Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load

Water Quality Improvement Report

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Water Quality Improvement Report

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Abstract

The Little Spokane River has been listed on the 303(d) list for fecal coliform, temperature, and turbidity. The federal Clean Water Act requires states to set priorities for cleaning up 303(d) listed waters by establishing a total maximum daily load (TMDL) for each.

This water quality improvement report includes TMDL analyses of how much fecal coliform, heat, and sediment loading the Little Spokane River and its tributaries can assimilate without violating Washington State water quality standards. Many of the TMDL findings are based on a 2004-2006 study conducted by the Washington Water Research Center, Washington State University, and the Spokane County Conservation District. Historical water quality and biological assessment data were also used.

This report also includes an implementation strategy with approaches to meet load limits by reducing point and nonpoint sources. The strategy emphasizes best management practices (BMPs) that target sources of high fecal coliform bacteria, temperature, and sediment. The BMPs and other alternatives discussed in the strategy should help reduce delivery of other pollutants on the 303(d) list in the Little Spokane River watershed.

Much of the strategy was taken from the *Little Spokane River Watershed Management Plan* and was a coordinated effort of the Spokane County Conservation District, Pend Oreille Conservation District, Washington State Department of Ecology, Washington Department of Fish and Wildlife, local landowners, and citizen groups.

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Executive Summary

Introduction

Sections of the Little Spokane River (LSR) and its tributaries do not meet Washington State water quality standards for fecal coliform bacteria, temperature, and turbidity. The Washington State Department of Ecology (Ecology) conducted a total maximum daily load (TMDL) evaluation to identify the sources of these pollution problems and recommend ways to reduce or remove them. The assessment drew from data and analyses contained in several past monitoring and watershed evaluation studies, including a comprehensive 2004-2006 monitoring study contracted by Ecology to Washington State University (WSU) and the Washington Water Research Center (WWRC).

In addition, this TMDL assessment coincides with the recently completed Spokane River/Lake Spokane dissolved oxygen TMDL and the Hangman Creek fecal coliform, temperature, and turbidity TMDLs. Future TMDLs in the Hangman Creek and LSR watersheds will address nutrient loading and their local and distant impacts on dissolved oxygen and pH problems. Completing this first set of LSR watershed TMDLs provides an area-wide approach to pollutant reduction needed for water quality concerns identified in the Spokane River basin. Actions completed in the TMDL Implementation Plan should reduce sources of bacteria, heat, and turbidity as well as sources of nutrients and other pollutants.

What is a total maximum daily load (TMDL)?

The federal Clean Water Act requires that a TMDL be developed for each of the water bodies on the 303(d) list. The 303(d) list is a list of water bodies, which the Clean Water Act requires states to prepare, that do not meet state water quality standards. The TMDL study identifies pollution problems in the watershed, and then specifies how much pollution needs to be reduced or eliminated to achieve clean water.

Then Ecology, with the assistance of local governments, agencies, and the community, develops a plan that describes actions to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities. This *water quality improvement report* contains the technical study that recommends the numeric goals to clean up the water bodies, and an *implementation strategy* that lays out roles and responsibilities for the cleanup process.

Watershed description

The LSR watershed consists of a 700-square-mile drainage area in northeast Washington State and 24 square miles in the state of Idaho (Figure ES-1). The LSR watershed is designated as Water Resource Inventory Area number 55 (WRIA 55). The LSR discharges into the head of Lake Spokane (Long Lake) at river mile (RM) 56.3, just downstream of Nine Mile Dam on the Spokane River.

The watershed can be naturally divided into four major sub-watersheds:

- Upper LSR above the confluence with the West Branch LSR including Chain Lake.
- West Branch of the LSR and its connections between Eloika, Horseshoe, Trout, and Sacheen Lakes through Moon Creek to Diamond Lake.
- Middle LSR with major tributaries Dragoon Creek, Deadman Creek, and Deer Creek from the confluence of the two branches to Dartford.
- Lower LSR below Dartford to the mouth at Lake Spokane (Long Lake).

The LSR watershed provides a recreational and scenic rural landscape consisting of forested ridges, small agricultural valleys, small urban centers, and abundant wildlife. However, historical resource extraction practices, development pressures, and insufficient land management have resulted in significant impacts to watershed water resources and water quality. Issues such as stormwater runoff, sedimentation, riparian vegetation losses, streambank erosion, wetland losses, and agricultural and forestry management are major concerns for the watershed. These concerns will remain as development pressure in the watershed increases.

The goal of the TMDL water quality improvement report (WQIR) is to identify the necessary improvements in water quality and riparian habitats so that the LSR watershed can support characteristic aquatic life and human recreational uses. Reducing solar heating, turbidity, and total suspended solids (TSS) pollutant sources will provide more functional habitat to native whitefish, rainbow trout, redband trout, and other aquatic species. Implementing water quality improvements recommended in the TMDL to reduce fecal coliform bacteria will also ensure safe swimming, fishing, and boating. In turn, water quality improvements in the LSR watershed will benefit the "downstream" water quality of Lake Spokane.

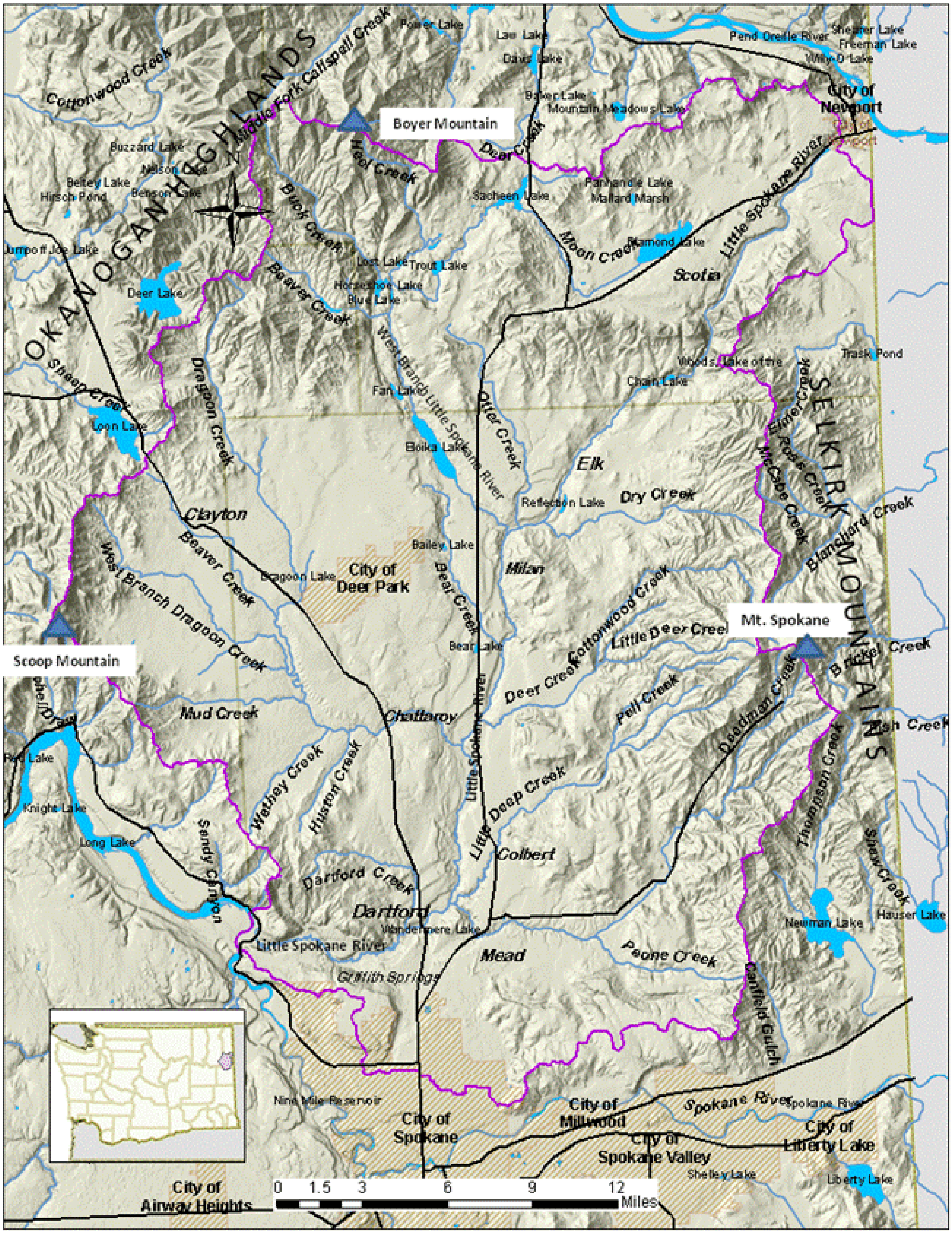

Figure ES-1. The Little Spokane River watershed in northeastern Washington State.

What needs to be done in this watershed?

Some sections of the LSR watershed exhibit fairly good water quality capable of supporting redband trout, mountain whitefish, and other native aquatic species, as well as primary contact recreation. Rural development and resource extraction in the sensitive headwater areas have moderated recently. Few point sources with direct surface water discharges are present. Large volumes of groundwater inflow into the lower ten miles of the LSR through deep canyons and wetland areas have kept urban development back from riparian areas, allowing water quality to recover.

Despite these positive factors, residents in the many other parts of the watershed need to (1) restore riparian vegetation and (2) implement best management practices (BMPs) to control nonpoint sources of fecal coliform bacteria, heat, turbidity, and TSS.

Fecal coliform bacteria

A total of 30 sites with fecal coliform data were evaluated. Sites were expected to meet *extraordinary primary contact recreation* criteria: a geometric mean less than 50 cfu/100 mL and not more than 10% of the samples exceeding 100 cfu/100 mL. The critical season for most sites was May through September. Based on the available data:

- Seven sites met water quality standards for *extraordinary primary contact recreation*:
  - Four on the West Branch LSR.
  - Three on the mainstem LSR: two sites above RM 23.1 and one site at RM 3.9.
- Non-compliance was usually based on failure of more than 10% of the samples to meet the 100 cfu/100 mL fecal coliform criterion.
- Sixteen sites failed to comply with both criteria.
- Tributaries to the Middle LSR sub-watershed with historical or active agriculture and rural residential uses will require the most BMP implementation work.
- Infiltration is the common practice for jurisdictions in the watershed with stormwater permits, so fecal coliform loads regulated by these permits are not considered significant. However, any bacteria loads from surface stormwater discharging directly to receiving waters in the watershed under Spokane County, city of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls through wasteload allocations (Table ES-4).
- Effluent from the Colbert Landfill and the Spokane Fish Hatchery are not expected to be significant sources of fecal coliform loading. Both outfalls are located in reaches that currently meet the designated beneficial use. Permit limits were recommended to ensure effluent fecal coliform counts from these two facilities (1) continue to be far below 50 cfu/100 mL and (2) do not increase downstream fecal coliform counts more than 2 cfu/100 mL (Table ES-4).

- The recommended fecal coliform bacteria load reductions, load allocations, reserve allocations, and load capacities for 30 sites in the Little Spokane River watershed are summarized in Table ES-1.

Table ES-1 . Recommended fecal coliform load reductions, load allocations, and average daily load capacity for sites in the Little Spokane River watershed.

Location	Fecal Coliform Reduction	Load Allocation* cfu/day x 10^{10}	Reserve Allocation** cfu/day x 10^{10}	Average Daily Load Capacity cfu/day x 10^{10}
LSR at Scotia Road	-	1.3	0.14	1.4
LSR at Elk	7%	3.4	0.38	3.8
LSR at Deer Park-Milan	-	3.9	0.43	4.3
LSR at Chattaroy	5%	7.2	0.80	8.0
LSR above Deadman Creek	60%	6.0	0.67	6.7
LSR at Painted Rock	-	32	3.6	36
LSR at mouth	20%	56	6.2	62
Moon Creek	28%	0.09	0.01	0.10
West Branch LSR below Sacheen Lake	-	0.11	0.01	0.12
Buck Creek	-	0.34	0.04	0.37
Beaver Creek	5%	0.10	0.01	0.11
West Branch LSR above Eloika Lake	-	0.30	0.03	0.33
West Branch LSR below Eloika Lake	-	0.52	0.06	0.58
Dry Creek	46%	0.59	0.07	0.66
Otter Creek	90%	0.03	0.003	0.03
Bear Creek	24%	0.13	0.01	0.14
Deer Creek	87%	0.31	0.03	0.34
Dragoon Creek at Oregon Road	94%	0.05	0.006	0.06
Dragoon Creek at Dahl Road	36%	0.29	0.03	0.32
Dragoon Creek at Crawford Road	95%	0.16	0.02	0.18
Dragoon Creek at Monroe	77%	0.36	0.04	0.40
West Branch Dragoon Creek	89%	0.31	0.04	0.35
Dragoon Creek at mouth	70%	2.0	0.2	2.2
Deadman Creek at Holcomb Road	85%	-	-	-
Deadman Creek at Heglar Road	70%	0.51	0.06	0.57
Peone Creek	71%	0.04	0.004	0.04
Deadman Creek above Little Deep Creek	56%	0.9	0.1	1.0
Little Deep Creek	95%	0.14	0.02	0.16
Deadman Creek at mouth	83%	1.0	0.1	1.1
Dartford Creek	63%	0.21	0.02	0.23

LSR: Little Spokane River
* Load allocation includes background and nonpoint sources of fecal coliform.
** Reserve allocation provided for anticipated growth in the watershed.

Temperature

Temperature criteria for all parts of the watershed are designated for *core summer salmonid habitat* protection: a 7-day average daily maximum (7-DADMax) temperature not to exceed 16 °C. Vegetation removed from riparian areas along large sections of the mainstem LSR cannot shade and cool the water during much of the late spring and summer to adequately protect cold water aquatic species. The presence of open wetlands and lakes also allow water temperatures to naturally rise in some sections of the watershed. Additional system-potential vegetative shade was calculated for the mainstem LSR (Figure ES-2; Appendix C, Table C-8).

Monitoring data and modeling of current and system-potential vegetative shade conditions provided the following results:

- Cool groundwater influx in the Lower LSR sub-watershed currently decreases maximum water temperatures, but not below the 7-DADMax criterion of 16 °C.
- Maximum mainstem LSR temperatures are currently located below Chain Lake and through the Middle LSR sub-watershed area (Figure ES-2).
- Few reaches of the LSR would meet the 16 ºC temperature criterion during high air temperature and low-flow summer critical conditions, even if system-potential shade were present.
- Under system-potential shade conditions, the average maximum temperatures along the mainstem LSR meet the 17.5 ºC criterion for salmon spawning, rearing, and migration as well as the 18 ºC criterion for redband trout.
- Most reaches with system-potential shade would meet the 16 ºC temperature criterion under average summer temperature and streamflow conditions.
- Tributaries require 11% to 61% increases in system-potential riparian shade (Table ES-2).
- Colbert Landfill and Washington Department of Fish and Wildlife (WDFW) Spokane Fish Hatchery effluents were cooler than the criterion and do not require additional cooling but should have permit limits (Table ES-4).
- Infiltration is the common practice for jurisdictions in the watershed with stormwater permits, so heat loads regulated by these permits are not considered significant. Excessive heat from any surface stormwater discharging directly to receiving waters in the watershed regulated under Spokane County, city of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls to prevent impairment of aquatic life (Table ES-4).

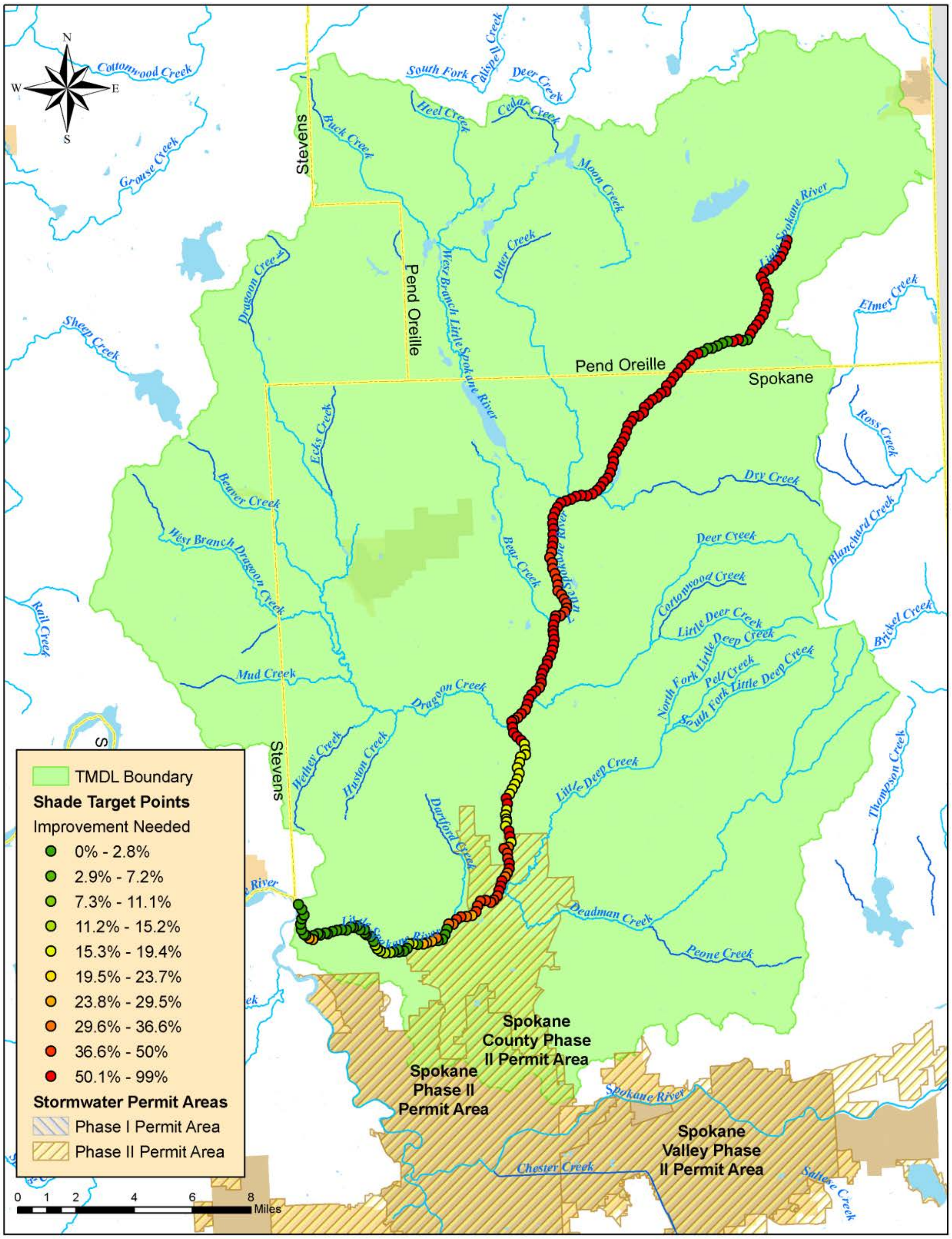

Figure ES-2. Additional system-potential shade needed from riparian vegetation along the mainstem Little Spokane River to meet temperature TMDL load allocation requirements.

Table ES-2. Average system-potential vegetation required as solar reduction) for eight tributaries to the Little Spokane River.

Tributary	Miles Evaluated	Recommended Additional Shade	Average Solar Heat Load Allocation (W/m^2/day)
Dry Creek	9.3	36%	17
Otter Creek	11.8	61%	17
West Branch LSR	18.6	11%	42
Bear Creek	6.2	19%	18
Deer Creek	15	39%	24
Dragoon Creek	25	55%	25
Deadman Creek	21	46%	39
Dartford Creek	6.8	40%	15

Turbidity

One 303(d) listing was identified along the LSR using the Washington State turbidity criterion of not more than 5 nephelometric turbidity units (NTUs) over background. However, according to published research studies, turbidity readings and TSS concentrations throughout the LSR watershed in early spring and early winter spawning periods are not protective for supporting healthy benthic macroinvertebrate, trout, and whitefish populations. Turbidity in the LSR watershed is caused by (1) TSS or sediment from streambank erosion or (2) sediment and solids runoff from riparian areas or uplands. TSS are used as surrogate loads for turbidity. Turbidity and TSS data were evaluated at 29 sites (Table ES-3).

Data analyses and modeling suggest:

- Based on limited data, Otter and Bear Creeks appear to require few sediment BMPs.
- Eighteen other sites required TSS load reductions from 25% to 95%.
- Colbert Landfill does not contribute turbidity and TSS loading, but permit limits are recommended (Table ES-4).
- WDFW Spokane Fish Hatchery has TSS effluent limits protective of LSR water quality (Table ES-4).
- Infiltration is the common practice for jurisdictions in the watershed with stormwater permits, so TSS loads regulated by these permits are not considered significant. Turbidity and TSS from any surface stormwater discharging directly to receiving waters in the watershed regulated under Spokane County, city of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls (Table ES-4)
- A 75% TSS reduction is necessary to limit the effects of TSS on fish and other aquatic life at the mouth of the LSR (Table ES-3).
- Severe TSS events would be reduced by 97%, and TSS loading to Lake Spokane would be reduced by an annual average of 15 tons/day, if recommended tributary and mainstem TSS targets were met.

Table ES-3. Required total suspended solids (TSS) load reductions, load capacities, and load allocations at sites evaluated in the Little Spokane River watershed.

Site Name	Required Reduction (%)	TSS Load Capacity (tons/day)	TSS Load Allocation[1] (tons/day)	Reserve Allocation[2] (tons/day)
LSR at Scotia	40	0.3	0.27	0.03
LSR at Elk	—	0.5	0.45	0.05
LSR at Deer Park-Milan Road	25	1.5	1.3	0.2
LSR at Chattaroy	40	2.6	2.3	0.3
LSR below Dragoon Creek	70	2.2	2.0	0.2
LSR above Deadman Creek	65	2.5	2.3	0.2
LSR at Rutter Parkway	65	5.1	4.6	0.5
LSR at the Mouth	75	4.9	4.4	0.5
Moon Creek above Sacheen Lake	—	0.04	0.04	0.004
West Branch below Sacheen Lake	—	0.08	0.07	0.008
Buck Creek	40	0.3	0.27	0.03
Beaver Creek	30	0.08	0.07	0.008
West Branch above Eloika Lake	—	0.66	0.60	0.07
West Branch below Eloika	—	0.62	0.56	0.06
Dry Creek	10	0.12	0.11	0.01
Otter Creek	—	0.03	0.03	0.003
Bear Creek	—	0.04	0.04	0.004
Deer Creek	80	0.2	0.18	0.02
Dragoon Creek above Deer Park	60	0.1	0.09	0.01
Dragoon Creek below Deer Park	65	0.1	0.09	0.01
West Branch Dragoon Creek	35	0.2	0.18	0.02
Dragoon Creek at Crescent Road	60	0.9	0.81	0.09
Deadman Creek at Holcomb*	40	-	-	-
Deadman Creek at Heglar	95	0.1	0.09	0.01
Peone Creek	40	0.04	0.04	0.004
Deadman Creek above Little Deep Creek	45	0.7	0.63	0.07
Little Deep Creek	80	0.1	0.09	0.01
Deadman Creek at Mouth	70	0.7	0.63	0.07
Dartford Creek	90	0.05	0.04	0.005

LSR: Lower Spokane River.

* Deadman Creek at Holcomb requires a 40% TSS reduction, but data were not available to calculate TSS loads.

[1] Load allocation include background and nonpoint sources of TSS.

[2] Reserve allocation provided for anticipated growth in the watershed.

The cumulative solids loading from the watershed affects aquatic life and human health in the LSR watershed and in Lake Spokane. Suspended sediments are transport mechanisms for nutrients and other pollutants. Stopping the sources of excessive TSS could also substantially reduce the delivery of phosphorus, polychlorinated biphenyls (PCBs), and other associated contaminants to Lake Spokane and the Columbia River.

Table ES-4. Wasteload allocations for NPDES dischargers in the Little Spokane River watershed.

Water Body Name	Permittee Name and ID	Permit Type	Parameter of Concern	Wasteload Allocation	Critical Period
Little Spokane River	Spokane County, City of Spokane, WSDOT	Municipal Stormwater**	Fecal Coliform	Maintain a geometric mean 50 cfu/ 100 mL and not more than 10% >100 cfu/100 mL in the receiving water	All year
			Temperature	(**See Note 1 below**)	May-Oct
			Turbidity and TSS	>80% removal of TSS	All year
	Colbert Landfill	Remediation	Fecal Coliform	<50 cfu/100 mL	All year
			Temperature	Set permit limits for 7-DADMax at <0.3 °C over background at edge of mixing zone	May-Oct
			Turbidity and TSS	<2 NTU or 3 mg/L TSS	All year
	Spokane Fish Hatchery	Upland Fin Fish	Fecal Coliform	<50 cfu/100 mL	All year
			Temperature	Set permit limits for 7-DADMax at <0.3 °C over background at edge of mixing zone	May-Oct
			Turbidity and TSS	5 mg/L TSS monthly average & <15 mg/L TSS at any time	All year
Deadman Creek, Little Deep Creek, and tributaries	Spokane County, City of Spokane, WSDOT	Municipal Stormwater**	Fecal Coliform	Maintain a geometric mean 50 cfu/ 100 mL & not more than 10% >100 cfu/100 mL in the receiving water	All year
			Temperature	**See Note 1 below**	May-Oct
			Turbidity and TSS	>80% removal of TSS	All year
	CDC Mead LLC	Industrial Stormwater and potential sanitary wastes	Fecal Coliform	*Extraordinary primary contact* at end of pipe and not > 2 cfu/100 mL increase downstream	All year
			Temperature	<0.3 °C over background	All year
			Turbidity and TSS	Monthly average 4 mg/L TSS & <5 NTU increase over background	All year
Dragoon Creek and tributaries	WSDOT	Municipal Stormwater**	Fecal Coliform	Maintain a geometric mean 50 cfu/ 100 mL & not more than 10% >100 cfu/100 mL in the receiving water	All year
			Temperature	See Note 1 below	May-Oct
			Turbidity and TSS	>80% removal of TSS	All year
Dartford Creek	Spokane County and WSDOT	Municipal Stormwater**	Fecal Coliform	Maintain a geometric mean 50 cfu/ 100 mL & not more than 10% >100 cfu/100 mL in the receiving water	All year
			Temperature	**See Note 1 below**	May-Oct

Water Body Name	Permittee Name and ID	Permit Type	Parameter of Concern	Wasteload Allocation	Critical Period
			Turbidity and TSS	>80% removal of TSS	All year
Basin-wide	Future development in Spokane County	Construction Stormwater	Fecal Coliform	Maintain a geometric mean 50 cfu/ 100 mL & not more than 10% >100 cfu/100 mL in receiving water	All year
			Temperature	See Note 1 below	May-Oct
			Turbidity and TSS	<5 NTU over background	All year
	Dairies*	State registration	Fecal Coliform	zero	All year
			Temperature	zero	All year
			Turbidity and TSS	zero	All year
	Sand and Gravel facilities*	Sand & Gravel	Fecal Coliform	zero	All year
			Temperature	zero	All year
			Turbidity and TSS	zero	All year

NPDES: National Pollutant Discharge Elimination System.
WSDOT: Washington State Department of Transportation.
*No direct discharge to surface waters allowed.
** For stormwater directly discharging to surface water and not treated by infiltration.
Note 1: Continue with permit-directed BMPs which infiltrate stormwater and prevent direct discharges to surface water. Where surface discharges are present, verify that volumes are <1% of receiving water volume from May through October, and temperatures do not exceed 7-DADMax criteria at a probability of once in 10 years.

Conclusions and recommendations

The Middle LSR sub-watershed from RM 10.1 at Dartford to RM 31.8 at Deer Park-Milan Road bridge exhibits the most effects of poor water quality. Although all portions of the LSR watershed need some restoration or protection, this section will require the most implementation actions to remove sources of bacteria, increase riparian shade, and reduce sources of TSS. Doing so will result in the greatest amount of pollutant reduction and habitat improvement in the shortest time.

Prevention and restoration actions will also be required along the mainstem LSR and in the major tributaries of Deadman Creek and Dragoon Creek, especially as the urbanizing influences of Spokane move north.

Further study of the West Branch LSR riverine sections is warranted to determine if designated uses are maintained and protected.

Implementation summary

The implementation strategy (1) describes the roles and authorities of cleanup partners and programs and (2) provides a strategy to achieve the water quality standards for fecal coliform bacteria, TSS, and temperature. Because of regional interest in reducing the Little Spokane's phosphorus contribution to the Spokane River, the implementation strategy also includes strategies to reduce nutrients. The development of this plan was a collaborative effort by a diverse group of interests in the watershed.

Implementation activities will generally involve the Spokane County Conservation District, Pend Oreille Conservation District, Washington State Department of Ecology (Ecology), Spokane County, Pend Oreille County, the city of Spokane, Washington Department of Transportation, Washington Department of Agriculture, and the Spokane and Tri-County Regional Health Districts. The implementation activities will also involve other agencies and groups such as the Pacific Northwest Direct Seed Association, Washington State University Extension, seed and fertilizer companies, local producer-based cooperatives, the Natural Resources Conservation Service, and the Farm Service Agency. To effectively reduce nonpoint source pollution, these agencies will need to seek cooperation with private landowners to implement BMPs designed to address the pollution issues.

After the U.S. Environmental Protection Agency (EPA) approves this TMDL, a water quality implementation plan (WQIP) must be developed within one year. Interested and responsible parties will work together to develop the WQIP. It will describe and prioritize specific actions planned to improve water quality and achieve water quality standards.

The three stormwater jurisdictions covered by stormwater permits were assigned wasteload allocations in this TMDL to ensure they do not contribute to water quality standards violations. These wasteload allocations will be implemented through their National Pollutant Discharge Elimination System (NPDES) permits. Ecology recognizes the difficulty of achieving some of the wasteload allocations established in this document and will work collaboratively with the dischargers to develop a comprehensive strategy to protect water quality.

A Little Spokane River Advisory Committee formed in early summer 2003. The committee identified 11 water quality nonpoint issues that were potential sources of the water quality problems in the watershed:

- Sediment/nutrients from agricultural operations.
- Sediment/fecal coliform from livestock and wildlife.
- Nutrients/chemicals from residential uses.
- Sediment/nutrients from agricultural field ditches.
- Nutrients/fecal coliform from improper functioning septic systems.
- Sediment from gravel and summer roads.
- Sediment from sheer or undercut banks.
- Sediment/fecal coliform from stormwater.
- Sediment from poor forestry management.
- Sediment from roadside ditching.
- Solar heating from lack of riparian shade.

To address the nonpoint sources, the advisory committee developed a list of BMPs to address each of the nonpoint source water quality issues identified. Stormwater is included because much of the watershed is not covered under a stormwater permit. Many of the BMPs address more than one of the water quality issues. For example, restoring riparian vegetation helps both stream cooling and reduces sediment delivery. To address the water quality parameters in this TMDL, pollution reductions will be accomplished through BMPs that:

- Reduce erosion.
- Reduce runoff carrying sediment.
- Reduce livestock impacts.
- Increase shading of streams.
- Inform and educate watershed residents about water quality issues.

Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this water quality improvement plan are met. There are many sources of funding and technical assistance to facilitate implementing this TMDL.

In developing the water quality implementation plan, Ecology and the Spokane County Conservation District, whose help in developing this plan has been invaluable and whose water quality goals for the watershed are closely aligned with Ecology's goals, will ensure the plan addresses the recommendations made in this report. They will work with local people to create this plan, choosing the combination of possible solutions they think will be most effective in their watershed. Elements of this plan include:

- Who will commit to do what.
- How to determine if the implementation plan works.
- What to do if the implementation does not occur or is not as effective as anticipated.
- Identify potential funding sources.

Why this matters

Water pollution can affect both people and aquatic life. This TMDL addresses fecal coliform bacteria, temperature, and turbidity:

- When we find *fecal coliform bacteria* in water, we know that human or animal waste is also in the water. Human and animal waste often contains many kinds of bacteria, viruses or other pathogens that can make people sick. Bacteria can get into our waters from untreated or partially treated discharges from wastewater treatment plants, improperly functioning septic systems, wildlife, and unknown sources.

- *Cool water temperatures* are vital to many native fish species. Without cool water species such as the redband trout, native to the LSR, will not survive.

- *Turbidity* is cloudy or muddy water that can irritate fish gills and reduce a fish's ability to find food. Turbidity is closely related to suspended sediment, which can carry harmful chemicals, such as pesticides or other toxics, into the water. When sediment settles to the bottom of a water body, it can alter and sometimes destroy essential habitats of fish as well as benthic macroinvertebrates.

What is a Total Maximum Daily Load (TMDL)

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. The Act requires each state to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.

The Water Quality Assessment and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet water quality standards. This list is called the Clean Water Act 303(d) List. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, the Washington State Department of Ecology (Ecology) compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

Category 1 – Meets standards for parameter(s) for which it has been tested.
Category 2 – Waters of concern.
Category 3 – Waters with no data or insufficient data available.
Category 4 – Polluted waters that do not require a TMDL because they:
- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website.

The Clean Water Act requires that a total maximum daily load (TMDL) be developed for each of the water bodies on the 303(d) list. A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. The TMDL study identifies pollution problems in the watershed, and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, with the assistance of local governments, tribes, agencies, and the community, then develops a strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy comprise the *water quality improvement report* (WQIR).

Once the U.S. Environmental Protection Agency (EPA) approves the WQIR, a *water quality implementation plan* (WQIP) is required to be completed within one year. The WQIP identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

Who should participate in this TMDL?

Nonpoint source pollutant load targets have been set in this TMDL and described in Figure 37, and Tables 38, 39 and 40. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have the potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices (BMPs) to reduce impacts to water quality. The area subject to the TMDL is shown in Figure 1, and the following groups will need to become involved in the nonpoint TMDL implementation activities:

- The Pend Oreille and Spokane County Conservation Districts are important participants for identifying and controlling many nonpoint sources.
- The Spokane County Water Resources Program is an important participant for organizing citizen advisory groups, coordinating studies, bringing larger Spokane River basin issues to light, and informing other county departments of water quality activities.
- The Little Spokane Watershed and West Branch Little Spokane Watershed Advisory Committees have been active players in the restoration and protection of water quality in the Little Spokane River watershed. They are necessary participants to make implementation possible among landowners in the watershed.
- The Washington Department of Fish and Wildlife should be active participants to monitor fisheries resources dependent on water quality actions in the watershed.

Similarly, all point source dischargers in the watershed must also comply with the TMDL and need to be participants. Spokane County, city of Spokane, and the Washington Department of Transportation will have monitoring and implementation responsibilities in this TMDL included in their future municipal stormwater permits. Permit reviewers and writers from Spokane County and Ecology's Eastern Regional Office need to be aware of construction and industrial stormwater permit requirements in the watershed.

Elements the Clean Water Act requires in a TMDL

Loading capacity, allocations, seasonal variation, margin of safety, and reserve capacity

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the standards.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from diffuse (non-point) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The TMDL must also consider *seasonal variations* and include a *margin of safety* that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A *reserve capacity* for future pollutant sources is sometimes included as well.

Therefore, a TMDL is the sum of the wasteload and load allocations, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

Surrogate measures

To provide more meaningful and measurable pollutant loading targets, this TMDL may also incorporate *surrogate measures* other than daily loads. EPA regulations [40 CFR 130.2(i)] allow other appropriate measures in a TMDL. See the Glossary (Appendix A) for more information.

Discussion of potential surrogate measures for use in this TMDL follows. The ultimate need for, and the selection of, a surrogate measure for use in setting allocations depends on how well the proposed surrogate measure matches the selected implementation strategy.

Fecal coliform (FC) bacteria

FC bacteria are the indicator organism used in Washington State to determine sanitary conditions of recreational waters. Bacteria counts are not reliably converted into loads. Therefore, Ecology evaluates the seasonal or monthly distribution of FC bacteria counts at individual sites to measure compliance with bacterial water quality standards. If the distributions do not match either the geometric mean or the 90^{th} percentile criteria, Ecology calculates the percentage of the bacterial distribution that must be reduced to meet the criteria. A target geometric mean or 90^{th}

percentile value is presented with the percentage reduction required to meet the targets. These are more meaningful surrogates than sets of bacteria loads.

For TMDL requirement purposes, *loads* of *coliform forming units per day (cfu/day)* are calculated by applying seasonal or monthly average streamflows to the current and target counts in the distribution. This method has been acceptable to EPA and stakeholders in past TMDLs.

Temperature

Water temperature responds to heat loads. The dominant source of heat energy to the LSR and its tributaries is solar radiation. The units of measure of solar heat energy used in TMDL analyses are watts per square meter (W/m^2) or langleys/day. The amount of solar radiation received by these water bodies can be modified by managing vegetation along the riparian zone. Therefore, topographic and riparian zone effective shade is used as a surrogate measure of the water bodies' exposure to solar radiation. The amount of system-potential effective shade required to meet instream water temperature criteria becomes the practical measure of TMDL compliance. Tables of heat flux of W/m^2 along the water bodies are generated to estimate solar exposure for loading capacities and load allocations.

Turbidity

Turbidity is a measure of light refraction and water clarity used to control the amount of suspended particles carried by a water body. Washington State turbidity criteria pose two problems for TMDL evaluations:

1. Water clarity cannot be expressed as a load, so turbidity must be correlated with a concentration of material to calculate a load [e.g., suspended solids and suspended sediment as milligrams per liter (mg/L) or as tons/acre].
2. Turbidity criteria are based on the difference in water clarity between a site and a background. Turbidity levels of the background water, defined as immediately upstream of the site, may not be protective of designated beneficial uses in the watershed (i.e., turbidities may be at intensities over durations harmful to aquatic communities).

Since the TMDL is required to meet the federal Clean Water Act, surrogate measures that prevent damage to the health of aquatic communities in the LSR watershed are used to address turbidity problems. Where enough data are present, severity scores are calculated to detect periods when deleterious effects of total suspended solids (TSS) concentrations on sensitive fish communities occur. Where fewer data are available, individual site TSS and turbidity values are (1) compared to ecoregional reference levels or (2) converted to ecoregional Water Quality Indices that take aquatic community effects into account. TSS load capacities and load allocations are used as surrogate measures to calculate any reductions needed to meet the turbidity TMDL goals.

Why Ecology Conducted a TMDL Study in this Watershed

Background

The LSR watershed is located in northeastern Washington. The LSR is a tributary to the Spokane River (Figure 1). Ecology is conducting TMDL studies in this watershed because several stream reaches in the watershed are not meeting water quality standards supporting *contact recreation* and *aquatic life* uses. Past studies reported water quality criteria violations, so that many water bodies in the LSR watershed are on the 1998 and 2008 303(d) list. FC bacteria, temperature, turbidity, pH, and dissolved oxygen listings, among others, require TMDL assessments to bring water quality back to standards.

Development over the past 150 years has changed the landscape and hydrology in the watershed. Recent population increases and insufficient land management has had significant impacts on the watershed water resources. Although the northern portion of the watershed is primarily rural, populations have increased nearly 72% since 1980 (U.S. Census, 2000). Population in the southern part of the watershed, which is more urban, has increased approximately 18% in the last 20 years. These trends are expected to continue.

The increase in watershed population places higher demands on the groundwaters and surface waters. Cumulative past and current land use and water resource activities within the watershed have impaired recreational contact and aquatic life uses. Issues such as stormwater runoff; new home construction and septic tank maintenance; increased sedimentation; streambank erosion; inappropriate urban development; wetland destruction; as well as poor agricultural and forestry practices are all major concerns for the area.

The LSR TMDLs coincide with the Spokane River and Hangman Creek TMDLs that are being developed. Phosphorus, biochemical oxygen demand (BOD), and ammonia TMDL load limits have been set at the mouth of the LSR by the Spokane River/Lake Spokane TMDL. Completing and implementing TMDLs in the LSR watershed provide an area-wide approach to reduce sediment-associated nutrients and BOD.

Because there are high concerns over water quality in the LSR watershed, a number of public and private organizations established programs for monitoring, protection, and restoration. This voluntary support for maintaining and improving water quality is vital to the success of the TMDLs. Information collected as part of the TMDL process could be useful to these restoration plans, and implementing the TMDLs could benefit the goals of the other processes.

The LSR TMDL evaluations are being divided into two separate efforts. This first effort includes the FC bacteria, temperature, and turbidity assessments. An assessment covering pH, dissolved oxygen, and nutrients will be completed at a future date. Monitoring data originally collected for the TMDLs were adequate for this first evaluation. Additional monitoring will be necessary to complete the second evaluation. The additional monitoring was completed in the summer of 2010 (Joy and Tarbutton, 2010).

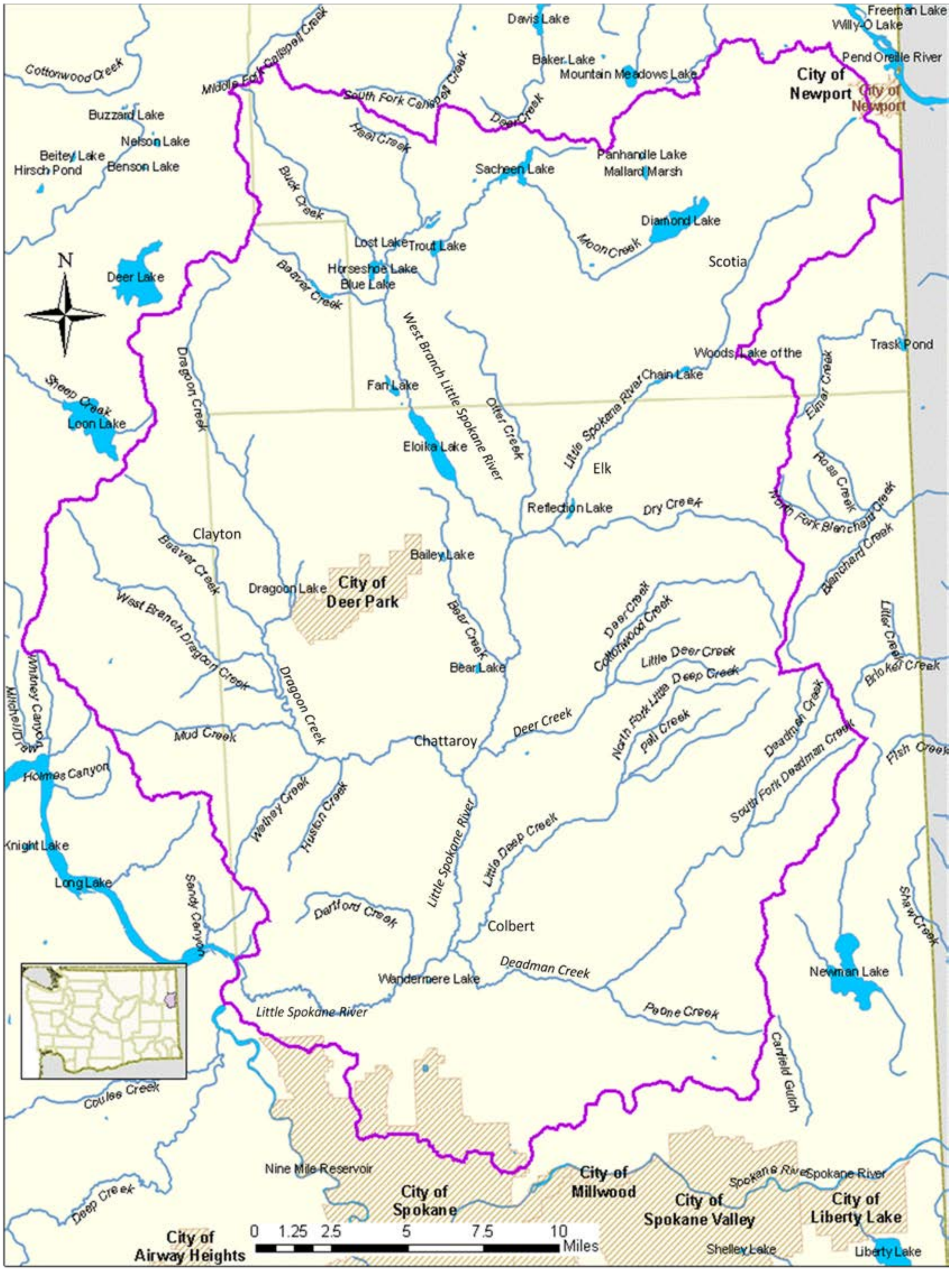

Figure 1. Map of the Little Spokane River watershed and vicinity in northeastern Washington.

Impairments addressed by this TMDL

The designated uses to be protected by this TMDL are contact recreation and aquatic biological communities. Water quality and biological monitoring data show that these uses are not fully supported in portions of the watershed (Table 1; Figure 2). FC bacteria levels are higher than allowed for swimming without fear of contracting illnesses. Temperature and turbidity levels are outside of the range that aquatic communities, especially salmonids, need to stay healthy.

