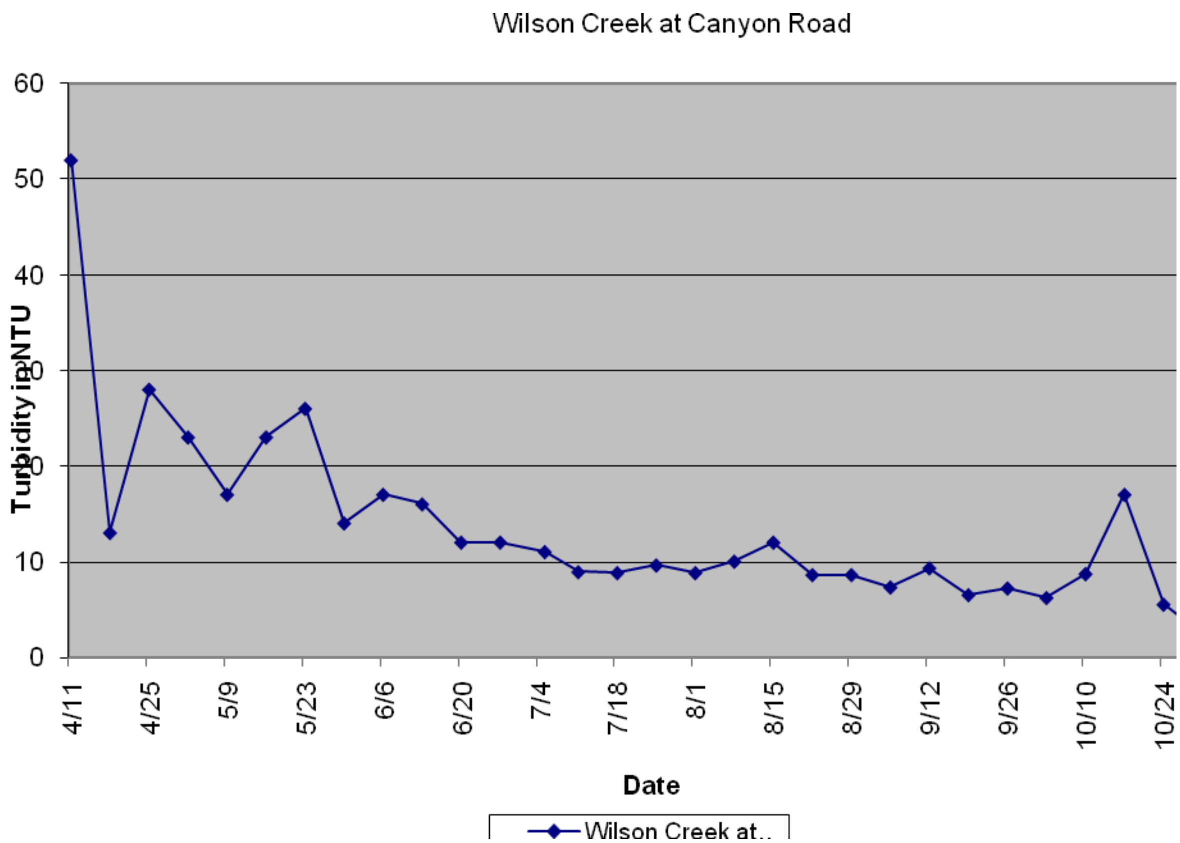


Figure 14. 2006 Turbidity Results from Wilson Creek at Canyon Road Collected Weekly

