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Introduction

The water quality of streams and lakes is a significant natural resource issue in the Long Tom Watershed. It affects fish and wildlife, such as cutthroat trout and red legged frog, and has an impact on human health through activities such as swimming and fishing in Fern Ridge Reservoir. The Council's watershed assessment (Thieman 2000) identified potential water quality problems in parts of the basin where water quality data had been collected by the Department of Environmental Quality (DEQ), City of Eugene, Army Corps of Engineers, Lane Council of Governments, and U.S. Geological Survey. However, for many parts of the watershed little or no data existed.

The Long Tom Watershed Council began its water quality monitoring program in September 1999. This report presents the findings and conclusions on water quality data collected from September 1999 through July 2003. Our primary goal for this program was to attain an accurate and comprehensive understanding of water quality in the watershed so that we could begin to understand contributions from different land use sectors and sub-watersheds. This information has enabled us to promote better watershed stewardship by sharing the data with local residents and collaborating on solutions to identified water quality problems. The monitoring program has also provided an opportunity to educate and involve landowners, residents, and youth in water quality monitoring, and to share water quality information with stakeholders and decision-makers.

Background on the Watershed

The Long Tom River Watershed drains 410 square miles of land at the southern end of the Willamette Valley. The headwaters of the Long Tom originate on the eastern side of the Coast Range and flow south through forested hills and small farms until reaching Noti where the river veers east near its confluence with Elk and Noti Creek. Coyote Creek, which drains the southern portion of the basin, and upper Amazon Creek, which drains the eastern portion, both merge with the upper Long Tom near what is now Fern Ridge Reservoir. The lower Long Tom starts at the spillway of the reservoir and flows north approximately 25 miles before its confluence with the Willamette River. Bear and Ferguson Creek, which drain from the Coast Range, and lower Amazon Creek are the major tributaries entering the lower Long Tom River.

Land Use

Forestry, agriculture, urban, rural residences, and industry are the primary land uses in the watershed. **Table 1** shows the proportion of land use in each sub-watershed and their total acreage.[1] Over 90% of the acreage in the watershed is privately owned with parcels ranging from small urban lots to several thousand acres.

[1] Land use acreage was determined from state-wide zoning maps.

Table 1. Sub-watershed Land Use

Sub-basin	Agri-culture	Forestry	Urban	Rural Resident	Parks & Rec.	Rural Industry	Other	Total Acres
Upper Long Tom R.	8%	80%	<1%	10%	2%	<1%	0%	35,605
Elk Cr.	9%	88%	0%	1%	0%	1%	0%	27,709
Coyote Cr.	31%	64%	0%	4%	2%	0%	0%	45,185
Spencer Cr.	22%	49%	1%	27%	<1%	0%	0%	21,320
Upper Amazon Cr.	6%	6%	80%	7%	<1%	0%	0%	19,710
Lower Amazon Cr.	62%	0%	21%	6%	<1%	0%	11%	19,292
Fern Ridge	25%	20%	5%	20%	5%	0%	25%	32,209
Bear Cr.	33%	57%	0%	10%	<1%	0%	0%	17,701
Ferguson Cr.	40%	59%	0%	<1%	0%	0%	0%	16,357
Lower Long Tom R.	81%	7%	1%	8%	2%	0%	<1%	27,784
Watershed Total	**31%**	**46%**	**8%**	**9%**	**1%**	**1%**	**4%**	**262,872**

Water Use

Most of the water originating from and used in the watershed comes from surface water, and a large percentage of this is stored in Fern Ridge Reservoir and other small, private reservoirs and ponds around the watershed. Approximately 98% of the water is used for irrigation of crops and pastures, 1.5% goes to industry, and the remaining fraction goes to rural residential use.[2] Sixtyseven percent of the irrigation water is used in the lower Long Tom and lower Amazon sub-watersheds where farmers have access to water stored in Fern Ridge Reservoir. Drinking water for Eugene residents comes from the McKenzie River. Monroe, Junction City, and Veneta acquire their drinking water from municipal wells.

Precipitation

The majority of precipitation in this watershed comes as winter rain. Average annual precipitation ranges from 35 to 74 inches, with the highest levels falling in the Coast Range. Most of the precipitation falls from November through March and generally corresponds with increased stream flow. However, the largest storms tend to come in November and December, whereas peak stream flows come in December and January. This is because in early winter soils are not yet saturated and there is little if any overland flow. Later in the winter, as soils become saturated, increased amounts of overland flow lead to higher stream flows.

Fish and Amphibians

The Long Tom Watershed is home to a variety of fish and wildlife that rely on its network of streams, lakes and wetlands. Some of these species are particularly sensitive to water quality conditions such as

[2] These percentages do not include drinking water for the cities of Monroe, Junction City, or Veneta.

water temperature, pesticide concentrations, dissolved oxygen, and sediment levels. Native fish species sensitive to poor water quality include cutthroat trout, paiute, torrent, and riffle sculpin, white sturgeon[3], mountain whitefish, and Pacific lamprey. Currently, no fish species that spawn in the Long Tom Watershed are on the federal list of Threatened and Endangered Species (TES). Historically, however, Oregon chub inhabited the watershed, and this species is currently listed. In addition, TES listed spring chinook use portions of the lower Long Tom for winter rearing habitat. Native amphibian species that are sensitive to poor water quality include red legged frog, southern seep salamander, and tailed frog.

Study Design and Methods

Training

The monitoring program has relied on volunteers and the monitoring coordinator to collect water quality data. A DEQ led training session on methods and equipment was held in August of 1999. Attendees were given hands-on experience in collecting and analyzing samples for dissolved oxygen, pH, conductivity, turbidity, and water temperature. The monitoring coordinator conducted subsequent training sessions for all new volunteers. In addition, participants continued to receive feedback on results and technical support from the monitoring coordinator throughout the program.

Parameters and Sampling Frequency

Council volunteers collected monthly surface water measurements of temperature, dissolved oxygen, pH, conductivity, and turbidity at 17 sites from September ’99 to August ’01 and at 18 sites from September ’01 to July ’03. Additional observations included recent rainfall, weather, water color, wildlife, and recent events in the watershed that may have influenced water quality at that site.

The monitoring coordinator and one volunteer collected grab samples for *E. coli*, nitrate-nitrite, ortho-phosphate, total phosphorus, and total suspended solids samples on a monthly to quarterly basis. From April 2000 to May 2001 we collected five *E. coli* samples at each site every quarter, with each 5-sample period occurring within a 30-day window. This allowed us to evaluate *E. coli* levels using the state’s 30-day average standard.

Continuous temperature monitoring was conducted from June through October of 2000, 2001, 2002, and 2003. In 2000 Vemco minilogs were used at 14 sites and Optic Stowaways at 8 sites around the watershed. In 2001 and 2002 minilogs were used at 32 sites and in 2003 they were used at 26 sites.

Table 2 summarizes the sampling frequency, data collector and method for each parameter. **Table 3** lists the 19 sites we have monitored during the past four years. All sites except CC3, CC4, and LL3 have been monitored all 4 years. CC3 was monitored from September 1999 through August 2001 and CC4 and LL3 were monitored from September 2001 through July 2003. Site locations were selected in order to characterize water quality in each sub-watershed, investigate the relationship between water quality and land-use, and assess upstream-downstream differences. To accomplish these objectives we located sampling sites at the mouths of each sub-watershed, at junctures between different land uses, and at different elevations in the watershed.

[3] Presence not documented, but other evidence suggests that their occasional presence in the lower Long Tom is likely.