Table 1. Study area water bodies on the 2008 303(d) list for fecal coliform (FC), temperature, and turbidity. *Details can be found in the 2008 Water Quality Assessment at http://www.ecy.wa.gov/programs/wq/303d/2008/index.html*

Water Body		Parameter	Listing ID	Township	Range	Section
Bear Creek		Temperature	48337	28N	43E	03
Beaver Creek		Temperature	48362	30N	43E	18
Buck Creek		Temperature	48364	30N	43E	06
Deadman Creek	at Mouth	FC	16854	27N	43E	33
	at Holcomb Rd.	FC	42539	27N	44E	23
	at Heglar Rd.	FC	46143	27N	44E	33
	at Heglar Rd.	Temperature	48361	27N	44E	33
Deer Creek		FC	16855	28N	43E	34
		Temperature	11365	28N	43E	34
Dragoon Creek	at Oregon Rd.	FC	8442	29N	42E	08
	at Mouth	FC	45514	28N	43E	33
	at Monroe Rd.	Temperature	48357	28N	42E	03
	at Dahl Rd.	Temperature	48358	29N	42E	34
West Branch Dragoon Creek		FC	46125	28N	42E	21
		Temperature	48383	28N	42E	21
Dry Creek		FC	45511	29N	44E	30
Otter Creek		FC	45512	29N	43E	12
Little Deep Creek		FC	45525	27N	43E	33
		Temperature	48360	27N	43E	33
Moon Creek		Temperature	48332	30N	44E	08
Peone Creek		Temperature	48314	26N	44E	08
Little Spokane River	at Mouth	FC	16861	26N	42E	05
	above Deadman Cr.	FC	46144	27N	43E	33
	at Rutter Parkway	Temperature	48384	26N	42E	03
	above Deadman Cr.	Temperature	48385	27N	43E	33
	above Dartford Cr.	Turbidity	15924	26N	43E	06
West Branch Little Spokane	below Eloika	Temperature	48334	29N	43E	15
	above Eloika	Temperature	48335	30N	43E	32
	below Sacheen	Temperature	48336	31N	43E	34

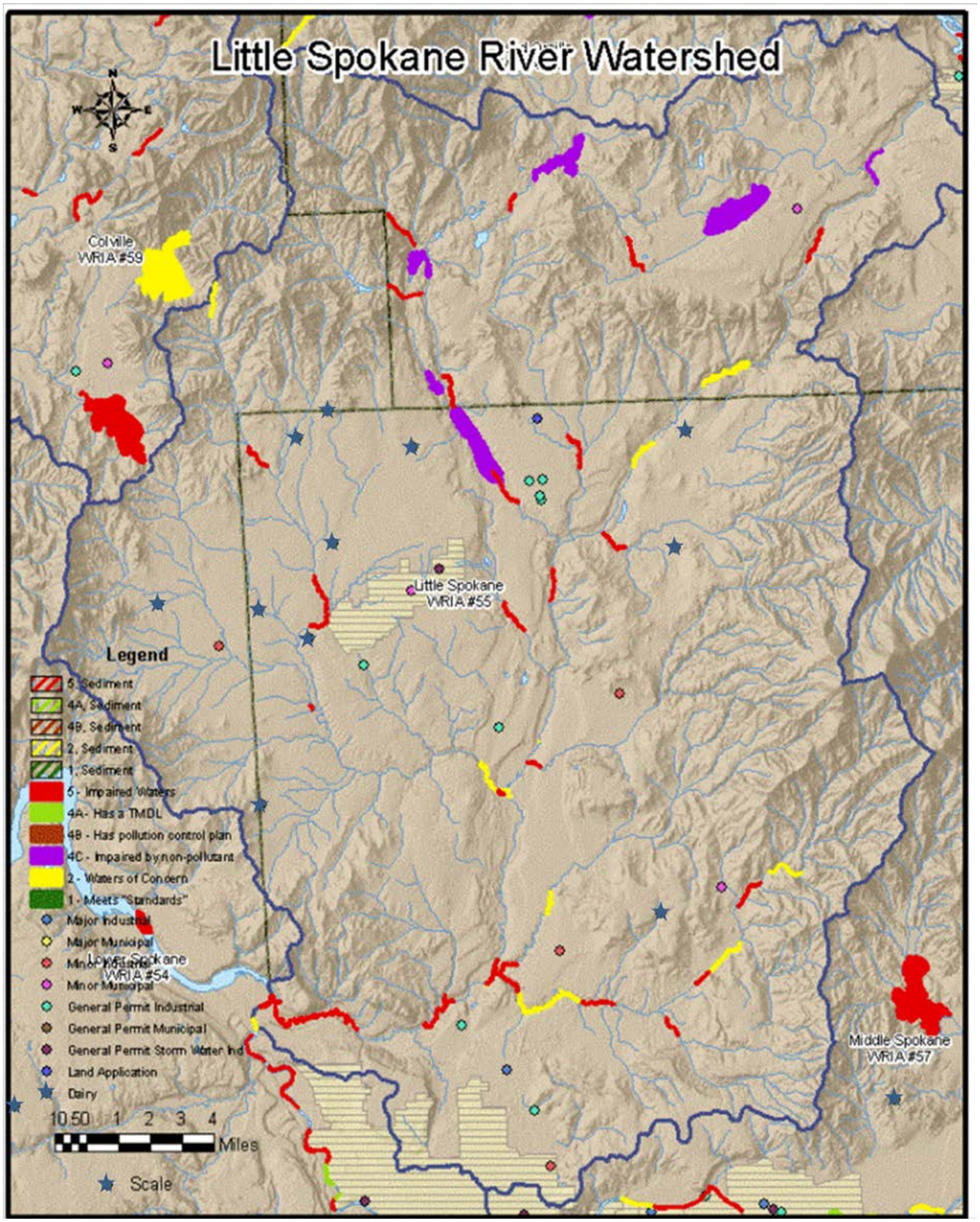

Figure 2. **Wastewater discharge permit locations, water quality assessment classification of streams and river segments, and lakes in the Little Spokane River watershed.**

WRIA: Water Resource Inventory Area.

This watershed has other water quality issues that will not be addressed in this TMDL. The 303(d) listings for PCBs, pH, and dissolved oxygen are not addressed in this report (Table 2). Other reaches of streams in the LSR watershed were not on the 303(d) list but were assessed with loading capacities and given allocations for FC bacteria, temperature, and turbidity (Table 3).

Table 2. Additional 303(d) listings not addressed by this report.

Water Body	Parameter	Medium	Listing ID	Township	Range	Section
Little Spokane River	Dissolved Oxygen	Water	42597	26N	42E	05
	Dissolved Oxygen	Water	47875*	30N	45E	08
	pH	Water	50434	27N	43E	33
	pH	Water	50436	29N	43E	35
	PCB	Tissue	9051	26N	42E	04
Dartford Creek	pH	Water	50416	26N	43E	06
Deadman Creek	Dissolved Oxygen	Water	41981	26N	43E	01
	pH	Water	50410	26N	43E	01
	pH	Water	50411	27N	44E	33
	pH	Water	11388	27N	43E	33
Little Deep Creek	pH	Water	50401	27N	43E	33
Peone Creek	Dissolved Oxygen	Water	47055	26N	44E	08
Dragoon Creek	Dissolved Oxygen	Water	47094	29N	42E	34
	pH	Water	50397	28N	43E	33
Unnamed Spring at Kaiser	Dissolved Oxygen	Water	42359	26N	43E	03
Dry Creek	pH	Water	50373	29N	44E	30
West Branch LSR	pH	Water	50379	29N	43E	15
	Dissolved Oxygen	Water	47073	29N	43E	15
	Dissolved Oxygen	Water	47862	30N	43E	32
	Dissolved Oxygen	Water	47863	31N	43E	34
Beaver Creek	Dissolved Oxygen	Water	47869	30N	43E	18
Buck Creek	Dissolved Oxygen	Water	47872	30N	43E	06
Moon Creek	Dissolved Oxygen	Water	47861	30N	44E	08

Table 3. **Unlisted water bodies addressed by this report.**

Water Body		Parameter	Township	Range	Section
Deadman Creek	All main channel	Temperature	All main channel		
	Above Little Deep Creek	Turbidity + FC	27N	43E	33
	At Holcomb Road	Turbidity	27N	44E	23
	At Heglar Road	Turbidity	27N	44E	33
	At Mouth	Turbidity	27N	43E	33
Dragoon Creek	At Dahl Road	Turbidity + FC	29N	42E	34
	At Monroe & Crawford Rds	Turbidity + FC	28N	42E	03
	At Mouth (Crescent Rd)	Turbidity	28N	43E	33
	All main channel	Temperature	All main channel		
Little Spokane River	Scotia to mouth	Temperature	All mainstem		
	Scotia	Turbidity + FC	30N	45E	08
	Elk	Turbidity + FC	29N	44E	08
	Deer Pk.-Milan	Turbidity + FC	29N	43E	35
	Chattaroy	Turbidity + FC	28N	43E	34
	Below Dragoon Creek	Turbidity + FC	27N	43E	04
	Above Deadman Creek	Turbidity	27N	43E	33
	At Rutter Pkwy	Turbidity + FC	26N	42E	03
	At Mouth	Turbidity	27N	42E	05
Peone Creek		Turbidity + FC	26N	44E	08
Little Deep Creek		Turbidity	27N	43E	33
Deer Creek		Turbidity	28N	43E	34
West Branch Dragoon Creek		Turbidity	28N	42E	21
Bear Creek		Turbidity + FC	28N	43E	03
Buck Creek		Turbidity + FC	30N	43E	06
Beaver Creek		Turbidity + FC	30N	43E	18
Dry Creek		Temperature	All main channel		
		Turbidity	29N	44E	30
Otter Creek		Temperature	All main channel		
		Turbidity	29N	43E	12
West Branch LSR	All non-lake areas	Temperature	All non-lake areas		
	Below Eloika Lake	Turbidity + FC	29N	43E	15
	Above Eloika Lake	Turbidity + FC	30N	43E	32
	Below Sacheen Lake	Turbidity + FC	31N	43E	34
Dartford Creek		Temperature	All main channel		
		Turbidity + FC	26N	43E	06
Moon Creek		Turbidity + FC	30N	44E	08

FC: fecal coliform bacteria.

Water Quality Standards and Numeric Targets

The Washington State Water Quality Standards are published pursuant to Chapter 90.48 of the Revised Code of Washington (RCW). The Washington State Department of Ecology (Ecology) has the authority to adopt rules, regulations, and standards necessary to protect the environment. The EPA Regional Administrator under Section 303(c) (3) of the federal Clean Water Act approves the state water quality standards adopted by Ecology. By adopting these standards, Washington lists characteristic uses to be protected and the criteria used to protect them (WAC 173-201A).

Under the 1997 version of WAC 173-201A, the LSR and its tributaries were classified as Class A water bodies as they had been since the 1970s. Ecology's Water Quality Assessments since the 1980s had been based on the Class A criteria. Acceptable and unacceptable water quality conditions in the LSR watershed were rated and categorized using these criteria, including 303(d) listings in 1998 through 2004 that require TMDL actions.

Since 2002, the water quality standards have included specific designated uses, replacing the old general classification system. In 2009, an Ecology Water Quality Program review found that a more restrictive set of criteria are required for the LSR because it discharges directly into Lake Spokane (O'Connor, 2009). Lake Spokane has *core summer salmonid* and *extraordinary primary contact recreation* uses. The designated beneficial use characteristics of these waters are:

- **Aquatic life** uses: "…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."
- **Water contact recreational** uses: "Extraordinary primary contact recreation provides extraordinary protection against waterborne disease…"

Under the proper interpretation of Chapter 173-201A-600(1)(a), the LSR and its tributaries now have *core summer salmonid habitat* and *extraordinary primary contact recreation* uses as well because by definitions:

(ii) All lakes and all feeder streams to lakes (reservoirs with a mean detention time greater than fifteen days are to be treated as lakes for this designation).

(iii) All surface waters that are tributaries to waters designated *core summer salmonid* or *extraordinary primary contact recreation.*

Table 4 summarizes the criteria for these uses. FC bacteria, temperature, and dissolved oxygen criteria are more restrictive under this new classification than under the previous Class A category. This TMDL must address water quality in terms of the new temperature and bacteria criteria, even if the listing was based on the older criteria. In addition, water quality data will be reviewed to ensure all stream reaches previously acceptable under the less stringent former criteria meet the new criteria.

Table 4. Criteria for the Little Spokane River and tributaries based on the most recent Washington State Water Quality Standards (Ecology, 2006).

Parameter	Criteria
Fecal coliform bacteria	Levels shall both not exceed a geometric mean value of 50 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
Temperature	Shall not exceed a 7-day average daily maximum temperature of 16 ºC due to human activities. When natural conditions exceed, or are within 0.3 ºC of the criterion, cumulative human-caused activities will not raise temperatures more than 0.3 ºC
Turbidity	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more than 50 NTU.
Dissolved oxygen	Shall exceed 9.5 mg/l. When natural conditions exceed, or are within 0.2 mg/L of the criterion, cumulative human-caused activities will not decrease the dissolved oxygen more than 0.2 mg/L
pH	Shall be within the range of 6.5 to 8.5 standard units with a human-caused variation within the range of less than 0.5 units.

Recreational uses

Recreational opportunities are somewhat limited along the mainstem LSR. One reason is the LSR has limited public access because of a court ruling in 1900 giving riparian landowners control of the stream bottom, the fishery within their property, and the right to place a fence across the stream. Public access is also limited through most of the Middle and Upper watershed. Although no officially designated swimming beaches (no lifeguards) are present, local citizens and visitors swim and boat along some reaches of the river and its tributaries. Riverside State Park, Little Spokane River Natural Area, Mt. Spokane State Park, and Pine River Park are among the few public areas providing opportunities for snorkeling, fishing, rafting, kayaking, and other aquatic activities (Figure 3).

Fecal coliform (FC) bacteria

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State, the water quality standards use FC as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). FC in water "indicates" the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The *Extraordinary Primary Contact* used in this TMDL is intended for waters capable of "providing extraordinary protection against waterborne disease …". More to the point, however, the use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant *primary contact* protection.

Figure 3. Primary contact recreation at Pine River Park on the Little Spokane River.

Aquatic life uses

McLellan (2005) of the Washington Department of Fish and Wildlife (WDFW) provided the following summary of the pre-settlement fish populations:

"When the first Europeans arrived in the region, the fish communities of the Spokane and Little Spokane River systems were comprised of chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), steelhead (*O. mykiss*), resident trout (*O.* spp.), whitefish (*Prosopium* spp.), and suckers (*Catostomus* spp.) (Scholz et al., 1985). There was reportedly a small run of sockeye salmon (*O. nerka*) that migrated up the Little Spokane River to Chain Lake (WDFW Region 1 lake management file, 1956). Prior to the construction of Little Falls Dam in 1911, the fish resources in the Spokane River system provided a subsistence fishery for local Native American tribes and a nationally recognized sport fishery for the early white settlers (Scholz et al., 1985)."

The surviving native species most sensitive to water quantity and quality are redband and rainbow trout and mountain whitefish. The distribution of important redband trout populations are shown in Figure 4. Based on the WDFW 2001 and 2002 surveys mountain whitefish, another salmonid species, are currently present in Bear Creek, Dry Creek, LSR, Otter Creek, West Branch LSR, Wethey Creek, Horseshoe Lake, and Chain Lakes (McLellan, 2002, 2003, 2005). Instream flow studies related to these two species are being conducted as part of the watershed planning assessment work (Spokane County, 2008). The watershed website summary states:

"Redband are a subspecies of rainbow trout and are the native resident trout in the Spokane area. Rainbow trout found here are remnant steelhead which were residualized after being trapped behind one of the dams. Historically, when these rainbow trout behaved like steelhead (i.e., they were anadromous) they did not spawn with resident rainbow trout (i.e., redband trout). Now, residualized steelhead/coastal rainbow trout tend to spawn at the same time and in the same locations as redband trout…

On-going WDFW studies have identified additional fish species in the Little Spokane River system: eastern brook trout, bluegill, bridgelip sucker, grass pickerel, green sunfish, northern pikeminnow, largemouth bass, longnose and speckled dace, pumpkinseed, sculpin, sucker, tench, yellow bullhead, and yellow perch" (Spokane County, 2008).

Appendix F, Table F-1, lists the fish species and their general location in the LSR watershed during various studies. Another sensitive species of interest for the local recreational fishery is eastern brook trout.

Adult and juvenile redband and rainbow trout and mountain whitefish are more tolerant of elevated temperatures and lower dissolved oxygen concentrations than some other salmonid species. Adult and juvenile rainbow and redband trout can tolerate temperatures in the range of 21 - 26 ºC (Wydoski and Whitney, 2003). Mountain whitefish have been classified as a cold water native but intermediate in their sensitivity to degraded water quality conditions such as siltation, elevated temperatures, and low dissolved oxygen concentrations (Zaroban et al., 1999). They can be found at temperatures up to 21 ºC (Hillman, Miller, and Nishitani, 1999). Adults and juvenile of all three species can tolerate summer dissolved oxygen concentrations to 6.5 mg/L (Zaroban et al., 1999; MacCoy, 2006).

Redband and rainbow trout in the LSR watershed typically spawn in March and April, while mountain whitefish spawn from December through January. The trout eggs hatch in about 50 days, and the whitefish eggs hatch in 30 days. Emerging fry spend most of their time in lower velocity pools and side channels until they are large enough to withstand higher velocity riffles and thalweg areas (Golder Associates, 2003).

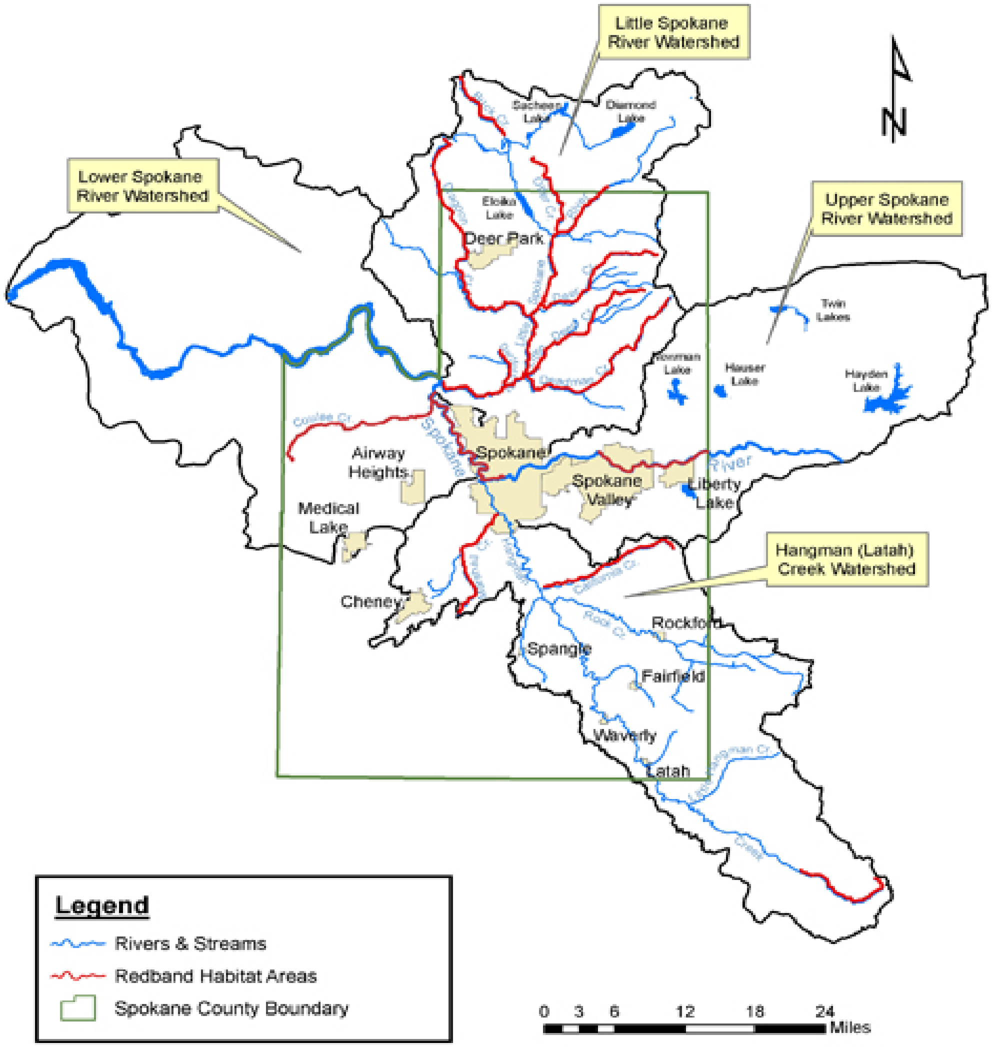

Figure 4. Distribution of redband trout habitat in the Little Spokane River and adjoining watersheds (Western Native Trout Initiative, 2010).

Ecology collected benthic macroinvertebrate samples at a few sites in 1994 and 2003. Canwell (2003) of Eastern Washington University (EWU) conducted a comprehensive study of 24 sites in the LSR watershed under an Ecology contract through the Spokane County Conservation District (SCCD, 2003). The benthic index of biological integrity (B-IBI) rated the 24 sites fair to poor in all sub-watersheds monitored (Table 5). In the same report (SCCD, 2003), Dr. Bruce Lang of EWU used historical data to show that Ephemeroptera, Plecoptera, and Trichoptera (EPT) counts at the LSR at Pine River Park had declined over three decades (Figure 5).

Table 5. Little Spokane River benthic invertebrate index of biological integrity (B-IBI) scores, sampled community statistics, and stream condition rating (SCCD, 2003).

Sub-watershed	Number of Sites	Mean B-IBI Score	Stream Condition	Mean Number of Taxa	Mean Number of EPT Taxa
Buck Creek	1	36.0	Fair	32.3	14.0
Otter Creek	1	31.5	Fair	26.6	9.6
Deer Creek	2	30.2	Fair	34.0	16.9
Deadman Creek	3	29.8	Fair	29.8	16.0
Little Deep Creek	2	29.2	Fair	32.0	18.8
East Branch LSR	2	27.8	Poor	30.5	17.5
Mainstem LSR	7	26.4	Poor	39.8	24.2
Dragoon Creek	3	25.5	Poor	29.4	17.4
West Branch LSR	3	22.5	Poor	32.1	16.5

B-IBI Score: Benthic index of biological integrity.
EPT: Ephemeroptera, Plecoptera, and Trichoptera.

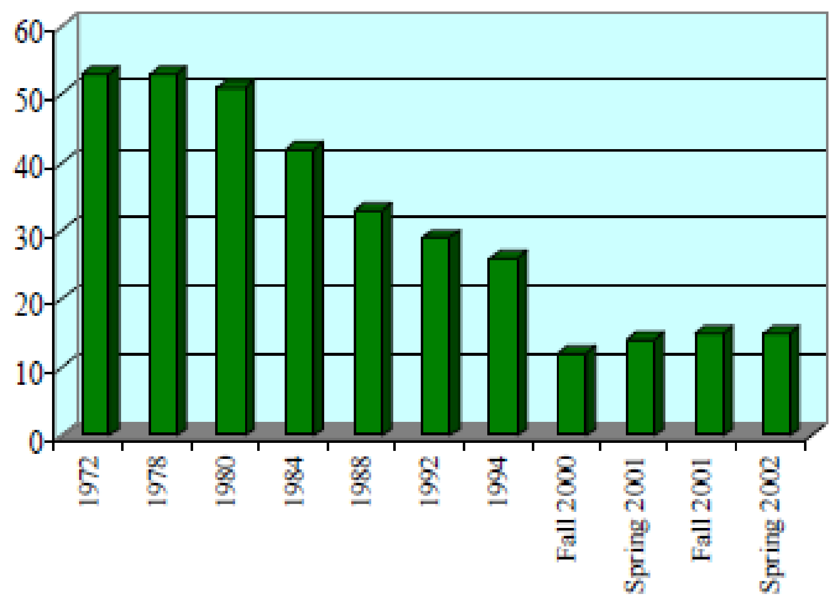

Figure 5. Ephemeroptera, Plecoptera, and Trichoptera (EPT) scores at the Little Spokane River at Pine River Park (from Figure 6 in SCCD, 2003).

Temperature and suspended sediment have been identified as limiting water quality factors for healthy aquatic communities in the LSR watershed (McLellan, 2005; Canwell, 2003).

Temperature

Water temperature affects the physiology and behavior of fish and other aquatic life. Temperature can be the most influential factor limiting the distribution and health of aquatic life, and it can be greatly influenced by human activities. Human management of water volumes, riparian vegetation, stream channel conditions, and wastewater disposal can affect instream temperatures that can eliminate certain species or encourage the presence of others.

Temperature levels fluctuate over the day and night in response to changes in climatic conditions and river flows. Since the health of aquatic species is tied predominantly to the pattern of maximum temperatures, the criteria are expressed as the highest 7-day average of the daily maximum temperatures (7-DADMax) occurring in a water body.

In the Washington State water quality standards, aquatic life use categories are described using key species (cold-water salmon versus warm-water species) and life-stage conditions (spawning versus rearing or migration) [WAC 173-201A-200; 2003 edition]. The following criterion applies to the LSR watershed:

"To protect the designated aquatic life uses of "*Core Summer Salmonid Habitat*," the highest 7-DADMax temperature must not exceed 16 °C (60.8 °F) more than once every ten years on average."

The state uses the criteria to ensure that where a water body is naturally capable of providing full support for its designated aquatic life uses, the condition will be maintained. The standards recognize, however, that not all waters are naturally capable of staying below the fully protective temperature criteria. When a water body is naturally warmer than the above-described criteria, the state provides an additional allowance for warming due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.3 °C (0.54 °F) increase above the naturally higher (inferior) temperature condition.

Whether or not the water body has a naturally high temperature is determined using a mathematical model. The model estimates the natural conditions under the "system thermal potential" or "system-potential" conditions. The modeling approximation done for this TMDL will estimate a natural condition based on system-potential effective shade after mature riparian vegetation is restored. The results are appropriate for determining the implementation of the temperature criteria.

In addition to the temperature criteria noted previously, compliance must also be assessed against criteria that limit the incremental amount of warming of otherwise cool waters due to human activities. When water is cooler than the 7-DADMax temperatures noted previously, the allowable rate of warming up to, but not exceeding, the numeric criteria from human actions is restricted to:

(A) Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/T+7 as measured at the edge of a mixing zone boundary (where "T" represents the background temperature as measured at a point or points unaffected by the discharge), and

(B) Incremental temperature increases resulting from the combined effect of all nonpoint source activities in the water body must not at any time exceed 2.8 °C (5.04 °F).

Special consideration is also required to protect spawning and incubation of salmonid species. Where Ecology determines the temperature criteria established for a water body would likely not result in protective spawning and incubation temperatures, the following criteria apply:

(A) Maximum 7-DADMax temperatures of 9 °C (48.2 °F) at the initiation of spawning and at fry emergence for char, and

(B) Maximum 7-DADMax temperatures of 13 °C (55.4 °F) at the initiation of spawning for salmon and at fry emergence for salmon and trout.

While the criteria generally applies throughout a water body, it is not intended to apply to discretely anomalous areas such as in shallow stagnant eddy pools where natural features unrelated to human influences are the cause of not meeting the criteria.

Global climate change

Changes in climate are expected to affect both water quantity and quality in the Pacific Northwest (Casola et al., 2005). Summer streamflows depend on the snowpack stored during the wet season. Studies of the region's hydrology indicate a declining tendency in snow water storage coupled with earlier spring snowmelt and earlier peak spring streamflows (Hamlet et al., 2005). Factors affecting these changes include climate influences at both annual and decadal scales, and air temperature increases. Increases in air temperatures result in more precipitation falling as rain rather than snow and earlier melting of the winter snowpack.

Ten climate change models were used to predict the average rate of climatic warming in the Pacific Northwest (Mote et al., 2005). The average warming rate is expected to be in the range of 0.1-0.6 °C (0.2-1.0 °F) per decade, with a best estimate of 0.3 °C (0.5 °F) (Mote et al., 2005). Eight of the ten models predicted proportionately higher summer temperatures, with three indicating summer temperature increases at least two times higher than winter increases. Summer streamflows are also predicted to decrease as a consequence of global climate change (Hamlet and Lettenmaier, 1999).

Site-specific predictions of climate change impacts in the LSR can be found at: www.hydro.washington.edu/2860/products/sites/?site=6030. Summer low flows are expected to decrease, air temperatures are expected to increase, and winter precipitation may increase. All these changes could increase the impacts of human activities and the pollutants covered by this TMDL.

The expected changes to our region's climate highlight the importance of protecting and restoring the mechanisms that help keep stream temperatures cool. Stream temperature improvements obtained by growing mature riparian vegetation corridors along streambanks, reducing channel widths, and enhancing summer baseflows may all help offset the changes expected from global climate change – keeping conditions from getting worse. It will take considerable time, however, to reverse those human actions that contribute to excess stream warming. The sooner such restoration actions begin, and the more complete they are, the more effective we will be in offsetting some of the detrimental effects on our stream resources.

These efforts may not cause streams to meet the numeric temperature criteria everywhere or in all years. However, they will maximize the extent and frequency of healthy temperature conditions, creating long-term and crucial benefits for fish and other aquatic species. As global climate change progresses, the thermal regime of the stream itself will change due to reduced summer streamflows and increased air temperatures.

Ecology is writing this TMDL to meet Washington State's water quality standards based on current and historic patterns of climate. Changes in stream temperature associated with global climate change may require further modifications to the human-source allocations at some time in the future. However, the best way to preserve our aquatic resources and to minimize future disturbance to human industry would be to begin now to protect as much of the thermal health of our streams as possible.

Turbidity

Turbidity is a measure of light refraction in the water, and one uses it to control the amount of sediment and TSS. TSS in the water column and sediment that has settled out on the bottom of the water body affect fish and other aquatic life.

The effects of TSS on fish and other aquatic life can be divided into four categories: (1) acting directly on the fish swimming in the water and either killing them or reducing their growth rate, resistance to disease, etc.; (2) preventing the successful development of fish eggs and larvae; (3) modifying natural movements, territorial behavior, and migrations; and (4) reducing the abundance of available food.

TSS may also serve to transmit attached chemical and biological contaminants to water bodies where they can be taken up in the tissue of fish. The health of humans or wildlife can be affected by eating the contaminated fish.

Turbid waters also interfere with the treatment and use of water as potable water supplies, and can interfere with the recreational use and aesthetic enjoyment of the water. For example, highly turbid waters can hide submerged rocks, logs, and other navigational hazards to boating. Highly turbid waters could also prevent lifeguards from locating a drowning swimmer. Settling of the solids creating the turbidity can eventually fill reservoirs and lakes.

Washington State established turbidity criteria in the state water quality standards primarily to protect aquatic life. These levels of turbidity are usually much lower than those interfering with water treatment or recreational uses. Two turbidity criteria are established to protect six categories of aquatic communities [WAC 173-201A-200; 2003 edition].

The following criteria apply to the LSR watershed:

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

In addition, suspended sediment (a component of TSS) in the LSR can be controlled under the "narrative criteria" description following. The water quality standards limit the effect of sediments or any other deleterious material on existing and designated aquatic life uses in the LSR watershed in the *Toxics and aesthetics criteria:*

"Toxic, radioactive, or deleterious material concentrations must be below those which have potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health…" [(WAC 173-201A-260 (1) (b)].

EPA (2000) suggested using ecoregional-based data to establish reference criteria. A healthy native aquatic community would be expected to be adapted to reference levels of water quality parameters, even as they changed with the seasons. For example, the criteria for turbidity could be based on the lowest 25th percentile of seasonal turbidities at sites in the Northern Rockies. The seasonal turbidities calculated using this procedure for 50 to 74 data collected at Northern Rockies sites throughout the western states prior to 2000 (EPA, 2000) were:

- Fall 0.60 Nephelometric turbidity unit (NTU)
- Spring 1.63 NTU
- Summer 0.90 NTU
- Winter 0.65 NTU

Ecology (Hallock, 2002) used this approach to develop an ecoregional Water Quality Index (WQI) for turbidity, TSS, and other parameters that do not have specific state water quality criteria. Separate high-flow and low-flow distributions of turbidity and TSS data collected from Washington State sites within the Northern Rockies ecoregion were set to quadratic equations.

Percentiles of the distributions were set to scores from 100 to 0 based on best professional judgment. WQI scores of 100 represent the best achievable TSS or turbidity using the lowest 10th percentile of data. WQI scores above 80 were equivalent to the lowest 20th percentile of turbidity and TSS values and considered capable of meeting water quality expectations. Scores below 40 represent the highest 5th percentile and should be of greatest concern for water quality managers (Hallock, 2002). The Northern Rockies WQI scores of 100, 80, and 40 are based on 250 to 339 samples collected during high- and low-flow periods. Table 6 shows the turbidity and TSS values equivalent to the above mentioned scores (Hallock, 2002).

Table 6. Turbidity and total suspended solids (TSS) values associated with Ecology's Water Quality Index (WQI) scores in the Northern Rockies ecoregion. *Turbidity values are in NTU units; TSS are in mg/L units. Taken from Appendix B of Hallock, 2002.*

	Samples	WQI 100	WQI 80	WQI 40
High-flow Turbidity	338	0.7	4.7	15.2
Low-flow Turbidity	250	0.7	2.1	6.2
High-flow TSS	339	1.0	8.0	26
Low-flow TSS	250	1.0	5.0	12

In another approach, Newcombe and Jensen (1996) developed formulae to describe the severity of impacts to various fish populations from the intensity and duration of exposure to suspended sediment. The severity score values and descriptions are shown in Table 7. The severity score for juvenile and adult salmonids, including trout, is calculated from the following formula:

$$\text{Severity score} = 1.0642 + 0.6068(\log_e \text{Hours of exposure}) + 0.7384(\log_e \text{TSS mg/L})$$

For example, an event with an average TSS concentration of 360 mg/L for nine days (216 hours) scores a 9, most likely resulting in lasting damage to a resident fish population. An event with an average TSS concentration of 16 mg/L for 108 days (5,760 hours) scores an 8, whereas if the same 16 mg/L lasted only two days, the event scores a 5. Both of these latter conditions are in the sub-lethal range, but trout populations exposed to two days of 16 mg/L TSS would probably recover and be in a healthy condition compared to a population exposed over a longer-term to the same concentration.

Table 7. Newcombe and Jensen (1996) scale of severity of ill effects to fish associated with excess turbidity or suspended sediment.

Severity Scale	Description of Effect
No Effect	
0	No behavioral effects
Behavioral Effects	
1	Alarm reaction
2	Abandonment of cover
3	Avoidance response
Sub-lethal Effects	
4	Short-term reduction in feeding rates or feeding success
5	Minor physiological stress; increased coughing, increased respiration rate
6	Moderate physiological stress
7	Moderate habitat degradation; impaired homing
8	Indications of major physiological stress; long-term
Lethal and Para-lethal Effects	
9	Reduced growth rate; delayed hatching; reduced fish density
10	0 – 20% mortality; increased predation; moderate to severe habitat degradation
11	>20 – 40% mortality
12	>40 – 60% mortality
13	>60 – 80% mortality
14	>80 – 100% mortality

Harmful exposure of mobile aquatic species to turbid water during fall and winter storms and spring runoff events is avoidable if the channel structure provides refuges. The most critical conditions for trout species and mountain whitefish in the LSR watershed occur in the spring and early winter, respectively, when adult spawning occurs and eggs are in the redds.

In comparing the Newcombe and Jensen (1996) severity scores below 4 to the Ecology WQI scores above 80 and the EPA reference values, the latter two do not assume any duration factor. Since the effects of turbidity and TSS are a function of both intensity and duration, it is difficult to know if the WQI is protective of aquatic life. However, in reviewing the research data used by Newcombe and Jensen (1996), TSS values of 5-8 mg/L appear to be below the threshold concentration for effects on salmonids in natural systems. In addition, TSS and turbidity events in the LSR watershed appear to be of shorter duration than those caused by irrigation returns or large expanses of agricultural lands. Further comparisons in the data analysis will show that the two methods appear to give similar levels of protection (see *TMDL Analysis – Turbidity and Total Suspended Solids*).

Watershed Description

Setting

The LSR basin consists of a 700-square-mile drainage area that includes regions located in north-central Spokane County, southern Pend Oreille County, and southeastern Stevens County in northeast Washington State, as well as Bonner County in the state of Idaho (Figure 6). The LSR is a tributary to Lake Spokane (Long Lake), an impoundment of the Spokane River. The Pend Oreille River basin lies to the northeast, and the Colville River basin lies to the northwest. The watershed has been designated as Water Resource Inventory Area 55 (WRIA 55).

The LSR watershed is a broad basin surrounded by the Okanogan bedrock highlands to the west and the Selkirk bedrock highlands to the east. Elevations range from 1,553 feet above sea level near the mouth of the watershed to 5,878 feet atop Mt. Spokane. The western edge of the basin is formed by Scoop Mountain west of Dragoon Creek at an elevation of 3,998 feet. To the north, the West Branch LSR tributaries form on Boyer Mountain at an elevation of 5,256 feet (Figure 6). According to EPA's ecoregional delineation, the entire watershed is considered to be part of the Northern Rockies ecoregion based on elements of geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (EPA, 2007).

Geological History

The oldest geologic history of this region for which we have some record in the rocks began more than two billion years before the present. The Belt Supergroup rocks are metasediments that were uplifted, folded, and faulted. These rocks are exposed in several places in the northern part of the LSR watershed, mostly in Pend Oreille County. Beneath the Belt rocks are even older crystalline basement rocks that were part of the edge of the continental land mass in what is now northeast Washington. These ancient rocks are exposed in a few locations in northeastern Spokane County and southeastern Pend Oreille County.

Approximately 100 million years ago, the molten rock material was intruded into and through the Belt series and then cooled and crystallized into a light-colored granitic rock known as granodiorite. That intrusive mass is now exposed in many of the local mountains including Mt. Spokane. The intrusive mass of granite is known as the Spokane Batholith or the Spokane dome.

About 17 million years ago, basalts began to erupt onto the surface of what is now the Columbia Basin. The basalt flows were extensive and prolonged with intermittent periods of calm between episodes of eruptions. We can see the remnants of some of these flows in the south part of the watershed today. The gray to black, sometimes columnar, basalts filled ancient valleys and lapped up the sides of exposed granitic rocks. These huge basalt flows ended about 5 to 6 million years ago. Two flow sequences reached the LSR valley in thicknesses up to 200 feet.

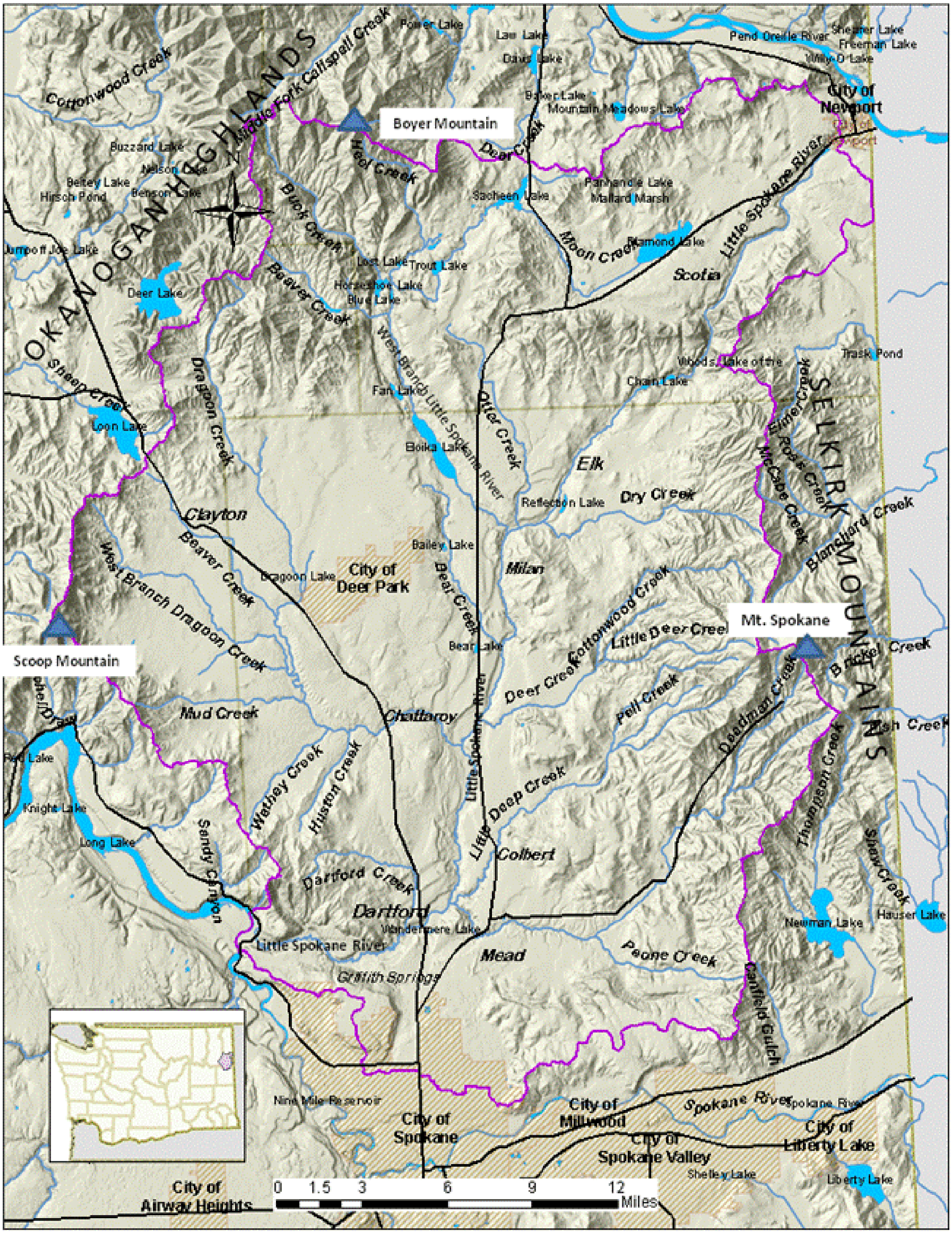

Figure 6. Geographic features of the Little Spokane River watershed.

The last ice advance for the LSR area reached its final peak about 18,000 years ago. This last major ice advance brought glacial ice south to near present day city of Newport. This advance of glacial ice also blocked the flow of the Columbia River, and Glacial Lake Spokane was created. The West Branch LSR and LSR were routes for meltwater during the intervening warming periods.

In addition, as the ice began its retreat, huge floods were caused by the repeated breakup of an ice dam across the Clark Fork River upstream a few miles from present day Lake Pend Oreille. These waters have been named Glacial Lake Missoula. Several times Glacial Lake Missoula filled with up to about 500 cubic miles of water. Periodically the dam would give way with a rushing flood of water, large chunks of ice, rocks, and other debris for hundreds of miles down the Spokane valley and across the Columbia Basin.

Eventually quiescent floodwaters dropped millions of tons of boulders, gravels, sands, silt, and clays. Following floodwaters reached the Newport area and flowed down the valley of the LSR. These floodwaters deepened and widened the stream valleys and deposited additional sediments of reworked glacial and flood debris. The deeper, coarser materials became a primary structure containing the Spokane-Rathdrum aquifer. Erodible glacial till and glacial lake sediments remained as soils on hillsides in the upper Deadman, Little Deep, Deer, and Dartford Creek sub-watersheds.

Settlement and historical land uses

The first human inhabitants of the LSR watershed were the Spokane, ancestors of the current day Spokane Tribe. They were a plateau people that shared numerous cultural traits with other Salish-speaking tribes. Due to the semi-nomadic life and relatively small population, it is unlikely these peoples had any significant negative impact on water quality in the LSR.

When the first Europeans arrived on the scene, population increased and new cultural values were employed, negatively affecting the quality of the river water. The first known European to explore the LSR watershed was David Thompson, an Englishman, born in 1770. During one of his forays into the LSR watershed, he probably crossed both the LSR and the West Branch of that river. Some of Thompson's documents and maps of the region were used by Lewis and Clark in their western explorations, and they in turn shared their findings with Thompson.

Wagon trails began to be established from several logging communities to the town of Spokane Falls, which was beginning to grow as the commercial center for the surrounding area. Many of the logging towns were established on the LSR or the West Branch, while Dragoon Creek became the focal point of Deer Park, Clayton, and Denison. Since most of the communities were built in the valleys of the streams, it was logical that the railroads would follow the same routes. The Great Northern main line, from the east to Spokane through the LSR valley, connected with Great Northern lines heading southwest and northwest through the towns of Scotia, Penrith, Camden, Elk, Milan, Chattaroy, Colbert, and Mead. These small logging communities with small sawmills supplied the railroads with trestle building materials and ties.

Tree harvesting was the major industry in the LSR watershed until the 1960s. For example, Deer Park was first settled in 1889, and a large lumber mill was the town's largest employer for 30 years. With the loss of easily accessible forests, the lumber mill closed in 1970. Some logging continues, and a few mills exist in the area.

