Upper Chehalis River Watershed Multi-Parameter Total Maximum Daily Load

Water Quality Data Review

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Cover photo: WRIA 23 Sampling Station, 2006, Chehalis River Council.

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Water Quality Data Review

by
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Olympia, Washington 98504-7710

Waterbody Numbers:

WA-23-1010	WA-23-1030
WA-23-1012	WA-23-1043
WA-23-1013	WA-23-1050
WA-23-1014	WA-23-1070
WA-23-1015	WA-23-1080
WA-23-1017	WA-23-1090
WA-23-1018	WA-23-1100
WA-23-1019	WA-23-1102
WA-23-1020	WA-23-1104
WA-23-1023	WA-23-1106
WA-23-1024	WA-23-2020
WA-23-1027	WA-23-4000

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Abstract

The Washington State Department of Ecology (Ecology) conducted multiple Total Maximum Daily Load (TMDL) studies for the Upper Chehalis River watershed from 1994 to 2004. These studies found that temperature, dissolved oxygen, and fecal coliform bacteria concentrations did not meet water quality standards at several monitoring locations.

In 2004, Ecology published the *Chehalis/Grays Harbor Watershed Detailed Implementation Plan* to guide water cleanup in the basin. Since the completion of the Plan, the Chehalis Basin Partnership (CBP) has continued to monitor selected TMDL sites, as well as additional sites, to determine if water quality is improving in the basin.

In 2009, Grays Harbor College published a report summarizing the CBP data. Ecology reviewed this report and compared the results for the Upper Chehalis watershed to current water quality standards. Ecology also analyzed long-term data sets for trends in temperature, fecal coliform, and turbidity.

As part of this report, Ecology reviewed water quality cleanup activities that have occurred in the watershed. This was done to link cleanup activities to changes in water quality and to provide guidance for future activities.

Fecal coliform levels within the Upper Chehalis watershed have significantly improved. All 63 stations sampled by the CBP from 2006-2009 met bacteria water quality standards. TMDL target stations sampled by the CBP also met target limits for bacteria. However, several of the TMDL target stations were either not sampled or sampling did not occur during the critical months.

Of the 63 stations sampled by the CBP, 47 did not meet water quality criteria for temperature, and 62 did not meet criteria for dissolved oxygen.

Data indicate a significant reduction of fecal coliform in the Upper Chehalis watershed from 1991-2009. An analysis of temperature, dissolved oxygen, and turbidity data collected at long-term monitoring stations at Porter and Dryad indicate little to no change has occurred.

Although most water cleanup activities were well summarized, details provided were often insufficient to link activities to water quality improvements.

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Background

The Washington State Department of Ecology (Ecology) is required, under Section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency (EPA) regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters. As part of this process, Ecology evaluates the effectiveness of water cleanup activities in improving water quality.

In 2004, Ecology developed a *Detailed Implementation (Cleanup) Plan* for the Chehalis/Grays Harbor watershed (Rountry, 2004). The Plan was developed to improve fecal coliform, dissolved oxygen, and temperature conditions in the watershed. The Plan is for 114 impaired river segments named in seven TMDLs in the Chehalis/Grays Harbor watershed.

Because of it size, the Chehalis River basin is divided into the Upper and Lower basin. The Lower basin is Watershed Resource Inventory Area 22 (WRIA 22), and the Upper basin is WRIA 23. The seven TMDLs and their associated number of impaired segments are:

- Upper Chehalis Dissolved Oxygen TMDL, 26 segments (Jennings and Pickett, 2000).
- Upper Chehalis Temperature TMDL, 19 segments (Ecology, 2001).
- Grays Harbor/Chehalis Fecal Coliform Bacteria TMDL, 23 segments (Rountry and Pelletier, 2001).
- Upper Chehalis Fecal Coliform Bacteria TMDL, 17 segments (Ahmed and Rountry, 2004).
- Upper Chehalis River Dry Season TMDL, 19 segments (Pickett, 1994a).
- Black River Wet Season Non-Point Source TMDL, 7 segments (Coots, 1994).
- Black River Dissolved Oxygen and Phosphorus TMDL, 3 segments (Pickett, 1994b).

At the request of the Ecology's Southwest Regional Office Water Quality Program, Ecology's Environmental Assessment Program reviewed post-TMDL data from WRIA 23 collected by the Chehalis Basin Partnership (CBP). This report compares these results with current water quality standards. It also determines if significant water quality improvement has occurred.

Study area

The Upper Chehalis River basin (WRIA 23) covers 1,293 square miles, extending from the city of Porter south of Olympia to the Willapa Hills. The basin area extends into five counties: Lewis, Thurston, Grays Harbor, Pacific, and Cowlitz. The Chehalis Tribal Reservation is in the northwestern area of the basin along the mainstem Chehalis River. The mainstem passes through the two largest cities in the basin, Centralia with a population of 15,700 and Chehalis with a population of 7,396.

Major tributaries to the Upper Chehalis River include the South Fork Chehalis, Newaukum, Skookumchuck, and Black Rivers. There are numerous creeks that feed into the mainstem and sub-tributaries (Figure 1).

Land use in the Upper Chehalis basin is predominated by forested areas (83%), followed by agricultural lands (14%), and urban areas (2%). Most of the population lives in unincorporated areas. Average annual precipitation is 57 inches; it ranges from 30 inches near the city of Chehalis to 120 inches near the headwaters of the Chehalis River in the Willapa Hills.

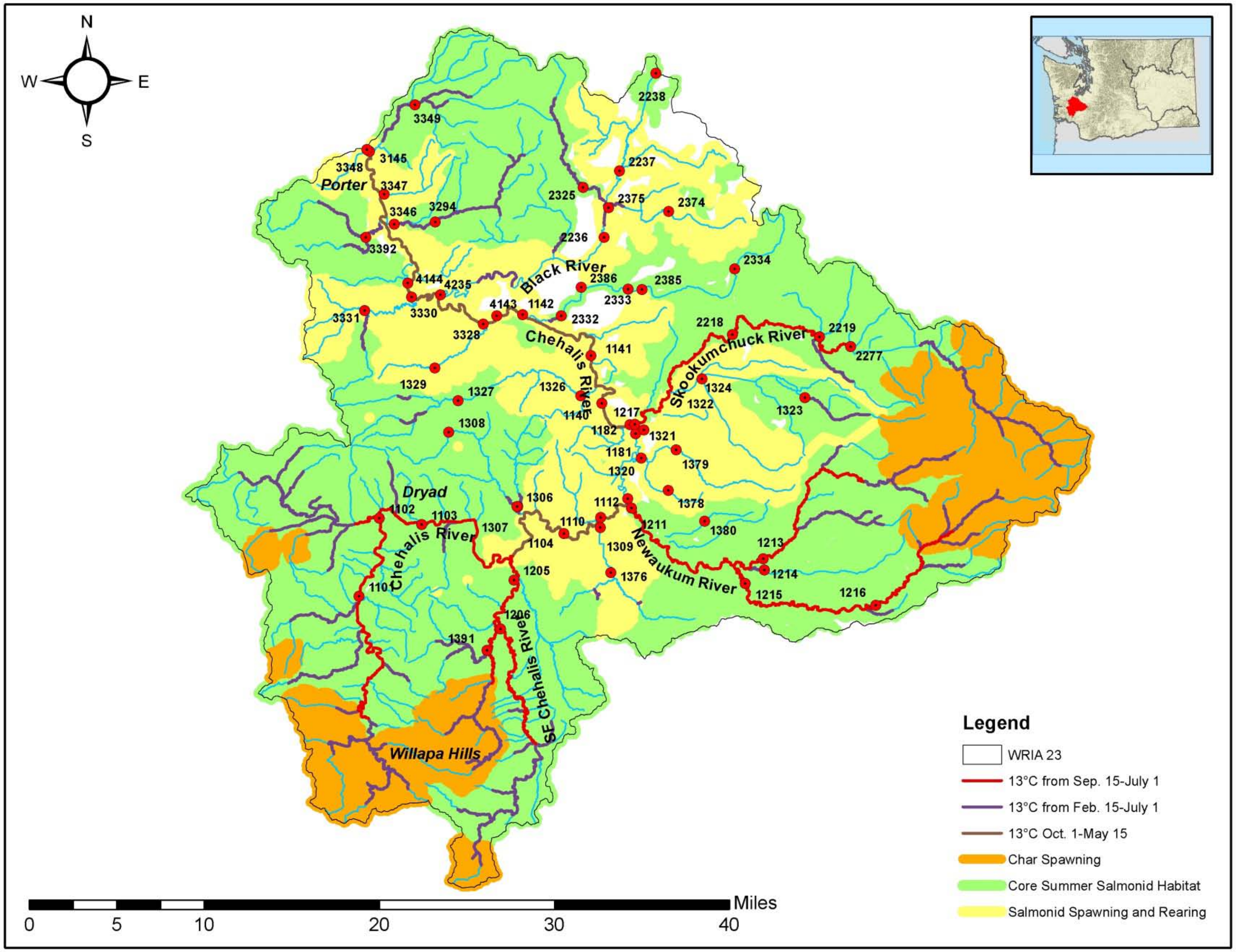

Figure 1. CBP monitoring stations in the Upper Chehalis River basin (WRIA 23), aquatic life use designation, and supplemental temperature criteria.

Watershed restoration activities

The most important part of any TMDL process is the water cleanup activities that occur within a TMDL area. These activities are meant to improve and protect water quality and habitat conditions within a waterbody. A *Detailed Implementation Plan* provides guidance for these activities by identifying stakeholders and actions that will help in this process. The tracking of these activities is important for connecting actions to improvements in water quality. Tracking is also important when making recommendations for future actions if water quality does not improve.

Ecology's 2004 *Detailed Implementation Plan* outlined implementation strategies and cleanup actions needed to meet targets and pollutant load reductions described in the Chehalis River watershed TMDL studies (Rountry, 2004). The Plan outlined management roles and activities that would contribute to cleanup efforts. This outline was updated in 2008 and is the most current centralized summary of implementation activities within WRIA 23 (Appendix B, Table B-1).

Water cleanup activities in WRIA 23 began prior to the 1994 TMDL. Early studies published by Sargeant (1996) and Sargeant et al. (2002) documented the effects of best management practices (BMPs) on water quality in five sub-basins within WRIA 23. Types of BMPs evaluated included animal exclusion, implementation of dairy waste management plans, restoration of riparian areas, and erosion control practices. While many of the BMPs resulted in initial improvements in water quality, water quality degraded in some areas when BMPs were not maintained properly (Sargeant et al., 2002).

Since Sargeant's initial BMP evaluation, various stakeholder groups have continued to implement cleanup activities. In 2009, Ecology published a summary of financial assistance provided to support water protection efforts within the Chehalis basin (Ecology, 2009b). In total, over $96 million has been distributed from 1996-2007. Of this, $91.5 million was distributed as loans for facility improvements while $2.6 million was distributed as grants for nonpoint restoration activities. The remainder was allocated as grants to support education and outreach activities and to support monitoring and mapping efforts within the basin.

In 2009, the CBP held a workshop to discuss recent implementation activities in the Chehalis basin (Ecology, 2009a). Implementation activities included but were not limited to: completion of farm plans, installation of riparian fencing and plantings, nutrient management activities, septic system management, land acquisition, and improvements to waste water treatment facilities. Details of the workshop are available at:
ftp://www.ecy.wa.gov/wq/Chehalis_12-Yr_Implementation_Story/index.htm.

Although recent cleanup activities have been well summarized, most implementation documentation lacks the detail necessary to link improvements in water quality to BMP activities. The lack of detail also makes it difficult to advance cleanup efforts when water quality has not improved. Specifically, details which better describe the location and time of the water cleanup effort are important. Also, information better describing broad actions, such as nutrient management activities and implementation of farms plans, are needed.

Water Quality Standards and Beneficial Uses

Fecal coliform bacteria

Two recreational uses apply to waters with the Upper Chehalis basin:

- *Primary Contact* criteria are intended for waters where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin-diving, swimming, and waterskiing. *Primary Contact* use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b)]. (Ecology, 2006)

- *Extraordinary Primary Contact* criteria are intended for waters capable of providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas. To protect these uses, "Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100/colonies mL" [WAC 173-201A-200(2)(b)] (Ecology, 2006). Although the *Extraordinary Primary Contact* criteria did not apply to any stations identified in the TMDL, they apply to four of the freshwater stations evaluated in this study (Table 1).

Ecology established TMDL stations and targets for fecal coliform in WRIA 23 (Ahmed and Rountry, 2004). Geometric mean targets were set to meet the 90^{th} percentile fecal coliform standard of 200 cfu/100 mL using the statistical roll-back method (Ott, 1995). Also, critical months for sampling fecal coliform were established at five of the target stations.

Stations, target values, and critical months are presented in Table 1. Table 1 also includes the CBP monitoring stations that correspond to TMDL target stations.

Table 1. Upper Chehalis River TMDL monitoring stations: river miles, corresponding CBP monitoring stations, locations, fecal coliform target limits, and critical months for sampling. *Units for geometric means (GM) and 90th percentile standards (90%^{tile}) are expressed in colonial forming units per 100 mL.*

RM	CBP Station ID	Location	GM	90%^{tile}	Critical Month
33.8	3145	Chehalis R. at Porter	37	200	-
54.7	1142	Chehalis R. at Ind. Rd.	32	200	Dec
59.9	1141	Chehalis R. at Prather	32	200	Nov
0.1	2375	Beaver Cr. at Porter Cr. Rd.	46	200	-
0.9	NS	Allen Cr. at mouth	53	200	-
1.5	NS	Dempsey Creek at Delphi Rd.	31	200	-
8	2333	Scatter Cr. at Case Rd.	33	200	-
19.9	2334	Scatter Cr. at Tenino	24	200	-
1.2	1326	Lincoln Cr. at L.C. Rd.*	32	200	-
8.8	NS	Lincoln Creek*	36	200	-
10.0	NS	Lincoln Creek*	73	200	-
67.5	1181	Chehalis R. at Mellen St.	36	200	Nov
0	1217	Skookumchuck R. at mouth*	24	200	Sept-Nov
0.6	1320	Salzer Cr. at Salzer Cr. Rd.	26	200	-
0.1	NS	Dillenbaugh Cr. at mouth	17	200	-
3.4	NS	Dillenbaugh Cr. above Berwick	44	200	-
0.0	NS	Berwick Cr. at mouth	30	200	-
0.15	1211	Newaukum R. at Shorey Rd.	25	200	-
101.7	NS	Chehalis R. at Dryad	37	200	Sept
0.6	1309	Stearns Cr. at Twin Oaks Rd.	35	200	-
0.5	NS	Bunker Cr. at mouth	50	200	-
2.4	NS	Deep Creek	20	200	-
4.0	1206	S. Fork Chehalis R. at Lv	49	200	-
1.5	NS	Lake Cr. at Curtis Hill Rd.	44	200	-
0.7	NS	Lost Cr. at Lost Valley Bridge	44	200	-

RM: River Mile.
GM: Geometric mean.
NS: Not sampled by CBP.
*Currently designated as Extraordinary Primary Contact.
- No critical month established.

Dissolved oxygen

In the Washington State surface water quality standards, freshwater aquatic life use categories are described using key species (salmonids versus warm-water) and life-stage conditions (spawning versus rearing). Minimum concentrations of dissolved oxygen (DO) are used as criteria to protect different categories of aquatic communities [WAC 173-201A-200]. (Ecology, 2006)

For WRIA 23, the following designated aquatic life uses and DO criterion are to be protected in freshwaters:

- *Core Summer Salmonids Habitat* where the lowest one-day minimum oxygen level must not fall below 9.5 mg/L more than once every 10 years on average. The key identifying characteristics of this use are summer (June 15 – September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids.
- *Salmonid Spawning, Rearing, and Migration* where the lowest one-day minimum oxygen level must not fall below 8.0 mg/L more than once every 10 years on average. The key identifying characteristic of this use is salmon or trout spawning and emergence that only occur outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.

Designated aquatic life uses within WRIA 23 are identified in Figure 1. A detailed list of CBP monitoring stations and their designated aquatic life uses are presented in Tables C-1 and C-2.

Surrogate targets for DO were identified in the 1994 TMDL at five mainstem stations in the Chehalis River (Pickett, 1994a). TMDLs were estimated for ammonia nitrogen (NH_3-N) and carbonaceous biochemical oxygen demand (CBOD) from May 1 to October 31 (Table 2). These loads were estimated to meet DO criteria in the mainstem of the Chehalis River. Stations were selected based on their proximity to historical ambient and flow monitoring stations.

Table 2. Recommended ammonia nitrogen (NH_3-N) and carbonaceous biochemical oxygen demand (CBOD) TMDLs to meet dissolved oxygen standards for key locations along the Chehalis River identified in the *Detailed Implementation Plan* (Pickett, 1994a).