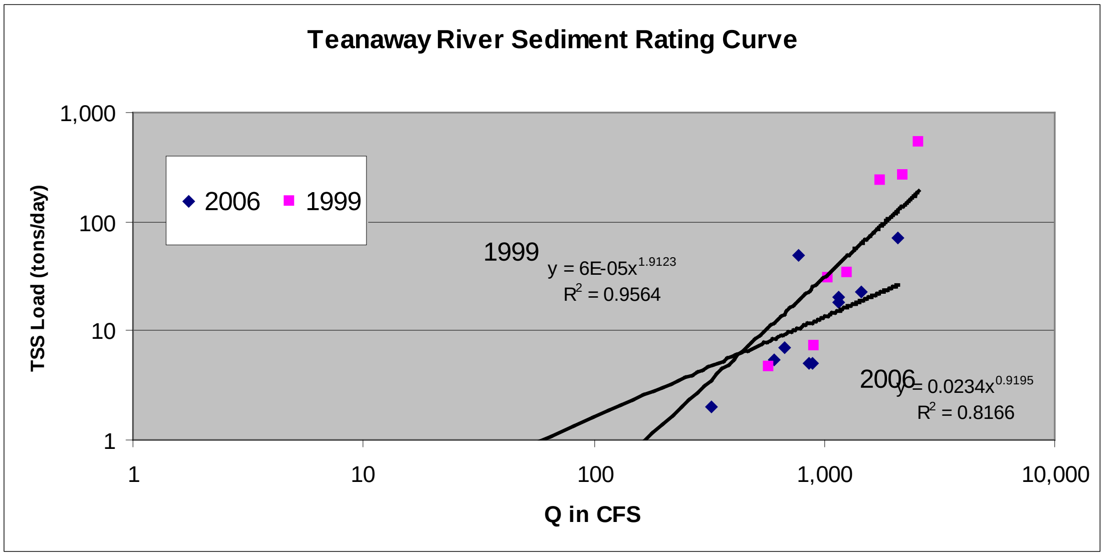
Joy (2002) noted that a review of published research does not provide a clear understanding of the responses of the most sensitive life stages of fish to increased turbidity and suspended sediment levels. But his report also notes that suspended sediment can effect more sensitive benthic invertebrate populations and algal communities. The results of some recent studies demonstrate the effects of turbidity and suspended sediment on these lower trophic levels. Henley et al. (2000) was consistent with Newcombe and McDonald's (1991) conclusion regarding fish. Henley et al. also concluded that individual, population and ecosystem effects were related to duration and level of exposure of increased suspended sediment. They hypothesized that high and sustained levels could cause permanent changes in community structure, density, biomass, growth, and rates of reproduction and mortality.

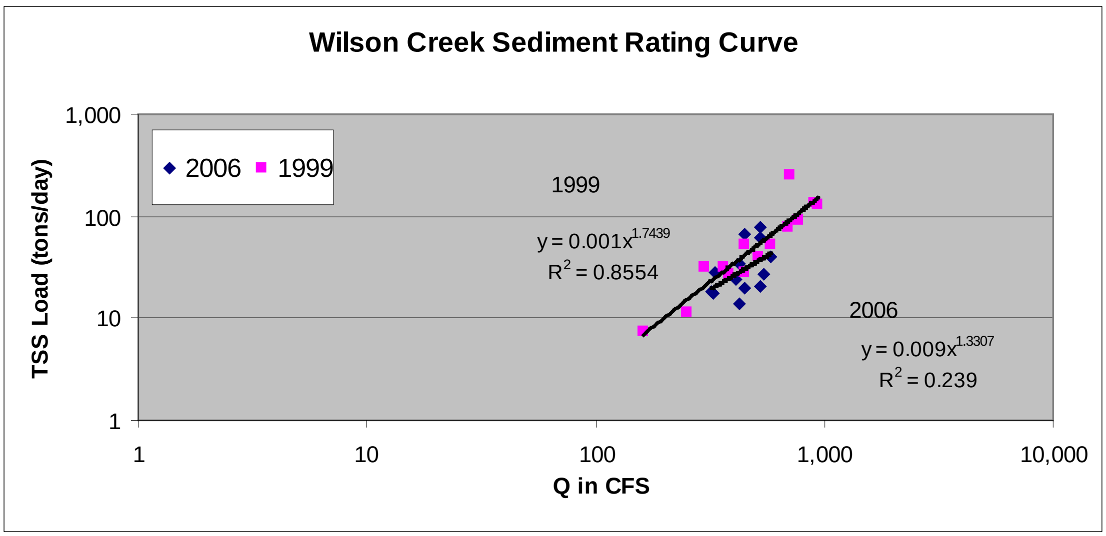
Bash, Berman and Bolton (2001) noted that other environmental factors could influence the effect of turbidity on salmonids. For example, temperature, toxicity, and access or lack of access to refuge could influence turbidity's effect on aquatic organisms. Interestingly, Stanford et al (2002) showed that lower Sorenson Creek and lower Wilson Creek may be disconnected floodplain channels of the Yakima River. Being such, they become valuable for juvenile salmonids seeking refuge from higher turbidity conditions in the main stem Yakima River. Turbidity and TSS reductions are important to protecting these valuable habitats from the seasonal increases of TSS and turbidity in the main stem Yakima River. If these creeks are experiencing harmful levels of turbidity during irrigation system charge-up and during first water applications to crops such as corn and freshly tilled timothy fields, then they are not available as refuges.