Table 2. Parameters & Sampling Frequency

# of Sites	Parameters	Sampling Frequency	Data collection responsibility	Method
17-18	Temperature	Monthly	Monitoring team	Conductivity meter probe
26-32	Temperature	Hourly March – Nov.	Monitoring coordinator	Continuous data-loggers
17-18	Turbidity	Monthly	Monitoring team	Portable field meter
17-18	pH	Monthly	Monitoring team and monitoring coordinator	Portable field meter
17-18	Flow	Variable	Monitoring coordinator	A & Pygmy current meters
17-18	Dissolved Oxygen	Monthly	Monitoring team	Winkler titration kit
17-18	Conductivity	Monthly	Monitoring team	Portable field meter
17-18	*E. coli*, NO_3-NO_2, ortho-PO_4, TP, TSS	Monthly - Quarterly	Monitoring coordinator	Samples taken to lab for analysis

Table 3. Monitoring Site Location and Land Use Information

Site	ID	Type	Predominant Upstream Land Use and *Ecoregion*	Elev. (ft.)
Tributary of Coyote Creek off Hamm Rd	CC3	1	Forestry; *Valley Foothills*	670
Tributary of Coyote Creek off Powell Rd.	CC4	1	Forestry; *Valley Foothills*	500
Ferguson Creek at Ferguson Rd.	FC2	1	Forestry; *Valley Foothills*	400
Tributary of Elk Cr (Cedar Cr.)	EC2	1	Forestry; *Valley Foothills*	540
Upper Long Tom at Alderwood State Pk.	UL2	2	Mixture: Forest/Rur.Residential; *Valley Foothills*	570
Bear Creek at Templeton Rd.	BC2	2	Mixture: Forest/Rur.Residential; *Valley Foothills*	710
Elk Creek at Crow-Vaughan Rd.	EC1	2	Mixture: Forest/Ag/Rur.Residential; *Valley Foothills*	420
Spencer Creek at Pine Grove Rd	SC1	2	Mixture: Forest/Ag/Rur.Residential; *Valley Foothills*	400
Spencer Creek at Summerville Rd.	SC2	2	Mixture: Ag/Rur.Residential; *Valley Foothills*	430
Coyote Creek at Powell Rd.	CC2	2	Mixture: Forest/Ag/Rur.Residential; *Valley Foothills*	460
Upper Long Tom at Hwy. 126	UL1	3	Mixture: Forest/Ag/Rur.Residential; *Prairie Terraces*	390
Coyote Creek at Petzold Rd	CC1	3	Mixture: Forest/Ag/Rur.Residential; *Prairie Terraces*	370
Upper Amazon at Danebo Ave.	UA1	3	Urban; *Prairie Terraces*	385
Lower Amazon at High Pass Rd	LA1	3	Mixture: Ag/Urban; *Prairie Terraces*	315
Bear Creek at Territorial Hwy.	BC1	3	Mixture: Forest/Ag/Rur.Residential; *Prairie Terraces*	310
Lower Long Tom at Fern Ridge Spillway/Clear Lake Rd.	LL3	3	Mixture: Forest/Ag/Rur.Residential/Urban; *Prairie Terraces*	360
Lower Long Tom at Hwy. 36	LL2	3	Mixture: Forest/Ag/Rur.Residential/Urban; *Prairie Terraces*	320
Ferguson Creek at Territorial Hwy.	FC1	3	Mixture: Forest/Ag/Rur.Residential; *Prairie Terraces*	305
Lower Long Tom at Bundy Bridge	LL1	3	Mixture: Forest/Ag/Rur.Residential/Urban; *Prairie Terraces*	260

Methods

Measurement of stream temperature, pH, turbidity, conductivity and dissolved oxygen was conducted using the standard protocols described in the Oregon Plan for Salmon and Watersheds Water Quality Monitoring Technical Guidebook. In addition, team members recorded stream height by measuring the distance from a fixed point above the stream to the water surface. Stream flow values will ultimately be estimated by relating recorded stream flow data with these measurements for each site. The monitoring coordinator has collected stream flow data twice at most sites using pygmy and "A" flow meters. This information is presented in **Appendix C**. When four to five measurements have been collected at each site at different stream levels a rating curve will be developed for that section of the stream. A rating curve shows the relationship between flow and water depth.

Volunteers measured and recorded water temperature, pH, conductivity, dissolved oxygen, and turbidity in the field. One exception to this is that beginning in August 2001 pH measurements were made at the Council office. Volunteers collected water samples in dark bottles, placed them in a cooler on ice, and took them back to the Council office. The monitoring coordinator then measured the pH within 24 hours. We made this change because of poor accuracy and precision levels when using the pH meters out in the field.

Surface water samples for *E. coli*, nutrients, and total suspended solids were collected either directly from the stream or by drawing a bucket of water from a bridge above the stream. The former method was used when streams were wadeable in the summer; the latter method was used when stream flows were high in the winter. We delivered the samples on ice to Delta Environmental Laboratories within 24 hours of collection. In addition, an agricultural research laboratory at Oregon State University analyzed some of the phosphate and nitrate-nitrite samples. Each sample was marked with the sample ID number, time, and date of collection. A chain of custody record was submitted to the laboratory upon delivery of samples.

Continuous temperature loggers were checked for accuracy before and after field deployment according to the procedures outlined in Chapter 6 of the Water Quality Monitoring Technical Guidebook. Loggers were set to record a data point once an hour. The monitoring coordinator conducted independent field audits at each site using a National Institute of Standards and Technology (NIST) traceable thermometer at the time of deployment, at least once during the monitoring season and at the time of removal.

Quality Assurance and Control

Methods for quality assurance and control included: 1) DEQ approved equipment, 2) regular calibration and accuracy checks of field equipment, 3) field checks by the monitoring coordinator, 4) duplicate sampling at 2 out of the 17-18 sites for each round of sample collection, and 5) pre and post-deployment accuracy checks and field audits of continuous temperature loggers using a NIST certified thermometer. For more details see the Quality Assurance Project Plan for the Long Tom Water Quality Monitoring Program.

Most of the data collected were rated A or B level based on accuracy and precision. Accuracy evaluates whether equipment is calibrated correctly and/or whether that equipment measures a known standard within an acceptable range. Precision reflects the degree of repeatability between measurements. We determined this by making duplicate measurements of each parameter at 2 out of 18 sites each time monitoring occurred. On a few occasions only one duplicate measurement was taken. See **Appendix B** for DEQ data quality levels for accuracy and precision.[4]

A variety of steps have been implemented over the past several years to improve accuracy and precision levels. The turbidity and pH meters lose their accuracy and precision when the machines are

[4] No official precision standards for nutrients and TSS exist yet. Interim precision standard for level A data for TSS is <5 mg/L or <20% difference between duplicate measurements. Interim precision standard for nitrate, total phosphorus and ortho-phosphate is <0.1 mg/L or <20% difference between duplicate measurements (pers. comm. Alan Hammhill, DEQ)

cold. The coordinator reminded volunteers to keep equipment indoors overnight and, if possible, use the equipment in their car on cold days. In August 2001, we changed our pH sampling protocol by having volunteers bring in samples to be analyzed for pH in the office. This step dramatically improved our accuracy and precision levels and allowed us to determine that pH was in fact not a problem in the watershed.

Another step we took to improve accuracy was to tape the acceptable ranges for turbidity and accuracy to the machine so the user could immediately see whether the machines were in range during accuracy checks. The coordinator also visited each volunteer every 3 to 4 months during sampling to observe their technique and make suggestions when necessary. We have also conducted split sampling with the DEQ volunteer monitoring coordinator twice in the past 4 years. There was a high level of agreement between the DEQ coordinator's results and Council monitoring volunteers' results.