Location	NH_3-N	CBOD
	lb -N/Day	lb -BOD_2/Day
Chehalis R. at Dryad	16.4	176
Chehalis R. at Claquato	23.6	236
Chehalis R. at Centralia	28.9	359
Chehalis R. at Grand Mound	84.8	1090
Chehalis R. at Porter	266.8	1870

Temperature

In the state water quality standards, aquatic life use categories are described using key species (salmon versus warm-water species) and life-stage conditions (spawning versus rearing) [WAC 173-201A-200; 2003 edition]. (Ecology, 2006)

For WRIA 23, the following designated aquatic life uses and temperature criterion are to be protected in freshwaters:

- *Core Summer Salmonids Habitat* where the highest 7-day average of the daily maximum temperatures (7-DADMax) must not fall above 16°C more than once every 10 years on average. The key identifying characteristics of this use are summer (June 15 – September 15) salmonid spawning or emergence, or adult holding; use as important summer rearing habitat by one or more salmonids; or foraging by adult and sub-adult native char. Other common characteristic aquatic life uses for waters in this category include spawning outside of the summer season, rearing, and migration by salmonids.

- *Salmonid Spawning, Rearing, and Migration* where the highest 7-DADMax must not fall above 16°C more than once every 10 years on average. The key identifying characteristic of this use is salmon or trout spawning and emergence that only occurs outside of the summer season (September 16 - June 14). Other common characteristic aquatic life uses for waters in this category include rearing and migration by salmonids.

Several waters within WRIA 23 have been identified as requiring supplemental spawning and incubation protection for salmonids (Payne, 2006). For WRIA 23, the following supplemental temperature criteria are used at selected locations:

- 13°C from September 15 – July 1.
- 13°C from October 1 – May 15.
- 13°C from February 15 – July 1.

Waters identified in WRIA 23 that have supplemental temperature criteria are presented in Figure 1. A detailed list of CBP monitoring stations and their temperature criteria are presented in Tables C-1 and C-2.

Percent shade targets for stream temperature were identified for 12 stream reaches in a WRIA 23 temperature TMDL (Ecology, 2001). Pollutant load allocations and percent shade needed to meet surface water temperatures are presented in Table 3.

Table 3. Shade targets to reach water temperature standards for the Upper Chehalis basin.

Stream Reach	Percent Vegetative Shade		
	Load Allocation	Estimated Existing Shade	Additional Shade Needed
Chehalis R. – Headwaters to Elk Cr.	49%	53%	0%
Chehalis R. – Elk Cr. to Newaukum R.	48%	18%	30%
Chehalis R. – Newaukum R. to Skookumchuck R.	64%	22%	42%
Chehalis R. – Skookumchuck R. to Scatter Cr.	43%	16%	27%
Chehalis R. – Scatter Cr. to Town of Porter	44%	16%`	28%
South Fork Chehalis River	74%	52%	22%
Newaukum River	78%	43%	35%
Dillenbaugh Creek	85%	64%	21%
Salzer Creek	81%	68%	13%
Skookumchuck River	79%	59%	20%
Lincoln Creek	78%	59%	19%
Scatter Creek	81%	69%	12%

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Water Quality Assessment and Impairments

Water Quality Assessment / Categories 1-5

Section 303(d) of the federal Clean Water Act requires Washington State to prepare a list of all surface waters in the state that are impaired by pollutants. Washington's Water Quality Assessment (303(d) list) identifies polluted waters in Washington. It is a state requirement to satisfy federal Clean Water Act requirements and to prioritize TMDL efforts.

This list divides waterbodies into five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – Lack of sufficient data.
- Category 4 – Polluted waters that do not require a TMDL because the problems are being solved in one of three ways:
  - 4a – Has an approved TMDL and it is being implemented.
  - 4b – Has a pollution control plan in place that should solve the problem.
  - 4c – Is impaired by a non-pollutant such as low water flow, dams, and culverts.
- Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Ecology's policy describing how waterbody segments will be assessed and placed in various categories is available here: www.ecy.wa.gov/programs/wq/303d/wqp01-11-ch1Final2006.pdf

Water quality impairments

Water quality impairments are documented in Washington's Water Quality Assessment Mapping Tool. (See www.ecy.wa.gov/programs/wq/303d/index.html for the most recent Water Quality Assessment information.)

This report addresses fecal coliform, DO, and temperature impairments at locations sampled by the CBP in WRIA 23 (Table 4). These listings are based on Washington's 2008 Water Quality Assessment approved by EPA.

Appendix C, Table C-3, presents a list of all stream segments in WRIA 23 identified as having fecal coliform, DO, and temperature impairments.

Table 4. CBP monitoring stations on the 2008 303(d) list for parameters, listing ID, and category.

Site #	Station Name	Parameter	Listing ID	Category
1101	Chehalis R. at Pe Ell	Fecal coliform	10430	4A
1102	Chehalis R. at Doty	Fecal coliform	10429	4A
1211	Newaukum R. at Shorey Rd.	Fecal coliform	16758	4A
		Temperature	7770	4A
1214	M. Fork Newaukum R. at Tauscher	Fecal coliform	45060	2
		Dissolved oxygen	47734	5
1306	Deep Creek	Dissolved oxygen	9975	4A
1391	Stillman Cr. at McDonald Rd	Fecal coliform	35394	5
1110	Chehalis R. at Hwy 603	Fecal coliform	16752	4A
		Temperature	10685	4A
		Dissolved oxygen	10686	4A
		Turbidity	15915	5
1112	Chehalis R. at SR 6	Fecal coliform	10417	4A
		Temperature	35939	4A
		Dissolved oxygen	5867	4A
1141	Chehalis R. at Prather	Fecal coliform	16755	1
		Temperature	10991	4A
		Dissolved oxygen	5865	4A
		Turbidity	15916	2
1181	Chehalis R. at Mellen St.	Fecal coliform	16753	4A
		Temperature	5874	4A
		Dissolved oxygen	5881	4A
1182	Chehalis R. at Borst Pk.	Fecal coliform	16753	4A
		Temperature	5874	4A
		Dissolved oxygen	5881	4A
1217	Skookumchuck R. at mouth	Fecal coliform	10402	4A
		Temperature	7778	4A
1309	Stearns Cr. at Twin Oaks Rd.	Fecal coliform	10406	4A
		Temperature	14145	4A
		Dissolved oxygen	7780	4A
1320	Salzer Cr. at Salzer Cr. Rd.	Fecal coliform	10406	4A
		Temperature	7772	4A
		Dissolved oxygen	47768	4A
1326	Lincoln Cr. at L.C. Rd.	Fecal coliform	10399	4A
		Temperature	35936	4A
		Dissolved oxygen	7762	4A
1376	Stearns Cr. at Pleasant Valley	Fecal coliform	14152	4A
1379	Salzer Cr. at Centrail. Rd.	Temperature	7774	4A
		Dissolved oxygen	7775	4A
2236	Black R. at Littlerock	Fecal coliform	6674	4A
2375	Beaver Cr. at Porter Cr. Rd.	Fecal coliform	6675	4A
		Temperature	15522	2
3145	Chehalis R. at Porter	Fecal coliform	9976	4A
		Temperature	9497	4A
3328	Independence Cr. at mouth	Dissolved oxygen	7761	4A
3330	Garrard Cr. at mouth	Dissolved oxygen	7760	4A
3348	Porter Cr. at Hwy 12	Fecal coliform	10398	4A
4144	Chehalis R. at Sickman-Ford	Temperature	5876	4A
4235	Black R. at mouth	Fecal coliform	6667	4A
		Temperature	35935	4A
		Dissolved oxygen	7745	4A

Data Analysis

Studies

All data used in this review were obtained from Ecology's Environmental Information Management (EIM) system (www.ecy.wa.gov/eim/). A list of studies and data used for some of the analysis are presented in Table 5.

Table 5. WRIA 23 studies in EIM used in the watershed-scale data analysis.

Study Name	User Study ID
Statewide River and Stream Ambient Monitoring - Pre 1980	AMS001B
Statewide River and Stream Ambient Monitoring - 1980 to 1988	AMS001C
Statewide River and Stream Ambient Monitoring - WY1989 through WY1999	AMS001D
Statewide River and Stream Ambient Monitoring - WY2000 to present	AMS001E
Statewide River and Stream Ambient Monitoring - WY2000 to present-2	AMS001-2
Beaver Creek Dairy pre- and post-BMP Groundwater Monitoring (1995-1999)	BEAVCKDA
Chehalis River Basin Water Quality Screening Study (1990-1992)	BEDI0001
Chehalis River Best Management Practices Evaluation Project (1994-2000)	DSAR0002
Chehalis River Council Volunteer Monitoring Project (2006-2009)	G0200280
WRIA 22-23 Water Quality Monitoring (2007-2009)	G0700116
Salzer Creek Watershed Restoration Project (1996-2001)	G9600263
Grays Harbor Fecal Coliform TMDL (1997-1998)	GPEL0007
Black River Dry-Season TMDL (1991-1994)	PPIC0001
Upper Chehalis River TMDL (1991-1994)	PPIC0002
Black River Wet-Season TMDL (1991-1994)	RCOO0001

WY: Water Year.

The most recent data collection effort was performed by CBP from 2006-2009. Fecal coliform, DO, pH, and turbidity measurements were collected approximately every four weeks at 94 sites throughout the Chehalis River watershed. A total of 63 of these stations were located in WRIA 23. Data were collected under the guidance of an Ecology-approved Quality Assurance Project Plan (Lehr, 2007). A report summarizing these data was published in 2009 (Green, 2009). Data from this study were evaluated against Washington State surface water quality standards and TMDL target limits.

Long-term trend analysis was performed for fecal coliform, DO, and temperature using data from studies presented in Table 5. Also, a trend analysis was performed using data collected by Ecology's ambient monitoring program. Specifically, data from two long-term monitoring stations (>50 years of data) on the Chehalis mainstem near the towns of Porter and Dryad were analyzed. Additional information on Ecology's ambient monitoring program is available at: www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

Although not initially part of the TMDL, turbidity data were analyzed for trends because of land-use concerns in the upper watershed. Slope failures and landslides in the upper Chehalis basin, caused by high rain events in the winters of 2007 through 2009, were the major cause of elevated turbidity levels (Green, 2009). Temporal trends were assessed throughout WRIA 23 and at ambient monitoring stations at Porter and Dryad.

Compliance with water quality standards and TMDL targets

Data collected by CBP in 2007-2009 were used to assess compliance with water quality standards and TMDL target limits. For fecal coliform, only the most recent 12 months of data were used. For DO and temperature, the entire data set was used (2007-2009).

Fecal coliform

Geometric means and 90^{th} percentiles for fecal coliform were calculated at each CBP monitoring station to assess compliance with water quality standards and TMDL targets. The most recent 12 months of data were used for these analyses. Fecal coliform geometric means were calculated by back-transforming the mean of log-transformed concentration values. Fecal coliform 90^{th} percentiles were calculated as the 90^{th} percentile of a log-normal distribution, where the mean and standard deviation are estimated from the log-transformed data. These methods were consistent with the methodologies used in the TMDL (Ahmed and Rountry, 2004).

Dissolved oxygen

DO data were first assessed against water quality standards. If violations of the DO standard were observed, data were assessed to determine if the waterbody met criteria to be listed on Washington's 303(d) list as impaired. Because only single DO samples (versus continuous DO samples) were collected, only Category 5 listings were determined. A waterbody segment was determined to be impaired if: (1) a minimum of three excursions exist from all data considered, and (2) at least 10% of single grab sample values in a given year do not meet the criterion. Waterbodies that did not violate water quality criteria based on single DO samples only cannot be removed from the 303(d) list.

Temperature

CBP temperature data were first assessed against water quality standards. If data indicated violations of water quality standards occurred, data were assessed to determine if the waterbody met criteria to be listed on Washington's 303(d) list as impaired. Because only single temperature samples (versus continuous temperature samples) were collected, only Category 5 listings were determined. A waterbody segment is impaired (i.e., in Category 5) if: (1) a minimum of three excursions exist from all data considered, and (2) at least 10% of single grab sample values in a given year do not meet the criterion. Waterbodies that did not violate water quality standards could not be removed from the 303(d) list based on a single temperature grab sample.

Ammonia loads

Ammonia and discharge data from ambient monitoring stations at Porter and Dryad were analyzed to evaluate whether loads are meeting TMDL targets. Ammonia loads were calculated for each sample event as the product of the sample concentration (mg/L) and the measured discharge (cfs). Non-detects in ammonia concentration were handled by dividing the detection limit by 2. These approaches were consistent with methods described in the original TMDL (Pickett, 1994a).

Trend monitoring

Testing for trends in long-term monitoring data collected from different studies and organizations can be problematic. Such data sets often violate the assumptions necessary to use traditional statistical approaches to measure the presence of trends. Statistical tests capable of measuring trends are often complex and time-consuming. For the purposes of this report, it is acknowledged that many outside variables can affect results.

For the purposes of this report, linear regression and nonparametric trend tests were used as a diagnostic tool for assessing water quality trends in WRIA 23 (Helsel and Hirsch, 2002). While the information is useful for interpreting potential relationships between water quality and time, caution should be used when using the results for other regulatory purposes.

To determine if the linear regression test was appropriate, data sets were tested for normal distribution using a Shapiro-Wilk test for normality (Shapiro et al., 1968). All statistical tests were performed using Systat® version 13.0.

Ordinary least square regression

Ordinary least squares (OLS) regression was used to test for trends in fecal coliform and DO data. OLS regression was used in these cases because the data sets were normally distributed, a requirement of the test. This approach was used for pooled WRIA 23 data and for data collected at ambient monitoring stations near the towns of Porter and Dryad.

Fecal coliform data were log normalized and averaged to give yearly geometric means before performing regressions. Monthly DO data were averaged to give the yearly average before performing regressions. Because trends are the result of yearly averages over time, violations of water quality criteria may not be interpreted from trend lines. This is because high values have been masked in the averaging process.

P values of <0.05 indicate if the relationship between the variables (parameter and year) is significant. The coefficient indicates the direction of the trend (negative or positive) as well as the rate of change over time. Summary statistics for OLS regression are presented in Appendix C, Table C-4.

Seasonal Kendall

Trends analysis for all parameters was conducted using the Seasonal Kendall test (Helsel and Hirsch, 2002). The test accounts for seasonal variations in data over time and for outliers in data sets. Both of these conditions are common in water quality data sets and can significantly influence regression results. Furthermore, data are not required to be normally distributed. This approach was used to assess for trends in pooled WRIA 23 fecal coliform and turbidity data. It was also used to assess for fecal coliform, DO, daily maximum temperature, and turbidity data from Ecology's ambient monitoring stations at Porter and Dryad.

The Seasonal Kendall test calculates the probability (p-value) of a relationship occurring between the variable (chemistry) and time (year). A $p<0.05$ means there are significant differences in the chemistry over time. A separate test (Sen) calculates the slope of the trend. A negative slope indicates a decreasing trend while a positive slope indicates an increasing trend. The greater or lesser the slope, the larger the rate of change over time.

Fecal coliform and turbidity data were log normalized before performing the test. Transforming the data has no effect on the trend analysis.

Daily maximum temperature trends were assessed at Ecology's ambient monitoring stations at Porter and Dryad. Data were collected using continuous temperature loggers during critical months (July-September) from 2000-2008. As part of the analysis, daily maximum temperatures were averaged for each month, then compared over the years data were collected.

Results and Discussion

Compliance with water quality standards and TMDL targets

Fecal coliform

TMDL targets

Table 6 lists the TMDL target stations and corresponding CBP sampling stations. Several stations outlined in the TMDL still require data to determine compliance with TMDL target limits (Ahmed and Rountry, 2004). Those stations are listed as NS (not sampled) in Table 6. Also, five of the TMDL target stations have associated critical months for estimating target limit compliance (Tables 1 and 6).

All TMDL target stations (with no critical period identified) monitored by the CBP were well within TMDL target limits and require no additional reduction in fecal coliform. Yearly fecal coliform geometric mean reductions ranged from 76-96% when compared to the original data used to calculate TMDL target limits. Although all percent reductions were relatively high, the largest yearly reduction occurred on Beaver Creek at Porter Creek Road.

Four stations identified in Table 6 are currently classified *Extraordinary Primary Contact* and were also evaluated against a geometric mean of 50 cells/100 mL and 90th percentile of 100 cells/100 mL. Geometric means and 90th percentiles from Lincoln Creek at L.C. Road and the Skookumchuck River at mouth were well within these more restrictive standards.

Based on data collected by the CBP at nine of the 25 TMDL target stations, overall fecal coliform loads appear to have decreased at selected sampling stations in WRIA 23. Additional data are needed for TMDL target stations and critical periods not sampled by the CBP in order to measure compliance with TMDL target stations.

Future sampling collection at these stations must be in accordance with criteria outlined in Ecology's Water Quality Program Policy 1-11(Water Quality Program Policy, 2006). In short, at least five samples meeting the criteria must be available from a critical period or other reporting period as described in the TMDL.

Table 6. Fecal coliform concentrations at CBP monitoring stations and corresponding TMDL concentrations for the Upper Chehalis River basin (WRIA 23).
Station descriptions in bold text indicate a critical month for sampling was identified in the TMDL.