Seasonal increases of TSS and turbidity in the Yakima River and its tributaries are expected when higher flows occur. The amount and duration of the increase is important to limit, because as discussed earlier, higher TSS and turbidity values for longer periods of time create greater disturbance to aquatic environments. Watanabe et al. (2005) developed a model that predicted that in order for a benthic macroinvertebrate community to fully recover from a short term pulse of suspended sediment and turbidity that resulted in a 92% reduction in community biomass, the community would need three years without increased turbidity. The study reports that other studies show as little as a year between events is sufficient for recovery. Nonetheless, in the upper Yakima River watershed, Joy (2002) showed that suspended sediment levels increase to very high levels on a yearly basis. Wilson Creek sustained high suspended sediment levels, between 10 and 132 mg/L throughout the 1999 irrigation season. For most of the 2006 sampling period, Wilson Creek sustained TSS levels above 10 and below 60 mg/L.

The highest turbidity level measured in 1999 in the upper Yakima River watershed was 70 NTU in Sorenson Creek at Fogarty Ditch. However, the effect of toxic chemicals brought with suspended sediment could have an adverse effect on benthic organisms that are tolerant of increased turbidity. In the upper Yakima River watershed, organochlorine pesticides associated with the suspended sediment could potentially affect communities of benthic macroinvertebrates. Turbidity-intolerant species of macroinvertebrates may experience adverse effects from turbidities found in the Yakima River and its tributaries. At the same time, turbidity tolerant species may experience adverse effects due to the chemicals brought with suspended sediment, such as organochlorine pesticides. It may be that the overall effect is lower biomass of macroinvertebrates.

Suspended sediment levels were lower in the upper Yakima River in 2006 than 1999. An important consideration is that average monthly discharge levels were lower in the upper Yakima River measured at Umtanum in four out of the seven months monitored in 2006 compared to 1999. Joy (2002) showed that TSS loads were well correlated with discharge in the Teanaway River, Wilson Creek and in the Yakima River at Umtanum. His correlations of discharge and TSS loading resulted in higher correlation coefficients than sediment rating curves developed for 2006 (Figure 15). This indicates that TSS loading was not as much a factor of flow during a low flow year when TSS concentrations were also lower. Figure 15 shows the resulting sediment rating curves comparing discharge and loading in metric tons per day at these sites in 1999 and 2006.