Results

For this report we evaluated water quality conditions using a number of frameworks. First, we evaluated stream conditions based on state water quality standards and guidelines. This tells us which streams have the potential to be listed on the state's 303(d) list of water quality limited streams. (**Appendix A** lists the streams currently on the 303(d) list.) Second, we looked at water quality conditions by sub-watershed, which allows us to target education and actions to improve specific water quality problems. Third, we assessed differences in water quality conditions based on ecoregions and land use.

Comparison to State Water Quality Standards

Table 4 shows the number of days at each site that did not meet the state temperature standard for the summers of 2000, 2001, and 2002. Temperature data came from hourly measurements recorded during the time period listed for each site and year. Temperature data for summer 2003 is still being collected and will be available in a separate report at a later date.

Table 5 shows the percentage of days at each site that did not meet state standards or guidelines for turbidity, dissolved oxygen, *E. coli*, pH, nitrate, and total phosphorus. The state standard or guideline for each parameter is listed in the second row of the table and is shown as the range of values that do *not* meet the state standard or guideline. Guidelines (denoted by * in table) are recommendations to protect freshwater organisms but are non-regulatory, which means they are not used as criteria to determine whether a stream will be listed on the state's 303(d) list of water quality limited streams. Data on turbidity and dissolved oxygen came from approximately 45 monthly measurements at each site from September 1999 to July 2003. *E. coli* data came from approximately 60 measurements made at each site between September 1999 and July 2003. Sampling frequency for *E. coli* ranged from 5 times/30-day period each quarter to once/month. Data on pH came from approximately 25 monthly measurements at each site from August 2001 to July 2003. pH data collected prior to August 2001 were not included because of poor accuracy and precision results. Nitrate and total phosphorus data came from approximately 32 and 27 measurements, respectively, made at each site from September 1999 to July 2003. Sampling frequency ranged from quarterly to monthly.

Table 4. Number of Days at each Site that did not Meet the State Temperature Standard

Site Description	Site ID	Start Date	End Date	Total days	Days over Std	Start Date	End Date	Total days	Days over Std	Start Date	End Date	Total days	Days over Std	Ave. # Days over Std.
Amazon Cr at Acorn Park Rd.	UAT1					6/29/01	10/16/01	109	101	5/7/02	11/5/02	182	145	123
Amazon Cr. at Oak Patch Rd.	UAT2					6/29/01	10/16/01	109	99	5/7/02	11/5/02	182	144	122
Battle Cr. at Battle Cr. Rd.	CCT3					6/21/01	10/11/01	112	16	5/24/02	10/18/02	147	27	22
Bear Cr. at Territorial Hwy.	BC1	6/27/00	10/3/00	98	80	7/2/01	10/18/01	108	73	4/29/02	10/16/02	170	105	86
Bear Creek at Templeton Rd.	BC2	4/21/00	lost			7/2/01	10/18/01	108	77	4/29/02	10/16/02	170	112	95
Coyote Cr. @ Franklin Rd.	CCT1	8/10/00	11/19/00	101	45					5/17/02	9/30/02	136	101	73
Coyote Cr. Kirk pond	CCT2	8/10/00	10/2/00	53	52	6/19/01	lost			5/17/02	10/18/02	154	136	94
Coyote Creek at Petzold Rd	CC1	4/21/00	10/2/00	164	83	6/21/01	10/15/01	116	69	5/7/02	10/15/02	161	85	79
Coyote Creek at Powell Rd.	CC2	4/21/00	10/2/00	164	86	6/21/01	10/15/01	116	75	5/24/02	10/18/02	147	75	79
Tributary of Coyote Creek off Hamm Rd	CC3	4/21/00	10/2/00	164	0	6/21/01	10/15/01	116	0					0
Tributary of Coyote Creek off Powell Rd.	CC4									5/24/02	10/18/02	147	79	79
Elk Creek at Crow-Vaughan Rd.	EC1	6/27/00	10/2/00	97	55	6/25/01	lost			4/29/02	10/14/02	168	65	60
Tributary of Elk Cr (Cedar Cr.)	EC2	6/27/00	10/2/00	97	0	7/2/01	10/16/01	106	0	5/1/02	10/18/02	170	0	0
Ferguson Creek at Territorial Hwy.	FC1	6/30/00	10/3/00	95	66	7/2/01	10/18/01	108	65	4/29/02	10/16/02	170	71	67
Ferguson Creek at Ferguson Rd.	FC2	6/30/00	10/3/00	95	15	7/2/01	10/18/01	108	9	4/29/02	10/16/02	170	15	13
Fox Hollow @Gillespie Corners	CCT5					6/20/01	10/11/01	113	53	5/7/02	10/18/02	164	36	45
Hayes Cr. @ Cook Rd.	ULT3					6/21/01	10/11/01	112	13	5/24/02	10/16/02	145	20	17

Site Description	Site ID	Start Date	End Date	Total days	Days over Std	Start Date	End Date	Total days	Days over Std	Start Date	End Date	Total days	Days over Std	Ave. # Days over Std.
Jones Cr. @ Hall Rd. near Alderwood Park	ULT2					6/21/01	10/11/01	112	9	5/24/02	10/16/02	145	26	18
Jones Cr. @ Hall Rd.(Bear Cr. subwatershed)	BCT2					6/21/01	10/11/01	112	94	5/24/02	10/16/02	145	43	69
Lower Amazon at High Pass Rd	LA1	6/30/00	10/3/00	95	90	7/2/01	10/18/01	108	91	5/17/02	lost			91
LL @ Franklin Rd.	LLT1	8/10/00	11/19/00	101	54	6/19/01	10/17/01	120	109	5/17/02	9/30/02	136	131	98
Lower Long Tom at Bundy Bridge	LL1	6/30/00	11/19/00	142	94	7/2/01	10/17/01	107	95					95
Lower Long Tom at Hwy. 36	LL2	4/21/00	lost			7/2/01	10/17/01	107	95	5/17/02	9/30/02	136	131	113
Lower Long Tom at Spillway/Clear Lake Rd	LL3	7/3/00	11/19/00	139	91	6/19/01	lost							91
Noti Cr. Mouth	NCT1					6/20/01	10/11/01	113	49	4/29/02	10/14/02	168	71	60
Owens Cr. @ Smythe Rd.	BCT1					6/21/01	10/19/01	120	60					60
Poodle Cr. @ Hwy. 126	PCT1					6/20/01	10/11/01	113	35	5/17/02	10/18/02	154	39	37
Spencer Creek at Pine Grove Rd	SC1	4/21/00	10/2/00	164	64	6/21/01	lost			5/7/02	7/16/02	70	28	46
Spencer Creek at Summerville Rd.	SC2	4/21/00	8/9/00	110	18					5/7/02	7/16/02	70	17	18
Sturtevant Creek @ Crow Road	CCT4									5/24/02	10/18/02	147	5	5
Spencer Cr. MP 6.8 Lorane Hwy	SCT1					7/3/01	11/28/01	148	0					0
Swamp Cr. Mouth	ULT1					6/25/01	10/11/01	108	15	5/24/02	10/16/02	145	31	23
Upper Amazon at Danebo Ave.	UA1	6/30/00	9/27/00	89	84	6/19/01	10/16/01	119	109	5/7/02	11/4/02	181	141	111
Upper Long Tom at Hwy. 126	UL1	6/27/00	10/2/00	97	73	7/2/01	10/19/01	109	73	5/24/02	10/18/02	147	76	74
Upper Long Tom at Alderwood State Park	UL2	6/27/00	10/2/00	97	25	6/25/01	10/11/01	108	24	4/29/02	10/14/02	168	26	25

Table 5. Percent of Samples at each Site that did not Meet State Standards or Guidelines