Station Locations		TMDL		CBP		Percent reduction needed
CBP ID	Station Description	GM	90^{th} %tile	GM	90^{th} %tile	
1141	**Chehalis R. at Prather**	231	1475	4.5	6.3	86
1142	**Chehalis R. at Ind. Rd.**	168	935	7.2	14.8	79
1181	**Chehalis R. at Mellen St.**	139	763	5.5	10.6	74
1206	S. Fork Chehalis R. at Lv	117	481	6.6	13.6	0
1211	Newaukum R. at Shorey Rd.	78	625	5.2	9.9	0
1217	**Skookumchuck R. at mouth**[1]	115	960	4.6	7.4	79
1309	Stearns Cr. at Twin Oaks Rd.	77	443	5.3	10.7	0
1320	Salzer Cr. at Salzer Cr. Rd.	61	460	5.7	10.3	0
1326	Lincoln Cr. at L.C. Rd.[1]	201	1240	9.4	29.7	0
2333	Scatter Cr. at Case Rd.	68	406	16.5	35.7	0
2334	Scatter Cr. at Tenino	124	1045	19.9	52.1	0
2375	Beaver Cr. at Porter Cr. Rd.	169	735	6.6	16	0
3145	Chehalis R. at Porter	95	563	10.1	25.2	0
NS	**Chehalis R. at Dryad**[2]	52	280	20.3	86	29
NS	Allen Creek at mouth	116	436	-	-	54
NS	Dempsey Creek at Delphi Rd.	439	2964	-	-	93
NS	Lincoln Creek[1] at RM 8.8	96	546	-	-	63
NS	Lincoln Creek [1] at RM 10	244	683	-	-	70
NS	Dillenbaugh Cr. at mouth	133	1532	-	-	87
NS	Dillenbaugh Cr. above Berwick	68	313	-	-	36
NS	Berwick Creek at mouth	228	1500	-	-	87
NS	Bunker Creek at mouth	71	286	-	-	30
NS	Deep Creek	136	1348	-	-	85
NS	Lake Cr. at Curtis Hill Road	74	320	-	-	40
NS	Lost Cr. at Lost Valley Bridge	56	462	-	-	57

[1] Extraordinary Primary Contact geomean 50 cells/100 mL and 90^{th} percentile 100 cells/100 mL.
[2] Geomean and 90^{th} percentile calculated (2009-2010) from Ecology's ambient monitoring station at Dryad.

Water quality standards

CBP monitoring results were compared with water quality standards for fecal coliform geometric mean and 90^{th} percentiles (Table 7). Methods for determining compliance with water quality standards are described earlier.

Based on the geometric means and 90^{th} percentiles calculated on the most recent 12 months of fecal coliform data, no water quality impairments were observed at any of the CBP sampling stations (Table 7). Geometric means ranged from 4.0 to 12.2 while 90^{th} percentiles ranged from 4.0 to 30.7. All stations were well within test criteria for clean water. Although violations of the standards were observed at some of the stations, the results were not frequent or high enough to elevate the values above water quality standards.

Table 7. Number of fecal coliform samples collected, percent of samples above water quality standards (% > STD), geometric means (GM), and 90th percentiles (90th %tile) at CBP monitoring stations without established TMDL target limits in WRIA 23.

ID	Station Description	# Samples	% > STD.	GM	90th %tile
1101	Chehalis R. at Pe Ell	28	0.0	6.7	15.8
1102	Chehalis R. at Doty	28	0.0	6.2	13
1103	Chehalis R. at Rainbow Falls St. Pk.	25	0.0	4.6	7.4
1104	Chehalis R. at Adna	28	3.6	6	11.7
1110	Chehalis R. at Hwy 603	29	3.4	6.1	10.8
1112	Chehalis R. at SR 6	29	0.0	4.8	8.3
1140	Chehalis R. at Galvin Rd.	25	0.0	5.2	10.3
1182	Chehalis R. at Borst Pk.	28	0.0	5.2	8.8
1205	S. Fork Chehalis R. at Bf	28	3.6	4.6	7.4
1213	N. Fork Newaukum R. at Tauscher	28	3.6	6.1	13.4
1214	M. Fork Newaukum R. at Tauscher	28	3.6	9.6	27.6
1215	S. Fork Newaukum R. at Mf Br.	28	3.6	8.3	21.7
1216	S. Fork Newaukum R. at Jr Br.	28	3.6	7.1	16.3
1306	Deep Cr.	27	0.0	10.6	26.5
1307	Bunker Cr. at Bunk. Cr. Rd.	28	0.0	4.9	8.1
1308	Bunker Cr. at Ingalls Rd.	24	0.0	6.4	14.8
1321	China Cr.	30	3.3	5.7	11.5
1322	Hanaford Cr. at Schaefer	30	3.3	5.9	13.1
1323	Hanaford Cr. at Rd. End	30	0.0	4.2	5.5
1324	S. Hanaford Cr.	29	0.0	5.5	9.4
1327	Lincoln Cr. at Ingalls Rd.	24	0.0	7.8	27.9
1329	Independence Cr.	21	0.0	6.4	23.2
1376	Stearns Cr. at Pleasant Valley	24	4.2	6.1	10.8
1378	Coal Cr.	26	3.8	6	15.6
1379	Salzer Cr. at Centrail. Rd.	28	3.6	5.2	8.8
1380	Dillenbaugh Cr.	27	3.7	5.8	10.8
1391	Stillman Cr. at McDonald Rd.	15	0.0	4.3	6.1
2218	Skookumchuck R. at Tono	26	7.7	8	21.2
2219	Skookumchuck R.	24	4.2	7.1	26.6
2236	Black R. at Littlerock	26	0.0	5.8	12
2237	Black R. at 110th Ave.	25	0.0	4.9	9.5
2277	Skookumchuck R. at Hatch	27	0.0	6.8	13.1
2298	Black R. at Belmore	27	0.0	4.8	9.1
2325	Waddell Cr. at Sw Bridge	26	0.0	6.9	15.4
2332	Scatter Cr. at James Rd.	30	3.3	5	7.8
2374	Beaver Cr. at Reeder Rd.	24	0.0	6.6	20.8
2385	Scatter Cr. at Leitner Rd. Sw	12	0.0	6.6	18.7
2386	Scatter Cr. at Sargent Rd.	15	0.0	4.5	6.3
3294	Cedar Cr. at Capital Forest Rd.	13	0.0	4	4
3328	Independence Cr. at mouth	23	0.0	6	10.4
3330	Garrard Cr. at mouth	24	0.0	5.4	9.7
3331	Garrard Cr. at Brooklyn Rd.	27	3.7	12.2	30.7
3346	Cedar Cr. at Elma Gate	27	3.7	5.6	11.4
3347	Gibson Cr. at Hwy 12	26	3.8	5.5	10.6
3348	Porter Cr. at Hwy 12	26	3.8	5.1	9
3349	Porter Cr. at Campgrd.	27	0.0	4.6	9
3392	Rock Cr. at Norton Rd.	15	0.0	4.8	9.1
4143	Chehalis R. at Bull Hole	29	0.0	6.9	18.8
4144	Chehalis R. at Sickman-Ford	25	0.0	8	23
4235	Black R. at mouth	29	0.0	6.2	11.8

The results presented in Tables 6 and 7 suggest that water quality cleanup efforts have succeeded in reducing fecal levels in WRIA 23. Also, it appears current watershed management activities are sufficient to prevent additional fecal coliform impairments from occurring at selected stations, as long as they are sustainable.

Dissolved oxygen

In a report summarizing the CBP data collection effort, it was reported that a DO equipment malfunction may have occurred during some of the sampling events (Green et al., 2009). This equipment malfunction appeared to result in extreme low DO values throughout the study period (2006-2009). Because of this, all DO data (mg/L), where corresponding percent oxygen saturation and temperature were recorded, were calculated using published mathematical relationships. DO data which still appeared to be extremely low were excluded from reporting, except where noted in their report.

Although methodologies for editing DO data are well documented, DO data from this study and summarized in this report should be interpreted carefully. At best, data should be used to prompt further studies in stream segments where low DO values were consistently observed.

Dissolved oxygen (Core Summer Habitat)

Based on single-sample DO collections, violations of the DO water quality standard were detected at all stations designated as Core Summer Habitat (Table 8). Consequently, all but three stations which violated water quality standards also met the criteria to be listed as impaired on Washington's 303(d) list.

The number of violations at any particular site ranged from 1 to 11, and percent violations ranged from 28.6 – 62.5% (Table 8). The Scatter Creek watershed had the highest percentage of violations while the Skookumchuck River, above the mouth, had the lowest percentage of violations (Table 8). Although violations were observed on the Skookumchuck River, the number and frequency of violations were not high enough to meet the criteria to be listed as impaired.

A total of 27 DO measurements below 9.5 mg/L were measured on Scatter Creek with values ranging from 5.5 to 9.4 mg/L. Of these measurements, more than half (63%) were observed from October through May. This is generally thought to be outside of the critical period and suggests results should be evaluated further. Also, an evaluation of current land use practices surrounding Scatter Creek that may affect DO is warranted before additional sampling is conducted.

Scatter Creek was identified in the original TMDL as having a high pH resulting from high productivity (Pickett, 1994a). The primary cause of the high productivity was suspected to be high nutrient loading from two aquaculture operations. At the time, discharges from these operations supplied most of the summertime flow in Scatter Creek. High nutrient loading could negatively affect DO levels.

Table 8. Dissolved oxygen (mg/L) recorded at CBP monitoring stations designated as Core Summer Habitat in WRIA 23.
Percentages in bold type indicate water quality impairment.

ID	Station name	No. of samples	< 9.5	%
2218	Skookumchuck R. at Tono	23	1	4.3
2219	Skookumchuck R.	23	1	4.3
2277	Skookumchuck R. at Hatch	23	1	4.3
2325	Waddell Creek at Sw Bridge	24	3	**12.5**
3349	Porter Creek at Campgrd.	28	4	**14.3**
3346	Cedar Creek at Elma Gate	27	4	**14.8**
1101	Chehalis R. at Pe Ell	25	4	**16.0**
1102	Chehalis R. at Doty	25	4	**16.0**
1103	Chehalis R. at Rainbow Falls St. Pk.	22	4	**18.2**
1206	S. Fork Chehalis R. at Lv	27	5	**18.5**
1216	S. Fork Newaukum R. at Jr Br.	26	5	**19.2**
1211	Newaukum R. at Shorey Rd.	27	6	**22.2**
1327	Lincoln Creek at Ingalls Rd.	22	5	**22.7**
1205	S. Fork Chehalis R. at Bf	26	6	**23.1**
1380	Dillenbaugh Creek	25	6	**24.0**
1323	Hanaford Creek at Rd. End	28	7	**25.0**
3294	Cedar Creek at Capital Forest Rd.	15	4	**26.7**
2332	Scatter Creek at James Rd.	28	8	**28.6**
1213	N. Fork Newaukum R. at Tauscher	26	8	**30.8**
1215	S. Fork Newaukum R. at Mf Br.	26	8	**30.8**
1214	M. Fork Newaukum R. at Tauscher	25	8	**32.0**
1306	Deep Creek	25	8	**32.0**
1391	Stillman Creek at McDonald Rd.	15	5	**33.3**
2385	Scatter Creek at Leitner Rd. SW	12	4	**33.3**
1307	Bunker Creek at Bunk. Cr. Rd.	26	9	**34.6**
3392	Rock Creek at Norton Rd.	14	5	**35.7**
1217	Skookumchuck R. at mouth	13	5	**38.5**
2386	Scatter Creek at Sargent Rd.	15	6	**40.0**
2334	Scatter Creek at Tenino	16	7	**43.8**
1308	Bunker Creek at Ingalls Rd.	23	11	**47.8**
2333	Scatter Creek at Case Rd.	8	5	**62.5**

Dissolved oxygen (Spawning, Rearing, and Migration)

Based on single-sample DO collections, violations of the water quality standard for DO were detected at all but one station designated for Spawning, Rearing, and Migration (Table 9). Consequently, all but eight stations which violated standards also met the criteria to be listed as impaired on Washington's 303(d) list.

The number of violations at any particular site ranged from 0 to 15, and percent violations ranged from 0 – 62.5 % (Table 9). The Black River at 110th Avenue had the highest percentage of violations of the DO standard while the Chehalis River at Sickman-Ford had the lowest percentage of violations (Table 9).

Table 9. Dissolved oxygen (mg/L) recorded at CBP monitoring stations designated as Spawning, Rearing, and Migration Habitat in WRIA 23.
Percentages in bold type indicate water quality impairment.

ID	Station name	No. of samples	<8	%
4144	Chehalis R. at Sickman-Ford	21	0	0.0
2298	Black River at Belmore	23	1	4.3
3145	Chehalis R. at Porter	28	2	7.1
3348	Porter Cr. at Hwy 12	28	2	7.1
4143	Chehalis R. at Bull Hole	25	2	8.0
4235	Black R. at mouth	25	2	8.0
3331	Garrard Cr. at Brooklyn Rd.	24	2	8.3
1140	Chehalis R. at Galvin Rd.	23	2	8.7
1142	Chehalis R. at Ind. Rd.	23	2	8.7
1104	Chehalis R. at Adna	26	3	**11.5**
2375	Beaver Cr. at Porter Cr. Rd.	25	3	**12.0**
1112	Chehalis R. at SR 6	29	4	**13.8**
1110	Chehalis R. at Hwy 603	28	4	**14.3**
1329	Independence Cr.	21	3	**14.3**
1141	Chehalis R. at Prather	27	4	**14.8**
3330	Garrard Cr. at mouth	20	3	**15.0**
1376	Stearns Cr. at Pleasant Valley	25	4	**16.0**
1182	Chehalis R. at Borst Pk.	28	5	**17.9**
3347	Gibson Cr. at Hwy 12	28	5	**17.9**
1378	Coal Cr.	26	5	**19.2**
1322	Hanaford Cr. at Schaefer	28	6	**21.4**
1181	Chehalis R. at Mellen St.	26	6	**23.1**
1379	Salzer Cr. at Centrail. Rd.	25	6	**24.0**
1309	Stearns Cr. at Twin Oaks Rd.	26	7	**26.9**
1321	China Cr.	28	8	**28.6**
1320	Salzer Cr. at Salzer Cr. Rd.	27	8	**29.6**
3328	Independence Cr. at mouth	20	6	**30.0**
1326	Lincoln Cr. at L.C. Rd.	23	7	**30.4**
2236	Black R. at Littlerock	26	9	**34.6**
1324	S. Hanaford Cr.	26	10	**38.5**
2374	Beaver Cr. at Reeder Rd.	23	12	**52.2**
2237	Black R. at 110th Ave.	24	15	**62.5**

DO measurements at the Black River 110th Avenue station ranged from 6.1 – 10.2 mg/L. A total of 8 of the 15 violations occurred from October through April. As with Scatter Creek, this is generally outside the critical low-flow, high-temperature period when DO violations are likely to occur.

The Black River at 110th Avenue is located in the Upper basin of the Black River. The Upper basin was identified in the original TMDL as having no DO results above the 8.0 mg/L criterion. The TMDL suggests the extensive wetlands in the Upper basin are likely responsible for low DO concentrations (Pickett, 1994b).

DO concentrations vary inversely with temperature and biological productivity. When assessing DO concentrations with water quality standards, it is necessary to take measurements during the warmest part of the day. This is when oxygen concentrations would be lowest. To accurately assess DO conditions, measurements must be taken on a continuous basis. Continuous DO monitoring is generally done during low-flow, high-temperature critical periods. In addition, waterbodies can only be removed from Washington's 303(d) list using data collected in this way (Water Quality Program Policy, 2006).

Dissolved oxygen targets

Ammonia data collected at Ecology's ambient monitoring stations at Porter and Dryad were used to assess compliance with surrogate targets for DO identified in the TMDL (Pickett, 1994a). CBOD was not available at these stations and was not assessed. Ammonia data from May 1 to October 31 were used to determine nitrogen loading in pounds per day from 2002 to 2010 (Figures 2 and 3). Although ammonia and flow data were available from 1959 to the present at these stations, loading was only assessed over the last eight years. This was because methodologies and detection limits varied prior to 2002.

Nitrogen loading at Porter and Dryad did not meet (exceeded) their respective TMDL target limits four times between 2002 and 2010. Most observed values fell well below the target over the last eight years.

Although a trend analysis was not performed on these data, there does appear to be a slight non-linear upward trend at both stations. The observed increase in loading at Dryad from 2006 – 2010 may be explained by high flows associated with numerous non-detects in ammonia concentrations. Out of the 101 ammonia samples taken, only nine were above detection limits at Dryad while 71 were above detections at Porter. Because the number of nondetects was relativity low at Porter, the observed increase may be a result of increased nitrogen loading. This observation should be further evaluated.