As the timber was cleared, Deer Park and many of the logging towns became agricultural centers. In 1904, an apple grower established orchards in the Deer Park-Loon Lake area that became the largest privately owned orchard company in the world in 1920. Water conflicts between lake residents and orchard irrigation requirements forced the company to close in 1922. Grain and vegetable farming grew in the LSR and tributary valleys, along with dairy and poultry farming. Deer Park and other towns in the watershed support agriculture and serve as bedroom communities for the city of Spokane. Deer Park remains one of the larger communities within the watershed.

The town of Clayton was established in 1889 near an important clay deposit found in the northwest corner of the LSR watershed. This deposit was developed into one of the largest brick and tile manufacturers in the region at that time. Clayton was also home to a large saw mill. The depression of the 1930s and World War II had a severe impact on many of the small towns in the watershed area. Clayton remains the only town in the LSR watershed in Stevens County.

Climate and hydrology

The basin climate ranges from semiarid to sub-humid, with precipitation increasing northerly and easterly with altitude. In the lower part of the LSR valley, the precipitation is usually less than 20 inches per year, whereas in the higher northern and eastern parts of the basin, it gradually increases to 44 inches per year. Table 8 shows the precipitation information measured at weather reporting stations at Deer Park, Mt. Spokane summit, Newport, and the Spokane Weather Bureau at the Airport (WRCC, 2009). In addition to spatial variations, values in Table 8 indicate that there are considerable temporal variations in precipitation amounts. Air temperatures tend to be warmer in the summer and colder in winter from southwest to northeast (Table 9). A more complete description of the climate is presented in the Quality Assurance (QA) Project Plan (Cichosz et al., 2005).

Table 8. Average monthly precipitation (inches) for 1971-2000.

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Deer Park	2.67	1.76	2.00	1.91	1.86	1.70	1.00	1.10	0.97	1.19	2.95	3.64	22.76
Mt. Spokane Summit	5.34	3.69	6.09	3.35	3.56	3.12	1.68	2.07	2.94	2.71	3.80	5.67	44.01
Newport	3.05	2.62	2.24	1.93	2.26	1.99	1.36	1.16	1.12	1.79	3.54	3.89	26.95
Spokane Airport	1.81	1.57	1.52	1.31	1.53	1.22	0.75	0.69	0.73	1.13	2.25	2.20	16.70

Table 9. Average mean and maximum air temperature (in degrees F) at selected stations.

Station Name		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Deer Park 2E	Max	31.6	39.1	46.6	57.7	68.3	74.9	85.0	82.9	73.5	59.1	41.9	33.9
	Mean	23.8	30.1	36.0	44.7	53.7	60.0	66.7	64.9	56.6	45.2	34.3	27.1
Mt. Spokane	Max	23.1	27.6	30.3	38.2	49.0	57.4	66.5	66.0	56.4	43.1	32.5	26.4
	Mean	18.1	22.8	24.8	31.7	41.9	49.3	57.8	57.5	48.7	37.0	27.5	21.6
Newport	Max	31.6	38.6	48.4	59.5	69.2	75.8	85.2	84.4	73.9	58.4	40.8	33.2
	Mean	24.7	29.8	37.1	45.3	53.6	59.9	65.8	64.4	56.2	45.4	34.0	27.4
Spokane Airport	Max	32.9	39.1	48.2	58.3	67.1	74.3	83.9	82.7	72.5	59.3	43.0	34.8
	Mean	27.2	32.1	39.4	47.4	55.4	62.2	69.8	68.6	59.5	48.5	36.5	29.6

With high mountains on the north and the east of the LSR basin, there is a large amount of surface water available on an annual basin-wide basis (Figure 6). However, the temporal variations in precipitation previously discussed produce large fluctuations in monthly runoff volumes. Precipitation in the high mountains to the east, largely in the form of snowfall during the winter months, produces high spring runoff when it is combined with spring rainfall. The tributary streams, having steep slopes in the headwaters, rapidly empty the surface runoff and suffer low summer flows. Meltwater and precipitation falling in the northern area of the watershed are retained in several lakes and wetlands (Figure 6).

Surface water

The watershed can be naturally divided into the four major sub-watersheds:

- Upper LSR, East Branch LSR, Chain Lake, and tributaries above the confluence with the West Branch LSR.
- West Branch LSR from the confluence below Eloika Lake through Horseshoe, Trout, and Sacheen Lakes to Moon Creek.
- Middle LSR and tributaries from the confluence of the two branches to Dartford.
- Lower LSR below Dartford to the mouth at Lake Spokane (Long Lake).

Three U.S. Geological Survey (USGS) gages are currently in operation:

- 12431000 – LSR at Dartford
- 12431500 – LSR near Dartford
- 12427000 – LSR at Elk

The first two are located in the two lower sub-watersheds at river miles 11.4 and 3.9, respectively. The gage at Dartford has a drainage area of 665 square miles, and the gage near Dartford has a drainage area of 698 square miles. The gage at Elk is located in the Upper LSR sub-watershed at river mile 37.6 with a drainage area of 115 square miles.

Recently the Spokane County Conservation District installed and maintained streamflow gages at several other sites:

- LSR, Scotia Road, near Newport, WA.
- Otter Creek, Elk-to-Highway Road, near Elk, WA.
- LSR, Deer Park-Milan Road, Riverside, WA.
- Dragoon Creek, Crescent Road, near Chattaroy, WA.
- Deadman Creek, Little Spokane River Drive, near Mead, WA.

In 2007 the Spokane County Conservation District installed gages in the West Branch LSR sub-watershed at the following locations:

- West Branch below Eloika Lake at Eloika Lake Road.
- West Branch at Fan Lake Road.
- West Branch at Harworth Road.

Surface water in the watershed includes numerous rivers, streams, wetlands, and lakes. The major tributaries are located in the Middle LSR sub-watershed: Dragoon, Deadman, Little Deep, and Deer Creeks, as well as the West Branch LSR. The largest lakes are in the West Branch LSR sub-watershed and include Eloika, Sacheen, Horseshoe, and Diamond Lakes.

A rough comparison of available streamflow records from the Spokane County Conservation District and the USGS gage at Dartford indicates the Upper LSR and West Branch LSR sub-watersheds contribute 40% - 50% of the annual streamflow to the Middle LSR sub-watershed. Tributaries in the Middle LSR sub-watershed contribute approximately another 30% - 40%, and the rest is comprised of groundwater and smaller surface drainages. Groundwater inputs below Dartford are much more substantial.

Streamflows in the LSR have declined since the 1960s (Figure 7). USGS gage records at Dartford and near Dartford show declines during all seasons except the March to May runoff period. However, groundwater input appears to have held steady based on trend analyses of the discharges calculated from the differences between the two gages operating simultaneously since 1997. Flows vary considerably on an annual and seasonal basis, but rarely fall below 250 cfs at the mouth (Figure 8). Streamflow declines in the Middle and Upper sub-watersheds during the summer, fall, and winter are the result of increased water use as well as lower than average precipitation (Ecology, 1995).

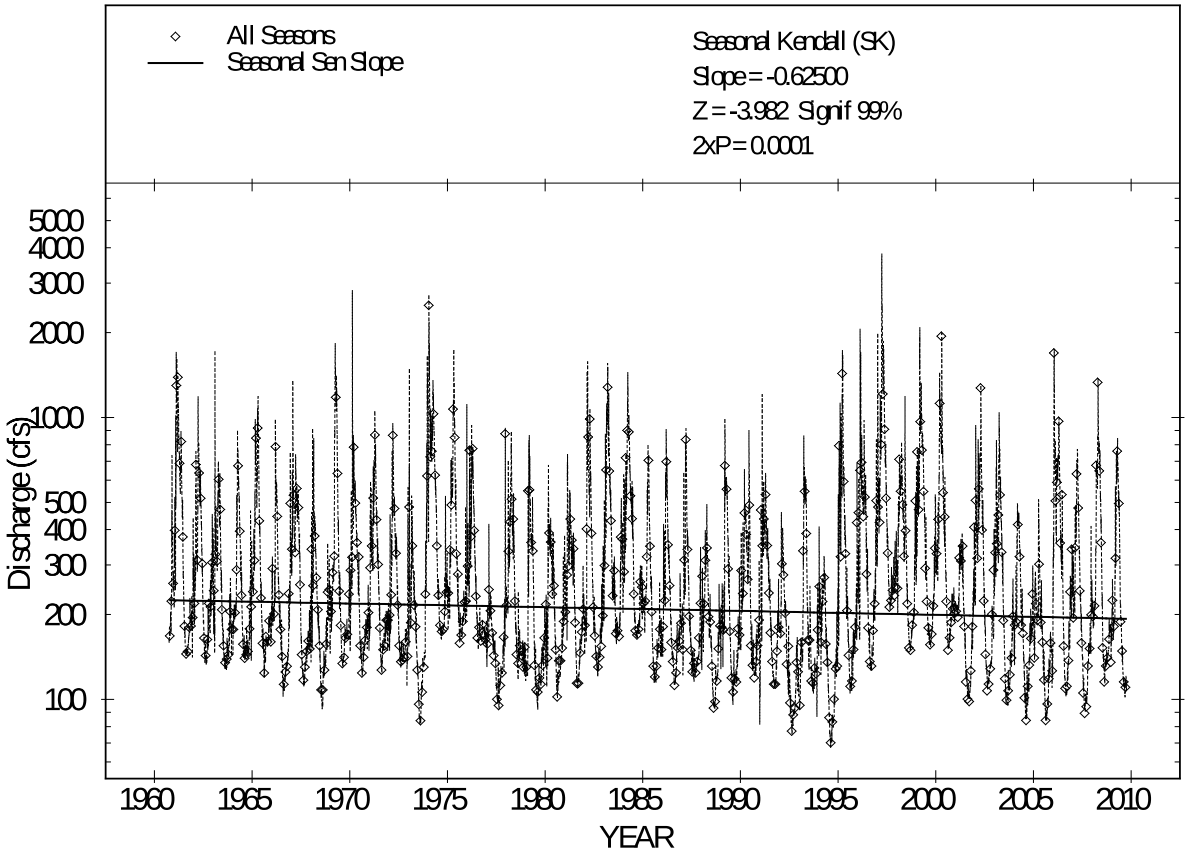

Figure 7. Results of a seasonal Kendall trend analysis depicting a declining trend of mean daily streamflows recorded by the USGS at the Little Spokane River at Dartford (12431000) from 1960 to 2009.

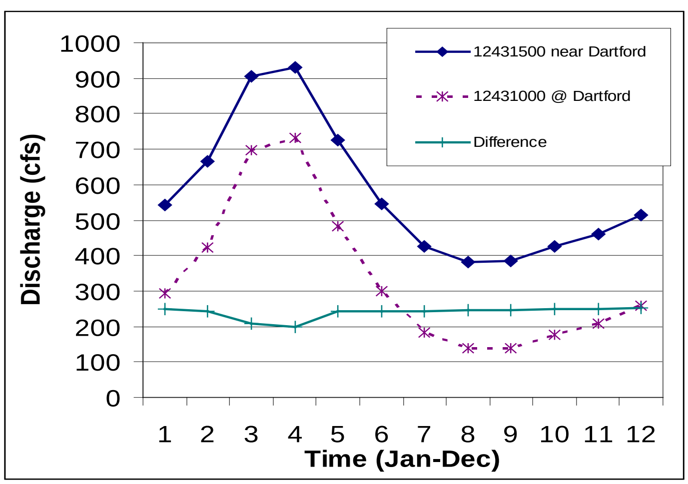

Figure 8. Comparison of flow between Little Spokane River at Dartford and Little Spokane River near Dartford gaging stations for the 12-year overlapping period of record through water year 2005 (Barber et al., 2007).

Groundwater

The significance of groundwater input from the Spokane Valley-Rathdrum Prairie (SVRP) aquifer to the Lower LSR sub-watershed below Dartford can be seen in Figure 8. The northwest edge of the SVRP aquifer intercepts the LSR just downstream of Dartford Creek (Figure 6). The two USGS gage stations, 12431000 and 12431500, are only 7.5 river miles apart; the substantial increase in flow every month is due primarily to subsurface discharge from the SVRP aquifer. On average, there is approximately 240-250 cfs of groundwater inflow in this short reach. The groundwater accounts for more than 56% of the LSR outflow to Lake Spokane during the low-flow periods of July, August, and September.

Groundwater is important throughout the watershed as a domestic drinking water supply. The SVRP aquifer, the Deer Park groundwater basin, and the Little Spokane aquifer are the three most important aquifers within WRIA 55. The Green Bluff, Peone Prairie, Orchard Prairie, and Five Mile Prairie aquifers provide considerably less water, but are nevertheless important locally. Descriptions of these aquifers are provided in Cichosz et al. (2005).

The majority of natural groundwater discharge in the watershed occurs as baseflow to the LSR. The discharge record for the LSR at Scotia also suggests that most of the water is derived from groundwater rather than surface runoff (SCCD, 2003). The mainstem LSR upstream of the confluence with the West Branch LSR makes its discharge through groundwater flow (Chung, 1975). In low-flow periods (especially during August and September), discharge volumes at the Dartford gage average approximately 150 cfs and consist primarily of groundwater inflows (Chung, 1975). As mentioned previously, the SVRP aquifer delivers approximately 240-250 cfs of groundwater inflow in the last eight miles of the river and accounts for more than 56% of the LSR outflow to Lake Spokane during the low-flow periods of July, August, and September.

Some human activities have altered streams in the LSR by removing riparian vegetation, draining wetlands, diverting water, building dams, logging, and straightening channels. These activities may also be altering the groundwater quantity and quality. Where natural disturbances or human activity have adversely impacted stream systems, the stream may need to be restored. Restoring these stream alterations to natural conditions is generally expensive and requires a long recovery time. Groundwater contamination can take even longer to restore, and groundwater depletion is difficult to correct once wells and distribution systems are constructed.

Current land use and potential pollutant sources

Most of the LSR watershed is primarily a rural landscape consisting of forested ridges, small agricultural valleys, small urban centers, and abundant wildlife. Agricultural activities are most concentrated in the Dragoon Creek and Deadman Creek sub-watersheds. Dairies and larger livestock operations are located in the Dragoon Creek, upper mainstem, and Deadman Creek sub-watersheds (Figure 2). Residential, commercial, and industrial developments from the city of Spokane urban influence are mostly evident in the Lower LSR sub-watershed and along the lower Deadman and Little Deep Creek drainages. A detailed land use map for the portion of the LSR watershed in Spokane County is available from the Spokane County Building and

Planning Department at
http://www.spokanecounty.org/bp/data/Documents/CompPlan/Maps/cp.pdf.

Agricultural areas

Agricultural land comprises almost 25% of the land base. Agricultural activities include orchards, hay, grain, rotational crops, and livestock. Historically, farming has had an impact on the LSR by removing riparian habitat and draining wetlands to raise crops. Farming practices potentially increase the nutrient loads with fertilizer runoff. Pesticide contamination is another possible result of poor agricultural practices. Some livestock owners in the watershed have not prevented their animals from trampling the banks of the river or contaminating the stream and banks with their urine and feces.

Residential areas

Population growth and increased residential development especially have impacted the Lower LSR sub-watershed. Approximately 24% of the land in the area below the confluence with Deadman Creek is designated urban (Figure 9). With the adoption of the Comprehensive Plan in Spokane County, all land immediately adjacent to the LSR is designated Rural Conservation. Other than the urban areas surrounding Riverside, Mead, Colbert, Chattaroy, and Eloika, the remainder of the land in the LSR watershed in Spokane County is designated Rural Conservation, Rural Traditional, Forest Land, or Small Tract Agriculture. These designations have a minimum lot size of 10 to 20 acres. But if the land was divided into smaller lots prior to the adoption of the Comprehensive Plan, the lots are still available for development.

Residential and commercial development within the watershed decreases the amount of land surface that is able to absorb moisture from rain and snowfall. Paved roadways and rooftops are impervious (impenetrable) surfaces that cause stormwater to run quickly off the landscape. Moisture is no longer stored within the topsoil and groundwater but rather enters the creeks and rivers quickly, causing flooding for short periods followed by reduced water flow over extended periods. Peak flows occur more frequently, increasing the erosive force and downstream sedimentation, as well as affecting groundwater infiltration and storage volumes. The city of Spokane, Spokane County, and Washington State Department of Transportation (WSDOT) have been issued stormwater permits for these urbanized areas (Figure 9).

Population pressures could increase noticeably in the LSR basin with the completion of the North-South Freeway. The northern terminus of the freeway will be just south of the LSR on Highway 395. There will also be an exit on Highway 2 near the current intersection with Shady Slope Road. This may encourage growth to the north as the commute is made easier. Growth management for this anticipated population shift will need the cooperation of building and planning departments, county commissioners, and county health departments.

The spread of residential development in the watershed poses a number of threats to the quality and level of river function. Spokane County's population has increased by an average 3,400 people per year since the census was taken in 2000, or a 5.5% change annually. During that same period, Pend Oreille County experienced an 8.1% increase. State projections expect this trend in population growth to continue (Washington State Office of Financial Management). Historically, increased population results in increased development and sprawl with a decrease in water quality.

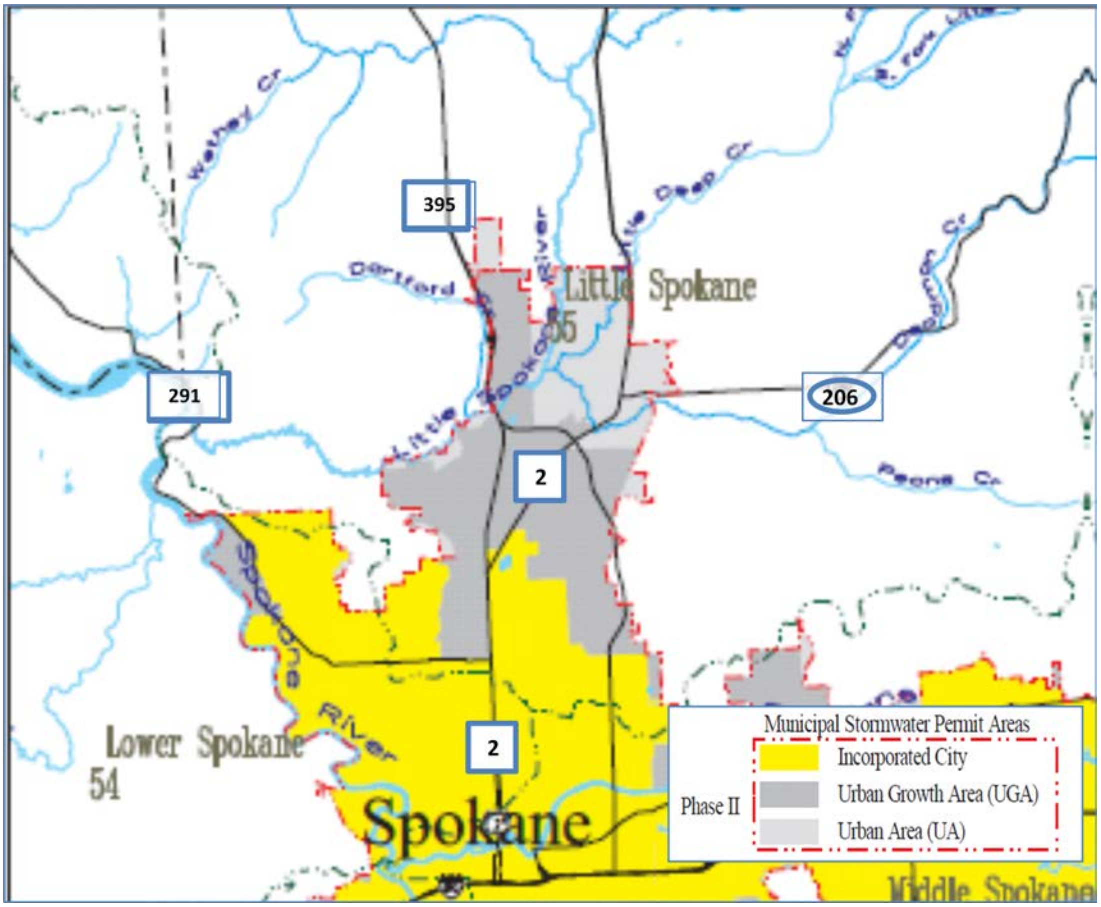

Figure 9. City of Spokane and Spokane County urbanized areas with stormwater management and permit jurisdictions.

Lawn and garden care in residential neighborhoods can impact the quality of the river by the misuse or overuse of chemical fertilizers and pesticides. These fertilizers and insecticides can run off to the river during rain events or with over watering. Some property owners adjacent to the waterways dump lawn clippings and other vegetative debris next to, or in, the river where it is washed down during high-flow events.

Residential areas on the edge of urban development are frequently beyond the areas served by sewage waste treatment facilities. Improperly maintained and poorly functioning septic systems increase contamination of the rivers by increasing nutrients and FC bacteria. Septic systems are designed to remove the solids from the water before it enters the ground water and surface water. Chemicals such as cleaning agents and medications such as antibiotics enter the septic tanks and can flow to the groundwater.

As population and development increase in the watershed, construction sites can pose problems by destabilizing soils and increasing sedimentation, causing changes in streamflows. These sites also compact the soil, creating less pervious surfaces that increase runoff that could result in flooding. Planning and installing stormwater infrastructure systems help protect surface waters from stormwater runoff (Figure 10).

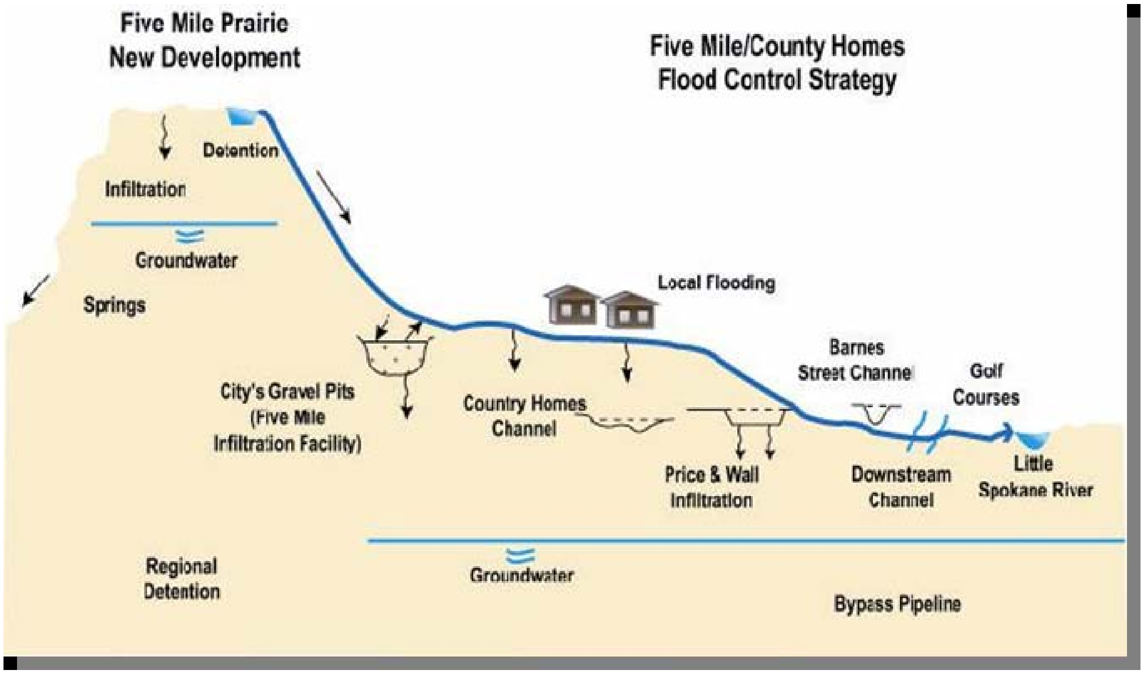

Figure 10. An example of stormwater treatment methods used in the urbanizing areas of the Little Spokane River watershed (Spokane County, 2009).

Forested areas

Almost 38% of the land in the LSR watershed is designated as forest. Forested land stabilizes hillsides, provides habitat for a variety of wildlife, and keeps streams cool. Logging, if not done properly, has the potential to destabilize soils and eliminate habitat. Logging close to wetlands can impact water quality. Along with possible wetland destruction, the construction of roads can be very damaging to streambeds, resulting in increased sedimentation in the stream.

Reforestation along streams in the LSR watershed is essential to not only decrease temperature and increase dissolved oxygen levels, but also to stabilize streambanks. Streambank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land-cover type and condition by (1) affecting flood plain and instream roughness, (2) contributing coarse woody debris, and (3) influencing sedimentation, stream substrate compositions, and streambank stability. Decreased turbidity is the benefit of stable streambanks.

Resort development has occurred around Eloika Lake, resulting in higher density development and elimination of habitat and increased runoff. Eco-tourism is a motivation to enhance and protect our natural environment. For example, nearby Lincoln County has found it to be an incentive and is supportive of the wildlife viewing area recently established on Sprague Lake. The Washington State Audubon Society is establishing a series of maps identifying wildlife viewing hotspots.

Permitted facilities

Relative to its size and proximity to the city of Spokane, there are few facilities in the LSR watershed with NPDES permits. Most small towns in the watershed use individual on-site septic tanks. Table 10 lists facilities with NPDES Permits, state General Permits, or dairy registration numbers:

- Deer Park, the community at Diamond Lake, and Mountainside Middle School have wastewater treatment plants (WWTP) that do not directly discharge to waterways.
- Several sand and gravel operations are permitted in the middle and upper regions of the watershed (Figure 2).
- Colbert Landfill discharges treated groundwater collected at wells surrounding the former dump site in the Middle Little Spokane River sub-watershed.
- The WDFW Spokane Fish Hatchery at Griffith Springs is located in the lower region of the watershed below Dartford.
- The former Kaiser Aluminum Mead plant is now CDC Mead LLC and is an inactive industrial site with an active NPDES permit.
- Spokane and surrounding suburbs in Spokane County have stormwater treatment systems, and the city and county have Phase II municipal stormwater (MS4) permits.
- The Washington State Department of Transportation also is required to manage stormwater within the urban area of Spokane County under its MS4 permit.

Table 10. Wastewater and stormwater permits and registered dairy and livestock facilities in the Little Spokane River watershed.

Permit Number	Permit Holder	Receiving Water	Permit Type
WAG137007D	WDFW Spokane Fish Hatchery	LSR	Upland Fin Fish General Permit
WAD980514541	Colbert Landfill	LSR	Remediation
ST0008016D	Deer Park WWTP	To Ground	Municipal
ST0008029D	Diamond Lake WWTP	To Ground	
ST0008111A	Mountainside Middle School	To Ground	
WAG507065C	WSDOT Denison-Chattaroy	--	Sand & Gravel General Permit
WAG507022C	Spokane County PWD Dalton	--	
WAG507008C	Toners Excavating	--	
WAG507095C	WSDOT PS-C-313 Elk	--	
WAG507067C	Central Premix Concrete Elk	--	
WAG507027C	Spokane Rock Products Elk	--	
	CDC Mead LLC	Deadman Creek	Industrial
WAR046506	Spokane County	LSR Deadman Creek Little Deep Creek	Stormwater
WAR046505	City of Spokane	LSR	
WAR04000A	WSDOT	LSR, Deadman Creek, Little Deep Creek, Dragoon Creek	
9160	Kimebert Farm	No Discharge	Dairy or Livestock Register
4204	Darilane Farms	No Discharge	
9191	Bettydon Jersey Farm	No Discharge	
9536	Reiters Holstein Dairy LLC	No Discharge	
6004	Schmidt Dairy	No Discharge	
9120	Dunrenton Ranch LLC	No Discharge	
4244	Hutchinson Dairy	No Discharge	

WDFW: Washington Department of Fish and Wildlife.
WWTP: Wastewater Treatment Plant.
WSDOT: Washington State Department of Transportation.
PWD: Public Works Department.
LLC: Limited Liability Company.

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Goals and Objectives

Project goals

The primary goal of this total maximum daily load (TMDL) project is to improve water quality in the LSR and its tributaries so that criteria and standards for FC bacteria, temperature, and turbidity are met. Secondarily, Ecology would like to make progress on more complex pollution problems such as dissolved oxygen and pH conditions in the watershed. Controlling sources of FC, heat, turbidity, and nutrients in the watershed may also help to control nutrient and biochemical oxygen demand loads that affect dissolved oxygen conditions locally and in Lake Spokane.

Study objectives

This study's technical analysis and implementation strategy will accomplish this goal by:

1. Characterizing FC bacteria, heat, turbidity, and suspended sediment loading from various parts of the LSR basin.
2. Conducting temperature modeling work for a temperature TMDL and recommending shade allocations.
3. Setting load and wasteload allocations for FC and TSS.
4. Developing a plan to implement actions to achieve the water quality goals of the project.

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Analytical Approach

Study area

The TMDL study area includes the mainstem and selected tributaries of the LSR (Figure 6). Data to evaluate the parameters of interest are available for sites from the upper reaches of the mainstem LSR up to Scotia (RM 46.7), the West Branch LSR to Moon Creek (WB-RM 20), and for the following tributaries:

- Dragoon Creek, including West Branch Dragoon Creek
- Deadman Creek, including Little Deep Creek and Peone Creek
- Deer Creek
- Bear Creek
- Dry Creek
- Otter Creek
- Dartford Creek
- Beaver Creek
- Buck Creek
- Moon Creek

As shown in Figure 2, most lakes are categorized as 4c, impaired by a non-pollutant, because their water quality problems are based on the presence of exotic invasive species. The influence of Eloika Lake on water temperatures of the West Branch LSR will be discussed.

The TMDL evaluation is broad in scope, addressing water quality in sub-watershed or drainage areas rather than identifying reach-specific or source-specific issues. This TMDL should allow Ecology and participating agencies and groups to set priorities for future reach-specific studies and implementation activities.

Modeling framework

Because this TMDL technical assessment has multiple parameters and uses data from several historical monitoring studies and one recent study, several analytical tools and models were employed. Each of the parameters addressed in the TMDL has analytical approaches specific for its spatial and temporal effects. For example, the 2004-2006 study by Washington State University (WSU) and Washington Water Research Center (WWRC) (Cichosz et al., 2005) required continuous monitoring of discharge volumes, and air and water temperature at a network of sites in the watershed so that a model, QUAL2K, could be used to assess maximum daily water temperatures. Common techniques and statistical analyses approved by Ecology (www.ecy.wa.gov/programs/eap/models.html) were used to analyze other parameters that were monitored without a particular model or analytical tool in mind.

In previous TMDL studies, Ecology used (1) the statistical rollback method to evaluate FC count distributions and (2) the fish impact severity score index to evaluate TSS concentrations. Some background formulae and descriptions are provided in Appendix D. Ecology used the WQI for general water quality data assessments for several years (Hallock, 2002). Its use for evaluating turbidity and TSS concentrations in this TMDL is new.

After verifying data usability, data for a site monitored during various studies were combined whenever collection and analytical techniques were similar. Seasonal and meteorological factors were evaluated by using statistical trend and parametric correlation analyses to examine the variability of streamflow, FC, and TSS at each site. These analyses are especially important for determining TMDL loading capacity during critical conditions. Critical conditions were based on an individual parameter's effect on human health and aquatic life uses. Possible changes in upstream source controls or land uses were also investigated when differences between monitoring periods were observed.

Study methods

This TMDL technical evaluation primarily relies on data generated by other agencies and groups. A key data source used in this TMDL is the recent WSU and WWRC study (Barber et al., 2007). The study was contracted by Ecology, and Ecology helped direct the QA Project Plan (Shrestha et al., 2004; Cichosz et al., 2005) but was not directly involved in data collection.

Data directly collected by Ecology were used in the analyses from the following monitoring sources:

- Water quality monitoring station 55B070, LSR near Mouth, is the only long-term station (1977– present) with trend analysis potential.
- Thirteen other water quality monitoring stations have been sampled over shorter durations at different times from the 1960s to the present to use in the loading calculations (Table 11).
- A Deer Park Wastewater Treatment Plant and Dragoon Creek receiving water survey in 1981 (Joy, 1981), and a post-TMDL data set conducted in April through September of 2004 (Ross unpublished, 2008) were used for Dragoon Creek water quality assessments.
- Short-term intensive analyses of water quality, based on monthly data (Hallock, 1991; 1996), were reviewed.
- Benthic macroinvertebrate sample collections at two sites in the LSR and one site in Dragoon Creek in 1994, and one site in Deadman Creek in 2003, were reviewed.

Ecology collected additional samples at the WDFW Spokane Fish Hatchery for use in this TMDL evaluation (Ross unpublished data, 2009).

Table 11. Ecology stream and river water quality network sites monitored in the Little Spokane River basin (Ecology, 2009).

Site ID	Location	River Mile	Water Years Monitored
55B070	LSR near Mouth	1.1	1971, 1973, 1977 to Present
55B075	LSR at Painted Rocks	3.9	1999
55B080	LSR near Griffith Springs	7.5	1991*
55B082	LSR above Dartford Creek	10.3	1990-91*, 1999
55B085	LSR near Dartford	11.4	1960-66
55B090	LSR above Wandermere	11.5	1973
55B100	LSR above Deadman Creek	13.5	1990-91*, 1994
55B200	LSR at Chattaroy	23.1	1999
55B300	LSR at Scotia	46.7	2004
55C065	Deadman Creek near Mouth	0.13	1994
55C070	Peone (Deadman) Creek above Little Deep Cr.	0.5	1990-91*, 2004
55C200	Deadman Creek at Holcomb Road	12.1	2004
55D070	Deer Creek at Highway 2	0.06	1994*
55E070	Dragoon Creek at Crescent Road	0.2	1994

* Partial record only.

Data quality

Several of the data sets used in this TMDL technical assessment are described in the following section. *Some information and data are from sources outside of Ecology*. All major data sets used in this TMDL assessment were collected under QA plans:

- Data for the 2004-2006 WSU/WWRC monitoring study were collected under an Ecology-approved QA Project Plan (Cichosz et al., 2005).
- Ecology water quality network collect samples under QA procedures available at www.ecy.wa.gov/programs/eap/qa/docs/ECY_EAP_SOP_034CollectionandProcessingofStreamSamples.pdf, and data are reviewed annually to ensure quality control.
- Ecology's Dragoon Creek effectiveness monitoring and Spokane Fish Hatchery data collection were done under a reviewed QA plan (Ross unpublished, 2004; Ross, 2008b).
- USGS gage data are collected, processed, stored, and published under a set of QA procedures: http://pubs.usgs.gov/of/2003/ofr03490/.
- The 1998-1999 Pend Oreille Conservation District data and the 2000-2001 Spokane County Conservation District data were collected under Ecology-approved QA Project Plans (POCD, 2000; SCCD, 2003).

  The following reports did not have QA plans but were reviewed and found to have reliably sound methods and data quality procedures:

- Dragoon Creek FC data collected by the Spokane County Conservation District (Lundgren, 1998).
- Water temperature and fish community data collected by WDFW (McLellan, 2005).
- Macroinvertebrate data collected by Canwell (2003).

- Riparian shade data collected by Canwell (2003) and Christian (2003).
- Dragoon Creek FC data collected by Ecology (Ross, 2008a).

Information and data from sources outside of Ecology

This TMDL technical analysis used historical and recently-collected data to evaluate water quality. The data were obtained from databases and reports by various agencies. As earlier described, additional field data were collected specifically for this TMDL under an Ecology contract for a 2004-2006 study. Previous studies and monitoring that had parameters of interest included work done under a QA Project Plan or with high levels of quality control. Following are summaries of relevant historical and ongoing data sources and the 2004-2006 study.

The U.S. Geological Survey

Streamflow measurements and the role of groundwater in the watershed were summarized from the following data sets and reports:

- Long-term and short-term streamflow data were obtained from mainstem LSR and tributary gage records:
    - 12431000 Little Spokane River at Dartford, WA
    - 12431500 Little Spokane River near Dartford, WA
    - 12427000 Little Spokane River at Elk, WA
    - 12426500 Little Spokane River at Scotia, WA
    - 12428600 West Branch Little Spokane River near Elk, WA
    - 12429000 Little Spokane River at Milan, WA
    - 12429200 Bear Creek near Milan, WA
    - 12429600 Deer Creek near Chattaroy, WA
    - 12429800 Mud Creek near Deer Park, WA
    - 12430100 Dragoon Creek at Mouth near Chattaroy, WA
    - 12430150 Little Spokane River below Dragoon Creek near Chattaroy, WA
    - 12430350 Deadman Creek near Mead, WA
    - 12430370 Bigelow Gulch near Spokane, WA
    - 12430400 Deadman Creek below US Hwy 195 near Mead, WA
    - 12430500 Deep Creek at Colbert, WA
    - 12430600 Little Spokane River below Deadman Creek near Dartford, WA
    - 12430800 Wandermere Lake Creek near Dartford, WA
- USGS also recently completed a groundwater study of the Spokane Valley – Rathdrum Prairie aquifer that affects the hydrology of the LSR (Kahle et al., 2005).

The Pend Oreille, Stevens, and Spokane County Conservation Districts

- The Spokane County Conservation District obtained water quality data from a Dragoon Creek monitoring study (1994-1996) conducted for a watershed management plan (Lundgren, 1998).
- The Pend Oreille Conservation District conducted a basic water quality study under an Ecology grant during 1998-1999 (POCD, 2000). One tributary and five mainstem stations were monitored in coordination with sampling at four additional sites by Ecology:
  - Little Spokane River at Scotia Road.
  - Little Spokane River at Elk Park on Camden Road.
  - Outlet of Eloika Lake at Eloika Lake Road.
  - Little Spokane River at Milan Road.
  - Little Spokane River below Dragoon Creek.
  - Little Spokane River below Deadman and Deep Creeks.
  - Ecology 55B200, Little Spokane River at Chattaroy.
  - Ecology 55B082, Little Spokane River above Dartford Creek.
  - Ecology 55B075, Little Spokane River at Painted Rocks.
  - Ecology 55B070, Little Spokane River near Mouth.

The data are available in Ecology's Environmental Information Management (EIM) System under User ID G9900036, Study Name *Little Spokane Water Quality Assessment.*

The Spokane County Conservation District conducted a water quality study in Deadman and Little Deep Creek during 2001 (SCCD, 2003). The data are available in EIM under User ID G0000198, Study Name *Little Spokane River Watershed Plan Development.*

- 2000-2006 discharge data were obtained from several Spokane County Conservation District gage records:
  - Little Spokane River, Scotia Road, near Newport, WA.
  - Otter Creek, Elk-to-Highway Road, near Elk, WA.
  - Little Spokane River, Deer Park-Milan Road, Riverside, WA.
  - Dragoon Creek, Crescent Road, near Chattaroy, WA.
  - Deadman Creek, Little Spokane River Drive, near Mead, WA.

Washington State University (WSU) and Washington Water Research Center (WWRC)

Ecology contracted WSU and the WWRC in 2004 to review the available data in the LSR watershed and recommend any further work. WSU and WWRC staff and students recommended further study of the mainstem LSR from river mile (RM) 46.7 to the mouth and several tributaries (Shrestha et al., 2004). Sampling was conducted primarily from December 2004 through April 2006 (water temperature and streamflow monitoring extended through summer 2006) under an approved QA Project Plan in cooperation with the Spokane County Conservation District (Chichoz et al., 2005). These data are available in EIM under User ID C0500017, Study Name *Little Spokane River Bacteria, Phosphorus, and Temperature TMDL Surveys*.

WSU and WWRC staff wrote a preliminary TMDL technical report based on the 2004-2006 data (Barber et al., 2007). The report is the major data source for the following technical analysis.

Eastern Washington University (EWU)

EWU worked with Kennedy Engineering and the Sacheen Lake Sewer District for several years collecting water quality data from tributaries to, and the surface of, an outlet of Sacheen Lake (Soltero et al., 1991). The work was performed under an Ecology Phase 1 Clean Lakes Restoration Project grant to examine general water quality and the effect of herbicide applications.

Macroinvertebrate and riparian mapping studies were conducted as part of the Spokane County Conservation District watershed grant from 2000-2002 (SCCD, 2003). Susanne Canwell, under the direction of Dr. Bruce Lang, collected and analyzed four sets of macroinvertebrate samples from 24 sites (Canwell, 2003). Habitat data were also collected at the sites. Paul Christian used Geographical Information System (GIS) analytical tools to delineate riparian areas from digital aerial photos (Christian, 2003). He also estimated historical riparian areas to calculate riparian losses in each sub-basin of the watershed.

Station co-location

Various surveys over the years have used the same sampling location but used different station identification codes or descriptions. Table 12 provides a matrix of some sites used by various studies on the LSR.

Table 12. Co-located water quality monitoring sites in the Little Spokane River watershed.

River Mile	General Location	2005-06 TMDL	2001-02 SCCD	1998-99 POCD	1994-96 NRCS	Ecology	Other
LS 46.7	LSR at Scotia	LSRTMDL-1		LS-1		55B300	WU/ SCCD gage
LS 37.1	LSR at Elk			LS2			USGS/ SCCD gage
LS 31.8	LSR at Deer-Milan	LSRTMDL-2		LS-4			
LS 23.1	LSR at Chattaroy					55B200	SCC gage
LS 21.2	LSR below Dragoon			LS-5			
LS 13.5	LSR above Deadman	LSRTMDL-3				55B100	
LS 11.4	LSR below Deadman					55B085	USGS gage
LS 10.3	LSR above Dartford			LS-6		55B082	
LS 7.5	LSR near Griffith Springs					55B080	
LS 3.9	LSR at Rutter Parkway	LSRTMDL-21				55B075	USGS gage
LS 1.1	LSR at Highway 291	LSRTMDL-26				55B070	
DC 0.06	Deer Cr at mouth	LSRTMDL-10				55D070	
DrC 0.2	Dragoon Cr at Crescent Road	LSRTMDL-13			DRT 9	55E070	SCCD gage
De 0.13	Deadman Cr at mouth	LSRTMDL-8				55C065	
LD 0.01	Little Deep Cr	LSRTMDL-16	LD-9				
De 0.5	Deadman Cr above Little Deep		DM-7			55C070	SCCD gage
WB 3.1	West Branch LSR below Eloika Lake	LSRTMDL-23		LS-3			SCCD gage

NRCS: U.S. Natural Resources Conservation Service.
WU: Whitworth University.
LSR: Little Spokane River.
SCCD: Spokane County Conservation District.
USGS: U.S. Geological Survey.
SCC: Spokane Community College.
POCD: Pend Oreille Conservation District.

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Study Results and Discussion

As indicated earlier, this TMDL assessment draws on several data sets. The most recent and comprehensive study used is the December 2004 to April 2006 TMDL report by WSU/WWRC (Barber et al., 2007). QA results from that report are summarized in the discussion that follows.

Quality assurance results

The WSU/WWRC study provided a quality control (QC) review in their report (Barber et al., 2007). The results are summarized in the following tables. A more complete description can be found in Appendix D of their report (Barber et al., 2007).

Quality objectives were met for laboratory analytical precision between duplicate samples of four parameters of interest. Results are listed in Table 13.

Table 13. Analytical precision expressed as percent relative standard deviation (%RSD) with results at or below the detection limit excluded.

Parameter	Target Precision (%RSD)	Average %RSD (# duplicate pairs)
Total Phosphorus	<10	9.68 (21)
Ammonia-N	<10	5.39 (9)
Nitrate+Nitrite-N	<10	3.49 (26)
Fecal Coliform	<25	14.9 (17)

An average %RSD was calculated for each parameter using field replicate results greater than reporting (detection) limits. Results are listed in Table 14.

Table 14. Total precision (field + lab) expressed as percent relative standard deviation (%RSD) with results at or below the detection limit excluded.

Parameter	Target Precision (%RSD)	Average %RSD (# duplicate pairs)
Total Phosphorus	<10	14.16 (35)
Ammonia-N	<10	25.64 (11)
Nitrate+Nitrite-N	<10	12.97 (36)
Fecal Coliform	<25	23.26 (50)
Turbidity	<10	18.18 (18)
TSS	<10	47.31 (34)

As expected, %RSD for field replicates was higher than %RSD for the lab-splits because %RSD is a measurement of total variability, including both field and analytical variability. Except for FC, the %RSD for all parameters did not meet the target precision objectives. The high %RSD can be attributed to the majority of the values being just above detection limits. As previously stated, the closer the measurements are to the detection limits, the higher the %RSD. Average standard deviations were calculated for total precision and are acceptable for use in this Ecology TMDL study with the observed variability taken into account. Standard deviation results are listed in Table 15. FC bacteria, TSS, and turbidity concentrations are inherently variable because of patchy distributions in the environment and intermittent discharge.

Table 15. Standard deviation (SD) results as a measure of total precision.

Parameter	Average SD (# duplicate pairs)
Total Phosphorus	0.008 (35)
Ammonia-N	0.006 (11)
Nitrate+Nitrite-N	0.13 (36)
Fecal Coliform	13.75 (50)
Turbidity	0.82 (18)
TSS	2.42 (34)

Field bias

Field-blank samples were submitted to the WSU Water Quality Laboratory blindly in order to determine bias from contamination in the field during the first 12 months of the WSU/WWRC project. Field bias results are listed in Table 16.

Table 16. Field bias results from field blank sample analyses.