		Turbi-dity	Dissolved Oxygen	*E. coli* (single)	*E. coli* (average)[5]	pH	Nitrate-Nitrite-N	Total Phosphorus
State standard or guideline*[6] (shown as values that do *not* meet criteria)	**Site ID**	**> 50 NTU***	**< 8 mg/L**	**> 406 cells/ 100 mL**	**>126 cells /100 mL**	**< 6.5 or > 8.5**	**> 0.3 mg/L***	**> 0.1 mg/L***
Approximate # of Samples		*45*	*45*	*60*	*5 sets*	*25*	*32*	*27*
Bear Cr. at Territorial (near mouth)	BC1	9%	27%	41%	80%	0%	13%	19%
Bear Cr. at Templeton Rd. (headwaters)	BC2	0%	49%	8%	0%	0%	10%	0%
Coyote Cr. at Petzold Rd. (near mouth)	CC1	6%	34%	14%	20%	0%	3%	19%
Coyote Cr. at Powell Rd. (mid-basin)	CC2	16%	26%	12%	20%	0%	3%	11%
Tributary of Coyote Cr. (headwaters)	CC3	4%	13%	6%	0%	0%	0%	33%
Coyote Cr. tributary off Powell Rd. (headwaters)	CC4	0%	39%	8%	N/A	0%	14%	19%
Elk Cr. at Crow-Vaughan Rd. (near mouth)	EC1	0%	15%	14%	40%	0%	22%	11%
Tributary of Elk Cr. (headwaters)	EC2	0%	0%	2%	0%	0%	30%	0%
Ferguson Cr. at Territorial (near mouth)	FC1	2%	20%	41%	60%	0%	25%	22%
Ferguson Cr. at Ferguson Rd. (mid-basin)	FC2	2%	2%	7%	0%	0%	6%	4%
Amazon at High Pass Rd. (near mouth)	LA1	9%	39%	18%	0%	0%	47%	89%
Long Tom at Bundy Bridge (near mouth)	LL1	13%	26%	12%	0%	0%	56%	26%
Long Tom at Hwy. 36 (mid-basin)	LL2	20%	33%	12%	20%	0%	10%	31%
Lower Long Tom @ Spillway (mid-basin)	LL3	26%	26%	26%	N/A	0%	10%	33%
Spencer Cr. at Pinegrove Rd. (near mouth)	SC1	4%	46%	9%	20%	0%	0%	19%
Spencer Cr. at Summerville Rd. (headwaters)	SC2	6%	31%	14%	75%	0%	0%	10%
Amazon at Danebo Ave. (mid-basin)	UA1	15%	54%	45%	100%	0%	38%	63%
Long Tom at Hwy. 126 (mid-basin)	UL1	4%	19%	5%	20%	0%	16%	7%
Long Tom at Alderwood State Park (mid-basin)	UL2	2%	0%	14%	20%	0%	19%	4%

[5] To calculate this average: $10^{[(\log A + \log B + \log C + \log D + \log E)/5]}$, where A – E are the *E. coli* levels (cells/100 mL) for 5 samples taken within a 30-day period

[6] These guidelines have been suggested by staff at the DEQ as interim evaluation criteria. These numbers may change when formal guidelines based on ecoregional data are available.

Temperature

The state standard for water temperature is 17.8° C (64° F). This standard is based on a 7-day moving average of daily maximum temperatures. Water temperatures above this can weaken or kill fish, especially salmonids, which include both trout and salmon. Salmonids are especially sensitive to temperature before they hatch and during their early life stages. The primary causes of high stream temperature include ambient air temperature, direct solar radiation on the creek due to lack of shade, and low stream flow

Dissolved Oxygen

The state dissolved oxygen standard requires that oxygen levels be 8 mg/L or above in order to protect cold-water aquatic life. Fish and other aquatic species experience some degree of stress or death at dissolved oxygen levels below 8 mg/L. One factor affecting the amount of dissolved oxygen in water is temperature. The higher the temperature, the less oxygen water can hold. Another factor is the amount of biological activity. If a lake or stream has high concentrations of algae it ultimately leads to a great deal of oxygen being consumed as bacteria break down dead algae. Low levels of dissolved oxygen and the large fluctuations in daily oxygen levels and temperature are stressful and sometimes deadly to fish and other aquatic life.

Turbidity

The informal guideline for turbidity is 50 nephalometric turbidity units (NTU). Conditions for fish and other aquatic life start to become impaired at turbidity levels of 50 NTU and above. High turbidity levels can impair visual feeding by fish, smother eggs, and impair gill respiration. Typically turbidity levels increase dramatically when there is a heavy rain event. Significant sources of sediment to streams include land slides and debris flows, road failures, and exposed soil along ditches, roads, driveways, and urban areas that are hydrologically connected to streams.

E. coli

E. coli originates from fecal matter and is an easily measured indicator of fecal contamination of surface waters. Two state standards have been developed to protect humans from pathogenic bacteria associated with fecal matter. *E. coli* is used as the indicator organism because it originates from fecal matter and is easy to measure. One standard applies to single samples and the second applies to the average of five samples taken within a 30-day period. The single sample standard is 406-cells/100 mL of water. Samples exceeding this concentration indicate that a water body at least occasionally has problems with *E. coli*. The 5-sample average standard is 126 cells/100 mL. Streams that have average levels above 126 cells/100 mL indicate chronic *E. coli* problems. Common sources include runoff carrying livestock manure, fecal matter from wildlife or domestic pets, and human sewage from leaking septic systems.

pH

The acceptable range for pH according to the state standard is 6.5 – 8.5. This measurement reflects the relative acidity of a liquid, and is measured on a scale of 1 to 14 (1 = highly acidic, 7 = neutral, 14 = highly alkaline). The pH of rainwater in the Pacific Northwest is between pH 5 and 6. As water hits the ground and intercepts soil particles and other substances its pH generally increases. The pH in a river or lake can be influenced by human activity (e.g., industry, automobile exhaust), the soil and rock types in the watershed, and the amount of algae in the water. Large concentrations of algae or aquatic plants can effect pH changes through photosynthesis. During the day pH levels are higher because photosynthesis is occurring, whereas at night pH levels are lower (i.e., more acidic) because no photosynthesis is occurring.

Nitrate-nitrite and total phosphorus

The guideline for total phosphorus is 0.1 mg/L and for nitrate-nitrite is 0.3 mg/L.[7] Surface water concentrations that are higher than this can lead to a number of problems. In our watershed, high phosphorus levels contribute to occasional blooms of algae in Fern Ridge Reservoir and slow moving streams. Algae blooms and dense aquatic vegetation lead to lower dissolved oxygen levels when the plant matter decays. Very high nitrogen levels can be toxic to fish and other aquatic life. Sources of nitrate and phosphorus include decaying plants or animals in the water, discharge from wastewater treatment plants, leaking septic systems, manure from livestock operations, and fertilizers or detergents that runoff from urban, rural, and agricultural land.

Sub-watershed Conditions

The **Water Quality Maps on pages 13 through 16** illustrate conditions across the watershed for several parameters. For water temperature, we classified stream segments as impaired if they did not meet the state standard an average of 40 or more days during the summer (red lines). Those that did not meet the state standard an average of 6 to 39 days we classified as moderately impaired (yellow lines) and segments that did not meet the standard an average of 0 to 5 days we considered in good condition (green lines). Our classification of stream segments for *E. coli*, nitrate, and phosphorus is as follows: if 40% or more of samples did not meet the state standard or guideline = impaired (red); 15% - 39% of samples not meeting state standard or guideline = moderately impaired (yellow); and 0% - 14% of samples not meeting state standard or guideline = good (green). For *E. coli* we used the single-sample standard to map conditions of stream segments because all of our data could be evaluated using this standard. In order to evaluate *E. coli* samples using the 5-sample average standard you must collect 5 samples within a 30-day period. We did this for 25 samples at each site between 4/26/00 and 5/1/01 (see results in **Table 5**). After this period we changed our frequency to monthly sampling due to limited time and money. At approximately half of the sites, both standards yielded the same classification. At the other half, the 5-sample average standard yielded higher impairment levels. And at one site, the single-sample standard indicated greater impairment than the 5-sample average standard.