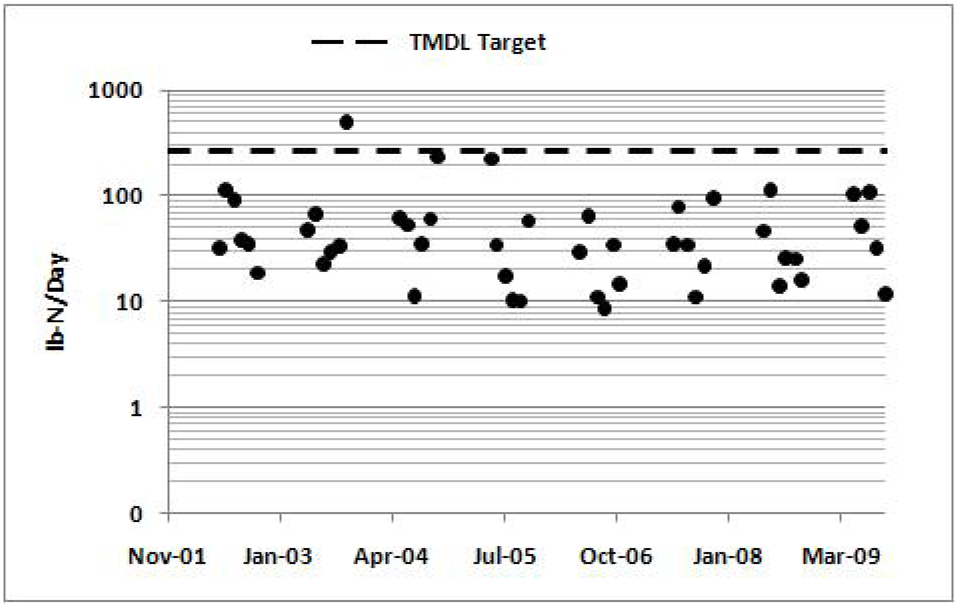

Figure 2. Pounds per day of nitrogen loading in the Chehalis River at Porter.

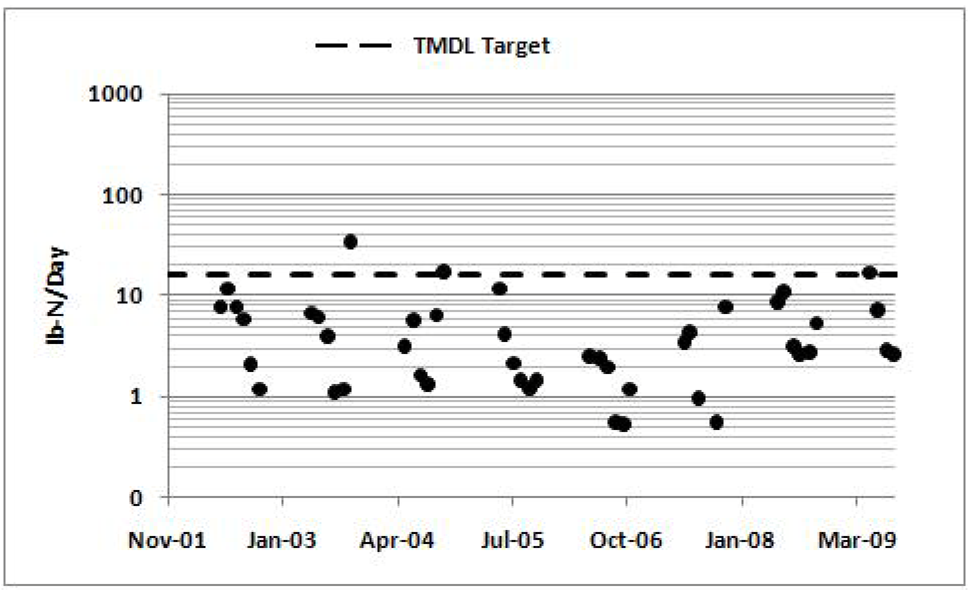

Figure 3. Pounds per day of nitrogen loading in the Chehalis River at Dryad.

Temperature

Core Summer Habitat designation

Based on single-sample temperature measurements, violations of either core summer or supplemental temperature criteria were detected at 26 stations designated as Core Summer Habitat (Table 10). However, only 12 of the stations that violated water quality standards also met the criteria to be listed as impaired on Washington's 303(d) list. All of these 12 stations had associated supplemental temperature criteria, although the majority of the violations occurred outside the supplemental criteria date range (Table 10).

The number of violations at any particular site ranged from 0 to 8, while percent violations ranged from 0 – 27.6 % (Table 10). The Skookumchuck River at the mouth and the Newaukum River at Shorey Road had the highest percentage of violations.

Spawning, Rearing, and Migration Habitat designation

Based on single-sample temperature measurements, violations of either the spawning, rearing, and migration or supplemental temperature criteria were detected at 21 stations designated as Spawning, Rearing, and Migration Habitat (Table 11). Only 13 of the stations that violated water quality standards also met the criteria to be listed as impaired on Washington's 303(d) list. Although 8 of the 13 stations had associated supplemental temperature criteria, the majority of the violations occurred outside the supplemental criteria date range.

The number of violations at any particular site ranged from 0 to 7, while percent violations ranged from 0 – 24.1 % (Table 11). All but two of the stations that met the criteria to be listed as impaired occurred on the Chehalis River mainstem. The Black River at mouth and Belmore also met the criteria that triggers listing as Category 5.

Temperature targets

Percent vegetative shade was not assessed for stream reaches identified in Table 3. Increasing vegetative shade on large river systems is generally a long-term assessment goal. However, interim measures of shade percentages should be evaluated periodically to track progress.

Although not related to temperature targets, the Lewis County Conservation District, with a grant from Ecology, conducted an extensive assessment of riparian condition on several streams in WRIA 23 that are contained within Lewis County. This assessment mapped the percentage of buffered area around stream reaches and identified areas in need of additional protection. Although a formal report was not produced, this information would be valuable for identifying future water cleanup activity in WRIA 23. Results of the riparian assessment are available from the Lewis County Conservation District in Chehalis, Washington.

Table 10. Temperature (°C) recorded at CBP monitoring stations designated as Core Summer Habitat[4] in WRIA 23.
Stations ranked in order of total percent water quality violations.
Percentages in bold type indicate water quality impairment.

ID	Station name	Core Summer (16°C)			Supplemental (13°C)			Total[3]
		No. of samples	> 16	%	No. of samples	> 13	%	%
1380	Dillenbaugh Cr.	27	0	0.0	-	-	-	0.0
2333	Scatter Creek at Case Rd.	9	0	0.0	-	-	-	0.0
2334	Scatter Creek at Tenino	17	0	0.0	-	-		0.0
2386	Scatter Creek at Sargent Rd.	15	0	0.0	-	-	-	0.0
3294	Cedar Creek at Capital Forest Rd.[2]	4	0	0.0	9	0	0%	0.0
3346	Cedar Creek at Elma Gate	29	1	3.4	-	-	-	3.4
1214	M. Fork Newaukum R. at Tauscher	28	1	3.6	-	-	-	3.6
2325	Waddell Creek at Sw Bridge[2]	14	0	0.0	11	1	9%	4.0
2332	Scatter Creek at James Rd.	31	2	6.5	-	-	-	6.5
1323	Hanaford Creek at Rd. End[2]	18	1	5.6	12	1	8%	6.7
3349	Porter Creek at Campgrd.[2]	16	1	6.3	13	1	8%	6.9
1216	S. Fork Newaukum R. at Jr Br.[1]	5	2	40.0	23	0	0%	7.1
1308	Bunker Creek at Ingalls Rd.	25	2	8.0	-	-	-	8.0
2218	Skookumchuck R. at Tono[1]	4	0	0.0	21	2	10%	8.0
2277	Skookumchuck R. at Hatch[1]	4	0	0.0	21	2	10%	8.0
1327	Lincoln Creek at Ingalls Rd.	24	2	8.3	-	-	-	8.3
2219	Skookumchuck R.[1]	4	0	0.0	20	2	10%	8.3
1101	Chehalis R. at Pe Ell[1]	5	3	60.0	23	1	4%	**14.3**
3392	Rock Creek at Norton Rd.[2]	6	2	33.3	8	0	0%	14.3
2385	Scatter Creek at Leitner Rd. Sw	12	2	16.7	-	-	-	16.7
1307	Bunker Creek at Bunk. Cr. Rd.[2]	17	2	11.8	11	3	27%	**17.9**
1306	Deep Creek[2]	16	2	12.5	11	3	27%	**18.5**
1103	Chehalis R. at Rainbow Falls St. Pk.[1]	6	3	50.0	20	2	10%	**19.2**
1391	Stillman Creek at McDonald Rd[1]	2	1	50.0	13	2	15%	**20.0**
1205	S. Fork Chehalis R. at Bf[1]	5	4	80.0	23	2	9%	**21.4**
1213	N. Fork Newaukum R. at Tauscher[1]	5	5	100.0	23	1	4%	**21.4**
1215	S. Fork Newaukum R. at Mf Br.[1]	5	5	100.0	23	1	4%	**21.4**
1102	Chehalis R. at Doty[1]	5	4	80.0	22	2	9%	**22.2**
1206	S. Fork Chehalis R. at Lv[1]	5	4	80.0	25	3	12%	**23.3**
1211	Newaukum R. at Shorey Rd.[1]	4	4	100.0	25	4	16%	**27.6**
1217	Skookumchuck R. at mouth[1]	5	3	60.0	9	2	22%	**35.7**

[1] Supplemental temperature criteria apply (13°C Oct. 1 - May 15).
[2] Supplemental temperature criteria apply (13°C Feb. 15 - July 1).
[3]Total percent of both Core Summer and supplemental temperature criteria.
[4]Temperature standard for Core Summer Habitat is 16°C unless station is designated as with supplemental temperature criteria. Temperature criteria outside the supplemental criteria date range reverts back to Core Summer Habitat criteria (16°C).

Table 11. Temperature (°C) recorded at CBP monitoring stations designated as Spawning, Rearing, and Migration Habitat[4] in WRIA 23.
Percentages in bold type indicate water quality impairment.

ID	Station name	Spawning, Rearing and Migration (17.5°C)			Supplemental (13°C)			Total[3]
		No. of samples	> 17.5	%	No. of samples	> 13	%	%
1321	China Creek	30	0	0	-	-	-	0.0
1329	Independence Creek	22	0	0	-	-	-	0.0
1378	Coal Creek	28	0	0	-	-	-	0.0
2236	Black R. at Littlerock	30	0	0	-	-	-	0.0
2237	Black R. at 110th Ave.	27	0	0	-	-	-	0.0
2374	Beaver Creek at Reeder Rd.	25	0	0	-	-	-	0.0
3328	Independence Creek at mouth	22	0	0	-	-	-	0.0
3330	Garrard Creek at mouth	23	0	0	-	-	-	0.0
3331	Garrard Creek at Brooklyn Rd.	25	0	0	-	-	-	0.0
3347	Gibson Creek at Hwy 12	29	0	0	-	-	-	0.0
3348	Porter Creek at Hwy 12	30	0	0	-	-	-	0.0
1309	Stearns Creek at Twin Oaks Rd.	29	1	3	-	-	-	3.4
1379	Salzer Creek at Centrail. Rd.	28	1	4	-	-	-	3.6
1376	Stearns Creek at Pleasant Valley	27	1	4	-	-	-	3.7
2375	Beaver Creek at Porter Creek Rd.[2]	11	1	9	15	0	0	3.8
1322	Hanaford Creek at Schaefer	30	2	7	-	-	-	6.7
1320	Salzer Creek at Salzer Creek Rd.	29	2	7	-	-	-	6.9
1324	S. Hanaford Creek	29	2	7	-	-	-	6.9
1326	Lincoln Creek at L.C. Rd.	25	2	8	-	-	-	8.0
4235	Black R. at mouth	28	4	14	-	-	-	**14.3**
1141	Chehalis R. at Prather[1]	22	1	5	7	4	57	**17.2**
4143	Chehalis R. at Bull Hole	22	1	5	6	4	67	**17.9**
1112	Chehalis R. at SR 6	30	6	20	-	-	-	**20.0**
1140	Chehalis R. at Galvin Rd.[1]	18	1	6	7	4	57	**20.0**
1142	Chehalis R. at Ind. Rd.[1]	18	1	6	7	4	57	**20.0**
3145	Chehalis R. at Porter	29	6	21	-	-	-	**20.7**
4144	Chehalis R. at Sickman-Ford	19	1	5	5	4	80	**20.8**
1104	Chehalis R. at Adna[1]	21	1	5	7	5	71	**21.4**
1181	Chehalis R. at Mellen St.	28	6	21	-	-	-	**21.4**
2298	Black R. at Belmore	26	6	23	-	-	-	**23.1**
1110	Chehalis R. at Hwy 603[1]	24	1	4	6	6	100	**23.3**
1182	Chehalis R. at Borst Pk.[1]	22	2	9	7	5	71	**24.1**

[1] Supplemental temperature criteria apply (13°C Oct. 1 - May 15).
[2] Supplemental temperature criteria apply (13°C Feb. 15 - July 1).
[3] Total percent of both Core Summer and supplemental temperature criteria.
[4]Temperature standard for Spawning, Rearing, and Migration Habitat is 17.5°C unless station is designated as with supplemental temperature criteria. Temperature criteria outside the supplemental criteria date range reverts back to Spawning, Rearing, and Migration Habitat criteria (17.5°C).

Trends in water quality

Fecal coliform

Pooled WRIA 23 data

Seasonal Kendall results for pooled WRIA 23 fecal coliform data indicate concentrations significantly decreased from 1971-2010 (Table 12). A total of 4,714 data points collected from 327 stations were used in the analysis. As part of the analysis, fecal coliform concentrations were averaged for each month, then compared over time (years). The number of observations each month ranged from 34-35. The statistical evidence for this decrease is strong (p=0.000). Systat® plots of individual months are presented in Appendix C, Table C-5. Monthly plots suggest decreases in fecal coliform occurred during all months.

Table 12. Seasonal Kendall and regression results for fecal coliform from pooled WRIA 23 data and monitoring stations at Dryad and Porter.

The slope and coefficient values indicate the magnitude of the trend and if the trend is decreasing (-) or increasing (+). A p-value of <0.05 indicates the trend is statistically significant.

Station	Seasonal Kendall		Regression	
	Slope	p-value	Coefficient	p-value
WRIA 23	-0.015	0.000	-0.014	0.003
Dryad	-0.002	0.192	-0.006	0.139
Porter	-0.016	0.000	-0.953	0.000

Regression results for pooled fecal coliform data from WRIA 23 indicate concentrations also significantly decreased (Figure 4). The data set used for this regression test was the same as used for the Seasonal Kendall test. The statistical evidence for this decrease was also strong (p=0.003) (Table 12). Summary statistics are presented in Appendix C, Table C-4.

Although the data set used for these pooled WRIA 23 analyses was large, there was little overall consistency in when and where the samples were taken. Greater than 60% of the data set used for this analysis comes from two studies: Ecology's ambient monitoring stations (18 in total) made up 30% of the data, while CBP's data set made up 34% of the data.

Ambient monitoring stations

Seasonal Kendall results for fecal coliform data from ambient monitoring stations at Dryad and Porter indicate concentrations decreased from 1975-2009 (Table 12). While this decrease was not significant (p=0.192) at Dryad, it was significant at Porter (p=0.000). Based on the trend slopes, the greatest decrease of fecal coliform occurred at Porter (Table 12). Systat® plots of individual months are presented in Appendix C, Tables C-6 and C-7.

Regression results from the ambient monitoring stations at Dryad and Porter are consistent with the Seasonal Kendall results (Figure 5, Table 12). Results suggest a decreasing trend in fecal coliform over time at both stations; however, this trend was only statistically significant at Porter. The statistical evidence for this decrease at Porter is strong (p=0.000).

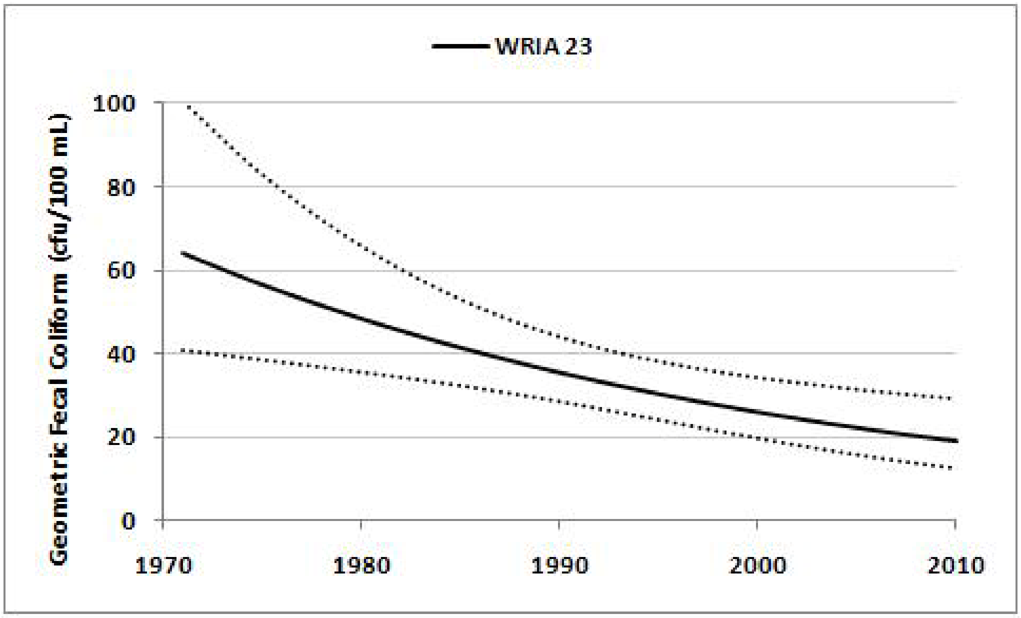

Figure 4. Trends in fecal coliform geometric means over time for pooled data from WRIA 23, 1971-2010.