Collection Date	Turbidity	Ammonia-N	Total Phosphorus	Nitrate+Nitrite-N	Fecal Coliform	TSS
	(NTU)	(mg N/L)	(mg P/L)	(mg N/L)	cfu/100 mL	(mg/L)
1/11/2005	BDL	BDL	BDL	0.18		
2/15/2005	6	BDL	BDL	0.42	44	3
3/8/2005	BDL	BDL	BDL	0.03	BDL	BDL
4/12/2005	BDL	BDL	BDL	BDL		BDL
5/19/2005	BDL	BDL	BDL	BDL	BDL	BDL
6/14/2005	BDL	BDL	BDL	BDL	BDL	BDL
7/12/2005	BDL	BDL	BDL	BDL	BDL	BDL
8/9/2005	BDL	BDL	BDL	BDL	BDL	BDL
9/13/2005	BDL	BDL	BDL	BDL	BDL	BDL
10/11/2005	BDL	BDL	0.02	BDL	BDL	BDL
11/8/2005	BDL	0.03	BDL	BDL	BDL	2
12/13/2005	BDL	BDL	0.03	BDL	BDL	BDL

BDL: below detection limit.

Turbidity, nitrate+nitrite-N, FC, and TSS were measured above reporting limits for the 2/15/06 field-blank sample. A review of laboratory QA/QC for these analyses did not show any laboratory bias or contamination. Other samples with measurable results above the reporting limits from that date did not have evidence of contamination (i.e., sample results were below the field-blank results). The sample is thought to be a misidentified replicate, so all data from that date were considered acceptable without qualification.

A review of the laboratory QA/QC for all other field blanks measured above reporting limits did not show any laboratory bias or contamination. Other samples with measurable results above the reporting limits from that date did not have evidence of contamination (i.e., sample results were below the field-blank results).

QA summaries from the following data sets or reports were reviewed, and the data used from them for this TMDL report are credible:

- Ecology's water quality network www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#3.
- Ecology's Dragoon Creek effectiveness monitoring data and Spokane Fish Hatchery data (Ross unpublished, 2004; Ross, 2008b).
- The 1998-1999 Pend Oreille Conservation District data and the 2000-2001 Spokane County Conservation District data (POCD, 2000; SCCD, 2003).
- Dragoon Creek FC data collected by the Spokane County Conservation District (Lundgren, 1998).
- Water temperature and fish data collected by WDFW (McLellan, 2005).
- Macroinvertebrate data collected by Canwell (2003).
- Riparian shade data collected by Canwell (2003) and Christian (2003).
- Dragoon Creek FC data collected by Ecology (Ross, 2008a).

Study results

The WSU/WWRC TMDL study (Barber et al., 2007) confirmed earlier monitoring work that FC, temperature, and turbidity problems were widespread in the LSR watershed. In general, the results suggest the upper mainstem and West Branch LSR sub-watershed areas have fewer reaches with water quality standard non-compliance than the Middle LSR reach. The tributaries to the Middle LSR contribute to LSR degradation. Large groundwater inputs to the Lower LSR sub-watershed dilute contaminants and cool water temperatures before the LSR discharges to Lake Spokane, although some carry-over loading from upstream remains.

The study provided a broad comprehensive look at water quality in the LSR watershed under below-average flow conditions. Of the 28 sites established (Figure 13, Table 17), 24 were used. Four sites selected for storm events were not used because runoff was not observed. Diel dissolved oxygen and pH monitoring and continuous temperature recording were successfully conducted in September 2005 (Table 17).

Monthly flows during the TMDL study were below average from December 2004 to December 2005, but rose above average in the last four months of the study (Figures 11 and 12). March through October 2005 monthly average flows were among the lowest on record (Appendix E, Table E-1). These conditions were not the most favorable to examine contaminant delivery from surface runoff, although flows did increase at the end of the study period and were sampled in March and April 2006 (Figure 12). In contrast, the October 1998 to September 1999 water quality survey (POCD, 2000) was conducted when monthly average streamflows were among the highest recorded (Appendix E, Table E-1).

Table 17. A summary of sites used during the WSU/WWRC Little Spokane River watershed TMDL surveys, 2004-2006.

Site ID Numbers are referenced to the map in Figure 13.

Site ID Number	Site Description	Staff Gage	Pressure Gage	Temp Logger	Standard WQ	Storm Sampling	Advanced WQ	Diel Sampling
1	(LS-1) Little Spokane River at Scotia Road	Y	SCCD	SCCD	Y	--	Y	
2	(LS-4) Little Spokane River at Deer Park Milan Road	Y	SCCD	SCCD	Y	--	Y	Y
3	Little Spokane River at LSR Dr. above Deadman Creek	Y	--	WSU	Y	--	--	Y
4	Bear Creek near Findley Road	Y	WSU	WSU	Y	--	--	
5	Beaver Creek below Horseshoe Lake	TD	--	WSU	Y	--	--	
6	Buck Creek above Horseshoe Lake	Y	WSU	WSU	Y	Y	--	
7	Dartford Creek at Hazard Road near Dartford, WA	Y	WSU	WSU	Y	--	--	
8	(LS-6) Deadman Creek at N Little Spokane Dr. near Mead,WA	Y	SCCD	SCCD	Y	--	Y	Y
9	Deadman Creek at Heglar Road	--	--	WSU	Y	Y	--	
10	Deer Creek at Hwy 2 near Chattaroy, WA	Y	WSU	WSU	Y	--	--	
11	Dragoon Creek at Dahl Road above Deer Park	--	--	WSU	Y	--	--	
12	Dragoon Creek at Monroe Road below Deer Park	--	--	WSU	Y	--	Y	
13	(LS-5) Dragoon Creek at Crescent Road near Chattaroy, WA	Y	SCCD	SCCD	Y	--	--	Y
14	WB Dragoon Creek at Monroe Road	Y	WSU	WSU	Y	Y	--	
15	Dry Creek at Milan-Elk Road	Y	WSU	WSU	Y	--	--	
16	Little Deep Creek at N Little Spokane Dr. near Mead, WA	Y	WSU	WSU	Y	--	--	
17	Moon Creek	Y	WSU	WSU	Y	--	--	
18	(LS-3) Otter Creek at Elk to Hwy Road	Y	SCCD	SCCD	Y	--	--	
19	Peone Creek at Peone Road	--	--	WSU	Y	--	--	
20	WB Little Spokane River below Sacheen	--	--	WSU	Y	--	Y	
21	Little Spokane River at Painted Rocks, Rutter Parkway	Y	USGS	WSU	Y	--	--	
22	WB Little Spokane River above Eloika Lake	Y	WSU	WSU	Y	--	Y	
23	WB Little Spokane River below Eloika Lake	TD	WSU	WSU	Y	--	Y	Y
24	Urban runoff - Pine River Park	--	--	--	Y	Y	Y	
25	Urban runoff - Waikiki Springs	--	--	--	Y	Y	--	
26	Little Spokane River near mouth (55B070 location)	--	--	--	--	--	Y	Y
27	Deadman Creek at Bruce Road (Downstream Ag influence)	--	--	--	--	Y	--	
28	WB Dragoon Creek btwn Gibson-Dahl/Swenson Rds. (above Ag)	--	--	--	--	Y	--	

WB: West Branch.
SCCD: Spokane County Conservation District.
WSU/WWRC: Washington State University & Washington Water Research Center.
Y: Yes.
TD: Tape-down measurement.
WQ: Water quality.

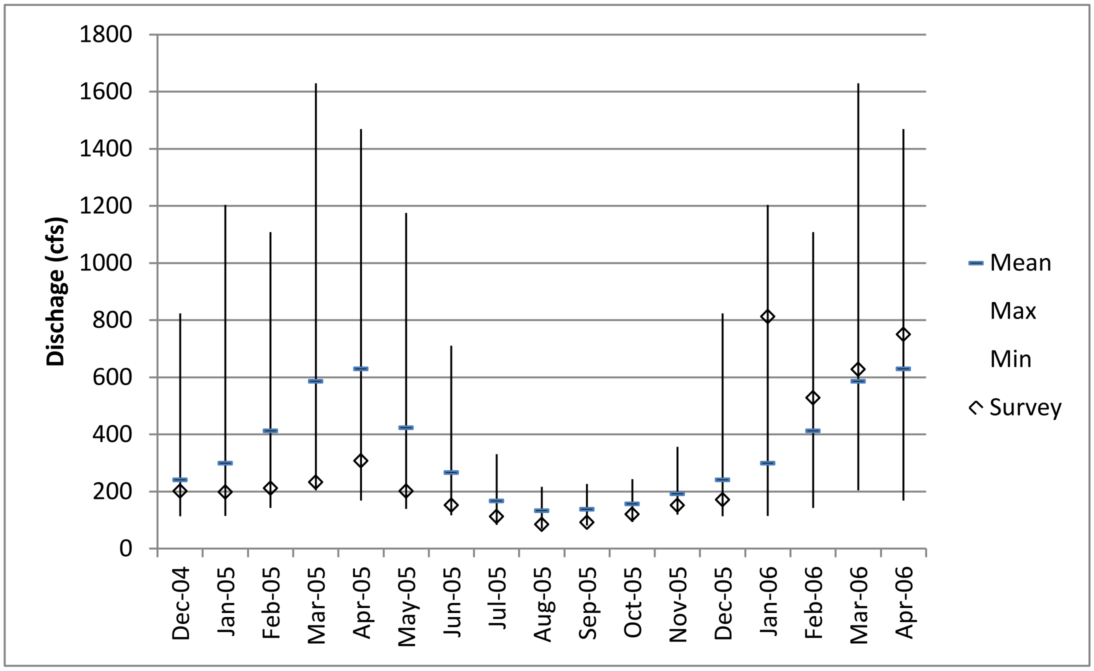

Figure 11. Monthly average discharges during the 2004-2006 TMDL survey (Barber et al., 2007) compared to monthly discharge statistics (mean, maximum, and minimum) at the Little Spokane River at Dartford.

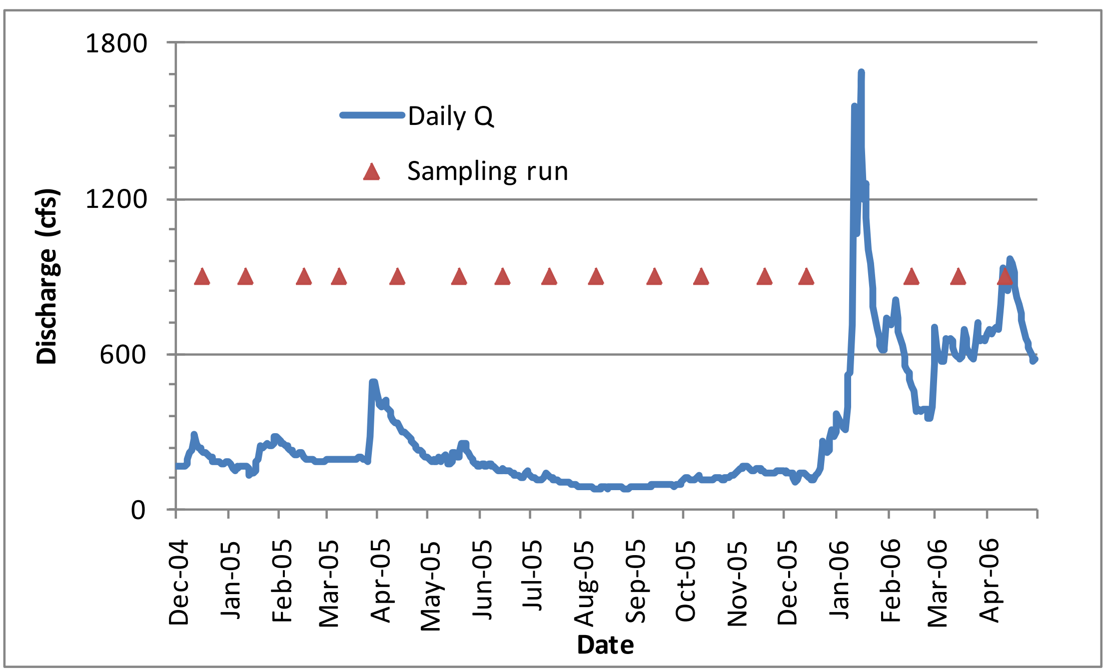

Figure 12. Daily average discharge at the Little Spokane River at Dartford relative to the dates of sampling runs for the 2004-2006 TMDL survey.

Q: Discharge in cubic feet per second (cfs).

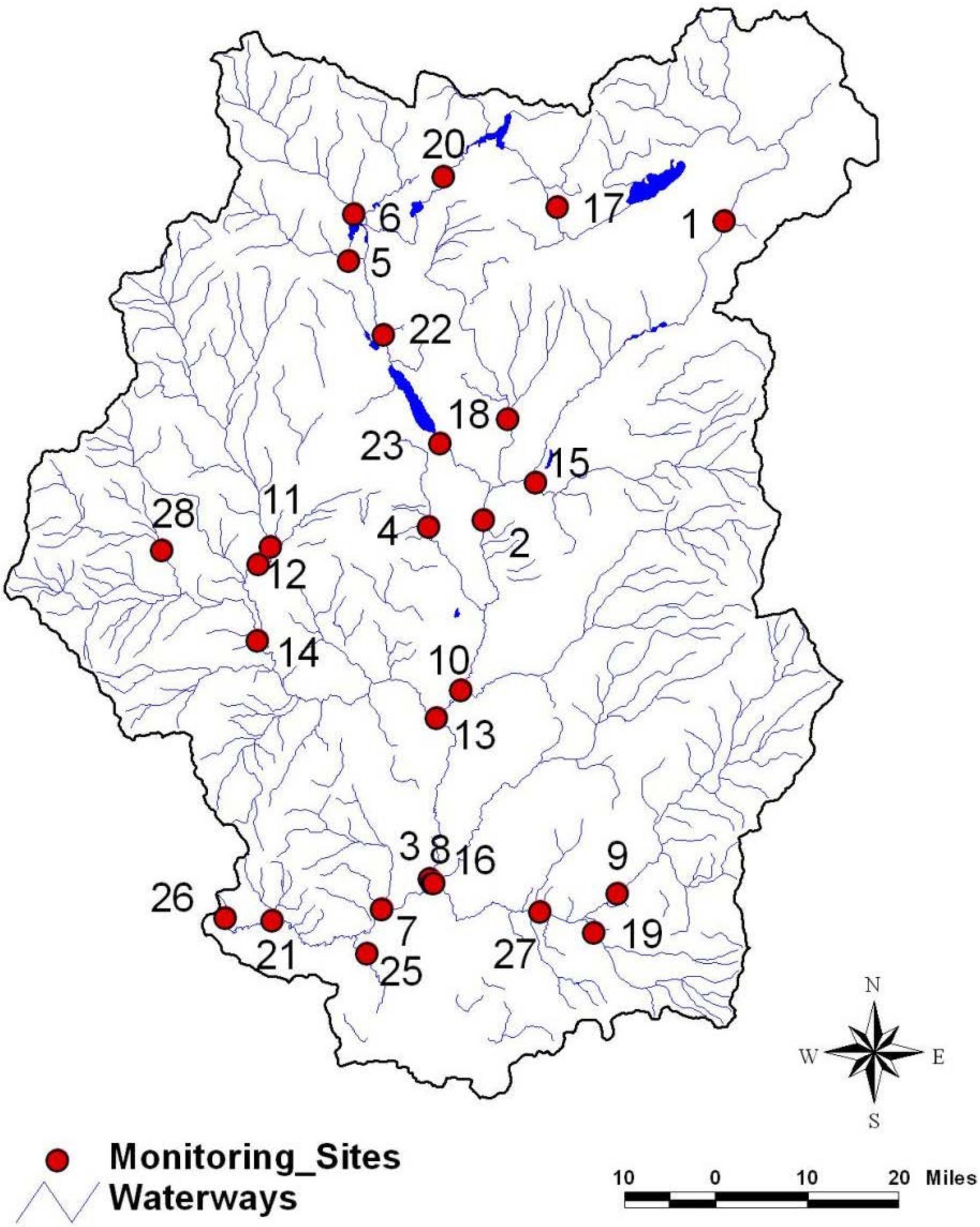

Figure 13. Monitoring sites for the 2004-2006 TMDL study conducted by WSU and WWRC in the Little Spokane River watershed (Barber et al., 2007).

Water temperature results

Instantaneous water temperature measurements taken during the 1998-99 (POCD, 2000) and 2004-2006 (Barber et al., 2007) studies were usually below 16 ºC at all sites during most of the year. In both studies, only the surveys conducted in July and August recorded instantaneous temperatures above 16 ºC at a majority of sites. Earlier studies on Dragoon Creek (Ross, 2008a; Lundgren, 1998) and Deadman Creek (SCCD, 2003) and at Ecology ambient program sites (Ecology, 2009) had similar findings for instantaneous measurements.

Continuous water temperatures recorded during the Pend Oreille Conservation District study (2000) exceeded the 16 ºC 7-day average daily maximum (7-DADMax) criterion at mainstem sites at Scotia, Deer Park-Milan Road, and below Deadman Creek, and at the West Branch below Eloika Lake. Late-spring and summer 7-DADMax violations were also recorded by the Spokane County Conservation District continuous water temperature probes from 1999 to 2003 at LSR at Scotia, Otter Creek, LSR at Deer Park-Milan, Dragoon Creek, and Deadman Creek (SCCD, unpublished data).

Table 18 shows the 7-DADMax statistics reported for water temperatures recorded continuously at the mouth of LSR (55B070) compared to Spokane County Conservation District data. All years monitored have exceeded the 16 ^{0}C 7-DADMax criterion at these sites.

Table 18. Maximum daily temperatures and the 7-day average daily maximum (7-DADMax). *Statistics recorded at the mouth of the Little Spokane River (55B070) by Ecology (2009), and by the Spokane County Conservation District at two mainstem sites upstream (SCCD, unpublished).*

Year	55B070 LSR at Mouth			LS-4 LSR at Deer-Milan			LS-1 LSR at Scotia		
	Max ºC	7-DADMax	Date	Max ºC	7-DADMax	Date	Max ºC	7-DADMax	Date
2007	18.5	18.2	July 8						
2005	17.8	17.4	July 21						
2004	18	17.7	July 23						
2003	18.1	17.9	July 21						
2002	19.1	18.4	July 14	23.2	22.1	July 15	20.9	19.8	July 12
2001	18.3	17.2	July 13				20.3	19.8	August 8

Barber et al. (2007) documented 7-DADMax water temperatures exceeding the criterion at 23 sites using continuous monitoring probes (Table 19). The highest 7-DADMax temperatures occurred at some sites as early as May, appeared at most sites in July, and occurred at a few sites in August. Over half of the sites monitored in 2006 recorded 7-DADMax temperatures above 20 ºC. Maximum 7-DADMax temperatures and the dates when they occur are shown for the two years of monitoring at individual sites in Table 19.

Table 19. The 7-day average daily maximum (7-DADMax) statistic recorded at Little Spokane River sites by continuously monitoring probes in 2005-2006 (Barber et al., 2007).

WSU Site No.	Site Name	Year	7-DADMax ºC	Dates of 7-DADMax
1	LSR at Scotia	2006	19.04	6/30 to 7/6
2	LSR at Deer-Milan Road	2006	24.18	6/30 to 7/6
3	LSR above Deadman Creek	2005	21.71	7/27 to 8/2
		2006	23.61	7/21 to 7/27
4	Bear Creek near Findley Road	2005	22.98	6/20 to 6/26
		2006	25.39	7/21 to 7/27
5	Beaver Creek	2005	17.08	6/28 to 7/4
		2006	18.26	6/25 to 7/1
6	Buck Creek	2005	16.49	7/28 to 8/3
		2006	18.36	7/22 to 7/28
7	Dartford Creek near mouth	2005	16.04	7/27 to 8/2
		2006	16.93	7/22 to 7/28
8	Deadman Creek at mouth	2006	20.02	7/1 to 7/7
9	Deadman Creek at Heglar Road	2005	20.11	8/5 to 8/11
		2006	18.50	8/7 to 8/13
10	Deer Creek near mouth	2005	19.91	7/2 to 7/8
		2006	21.63	7/22 to 7/28
11	Dragoon Creek at Dahl Road	2005	21.90	7/18 to 7/24
		2006	22.24	7/22 to 7/28
12	Dragoon Creek at Monroe Road	2005	17.42	6/20 to 6/26
		2006	17.62	7/2 to 7/8
13	Dragoon Creek near mouth	2006	22.92	7/22 to 7/28
14	West Branch Dragoon Creek	2005	17.67	7/27 to 8/2
		2006	19.97	7/22 to 7/28
15	Dry Creek at Milan-Elk Road	2006	16.56	6/30 to 7/6
16	Little Deep Creek near mouth	2005	17.47	5/25 to 5/31
		2006	20.85	6/30 to 7/6
17	Moon Creek	2005	18.15	5/24 to 5/30
		2006	21.09	7/22 to 7/28
18	Otter Creek at Elk to Highway Road	2006	18.39	7/22 to 7/28
19	Peone Creek near mouth	2005	17.51	6/30 to 7/6
		2006	19.50	5/14 to 5/20
20	West Branch LSR below Sacheen Lake	2005	22.38	8/5 to 8/11
		2006	24.37	7/22 to 7/28
21	LSR at Rutter Parkway	2005	17.02	6/20 to 6/26
		2006	18.33	7/21 to 7/27
22	West Branch LSR above Eloika Lake	2005	23.98	7/25 to 7/31
		2006	26.40	7/21 to 7/27
23	West Branch LSR below Eloika Lake	2005	25.82	7/25 to 7/31
		2006	29.16	7/21 to 7/27

At most sites, 7-DADMaxs above the criterion were not continuously elevated; they often rose above and fell below the criterion over the spring and summer. For example, the 7-DADMax exceeded the 16 ºC criterion near the headwaters of the LSR at Scotia (Site 1) during three or four intervals between May and August 2006 (Figure 14).

Not only shade and stream volume, but other local hydrologic features appear to have an effect on water temperatures. The maximum and 7-DADMax water temperatures at the mouth of LSR and Site 21 for 2005 are cooler than the upstream mainstem Sites 1, 2, and 3 (Tables 18 and 19).

The large groundwater input is thought to have a moderating effect in the lower reaches of the LSR. In contrast, lakes along the West Branch LSR (Sites 20 and 23), because of their warmer surface waters, appear to warm reaches downstream of their outlets (Table 19).

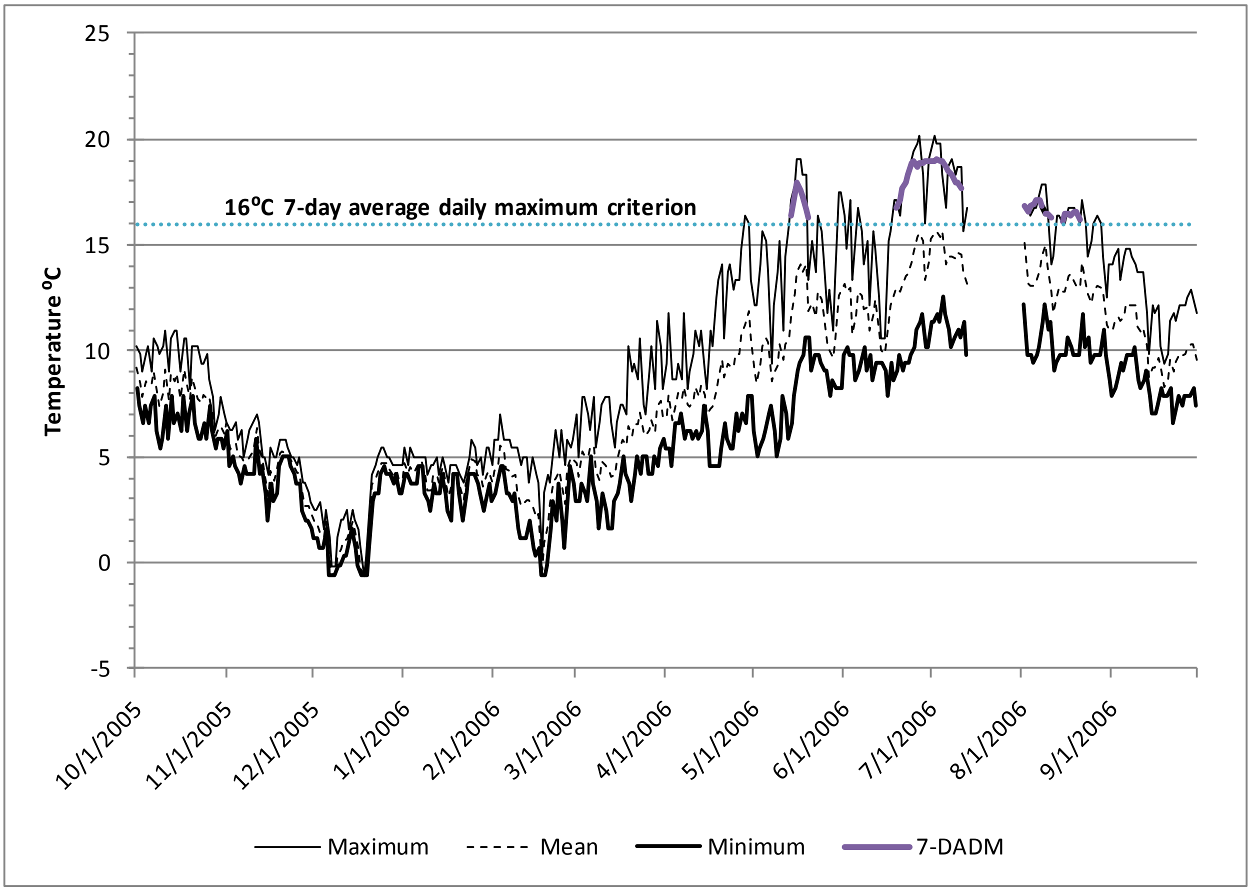

Figure 14. Daily minimum, mean, and maximum water temperatures recorded at the Little Spokane River at Scotia (Barber et al., 2007).

The periods where the 7-day average daily maximum (7-DADMax) statistic exceeds the 16 ºC water quality criterion are shown.

Fecal coliform (FC) results

Over 1,000 FC results at 30 sites were available from several studies (Ecology, 2009; Ross, 2008a; Barber et al., 2007; POCD, 2000; Lundgren, 1998; Soltero et al., 1991; Joy, 1981). The data sources and number of data used at each site are summarized in Table 20. The Ecology site at the mouth of the LSR (55B070) provided the largest number of sample results (363), and another 690 results were distributed among the other 28 sites. Fifteen sites had less than 20 results, a less-than-optimal condition for statistical analysis that warrants some caution when interpreting results.

Table 20. Number of fecal coliform (FC) data sources used for the TMDL evaluation of the Little Spokane River.

WSU/WWRC (Barber et al., 2007); Ecology (Joy, 1981; Ross, 2008a; Ecology, 2009); Pend Oreille Conservation District (2000); Spokane County Conservation District (Lundgren, 1998); Eastern Washington University (Soltero et al., 1991).

Map Site ID	Location	WSU/ WWRC	Ecology	POCD/ SCCD	EWU	Total
1	LSR at Scotia Road	17	12	12		41
	LSR at Elk			12		12
15	Dry Creek	16				16
18	Otter Creek	15				15
17	Moon Creek	16			12	28
20	West Branch LSR	16				16
6	Buck Creek	18				18
5	Beaver Creek	16				16
22	West Branch LSR above Eloika Lake	16				16
23	West Branch LSR below Eloika Lake	16		12		28
2	LSR at Deer Park-Milan Rd	16		12		28
4	Bear Creek	17				17
11	Dragoon Creek at Dahl Road	16				16
	Dragoon Creek at Crawford Road		7	27		34
	Dragoon Creek at Oregon Road		5	27		32
12	Dragoon Creek at Monroe Road	17	7			24
14	Dragoon Creek (West Branch)	18		26		44
13	Dragoon Creek at Crescent Road	16	16	27		59
10	Deer Creek	16				16
	LSR at Chattaroy		24			24
3	LSR above Deadman Creek	18	23			41
8	Deadman Creek below Little Deep Creek	15	12			27
16	Little Deep Creek	16				16
	Deadman Creek above Little Deep Creek		22			22
19	Peone Creek	11				11
9	Deadman Creek above Peone Creek	17				17
	Deadman Creek at Holcomb Road		11			11
7	Dartford Creek	17				17
21	LSR at Painted Rock	16	12			28
26	Ecology 55B070 station at mouth of LSR		363			363
	Totals	**379**	**514**	**155**	**12**	**1053**

Comparisons between the FC counts at several sites monitored during multiple studies showed little improvement from the 1990s to 2006. Most sites did not have enough data to perform a robust trend analysis. The trend analysis of FC samples collected by Ecology at the mouth of the LSR indicates a significant increasing trend in FC concentrations from the 1970s to the present (Figure 15). Further analysis of the trend shows the increasing trend is more statistically significant during May through December, especially in July, August, and September. The months of January through April show a significant declining trend. These opposing trends were statistically significant for FC loads as well (Appendix E, Figure E-1).

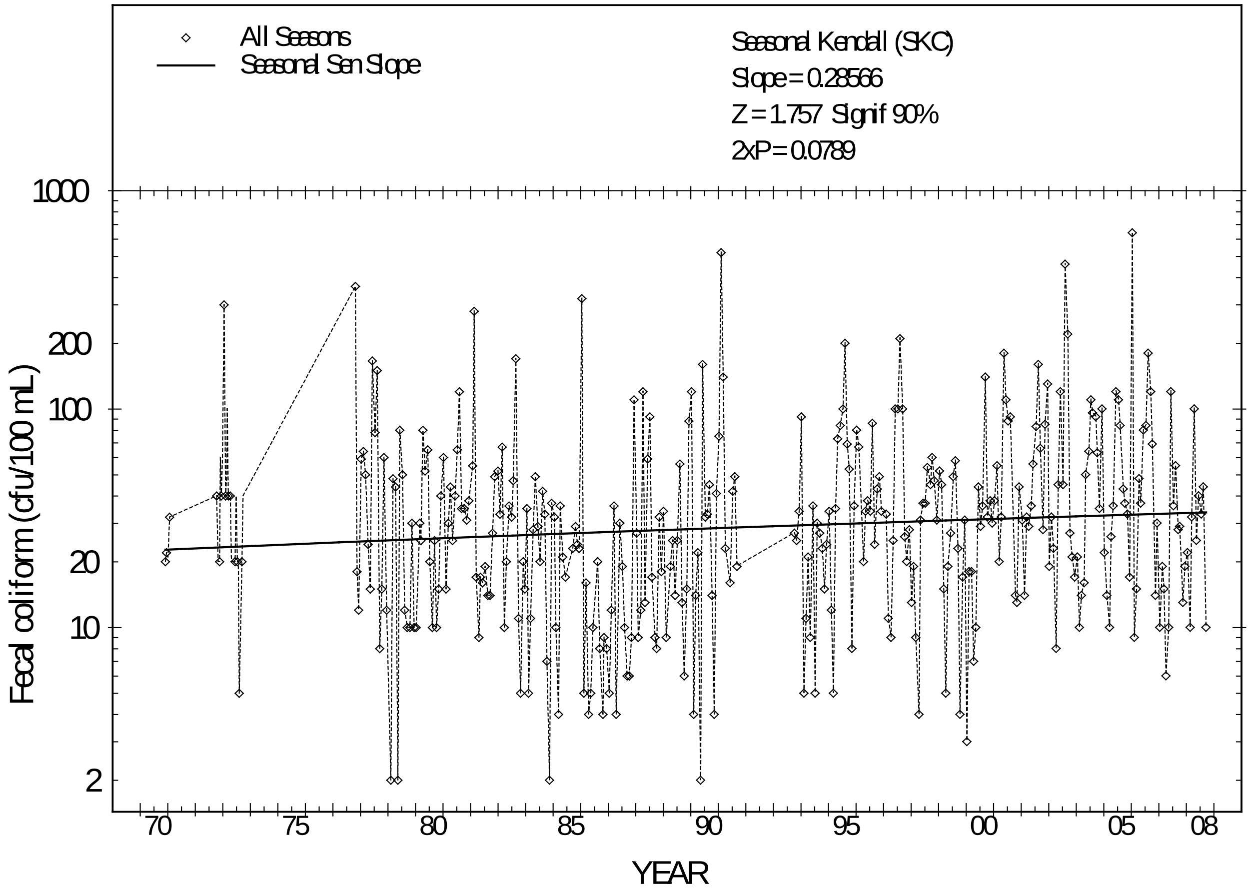

Figure 15. Fecal coliform (FC) trend at the mouth of the Little Spokane River (55B070).

Increased FC counts were common among most sites in the watershed in May to September, and seem to have been a characteristic in the historical data as well. A few sites (Dragoon, Dartford, Deadman, and Little Deep Creeks) had FC criteria compliance problems throughout the entire year. Sites monitored during the 1998-1999 study with greater discharge did not have higher or lower counts than in 2004-2006. No correlation was observed between discharge volume and FC count (n=358 pairs) at the mouth of the LSR (55B070). However, as earlier noted, the site has large groundwater inflows upstream.

The correlation with discharge was difficult to evaluate at other sites in the watershed because FC samples have not been collected during many high-flow conditions. Dragoon Creek at Crescent Road (n=52 pairs) appeared to demonstrate some inverse correlation between discharge and FC counts, but only a few samples have been collected when streamflows have been greater than 50 cfs.

Turbidity and total suspended solids (TSS) results

Turbidity and TSS levels were elevated during a few winter and spring events during the 2004-2006 surveys (Barber et al., 2007). The elevated levels were most apparent in the middle reaches of the mainstem (Deer Park-Milan Road to Dartford) and in some tributaries. The Pend Oreille Conservation District study (2000) and earlier Ecology monitoring data (Ecology, 2009) had similar findings in the reaches below Deer Park-Milan Road during high-flow events in winter and spring (Figure 16). The lone LSR 303(d) turbidity listing is the mainstem LSR reach containing Ecology site 55B082 at RM 10.3 above Dartford Creek.

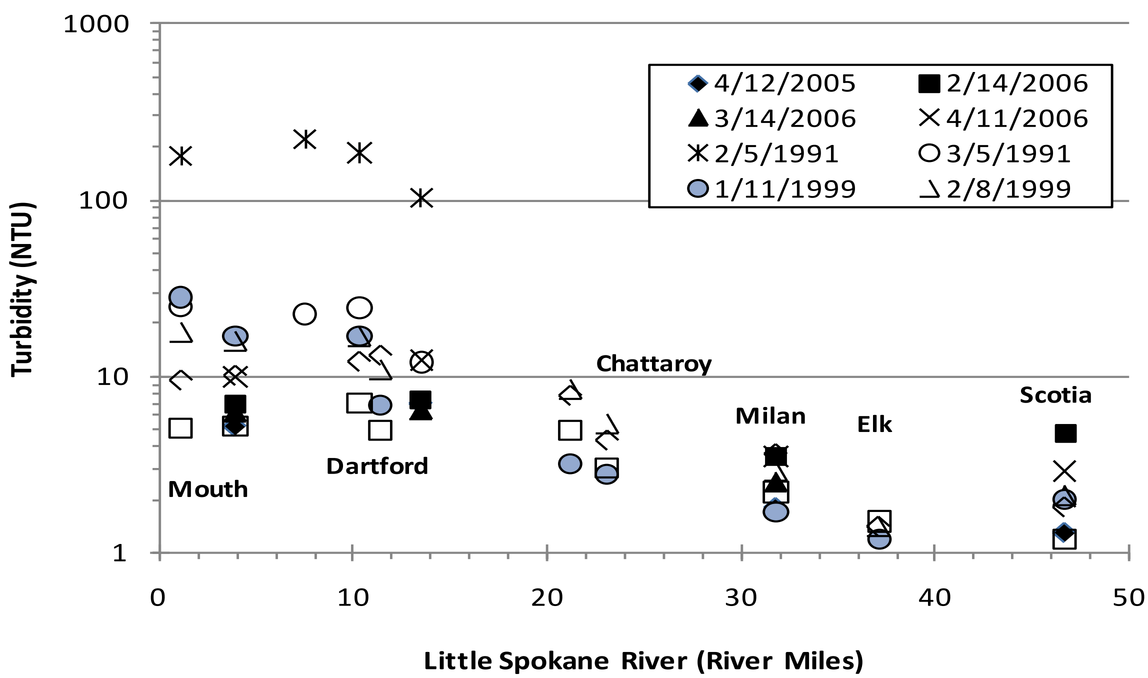

Figure 16. Turbidity values along the mainstem of the Little Spokane River during various water quality surveys.

The reaches of the LSR closest to the mouth also usually see reductions in turbidity values, most likely from the dilution effect of groundwater inflow or settling in slower currents as the river approaches Lake Spokane. Despite lower turbidities, loading analyses suggest TSS sources in the lower reaches deliver additional loads from the LSR to Lake Spokane during high-flow events. The annual turbidity and TSS WQI scores reported for Ecology sites monitored in the lower section (55B070, 55B075, and 55B085) have always been in the “moderate concern” category with one or two “high concern” scores (Ecology, 2010).

Sediment eroded from exposed soils after freezing, followed by snowmelt runoff and streambank cutting are considered the likely causes of increased turbidity and TSS in the watershed. Conventional tillage practices that leave bare soils exposed in the winter and early spring, poor logging practices, poor construction practices, and inadequate treatment of stormwater are some common sources of eroded soils. Channel modifications and poor riparian functionality contribute to streambank erosion in the watershed.

The station at Chattaroy (RM 23.1) was considered a background site in the original 303(d) listing (Hallock, 1996). Violations of the turbidity criteria occurred during several events at downstream sites all the way to the mouth of the LSR (Figure 16). In the 2004-2006 study, the greatest increases in turbidity on the mainstem were observed between Deer Park-Milan Road and above the confluence with Deadman Creek (RM 13.5). Dragoon and Deer Creeks are major tributaries between these mainstem sites with sediment load potential. Ecology (2009) monitoring in 1991 and 1999, and the Pend Oreille Conservation District study (2000) indicated Deadman and Dartford Creeks are also potential sources of sediment loading to the LSR. High turbidity and TSS values were present in all four creeks during spring-flow events in 2006 (Barber et al., 2007). All are considered current areas of redband trout habitat (Figure 4).

Past Ecology ambient monitoring sites within the Middle LSR sub-watershed and Deadman and Dragoon Creeks have reported annual turbidity and TSS WQI scores in the “moderate concern” category (Ecology, 2010). Riparian and channel assessments of the reaches within the sub-watershed area were alternately “properly functioning” and “at risk” (SCCD, 2005b). Streambank sediment, livestock access, road crossings, and residential development were noted sources of sediment.

Tributaries and mainstem LSR reaches upstream of the confluence of the West Branch LSR appear to have fewer problems with turbidity and TSS. The lakes and wetlands may help to settle sediment generated in the Upper sub-watershed. Also, riparian areas appear to be better established in the upper reaches where there is more undeveloped land (SCCD, 2005b). The historical Ecology site at Scotia (55B300) had the only favorable Ecology WQI score (i.e., above 80) for turbidity of all the Ecology sites monitored in the LSR watershed (Ecology, 2010). However, McLellan (2005) observed that reaches downstream of Chain Lake required substrate and channel restoration to improve trout habitat.

TSS loads have demonstrated an overall declining trend based on Ecology monthly monitoring at the mouth of the LSR (55B070) over the past 14 years (Figure 17). This may be due to the declining streamflows (Figure 7) and associated TSS load from the Middle and Upper sub-watersheds previously described. The seasonal trends results are more complex. The TSS loads for June through October show a significant decreasing trend; loads for November through February show no significant trend; and the TSS loads for March through May show a significant increasing trend.

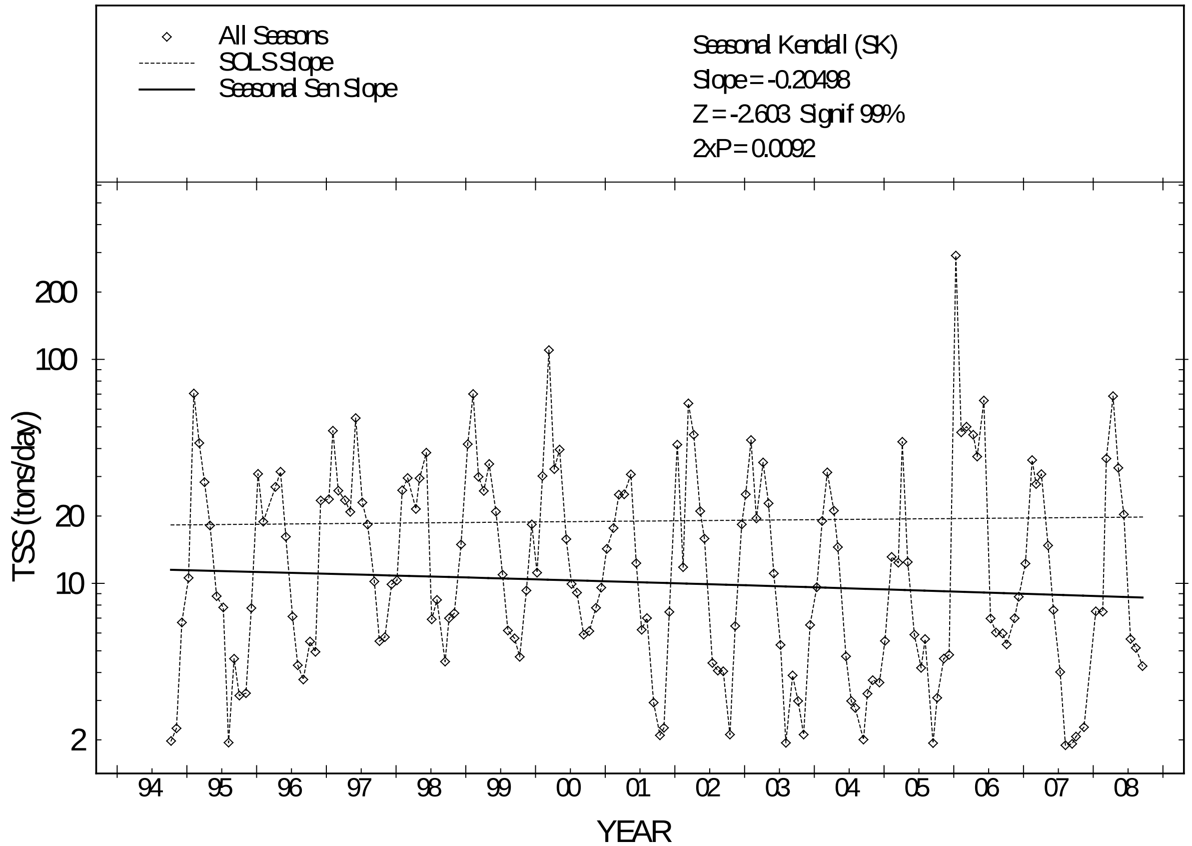

Figure 17. Results of a seasonal Kendall trend analysis depicting declining trend TSS loads based on instantaneous measurements collected by Ecology at the mouth of the Little Spokane River (55B070) from 1994 to 2008.

Recommendations for future study

The historical review by WSU and WWRC (Shrestha et al., 2004) showed that water quality monitoring has occurred somewhat sporadically in the LSR watershed since 1960 (Ecology 2000). There was a wide gap between the sampling years and geographic focus in past studies. As a result, a comprehensive monitoring study was implemented in the watershed in 2004-2006 to examine the extent and severity of water quality problems in the watershed. The historical studies and results provided by Barber et al. (2007) generally characterize FC, temperature, and turbidity for many areas of the LSR watershed.

The 2004-2006 study did not adequately address FC and TSS delivery during a year with many high-flow events. Pollutant loads during runoff events affect average loading estimates. This Ecology TMDL assessment used all available data from as many sources as possible to get a clear picture of long-term trends and the variability in seasonal loads, especially for the Middle LSR sub-watershed and its tributaries.

Because the Ecology sampling location (Ecology Station 55B070) has been the only long-term site routinely monitored over the past decade, trend analyses for all parameters were not possible for any other location. While this is an important reach, this TMDL assessment will show that the mainstem LSR water quality above RM 10 and all the upstream tributaries is not adequately reflected at the mouth because of the significant groundwater inflow in the lower ten river miles of the river. Water quality in the upstream reaches and tributaries appear to be more significantly affected by sediment, fecal bacteria, and heat than the downstream reaches of the river. A monitoring site is needed in this area to evaluate changes in water quality for a majority of the LSR watershed.

A more intensive study of the West Branch LSR will be necessary to determine if temperature and turbidity conditions are natural or if wide-spread problems exist. Since the lotic West Branch LSR is broken up with large wetlands and lakes, the interaction of these features with water quality is complex. Monitoring in the 2004-2006 TMDL study did not have the site intensity to determine if the low turbidities and TSS loads observed at most of the West Branch LSR sites were the exception rather than the rule. Planting system-potential vegetation to shade lotic reaches in the West Branch LSR will bring heat loads into compliance with natural condition temperature criteria, but the impact of open water upstream of these reaches may diminish the usual benefits of the additional shade.