One potentially misleading aspect of these maps is that we are extrapolating conditions between monitoring sites. For mapping purposes we assumed the conditions at downstream sites were consistent to the next upstream monitoring site and that conditions at upstream sites were consistent up to the headwaters of the stream. In reality, water quality may fluctuate between sites and often is good in headwater streams.

Upper Long Tom (80% forestry, 10% rural residential, 8% agriculture, 2% urban & rural industrial)

The upper Long Tom sub-watershed originates in the Coast Range. Most of it is covered in forestland with rural residences and small-scale ranching and farming in the valley bottomland. The monitoring

[7] It is important to note that these are interim guidelines. The Environmental Protection Agency is currently developing nutrient guidelines based on ecoregional data. When these are finalized the state of Oregon may choose to adopt these criteria as guidelines or regulatory standards for nitrogen and phosphorus.

Insert map

Insert map

Insert map

Insert map

sites in this sub-watershed are located along the valley bottom with the mixture of upstream land uses as described above. *E. coli* results indicate good to moderately impaired conditions from bacteria. The slightly higher levels at UL2 probably indicate sources immediately upstream of the site on either Jones Creek or the Long Tom River. These sources may be leaking septic systems, livestock manure, or a combination of the two. Human or livestock waste may also be contributing to slightly higher nitrate levels in this sub-watershed as could nitrate from fertilizers used in forestry operations.

Water temperature and dissolved oxygen follow predictable trends in this sub-watershed. The upper Long Tom and several of its major tributaries (Hayes Creek, Swamp Creek, & Jones Creek) show moderate impairment for temperature with an average of 17 to 25 days in the summer not meeting the state standard. Farther downstream at UL1, the average number of days not meeting the standard is 74. The higher downstream temperature is due to a combination of slower stream flow (stream gradients are lower), lack of shade, and water withdrawals.

Elk Creek (88% forestry, 9% agriculture, 1% rural residential, 1% rural industrial)
Elk Creek also flows out of the Coast Range with almost the entire sub-watershed covered by forestland. Land use above the upstream monitoring site (EC2) is entirely forestry. Water quality at this site is generally very good and provides useful information on what we could reasonably expect for similar sized streams in the watershed where adequate shade and riparian buffers exist. The one exception to this is nitrate levels for which 30% of samples did not meet the guideline. The downstream site on Elk Creek (EC2) has poorer water quality. Here the creek is impaired for water temperature and moderately impaired for dissolved oxygen and nitrate. The high summertime water temperature and low dissolved oxygen levels are very likely due to insufficient shade along the creek, low stream flows, and a large impoundment several miles upstream of the mouth of Elk Creek. Poodle Creek, a major tributary to Elk Creek, is moderately impaired for water temperature, with an average of 37 days not meeting the state standard. Noti Creek, another major tributary that joins Elk Creek just downstream of EC1, is impaired for water temperature, with an average of 60 days in the summer not meeting the state standard.

The classification for *E. coli* levels at EC1 depends on which standard is used. The site shows good conditions when using the single sample standard and impaired when using the 5-sample average standard. This may mean that the lower reaches of Elk Creek are chronically impaired for *E. coli* but seldom reach the very high bacteria concentrations that exceed the single sample standard (i.e., 406 cells/100 mL). Alternatively, conditions in Elk Creek may have improved since we stopped sampling 5 times/month for bacteria. In either case, the higher bacteria levels at EC1 are probably in large part coming from either leaking septic systems, livestock, or some combination. This conclusion is based on the fact that *E. coli* levels at EC2, a site with no upstream septic systems or livestock, have been consistently low for the past 4 years. Furthermore, *E. coli* levels at this site provide a reasonable estimate of the relative contribution of bacteria from wild animals, which can be extrapolated to other parts of the watershed.

Like the upper Long Tom, nitrate levels in the Elk Creek sub-watershed are relatively high. Given that forestry is by far the predominant land use it is possible that nitrogen-containing fertilizer from forestry operations is entering the creeks.

Coyote Creek (64% forestry, 31% agriculture, 4% rural residential, 2% parks)
Coyote Creek drains the southern portion of the watershed. Forestry dominates the steeper, upland areas and ranching, small-scale farming, and rural residences cover the foothills and valley. There are three regularly monitored sites in this sub-watershed that characterize headwater, mid-watershed, and lower-watershed conditions. We have had two different headwater sites over the past four years. CC3 was monitored from September '99 - August '01 and CC4 has been monitored from September '01 – present. Upstream landuse at both these sites is forestry. One distinction between these sites is an off-channel pond immediately upstream of CC4. The pond may be contributing to lower dissolved oxygen levels and high water temperature in the summer because the water that is diverted from the creek into the pond lowers stream flow (little if any water returns from the pond into the creek during the summer). Other possible reasons for high temperatures and low dissolved oxygen at CC4 include naturally low stream flows and insufficient shade upstream of the site. In contrast, CC3 meets the state standards for both water temperature and dissolved oxygen most of the time. This is probably due to abundant shade on the creek upstream of CC3.

The mid and lower portions of Coyote Creek are moderately impaired for dissolved oxygen and impaired for water temperature. At both CC1 and CC2 an average of 79 days in the summers of '00, '01, and '02 did not meet the state temperature standard. This is consistent with the rest of the watershed where we see low summertime dissolved oxygen levels and high water temperatures in the low gradient parts of the basin. Again, this is due to a combination of slower stream flow, lack of shade, and water withdrawals. Temperature data from three major tributaries of Coyote Creek have yielded varying results. Fox Hollow Creek (CCT5) did not meet the standard an average of 45 days in the summers of '01 and '02. Battle Creek (CCT3) did not meet the standard an average of 22 days in '01 and '02. Sturtevant Creek (CCT4) did not meet the state standard for 5 days in '02. Since the Battle and Sturtevant Creek basins are similar in size and lie adjacent to each other, their difference in stream temperature is probably due to the relative amount of shade and flow in each tributary.

The mid and lower sites on Coyote Creek, CC2 and CC1, show good to moderately impaired conditions for bacteria depending on whether one uses the single or 5-sample average standard. The explanation for this is similar to the one for bacteria levels at EC1. Turbidity is moderately impaired at CC2 and good at the other sites.

Coyote Creek is moderately impaired for total phosphorus at CC1, CC3, and CC4. The higher levels at the headwater sites suggest that the source is natural in origin. Compared to other headwater sites, turbidity levels at CC3 and CC4 are slightly higher. This may explain the relatively high phosphorus levels given that phosphorus primarily enters water bound to soil particles.

Spencer Creek (49% forestry, 27% rural residential, 22% agriculture, 1% urban, 1% parks)
Spencer Creek, a major tributary to Coyote Creek, originates from the western side of Spencer's Butte. Both the upper (SC2) and lower monitoring sites in this sub-watershed have a combination of upstream land use. Due to its proximity to Eugene, rural residences occupy a relatively greater proportion of the landscape and the most common agricultural activity is raising livestock. The combination of porous, volcanic bedrock underlying most of this sub-watershed and an increasing number of wells causes most streams to dry up in the summer. Consequently, the data for SC1 and SC2 come from monitoring done from November through June most years.