Geometric means were calculated by back-transforming yearly log values predicted by the regression equation. Dashed lines delineate 95% confidence intervals.

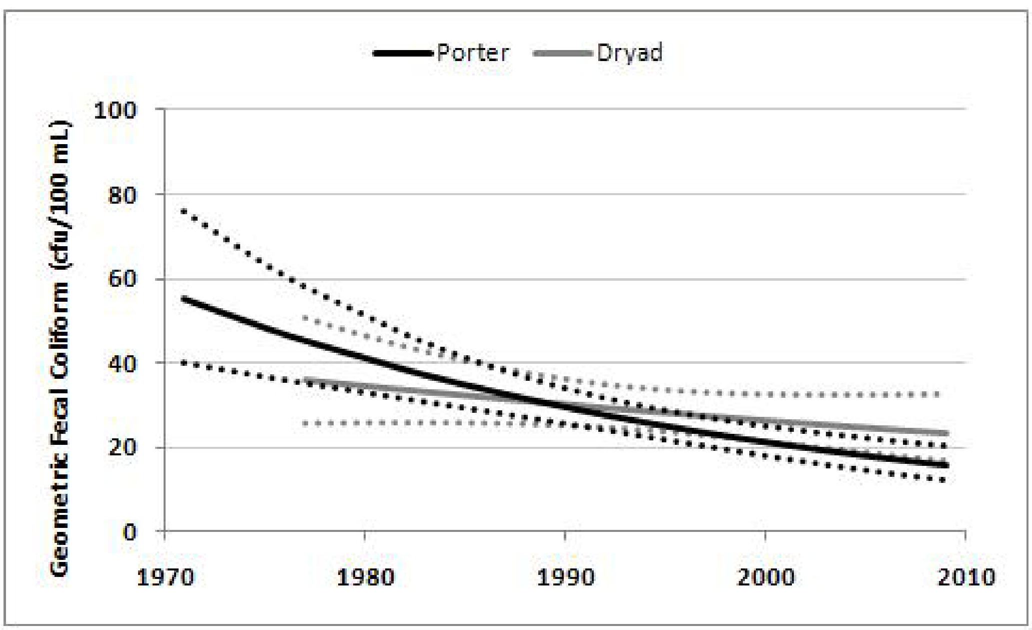

Figure 5. Trends in fecal coliform geometric means over time from Ecology's ambient monitoring stations at Porter and Dryad, 1971-2010.

Geometric means were calculated by back-transforming log values predicted by the regression equation. Dashed lines delineate 95% confidence intervals.

The regression coefficient indicated the greatest decrease of fecal coliform over time occurred at Porter (Appendix C, Table C-4). This is indicated by the lesser regression coefficient and is consistent with the Seasonal Kendall slope (Table 12).

These observations are consistent with fecal coliform results of the WRIA 23 pooled data, and with the results presented in Tables 6 and 7. This weight of evidence suggests fecal coliform concentrations have decreased in WRIA 23. Trend results from Porter and Dryad suggest a larger proportion of the decrease occurred above the town of Porter. This is evident from the steeper trend line and lesser coefficients observed at Porter.

Future trend tests using pooled data from large areas should use statistical approaches that account for outside variables that could influence the results. Variables such as site location, sampling frequency, methodologies, flow, and precipitation can be accounted for using more comprehensive approaches. Multi-linear regression models can be used to evaluate the effects of these variables on water quality parameters (Helsel and Hirsch, 2002; Ecology, 2010). These types of tests can provide value as an exploratory tool for watershed management.

Dissolved oxygen

Seasonal Kendall results for DO data from ambient monitoring stations at Dryad and Porter indicate no trends in DO from 1960-2009 (Table 13). Slopes of 0 were estimated for both stations. Monthly Seasonal Kendall plots for both stations indicate DO concentrations peak in February then decrease through September. The lowest observed monthly DO values occur during June, July, and August. Systat® plots of individual months for Dryad and Porter are presented in Appendix C, Tables C-8 and C-9.

Table 13. Seasonal Kendall and regression results for dissolved oxygen from monitoring stations at Dryad and Porter.

The slope and coefficient values indicate the magnitude of the trend and if the trend is decreasing (-) or increasing (+). A p-value of <0.05 indicates the trend is statistically significant.

Station	Seasonal Kendall		Regression	
	Slope	p-value	Coefficient	p-value
Dryad	0.000	0.856	0.006	0.189
Porter	0.000	0.268	-0.001	0.804

Regression results from the ambient monitoring stations at Dryad and Porter are consistent with the Seasonal Kendall results (Figure 6, Table 13). Results suggest a small increasing DO trend at Dryad and a small decreasing trend at Porter. Neither of these trends was significant based on p-values.

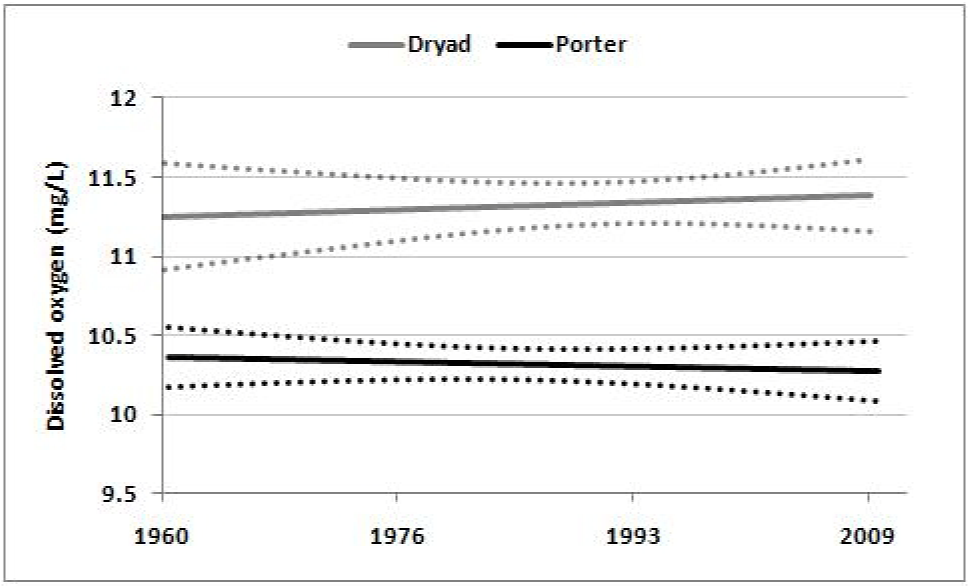

Figure 6. Trends in dissolved oxygen concentrations over time from Ecology's ambient monitoring stations at Porter and Dryad, 1960-2009.

Dashed lines delineate 95% confidence intervals.

Temperature

A Seasonal Kendall test was performed on daily maximum temperatures collected from ambient monitoring stations at Dryad and Porter. Data were collected using continuous temperature loggers during July through August from 2000-2008. Based on slopes, overall trends in yearly maximum daily temperature appear to be increasing at both stations (Table 14). This increase in daily maximum temperature was greater at the Dryad station as indicated by the greater slope. The trends were not significant at either station based on p-values (Table 14).

Table 14. Seasonal Kendall results for maximum daily temperature measurements from monitoring stations at Dryad and Porter, 2000-2008.

The slope value indicates the magnitude of the trend and if the trend is decreasing (-) or increasing (+). A p-value of <0.05 indicates the trend is statistically significant.

Station	Slope	p-value
Dryad	0.065	0.260
Porter	0.031	0.360

Individual monthly Kendall plots for Dryad and Porter are present in Figures 7 and 8. They suggest an increasing average monthly maximum temperature in July and August from 2000 through 2004. This is followed by a decrease of average maximum temperature from 2004 to 2008. Although daily maximum temperatures were the highest in July and August of 2004, they were also the lowest in September of 2004. This trend was observed at both stations, although the magnitude of the trend was not as great at Porter.

The similarity in shifting daily maximum temperatures at both stations suggests that natural or similar circumstances may be driving the trends. A combination of fluctuating river flows and air temperature most likely would track with temperature trends.

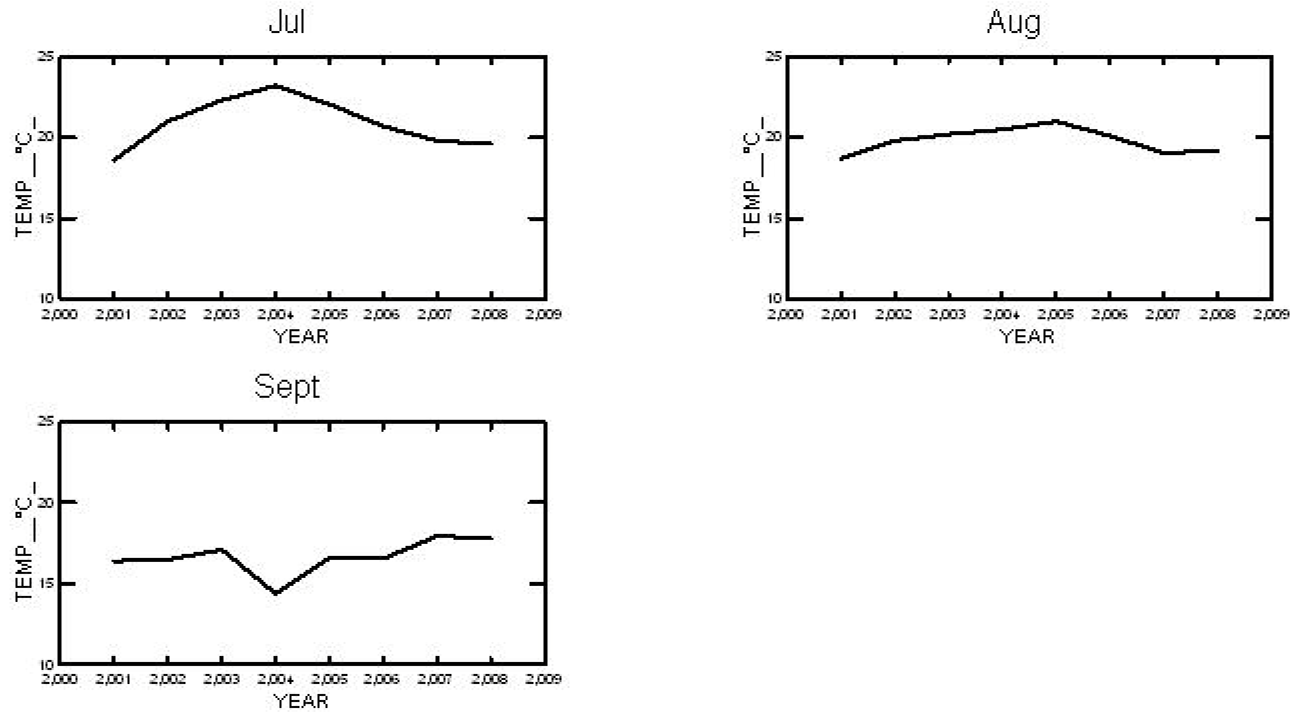

Figure 7. Systat® output of Seasonal Trend Plot of average daily maximum temperature at Dryad.
Data were collected from 2001-2008 using continuous temperature loggers from July through September.

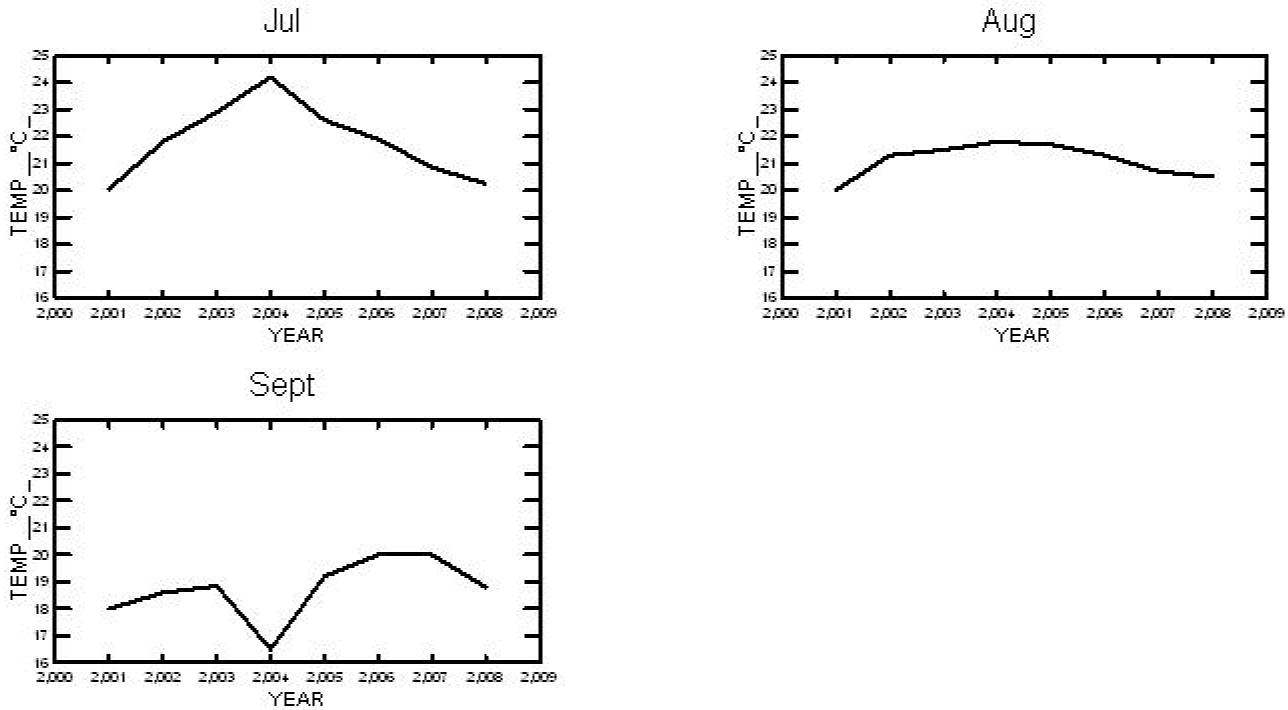

Figure 8. Systat® output of Seasonal Trend Plot of average daily maximum temperature at Porter.
Data were collected from 2001-2008 using continuous temperature loggers from July through September.

Turbidity

A Seasonal Kendall test was performed using pooled WRIA 23 turbidity data (Table 15). A total of 4,981 turbidity measurements collected from 296 monitoring stations from 1961-2010 were used for this analysis. As part of the analysis, turbidity concentrations were averaged for each month, then compared over time (years). The number of observations each month ranged from 40-42. The resulting slope estimate suggests a small decrease in turbidity was observed over time. This small decreasing trend was not significant based on a p-value of 0.111.

Table 15. Results of Seasonal Kendall tests for turbidity.
The slope indicates the magnitude and direction of the trend.
A p-value <0.05 indicates if trend is statistically significant.

Station	Slope	p-value
WRIA 23	-0.001	0.111
Dryad	0.000	0.794
Porter	0.000	0.136

Individual monthly Kendall plots presented in Appendix C, Table C-10, for pooled WRIA 23 data also show no discernable trends in months over time. Average monthly plots suggest turbidity concentrations begin increasing in September and then peak in December and January. Turbidity begins steadily decreasing into August. This observed pattern may be consistent with patterns in flow and precipitation.

As with fecal coliform, the data set used for these pooled WRIA 23 analyses was large, although there was little overall consistency in when and where the samples were taken. A total of 33% of data was collected from 18 ambient monitoring stations throughout WRIA 23. The CBP turbidity data made up 31% of the data set and was collected at 63 monitoring stations from 2007-2009.

Seasonal Kendall tests were also performed using turbidity data collected from ambient monitoring stations at Dryad and Porter. No significant trends in Dryad and Porter turbidity data were observed based on p-values (Table 15). The resulting slope estimates suggest no change in turbidity was observed over time (Slope=0.000).

Individual monthly Kendall analyses for pooled WRIA 23, Dryad, and Porter turbidity data were similar to average monthly plots for pooled WRIA 23 data (Table 15).

Overall, results from Seasonal Kendall tests using pooled WRIA 23 and ambient monitoring turbidity data are consistent. No trends between year and turbidity were observed. Average monthly plots suggest turbidity levels begin increasing in September and peak in December and January. Lowest turbidity levels are generally observed in August and September.