Measuring the effectiveness of local best management practices (BMPs) will require knowledge of sources and monitoring of key indicators. The sources and mechanisms causing severe turbidity and suspended sediment impacts have not been fully evaluated. Assessing streambank erosion and upland sources of sediment delivery to creeks and the LSR are needed. Primary fish habitat areas should be a priority for these assessments. And, additional work to relate fish and macroinvertebrate habitat quality with improvements in water temperatures, turbidity, and TSS would be helpful to assess local BMP effectiveness.

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TMDL Analysis

Fecal coliform bacteria

Analytical framework

The FC evaluation is approached conservatively to account for the naturally wide daily and seasonal variability in bacteria counts. All of the FC sample counts from a site are used to analyze statistical distributions for the site. At sites with historical data, both step trends and monotonic trend analyses were performed on FC counts and streamflows to determine the most recent and stable dataset (i.e., to ensure that high water and drought years are represented equally). Trend analyses, tests for seasonality, and statistical tests for lognormal distributions were performed using WQHYDRO, a statistical software package for environmental data analysis (Aroner, 2007).

The statistical rollback method (Ott, 1995) was used to determine if the FC distribution statistics for individual sites meet the *extraordinary primary contact recreation* criteria in the LSR watershed. Ecology successfully applied this method in other FC bacteria TMDL evaluations (Cusimano and Giglio, 1995; Joy, 2000; Coots, 2002; Joy and Swanson, 2005). The rollback method was applied to the most representative distribution from the trend and seasonal analyses steps. Most distributions are lognormal, so the following assumptions are made with reference to FC criteria:

- The geometric mean of the samples is equal to the transformed mean of the lognormal distribution.
- The transformed 90th percentile of the lognormal distribution is equal to the value that not more than 10% of the counts should exceed.

In most cases the 90th percentile value is more conservative (restrictive or protective) than the ranked observed "not more than 10% of the values to exceed" count. The statistical variability of the distribution is considered in calculating the 90th percentile rather than a simple ranking. Data sets with high variability may have 90th percentile values higher than any of the FC counts observed. Also, statistics based on 10 or fewer samples should be viewed with greater caution, since all types of conditions may not be represented in the dataset.

The geometric mean and 90th percentile statistics for various seasonal or hydrological subsets of data were then calculated and compared to determine the most critical condition at each site. When averaging data for comparison to the criteria, it is preferable to use a 30-day period containing five or more data (Chapter 1173-201A-200(2)(b)(i) WAC). However, the same rule allows averaging data over longer periods if the averaging does not skew the data to mask criteria violations. Because the data sets for most sites in the LSR watershed were small, seasonal or hydrological periods longer than 30 days were explored. Seasonal data from one or more years were also evaluated as a single dataset.

The method is applied as follows:

The geometric mean and 90th percentile statistics are compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is “rolled-back” to match the more restrictive of the two criteria. The 90th percentile criterion is usually the most restrictive. So rolling-back means maintaining the slope of the original lognormal FC data distribution with the 90th percentile of the distribution set at 100 cfu/100 mL.

The rolled-back geometric mean and 90th percentile FC value then define the “target” FC distribution for the site. (The term “target” is used to distinguish these estimated numbers from the actual water quality criteria.) The amount a distribution of FC counts is “rolled-back” to the target values is the estimated percent of FC reduction required to meet the FC water quality criteria and *contact recreation* water quality standards. A detailed graphical example is shown in Appendix D, Figure D-1.

The FC TMDL targets based on the statistical rollback are only in place to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance with state water quality standards is measured as meeting water quality criteria. Any water body with FC TMDL targets is expected to meet both the applicable 50 cfu/100 mL geometric mean and ‘not more than 10% of the samples’ exceeding 100 cfu/100 mL criteria.

A Beales ratio estimator formula (Dolan et al., 1981) was used to calculate the estimated annual FC loads at sites from FC counts and streamflow data (Appendix D). Once the FC rollback percentage for a site was determined, it was applied to the annual load to estimate FC load capacity. The Beales formula provides a better estimate of annual pollutant loads compared to the average of instantaneous loads obtained from a few sampling events.

Compliance with standards

Thirty sites with FC data were evaluated against the Washington State water quality criteria (Table 21). Using the analytical procedures described previously, the critical season for all but two sites was May through September. Increased FC counts with warmer water temperatures and declining streamflows in May through September also bring the highest risk to human health because of the likelihood of more frequent recreational water exposure. Statistics for Little Deep Creek and seven other sites did not meet FC criteria for both seasons, especially Dartford Creek. Only Little Deep Creek statistics were higher in the October through April period than the May through September period (Table 21).

Based on the available data, only eight sites met water quality standards after critical period analyses were performed. Except for the LSR at Chattaroy, the other seven sites were located near the headwaters and near the mouth of the river:

- Four sites on the West Branch LSR with its chain of lakes.
- Two sites on the upper mainstem LSR at sites above RM 23.1.
- One site at RM 3.9 that is heavily influenced by large quantities of groundwater inflow.

Table 21. Geometric mean and 90th percentile values calculated for two seasons from fecal coliform (FC) data collected at sites in the Little Spokane River watershed.

Non-compliance with the state water quality criteria is indicated by bold values.

2008 Water Quality Category*	Location	October-April			May-September		
		Number of Samples	Geometric mean cfu/100 mL	90th percentile cfu/100 mL	Number of Samples	Geometric mean cfu/100 mL	90th percentile cfu/100 mL
1	LSR at Scotia	26	8	43	15	30	86
-	LSR at Elk	7	9	37	5	41	**108**
1	LSR at Milan	18	3	18	10	23	60
2	LSR at Chattaroy	14	9	62	10	26	99
5/1	LSR above Deadman Cr	26	19	**136**	15	**65**	**253**
1	LSR at Painted Rock	18	12	60	10	26	61
5	LSR at mouth	216	23	80	146	37	**125**
1	Moon Creek	18	4	32	5	31	**139**
1	West Branch LSR below Sacheen Lk	11	2	3	5	15	45
1	Buck Creek	13	3	13	5	11	38
1	Beaver Creek	11	2	7	5	30	**105**
1	West Branch LSR above Eloika Lk	11	1	2	5	11	46
2	West Branch LSR below Eloika Lk	18	2	7	10	23	89
5	Dry Creek	11	10	**163**	5	31	**184**
5	Otter Creek	11	24	97	4	**181**	**1014**
1	Bear Creek	12	4	14	5	**58**	**131**
5	Deer Creek	11	13	72	5	**260**	**784**
5	Dragoon Creek at Oregon Road	16	33	**213**	16	**312**	**1640**
1	Dragoon Creek at Dahl Road	11	7	21	5	38	**157**
2	Dragoon Creek at Crawford Rd	18	**57**	**198**	16	**369**	**1972**
2	Dragoon Creek at Monroe Rd	15	16	53	9	**153**	**443**
5	West Branch Dragoon Creek	27	20	**122**	17	**146**	**887**
5/2	Dragoon Creek at Crescent Rd	33	14	96	26	**81**	**338**
5	Deadman Creek at Holcomb Rd	6	6	41	5	**52**	**672**
5	Deadman Creek at Heglar Rd	12	8	52	5	**190**	**328**
2	Peone Creek	8	6	93	3	**166**	**889**
5	Deadman Creek above Little Deep Cr	13	12	33	9	**84**	**228**
5	Little Deep Creek	11	**109**	**1835**	5	**470**	**1150**
5	Deadman Creek at mouth	18	23	**113**	9	**129**	**598**
2	Dartford Creek	12	21	**184**	5	**108**	**221**

* The Ecology 2008 Water Quality Assessment found at http://www.ecy.wa.gov/programs/wq/303d/2008/index.html

All 12 sites that were Category 5 (303(d) list) in the 2008 Water Quality Assessment (2008 WQA) in Table 1 were out of compliance with the *extraordinary primary recreational contact* criteria (Table 21). Sites at Deadman Creek above and below Little Deep Creek were combined into one Category 5 listing in the 2008 WQA. Dragoon Creek at Crescent Road and the LSR above Deadman Creek have conflicting categories. Four sites in 2008 WQA Category 2, "Waters of Concern", are out of compliance, and two Category 2 sites are not, although the 90th percentile for the LSR at Chattaroy is at the maximum criterion. Four sites in Category 1, "Meets tested standards for clean waters," did not meet criteria, and six other Category 1 sites did. The LSR at Elk was not categorized in the 2008 WQA and did not meet criteria.

The FC data appeared to show that storm events were not important drivers of criteria violations at most sites in the watershed. Except for a few sites, criteria violations occurred more often in the low-flow period when fewer storm events occur. This is uncommon compared to Hangman Creek (SCCD, 2005a), but similar to the Colville River findings (Coots, 2002). Stormwater runoff is often a transport mechanism for FC bacteria generated near the stream channels by livestock, or delivered by stormwater infrastructure.

The results suggest that either the FC sources are primarily seasonally present, or some constant sources in the watershed are diluted at higher flows. Some sources of seasonal FC bacteria present in the watershed are livestock and pets with direct access to waterways and riparian areas. Critical season FC counts could be decreased by providing water for livestock away from streambanks and channels. Areas subject to runoff would see FC reductions during storm-event loading as well if livestock are kept out of the riparian areas. Another possible FC source could be failing onsite septic systems or sanitary sewer misconnections to stormwater drains. Failing onsite systems with a direct discharge to the stream might be more noticeable downstream during low-flow conditions.

Loading capacity

EPA regulations define loading capacity as "the greatest amount of pollutant loading that a water body can receive without violating water quality standards" [40CFR§130.2(f)]. The loading must be expressed as mass-per-time or other appropriate measure. Also, the critical conditions that cause water quality standard violations must be considered when determining the loading capacity.

Washington State FC bacteria TMDLs use a combination of mass-per-time units and statistical targets to define loading capacities. This is necessary since mass-per-time units (loads) do not adequately define periods of FC criteria violations. Loads are instructive for identifying changes in FC source intensity between sites along a river, or between seasons at a site. However, FC sources are quite variable. Different sources can cause FC criteria violations under different loading scenarios (e.g., poor dilution of contaminated sources during low-streamflow conditions or increased source loading during run-off events).

The statistical targets provide a better measure of the loading capacity during the most critical period. The FC loading capacities at 30 sites in the LSR watershed are based on the applicable two statistics in the state FC criteria (e.g., the geometric mean and the value not to be exceeded by more than 10% of the samples). As discussed in the *Analytical Framework* section, the 90th percentile value of samples is used in TMDL evaluations for the latter criteria statistic. The FC TMDL target loading capacities in Table 22 are either the current annual statistics in compliance with criteria, or they are the annual statistics that estimate the reductions necessary to meet the criteria.

Table 22. Annual fecal coliform (FC) loading capacities at sites in the Little Spokane River watershed expressed as percentage reduction and statistical target values.

River Mile	Location	Required FC Reduction	FC Target Capacity (cfu/100 mL)	
			90th percentile	Geomean
46.7	LSR at Scotia Road	-	71	13
37.1	LSR at Elk	7%	75	15
31.8	LSR at Deer Park-Milan	-	44	7
23.1	LSR at Chattaroy	5%	80	14
13.5	LSR above Deadman Cr.	60%	70	12
3.9	LSR at Painted Rock	-	68	16
1.1	LSR at mouth	20%	92	28
	Moon Creek	28%	28	4
WB 15.6	West Branch LSR below Sacheen Lake	-	15	4
	Buck Creek	-	21	4
	Beaver Creek	5%	34	5
WB 7.3	West Branch LSR above Eloika Lake	-	12	2
WB 3.1	West Branch LSR below Eloika Lake	-	38	5
	Dry Creek	46%	100	8
	Otter Creek	90%	26	4
	Bear Creek	24%	48	7
	Deer Creek	87%	46	4
~ Dr 21	Dragoon Creek at Oregon Road	94%	64	7
Dr 15.3	Dragoon Creek at Dahl Road	36%	36	7
Dr 15.0	Dragoon Creek at Crawford Road	95%	46	7
Dr 14.5	Dragoon Creek at Monroe	77%	56	9
	West Branch Dragoon Creek	89%	43	5
Dr 0.2	Dragoon Creek at mouth	70%	71	9
De 12.1	Deadman Creek at Holcomb Road	85%	51	3
De 8.2	Deadman Creek at Heglar Road	74%	62	7
	Peone Creek	71%	100	4
De 0.5	Deadman Creek above Little Deep Creek	56%	58	11
	Little Deep Creek	95%	100	8
De 0.13	Deadman Creek at mouth	83%	44	7
	Dartford Creek	63%	100	13

The percentage reduction values in Table 22 indicates the relative degree the water body is out of compliance with criteria (i.e., how far it is over its capacity to receive FC source loads and still provide the designated beneficial uses). Seven sites currently meet their loading capacities and do not require FC reduction values. Thirteen sites require aggressive reductions in FC sources because they have a high FC percentage reduction value (greater than 60%). Six sites with minor problems have a low FC percentage reduction value (less than 30%). Four sites are transitional because they have reduction values between 30% and 60%. However, LSR sites with limited data have less reliable load capacity targets. To confirm their level of compliance they require more data collected over a wider range of climatic and hydrologic conditions.

A load duration analysis was performed to evaluate the expected FC load improvement after TMDL activities are implemented in the watershed (Figure 18). A more detailed explanation of the load duration graph can be found in Appendix D. The results suggest that when a 20% reduction is achieved at the mouth of the LSR, FC criteria are met under all flow and seasonal conditions. Not all counts are below 100 cfu/100 mL. But, not more than 10% of the total counts, or the counts in the low (60% to 100% flow exceeded), middle (30% to 60% flow exceeded) or high (0% to 30% flow exceeded) flow seasons are above this criterion. May through September (critical period) improvements are reflected in counts reduced in the low and middle flow ranges.

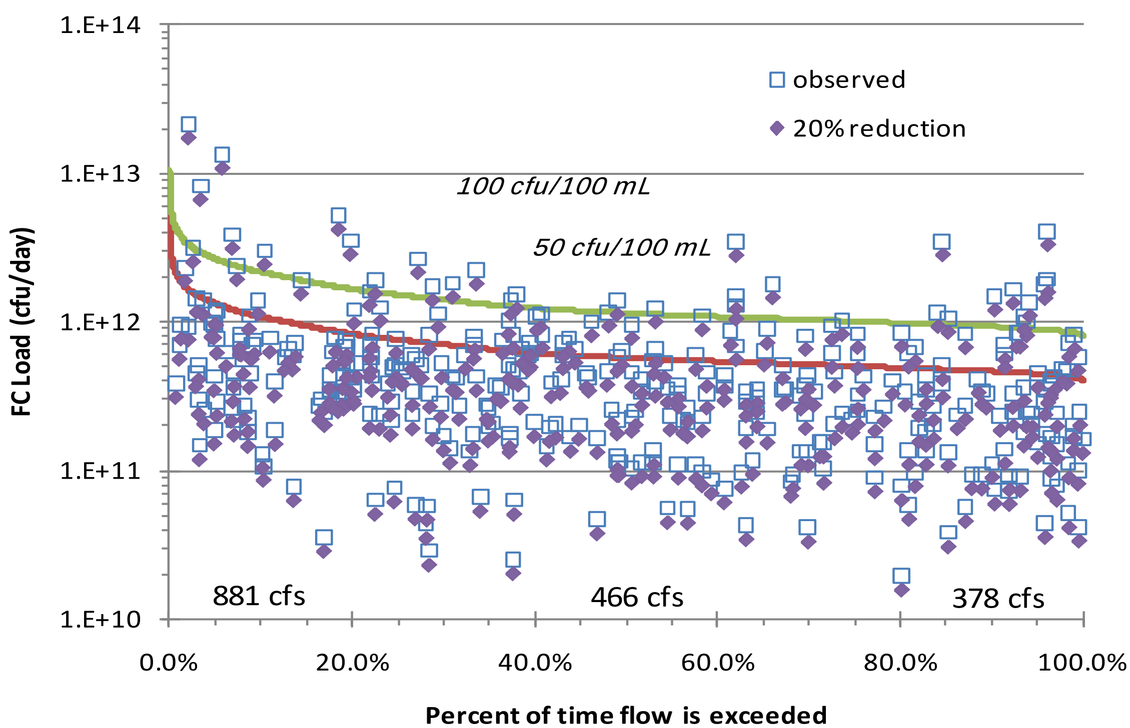

Figure 18. A set of fecal coliform (FC) criteria load duration curves with observed FC loads at the mouth of the Little Spokane River (55B070) from 1971 to 2006 compared to loads if they had been reduced by 20% under the TMDL recommendation.

Based on the findings in Table 22, the estimated average daily FC load capacity at each evaluated site is presented in Table 23. The loading calculations are based on estimated average annual streamflows, not critical season streamflows. The data used for the load balance are not detailed enough to determine where (1) FC die-off affects loads and (2) new sources are located along the LSR or larger tributaries with multiple sites. Therefore, FC loads upstream to downstream do not exactly balance, but they are descriptive of the general pattern in the watershed.

Table 23. Estimated annual fecal coliform (FC) loading capacities for sites evaluated in the Little Spokane River watershed.

River Mile	Location	FC Reduction	Average Daily FC Capacity Load cfu/day x 10^{10}
46.7	LSR at Scotia Road	-	1.4
37.1	LSR at Elk	7%	3.8
31.8	LSR at Deer Park-Milan	-	4.3
23.1	LSR at Chattaroy	5%	8.0
13.5	LSR above Deadman Cr.	60%	6.7
3.9	LSR at Painted Rock	-	36
1.1	LSR at mouth	20%	62
	Moon Creek	28%	0.10
WB 15.6	West Branch LSR below Sacheen Lake	-	0.12
	Buck Creek	-	0.37
	Beaver Creek	5%	0.11
WB 7.3	West Branch LSR above Eloika Lake	-	0.33
WB 3.1	West Branch LSR below Eloika Lake	-	0.58
	Dry Creek	46%	0.66
	Otter Creek	90%	0.03
	Bear Creek	24%	0.14
	Deer Creek	87%	0.34
~ Dr 21	Dragoon Creek at Oregon Road	94%	0.06
Dr 15.3	Dragoon Creek at Dahl Road	36%	0.32
Dr 15.0	Dragoon Creek at Crawford Road	95%	0.18
Dr 14.5	Dragoon Creek at Monroe	77%	0.40
	West Branch Dragoon Creek	89%	0.35
Dr 0.2	Dragoon Creek at mouth	70%	2.2
De 12.1	Deadman Creek at Holcomb Road	85%	-
De 8.2	Deadman Creek at Heglar Road	70%	0.57
	Peone Creek	71%	0.04
De 0.5	Deadman Creek above Little Deep Creek	56%	1.0
	Little Deep Creek	95%	0.16
De 0.13	Deadman Creek at mouth	83%	1.1
	Dartford Creek	63%	0.23

The recommended FC reductions are based on the critical season statistics identified in Table 21. The average daily statistics in Table 22 protect water quality for the critical season. The severity of the bacteria contamination problem during the critical season provides water quality managers and local citizens a sense of what type of FC sources may require the most work.

The large FC load increase between LSR above Deadman (RM 13.5) and LSR at Painted Rock (RM 3.9) is due to the large groundwater volume inflow. The annual geometric mean FC counts at these two sites are estimated to be 12 cfu/100 mL and 16 cfu/100 mL, respectively, to meet the loading capacity target. The average load is higher at the mouth of the LSR because of the larger flows monitored and sampled over several more years than at any other site in the watershed.

Temperature

Analytical framework

The theory and physical laws governing temperature and heat in streams are outlined in Appendix B. Equations based on these concepts have been applied to various tools and models used by scientists to simulate water temperature data. Ecology's scientists calibrate these models to local conditions after collecting information from the stream, lands surrounding the stream, local weather stations, and maps. Then historical, current, and future stream temperatures are simulated to find the best ways to evaluate and protect aquatic organisms against extreme temperature effects.

The temperature TMDL is built from work previously conducted for the LSR under the Watershed Planning process (POCD, 2000; SCCD, 2003), Ecology ambient monitoring data (Table 18), and data collected under an Ecology contract with WSU/WWRC (Barber et al., 2007). Additional work conducted for the Spokane County Conservation District (2003) by Canwell (2003) and Christian (2003) documented habitat and riparian vegetation characteristics important to temperature control. WSU/WWRC scientists also analyzed LSR water temperature conditions using mathematical models (Barber et al., 2007).

WSU/WWRC scientists used many tools and methods similar to Ecology scientists to estimate effective shade and system-potential effective shade for the LSR temperature analysis (Barber et al., 2007). Effective shade is a combination of topographic features and riparian vegetation capable of shielding the river from solar heating. System-potential effective shade is the estimated maximum geographic and mature riparian vegetation shade given soil, climate, elevation, hydrologic properties, and native vegetation characteristics normally found in an undisturbed riparian area. The system-potential shade is compared to the existing effective-shade condition to determine if additional shading is necessary to meet the thermal loading capacity of the water body. The thermal-loading capacity is then compared to the designated water quality standard.

Figure 19 shows how effective shade from the two conditions is provided as input to a QUAL2K model (Barber et al., 2007). QUAL2K is a river and stream water quality model which has been widely used for studying the impact of conventional pollutants on free flowing streams (Chapra and Pelletier, 2003). The QUAL2K model is designed to simulate the hydrological and water quality conditions under influence of temperature and hydrodynamic factors. It is a one-dimensional model which simulates basic stream transport and mixing processes using steady-state hydraulics. The model incorporates climate conditions, shade, physical channel and hydrologic characteristics, and groundwater influences to estimate stream temperatures.

Observed and system-potential temperatures on the mainstem LSR from near Scotia (RM 42.8) to the LSR mouth were modeled using QUAL2K by WSU/WWRC scientists (Barber et al., 2007) with some later revisions by Ecology scientists. Temperatures along the West Branch LSR and main tributaries were not modeled using QUAL2K. However, current and system-potential shade were estimated.

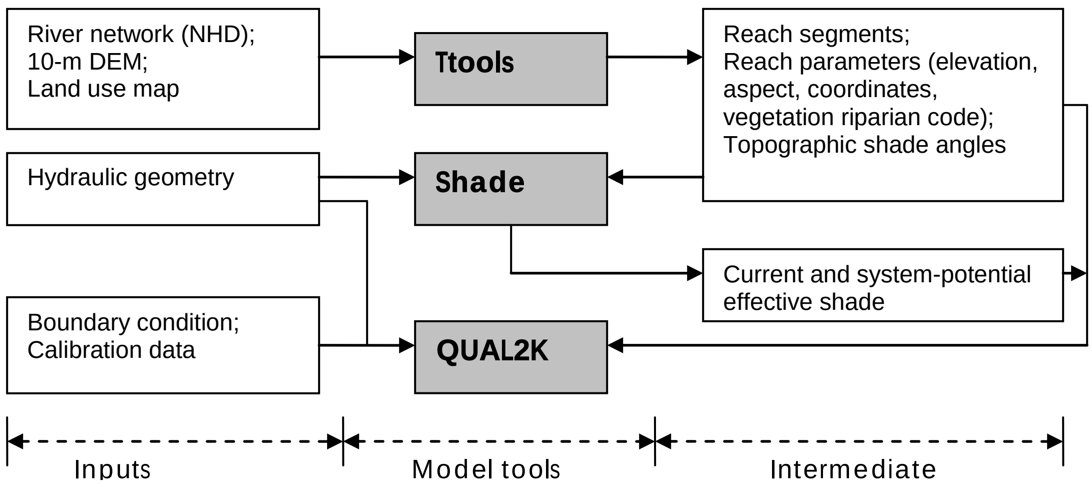

Figure 19. Analytical framework of GIS and modeling analysis for water temperature simulation (Barber et al., 2007).

Riparian vegetation and shade modeling

WSU scientists estimated the effective vegetation shade along a 90-meter-wide riparian corridor using two data sources:

- 1:250,000 scale quadrangles of land use/land cover geographical information retrieval and analysis system (GIRAS) digital spatial data (Anderson et al., 1976; USGS, 1994).
- WSU/WWRC tree survey data measured on August 19, 2005.

WSU/WWRC scientists generalized the riparian vegetation into nine classes (Table 24). The vegetation class given to a reach was not varied over the width of the corridor. In riparian reaches with forest land use, the heights and densities of trees were interpolated from the measurements taken at similar areas during the tree survey (Table 25). For the riparian area with other land use types (e.g., wetland, rangeland, and residential land), a riparian shrub/scrub type was applied. The height of vegetation was assumed to be 2.95 ft (0.9 m) with a density of 25% (Barber et al., 2007). The barren category was applied at Chain Lake and when the river ran along railroads and highways. These two categories comprised 47% of the current riparian condition (Table 24).

Table 24. Riparian vegetation classes and statistics used by WSU/WWRC for current conditions along the Little Spokane River (Barber et al., 2007).

Description	Height (m)	Density (%)	Overhang (m)	Reach Count	Percentage of riparian
Barren/water	0.0	100%	0	40	19%
Shrub/scrub	0.9	25%	0.1	61	28%
Dense tall shrub	4.3	50%	0.6	3	1%
Mixed small sparse	7.7	33%	1	50	23%
Mixed medium sparse	12.9	25%	1.7	21	10%
Deciduous medium sparse	15.6	33%	2	14	7%
Deciduous medium dense	18.6	60%	2.4	7	3%
Conifer large sparse	23.2	25%	3	2	1%
Conifer large dense	24.1	50%	3.1	17	8%

Table 25. Heights and densities of riparian vegetation from the WSU tree survey, August 2005 (Barber et al., 2007).

Tree survey site #	Longitude	Latitude	Description	Water quality site #	Average vegetation height (ft)	Average canopy density
1	-117.1524	48.1083	LSR above Scotia	1	1.97	NA
2	-117.1530	48.1056	LSR below Scotia	1	49.18	NA
3	-117.2440	48.0408	LSR below Chain Lake	NA	44.59	NA
4	-117.3625	48.0070	Eloika Lake Outlet	23	31.48	48%
5	-117.3993	48.0606	Eloika Lake Inlet	22	112.79	58%
6	-117.4228	48.0968	West Branch LSR at Beaver Creek	5	98.03	71%
7	-117.4182	48.1192	West Branch LSR at Buck Creek	6	75.08	65%
8	-117.2737	48.1180	Moon Creek	17	85.57	80%
9	-117.3527	48.1354	West Branch LSR below Sacheen Lk	20	75.74	65%
10	-117.3336	47.9696	LSR at Milan-Elk Rd	2	33.51	25%
11	-117.3246	47.9853	LSR above West Branch	NA	14.26	50%
12	-117.3175	47.9856	LSR above Otter	NA	25.21	33%
13	-117.2952	47.9864	Dry Creek	15	76.00	76%
14	-117.3745	47.8425	LSR at Woodland Bridge	NA	78.95	50%
15	-117.3739	47.8753	Dragoon Creek at mouth	13	76.07	40%
16	-117.3530	47.8917	LSR at Chattaroy	NA	3.02	25%
17	-117.3416	47.9297	Bear Creek at Milan Rd	NA	57.05	64%
18	-117.4871	47.9603	Dragoon above Deer Park	11	26.23	50%
19	-117.4960	47.9527	Dragoon below Deer Park	12	70.16	40%
20	-117.4984	47.9321	Dragoon at Burroughs Rd	NA	17.70	30%
21	-117.4984	47.9157	West Branch Dragoon	14	23.61	34%
22	-117.4654	47.8860	Dragoon at Dalton Rd	NA	26.98	20%
23	-117.4233	47.8880	Dragoon at N Dragoon Rd	NA	32.79	7%
24	-117.3825	47.7982	LSR above Deadman Creek	3	51.25	33%
25	-117.4962	47.7809	LSR at Rutter Parkway	21	60.92	60%
26	-117.5299	47.7832	LSR at mouth	70	75.93	25%

WSU then developed topographic shade and the river path and geometry with GIS spatial data sets (Figure 19):

- 10-meter digital elevation model (DEM) data supplied by Earth and Space Sciences, University of Washington.
- 1:100,000 scale National Hydrography Dataset (NHD) (USGS, 2005).

  They used riparian vegetation and topographic heights and river data as input for GIS and modeling analysis in two specialized software tools (Figure 19):
- Oregon Department of Environmental Quality's (ODEQ) Ttools extension for ArcView (ODEQ, 2001) was used to sample and process GIS data for input to the Shade model.
- Shade model (Ecology, 2003) was used to estimate effective shade along the mainstem LSR from Scotia to the mouth. Effective shade was calculated at 100-meter intervals along the streams and then averaged over 1000-meter intervals.

WSU/WWRC scientists verified that all input data for the Shade model were longitudinally referenced, allowing spatial inputs to apply to certain zones or specific river segments (Barber et al., 2007). The model self-adjusted the shading (based on the angle of the sun) when Ecology changed the simulation date to August 9, 2005 from July 23, 2003 because more field observation data were available for the August date.

WSU scientists analyzed current and system-potential effective shade in tributaries using the GIS tools and the riparian vegetation survey data (Barber et al., 2007). The observed temperatures in the tributaries were not calibrated to a QUAL2K model. Current effective shade for tributaries without vegetation survey data was estimated by using the average tree height and density of the survey data, 15 meters and 40%, respectively.

Little Spokane River (LSR) QUAL2K model

Water temperatures in three of the four sub-areas of the LSR were simulated using QUAL2K. The WSU/WWRC model included the Upper, Middle, and Lower LSR (Barber et al., 2007). The West Branch LSR was not included. The headwater boundary for the model in the Upper LSR was water quality monitoring site #1 at Scotia Road. The simulation length of the mainstem LSR was 68.87 km (42.8 miles). The mainstem LSR was divided into 214 computational elements. A length of 322 m (1,056 ft) was assigned to each computational element. Tributaries and the West Branch LSR were not modeled explicitly, but were represented as point sources to the mainstem LSR. Groundwater was entered as diffusive input at three locations.

Based on a review of river mile points and landmarks, the last reach of the WSU/WWRC model should be near Rutter Parkway, 4.1 miles upstream of the mouth. The model appears to have the correct distance from Scotia to the confluence with the West Branch LSR. The divergence in distances starts at the Deer Park-Milan Road Bridge, where the channel begins to meander more. Relative distances between landmarks below Deadman Creek appear to be correct.

The reason for the differences in distance could be the use of LSR hydrography coverage interpreted by GIS. Locations and distances in the model were not revised because shade and channel placements were based on the hydrography coverage. The model discrepancies should not seriously alter the primary findings of the temperature model.

Colbert landfill treatment and WDFW Spokane Hatchery effluents were not designated inputs to the WSU/WWRC temperature model, but were added by Ecology. The effluents from these sources are small compared to the volume of the receiving water. Since they are groundwater or spring sources, they tend to be cooler than low-flow maximum water temperatures in the LSR, and cooler than the 16 ºC criterion. WDFW Spokane Hatchery effluent temperatures measured in 2009 was never above 12.7 ºC (Ross unpublished data, 2009). For several years, summer Colbert landfill-treated effluent temperatures have been 11.0 to 13.2 ºC (Spokane County, 2010).

Calculated shade output from the Ttools and Shade modeling was entered into the QUAL2K model and run under various flow and climate scenarios. Riparian microclimate functions were not considered in the model runs.

Temperature model calibration and confirmation

Riparian vegetation and shade conditions

Although the riparian zone of the LSR is reported to be fairly well-vegetated compared to other eastern Washington rivers of similar size, it has gone through some changes. Agricultural, residential, transportation, and forest harvest uses have disturbed the native riparian vegetation and function. A comparison of 2002 riparian conditions to estimated conditions based on historical maps, altitude, native vegetation, soil, and slope characteristics was conducted by Christian (2003). He estimated the mainstem LSR had lost 61% of its natural riparian area. Major tributaries to the LSR fared worse, with losses from 70% in Dragoon Creek to 93% in Little Deep Creek.

The 41 riparian reaches assessed on the mainstem LSR had intact widths of 21.6 to 1640 ft (Christian, 2003). The 26 assessed reaches on the West Branch LSR had similar statistics. The broad wetland areas in the lower reaches below Dartford, and the lake-like areas in the upper reaches of the watershed above the West Branch had the widest average intact riparian zones along the mainstem LSR. The narrowest average intact riparian zones of the LSR were in the middle reaches between Dragoon Creek and Deadman Creek.

Christian characterized vegetation in cooperation with the macroinvertebrate studies performed by Canwell (SCCD, 2003). Vegetation identification and canopy density measurements in 2002 were conducted at 25 sites throughout the watershed (SCCD, 2003). Heights were generally categorized, but maximum heights were not measured. WSU/WWRC also performed some vegetation density and height measurements in 2005 (Barber et al., 2007). As described earlier in the *Riparian shade and vegetation modeling* section, WSU/WWRC measured vegetation heights and canopy density at 26 sites throughout the watershed (Table 25).

As shown in Figure 20, residential areas in the Middle LSR sub-watershed commonly had willows, cherry trees, grass, and shrubs (SCCD, 2003). Agriculture and transportation intrusions into riparian areas of the Middle sub-watershed were also more common and had few medium-height or tall trees.

Figure 20. Typical riparian vegetation along the Middle Little Spokane River sub-watershed.

WSU/WWRC and Christian (SCCD, 2003) had similar highly variable canopy densities in the lower reaches of the LSR (Figure 21). Average canopy closure levels varied by riparian vegetation heights and densities and by the width of channel. For example, some wider channels in the Lower LSR sub-watershed were not shaded in the center of the channel but were well shaded along the banks by pine, willow, and alder. Other bank-side areas were not well shaded because riparian vegetation was shorter wetland forbs and shrubs such as roses, sedges, and rushes.

More areas with taller and denser stands of trees were present in the Upper LSR sub-watershed. But like the wetlands in the Lower LSR, some lake or wetland areas of the Upper LSR around Chain Lake were not well shaded because of a wider channel with shorter wetland vegetation.

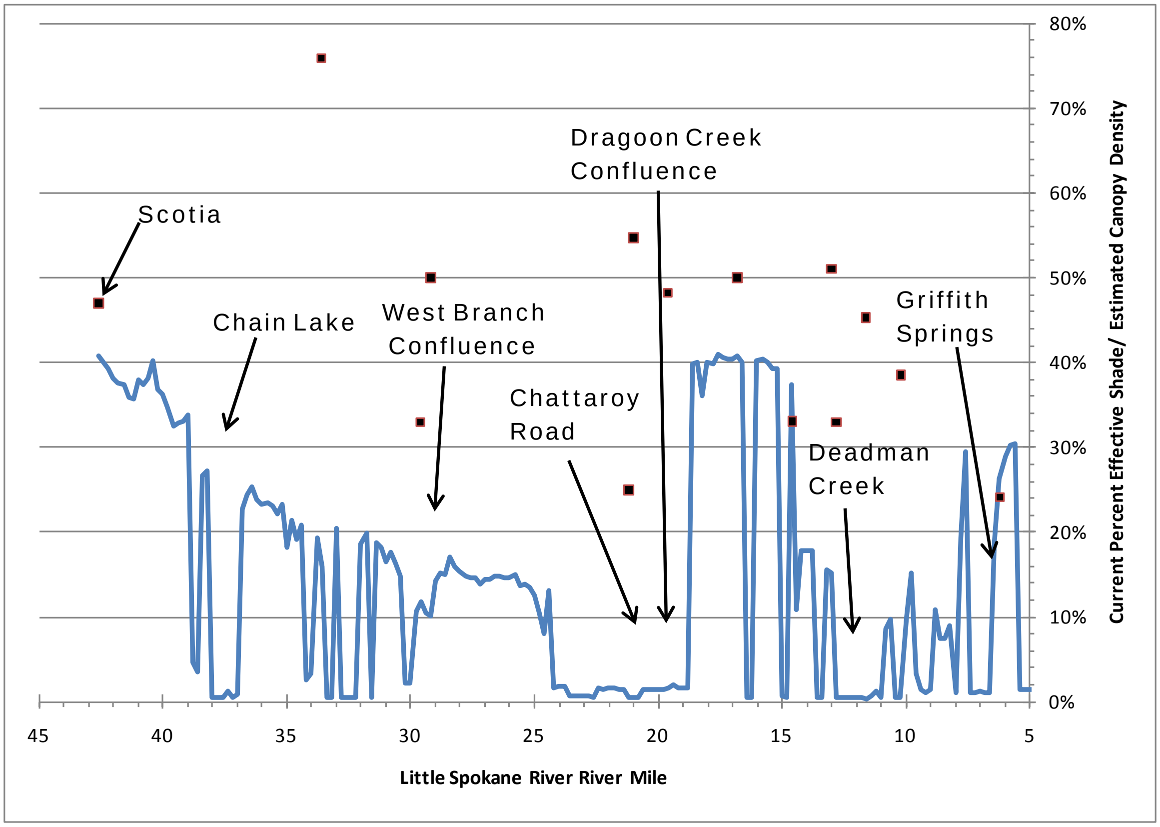

Figure 21. Current shade conditions along the Little Spokane River based on effective shade model results (line), and EWU and WSU field transect canopy density readings (■) in 2002 and 2005, respectively (Barber et al., 2007; SCCD, 2003).

These riparian-vegetation and channel-width characteristics are evident in the effective shade model results calculated by the Shade model using the GIS tools described earlier (Figure 19). Also evident is a change in mainstem LSR channel orientation from east/west, to north/south, and back to east/west. Average effective shade values were 20% in the Upper LSR sub-watershed; 13% in the Middle LSR sub-watershed from the confluence with the West Branch to Dartford Creek; and 6% in the Lower LSR sub-watershed.

Canopy densities from the field were generally higher than the effective shade model results (Figure 21). The values from the two techniques follow a similar longitudinal pattern. The differences may be because average canopy density statistics are biased towards shaded stream edges or because WSU/WWRC applied low vegetation heights to non-forested riparian land uses in the Shade model. The Shade model effective shade results should be seen as a very rough estimate of current effective shading.

Climate and hydrology conditions

The QUAL2K model requires hourly air temperatures, dew point temperatures, wind speeds, and cloud cover as inputs. To generate consistent results of model calibration and scenario analyses, WSU/WWRC scientists used the climate data collected at Deer Park Airport (DEW) and

Spokane International Airport (GEG) during August 9, 2005 and summarized them in Appendix C, Table C-1. The DEW data were applied from the headwater at river kilometer (RKM) 68.87 to RKM 33.5 near the Deer Creek confluence. The GEG data were applied from the RKM 33.5 to the mouth of the LSR. The hourly weather station data were available at www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html.

WSU/WWRC installed a weather station on July 28, 2005 at Site #1 near Scotia. Wind speeds at DEW and GEG were much higher than the values recorded at the WSU station. The measurements at airports reflected wind speeds over a large open and flat space rather than more protected woodland valleys. Therefore WSU/WWRC scientists used the average summer wind speed of 0.9 knots (0.46 m/s) measured during 2005 at the WSU/WWRC weather station.

Hourly water temperature and daily average streamflow are important boundary conditions at the headwater site for the model, Little Spokane River Site #1 at Scotia. Unfortunately, only instantaneous water temperature and streamflow measurements at Scotia were reported for August 9, 2005 when the modeling task was begun (Barber et al., 2007). Therefore, WSU/WWRC scientists estimated hourly water temperatures for the site from diel water temperatures observed on the same day downstream at Little Spokane River Site #3 above Deadman Creek. Ecology scientists made revisions to the headwater hourly temperatures after reviewing additional Scotia water temperature data previously unavailable to WSU/WWRC scientists (Figure 22). An average headwater discharge of as 18.3 ft^3/s (0.52 m^3/s) was obtained from the Spokane County Conservation District who maintained the Scotia (Site #1) gage.

WSU/WWRC scientists calculated the half-range of water temperature ([daily maximum - daily minimum]/2) from continuous water temperature measurements at the mouth of tributary sites, or estimated the data by extrapolating from instantaneous measurements. The latter results were revised by Ecology from additional data sources and used as inputs to the QUAL2K model simulation for the calibration condition (Table 26).

WSU scientists set groundwater temperature for the critical condition at 53.6 ^oF (12 ºC), as suggested by the temperature TMDL studies conducted in the Little Klickitat River watershed and Wind River watershed (Brock and Stohr, 2002; Howard and Pelletier, 2002). More recent water temperature data collected from Griffith Springs suggests a 11.5 ºC groundwater temperature is more appropriate (Ross unpublished data, 2009). The revision was made in the QUAL2K model by Ecology scientists.

Streamflow measurements for August 9, 2005 were obtained from gaged and ungaged sites to construct a flow budget for the QUAL2K model (Table 27). The Spokane County Conservation District continuously recorded streamflows at gages at Scotia and the mouths of Otter, Dragoon, and Deadman Creeks. Instantaneous streamflow measurements were taken at other tributary monitoring sites sometime between 9 a.m. to 3 p.m. Mean daily streamflows from continuous measurements at the USGS gages were also obtained (USGS, 2006).

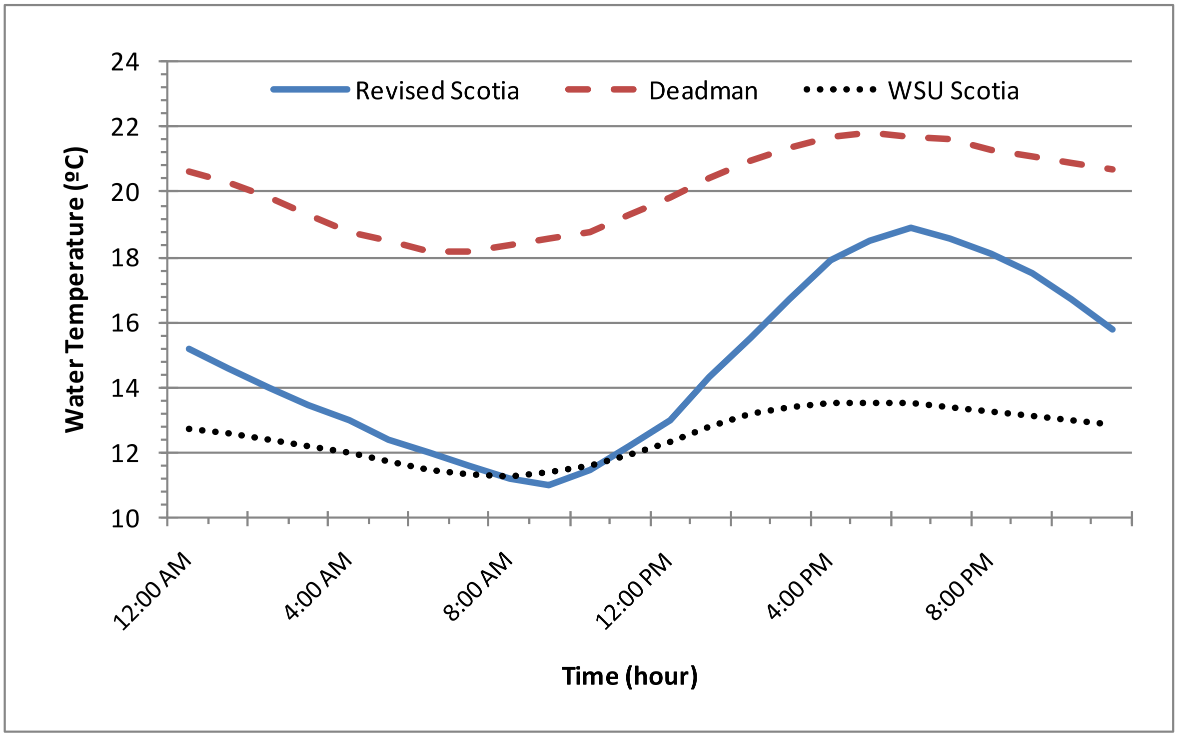

Figure 22. Hourly water temperatures at headwaters (Scotia) estimated by WSU (Barber et al., 2007) and revised by Ecology for the QUAL2K model simulation from data recorded in the Little Spokane River above Deadman Creek on August 9, 2005.

Table 26. Water temperatures in tributaries used in the QUAL2K model simulation.

Site ID	Tributary	Distance from mouth (km)	Water temperature (ºC)	
			mean	half range
15	Dry Creek	55.7	11.77	2.21
18	Otter Creek	53.9	14.70	1.75
23	West Branch LSR	52.9	23.90	2.48
4	Bear Creek	44.7	18.10	5.0
10	Deer Creek	37.0	15.70	2.54
13	Dragoon Creek	34.3	18.00	2.86
8	Deadman Creek	21.1	16.70	2.28
17	Dartford Creek	17.4	14.60	1.62

Diffusive groundwater sources were estimated by differences between the gaged mainstem sites after accounting for tributary inflows. WSU/WWRC scientists (Barber et al., 2007) calibrated groundwater flow rates for three reaches with the August 9, 2005 flow condition (Table 27). For example, a comparison of flow rates at USGS gages 12431000 and 12431500 yielded an estimated groundwater inflow gain of 260 cfs (7.36 m^3/s). Ecology scientists slightly adjusted the placement of the groundwater inputs to better match the observed gaging values.

Table 27. Little Spokane River water balance for the August 9, 2005 QUAL2K model calibration simulation.