E. coli levels indicate good to impaired conditions at SC2 and good to moderately impaired conditions at SC1. The chronically high levels at SC2 (75% of samples don't meet "5-sample average" state standard) are very likely due to livestock that graze immediately upstream of the site. This does not mean that upstream livestock management is significantly different at this site compared to others in the watershed. Rather, because the monitoring site happens to be directly downstream from livestock it reflects the immediate impact livestock can have on a stream. If we were to sample below all pastures where livestock were not fenced away from the creek we would probably find very similar results. At SC1, the stream is bigger and upstream livestock are farther away. Hence, only 20% of samples do not meet the 5-sample average state standard. At both SC1 and SC2, the number of samples not meeting the single sample standard is 9 and 14%, respectively. This means that high levels of bacteria are not typical at either location but that chronic low levels are a problem at SC2. Another likely source of bacterial pollution in this sub-watershed is leaking septic systems given the large number of rural residences.

Summertime temperature and dissolved oxygen at SC2 shows moderate impairment with an average of 18 days not meeting the state temperature standard before the stream dries up in mid-July to early August. At SC1, the stream is impaired for both dissolved oxygen and water temperature. An additional temperature-monitoring site on Spencer Creek (SCT1), which flows year-round because it is downstream of a spring, showed no impairment for temperature. Low stream flow is probably the biggest factor determining high water temperatures and low dissolved oxygen in the summer.

Upper Amazon Creek (80% urban, 7% rural residential, 6% forestry, 6% agriculture, 1% parks)
The water quality and instream conditions in upper Amazon Creek are determined by the impacts of an urban area. Eugene residents, businesses, and industry cause sediment, oil, household and industrial chemicals, and other pollutants to reach storm drains and ultimately the creek. This is facilitated by the thousands of acres of impervious surfaces, such as pavement, concrete, and roofs throughout the City. Impervious surfaces accumulate pollutants during dry periods and are washed into the creek with the next rain.

Overall water quality conditions in the upper Amazon are the worst in the Long Tom Watershed. Water temperature and dissolved oxygen levels do not meet the state standard from April through October most years. The low dissolved oxygen levels are due to high water temperature, low stream flow, and the abundant algal growth in the creek that is stimulated by nutrients in runoff. High water temperature is a result of lack of shade and low flows. Historically, Amazon Creek was more of a marsh than a creek so it is difficult to know how warm stream temperatures were in the summer before it was changed to its current configuration in the 1950s. Given its marsh-like characteristics, a greater proportion of the creek's flow would have been sub-surface, keeping the water cooler until it either surfaced downstream or entered aquifers below. Surface water that did flow during the summer was probably divided into several small channels that were shaded by the dense wetland grasses that grew in the creek.

45% of *E. coli* samples do not meet the single-sample standard and 100% do not meet the 5-sample average standard. There are multiple sources of *E. coli* in an urban environment, including fecal matter from pet waste, ducks and geese, nutria, and failing sewer lines. In the recent past there were also problems with livestock waste from the County Fairgrounds reaching the creek. A recent multimillion dollar storm-drain renovation may have solved this problem because surface runoff from livestock areas is now sent to the City's wastewater treatment plant.

Amazon Creek is moderately impaired for nitrate and turbidity and impaired for phosphorus. The main sources of nutrients in this sub-watershed are likely to be fertilizers used for landscaping, fecal matter from a variety of sources, and sediment that washes into the stream from construction sites, driveways, and eroding stream banks.

Fern Ridge (25% agriculture, 25% other, 20% forestry, 20% rural residential, 5% urban, 5% parks)
The Fern Ridge sub-watershed is comprised of the reservoir and several small tributaries that drain directly into it. The reservoir's major tributaries (Coyote Creek, the upper Long Tom River, and Amazon Creek) and the shallow nature of the lake determine its water quality. Turbidity levels at the spillway (LL3) and the next downstream site on the lower Long Tom (LL2) are the highest in the watershed. This is because the reservoir is shallow and its muddy bottom gets stirred up by wind-generated waves. Turbidity levels are highest at the spillway during the reservoir's draw down period from the beginning of October to mid-November and during heavy winter rain events. Because most phosphorus in river and lake water is bound to sediment, moderately high total phosphorus levels at LL3 and LL2 are not surprising. The high phosphorus levels coming from Amazon Creek and Coyote Creek are also a contributing factor. The reservoir is moderately impaired for dissolved oxygen and impaired for water temperature. This is expected because the reservoir is shallow and unshaded.

Bear Creek (57% forestry, 33% agriculture, 10% rural residential)
The Bear Creek sub-watershed is impaired for water temperature and *E. coli* and moderately impaired for dissolved oxygen and phosphorus. Nitrates, turbidity, and pH do not appear to be a problem. In the summer, high water temperature and low dissolved oxygen levels are problems along many of the streams in the middle and lower portion of the sub-watershed. Much of the stream length in Bear Creek is low gradient with an abundance of instream wetlands. In the summer, these riverine wetlands allow the water to heat up more than a shaded, fast moving stream would. Another reason for high water temperature and low dissolved oxygen is lack of sufficient shade along many sections of stream. Finally, water withdrawals during the summer decrease stream flow causing streams to heat up more quickly.

E. coli and phosphorus show impairment at the downstream location in Bear Creek (BC1), but not at the upstream site (BC2). This suggests the sources are human in origin. There are many rural residences in this sub-watershed, which raises the possibility that malfunctioning septic systems could be contributing both bacteria and phosphorus. There are also many livestock that are not fenced or otherwise kept away from streams and some pastures are overgrazed and compacted, which leads to manure left on the pasture not having sufficient time to break down and become incorporated into the soil matrix. When winter floodwater washes over the floodplain this uncomposted manure washes into the stream. This scenario is common across the watershed where flood prone valley lowlands are used for livestock grazing. Agricultural activities in the sub-watershed (Christmas tree production, vineyards, other) may be contributing to the relatively high phosphorus levels in the creek.

Ferguson Creek (59% forestry, 40% agriculture, 1% rural residential)
Like Bear Creek, water temperature and *E. coli* show significant impairment along the middle and lower segments of Ferguson Creek and its tributaries. Dissolved oxygen, phosphorus, and nitrates

show moderate impairment along the middle and lower segments. Turbidity and pH do not appear to be a problem. The reasons for high summertime water temperature and low dissolved oxygen levels are similar to those for Bear Creek. Wetlands along South Fork Ferguson Creek and other tributaries allow water to heat up in the summer and there is much less shade along creeks in the sub-watershed than there was historically. Summertime water withdrawals also contribute to stream heating.

The results for water temperature, dissolved oxygen, *E. coli*, phosphorus, and nitrates at the lower monitoring site on Ferguson Creek at Territorial Highway (FC1) vary significantly from those at the upstream site on Ferguson Creek Road (FC2). Land use between FC2 and FC1 includes grazing of cattle and sheep, rural residences, and agriculture (vineyards, Christmas trees, annual rye, and mint). In contrast, land use upstream of FC2 is entirely forestry with the exception of one residence. Temperature is the only parameter that shows moderate impairment at FC2, with an average of 13 days during the summer that do not meet the state standard. Thus, most of the factors affecting water temperature and other pollutants are occurring downstream where there are livestock, agriculture uses, and residences.