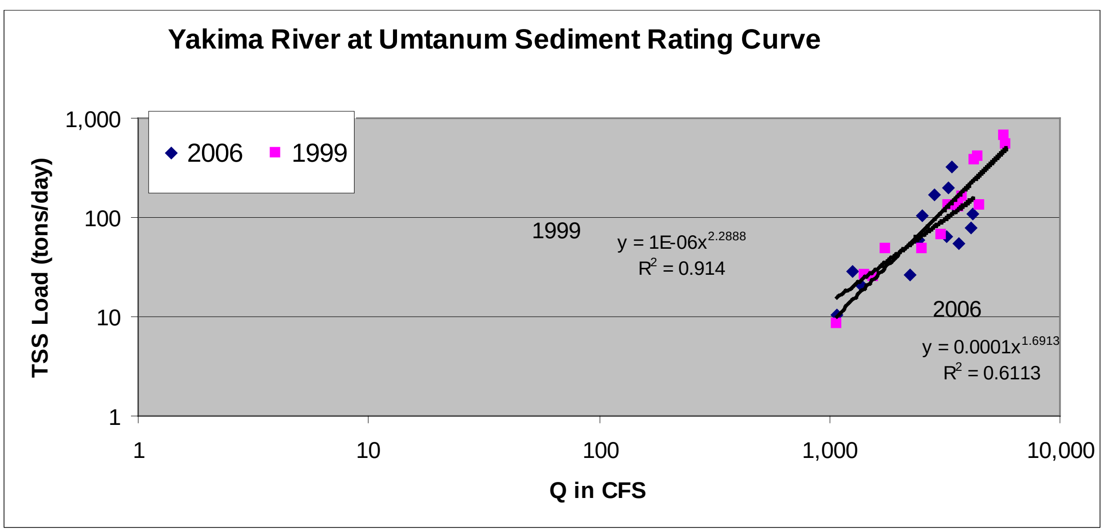


Figure 15. Sediment Rating Curves Comparing Discharge in cfs to Loading in tons day-at Three Sites in the Upper Yakima River Watershed during 1999 and during 2006

Creech and Joy (2002) set a loading capacity for the main stem upper Yakima River based on reductions in suspended-sediment loading by tributaries (see Table 6). Table 20 presents a comparison of the observed load in 2006 with the target loads set by Creech and Joy (2002). They used the correlation between TSS and turbidity to predict the resulting TSS loading that would result in a 10 NTU increase in turbidity from the background conditions. Under the discharge conditions of 2006, Wilson Creek carried less TSS than predicted by Joy (2002) and Creech and Joy (2002), but did not meet the turbidity target set by the TMDL.

In 2012, the loading capacity for Wilson Creek may have to be lower than originally predicted in order to meet the turbidity target depending on discharge conditions. Ecology and others implementing the TMDL may need to focus on turbidity reduction targets that result in daily loading of TSS possibly much lower than predicted by Joy (2002). This will depend on the type of water year experienced in 2012.

Table 20. The 2006 Loading Targets in Tons Per Day Predicted to Meet Turbidity Targets and Observed Loading in 2006

Site Name	1999 Load (tons day^{-1})	Tributary based 2006 target load	Observed load 2006
Teanaway River	77	43	33
Manastash Creek	4.4	4.2	Unknown
Sorenson Creek	3.2	2.7	Unknown
Wilson Creek	71	47	34
Yakima River at Umtanum	215	159	103
Yakima River at Harrison Bridge	131	98	46

Evaluation of background monitoring locations

The 90th percentile background turbidity value presented by the *Upper Yakima River Watershed Suspended Sediment, Turbidity and Organochlorine Pesticide TMDL* by Joy (2002) for tributaries was 7.5 NTU. He hypothesized that if the Teanaway River, Manastash Creek, Sorenson Creek, and Wilson Creek had no more than a 10 NTU increase over the 90th percentile turbidity background value, then the load of suspended sediment to the Yakima River would decrease by 26%. Joy (2002) compiled data collected from Naneum Creek, Coleman Creek, Cooke Creek, and Schnebly Creek to calculate the 1999 tributary background value used to set the 2006 and 2012 targets. Monitoring from the Teanaway River watershed, however, was not used by Joy (2002) to establish a background turbidity value.

The 2006 data set used in this report included data from a background monitoring station in the Teanaway River watershed. This background station established that the 90th percentile turbidity value for the Teanaway River background site was 12.4 NTU. The 2006 background value for Wilson Creek at Canyon Road was established by monitoring Naneum Creek at Naneum Road and was 5.5 NTU. The background site for Manastash Creek at Brown Road and Sorenson Creek at Fogarty Ditch was set at Manastash Creek at Manastash Road. Its 90th percentile turbidity value was 8.4 NTU. It appears to be more appropriate to set background conditions using the background sites from this study, particularly for the Teanaway River site.