It is likely that high turbidity events outlined by Green et al. (2009) during the winters of 2007-2009 were not high or prolonged enough to increase trends over time. The authors indicate more than 1,500 landslides occurred in the headwaters of the Chehalis basin during a 2007 winter storm event. A large portion of these landslides occurred in areas where past and recent timber harvest activity had occurred (Sarikhan et al., 2008). The landslides appeared to contribute to elevated turbidity levels at several of the CBP sampling stations in the upper Chehalis basin (Green et al., 2009).

Assessing trends for water quality parameters that have fluctuating values, such as turbidity, can be difficult. This is because the more unexplained variance in the data, the less the power of the statistical test. Accurately determining whether trends exist may require additional analyses to explain some of the variance or more years of data collection to increase the sample size.

Conclusions

Many water cleanup activities have occurred in the Upper Chehalis River basin (WRIA 23). However, there needs to be an additional effort to track and summarize these activities in a comprehensive and detailed manner. Although most cleanup efforts have been tracked individually, the details provided have often been insufficient. Detailed information is needed to determine the effectiveness of cleanup efforts and their associated impacts on water quality improvements. This will help guide future cleanup and watershed management efforts.

Based on Washington State water quality standards and trend analysis, fecal coliform concentrations within WRIA 23 have been reduced significantly. Also, water quality management efforts within WRIA 23 appear to be sufficient in preventing additional fecal coliform violations as long as the efforts are sustainable. However, additional monitoring needs to occur to determine if target limits identified within the TMDL are being met.

No given BMP or water cleanup activity can be attributed to the reductions in fecal coliform at TMDL target stations monitored in the Chehalis Basin Partnership (CBP) study. The reductions likely came from a combination of early efforts involving (1) updates of wastewater treatment facilities in Chehalis (2007) and Centralia (2004), (2) updates and loss of large dairy operations in the watershed, and (3) individual BMPs.

Temperature and dissolved oxygen violations continue to be problematic through WRIA 23. Based on single-sample temperature and dissolved oxygen measurements, additional stream reaches would be listed as impaired on Washington's 303(d) list. Although problems with dissolved oxygen results from the CBP study do not allow these data to be used to identify impairments for this purpose.

Trend results from Ecology's long-term ambient monitoring stations at Porter and Dryad suggest little change has occurred in dissolved oxygen concentrations over time. Neither of the small increases in dissolved oxygen at Dryad or Porter was statistically significant based on regression tests. Seasonal Kendall tests are consistent with regression results, although no change was detected based on the slope.

Based on trend analysis, turbidity does not appear to have increased over time. However, the variability of turbidity measurements and the influencing factors reduce the power of this type of trend analysis. Trends or patterns in turbidity may exist but may require additional, more complex data analysis or a larger data set. Multiple-linear regression (MLR) could be helpful in this effort. MLR could account for the influence of outside parameters such as precipitation, streamflow, and time to produce better trend results. MLR could also link water quality with land use using geographic information systems (GIS) (Diebel, 2009).

Recommendations

- Begin to inventory implementation of BMP practices throughout the Upper Chehalis River basin (WRIA 23) in a comprehensive way using the following questions as a guide:
    1. Describe in detail the BMP being implemented and how it is expected to improve water quality in the Chehalis River watershed.
    2. Is the BMP sustainable?
    3. When and where was the BMP implemented?
    4. What is the spatial extent of the BMP?
- Monitor fecal coliform at TMDL target stations not sampled by the Chehalis Basin Partnership (CBP) and compare results to TMDL target limits.
- Monitor fecal coliform at stations and critical periods identified in the TMDL.
- Use the Lewis County Conservation District's riparian assessment maps to implement BMPs on impaired stream reaches with low buffer percentages.
- Use and explore the numerous past assessment efforts to guide new BMP implementation efforts in the watershed: http://wcssp.org/WCSSP_library/wria22_23/wria22_23.htm
- Assess percent shade at target stations identified within the Upper Chehalis Temperature TMDL to track progress for this long-term goal.
- Continue to explore data from WRIA 23 using appropriate statistical techniques, such as multi-linear regression, to better detect long-term trends. Also explore techniques for linking land use and other activities with water quality data.
- Consider monitoring temperature using continuous temperature loggers at stations with the highest number of temperature violations.
- Assess land use using ground sleuthing and GIS in surrounding areas where dissolved oxygen continues to be a problem. Based on this approach, design a monitoring strategy in areas that have the greatest risk to negatively affect dissolved oxygen and where low dissolved oxygen values are observed.
- Consider monitoring dissolved oxygen using continuous loggers at stations with the greatest number of violations. Also, periodically supplement dissolved oxygen data during critical periods with ammonia, carbonaceous biochemical oxygen demand (CBOD), and streamflow data to determine what is driving low dissolved oxygen levels.
- Use a source tracking component in all future water quality sampling designs to help define major pollutant sources when water quality violations are identified.
- Consider using instream biological and habitat methodologies in the upper reaches of WRIA 23 to address fine sediment concerns (Cusimano et al., 2006; Rosgen, 1994).

- Continue to support ambient monitoring efforts in the Chehalis River watershed and consider the reactivation of some of Ecology's ambient monitoring stations with the basin: www.ecy.wa.gov/apps/watersheds/riv/stationlistbywria.asp?wria=23

- Once TMDL compliance stations and critical periods are determined to be meeting targets, change the fixed-station, WRIA-wide sampling strategy to a probability (random)-based sampling design to monitor the status and trends of fecal coliform concentrations. Sampling should be conducted every 3-5 years and should follow probability survey designs outlined by EPA: www.epa.gov/nheerl/arm/designpages/monitdesign/monitoring_design_info.htm.

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Appendices

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Appendix A. Glossary and Acronyms

Glossary

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 waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards, and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

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

Char: Char (genus *Salvelinus*) are distinguished from trout and salmon by the absence of teeth in the roof of the mouth, presence of light colored spots on a dark background, absence of spots on the dorsal fin, small scales, and differences in the structure of their skeleton. (Trout and salmon have dark spots on a lighter background.)

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

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Effectiveness monitoring: Monitoring to determine whether the recommended *Detailed Implementation Plan*, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal coliform: That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 + or - 0.2 degrees Celsius. Fecal coliform are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either:

(1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

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

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is 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 (NPDES) 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.

Point source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than five acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Reach: A specific portion or segment of a stream.

Salmonid: Any fish that belong to the family *Salmonidae*. Basically, any species of salmon, trout, or char. www.fws.gov/le/ImpExp/FactSheetSalmonids.htm

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody 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 for point sources, (2) the load allocations 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.

Turbidity: A measure of the amount of suspended silt or organic matter in water. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocation constitutes one type of water quality-based effluent limitation.

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.

Acronyms and Abbreviations

BMP	(See Glossary above)
CBOD	Carbonaceous biochemical oxygen demand
CBP	Chehalis Basin Partnership
DO	Dissolved oxygen
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
GIS	Geographic information systems
RM	River mile
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
WRIA 23	Upper Chehalis River watershed
WSCC	Washington State Conservation Commission

Units of measurement

°C	degrees centigrade
cfs	cubic feet per second
mg/L	milligrams per liter

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Appendix B. Implementation Activities

Table B-1. Chehalis River Watershed 2004 Detailed TMDL Implementation Plan Work Commitments. Schedule Updated March 2008.

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
Animal-Livestock Waste	NRCS	Comprehensive Nutrient Management Plans and Livestock Conservation Plans.	Contract participants have implemented 2 CNMP plans, 1 waste storage facility, 1 roof runoff structure with 450 feet of underground outlets, 1 animal mortality facility, 1,451 feet of fence, 2 manure transfer systems, 116 acres of nutrient management, 187 acres of prescribed grazing, 5 acres of livestock-use exclusion, 2,500 feet of livestock pipeline, and 3 livestock watering troughs.	EQIP - Farm Bill Programs
Agrichemicals	NRCS	Cropland Conservation Plans to treat water quality concerns.	Contract participants have implemented 100 acres of drainage water management and 1061 acres of pest management.	EQIP-Farm Bill Programs
Soil Erosion	NRCS	Forestry Conservation Plans to treat soil erosion problems for water quality concerns.	Forestry contract participants have implemented 16,241 feet of forest roads, and seeded and mulched on 15 acres with critical-area planting and 135 feet of streambank and shoreline protection.	EQIP-Farm Bill Program
Forestry Practices	NRCS	Forestry and Wetland Conservation Plans to treat forest health concerns following the blowdown from Dec '07 wind storm, and riparian habitat concerns.	Contract participants have implemented 21 acres of upland wildlife habitat management, 1322 acres of forest stand improvement, 17 acres of forest harvest management, 339 acres of forest slash treatment, 467 acres of tree and shrub establishment, 1185 acres of tree and shrub site preparation, 2010 acres of restoration and management of rare and declining habitats, 371 acres of stream habitat improvement and management	EQIP, WRP-Farm Bill Programs
Wetland Enhancement and Restoration	NRCS	Wetland and wildlife habitat on agricultural lands. Conservation Plans to enhance and/or restore wetland functions.	Contract participants have implemented 10,849 feet of fence, 1805 ft of recreational trail and walkways, 136 acres of wetland enhancement, 1137 acres of wetland restoration, 599 acres of wetland wildlife habitat management, 23 acres of early successional habitat development and management, and 1098 acres of restoration and management of rare and declining habitats.	WRP, WHIP-Farm Bill Programs
Animal-Livestock Waste	CD and NRCS	Farm planning and technical assistance on BMPs.	Lewis CD (LCD): 57 Plans, 20 implemented without cost-share, 6609 acres.	CCWF through 6/03
Animal-Livestock Waste	CD and NRCS	Install riparian livestock-exclusion fencing and plantings.	LCD: 47.44 miles of riparian fence and planting.	CREP
		BMP workshops to reduce the amount of manure	LCD: County Fair demos each year. Two watershed festivals.	Conservation Commission

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
		reaching waterways.		base funding allotment
		Conservation Reserve Enhancement Program (riparian protection)	Thurston CD: 4 contracts on 27.1 acres, 1.4 miles of shoreline planting. Fencing of 1.8 miles. Grays Harbor CD:10 contracts on 87.1 acres, 4.3 miles of shoreline planting, 1.35 miles of fencing. LCD: Included in above.	CREP
	Chehalis Basin Partnership Chehalis Tribe and Grays Harbor College	Facilitate partner's implementation of habitat and riparian enhancements. Design and Implement comprehensive WQ monitoring program. Develop GIS program data and activity tracking.	SRFB unknown amounts. Wishkah LWD. Sample 83 sites for 2 yrs. Develop 2007/08, Implement '08.	Terry Husseman Grant Ecology WQ Account Ecology WQ Account
	WA Dept. of Agriculture	Conduct routine inspection activity with all dairies approximately every 22 months. Provide technical assistance to meet compliance with water quality rules and regulations. Take enforcement when management practices are resulting in a potential to pollute waters of the state or when water quality standards have been violated. Dairy Nutrient Management Act RCW 90.64 and Concentrated Animal Operations (CAFO) rules.	As of May 1, 2009, all dairies operating in the Chehalis watershed have had routine inspections within the last 12 months. One dairy was identified for additional follow-up in summer 2009. No discharges reported. No enforcement actions necessary. 2009 lagoon assessments will be conducted in Lewis and Thurston Counties. Provide tech. assistance as needed to reduce delivery of manure or other BOD materials to waterways. Enforcement when voluntary compliance has not been achievable.	WA Dept. of Agriculture

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
Animal-Livestock Waste	All stakeholders Volunteer, Non-Profit Groups	Investigate manure management options. Plan and conduct comprehensive water quality monitoring. Conduct riparian planting, wetland preservation, and conservation easements. Heernet Foundation-Scatter Creek restoration Chehalis River Council Chehalis Basin Education Consortium Capitol Land Trust-Chehalis River Basin Land Trust Grays Harbor Audubon Society Nature Conservancy	All these things are happening now in several priority sub-basins WQ sampling and study by college interns, riparian cover improvements. South Fork Chehalis, monitoring, classroom and field education projects, landowner education, Drops-Of-Water monthly newsletter. Basin-wide sampling, sponsor Student Congress, install riparian and interpretive trail at Centralia. 9 properties and 143 acres of Conservation easements, Reforestation, Litter control at WDFW sites, and sponsor of school projects. 3,000 acres of surge-plain management-reforestation. Easements for land and habitat protection, noxious plant mgmt.	CCWF CCWF, 319 Grants, private foundations
Support Industries	Innovative technologies. Investigate potential approach to reduce sources and delivery of manure to waterways.	Unknown, undocumented	CCWF	Support Industries
WA Dept. of Ecology	Technical Assistance and Enforcement (agricultural nonpoint sources other than permitted livestock facilities regulated		WA Dept. of Ecology U.S. EPA	WA Dept. of Ecology

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
	primarily by WA. State Dept. of Agriculture) Water Quality Monitoring	Chehalis BMP Eval. Project, Ambient Monitoring Program at 4 stations.	USFWS contract	
Septic Systems	Gray's Harbor County Health	County-wide O&M Program	Ongoing –level is dependent on permit fees.	CCWF St Loan Program administered for use by households.
		Investigate commercial septic storage along waterways.	As budget allows in O&M Program.	User fees by permittees.
		Windshield survey to identify high-risk septic systems.	As budget allows in O&M Program.	User fees by permittees.
		Oversee septic repairs.	Average of 31 per year.	County, SLRP.
		Evaluate existing systems.	Evaluated average of 82 systems per year.	County and user fees.
	Lewis County Health	Identify high-risk sites, characterize failures, problem sources.	Results unknown, no response to update requested by CBP.	County Budget CCWF, 319.
		Monitor conditions, conduct technical assistance in high-risk septic locations.	Results unknown, no response to update requested by CBP.	County budget CCWF, 319.
		Coordinate w/ Lewis Cons. District to follow-up on high-risk sites Collaborate w/CD on funding-requests to expand response capabilities.	Results unknown, no response to update requested by CBP.	------------
		Develop/conduct community education, broker financial assistance to fix failing systems.	Results unknown, no response to update requested by CBP.	County budget, CCWF, 319, State Loan.
	Thurston County Health	Permit installation of new/expanded septic systems, oversee operations and maintenance program, and review land-use proposals to protect sensitive areas.	Thurston County's on-site sewage system (OSS) regulations, Article IV, were amended July 2, 2007 to comply with new state regulations - WAC 246-272A. The new regulations require all OSS owners to regularly evaluate their systems. We are working to set up an on-line system so we can receive and manage records electronically – both for systems that require operational certificates and ones that don't. Renewable operational certificates are still required for large and complex OSS.	DOH grant (ends 6/09), fees and county funds.

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
			The Thurston County On-site Sewage System Management Plan (see www.co.thurston.wa.us/health/ehadm/OSS_lmp.html) was adopted by the Thurston County Board of Health on January 7, 2008. The plan identifies several areas where OSS may pose a significant risk to public health, including portions of southern Thurston County. A workgroup will be formed to determine if special permit and O&M standards should apply to these areas. The management plan includes recommendations for OSS monitoring, maintenance, and education. We will need to revise Article IV to implement some plan recommendations. We plan to revise Article IV again in 2008 and implement plan recommendations as funding allows (see attached table). We will soon start a groundwater monitoring program in the Scatter Creek watershed to evaluate land use impacts on groundwater quality. The results of this evaluation will be used to help evaluate our land use policies. We will convene a work group to evaluate our policy regarding OSS densities and the impact of OSS on ground and surface water resources (the Assimilative Capacity Policy).	
Septic Systems	Thurston County Health	Conduct technical assistance for system operators, provide education programs, investigate complaints, and conduct septic surveys in areas of high concern.	We conduct 6-8 "Septic Sense" workshops each year to teach OSS owners how to properly operate and maintain their systems. These are conducted at locations throughout the county. We operate the "Septic Help Line" where OSS owners can call to receive assistance regarding septic system problems and questions. Our web site (www.co.thurston.wa.us/health/ehoss/index.html) has information about many elements of our program, including workshops, loans, and O&M. We investigate 150 – 200 OSS complaints each year. High priority	Fees and DOH grant (ends 6/09)

Pollution Source	Responsible Agency	Action	Status/Schedule	Funding*
			complaints are responded to within one business day. Most complaints are investigated within one week.	
Septic Systems	Thurston County Health	Broker financial assistance to fix failing systems.	We continue to offer low interest loans for owners of failing OSS. Interest rates are 3.5% or less. The family income limit associated with previous programs has been eliminated. We currently have grant program that provides up to $3,000 (depending on the cost of the repair) for owners of failing OSS. See www.co.thurston.wa.us/health/ehoss/loan_program.html#loans for more information about our loan and grant programs	State Revolving Fund and grant programs administered by Ecology
	Chehalis Tribe, WA. DOH	Conduct survey of on-site septics on the reservation	Unknown- Number of systems fixed, other significant outcomes?	Tribe, DOH assistance
	Cities of Chehalis and Centralia	Adopt stormwater management manual and implement BMPs	Ongoing infrastructure maintenance at both Cities. '08 new stormwater program, and pilot project in Centralia- $178K grant	State Revolving Fund (loans) CCWF, Stormwater Grant Program

BOD	Biological oxygen demand
CBP	Chehalis Basin Partnership
CCWF	Centennial Clean Water Fund
CD	Conservation District
CNMP	Comprehensive Nutrient Management Plan
CREP	Conservation Reserve Enhancement Plan
DOH	Washington State Department of Health
EQIP	Environmental Quality Incentives Program
LCD	Lewis Conservation District
LWD	Large woody debris
O&M	Operations and maintenance
OSS	Onsite sewage system
RCW	Revised Code of Washington
SLRP	Sewer lateral repair
SRFB	Salmon Recovery Funding Board
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WQ	Water quality
WRP	Wetlands Reserve Program

Appendix C. Supplementary Tables and Figures

Table C-1. CBP monitoring stations in the Upper Chehalis River basin (WRIA 23) which have an aquatic life use designation of Core Summer Habitat.