Site ID	Mainstem reach/tributary	Distance from mouth (km)	Calibration (ft^3/s)		Observed (ft^3/s)
			Tributary source	Diffusive source	
1	LSR at site #1	75.1	18.3		18.3
15	Dry Creek	55.7	1.4	35	
18	Otter Creek	53.9	0.2		
23	WB LSR	52.9	4.6		
2	LSR at site #2	51.4			57.6
4	Bear Creek	44.7	1.1		
10	Deer Creek	37.0	0.35	17	
13	Dragoon Creek	34.3	11.8		
3	LSR at site #3	21.5			76
8	Deadman Creek	21.1	6.4		
	USGS at Dartford	17.5		260	82
17	Dartford Creek	17.3	2.1		
21	USGS near Dartford	6.3			351
26	55B070 at mouth	1.8		21	372

Hyporheic exchange (exchange between surface and sub-surface water in the river channel) is a common feature in many rivers with gravel and sand channels. If present, hyporheic exchange can play a part in thermal regulation in the river. QUAL2K has capabilities to model this feature. Hyporheic interaction was not simulated or used as a calibration term because a simple water balance would not detect its presence.

The hydraulic geometry parameters required to perform simulations for effective shade and water temperature were bottom width, top width (wetted width), bankfull width, side slope, Manning's coefficient, and channel incision. WSU/WWRC scientists estimated these parameters from field data taken during discharge measurements and during the tree surveys. They then assigned values to each parameter for each reach by linearly interpolating the parameter values between upstream and downstream sites (Barber et al., 2007). The 60-125 ft (18-38 m) depths and 150-800 ft (46-244 m) widths of Chain Lake were not characterized in the WSU/WWRC model, but were more closely simulated in the Ecology revised version.

Manning's equation was used in QUAL2K to describe stream hydraulic characteristics for the mainstem LSR. Each reach was idealized as a trapezoidal channel. Under conditions of steady flow, Manning's equation can be use to express the relationship between flow and depth as:

$$Q = 1.49 \frac{S_0^{1/2}}{n} \frac{A_c^{5/3}}{P^{2/3}} \tag{4.2}$$

where Q is the flow (ft^3/s), S_0 is the bottom slope (ft/ft), n is Manning's roughness coefficient, A_c is the cross-sectional area (ft^2), and P is the wetted perimeter (ft). WSU/WWRC scientists used a Manning's n roughness coefficient of 0.12 for the entire mainstem LSR to calibrate their QUAL2K model (Barber et al., 2007).

The Manning roughness coefficient for natural channels typically ranges from 0.025 for reaches without riffles or pools to 0.10 for rough natural channels or extremely swampy reaches (Barnes, 1967). Ecology revised the n values in WSU/WWRC's QUAL2K model based on stream channel data from habitat surveys (McLellan, 2005; SCCD, 2003). Runs are the dominant LSR flow/habitat type, and sand is the dominant channel substrate. Manning n values of 0.030 to 0.060 were used in these reaches. For QUAL2K to simulate Chain Lake and the Lower LSR wetlands, higher Manning values were necessary; values were raised to 0.15 and 0.10, respectively.

In summary, Ecology made several revisions to the WSU/WWRC version of the QUAL2K model calibration condition. These revisions included:

- Recalculation of headwater hourly water temperatures and the daily average flow.
- Changes in tributary and groundwater temperature ranges.
- Changes in channel slopes and Manning roughness coefficients.
- Characterization of Chain Lake dimensions.
- Slight adjustments in groundwater inflow placement.
- Slight adjustments in shade calculations by correcting calibration date in Shade model.

The maximum water temperature estimates for August 9, 2005 from the two versions of the model are shown in Figure 23. The primary difference involves where the groundwater input area begins near Deadman Creek. Although the simulations are quite different in detail, they have several similarities:

- Water temperatures rise in response to Chain Lake just downstream of the LSR headwaters, and in response to the West Branch LSR input whose source is Eloika Lake.
- Water temperatures through the Middle LSR sub-watershed increase as the river flows north to south through less forested riparian zones.
- Maximum daily average temperature peaks at RKM 31.5, just above Dragoon Creek.
- Large Spokane-Rathdrum Aquifer groundwater inflows cool water temperatures through the Lower LSR sub-watershed.
- Water temperatures slightly increase as the LSR slows and is exposed to solar heating in the wetlands near the confluence with the Spokane River.
- As previously documented, many reaches in the Middle and Upper LSR sub-watersheds have maximum daily water temperatures much higher than the 16 ºC criterion during existing summer low-flow conditions.

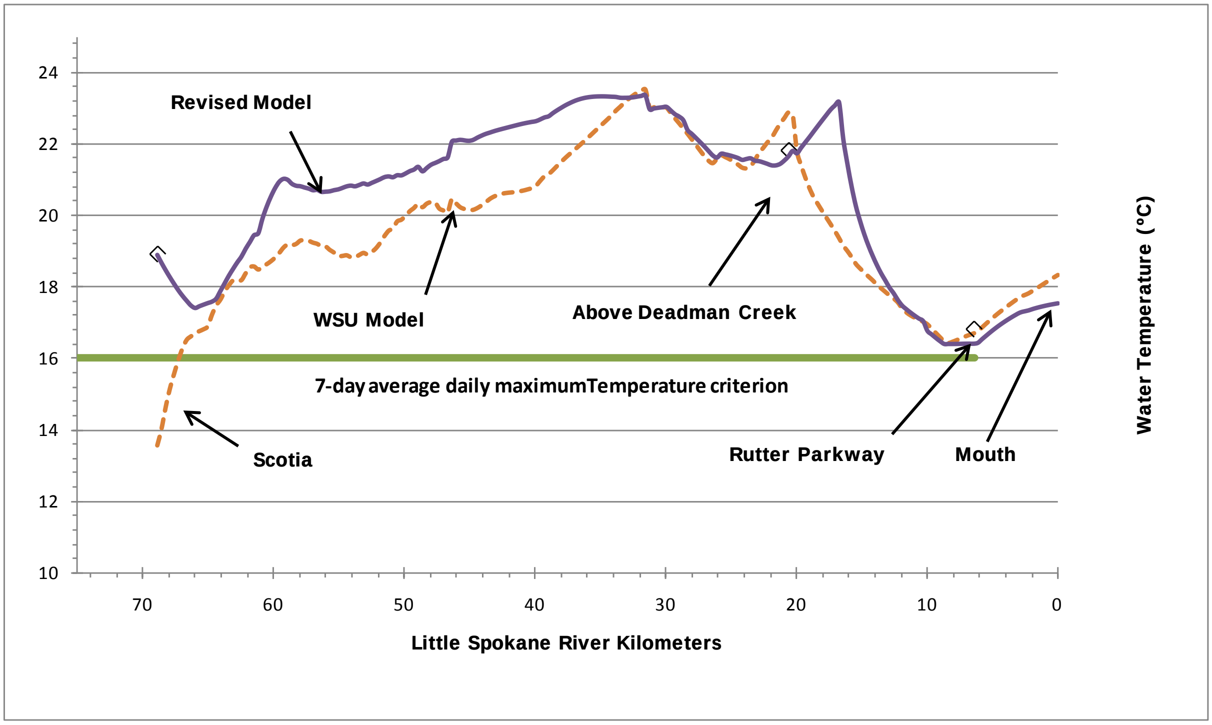

Figure 23. Maximum water temperatures estimated for August 9, 2005 in the Little Spokane River by two QUAL2K models calibrated by WSU/WWRC (Barber et al., 2007) and revised by Ecology.

Ecology's QUAL2K model calibrated to August 9, 2005 discharge and temperature conditions is shown in Figure 24. Water temperature in the Middle LSR sub-watershed appears to be especially vulnerable to solar heating. The cause could be a combination of the LSR's north-to-south orientation, discontinuous riparian vegetation, and its lack of groundwater input during the low-flow season.

The calibrated QUAL2K model's ability to simulate critical-period water temperatures was tested by conducting a second summer low-flow run. LSR maximum water temperatures observed on July 8, 2006 at Scotia and three other sites were compared to the model output (Figure 25). Only climate, date-adjusted shade, point-source water temperatures, and water-volume inputs were changed from the original calibrated model (Appendix C, Tables C-2 and C-3). The model compared favorably with the observed data with a root mean square error of 0.58 ºC.

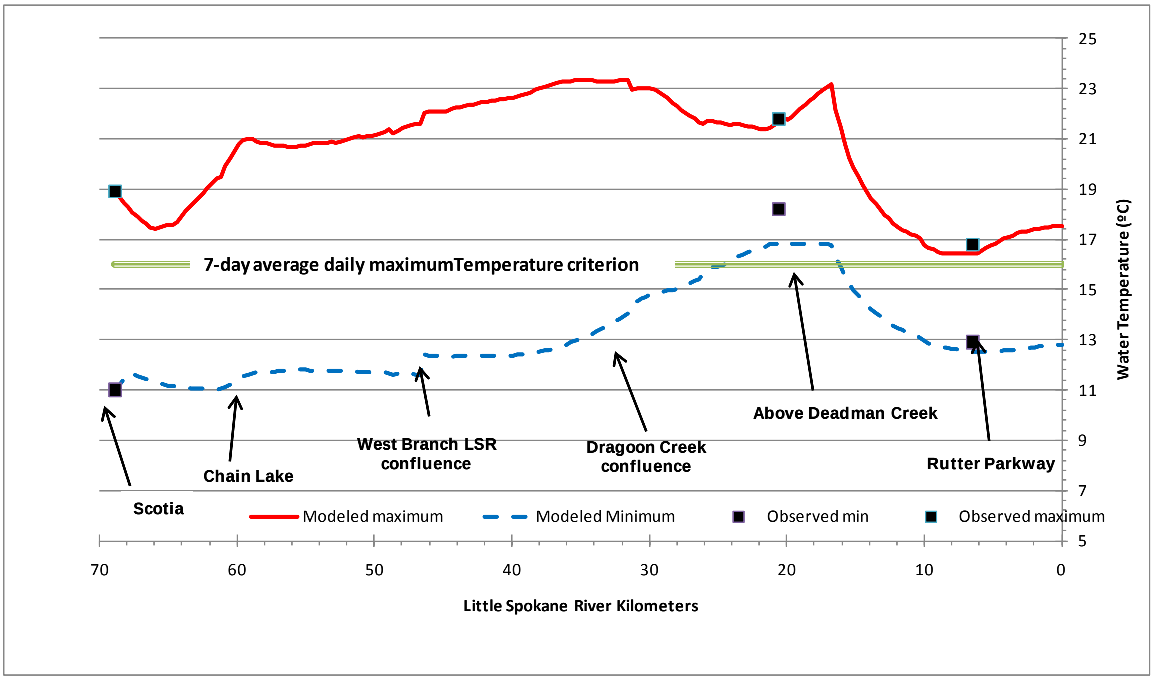

Figure 24. Calibrated QUAL2K model results of maximum and minimum daily temperatures along the Little Spokane River for August 9, 2005.

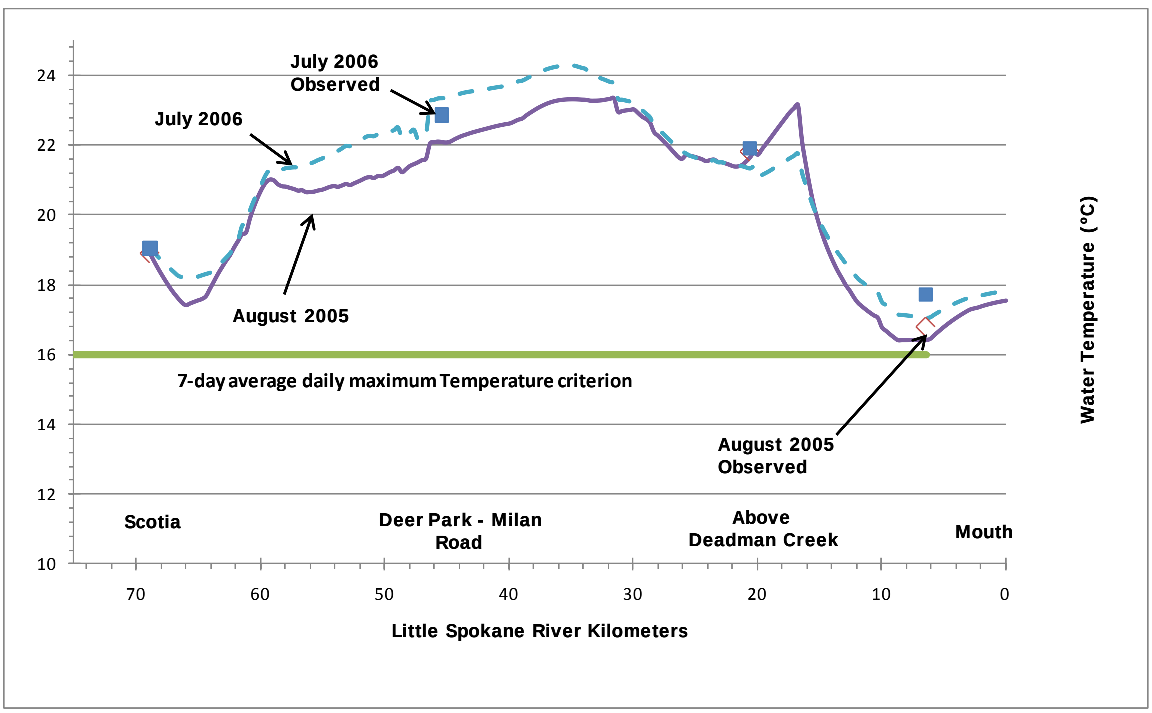

Figure 25. Results of a QUAL2K model calibrated for August 2005 (solid line) and run under July 2006 (dashed line) conditions.

Observed maximum daily temperatures along the Little Spokane River are shown with model results.

Compliance with standards

Instantaneous and continuous water temperature data demonstrated that the older (17.5 ºC) and newer (16 ºC) temperature criteria are not met in several reaches of the LSR watershed during summer low-flow conditions. QUAL2K model simulations of maximum summer water temperatures in 2005 and 2006 confirmed the extent of the temperature standard violations along the mainstem LSR (Figure 25). The sites at the upper end of the mainstem LSR (Scotia and Deer Park-Milan Bridge) were not in the 2008 Water Quality Assessment (WQA) but do not meet the new criterion according to data collected in 2006 (Tables 18 & 19). Temperatures at the mouth of the LSR also exceeded the 7-DADMax of 16 ºC (Table 18), and the site no longer fits the WQA Category 2 status (www.ecy.wa.gov/programs/wq/303d/2008/index.html).

All tributary sites shown earlier in Table 19 reported 7-DADMax temperatures beyond the 16 ºC criterion. Some of these had been 303(d) listed, but others had been listed as Category 1 or 2 in the 2008 WQA (www.ecy.wa.gov/programs/wq/303d/2008/index.html). The assessment based compliance on the older 17.5 ºC, so the following tributaries formerly assigned to Category 1 and 2 are now not meeting the new temperature criterion:

- Dartford Creek
- Deadman Creek at the mouth
- Dragoon Creek at the mouth
- Dry Creek
- Otter Creek

Average maximum temperatures in many reaches of the mainstem LSR approach the 21-26 ºC lethal limits for trout (Wydoski and Whitney, 2003). Rainbow and redband trout can tolerate infrequent maximum water temperatures up to 27 ºC, but mountain whitefish are not usually found in water warmer than 21 ºC (Wydoski and Whitney, 2003; Hillman et al., 1999). WDFW (McLellan, 2005) fish survey results from the LSR watershed confirm that fish communities change in response to water temperatures.

A Fish Assemblage Score (Appendix F) was calculated by applying species attributes from Zaroban et al. (1999) to a set of WDFW fish survey data collected from the LSR in 2003 (McLellan, 2005). The site scores closely followed the maximum daily water temperature model results along the mainstem LSR (Figure 26). Low scores representing native cold or cool-water salmonid assemblages (trout and whitefish) were present in the Upper and Lower LSR sub-watersheds, and higher scores representing a more frequent presence of cool or warm-water tolerant species (suckers, northern pikeminnow) and invasive species were common the Middle LSR sub-watershed. The water quality criteria applied to the LSR watershed is meant to enhance native, cold water, fish communities.

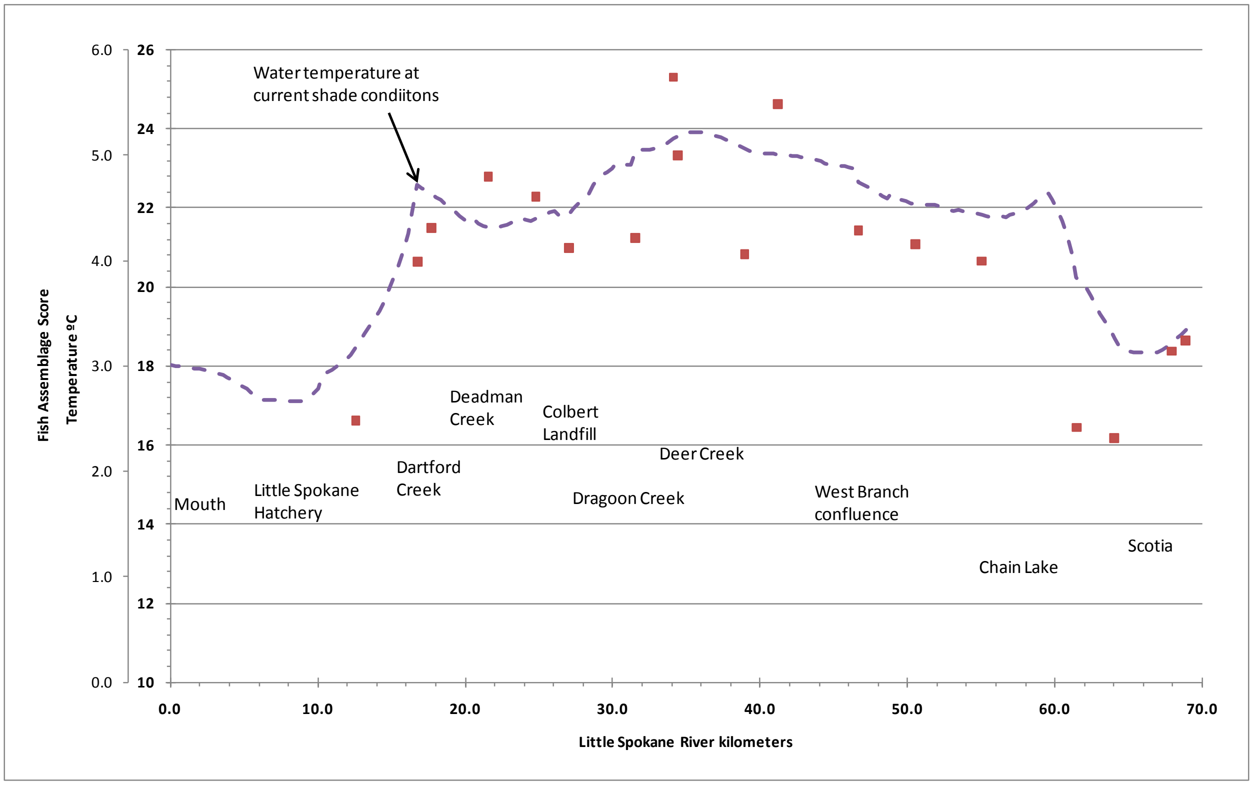

Figure 26. Fish assemblage scores(■) compared to calibrated temperature model results along the Little Spokane River mainstem.

A fish assemblage score of 1 represents a predominant presence of cold-water, thermal-sensitive species; a score of 6 represents a population of thermal-tolerant cool-water or warm-water species (see Appendix F for details).

Riparian shade in some reaches of the watershed is not adequate to prevent excessive heating that is protective of the cold-water aquatic species. Other reaches are subject to natural conditions that raise temperatures above criteria. For example, the modeling suggests that extended periods of high air temperatures and solar exposure to LSR lakes and wetlands raise the maximum mainstem water temperature in these areas to above 16 ºC during summer low streamflows. Data shown in Table 19 for sites 20, 22, and 23 suggest several outlet reaches of lakes and wetlands in the West Branch LSR are subject to this effect as well.

Modeling also showed that cool groundwater influx in some reaches of the mainstem LSR currently decreases maximum water temperatures, but not below the 7-DADMax 16 ºC criterion (Figure 24). The lower reaches of Dartford Creek, Dry Creek, and some other tributaries may be receiving cool groundwater inputs that help to bring down surface water temperatures during summer low-flow conditions (Table 19). Effective system-potential shade as well as maintaining cool groundwater inputs will be essential for bringing natural thermal conditions back to these tributaries.

If the water temperature of portions of a water body cannot meet the assigned criterion due to natural conditions, then the temperatures under natural conditions constitute the water quality criterion. The maximum water temperature allowable under natural conditions is determined by modeling the system-potential effective shade with all other groundwater and surface water inputs in place. The modeling results determine the loading capacity of the water body. Once the natural water temperature is determined, collective human actions are not allowed to increase temperatures by more than 0.3 ºC (Chapter 173-201A-200-1(c)(ii) WAC).

Loading capacity

The loading capacity provides a reference for calculating the amount of heat reduction needed to bring water into compliance with standards. EPA's current regulation defines loading capacity as "the greatest amount of loading that water can receive without violating water quality standards" (40 CFR § 130.2(f)).

The thermal loading capacity of the mainstem LSR is calculated in the TMDL by applying the system-potential shade estimates under critical conditions to the calibrated QUAL2K model. The July-August, seven-day, ten-year (7Q10) low-flow with the 90th percentile highest air temperatures (1890-2005 period of record) and other state variables (e.g., elevated tributary temperatures and 7Q10 low flows) are used to approximate a critical condition. By establishing the water temperatures and heat loading capacity during a critical condition, load and wasteload allocations can be set that will be protective for a majority of the year.

The average summer low-flow condition was also simulated with the calibrated QUAL2K model to provide an idea of typical water temperatures. Seven-day, two-year (7Q2) low flows with average (50th percentile) July-August air temperatures were used to predict what water temperatures might typically occur every other year. The 7Q2 set of scenarios does not provide load allocations, but it does provide information on how often and where water quality standards are met.

Maximum system-potential shade was calculated from mature riparian vegetation buffers with current topographical shade. Mature riparian vegetation was defined by WSU/WWRC as the climax riparian vegetation which would occur during summer under natural conditions (Barber et al., 2007). In the mature vegetation scenario, land uses in most riparian zones were replaced by pine forest with a canopy height of 82 ft (25.0 m), a density of 70%, and a 10 ft (3.3 m) overhang based on the measurements in the 2005 field tree survey along the mainstem LSR.

WSU/WWRC set the riparian buffer width at 150 feet (45 meters), 75 feet for each side. The shores of Chain Lake were left bare to simulate lack of effective shade, and the wetland reaches in the Lower LSR were provided with shrub/scrub vegetation (Luo, 2007). Buildings, roads, and railroads in previously forested riparian areas were replaced with mature shade.

A comparison of the mature system-potential shade to current estimated shade conditions along the mainstem LSR is shown in Figure 27. With mature system-potential vegetation in place, the average effective shade increased to 81% in the Upper LSR sub-watershed, 57% in the Middle LSR sub-watershed, and 14% in the Lower LSR sub-watershed. Average system-potential effective shade would be quadruple current shade conditions in the Upper LSR and Middle LSR, and it would be double that of the Lower LSR condition.

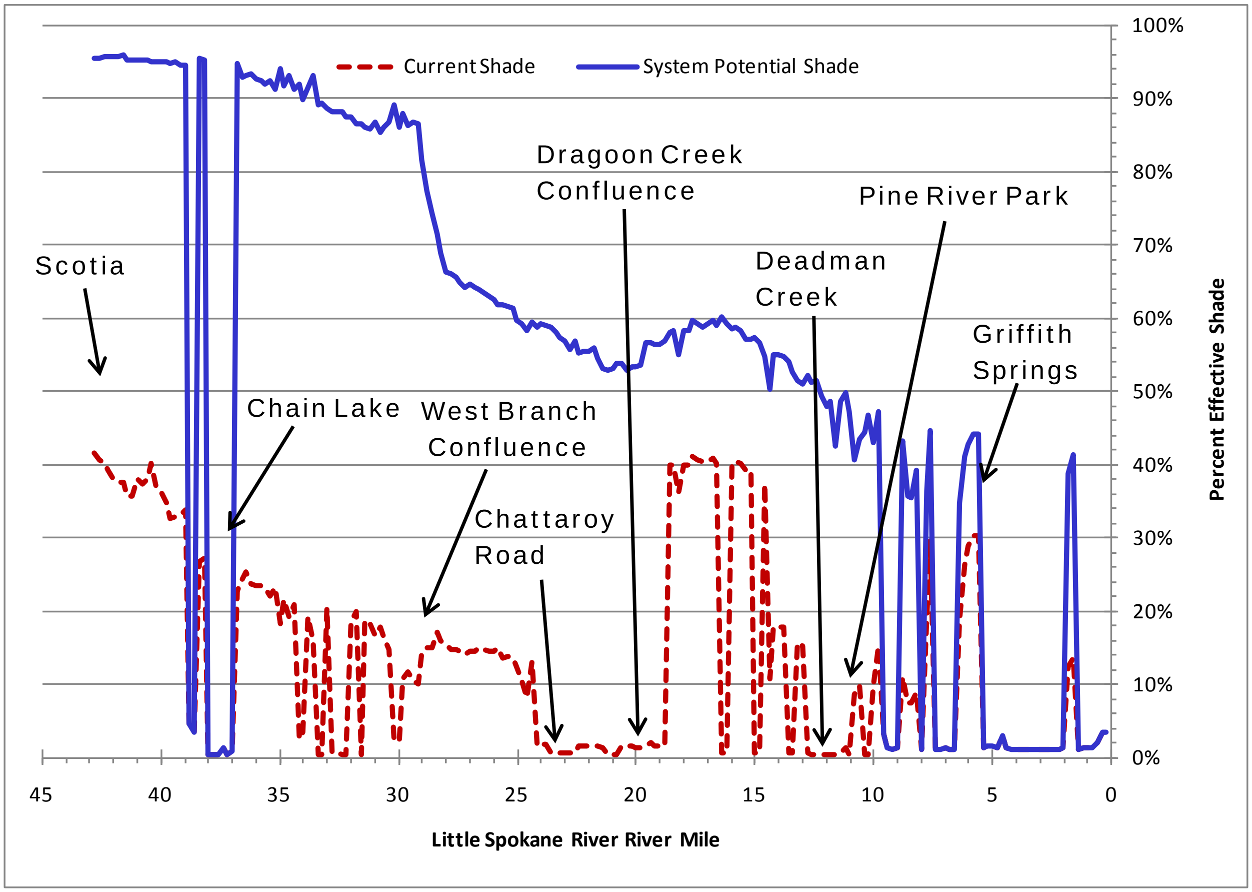

Figure 27. Current and mature system-potential effective shade along the mainstem Little Spokane River from Scotia to the mouth.

Microclimate effects, streamflow augmentation, and reach-specific channel modifications are sometimes modeled as part of the system-potential shade simulation. None of these additional effects or modifications was modeled. Increased vegetation density and height, and increased riparian width, can have a localized effect of reducing air temperature. These microclimate effects usually decrease daytime maximum air temperatures and increase minimum night air temperatures, resulting in slightly lower stream temperatures (Moore et al., 2005). Flow augmentation techniques, such as groundwater recharge and storage and wetland and forest preservation, are mentioned in the WRIA 55 Watershed Management Plan (Spokane County, 2005) but were not modeled for lack of details.

USGS 7Q10 and 7Q2 low-flow discharge statistics were available for the USGS gages on the LSR at Dartford (12431000) and at Elk (12427000) at http://streamstats.usgs.gov. The values are shown in Appendix C, Table C-6. The 7Q10 and 7Q2 low flows for the USGS gage near Dartford (1243500) were calculated by adding 220 cfs and 240 cfs as groundwater, respectively. The former value is the lowest observed difference observed between the two stations in the gaging record. The estimated 7Q10 and 7Q2 low flows at Scotia were the 10th percentile and 50th percentile lowest 7-day July and August flows from the Spokane County Conservation District gage records for 2000 to 2007.

Changes to tributary and diffuse source flows upstream of the Dartford gage were minimal (Appendix C, Table C-6). Tributary flows were not changed from calibration conditions for the 7Q10 critical condition. Tributary flows were increased by half in the 7Q2 scenario, which balanced the 7Q2 water budget. Diffuse inputs were not changed. Water balances matched estimated gage values. The USGS streamflow at Dartford during the 2005 calibration condition was 11% greater than the estimated 7Q10 discharge and 6% lower than the estimated 7Q2 discharge.

Air temperatures recorded at Geiger Field in Spokane, representing a 90th percentile daily maximum condition, occurred on July 31, 2003, according to statistics available between 1890 and 2005 at www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html. Maximum daily temperatures had been above 32 ºC (90ºF) for six days prior. No cloud cover was present. Deer Park records were available for that day as well. Climate data for the two stations on that date are shown in Appendix C, Table C-5. The average daily temperatures on that date at Deer Park and Geiger Field were 8% and 10% higher, respectively, than the 2005 calibration condition.

A summer day with historically average air temperature at Geiger Field occurred on August 13, 2003 (www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html). The average daily temperatures were approximately 5.5 ºC cooler at both Geiger Field and Deer Park than the July 31 temperatures of the critical condition. Climate data for the two stations on that date are shown in Appendix C, Table C-4.

Tributary water temperatures were not changed from the calibration condition, but the headwater hourly temperatures were adjusted to estimate a system-potential shade condition. Initial modeling with system-potential shade suggested that headwater areas could meet the 16 ºC criterion, so a conservative estimate was calculated. The estimated headwater hourly temperatures under system-potential shade conditions were a minimum, mean, and maximum temperatures of 10.9 ºC , 12.9 ºC , and 15.9 ºC , respectively.

The two QUAL2K model simulations were run to predict maximum daily water temperatures in the LSR from Scotia to the mouth. A comparison of the estimated maximum daily temperatures under 7Q10 critical flow and climate conditions with current shade and system-potential shade conditions are shown in Figure 28. The maximum daily temperatures for the 7Q2 average summer flow and average meteorological conditions are shown in Figure 29. The average maximum temperatures in each mainstem LSR sub-watershed for all four simulations are summarized in Table 28.

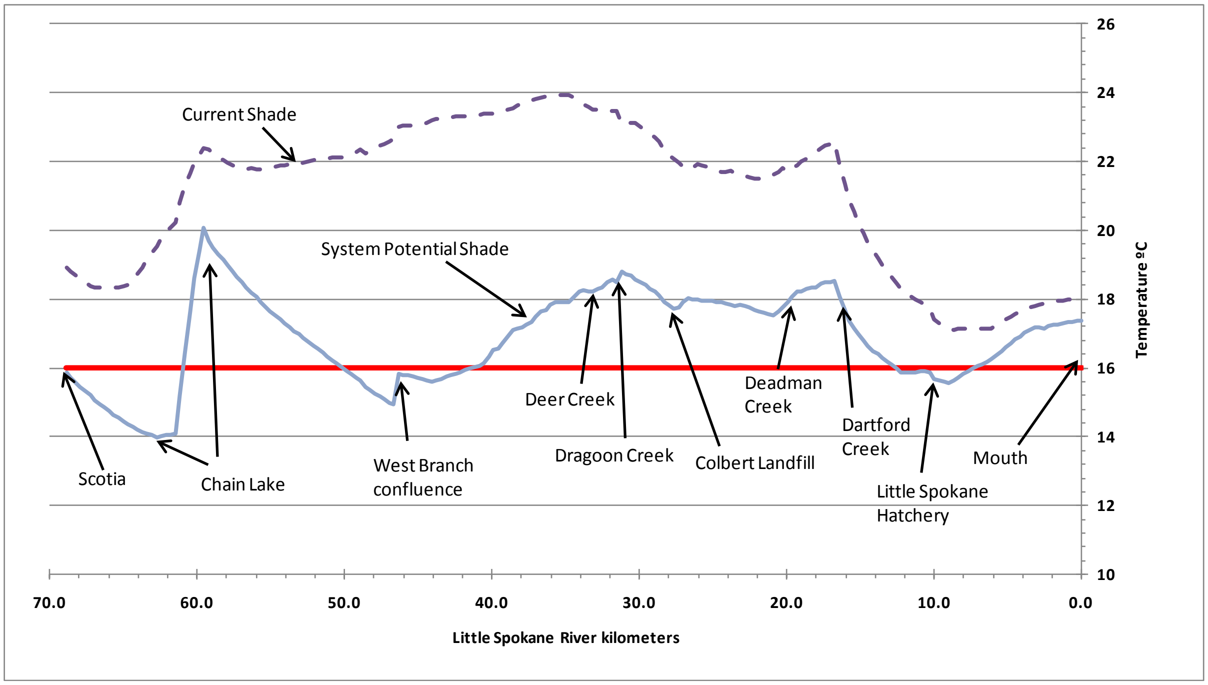

Figure 28. Predicted maximum daily water temperatures in the Little Spokane River for critical flow (7Q10) and meteorological (90th percentile) conditions with current and system-potential shade.

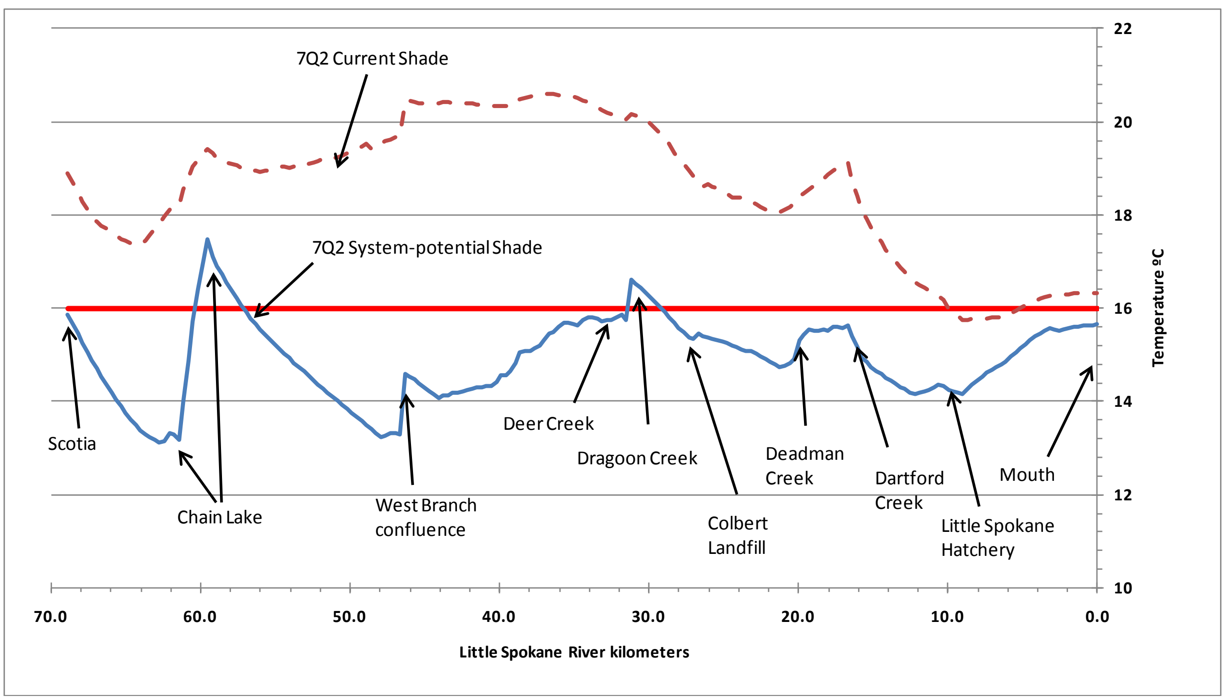

Figure 29. Predicted maximum daily water temperatures in the Little Spokane River for average low flow (7Q2) and meteorological (50th percentile) conditions with current and system-potential shade.

Table 28. A summary of predicted maximum average daily water temperatures at critical (7Q10) and average (7Q2) low-flow and meteorological conditions in the Little Spokane River and specific sub-watersheds.

Scenario	Average Maximum Temperature			
	All reaches	Scotia to West Branch Confluence	West Branch Confluence to Dartford	Dartford to Mouth
7Q10 Critical w/current shade	21.1	20.9	22.8	18.1
7Q10 Critical w/system-potential shade	16.9	16.3	17.5	16.5
Difference	4.2	4.6	5.3	1.6
7Q2 Average w/current shade	18.6	18.8	19.2	16.1
7Q2 Average w/system-potential shade	14.9	14.6	15.2	14.8
Difference	3.7	4.2	4.0	1.3

The QUAL2K model results suggest that few reaches of the LSR would meet the 16 ºC temperature criterion during critical conditions if system-potential shade were present. Those reaches meeting the criterion are in the Upper LSR above Chain Lake and at the LSR confluence with the West Branch LSR before it travels very far on a north-to-south route (Figure 28). Increased riparian shade reduced the average maximum water temperature of all reaches along the mainstem by 4.2 ºC (Table 28). The greatest temperature reduction was in the Middle LSR watershed between the West Branch confluence and Dartford Creek. The average maximum temperatures for the three sub-watersheds meet the 17.5 ºC criterion for salmon spawning, rearing, and migration; and the 18 ºC criterion for redband trout (Table 28).

In contrast, most reaches with system-potential shade would meet the 16 ºC temperature criterion under 7Q2 average summer conditions (Figure 29). Only three reaches exceeded the criterion. The average maximum water temperature for all reaches is estimated to be 14.9 ºC (Table 28). Mature riparian vegetation would be effective in reducing average maximum temperatures in the river by 3.7 ºC compared to current shade conditions. The average maximum water temperature in the Middle LSR sub-watershed would be reduced by 4.0 ºC if riparian shade was increased (Table 28).

WSU/WWRC scientists estimated average current and system-potential shade in eight tributaries (Table 29). QUAL2K modeling of the system-potential riparian vegetation was not conducted to check if temperatures would be brought down to the 16 °C criterion for 303(d) temperature listings in Bear, Deadman, Deer, and Dragoon Creeks. Water temperatures under natural conditions may be higher than the criterion. Beaver, Buck, Moon, West Branch Dragoon, Peone, and Little Deep Creeks, also on the 303(d) list, can be assessed using the shade curve data in Appendix C, Table C-7. The WSU/WWRC tree survey site data and the riparian characterization work by Christian (2003) may be helpful in identifying specific areas where current conditions in these tributaries are poorly shaded.

Table 29. Average percent effective shade under current and system-potential riparian vegetation conditions for eight tributaries in the Little Spokane River watershed (Barber et al., 2007).

Tributary	Miles Evaluated	Average Current Effective Shade	Average System-Potential Effective Shade
Dry Creek	9.3	58%	94%
Otter Creek	11.8	34%	95%
West Branch LSR	18.6	76%	87%
Bear Creek	6.2	75%	94%
Deer Creek	15	53%	92%
Dragoon Creek	25	37%	92%
Deadman Creek	21	42%	88%
Dartford Creek	6.8	55%	95%

Turbidity and total suspended solids (TSS)

Analytical framework

Data collected by WSU/WWRC, Ecology, Pend Oreille Conservation District, Spokane County Conservation District, and USGS were used to evaluate the relationships between streamflow, turbidity, and TSS in the LSR watershed. These data were compared to Ecology WQI scores (Hallock, 2002) and EPA reference values (EPA, 2000) for the Northern Rockies ecoregion. Multiple regression analysis and fish tolerance 'Severity Scores' (Newcombe and Jensen, 1996) were calculated where enough data at an individual site were available. These measures and procedures were summarized earlier in the *Water Quality Standards* and *Numeric Targets – Turbidity* sections.

Surrogate measures

As discussed earlier in the *Surrogate Measures* section, turbidity is regulated under Washington State water quality standards with specific criteria; TSS are not. But turbidity loads cannot be calculated since turbidity is a measure of visibility through water, not a concentration of something specific (like TSS) in the water. Also, Washington State turbidity criteria are limited to comparisons between water clarity immediately upstream and downstream of a point of interest. If the upstream turbidity is not protective of designated beneficial uses, then the purpose of the comparison is called into question. The narrative rule in the water quality standards (WAC Chapter 173-201A-260 (1) (b)) allows TSS to be used as a surrogate measure to conduct a TMDL for turbidity, with aquatic community protection as the water quality goal.

TSS are part of the matrix of soil, sediment, or organic solids particles carried from uplands, streambanks, and streambeds. Movement of suspended sediments (or TSS) that increase turbidity is often associated with rapid streamflow changes. Periods of intense rainfall or rain-on-snow events are seasonal occurrences in the LSR watershed. The intensity and duration of turbidity events determine the effect on aquatic communities.

The LSR data present some challenges for relating turbidity and TSS:

- Turbidity measurements rely on particles remaining in solution. If the TSS particles sink or float, the correlation between the turbidity and TSS becomes more variable. LSR streambeds and banks contain a large percentage of sand that sinks.
  - Ecology's sampling method collects only a single sample from near the surface rather than from the entire depth of the water column at multiple points across the stream. This eliminates some denser sand particles, even in well-mixed conditions.
  - Similarly, TSS and turbidity laboratory methods use only a portion of the entire sample collected. Heavier and lighter materials can be left out of the portion of the sample that is drawn and analyzed.
- Turbidity to TSS is linear over a wider range of values with ratio turbidimeters used by Ecology since 1993 and by WSU. Samples collected prior to 1993 may produce a different regression equation.
- The turbidity and TSS content of samples collected from different sites within the LSR watershed showed a wide range of statistical relationships (Figures 30 and 31).

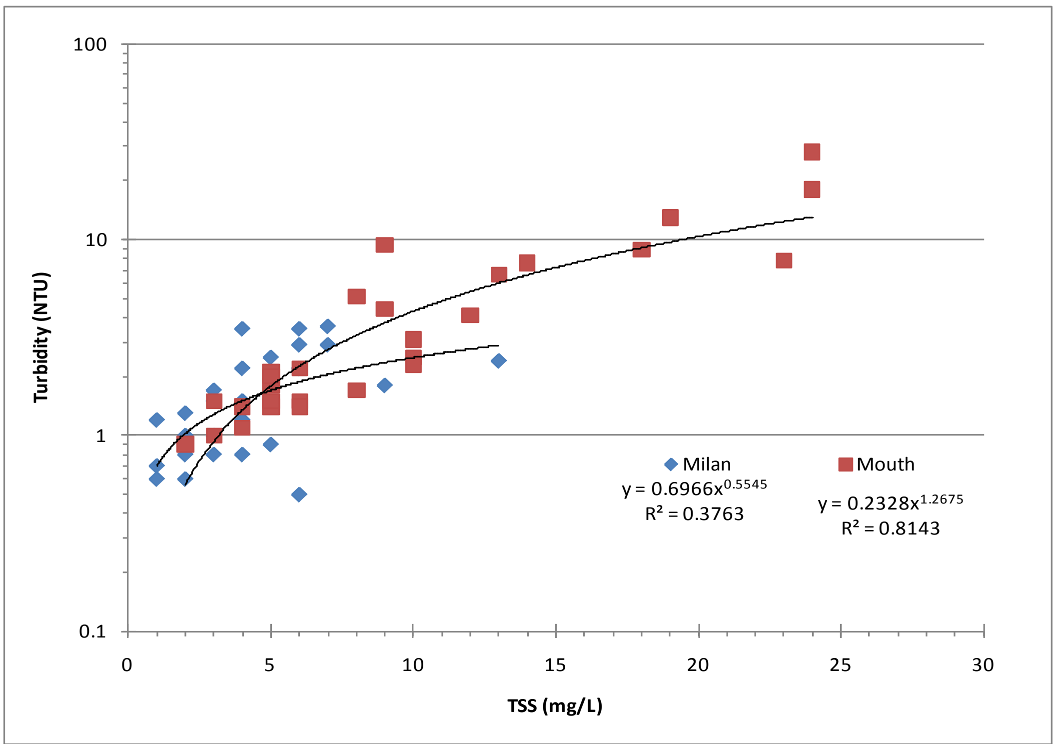

Figure 30. Relationships between total suspended solids (TSS) concentrations and turbidity values for samples collected at two sites along the Little Spokane River.

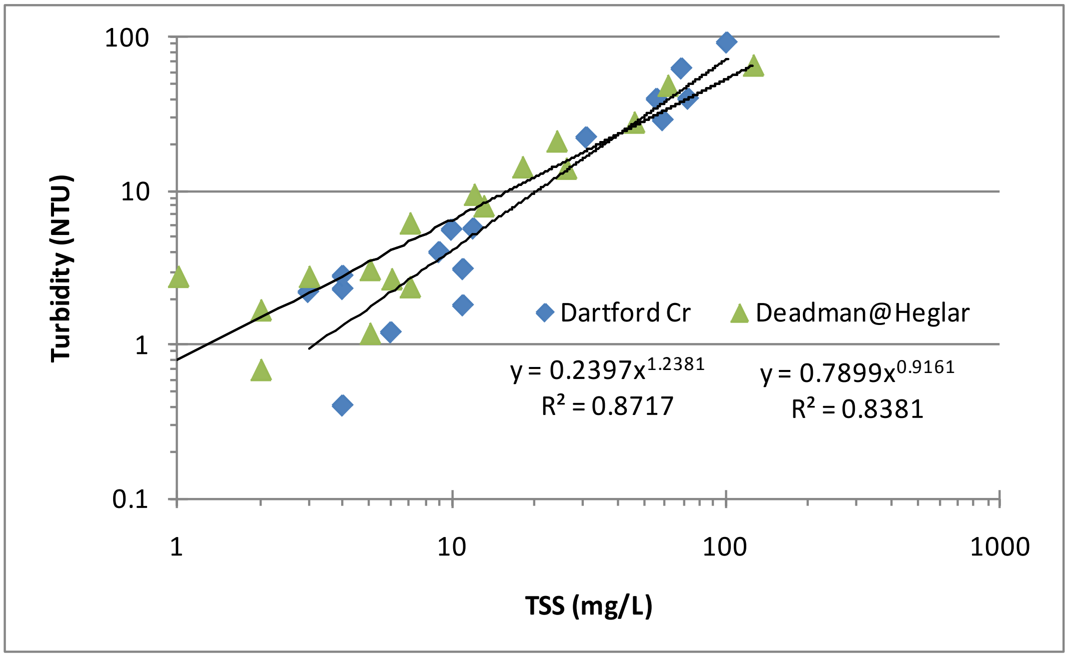

Figure 31. Relationship between total suspended solids (TSS) concentrations and turbidity values for samples taken in 2004-2006 from Dartford Creek and Deadman Creek at Heglar Road.