Lower Amazon Creek (62% agriculture, 21% urban, 11% other (airport, etc.), 6% rural residential)
The lower Amazon sub-watershed is predominately influenced by agriculture, and like upper Amazon Creek the channel has been significantly changed from pre-settlement times. Lower Amazon Creek receives approximately 10% of the flow from upper Amazon Creek with the remainder flowing into the Amazon Diversion Canal going into Fern Ridge Reservoir. Additional flow into lower Amazon comes from surface runoff and tile drains in agricultural fields. Results from LA1, at the lower end of the creek, show impairment for both nitrate and total phosphorus. 47% of nitrate samples and 89% of phosphorus samples did not meet the guideline. At UA1, which is located just upstream of the Amazon's diversion to Fern Ridge Reservoir, the results were 38% and 63%, respectively. Because most of the flow in lower Amazon Creek comes from upper Amazon Creek, a significant proportion of the nitrate and phosphorus in the lower creek probably comes from Eugene. However, water also enters lower Amazon Creek via surface runoff and tile drains. The original source of this water is either precipitation, withdrawal from lower Amazon Creek, or well water. Thus, it is difficult to determine the relative proportion of nitrates and phosphorus coming from upper Amazon Creek versus surface runoff and tile drains within the lower Amazon. What is clear is that nitrate and phosphorus concentrations increase between UA1 and LA1, which indicates that there is some level of nutrient input from the surrounding agricultural lands in the lower Amazon.

Dissolved oxygen levels are moderately impaired and temperature is impaired on lower Amazon Creek. Like upper Amazon Creek, the lower creek has low stream flow in the summer and there is little shade along the banks. These two factors are the biggest contributors to high water temperature and low dissolved oxygen levels in the summer.

E. coli levels are moderately impaired on lower Amazon Creek. Given that the percentage of samples not meeting state standards at LA1 is 18% compared to 45% at UA1 it is likely that upper Amazon Creek water is a significant contributor to the bacteria in the lower creek. It is also possible that bacteria from fecal matter are entering the creek from grazing livestock, migrating waterfowl, and leaking septic systems. Of the three, migrating waterfowl and grazing livestock are the likeliest contributors given the few residences within this sub-watershed.

Lower Long Tom (81% agriculture, 8% rural residential, 7% forestry, 2% parks, 1% urban)
The lower Long Tom starts at the spillway of Fern Ridge Reservoir and joins the Willamette 25 river-miles downstream. Most of the land adjacent to the river is in agricultural production and because of the stored water provided by Fern Ridge Reservoir many of the crops are irrigated during the summer. Bear Creek, Ferguson Creek, and lower Amazon Creek are the three major tributaries along the lower Long Tom. Their influence on the Long Tom's water quality is reflected in the results for LL1, whereas the water coming out of Fern Ridge Reservoir largely determines water quality at LL2.

Water temperatures in the lower Long Tom River did not meet the state standard between 91 and 131 of the days that were monitored during the summers of 2000, 2001, and 2002. This is probably an underestimate of the actual number of days not meeting the state standard because temperature probes on the lower Long Tom generally must be removed before the reservoir draw down in October when water temperature is still warm. Correspondingly, dissolved oxygen levels are moderately impaired on the lower Long Tom with 26% to 33% of samples not meeting the state standard.

E. coli levels on the lower Long Tom are moderately impaired at the Spillway, moderately impaired to good at LL2, and good at LL1. These results are somewhat surprising given the high bacteria concentrations entering the Long Tom from Ferguson and Bear Creek and are probably due to the higher flows of the Long Tom diluting the concentration of bacteria.

Phosphorus levels are moderately impaired at all sites on the lower Long Tom. In contrast, nitrate varies dramatically along the river. At LL3 and LL2 only 10% of samples did not meet the guideline, in contrast to LL1 where 56% of samples did not meet the guideline. This may indicate chronic sources of nitrate somewhere within the lower Long Tom Sub-watershed as well as reflecting the high to moderate levels coming lower Amazon, Ferguson, and Bear Creek.

Water Quality and Land Use

To understand how water quality correlates with land use and ecoregion in the watershed we evaluated water quality results for three types of sites (see **Table 3**). Type 1 sites have forestry as the predominant upstream land use and are within the Valley Foothills and Mid-coastal Sedimentary Ecoregions. Type 2 sites have mixed upstream land use (forestry, agriculture, rural residential) and are also within the Valley Foothills and Mid-coastal Sedimentary Ecoregions. Both of these ecoregions are within the foothills of the Coast Range. Near headwaters, stream channels are confined within steep, narrow valleys, becoming more sinuous downstream where the valleys widen. The underlying geology is mostly sedimentary rock with some igneous rock. The combination of soft sedimentary rock and relatively high precipitation rates in this region contributes to higher erosion rates. Native vegetation in this ecoregion includes western hemlock, western red cedar, Douglas fir, grand fir, big leaf maple, and red alder.

Type 3 sites have mixed upstream land use (forestry, agriculture, rural residential, & urban) and are within the Prairie Terraces Ecoregion. The Prairie Terraces Ecoregion covers most of the low gradient valley lands except for a small portion along the lower Long Tom River, which is part of the Willamette River and Tributaries Gallery Forest Ecoregion. Historically, streams in these regions meandered across the valley floor and larger streams were deeply entrenched in the thick sedimentary clay soils deposited by the Missoula floods thousands of years ago. Currently many streams have been channelized or re-routed in order to develop adjacent land and prevent flooding, which has resulted in streams with less sinuosity and narrower riparian areas. The native vegetation within the Prairie Terraces region includes white oak, ash, and a variety of shrubs, grasses, sedges, rushes, and forbs.

The box plots in **Figures 1 through 5** show the range of data for turbidity, dissolved oxygen, *E. coli*, nitrate, and total phosphorus for each site type from September 1999 through July 2003. The length of each box corresponds with the data that fall between the 25th and 75th percentile, which means that the box represents 50% of the data. Another way of explaining this is that 25% of measurements were less the value corresponding with the bottom of the box and 25% of the measurements were greater than the value corresponding with the top of the box. The lines extending from the top and bottom of each box show the maximum and minimum values measured for that parameter. For **Figures 1, 3, and 4** the maximum value for some or all site types is noted on the graph because the values were well above most of the data for that parameter.

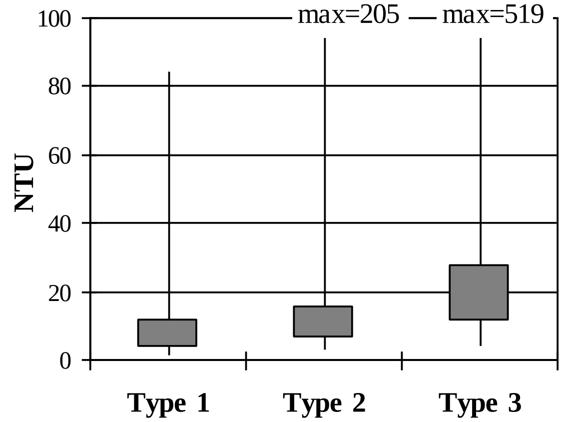

Figure 1. Range in Turbidity Levels for Type 1, 2, and 3 Sites

Figure 1 shows that the majority of turbidity data for all site types fell well below the guideline of 50 NTU. However, during the winter many sites had measurements above 50 NTU due to pulses of sediment washed into streams during intense rainy periods. Type 2 sites showed slightly higher average turbidity levels than Type 1 sites with the majority of measurements falling between 6 and 16 NTU. In contrast turbidity levels at Type 3 sites were significantly higher, with the majority of measurements falling between 11 and 28 NTU. The maximum level for type 2 and 3 sites was 205 and 519, respectively. These levels are significantly higher than the maximum level of 84 NTU for Type 1 sites. Despite the comparatively high levels found in the lower, more developed reaches of the watershed turbidity levels do not appear to be a significant problem when compared to the guideline of 50 NTU. It is possible however that this guideline is not stringent enough. If funding is available, the Council will collect macroinvertebrate data across the watershed beginning in 2004. These aquatic insects tend to be sensitive to sediment levels and may show different results regarding impairment of streams due to turbidity.