Conclusions and Recommendations

Implementation activities and reduced stream discharge from snowmelt considerably reduced suspended sediment loading to the upper Yakima River from the tributaries monitored by this project. Many implementation activities occurred throughout the upper Yakima River watershed that lowered TSS concentrations and thus lowered turbidity values in the watershed.

Despite these implementation activities, the interim TMDL targets were not entirely met. One of the compliance sites had 90th percentile turbidity values greater than 10 NTU over the background 90th percentile values. Wilson Creek, despite a considerable decreased load of TSS, did not meet the 2006 turbidity target set by the TMDL.

However, the main stem Yakima River and all other tributaries did meet interim compliance targets. The TSS loading from tributaries decreased enough to meet targets set for turbidity in the Yakima River and in three out of four tributaries monitored during April through October of 2006. The Teanaway River, Manastash Creek, and Sorenson Creek at Fogarty Ditch did meet the interim turbidity targets set by the TMDL for 2006.

Stream discharge influences suspended sediment concentration, and thus, loading in the upper Yakima River and its tributaries. TSS loading was reduced in 2006 compared to 1999. Additionally, TSS loading in 2006 showed a lower correlation with discharge in the Teanaway River watershed, the Wilson Creek watershed, and in the Yakima River at Umtanum. These changes may be due to two main factors:

- The normal average monthly discharge in the upper Yakima River watershed compared to a higher than average discharge in 1999.
- Implementation of BMP use to control suspended sediment pollution .

Comparing 2006 with 1999, there appears to be little improvement in turbidity levels in Wilson Creek. Wilson Creek and its tributaries should be a focus for implementation activities in the next five years to meet turbidity targets set for 2012. The primary land use in the Wilson Creek watershed that affects turbidity is irrigated agriculture. Implementation of BMPs that reduce turbidity caused by irrigated agriculture should be applied more aggressively in this area. Many projects noted in this study involved improving the method of irrigation delivery to row and forage crop fields. For example, many projects completed included the installation of gated pipe to better control furrow irrigation rates. This practice may eliminate some polluted runoff by controlling the flow across individual fields; however, additional soil conservation practices may need to be employed.

The following recommendations are provided to help TMDL implementation to reach *Upper Yakima River Basin Suspended Sediment, Turbidity and Organochlorine Pesticide TMDL* turbidity targets for the year 2012.

- Background stations for future effectiveness monitoring should be located in the same locations as they were for this effectiveness monitoring study.

- Complete implementation of additional BMPs to control suspended sediment loading from irrigated lands, especially in the irrigated portion of the Wilson Creek watershed, such as the Cherry Creek and Wipple Wasteway drainages.

- Irrigators, irrigation districts, and the KCCD should develop a set of BMPs, policy decisions, outreach and technical assistance strategies to address irrigation of freshly planted fields. This seems to be a particular concern following years of drought.

- Create opportunities to convert furrow and rill irrigation systems to sprinkler or drip irrigation systems.

- The KCCD and NRCS should evaluate the effectiveness of individual BMPs for specific crop types, and provide technical assistance to irrigators accordingly.

- Continue to fix roads that contribute sediment in the Teanaway River watershed and other watersheds with forest access roads. [Was this supported by findings?]

- Evaluate the effectiveness of the KCWP water quality policy and enforce state law outside of local policy jurisdiction.

- Monitoring of turbidity of Wilson Creek at Canyon Road is encouraged for each irrigation season. Collection of several more years of data at this site may allow better understanding of the trend of turbidity values, as reported by KCWP in unpublished data.

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Appendices

Appendix A. Glossary and acronyms

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act (CWA): Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the CWA establishes the TMDL program.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Load allocation (LA): The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a water body can receive and still meet water quality standards.

Margin of safety (MOS):   Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving water body.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the state of Washington.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations (WLAs) for point sources, (2) the load allocations (LAs) for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.