Core Summer Habitat				Supplemental Temperature Criteria		
Site #	Station name	Latitude	Longitude	13°C Sept. 15-July 1	13°C Feb. 15-July 1	13°C Oct. 1-May 15
1101	Chehalis R. at Pe Ell	46.5696	-123.3038	√		
1102	Chehalis R. at Doty	46.6347	-123.2829	√		
1103	Chehalis R. at Rainbow Falls St. Pk.	46.6307	-123.2318	√		
1205	S. Fork Chehalis R. at Bf	46.5876	-123.1190	√		
1206	S. Fork Chehalis R. at Lv	46.5467	-123.1331	√		
1211	Newaukum R. at Shorey Rd.	46.6500	-122.9809	√		
1213	N. Fork Newaukum R. at Tauscher	46.6115	-122.8207	√		
1214	M. Fork Newaukum R. at Tauscher	46.6024	-122.8191			
1215	S. Fork Newaukum R. at Mf Br.	46.5906	-122.8414	√		
1216	S. Fork Newaukum R. at Jr Br.	46.5757	-122.6843	√		
1217	Skookumchuck R. at mouth	46.7194	-122.9800	√		
1306	Deep Creek	46.6483	-123.1184		√	
1307	Bunker Creek at Bunk. Creek Rd.	46.6483	-123.1175		√	
1308	Bunker Creek at Ingalls Rd.	46.7079	-123.2033			
1323	Hanaford Creek at Rd. End	46.7456	-122.7765		√	
1327	Lincoln Creek at Ingalls Rd.	46.7341	-123.1933			
1380	Dillenbaugh Creek	46.6412	-122.8923			
1391	Stillman Creek at McDonald Rd.	46.5287	-123.1486	√		
2218	Skookumchuck R. at Tono	46.7962	-122.8659	√		
2219	Skookumchuck R.	46.7962	-122.7609	√		
2277	Skookumchuck R. at Hatch	46.7889	-122.7230	√		
2325	Waddell Creek at Sw Bridge	46.9140	-123.0514		√	
2332	Scatter Creek at James Rd.	46.8071	-123.0723			
2333	Scatter Creek at Case Rd.	46.8309	-122.9931			
2334	Scatter Creek at Tenino	46.8503	-122.8656			
2385	Scatter Creek at Leitner Rd Sw	46.8311	-122.9764			
2386	Scatter Creek at Sargent Rd.	46.8311	-123.0498			
3294	Cedar Creek at Capital Forest Rd.	46.8813	-123.2284		√	
3346	Cedar Creek at Elma Gate	46.8780	-123.2775			
3349	Porter Creek at Campgrd.	46.9774	-123.2576		√	
3392	Rock Creek at Norton Rd.	46.8664	-123.3113		√	

Table C-2. CBP monitoring stations in the Upper Chehalis River basin (WRIA 23) which have an aquatic life use designation of Salmonid Spawning, Rearing, and Migration Habitat.

Spawning, Rearing, and Migration				Supplemental Temperature Criteria		
Site #	Station name	Latitude	Longitude	13°C Sept. 15-July 1	13°C Feb. 15-July 1	13°C Oct. 1-May 15
1104	Chehalis R. at Adna	46.6274	-123.0607			√
1110	Chehalis R. at Hwy 603	46.6417	-123.0174			√
1112	Chehalis R. at SR 6	46.6577	-122.9854			
1140	Chehalis R. at Galvin Rd.	46.7359	-123.0204			√
1141	Chehalis R. at Prather	46.7752	-123.0355			√
1142	Chehalis R. at Ind. Rd.	46.8069	-123.1189			√
1181	Chehalis R. at Mellen St.	46.7118	-122.9787			
1182	Chehalis R. at Borst Pk.	46.7192	-122.9855			√
1309	Stearns Creek at Twin Oaks Rd.	46.6331	-123.0173			
1320	Salzer Creek at Salzer Creek Rd.	46.6917	-122.9711			
1321	China Creek	46.7150	-122.9688			
1322	Hanaford Creek at Schaefer	46.7535	-122.9405			
1324	S. Hanaford Creek	46.7588	-122.9009			
1326	Lincoln Creek at L.C. Rd.	46.7415	-123.0457			
1329	Independence Creek	46.7604	-123.2227			
1376	Stearns Creek at Pleasant Valley	46.5964	-123.0031			
1378	Coal Creek	46.6656	-122.9374			
1379	Salzer Creek at Centrail. Rd.	46.6993	-122.9293			
2236	Black R. at Littlerock	46.8731	-123.0239			
2237	Black R. at 110th Ave.	46.9283	-123.0081			
2374	Beaver Creek at Reeder Rd.	46.8962	-122.9472			
2298	Black River at Belmore	47.0085	-122.965			
2375	Beaver Creek at Porter Creek Rd.	46.8977	-123.0198		√	
3145	Chehalis R. at Porter	46.9392	-123.3135			
3328	Independence Creek at mouth	46.7981	-123.1661			
3330	Garrard Creek at mouth	46.8186	-123.2536			
3331	Garrard Creek at Brooklyn Rd.	46.8061	-123.3095			
3347	Gibson Creek at Hwy 12	46.9028	-123.2911			
3348	Porter Creek at Hwy 12	46.9377	-123.3106			
4143	Chehalis R. at Bull Hole	46.8055	-123.1500			√
4144	Chehalis R. at Sickman-Ford	46.8298	-123.2587			√
4235	Black R. at mouth	46.8213	-123.2189			

Table C-3. Study area waterbodies with impairments addressed by this report.

Waterbody Name	Parameter	Listing ID	Category
Allen Creek	Fecal Coliform	8004	4A
	Dissolved Oxygen	41432	4A
Beaver Creek	Dissolved Oxygen	41430	4A
		41431	4A
	Fecal Coliform	6675	4A
		8006	4A
		9964	4A
		9965	4A
	Temperature	15522	2
		41117	2
		41118	2
Berwick Creek	Fecal Coliform	9966	4A
		9971	4A
		9972	4A
		9973	4A
		9974	1
Black River	Dissolved Oxygen	7744	4A
		7745	4A
		10999	4A
	Fecal Coliform	6666	4A
		6667	4A
		6673	4A
		6674	4A
		6676	4A
		6677	4A
		6678	4A
		6679	4A
		6680	4A
	Temperature	7746	4A
		11000	4A
		35935	4A
Bunker Creek	Dissolved Oxygen	7747	2
	Fecal Coliform	9975	4A
		10422	4A
Cedar Creek	Fecal Coliform	10403	4A
Chehalis River	Dissolved Oxygen	5865	4A
		5867	4A
		5868	4A
		5878	4A
		5879	4A
		5880	4A
		5881	4A

Waterbody Name	Parameter	Listing ID	Category
		7749	4A
		10686	4A
		10979	2
	Fecal Coliform	9976	4A
		10400	2
		10411	2
		10417	4A
		10424	2
		10429	4A
		10430	4A
		10431	4A
		6409	1
		16752	4A
		16753	4A
		16755	1
		16756	1
	Temperature	35939	4A
		5869	4A
		5871	4A
		5872	4A
		5873	4A
		5874	4A
		5875	4A
		5876	4A
		5877	4A
		6583	4A
		9497	4A
		10685	4A
		10991	4A
	Turbidity	15915	5
		15916	2
Chehalis River, South Fork	Dissolved Oxygen	10970	4A
	Fecal Coliform	14155	2
		16761	4A
		10423	4A
	Temperature	7750	4A
Coal Creek	Dissolved Oxygen	7751	4A
		47765	4A
		47767	2
	Fecal Coliform	10408	4A
		46502	2
		46504	4A

Waterbody Name	Parameter	Listing ID	Category
Deep Creek	Fecal Coliform	9978	4A
		9979	4A
Demsey Creek	Dissolved Oxygen	7752	4A
	Fecal Coliform	7753	4A
Dillenbaugh Creek	Dissolved Oxygen	7756	4A
		7754	4A
	Fecal Coliform	6669	4A
		6670	4A
		6671	4A
		6672	4A
	Temperature	7755	4A
		7757	4A
Elk Creek	Dissolved Oxygen	47805	5
	Fecal Coliform	10427	4A
		45415	2
Garrard Creek	Dissolved Oxygen	7760	4A
Independence Creek	Dissolved Oxygen	7761	4A
Lake Creek	Fecal Coliform	14153	4A
Lincoln Creek	Dissolved Oxygen	7762	4A
		7764	4A
		7766	4A
		7768	4A
	Fecal Coliform	7769	4A
		10399	4A
	Temperature	7763	4A
		35936	4A
Lincoln Creek, North Fork	Temperature	35387	4A
		35388	4A
Littlerock Ditch	Fecal Coliform	6682	4A
Lost Valley Creek	Fecal Coliform	14154	4A
		14157	4A
		14158	4A
Mill Creek	Temperature	35386	5
		35940	5
Mima Creek	Fecal Coliform	6683	4A
Newaukum River	Fecal Coliform	16758	4A
		16759	4A
	Temperature	7770	4A
		11008	4A
		35938	4A
Newaukum River, Middle Fork	Dissolved Oxygen	47734	5
	Fecal Coliform	45060	2
Porter Creek	Fecal Coliform	10398	4A

Waterbody Name	Parameter	Listing ID	Category
Rock Creek	Dissolved Oxygen	11617	4A
	Fecal Coliform	10405	4A
Salzer Creek	Dissolved Oxygen	7771	4A
		7773	4A
		7775	4A
		47749	4A
		47758	4A
		47768	4A
		47769	4A
		47770	4A
	Fecal Coliform	6668	4A
		10406	4A
		10407	4A
		10409	4A
		45788	4A
		45789	4A
		46506	4A
	Temperature	7772	4A
		7774	4A
		35389	4A
		35390	1
Scatter Creek	Fecal Coliform	10393	4A
	Temperature	7776	4A
Sponenbergh Creek	Dissolved Oxygen	7767	4A
Skookumchuck River	Fecal Coliform	10402	4A
		16760	2
	Temperature	7778	4A
Stearns Creek	Dissolved Oxygen	7780	4A
	Fecal Coliform	14151	4A
		14152	4A
	Temperature	14145	4A
Stillman Creek	Temperature	35393	5
		35394	5
		35395	5
Unnamed Creek	Temperature	35391	2
Unnamed Creek	Temperature	35392	1
Unnamed Creek	Temperature	35396	5
Unnamed Creek	Temperature	35397	1
Williams Creek	Dissolved Oxygen	11620	2

Table C-4. Summary statistics for ordinary least squares regressions for fecal coliform and dissolved oxygen.

Test	N	R^2	Coefficient	Standard Error	Standard Coefficient	p-Value
Fecal coliform						
Watershed	37	0.479	-0.014	0.004	-0.479	0.003
Dryad	33	0.263	-0.006	0.004	-0.263	0.139
Porter	32	0.632	-0.953	0.213	-.632	0.000
Dissolved oxygen						
Dryad	41	0.209	0.006	0.004	0.209	0.189
Porter	50	0.036	-0.001	0.003	-0.036	0.804

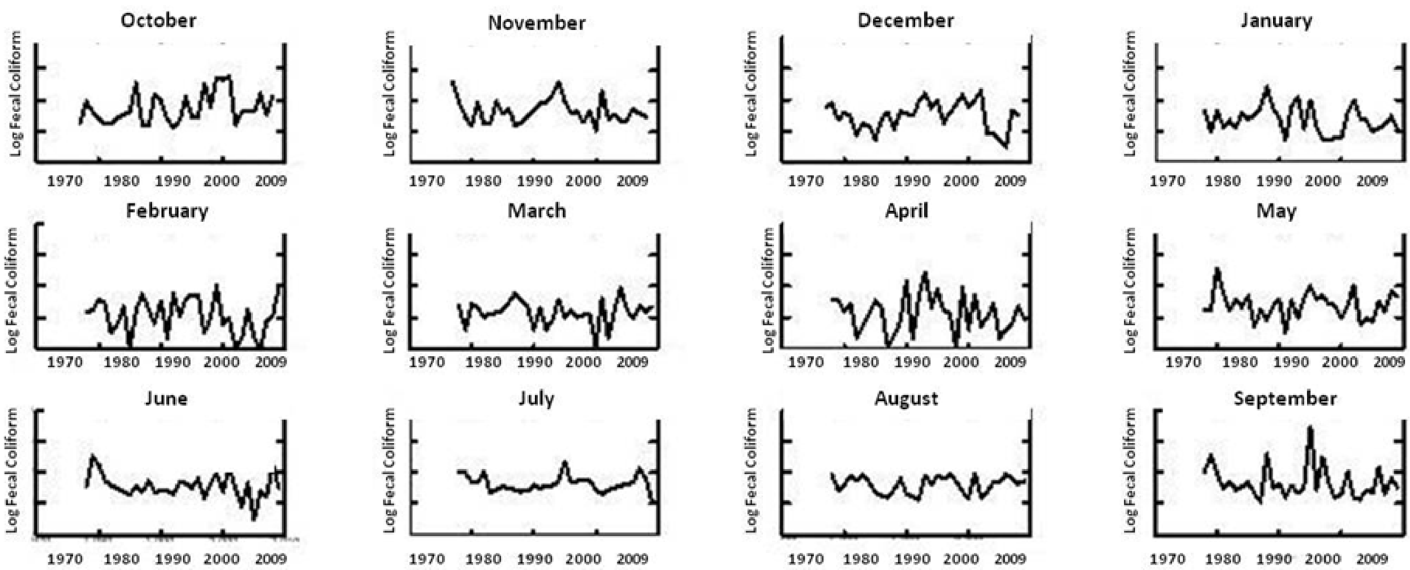

Figure C-1. Seasonal Trend Plot of pooled fecal coliform data from WRIA 23, 1994-2010.

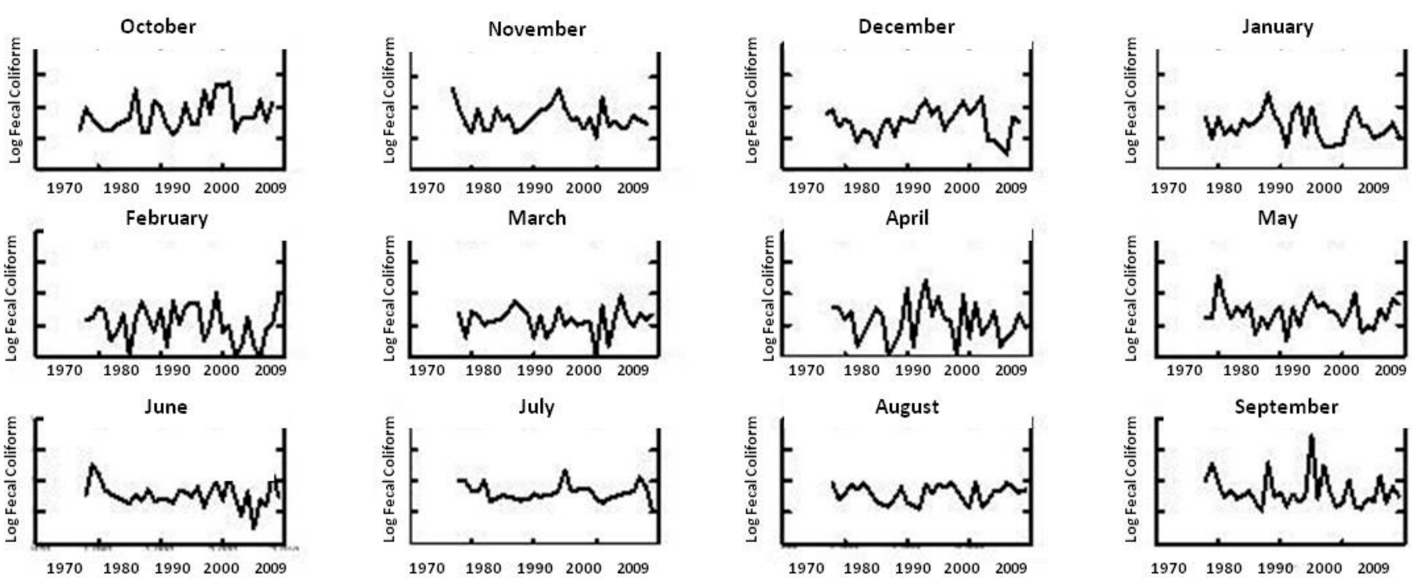

Figure C-2. Seasonal Trend Plot of fecal coliform data from ambient monitoring station at Dryad, 1977-2009.