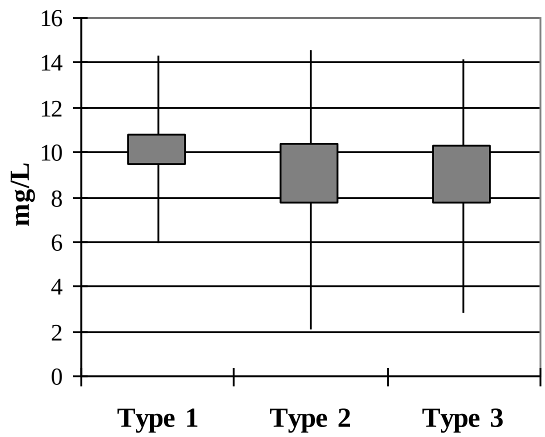

Figure 2. Range of Dissolved Oxygen Levels for Type 1, 2, and 3 Sites

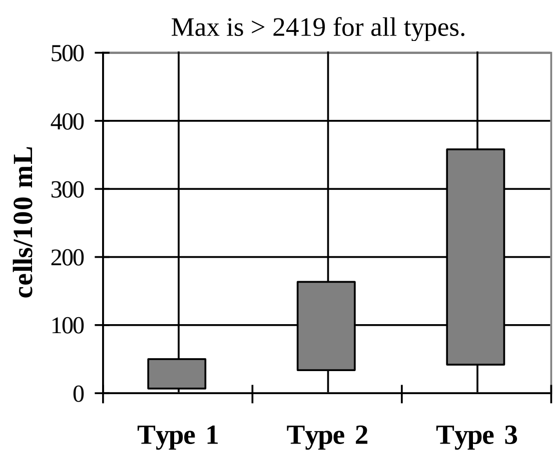

Figure 3. Range of *E. coli* Levels for Type 1, 2, and 3 Sites

Figure 2 shows the range of dissolved oxygen levels for each site type. Type 1 sites met the state standard most of the time, whereas Type 2 and 3 sites had a significantly greater percentage of measurements that fell below 8 mg/L. The lower reaches of the watershed tend to have less shade along rivers and streams, which leads to warmer stream temperatures in the summer and consequently less dissolved oxygen. Another reason for lower dissolved oxygen at Type 2 and 3 sites is greater biological oxygen demand. Typically, larger, lowland streams contain more organic matter such as dead leaves, insect and fish carcasses, and fecal matter. Up to a certain point this organic matter is an essential component of a river's food chain. However, if the amount of organic matter becomes too great, dissolved oxygen levels sink below the concentrations needed for trout and other aquatic life. This is the case during the summer at the sites on upper and lower Amazon Creek and may occasionally occur at other locations. Nutrients from fertilizers exacerbate this problem by fueling algal growth, which adds even more organic matter to the stream.

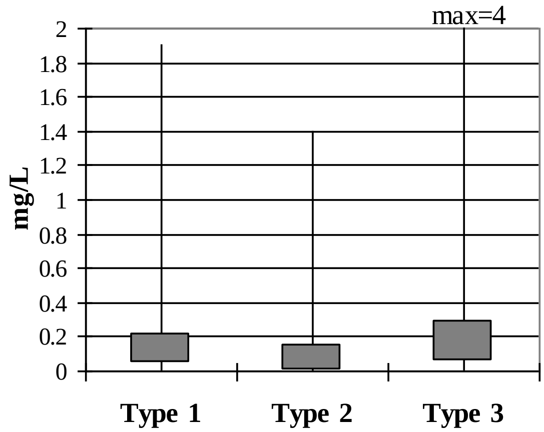

Figure 4. Range of Nitrate Levels for Type 1, 2, and 3 Sites

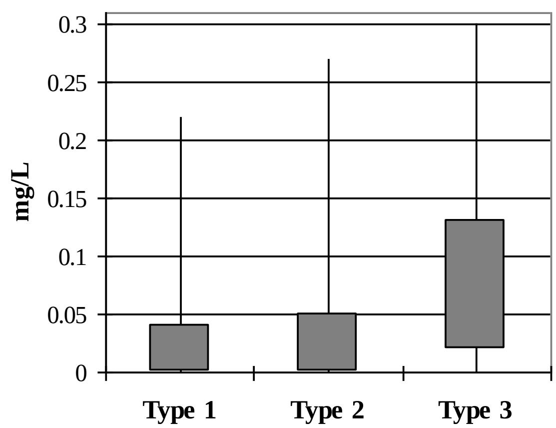

Figure 5. Range of Phosphorus Levels for Type 1, 2, and 3 Sites

Like turbidity, *E. coli* levels vary greatly over the course of a year and tend to be highest during winter months when fecal matter washes off of saturated fields or urban streets and sidewalks. **Figure 3** shows that all site types had maximum levels that did not meet state standards. However, the measurements that fell between the 25th and 75th percentile varied greatly between site types. In the upper reaches of the watershed, at Type 1 sites, bacteria levels were generally well below both state standards for *E. coli*. This range in bacteria levels is a reasonable estimate of the contribution from wild animals. Type 2 sites showed a wider and higher range of *E. coli* levels although they were still typically below both state standards. A majority of the measurements for Type 3 sites did not meet the 5-sample average standard of 126 cells/100 mL and many did not meet the single sample standard. The difference between bacteria levels at Type 1 and 3 sites illustrates the likely contribution of humans and livestock to bacteria levels in the lower watershed.

Nitrate and total phosphorus levels are relatively low at both Type 1 and 2 sites (**Figures 4 & 5**). The fact that Type 1 sites have higher nitrate levels than Type 2 can be attributed to the relatively high levels at EC2. Type 3 sites show the highest nitrate and phosphorus levels with maximum levels well above the recommended guidelines. These relatively high nutrient levels affect the stream system in a number of ways. High nitrate levels may create conditions of chronic toxicity for aquatic insects and amphibians. Both phosphorus and nitrogen are major plant nutrients that promote the growth of algae in streams. Too much algae can choke a stream, causing higher turbidity levels and low dissolved oxygen.

Conclusions

Water quality data collected over the past four years have served two important roles. First, this information has given us an understanding of what conditions are like for aquatic organisms in the watershed. We see that during the summer the mid and lower portions of the watershed have poor conditions for trout and other aquatic organisms due to high water temperatures and low dissolved oxygen levels. We know that high nutrient levels stimulate the growth of algae and may at times be toxic to aquatic organisms. In the winter, high turbidity levels in some areas may impair fish and aquatic insects by clogging their gills and interfering with feeding and spawning. This information, coupled with Watershed Assessment findings that indicate loss of ecological function along many miles of riparian zone, highlights a need to improve both water quality and the landscape-level conditions that supports good water quality and habitat.

The second role of this water quality information is to provide a basis for engaging in watershed enhancement and restoration at a sub-watershed level. Beginning in 2002, we shared results from the monitoring program with residents in the Ferguson and Elk Creek sub-watersheds. Out of these meetings five watershed enhancement projects were created. Many of these landowners were motivated by the water quality data from their sub-watershed. Each wanted to do their part in improving watershed conditions. Over time we will meet with residents in all ten sub-watersheds and hope to collaborate on many other projects to improve watershed health.

Although water quality data are an important component of understanding watershed conditions it is also essential to collect information on the biological and physical components of the watershed. A common method of assessing these components is to sample stream macroinvertebrates and the instream conditions surrounding the collection sites. In a recent proposal, the Council applied for funding to sample macroinvertebrates and collect stream habitat data at 100 sites around the watershed during a two-year period. This proposal also includes continued water quality monitoring (see **Appendix D** for new monitoring sites). If funded, this information would enhance our understanding of the combined effect of water quality and habitat conditions on aquatic organisms in the watershed.