The turbidity criteria are difficult to establish for a site in a watershed when nonpoint sources and natural events are the dominant factors of interest. A reference turbidity value is required to measure against turbidity increases at the point of interest. In a watershed with several soil and land use types, an adequate reference site, or set of reference sites, is difficult to obtain. Also, rivers and streams can naturally gain 5 NTUs over a few reaches during short-duration, intense, runoff events.

These short, intense events may not be as harmful to aquatic organisms as long periods of turbidity at levels that do not increase turbidity 5 NTU over an upstream site. For example, although the Chattaroy site was used as a reference site for the LSR turbidity listing at Dartford, Ecology's (2009) WQI scores at Chattaroy indicate moderate turbidity levels and TSS concentrations may impact aquatic life there and upstream at Deer Park-Milan Road. Therefore, this TMDL will not be based on 5 NTU turbidity increases, but instead on reductions of turbidity and TSS to levels protective of aquatic organisms.

Biological data

Fish and macroinvertebrate surveys had an important role in the analytical framework. McLellan (2005) recommended that instream habitat be restored by decreasing sediment loading in the LSR watershed so that trout survival could be noticeably improved. Substrate embeddedness was a problem at all sites visited. The broad extent of the problem was corroborated by the relatively low benthic index of benthic integrity (B-IBI) scores (*Water Quality Standards and Numeric Targets – Aquatic Life Uses*, Table 5) calculated from macroinvertebrate samples collected by Canwell (2003) at several sites throughout the watershed. Substrate instability was noted as a contributor to poor macroinvertebrate community assemblages and B-IBI scores.

The work by these researchers provides geographic focus to the analysis of the water quality data. For example, McLellan (2005) noted that Deadman, Little Deep, Dartford Creeks, the LSR from Deer Park-Milan Road to Bear Creek, and the Upper LSR reaches above Chain Lake were especially important for restoration. Some of these areas did not have a robust water quality data set, but what data were available were used to provide an estimate of the loading capacity.

The failure to support healthy aquatic communities is out of compliance with the narrative water quality standard (WAC Chapter 173-201A-260 (1) (b)). Currently, Washington State does not have reference populations for using B-IBI scores and fish populations as measures of compliance with water quality standards in this area of the state. However, the preponderance of biological, habitat, and water column evidence is present in the LSR watershed to demonstrate aquatic life is being harmed (McLellan, 2005; McLellan, 2002; McLellan, 2003; Canwell, 2003; Ecology, 2009; Plotnikoff, 1994; POCD, 2002; Barber et al., 2007).

Methods of data analysis

Turbidity and TSS data were evaluated to ensure maximum aquatic life protection for spawning and incubation March through May (trout), and December through January (whitefish). This critical period defined for the TMDL also complies with the definition of the "core summer salmonid habitat" (see *Water Quality Standards and Numeric Targets)*. Winter storm and rain-on-snow events in adjacent months like November, February, and June were not considered in the analysis. Two types of analyses were performed depending on the size of the dataset available at a site. Summaries of these analytical techniques and equations, which are described in detail in Appendix D, follow.

For sites where few data were available, turbidity and TSS values were compared to Ecology WQI scores and EPA reference values presented in *Water Quality Standards and Numeric Targets – Turbidity*. Iterative reductions were applied to all turbidity and TSS values in each site's dataset, and the WQI scores were recalculated until the average scores for the critical months turbidity and TSS were 80 or better. This is similar to the roll-back method used to estimate FC reductions. The most restrictive reduction percentage was used to apply to load calculations when turbidity and TSS reduction estimates were different. Data for Little Deep Creek are used as an example to demonstrate the technique (Appendix D).

Some LSR sites had a year or more of daily flow measurements and an adequate number of TSS data to perform more detailed analyses. The TSS data analysis for these sites follows the similar procedures as previously described in the Hangman Creek TMDL (Noll et al., 2009). Multiple regression analyses were run using a method by Cohn (2002) with SYSTAT® software. The Cohn (2002) analysis uses average daily streamflow, TSS grab sample results, and seasonal factors to find the best-fit log-linear multiple regression equation to generate daily TSS loads and concentrations (Appendix D).

The mass balance of TSS loads along the mainstem LSR was checked for the current and recommended TMDL conditions. The Beales ratio estimator method was used to calculate seasonal TSS loads at sites with small data sets (Appendix D). Seasonal TSS loads from sites with multiple regression analyses were used directly.

Daily TSS concentrations generated by multiple regression models at three sites in the LSR watershed were reviewed for periods of elevated TSS. Severity scores, as previously described in *Water Quality Standards and Numeric Targets*, were calculated for juvenile and adult salmonids using the following formula (Newcombe and Jensen, 1996):

$$\text{Severity score} = 1.0642 + 0.6068(\log_e \text{Hours of exposure}) + 0.7384(\log_e \text{TSS mg/L})$$

The severity score values and descriptions are shown in Table 7 of the *Water Quality Standards and Numeric Targets – Turbidity*. Ecology uses this scoring tool to determine the level of control needed to fully protect redband trout, rainbow trout, whitefish, and other salmonids that are considered keystone sensitive species in the LSR watershed.

These analyses were used to determine how much TSS must be reduced in duration and intensity to fully protect aquatic biota. The range of severity scores used by Ecology to estimate full protection for the designated and existing uses in the watershed is 0-4. The score of 4 represents a short-term reduction in feeding rate or feeding success, which should only be rarely exceeded in the critical period, as during extreme rain-on-snow or extreme storm events. The scores below 4 should be the norm within the watershed during the spawning and incubation season and found in channel refuge areas during the high-flow season.

The reduced TSS loads associated with the severity scores below 4, or the turbidity and TSS WQI scores above 80, become the load capacities for sites in the LSR watershed. In developing this approach, Ecology took into consideration the temporal relationships between flow, TSS, and life-cycles of the salmonids present in the system. The load capacities were estimated to ensure reasonable protection during trout and whitefish spawning and incubation periods.

This approach relies on developing instream refuges, as needed by the biota, through channel restoration activities in a manner consistent with a naturally functioning system. Natural, highly turbid events can be damaging to aquatic populations and habitats if functional elements are missing in the stream corridor. Upland and riparian best management practices alone cannot prevent damage to aquatic ecosystems. A properly functioning stream environment protective of aquatic organisms requires healthy riparian and instream channel elements.

Model calibration and validation

The long-term monthly TSS data record collected by Ecology at the mouth of the LSR (station 55B070) provides the primary calibration dataset for the LSR multiple regression and Beales ratio estimator models. Multiple regression analysis was also performed on data from LSR sampling sites with continuous streamflow gaging used in the TMDL and Pend Oreille Conservation District surveys.
However, all data sets have some limitations:

- Single samples collected at the surface can under-represent the true average TSS concentration and load, especially during high-flow events.
- Monthly grab samples do not reflect changes in discharge and TSS concentrations within a day or over a month.
- Watershed land uses, local increasing or decreasing streamflow trends, and crop rotation and management patterns have changed. So, consistent statistical relationships between season, streamflow, and TSS cannot be assumed.

The multiple regression equations were applied to three sites in the LSR watershed:

- The mouth of the LSR (55B070): monthly TSS concentrations collected by Ecology with mean daily streamflow calculated by USGS for water years 1999-2006
- LSR at Deer Park-Milan Road, river mile 31.8: monthly TSS concentrations collected by the Pend Oreille Conservation District (POCD, 1999) in water year 1999, and by the Spokane County Conservation District (SCCD, 2009) from December 2004 to April 2006 (Barber et al., 2007) with mean daily streamflows reported for 2001 to 2006.
- The mouth of Deadman Creek (LSRTMDL – 8): monthly TSS concentrations from October 1993 to September 1994 (Ecology, 2009) and from December 2004 to April 2006 (Barber et al., 2007) with mean daily streamflows reported by the Spokane County Conservation District (SCCD, 2009).

The Nash-Sutcliffe coefficient was used to evaluate the regression model fit to observed data. The model and the observed TSS/suspended sediment load estimates at the mouth of the LSR matched fairly well (Figure 32). The Nash-Sutcliffe coefficients of observed TSS data and model loads are 0.36, 0.77, and 0.98 (where 1.0 is ideal) for 55B070, LSR at Deer Park-Milan Road, and Deadman Creek, respectively.

WQI scores were calculated for the three sites where multiple regression equations were used to develop TSS load reductions. The seasonal WQI scores over 80 consistently required 5% less reduction than when the multiple regression equation method was used (Table 30). Considering these results, Ecology and local stakeholders might want to add a 5% margin of safety to the load reductions for sites analyzed by the WQI score alone.

Table 30. A comparison of recommended total suspended solids (TSS) load reductions at three sites where both multiple regression equations and Water Quality Index (WQI) analysis methods were used.

Site	Multiple Regression TSS	WQI TSS and Turbidity
LSR at Mouth	75%	70%
LSR at Deer Park Milan	25%	20%
Deadman Creek at Mouth	70%	65%

Another calibration check was conducted by calculating TSS loads at these sites by comparing two methods. The 2004-2006 WSU/WWRC study and the 1998-1999 Pend Oreille

Conservation District study average daily suspended sediment load estimates for mainstem LSR sites from the multiple regression models matched the Beales ratio estimator values very well (Table 31). The Deadman Creek 2004-2006 loads were also similar 2.4 tons/day compared to 2.8 tons/day.

Table 31. A comparison of total suspended solids (TSS) load estimates at three sites in the Little Spokane River watershed for two studies using two load calculation methods.

Site:	Deer Park-Milan Road		Deadman Creek		Mouth (55B070)	
Study	Multiple Regression	Beales Estimator	Multiple Regression	Beales Estimator	Multiple Regression	Beales Estimator
POCD 1998-1999	2.6 tons/day	2.5 tons/day	—	—	29 tons/day	23 tons/day
WSU/WWRC 2004-2006	1.6 tons/day	1.4 tons/day	2.4 tons/day	2.3 tons/day	16 tons/day	17 tons/day

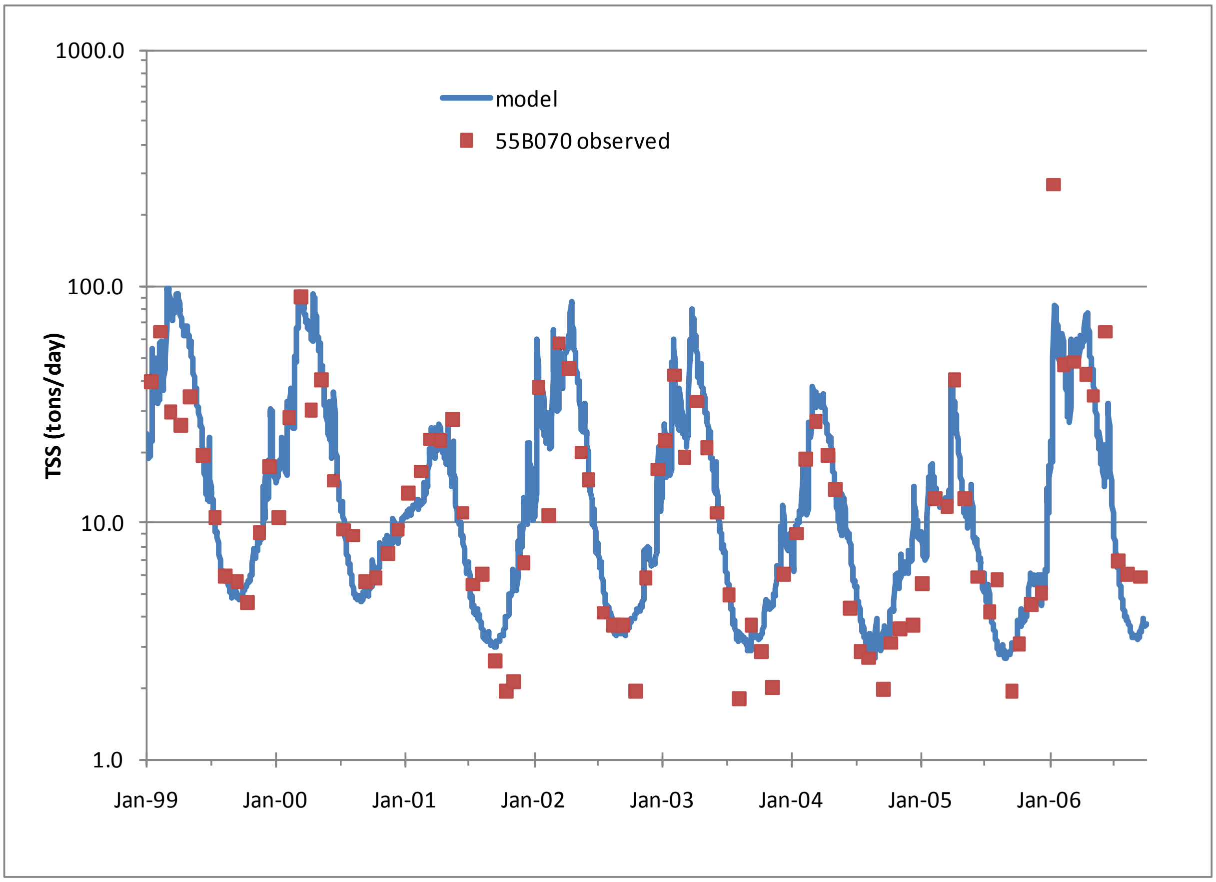

Figure 32. A comparison of daily total suspended solids (TSS) load estimates at the mouth of the Little Spokane River (55B070) from a multiple regression model (model) and instantaneous sample collection (observed).

Compliance with standards

Based on analyses of historical and WSU/WWRC TMDL data, turbidities and TSS at several sites in the LSR watershed are not protective of sensitive aquatic communities. The duration and intensity of TSS concentrations in early spring and early winter spawning periods suggest unacceptable conditions for supporting healthy trout and whitefish populations in the mainstem LSR and most tributaries. In corroboration, WDFW fish surveys (McLellan, 2002; 2003; 2005) and benthic macroinvertebrate surveys (Canwell, 2003) noted sediment as a primary habitat problem in the Upper LSR above the confluence with the West Branch LSR, throughout the Middle and Lower LSR sub-watersheds, and in most major tributaries.

Ecology calculated moderate and poor WQI scores for TSS and turbidity data collected at the mouth of the LSR in 1994 to 2008 (Ecology, 2009). The monitoring site at the mouth is 10 miles downstream of the 303(d) listed reach. It is an area of high importance for aquatic communities in the watershed because of its cool summer water temperatures brought about by groundwater inflows and properly functioning channel conditions. Further analysis of the data yields high severity scores occurring frequently and for long periods (Figure 33). The results suggest a chronic and cumulative problem with suspended sediment and turbidity in the watershed.

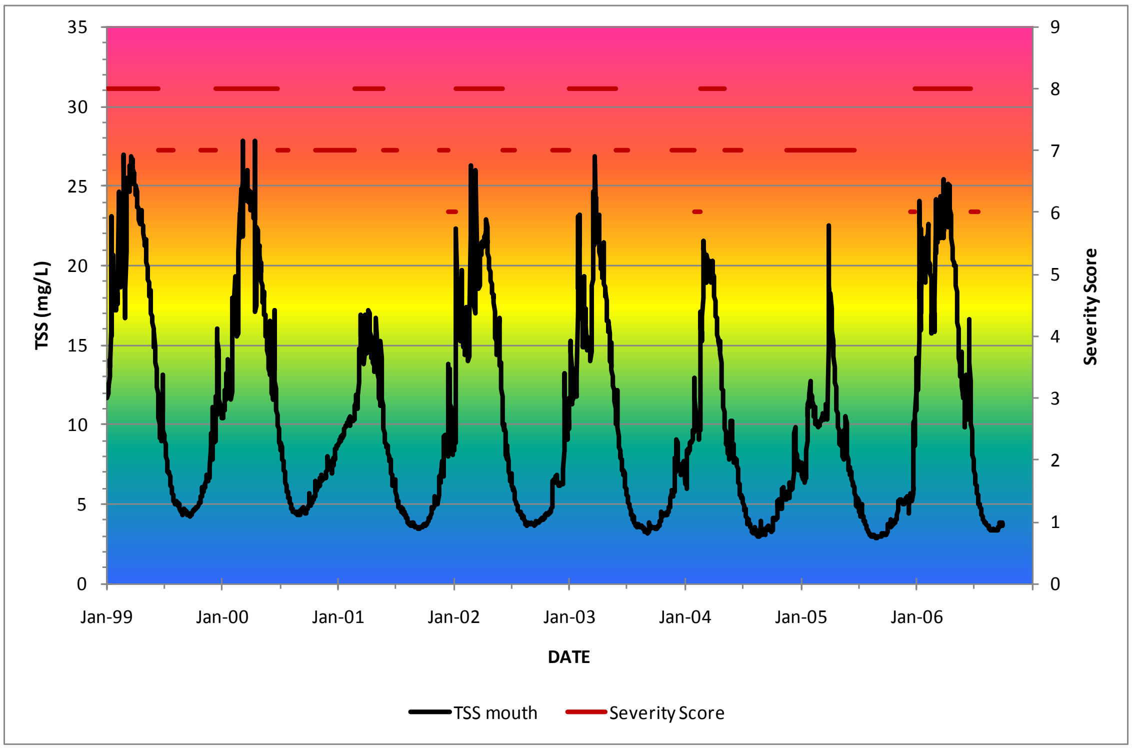

Figure 33. Estimated daily total suspended solids (TSS) concentrations and calculated TSS effect severity scores at Ecology station 55B070 at the mouth of the Little Spokane River.

Turbidity and TSS data were used to generate WQI or fish impact severity scores, and biological and habitat data were reviewed at sites throughout the watershed. Based on these assessments, the following areas do not provide aquatic life with adequate protection from the effects of turbidity/TSS during the critical trout and whitefish spawning periods:

- Upper LSR: the East Branch LSR above the confluence with the West Branch LSR
- Middle LSR: from the confluence of the two branches to Dartford
- Lower LSR: below Dartford to the mouth at Lake Spokane (Long Lake)
- Little Deep Creek
- Deadman Creek
- Deer Creek
- Dragoon Creek
- Dartford Creek
- Buck Creek
- Beaver Creek

Dry, Moon, Bear, and Otter Creeks and sites along the West Branch LSR appeared to be maintaining water quality beneficial uses by having favorable WQI scores. However, monitoring at these sites has been very limited.

The erosion of sediment from uplands and streambanks occurs outside of the critical period, especially when snowmelt drives exposed soils from agricultural lands, logging areas, or construction sites. The best management practices selected for agricultural, range, urban, forest, and residential upland and riparian sources should consider sediment reduction during the entire year and not just during the critical period.

Although only minor TSS loading appears to be evident from upstream tributaries, Dry Creek and Otter Creek, bank erosion exacerbated by livestock access, old logging practices, and poor rural residential development were noted upstream (SCCD, 2005b). These TSS sources will need attention to reduce TSS loading and to improve the proper functioning condition of the channel.

The erodible soils of Little Deep Creek, combined with various poor agricultural and rural residential activities, may be contributing to the TSS load in the Upper Little Deep Creek watershed. Residential development, livestock access, poorly planned recreational trail crossings, stormwater, and road runoff may be suspended sediment sources in the Lower watershed.

Loading capacity

The loading capacities for turbidity and TSS are based on conditions that support healthy aquatic populations. The loading capacities should represent favorable conditions in a habitat unit during salmonid spawning, incubation, and emergence. The loading capacities should reduce the frequency of harmful TSS exposure during the critical period to occasional rain-on-snow or extreme rainfall events. Instream refuges with tolerable TSS should be available during the entire year.

As described earlier, two levels of data were available to determine load capacities. For small data sets, loading capacities were estimated from loading calculations of adjusted data distributions that meet average seasonal WQI scores better than 80 or that meet EPA reference values. Fish impact severity scores were developed from more robust data sets. Ecology uses the TSS impact severity scores of 0-4 to demonstrate full protection for the designated and existing aquatic life uses at sites with TSS and continuous streamflow data. The high WQI and low severity scores were calculated to be present within an aquatic habitat unit during the critical salmonid spawning and incubation months of March through May and December through January. Attaining loading capacity scores during these periods protects the aquatic community the rest of the year when properly functioning habitat conditions are present.

Loading capacities were calculated for the main channels in three mainstem areas and for nine tributaries:

- Upper Little Spokane sub-watershed at LSR at Scotia and the Deer Park-Milan site
- Middle Little Spokane sub-watershed at LSR at Chattaroy and above Deadman Creek
- Lower Little Spokane sub-watershed at LSR at Rutter Parkway and at the mouth
- Little Deep Creek
- Peone Creek
- Deadman Creek
- Deer Creek
- Dragoon Creek
- West Branch Dragoon Creek
- Dartford Creek
- Buck Creek
- Beaver Creek

The West Branch LSR has several lakes and wetlands along its course that make turbidity and TSS assessment difficult. Lakes and wetlands act as sediment sinks, so short reaches of the West Branch need additional monitoring to identify any problems. Only Buck Creek and Beaver Creek near Horseshoe Lake appeared to be impaired by elevated TSS events.

The loading capacities and the reductions in Table 32 are expressed as the annual average TSS loads in tons/day. The associated WQI scores for the critical period and post-TMDL WQI improvement scores are in Table 33. Where data are available, averages are calculated from water years 1999 to 2006. These water years are representative of a wide range of climatic and hydrological conditions. Other sites use available data: usually the 2004-2006 TMDL study data, or sometimes older data (1994-1996). The data used for the load balance are not detailed enough to determine where TSS loads settle and where new sources are located. Therefore, TSS loads upstream to downstream do not exactly balance, but they are descriptive of the general pattern in the LSR watershed.

Table 32. Current annual average total suspended solids (TSS) loads compared to estimated load capacities at assessed sites in the Little Spokane River watershed.

River Mile or Site ID	Site Name	Current TSS Load (tons/day)	Load Capacity (tons/day)	Reduction Required
RM 46.7	LSR at Scotia	0.4	0.3	40%
RM 37.1	LSR at Elk	0.5	—	—
RM 31.8	LSR at Deer Park-Milan Road	2.0	1.5	25%
RM 23.1	LSR at Chattaroy	4.3	2.6	40%
RM 21.2	LSR below Dragoon Creek	7.3	2.2	70%
RM 13.5	LSR above Deadman Creek	7.1	2.5	65%
RM 3.9	LSR at Rutter Parkway	15	5.1	65%
RM 1.1	LSR at the Mouth	20	4.9	75%
LSRTMDL-17	Moon Creek above Sacheen Lake	0.04	—	—
LSRTMDL-20	West Branch below Sacheen Lake	0.08	—	—
LSRTMDL-6	Buck Creek	0.5	0.3	40%
LSRTMDL-5	Beaver Creek	0.1	0.08	30%
LSRTMDL-22	West Branch above Eloika Lake	0.66	—	—
LSRTMDL-23	West Branch below Eloika	0.62	—	—
LSRTMDL-15	Dry Creek	0.13	0.12	10%
LSRTMDL-18	Otter Creek	0.03	—	—
LSRTMDL-4	Bear Creek	0.04	—	—
LSRTMDL-10	Deer Creek	1.0	0.2	80%
LSRTMDL-11	Dragoon Creek above Deer Park	0.2	0.1	60%
LSRTMDL-12	Dragoon Creek below Deer Park	0.4	0.1	65%
LSRTMDL-14	West Branch Dragoon Creek	0.3	0.2	35%
LSRTMDL- 13	Dragoon Creek at Crescent Road	2.3	0.9	60%
55C200	Deadman Creek at Holcomb*			40%
LSRTMDL-9	Deadman Creek at Heglar	1.9	0.1	95%
LSRTMDL-19	Peone Creek	0.07	0.04	40%
55C070	Deadman Creek above Little Deep Cr.	1.2	0.7	45%
LSRTMDL-16	Little Deep Creek	0.5	0.1	80%
LSRTMDL-8	Deadman Creek at Mouth	2.3	0.7	70%
LSRTMDL-7	Dartford Creek	0.5	0.05	90%

* No streamflow data were reported for Deadman Creek at Holcomb.

Table 33. Total suspended solids (TSS) and turbidity Water Quality Index (WQI) scores at sites in the Little Spokane River watershed, and reductions to meet TMDL loading capacities.

Site ID	Site Name	Sample Size	Current WQI		TMDL WQI		Required Reduction
			TSS	Turbidity	TSS	Turbidity	
LSRTMDL-1	LSR at Scotia	18	72	88	80	96	40%
LS-2	LSR at Elk	5	84	92	—	—	N/A
LSRTMDL-2	LSR at Deer Park-Milan Rd	13	78	85	82	88	25%
55B200	LSR at Chattaroy	10	72	78	80	87	40%
LS-5	LSR below Dragoon Creek	5	63	71	83	92	70%
LSRTMDL-3	LSR above Deadman Creek	18	70	77	83	88	65%
LSRTMDL-21	LSR at Rutter Parkway	13	70	72	86	86	65%
55B070	LSR at mouth	54	62	68	84	90	75%
LSRTMDL-17	Moon Creek	8	93	100	—	—	N/A
LSRTMDL-20	West Branch below Sacheen Lk	8	98	94	—	—	N/A
LSRTMDL-6	Buck Creek	10	80	73	85	80	40%
LSRTMDL-5	Beaver Creek	8	89	74	94	80	30%
LSRTMDL-22	West Branch above Eloika Lk	8	87	85	—	—	N/A
LSRTMDL-23	West Branch below Eloika Lk	13	91	91	—	—	N/A
LSRTMDL-15	Dry Creek	8	79	81	81	82	10%
LSRTMDL-18	Otter Creek	8	85	91	—	—	N/A
LSRTMDL-4	Bear Creek	8	84	93	—	—	N/A
LSRTMDL-10	Deer Creek	8	66	62	89	82	80%
LSRTMDL-11	Dragoon Creek above Deer Pk	8	86	66	94	81	60%
LSRTMDL-12	Dragoon Creek below Deer Pk	9	79	68	90	86	65%
LSRTMDL-14	West Branch Dragoon Creek	9	80	76	85	81	35%
LSRTMDL-13	Dragoon Creek near mouth	23	79	75	89	84	60%
55C200	Deadman Creek at Holcomb	4	72	71	80	80	40%
LSRTMDL-9	Deadman Creek at Heglar	10	61	57	95	73	95%
LSRTMDL-19	Peone Creek	7	82	73	89	82	40%
55C070	Deadman Creek above Little Deep Creek	5	71	77	80	87	45%
LSRTMDL-16	Little Deep Creek	8	62	56	86	80	80%
LSRTMDL-8	Deadman Creek at mouth	13	64	63	83	83	70%
LSRTMDL-7	Dartford Creek	9	50	52	83	85	90%

Table 33 shows the average WQI scores for the current conditions and reductions required to meet the loading capacity for all evaluated LSR watershed sites. Average seasonal WQI scores below 80 were only allowed when the complementary TSS or turbidity WQI scores reach 90 and a single event in the dataset created a low-biased score. Some scores were developed from older data or a mix of older and more recent data (e.g., Chattaroy, Dragoon Creek, and LSR above Deadman Creek) where some progress reducing turbidity and TSS may have occurred.

Data from the Upper LSR at the Deer Park-Milan Road site provide an example of the salmonid severity score approach to establishing the load capacity. At this site, a 25% TSS reduction was calculated to support sensitive aquatic life species. The 25% TSS reduction (or more if a margin of safety is desired) during the critical season should protect trout and whitefish most years by reducing impacts during all but the highest streamflow events. Over the nine-year simulation period, we estimate only three extreme events would have severity scores over 4, compared to 18 events under current conditions. Scores over 4 would drop 71%, from 62 days to 18 days (Figure 34). The annual average TSS loading is estimated to decrease from 2.0 tons/day to 1.5 tons/day (Table 32).

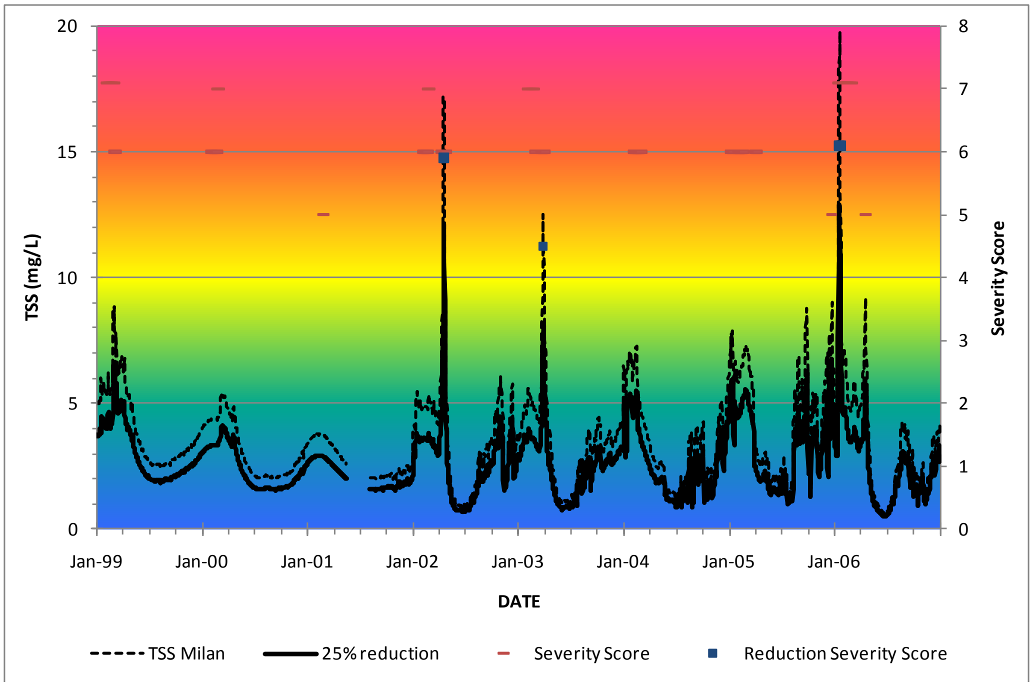

Figure 34. Daily TSS concentrations and salmonid effect severity scores estimated for the Little Spokane River at Deer Park-Milan Road under current conditions with reduced loading.

Dragoon Creek and Deer Creek require estimated TSS reductions of 60% and 75%, respectively, to meet a loading capacity that supports sensitive aquatic life species during the critical season. The combined annual average TSS loading from these two tributaries is estimated to drop from 3.3 tons/day to 1.1 tons/day when reductions are accomplished (Table 32).

The Middle LSR TSS loading capacity is affected by upstream loads from the Upper LSR, Dragoon Creek, Deer Creek, Deadman Creek, and riparian land-use activities along the mainstem LSR. As discussed in the *TMDL Analysis - Temperature* section, fish communities in the Middle LSR sub-watershed have fewer sensitive native species compared to other mainstem reaches (Figure 26). The sub-watershed recently underwent significant changes from rural to residential and commercial land uses. This trend will continue because of its proximity to Spokane and upgrades of local and regional transportation networks. Therefore, it is important to ensure that riparian areas are protected or enhanced and further decline is prevented.

Deadman Creek requires a 70% TSS reduction, similar to the upstream tributaries (Figure 35). TSS reductions in Little Deep Creek, Peone Creek, and upstream sites on Deadman Creek are necessary to support aquatic communities and reduce the total TSS load from Deadman Creek to the LSR by an annual average of 1.6 tons/day (Table 32). The likelihood of events with severity scores over 4 would be greatly reduced, and the events would be of much shorter duration than currently observed (Figure 35).

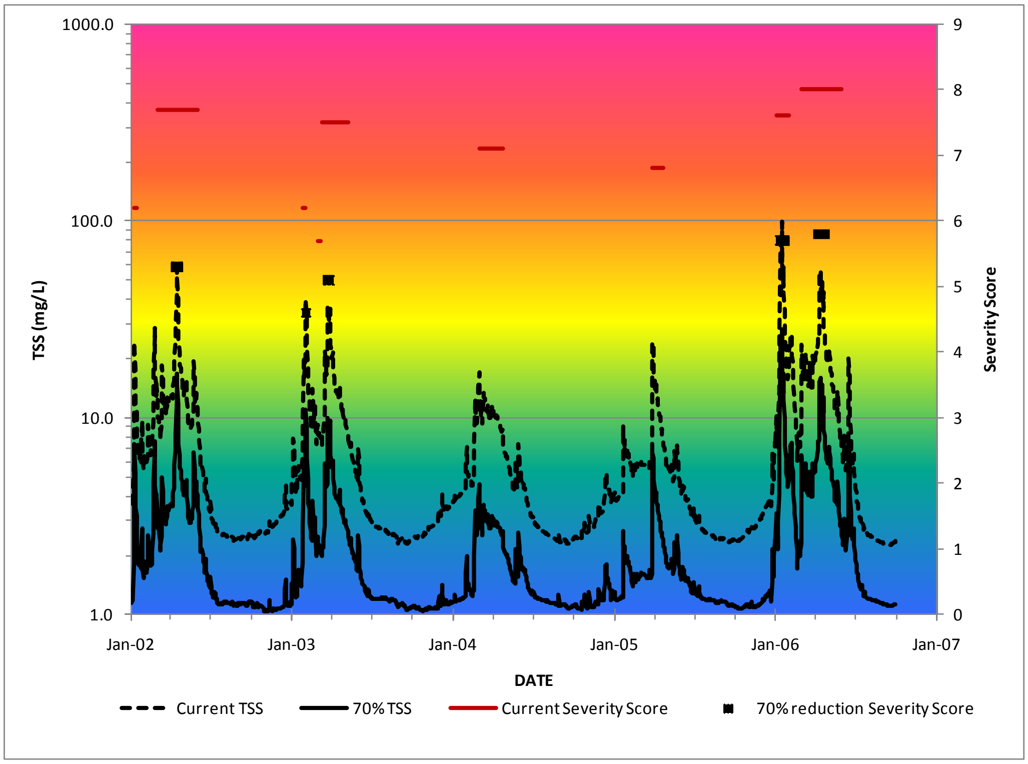

Figure 35. Total suspended solids (TSS) concentrations and fish severity scores for current conditions at the mouth of Deadman Creek and estimated values under a 70% solids reduction.

The Lower LSR shows the cumulative effect of TSS loading from the watershed and local sources. Although it does not deliver a huge TSS load, Dartford Creek will need to reduce loading by 90% to protect aquatic communities and lower its annual average load to the LSR to 0.1 tons/day (Table 32). Despite the influx of groundwater, TSS concentrations are elevated over long periods of the trout and whitefish spawning season (Figure 36). A 75% TSS reduction is necessary to limit the effects of TSS on fish and other aquatic life. The modeling estimated that severe TSS events would be reduced by 97%; events with a severity score over 4 would be reduced from 23 to 6 (Figure 35). TSS loading to Lake Spokane would be reduced by an annual average of 15 tons/day (Table 32). This reduction could also substantially reduce the delivery of phosphorus, PCBs, and other contaminants associated with TSS.

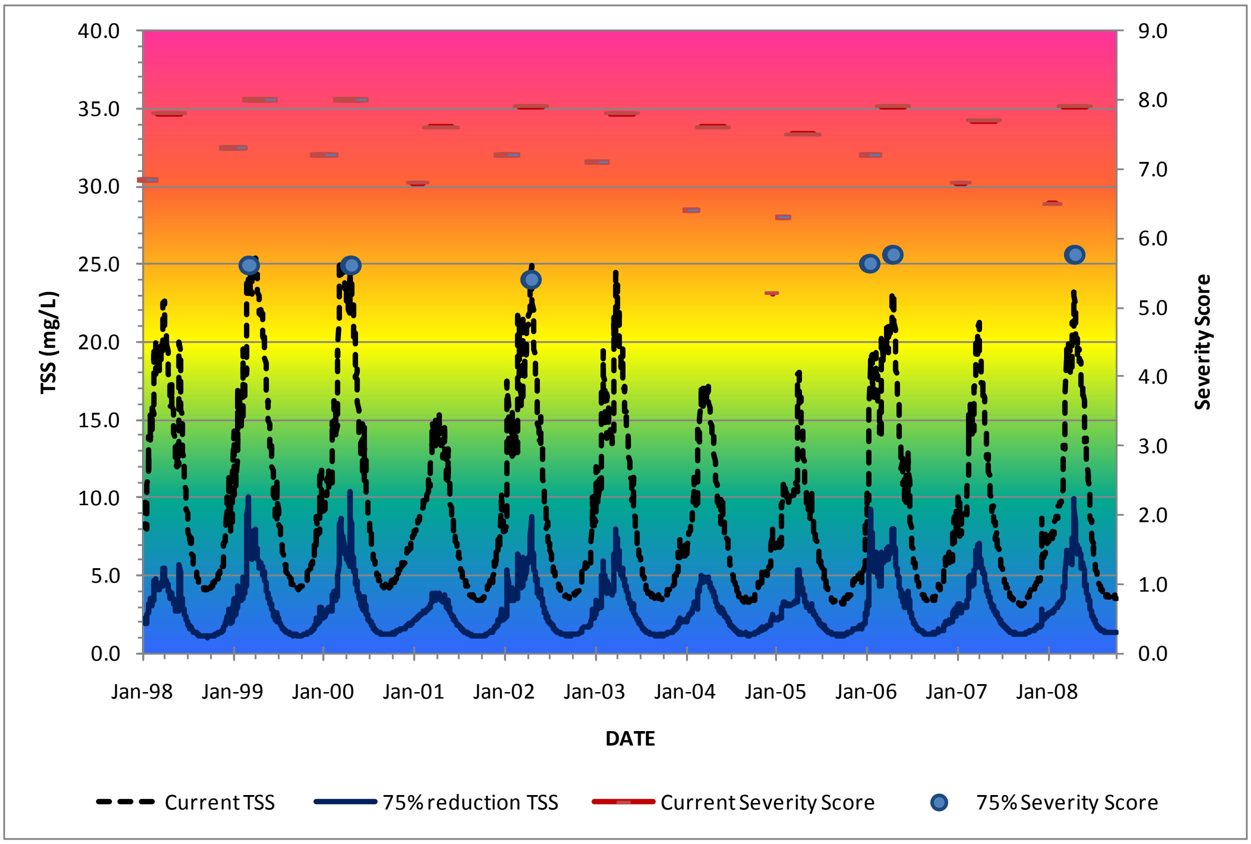

Figure 36. Total suspended solids (TSS) concentrations and fish severity scores for current conditions at the mouth of the Little Spokane River and estimated values under a 75% solids reduction.

Load and Wasteload Allocations

Wasteload allocations

Fecal coliform (FC) bacteria

Point sources

Few point sources in the LSR watershed are potential contributors to the current FC load because their wastewater sources, modes of discharge, and operation and maintenance programs are low-risk. For example, land-applied municipal wastewater at Deer Park, Diamond Lake, and Mountainside Middle School should not be FC sources if permit requirements are followed. As mentioned earlier, county and city stormwater infrastructures in the LSR watershed area have relied on infiltration-type systems rather than discharges to surface waters. These types of systems are less likely to carry bacteria into receiving waters. Sand and gravel facilities and dairies in the watershed have not been identified as having discharges to surface waters.

CDC Mead LLC is the only surface water NPDES permit in the watershed with limits for FC. Although the facility is not currently operating, the permit has been renewed and is active. The permit contains FC limits for sanitary wastes discharged from the facility to Deadman Creek. The limits are based on "all known and reasonably available technology" that require a 7-day average limit of less than 400 cfu/100 mL and a 30-day limit not to exceed 200 cfu/100 mL. The discharge site does not have an authorized mixing zone because Deadman Creek is so small. Currently (February 2011) only stormwater during exceptionally high-intensity storm events is discharged from the facility (Hallinan, personal communication, 2011).

The FC loading capacity of Deadman Creek is already exceeded at sites above (Deadman Creek at Heglar) and below (Deadman Creek above Little Deep Creek) the CDC Mead outfall (Table 22). Given that streamflows in the vicinity of the outfall during the May through September critical period are less than 1 cfs (SCCD, 2003), the sanitary or combined effluent CDC Mead must meet *extraordinary primary contact* criteria at the end of the outfall and not increase FC downstream more than 2 cfu/100 mL over background.

When streamflows are greater in October through April, the FC criteria must be met at the end of the outfall with not more than a 2 cfu/100 mL increase over instream background FC counts. A complete analysis of October -April streamflows, dilution capacity, and background FC loading in the vicinity of the outfall, along with effluent volume estimates and disinfection efficiencies, should be conducted before sanitary, process, and stormwater waste limits for FC are set.

FC bacteria samples have not been collected from the Colbert Landfill and the Spokane Fish Hatchery in recent years. Neither has FC limits in their permits, and they were not expected to be significant sources of FC loading. Both outfalls are located in reaches that currently meet the designated beneficial use. We suggest that permit managers require periodic monitoring to ensure effluent FC counts from these two facilities continue to be far below 50 cfu/100 mL, and they do not increase downstream FC counts more than 2 cfu/100 mL.

Waste management operations at dairies in the Dragoon Creek, Deadman Creek, and Upper LSR sub-watersheds should be given priority for annual inspections. These water bodies already exceed their FC loading capacities, so proper manure management is essential. Herd access to surface waters is another issue, at some dairies that requires careful management and needs to be solved in reaches with known FC loading problems. The FC wasteload allocation recommended for dairies is zero.

Sand and gravel facilities that adequately treat stormwater and effluent to meet turbidity requirements of this TMDL are not expected to contribute the FC loading. Since none of the facilities discharge to surface water, the FC wasteload allocation for these sources is zero.

Stormwater

Spokane County and the city of Spokane are responsible for municipal stormwater (MS4) control in urbanized areas of the Middle and Lower LSR sub-watersheds (Figure 9). This is also the area in the watershed most likely to continue having construction activity under Ecology-directed permits. Little Deep Creek, Deadman Creek, and Dartford Creek sub-watersheds and LSR drainage between RM 7.5 at Waikiki Road and RM 16 near Colbert are located in these jurisdictions. Most of these water bodies had FC criteria violations in both seasons evaluated in the TMDL and require FC load reductions (Table 34). The Washington State Department of Transportation (WSDOT) is responsible for stormwater in the urbanized area and any other TMDL water body potentially affected by runoff from highways, rest areas, or any other WSDOT facility.

Table 34. Fecal coliform (FC) statistics for water bodies in the urbanized areas of the Little Spokane River watershed subject to MS4 stormwater permit limits.

Location	October-April			May-September		
	Number of Samples	Geometric mean cfu/ 100 mL	90th percentile cfu/ 100 mL	Number of Samples	Geometric mean cfu/ 100 mL	90th percentile cfu/ 100 mL
LSR above Deadman Cr	26	19	**136**	15	**65**	**253**
Deadman Cr above Little Deep Cr	13	12	33	9	**84**	**228**
Little Deep Creek	11	**109**	**1835**	5	**470**	**1150**
Deadman Creek at mouth	18	23	**113**	9	**129**	**598**
Dartford Creek	12	21	**184**	5	**108**	**221**

Bold values: Do not meet Washington State criteria.

Monitoring data were not collected to adequately provide numeric FC loads from MS4 and WSDOT stormwater sources. When data are available, EPA guidance requires numeric loads to be established in the stormwater permits (Hanlon and Keehner, 2010). Also as noted earlier, these jurisdictions commonly use infiltration treatment, a method very effective in reducing fecal coliform loads. In the interim, the three jurisdictions will be required to identify surface discharges of stormwater directly to receiving waters and implement best management practices (BMPs) that reduce FC counts in stormwater to achieve *extraordinary primary recreation* criteria in these receiving waters.

Construction-related activities regulated under permit are not expected to have FC loads associated with runoff. Following standard treatment procedures for TSS and turbidity at construction sites should prevent any incidental FC loading for a site.

The FC wasteload allocations recommended in the LSR watershed are summarized in Table 35. Meeting these wasteload allocations will maintain *extraordinary primary contact recreational* uses or bring receiving waters back in compliance with the FC criteria.

Table 35. Recommended fecal coliform (FC) wasteload allocations for dischargers in the Little Spokane River watershed covered by NPDES and State General Permits.