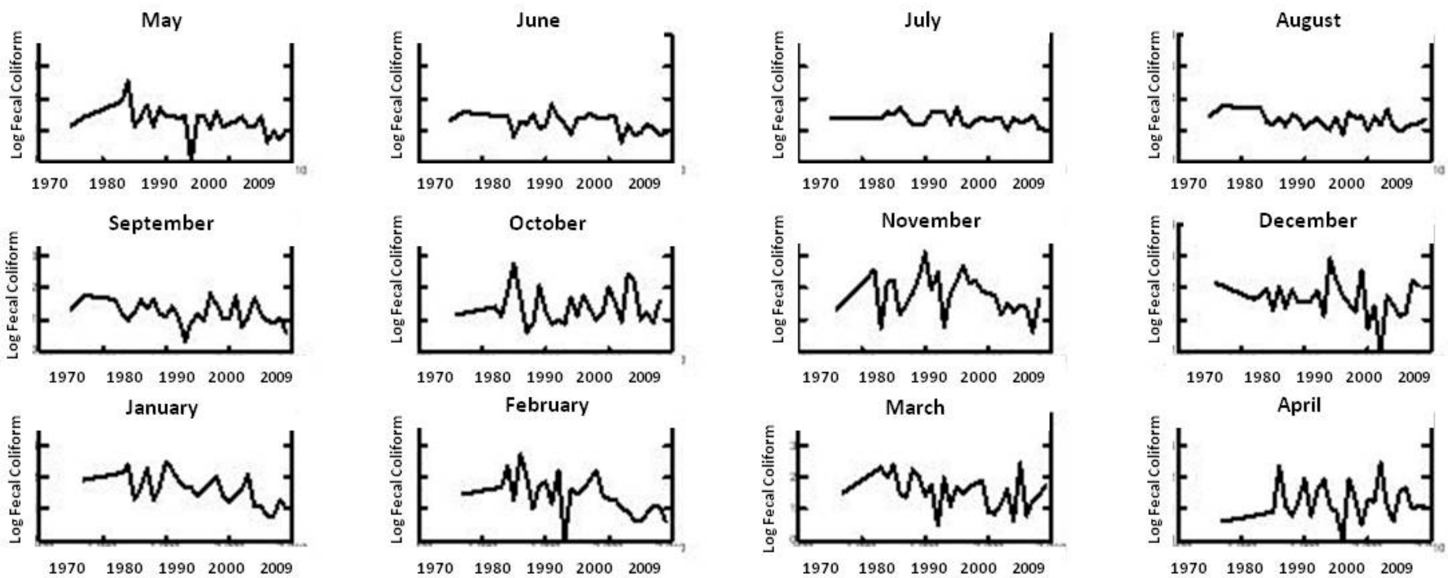

Figure C-3. Seasonal Trend Plot of fecal coliform data from ambient monitoring station at Porter, 1975-2009.

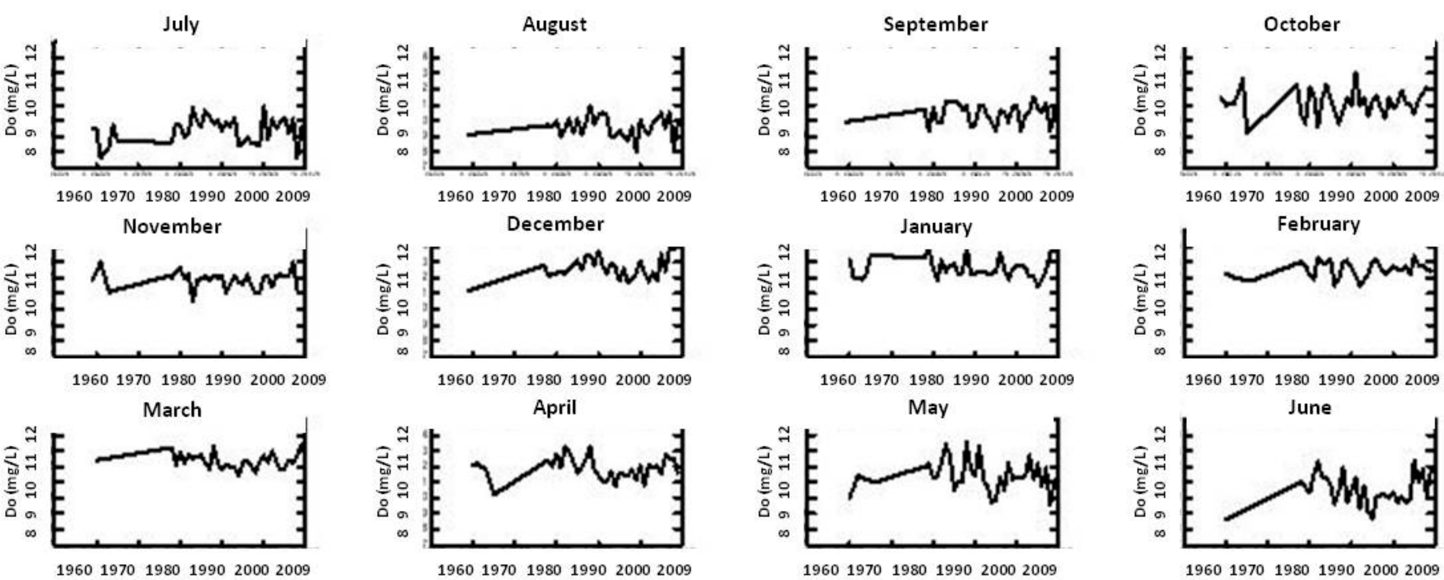

Figure C-4. Seasonal Trend Plot of dissolved oxygen (mg/L) data from ambient monitoring station at Dryad, 1959-2009.

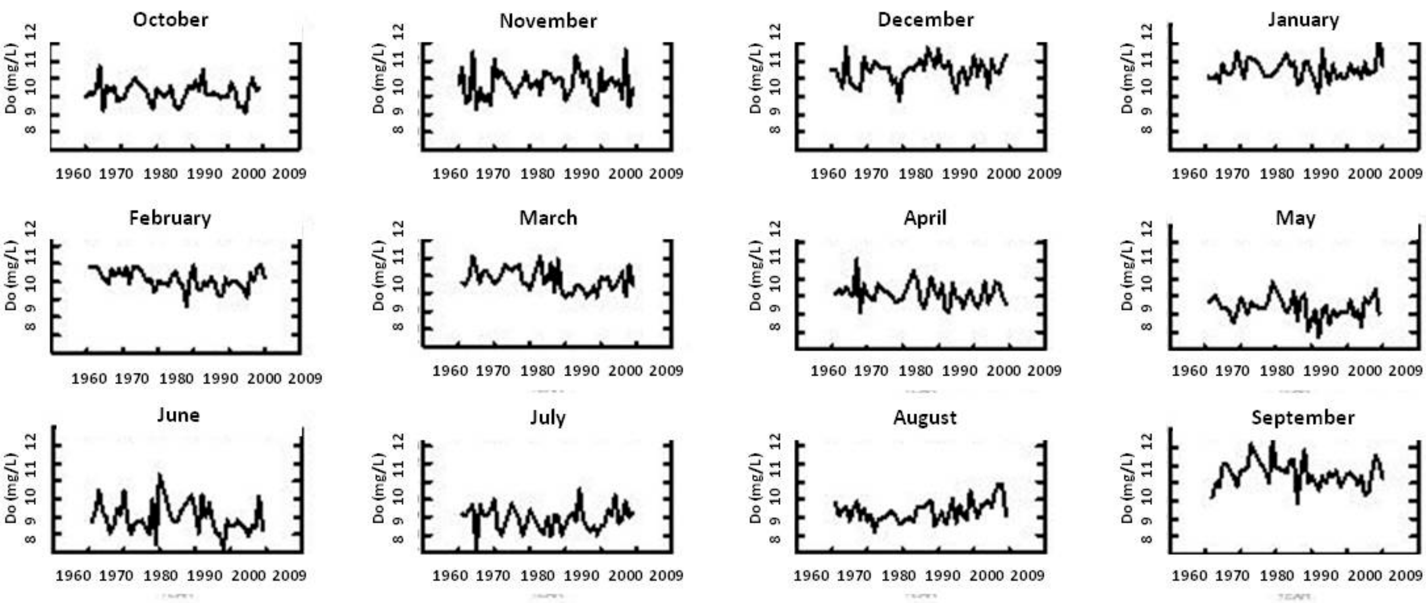

Figure C-5. Seasonal Trend Plot of dissolved oxygen (mg/L) data from ambient monitoring station at Porter, 1960-2009.

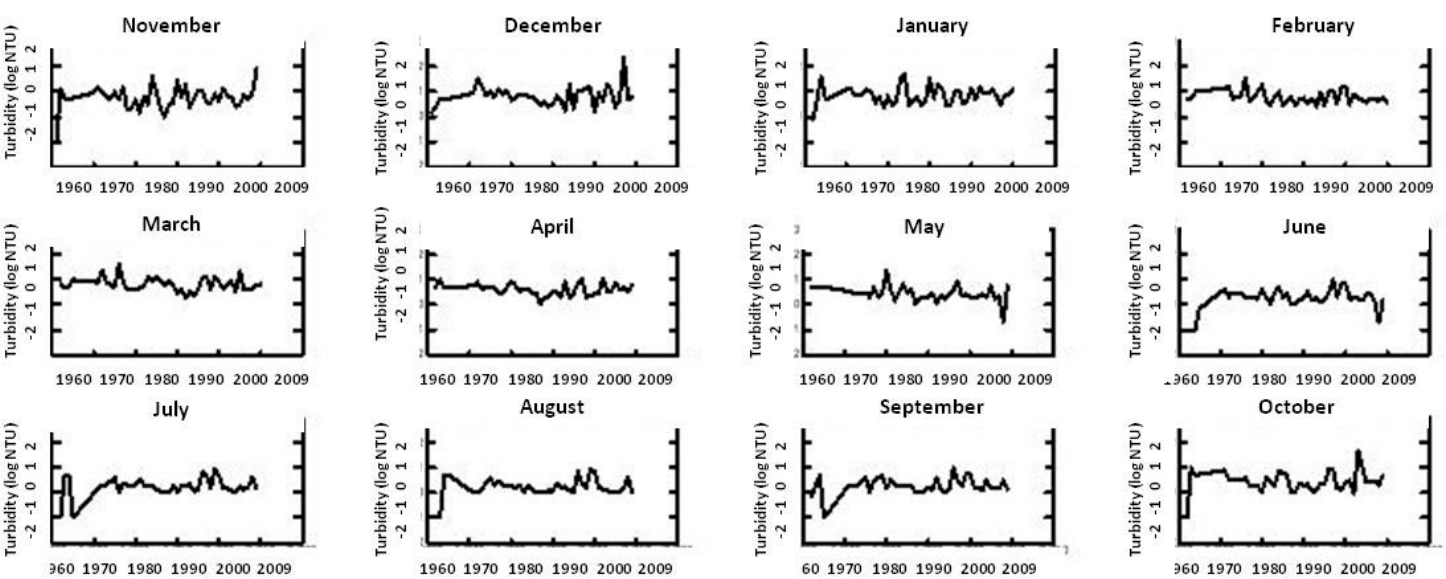

Figure C-6. Monthly seasonal plots of surface water turbidity over time for pooled data from WRIA 23, 1961-2010. Note the log scale.

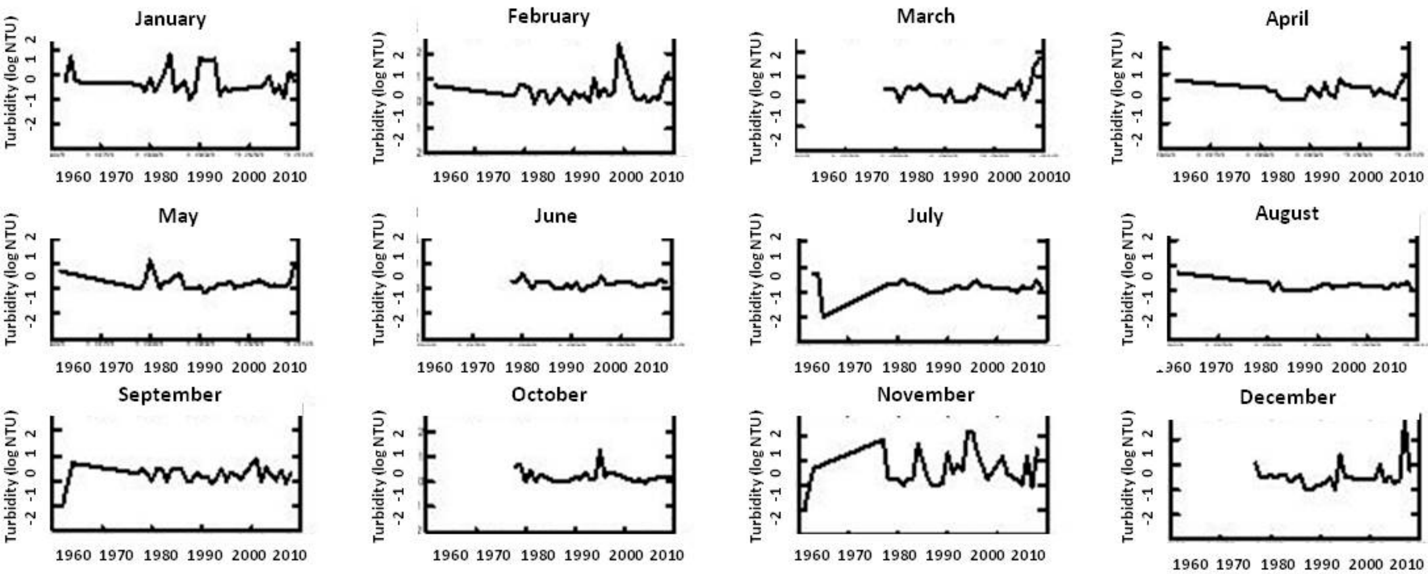

Figure C-7. Monthly seasonal plots of surface water turbidity over time for monitoring station at Dryad, 1961-2010. Note the log scale.

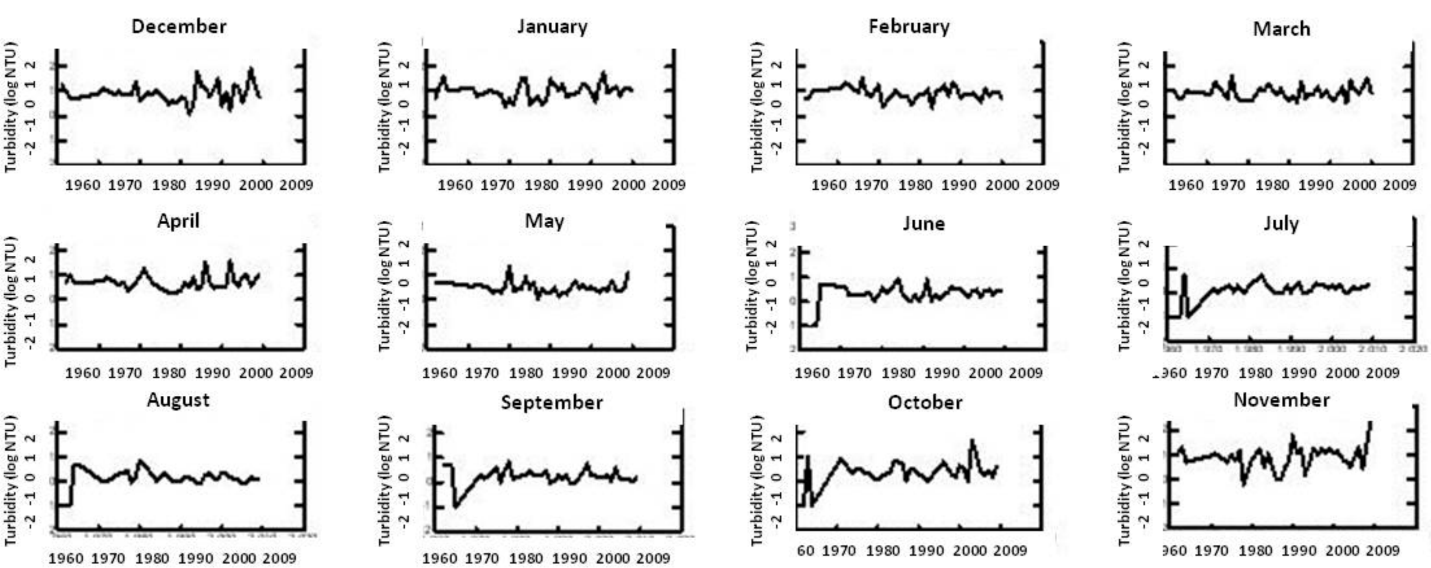

Figure C-8. Monthly seasonal plots of surface water turbidity over time for monitoring station at Porter, 1961-2010. Note the log scale.