<table>
<tr><th>Permittee Name and ID</th><th>Permit type</th><th>Period</th><th>Water Body Name</th><th>Wasteload Allocation</th></tr>
<tr><td>WDFW Spokane Fish Hatchery WAG137007D</td><td>General Permit</td><td>All year</td><td>Little Spokane River</td><td rowspan="2">Extraordinary primary contact criteria met at edge of mixing zone</td></tr>
<tr><td>Colbert Landfill WAD980514541</td><td>Remediation</td><td>All year</td><td>Little Spokane River</td></tr>
<tr><td rowspan="4">Spokane County WAR046506</td><td rowspan="4">Stormwater</td><td rowspan="4">All year</td><td>Little Spokane River</td><td rowspan="6">Maintain extraordinary primary contact criteria in receiving waters</td></tr>
<tr><td>Deadman Creek</td></tr>
<tr><td>Little Deep Creek</td></tr>
<tr><td>Dartford Creek</td></tr>
<tr><td>Washington State Department of Transportation WAR04000A</td><td>Stormwater</td><td>All year</td><td>All TMDL-listed surface waters</td></tr>
<tr><td>City of Spokane WAR046505</td><td>Stormwater</td><td>All year</td><td>Little Spokane River</td></tr>
<tr><td>CDC Mead LLC</td><td>Industrial</td><td>All year</td><td>Deadman Creek</td><td>Extraordinary primary contact criteria at end of pipe and not raise FC more than 2 cfu/100 mL</td></tr>
<tr><td>Dairies</td><td></td><td>All year</td><td>All TMDL-listed surface waters</td><td rowspan="2">Zero</td></tr>
<tr><td>Sand and Gravel Facilities</td><td>General</td><td>All year</td><td>All TMDL-listed surface waters</td></tr>
</table>

Temperature

Point sources

Point sources in the LSR watershed are not considered significant potential contributors to the current thermal load to surface waters. Land-applied municipal wastewater at Deer Park, Diamond Lake, and Mountainside Middle School, infiltration-type treatment systems for stormwater infrastructures, and sand and gravel facilities are low-risk for thermal loading. Dairies in the watershed have not been identified as having discharges to surface waters.

Two regulated surface water discharges into the LSR originate from groundwater sources that are cooler than local receiving waters. The Colbert Landfill treats groundwater and discharges it at RM 19.7 (RKM 31.7). The effluent has had a maximum summer temperature of 13.3 ºC (Spokane County, 2010). The WDFW Spokane Fish Hatchery at RM 6.9 (RKM 11.1) discharges hatchery run water from Griffith Springs. The hatchery effluent at the main outfall and brood outfall consistently run at 12º to 13 ºC during the summer. These temperatures are cooler than the 7-DADMax 16 ºC criterion for all water bodies in the LSR watershed.

The effluent temperatures of these two sources are (1) lower than the receiving waters under critical conditions with mature system-potential shade in place and (2) provide localized cooling (Figures 28 and 29). Therefore, no alteration of effluent treatment is needed. However, their permits should have temperature limits consistent with the receiving water criteria. The permit limits should follow WAC 173-201A-200(1)(c)(i), limiting the 7-DADMax temperature increase outside the mixing zone to less than 0.3 ºC over background.

CDC Mead LLC holds an active NPDES permit for sanitary, process, and stormwater discharges to Deadman Creek. Although the facility is not active, the permit has been renewed. Low flows 550 feet upstream of the outfall on Deadman Creek are less than 1 cfs according to monitoring data collected by the Spokane County Conservation District in 2001 (SCCD, 2003). Water temperatures at the upstream site during low flow were 11.9 ºC to 13 ºC, suggesting the source was groundwater inflow. The NPDES permit does not allow a mixing zone.

Without a mixing zone and with receiving water temperatures below the 7-DADMax 16 ºC criterion in the receiving water, CDC Mead effluent cannot comply with the mixing formula in WAC 173-201A-200(1)(c)(ii)(A):

Incremental temperature increases resulting from individual point source activities must not, at any time, exceed 28/(T+7) as measured at the edge of the mixing zone boundary (where 'T' represents the background temperature as measured at a point or points unaffected by the discharge and representative of the highest ambient water temperature in the vicinity of the discharge).

In addition, the effluent temperature and volume of the combined discharge from CDC Mead is unknown. Therefore, no discharge is allowed unless effluent temperatures do not increase temperatures more than 0.3 ºC immediately downstream of the outfall.

Stormwater

Stormwater (MS4) permits are held by the city of Spokane, Spokane County, and the WSDOT. Although the likelihood of a storm event raising water temperatures above the 7-DADMax is remote, runoff from highways, roads, and developed lands within these jurisdictions is required to be treated before reaching receiving waters. Infiltration treatment, most commonly used by these jurisdictions, is effective in reducing runoff temperatures during summer storm events so that receiving water temperatures are not increased above 0.3 ºC. Wasteload allocations may be necessary for MS4 thermal pollutant loading from some remaining surface stormwater discharges to receiving waters in the watershed, but it is expected that implementation of the NPDES permit-mandated stormwater control program will achieve compliance with targets for temperature.

Thermal loading from direct MS4 stormwater discharges can increase the temperature of small receiving waters at certain times of the year. Runoff from late spring or early fall rainfall onto heated pavement may be quite warm initially, but that runoff cools rapidly during long rain events and is not expected to warm receiving waters to cause a 0.3 °C increase of the 7-day average criteria. As in the following discussion, this presumption must be verified after identifying any direct MS4 discharges to surface waters, and by then monitoring temperature in the receiving water and the stormwater discharges.

The highest water temperatures in Eastern Washington typically occur in July and August. These water temperatures are caused by a combination of weather conditions and lower summer streamflows. Table 8 shows that average precipitation is extremely low during the hottest months of July and August. Although short-duration thunderstorms are not uncommon in the summer, these localized storms produce a moderate quantity of runoff for a very short time. Also, most stormwater in the LSR watershed part of the county and city is discharged to the ground through dry wells and swales, and is less likely to directly discharge to surface water (www.spokanecounty.org/loaddoc.aspx?docid=5080).

Stormwater is also not a likely heat source during October to April. These months are typically much cooler and also may have higher streamflow (Table 9). Precipitation and stormwater runoff is most likely during this period. Therefore it is expected that storm-generated flow will occur during periods that are cool enough to not impact stream temperature.

In the LSR watershed, May and September are the most likely months for stormwater to have an impact on water temperatures that could potentially exceed water quality criteria. There is a potential for May stormwater to be warmer than the 16 °C numeric criteria in some of the smaller tributaries, but it is unlikely that prolonged rainfall will occur during these times to cause the applicable 7-day average daily maximum criteria to be exceeded.

September streamflows are typically some of the lowest of the year and rainfall is also typically low, but early fall rainstorms could cause increased stream temperatures. Whether stormwater runoff is affecting temperature by 0.3 °C would be determined using streamflow and stormwater flow volumes and the temperature difference between them. The standards also allow for a one in ten year exception (i.e., they need to be met in nine of ten years).

Spokane County and the city of Spokane have stormwater programs in place. They are locating all dry wells, swales, and outfalls. The program inventories and maps storm-sewer infrastructure built in the course of development and public capital improvement projects. The inventories include all stormwater infrastructures inside of the MS4 area: www.spokanecounty.org/loaddoc.aspx?docid=5080. Spokane building standards for new development require that stormwater flows mimic natural conditions.

As data are collected, any large stormwater discharges to surface waters should be evaluated for contribution of heat to the stream. This may involve adding continuous temperature monitors to those discharges. The same default equations as for other point sources (shown above under NPDES) can be applied to stormwater discharges and used to verify that these are meeting the wasteload allocation. Smaller discharges, those with flows less than 1% of the receiving water flow, are considered to have negligible individual impact on stream temperature. Monitoring is necessary to determine if the cumulative impact of multiple discharges to a stream reach raises stream temperature.

Our recommendation is that Spokane County, the city of Spokane, and WSDOT continue with best management practices which infiltrate stormwater into groundwater to the maximum extent possible, if other contaminants are well controlled. Infiltration into groundwater cools the runoff and also helps restore the hydrologic regime of the watershed toward natural conditions.

Monitoring data were not collected to adequately provide numeric heat loads from MS4 and WSDOT stormwater sources. When data are available, EPA guidance requires numeric loads to be established in the stormwater permits (Hanlon and Keehner, 2010). Until full inventories of stormwater systems are completed, interim heat loads are established for this TMDL. The temperature wasteload allocations and permit recommendations for stormwater and other point sources in the LSR watershed are summarized in Table 36.

Table 36. Temperature wasteload allocations for point sources in the Little Spokane River watershed.

Permittee Name and ID	Permit type	Period	Water Body Name	Wasteload Allocation
WDFW Spokane Fish Hatchery WAG137007D	General Permit	All year	Little Spokane River	Set permit limits for a 7-DADMax temperature increase outside the mixing zone of less than 0.3 ºC over background.
Colbert Landfill WAD980514541	Remediation	All year	Little Spokane River	
Spokane County WAR046506	Stormwater	All year	Little Spokane River	Continue with permit-directed BMPs which infiltrate stormwater and prevent direct discharges to surface waters. Where surface discharges are present, verify that volumes are < 1% of the receiving water volume from May through October, and temperatures do not exceed 7-DADMax temperature criteria at a probability of more than 1 in 10 years.
			Deadman Creek	
			Little Deep Creek	
			Dartford Creek	
Washington State Department of Transportation WAR04000A	Stormwater	All year	All TMDL-listed surface waters	
City of Spokane WAR046505	Stormwater	All year	Little Spokane River	
CDC Mead LLC	Industrial	All year	Deadman Creek	Zero unless effluent temperatures do not increase temperatures more than 0.3 ºC immediately downstream of the outfall
Dairies		All year	All TMDL-listed surface waters	Zero
Sand and Gravel Facilities	General	All year	All TMDL-listed surface waters	

Turbidity and total suspended solids (TSS)

Point sources

As with FC and temperature, point sources in the LSR watershed may not be large contributors to the current turbidity and TSS load because of their wastewater sources, modes of discharge, and operation and maintenance programs. Land-applied municipal wastewater, infiltration-type systems to treat stormwater, and treated groundwater sources as effluent should not be turbidity and TSS sources if permit requirements are followed.

Because groundwater is the source water, the Colbert Landfill effluent has no permit limit for turbidity and TSS. The geometric mean of 95 turbidity results in the Ecology EIM database for groundwater sampled in the LSR watershed, mostly near the Colbert site, is 0.35 NTU. The wasteload allocation for Colbert effluent is 2 NTU turbidity or 3 mg/L TSS. The limit would safeguard instream aquatic habitat and fish health. These values are equivalent to WQI scores of 90.

The WDFW Spokane Fish Hatchery has monthly average and maximum daily effluent limits in its NPDES permit for TSS. We believe the monthly average and instantaneous maximum daily limits of 5 mg/L and 15 mg/L TSS, respectively, are protective of LSR water quality, especially when dilution within the hatchery embayment is considered, so this is the wasteload allocation for the WDFW Spokane fish Hatchery. The effluent limits result in an acceptable WQI score of 80 for high-flow conditions required in the Lower LSR. Available discharge monitoring reports (DMRs) suggest the hatchery effluent TSS concentrations are much lower than their current limits (Ecology, 2010).

Sand and gravel facilities and dairies are potential sources of TSS and turbidity if they are not maintained and operated properly. Sand and gravel facilities operate under a state General Permit. None of the sand and gravel operations in the LSR watershed discharge to surface water (Chulos, 2011). Their wasteload allocations are zero for turbidity or TSS. None of the dairies in the Dragoon Creek, Deadman Creek, and Upper LSR sub-watershed is currently under an NPDES permit. Currently, dairies in the LSR watershed undergo regular inspections to prevent TSS and turbidity loading problems. The turbidity and TSS wasteload allocations for LSR dairies are zero.

CDC Mead LLC holds an active NPDES permit for sanitary, process, and stormwater discharges to Deadman Creek. Although the facility is not active, the permit has been renewed (Ecology, 2010). Low flows 550 feet upstream of the outfall on Deadman Creek are less than 1 cfs, according to monitoring data collected by the Spokane County Conservation District in 2001 (SCCD, 2003). According to the current permit, the facility is allowed a 15 mg/L TSS daily maximum limit to Deadman Creek (Kraege, 2003). We believe these limits are not protective of aquatic life in Deadman Creek.

The turbidity and TSS loading capacity is exceeded (not met) in Deadman Creek above (Deadman Creek at Heglar) and below (Deadman Creek above Little Deep Creek) the CDC Mead outfall (Table 33). Redband trout have been found in Deadman Creek and require habitat protection and restoration (Figure 4). The facility's permit does not allow a mixing zone because of the small size of Deadman Creek. Therefore, permit limits will need to meet downstream TMDL loading capacities. A TSS concentration of 4 mg/L has a TMDL target WQI score of 80. The wasteload allocation is a monthly average effluent concentration of 4 mg/L TSS and shall not increase downstream turbidity 5 NTU over background to meet TMDL requirements throughout the year. A weekly maximum concentration and loads for the facility cannot be determined until it becomes active.

Stormwater

Stormwater runoff is another potential source of TSS and turbidity in the critical months. The city of Spokane, Spokane County, and WSDOT are responsible for stormwater controls in urban jurisdictions within the Lower LSR and Deadman Creek areas. Construction stormwater is also regulated by Ecology at a local level.

As mentioned earlier, infiltration has been the treatment system of choice in this part of the county. However, permit holders are required to inventory their systems. This TMDL will require treatment of any stormwater for turbidity and TSS that directly discharges to surface waters. According to stormwater treatment manuals, 80% removal of TSS is easily achievable. Considering the magnitude of TSS removal and turbidity improvement needed in the affected water bodies, all MS4 stormwater must be treated to remove > 80% of the TSS.

The *Spokane Regional Stormwater Manual* (SRSM) which was adopted by the Board of County Commissioners in June 2008 has been accepted by Ecology as being equivalent to Ecology's *Stormwater Management Manual for Eastern Washington*.

Spokane County included the following within the site-plan review permitting process for new construction notification to applicants regarding the criteria and potential need for coverage under Ecology's Construction Permit (www.spokanecounty.org/loaddoc.aspx?docid=5080):

"In Spokane County, under the SRSM, the *Erosion and Sediment Control Plan* (ESC Plan) is equivalent (as approved by Ecology) to the *Construction Stormwater Pollution Prevention Plan*, referenced as in Appendix 1 of the Permit. An ESC Plan shall be submitted with each proposed application for development that is proposing to disturb more than one acre of land, as required within the municipal permit, and for projects of less than one acre that are part of a common plan of development or sale, as required within the municipal permit."

Proper permitting and inspection of construction sites will reduce the potential for loading from these activities. Sedimentation is such a problem in the LSR watershed that construction stormwater discharges to TMDL-listed waters should be avoided. If discharge is unavoidable, we recommend that turbidity should not exceed 5 NTUs over background at any time.

Monitoring data were not collected to adequately provide numeric TSS loads and turbidity from MS4 and WSDOT stormwater sources. When data are available, EPA guidance requires numeric loads to be established in the stormwater permits (Hanlon and Keehner, 2010). The turbidity and TSS wasteload allocations for stormwater and other point sources in the LSR watershed are summarized in Table 37.

Table 37. Suggested turbidity and total suspended solids (TSS) wasteload allocations for dischargers in the Little Spokane River watershed covered by NPDES permits.

Water Body Name	Season	Permittee Name and ID	Permit Type	Wasteload Allocation
Little Spokane River	Year-round	WDFW Spokane Fish Hatchery WAG137007D	General Permit	5 mg/L TSS monthly avg./ 15 mg/L TSS at any time
Little Spokane River	Year-round	Colbert Landfill WAD980514541	Remediation	<2 NTU or <3 mg/L TSS
Deadman Creek	Year-round	CDC Mead LLC	Industrial	Monthly average of 4 mg/L TSS
Little Spokane River	Year-round	Spokane County WAR046506	Stormwater	>80% removal of TSS
Deadman Creek				>80% removal of TSS
Little Deep Creek				>80% removal of TSS
Little Spokane River	Year-round	City of Spokane WAR046505	Stormwater	>80% removal of TSS
All TMDL-listed surface waters	Year-round	Washington State Dept. of Transportation WAR04000A	Stormwater	>80% removal of TSS
All TMDL-listed surface waters	Year-round	Construction Stormwater	General Permit	<5 NTU turbidity over background
All TMDL-listed surface waters	Year-round	Sand & Gravel facilities	General Permit	Zero
All TMDL-listed surface waters	Year-round	Dairies		Zero

Load allocations

Fecal coliform (FC) bacteria

Load allocations are set to limit the effect of nonpoint sources on *contact recreation* uses. FC load allocations include nonpoint-source and background load estimates.

The average daily FC load capacity from Table 23 is shown in Table 38 with 10% reserve allocations for growth and margin of safety, and the remainder as daily average load allocations representing background and nonpoint sources.

Table 38. Fecal coliform (FC) daily average load allocations for sites monitored in the Little Spokane River watershed.

Location	FC Reduction	Load Allocation* cfu/day x 10^{10}	Reserve Allocation** cfu/day x 10^{10}	Average Daily Load Capacity cfu/day x 10^{10}
LSR at Scotia Road	-	1.3	0.14	1.4
LSR at Elk	7%	3.4	0.38	3.8
LSR at Deer Park-Milan	-	3.9	0.43	4.3
LSR at Chattaroy	5%	7.2	0.80	8.0
LSR above Deadman Cr.	60%	6.0	0.67	6.7
LSR at Painted Rock	-	32	3.6	36
LSR at mouth	20%	56	6.2	62
Moon Creek	28%	0.09	0.01	0.10
West Branch LSR below Sacheen Lake	-	0.11	0.01	0.12
Buck Creek	-	0.34	0.04	0.37
Beaver Creek	5%	0.10	0.01	0.11
West Branch LSR above Eloika Lake	-	0.30	0.03	0.33
West Branch LSR below Eloika Lake	-	0.52	0.06	0.58
Dry Creek	46%	0.59	0.07	0.66
Otter Creek	90%	0.03	0.003	0.03
Bear Creek	24%	0.13	0.01	0.14
Deer Creek	87%	0.31	0.03	0.34
Dragoon Creek at Oregon Road	94%	0.05	0.006	0.06
Dragoon Creek at Dahl Road	36%	0.29	0.03	0.32
Dragoon Creek at Crawford Road	95%	0.16	0.02	0.18
Dragoon Creek at Monroe	77%	0.36	0.04	0.40
West Branch Dragoon Creek	89%	0.31	0.04	0.35
Dragoon Creek at mouth	70%	2.0	0.2	2.2
Deadman Creek at Holcomb Road	85%	-	-	-
Deadman Creek at Heglar Road	70%	0.51	0.06	0.57
Peone Creek	71%	0.04	0.004	0.04
Deadman Creek above Little Deep Creek	56%	0.9	0.1	1.0
Little Deep Creek	95%	0.14	0.02	0.16
Deadman Creek at mouth	83%	1.0	0.1	1.1
Dartford Creek	63%	0.21	0.02	0.23

* Load allocation includes background and nonpoint sources of FC.
** Reserve allocation provided for anticipated growth in the watershed.

Temperature

Temperature load allocations are based on re-establishing mature riparian vegetation along the LSR and its tributaries. The daily heat and shade allocations for the mainstem LSR from the QUAL2K analysis are quantified in Appendix C, Table C-8. System-potential shade requirements along the mainstem LSR are graphically displayed in Figure 37. Since there are no significant point-source thermal loads to the mainstem, heat load allocations by kilometer are recommended as increases in riparian shade and reductions in solar heat loading as average watts/meter squared/day ($W/m^2/d$).

Some tributary load allocations, like for Bear Creek pictured in Figure 38, were assessed by WSU/WWRC (Barber et al., 2007) using the Shade model. Results are presented in Table 39. The solar heat load reductions and load allocation estimates are based on the riparian vegetative shade assessments previously shown in Table 25.

Mature riparian vegetation along other tributaries that were not modeled can be estimated using the site-specific channel geometry and the effective shade curve in Appendix C, Table C-7. This is equivalent to establishing heat and shade allocations. The effective shade is based on mature system-potential vegetation assuming a pine forest with a canopy height of 82 ft (25.0 m), a density of 70%, and a 10-ft (3.3-m) overhang set in a riparian buffer width of 75 ft (22.9 m) from each bank.

Establishing riparian vegetation and increasing shade will decrease solar exposure of the LSR and increase channel complexity. Redband and rainbow trout, mountain whitefish, and other sensitive aquatic species require water temperatures less than 20 ºC, a variety of riffle, run and pool habitats, and adequate spawning substrate. Mature system-potential riparian vegetation will assist in lowering temperatures, stabilizing streambanks, and eventually allow large woody debris to increase channel complexity. Future temperatures will not meet the 16 ºC *core summer salmon* criteria during critical conditions, but the temperatures will be protective of cold-water native fish communities.

These allocations will result in water temperatures that are equivalent to the temperatures that would occur under natural conditions. When mature shade is attained, either the stream temperatures will meet, or be cooler than, the numeric criterion, or the stream will have cooled to a natural temperature that is higher than the numeric criterion. The standard will be met based on the natural conditions provision of the water quality standards, WAC 173-201A-070(2), which states: "*Whenever the natural conditions of said waters are of a lower quality than the criteria assigned, the natural conditions shall constitute the water quality criteria*."

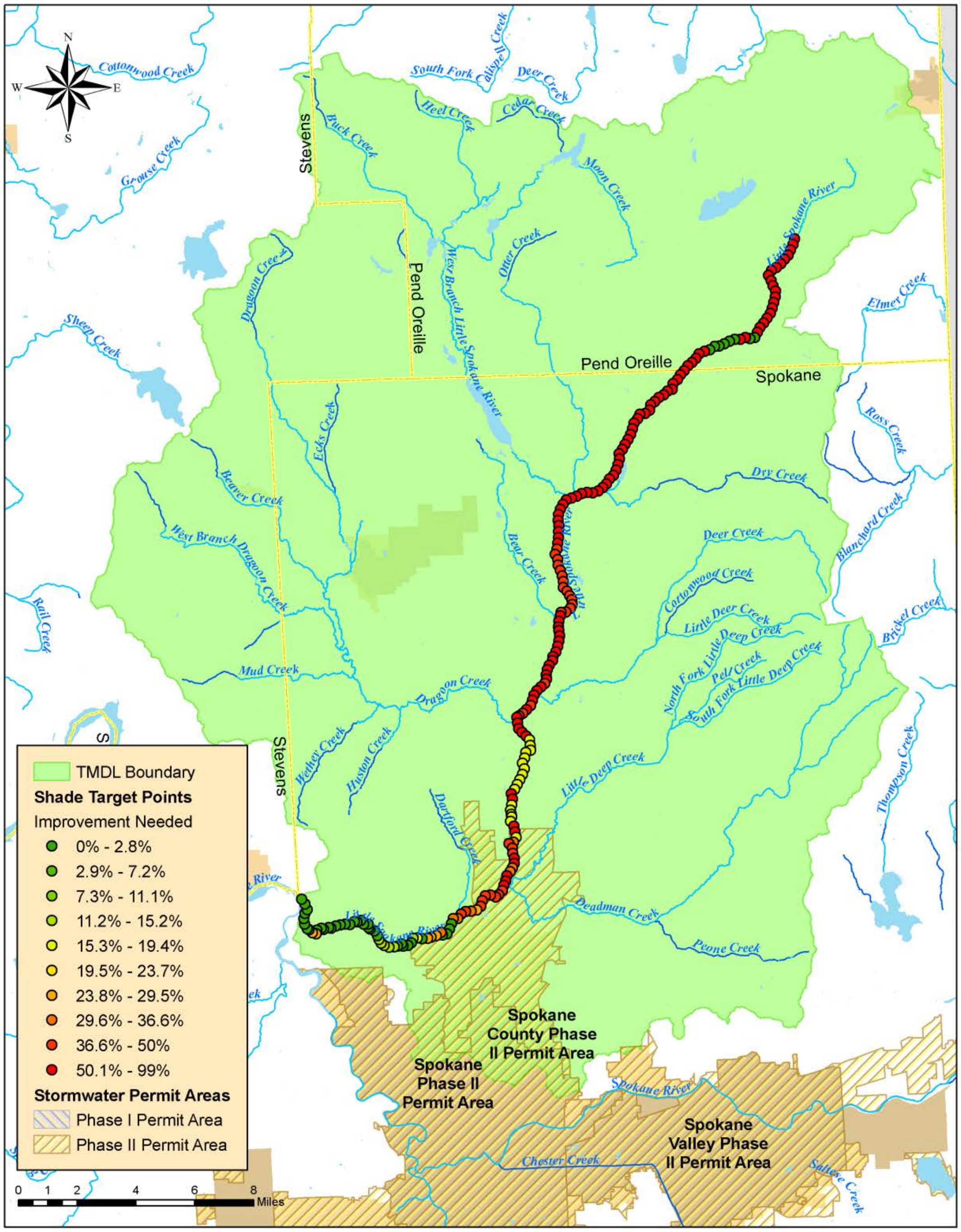

Figure 37. Additional system-potential shade needed from riparian vegetation along the mainstem Little Spokane River to meet temperature TMDL load allocation requirements.

Table 39. Average daily heat load allocations for tributaries in the Little Spokane River (LSR) watershed.

Tributary	Miles Evaluated	Recommended Additional Shade	Recommended Solar Reduction	Average Solar Heat Load Allocation ($W/m^2/day$)
Dry Creek	9.3	36%	87%	17
Otter Creek	11.8	61%	92%	17
West Branch LSR	18.6	11%	44%	42
Bear Creek	6.2	19%	77%	18
Deer Creek	15	39%	83%	24
Dragoon Creek	25	55%	87%	25
Deadman Creek	21	46%	78%	39
Dartford Creek	6.8	40%	89%	15

Figure 38. Bear Creek riparian area through a former pasture.

Turbidity and total suspended solids (TSS)

WQI scores were calculated for the three sites where multiple regression equations were used to develop TSS load reductions. The seasonal WQI scores over 80 consistently required 5% less reduction than when the multiple regression equation method was used (Table 30). Considering these results, the average daily TSS load capacity from Table 32 is shown in Table 40, with 10% reserve allocations for growth and margin of safety, and the remainder as daily average load allocations representing background and nonpoint sources.

Table 40. Daily average total suspended solids (TSS) load allocation for sites monitored in the Little Spokane River watershed.

Site Name	Required Reduction (%)	TSS Load Capacity (tons/day)	TSS Load Allocation[1] (tons/day)	Reserve Allocation[2] (tons/day)
LSR at Scotia	40	0.3	0.27	0.03
LSR at Elk	—	0.5	0.45	0.05
LSR at Deer Park-Milan Road	25	1.5	1.3	0.2
LSR at Chattaroy	40	2.6	2.3	0.3
LSR below Dragoon Creek	70	2.2	2.0	0.2
LSR above Deadman Creek	65	2.5	2.3	0.2
LSR at Rutter Parkway	65	5.1	4.6	0.5
LSR at the Mouth	75	4.9	4.4	0.5
Moon Creek above Sacheen Lake	—	0.04	0.04	0.004
West Branch below Sacheen Lake	—	0.08	0.07	0.008
Buck Creek	40	0.3	0.27	0.03
Beaver Creek	30	0.08	0.07	0.008
West Branch above Eloika Lake	—	0.66	0.60	0.07
West Branch below Eloika Lake	—	0.62	0.56	0.06
Dry Creek	10	0.12	0.11	0.01
Otter Creek	—	0.03	0.03	0.003
Bear Creek	—	0.04	0.04	0.004
Deer Creek	80	0.2	0.18	0.02
Dragoon Creek above Deer Park	60	0.1	0.09	0.01
Dragoon Creek below Deer Park	65	0.1	0.09	0.01
West Branch Dragoon Creek	35	0.2	0.18	0.02
Dragoon Creek at Crescent Road	60	0.9	0.81	0.09
Deadman Creek at Holcomb*	40	-	-	-
Deadman Creek at Heglar	95	0.1	0.09	0.01
Peone Creek	40	0.04	0.04	0.004
Deadman Creek above Little Deep Cr.	45	0.7	0.63	0.07
Little Deep Creek	80	0.1	0.09	0.01
Deadman Creek at Mouth	70	0.7	0.63	0.07
Dartford Creek	90	0.05	0.04	0.005

* Deadman Creek at Holcomb requires a 40% TSS reduction, but data were not available to calculate TSS loads.
[1] Load allocation includes background and nonpoint sources of TSS.
[2] Reserve allocation provided for anticipated growth in the watershed.

Seasonal variation

Seasonal variation for each of the three parameters has been discussed. The critical-season conditions on which to base wasteload and load allocations were taken into account. Briefly, the seasonal conditions best defining the critical conditions were:

- Fecal coliform (FC) bacteria – May through September at the majority of sites.
- Temperature – July and August high seasonal temperatures.
- Turbidity and TSS – March through May and December and January trout and whitefish spawning periods.

Reserve capacity for future growth

Urban development and changes to more intensive residential land use are imminent in the LSR watershed. Major transportation corridors are currently under development linking Spokane to Deer Park. One of Spokane's major urban growth areas is along the LSR at the confluence with Deadman Creek and Little Deep Creek. Other commercial service areas follow the LSR north to the confluence with the West Branch LSR.

A 10% reserve allocation at all monitored sites was recommended for FC and TSS loads, in part, for pollutant loading from future land-use conversions. Heat loads are based on forest-type riparian vegetation that would significantly limit the impacts of land-use changes.

Margin of Safety

As previously stated, an explicit or implicit margin of safety (MOS) is required for TMDL analyses based on the level of uncertainty in the TMDL evaluation. Implicit expressions are integrated into conservative modeling and data analysis assumptions. Explicit expressions would be declarations that the sum of the load and wasteload allocation will also set aside a load dedicated to the MOS that will still meet the loading capacities.

Fecal coliform bacteria

Since the statistical roll back method used to compute the 90^{th} percentile values is generally considered conservative, an implicit MOS was assumed. This is particularly true with limited data sets, as extrapolation can produce higher 90^{th} percentile values than were actually measured. Further adding to the conservative approach was the analysis of seasonal critical period. By excluding low values typically associated with high flows, the reductions required to meet state standards were higher.

An explicit MOS was added in the form of a 10% reserve FC load allocation. The reserve allocation, in addition to the implicit MOS, was determined to adequately address uncertainty in the relatively small data sets and to address some issues with future growth in the watershed.

Temperature

The temperature analysis was developed with a large implicit MOS. The current vegetation could be underestimated in some reaches, so additional shade requirements may be overestimated. The differences in the model results likely overestimate the shade targets required in the temperature TMDL. The following are examples:

- The current riparian vegetation mapped for the Shade model was given a vegetation code based on current land use and a few field observations (Barber et al., 2007). If a riparian land use was not in a forest category, a shrub-type code was allotted with a maximum height of 0.9 meters and 25% density. This generally underestimated residential landscapes of large willows, firs, cherry, and other large trees commonly observed by Christian (SCCD, 2003) in residential areas.
- Microclimate effects, streamflow augmentation, and reach-specific channel modifications are sometimes modeled as part of the system-potential shade simulation. None of these additional effects or modifications was used in the QUAL2K model.
- Hyporheic cooling effects can be locally important features, but they were not simulated in the QUAL2K model.

Turbidity and total suspended solids (TSS)

Turbidity and TSS modeling included implicit MOS assumptions by drawing on the most conservative interpretation of data to protect redband trout and whitefish health and habitat. Examples include:

- The loading capacities were based on application of seasonal capacities to the entire year to ensure more sediment source-control measures.
- Both turbidity and TSS measurements were analyzed, and the most restrictive of WQI values was used.
- Results of more conservative multiple regression model techniques were used where available.

An explicit MOS was added in the form of a 10% reserve TSS load allocation. The reserve allocation, in addition to the implicit MOS, was determined to adequately address (1) uncertainty in the relatively small data sets and (2) some issues with future growth in the watershed.

Reasonable Assurance

When establishing a TMDL, reductions of a particular pollutant are allocated among the pollutant sources (both point and nonpoint) in the water body. In the Little Spokane River, TMDL, both point and nonpoint sources exist for FC bacteria, temperature, and turbidity. TMDLs (and related implementation plans) must show “reasonable assurance” that these sources will be reduced to their allocated amount. Education, outreach, technical and financial assistance, permit administration, and enforcement will all be used to ensure that the goals of this TMDL are met.

Ecology believes that the following activities already support this TMDL and add to the assurance that FC, temperature, and turbidity in the LSR will meet conditions provided by Washington State water quality standards. This assumes that the activities described below are continued and maintained.

The goal of the LSR *Water Quality Improvement Report* for FC, temperature, and turbidity is to help the waters of the basin meet the state’s water quality standards. Ecology believes the work completed and the plans in place provide reasonable assurance that the LSR TMDL goals for FC, temperature, and turbidity will be met in 25 years.

The ability to meet specific interim targets and milestones will depend on the funds available, the personnel and resources available, and the producers in the watershed. Some pollutants will take longer to reach water quality standards than others. For example, it may take up to 50 years to reach the temperature standards because of the time it takes to grow plants and trees that will provide shade to the streams. Turbidity will require establishing functioning riparian areas, streambank stabilization, and other measures throughout the watershed.

Table 41 shows interim reduction targets for FC, temperature, and turbidity. Once implementation begins, it will become obvious whether the table is accurate. Adjustments should be made accordingly.

Table 41. Schedules for achieving water quality standards.

Percentage of TMDL targets achieved	Number of years after TMDL *Water Quality Improvement Plan* completion		
	FC bacteria	Temperature	Turbidity/TSS
25%	3	10	5
50%	5	15	7
75%	8	20	10
100%	10	25	15

The following entities will help ensure the TMDL targets will be met:

Spokane County Conservation District

The Spokane County Conservation District has authority under Chapter 89.08 RCW to develop farm plans and protect water quality, and to provide animal waste management information, education, and technical assistance to residents on a voluntary basis. Ecology will refer landowners' water quality issues to the conservation district, and the conservation district will provide technical assistance to the landowners in order to meet water quality standards. When developing farm plans, the conservation district uses guidance and specifications from the U.S. Natural Resources Conservation Service.

Pend Oreille Conservation District

The Pend Oreille Conservation District works closely with the Spokane County Conservation District. Both of their missions fall within the jurisdiction of Chapter 89.08 RCW. The Pend Oreille Conservation District works in the northern portion of the LSR watershed.

U.S. Natural Resources Conservation Service (NRCS)

The NRCS works closely with the conservation districts to implement farm plans and agricultural best management practice (BMP) programs. NRCS is one of the primary entities for technical assistance and financial support to assist in the implementation of agricultural and livestock BMPs throughout the LSR watershed.

Spokane River and Lake Spokane Dissolved Oxygen TMDL

The *Spokane River and Lake Spokane Dissolved Oxygen TMDL* relies partially on the reduction of phosphorous coming from the LSR. Therefore, Spokane River dischargers have an interest in implementing BMPs in the LSR to help offset portions of their total phosphorous allocations. BMPs that reduce phosphorus will likely also reduce FC, temperature, and turbidity. Ecology and the Spokane County Conservation District anticipate that many cooperative partnerships will be formed between entities involved in both TMDLs.

West Branch Lake Group

The West Branch Lake Group is a voluntary group made up of residents along the West Branch LSR that is dedicated to improving of water quality in the West Branch LSR. The group is well established and holds regular meetings. Because the group is made up of residents, they provide a landowner's perspective in achieving better water quality.

Spokane and Tri-County Regional Health Districts

The health department regulates on-site sewage systems in the watershed in accordance with Chapter 246-272 WAC. When the department receives a complaint about a failing system, the department verifies the failure and assists the landowner with coming into compliance with

Chapter 246-272 WAC. In addition, the health department is often involved in the investigation of complaints about agricultural animal waste.

Spokane County and City of Spokane

The LSR falls under the requirements of the Shoreline Management Act (SMA) (RCW 90.58). The SMA is administered principally by local governments through locally developed Shoreline Master Programs (SMPs). Ecology provides technical and financial assistance for the development and implementation of the SMPs.

WRIA 55/57 Watershed Planning Unit

Among the implementation actions taken by the watershed group are efforts to enhance recreation. These efforts include investigating surface water storage and identifying potential wetland storage sites as well as creating new wetlands. Participation in the TMDL process for the LSR is also one of the unit's action items.

Spokane County

Spokane County is currently administering a water conservation grant in the LSR. The project is focused on water conservation and improving flows in the LSR.

Pend Oreille County

Pend Oreille County signed an Interlocal agreement with Spokane County to cooperate with Spokane County in administering their water conservation project.

Washington State Department of Ecology (Ecology)

Ecology has the authority under the federal Clean Water Act through EPA to establish water quality standards and administer the NPDES wastewater permitting program. Ecology has additional state authority to enforce water quality regulations under Chapter 90.48 RCW. Ecology responds to complaints, conducts inspections, and issues NPDES permits as part of its responsibilities under state and federal laws and regulations.

In cooperation with conservation districts, Ecology will pursue implementation of BMPs for agricultural and other land uses. Ecology may use formal enforcement, including fines, if voluntary compliance is unsuccessful; however, it is the goal of all participants in the LSR TMDL process to achieve clean water through voluntary control actions.

Ecology also provides financial assistance in the form of grants and loans to local governments and non-profit organizations to help apply and install BMPs.

Washington State Department of Transportation (WSDOT)

Compliance with WSDOT's municipal stormwater permit in all Phase II coverage areas constitutes compliance with the goals of this TMDL.

Washington Department of Fish and Wildlife (WDFW)

WDFW will be an active participant to monitor fisheries resources dependent on water quality actions in the watershed.

Spokane County Water Resource Program

This program is an important participant for organizing citizen advisory groups, coordinating studies, bringing larger Spokane River basin issues to light, and informing other county departments of water quality activities.

Implementation Strategy

Introduction

This implementation strategy describes what will be done to improve water quality. It explains the roles and authorities of cleanup partners (those organizations with jurisdiction, authority, or direct responsibility for cleanup), along with the programs or other means through which they will address these water quality issues.

After EPA approves this TMDL, interested and responsible parties work together to develop a detailed *water quality implementation plan*. The plan describes and prioritizes specific actions planned to improve water quality and achieve water quality standards.

What needs to be done?

A local workgroup made up of concerned citizens and agencies was formed in May 2003. Goals of the workgoup were to identify water quality issues in the watershed and to recommend best management practices (BMPs) that offer solutions to water quality issues. This implementation strategy reflects the local needs, values and priorities. Although total phosphorus is not specifically targeted by this TMDL, the workgroup is aware of the need to address the phosphorus load at the mouth of the LSR and added activities to address nutrients. It was the intent of the workgroup to identify activities that will also reduce contributions of phosphorous. The water quality-related issues evaluated for the TMDL by the workgroup were:

Issue 1: Sediment/nutrients from agricultural operations
Issue 2: Sediment/fecal from livestock
Issue 3: Nutrients/chemicals from residential areas
Issue 4: Nutrients/fecal from septic systems
Issue 5: Sediment/chemicals from gravel and summer roads
Issue 6: Sediment from storm water
Issue 7: Forestry management
Issue 8: Recreation impacts

The consensus of the group was that if issues 1 through 8 were addressed, stream temperature would also benefit. For example, riparian planting is a component of installing buffers. Although the primary purpose of stream buffers is for sediment control, the planting will eventually provide shade to cool the water.

Other water quality issues were identified for the LSR watershed during the public meetings and by the workgroup. The following issues were reviewed by the workgroup, but because they did not significantly affect the parameters of interest (fecal, sediment, and temperature), they were not included in the detailed work for the TMDL.

Chemicals from road deicer

Chemicals from agricultural application
County enforcement of regulations
State enforcement of regulations
New wetland construction and maintenance of existing wetlands
Maintain/increase existing healthy, functioning riparian areas
Invasive aquatic plants
Beaver ponds

General benefits or motivations common to most desired practices were identified as:
Improves water quality.
Decreases any penalties associated with water quality violations.
It is the right thing to do, may influence neighbors.
Reduces health risk?
Increases healthy fish populations?
Potential financial or technical assistance?

General costs or barriers common to most desired practices were identified as:
Costs more money.
Inconvenient, need more equipment or infrastructure.
Increased maintenance.
Takes land out of production.

General benefits or motivations common to most current practices were identified as:
Easy, convenient.
Costs less, cheaper.
No government interference.
More land in production, especially for leased land.

General costs or barriers common to most current practices were identified as:
Possible fines, enforcement actions.
Future regulations.
Contributes to pollution.
Missed opportunities for financial assistance.

The anticipated approaches to meet load allocations for each pollutant are outlined under Next Steps. The approaches that are expected to be used include the implementation of sediment reducing and livestock management BMPs, along with an information and education program. As incentive and implementation programs for BMPs are developed, monitoring and mapping efforts will continue to assess the benefits of the implementation. Schedules and milestones for the implementation will be developed during the detailed implementation plan phase.

For each water quality issue evaluated by the workgroup, implementation activities (BMPs) were proposed for each issue. Along with each issue and BMP, the targeted water quality parameter and potential problems to implement the BMP were identified. Following are the BMPs, parameters addressed, and the potential problems for implementing the BMPs.

For each of these issues, the current practice(s) and the desired practice(s) were identified. In general, the desired practice is a management practice that tends to improve water quality for the issue being discussed. Along with the desired practices, both barriers and benefits for continuing the current practices, and barriers and benefits for changing to the desired practices were evaluated.

A summary of the issue list, along with the benefits and costs, follows. Specific costs and benefits for each issue are listed under the specific issue. The costs and benefits common to most of the issues and practices are listed first. There were several issues where the desired practice and current practice could be switched, depending on a person's point of view. It was recognized that most issues would benefit from continued, if not more public education. BMPs, the parameters addressed, and the potential problems associated with implementation of the BMPs are detailed in Section 4.3.

Issue 1: Sediment/nutrients from agricultural operations

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Direct seed system	Sediment, Nutrients, Turbidity	Keeps sediment on field, less precipitation runoff, lower fuel costs, less time preparing fields, and improves soil health.	Equipment change, change in farm plans and practices, owner vs. leaser, initial decrease in yields, increase in chemical use, colder soil temperature, fields stay wetter.
Riparian buffers	Sediment, Nutrients, Temperature, Dissolved Oxygen	Increases local water quality, better stream side habitat, reduces erosion, reduces solar heating of water, and helps reduce flood damage.	Loss of highly productive cropland, harder to farm, weeds, costs in time and money to establish, potential wildlife fecal inputs.
Sediment basins	Sediment, Nutrients	Traps sediment on farm. Reduces runoff from fields.	Cost to install, have to be able to farm around, may need to clean out, small loss of farmland.
Grassed waterway	**Sediment,** Nutrients	Slows water and reduced sediment to streams. Keeps sediment on farm fields.	Hay usually produces less return than other crops, maintenance, limited habitat, establishment time can be long.
Filter strips	Sediment, Nutrients, Temperature	Reduces hillside erosion and keeps sediment from entering streams. Increases wildlife habitat.	Reduces farmable land, weed problems, requires maintenance.
Divided slopes and strip cropping (NRCS practice 585 and archived practice 586)	**Sediment,** Nutrients	Reduces hill slope, keeps sediment on fields.	Harder to farm, may not work with all crops, increased turning time, pesticide and herbicide application harder and less precise.

Issue 2: Sediment/fecal from livestock

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Riparian buffer	Sediment, Nutrients, Fecal	Increases local water quality, better stream side habitat, reduces erosion, reduces solar heating of water, and helps reduce flood damage.	Requires new water access or source, more maintenance, weed problems.
Livestock fencing	Sediment, Nutrients, Fecal	Reduces fecal contamination, cows prefer clean water from an system, improves riparian areas and habitat.	Requires new water access or source, more maintenance, potential problem during high water events.
Manure retention facilities	Nutrients, Fecal	Provides a central location for manure handling. Allows for easier application on fields.	Initial costs, requires truck access and space may be a problem.
Off-creek watering	Sediment, Nutrients, Fecal	Improves water quality, reduces bank erosion, reduced fecal to water, cows prefer clean water from a system.	Need year-round water source, may need numerous sources if large number of livestock, maintenance.
Intensive grazing management	Sediment, Nutrients, Fecal	Prevents pasture damage from overgrazing. Makes better use of pasture land. Can make land more productive	Requires more land. Added fence costs.
Nutrient/fecal management NRCS Standard 590	Sediment, Nutrients, Fecal	Provides nutrients back to pastures. Discourages over-fertilization.	Requires soil testing, may require more equipment.
Composting	Nutrients, Fecal	Provides nutrients back to pastures.	Limited by size, need an extra area for composting storage.
Reduce/remove runoff through livestock areas	Sediment, Nutrients, Fecal	Reduces runoff damage, diverts water away from active eroding areas, better livestock health.	Initial costs, may require some water routing space and materials.

Issue 3: Nutrients/Chemicals from Residential uses

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Fertilizer management	Nutrient	Saves money on fertilizer purchases.	Need better education at local level.
Septic maintenance	Nutrients, Fecal	Prolongs life of system.	Increased maintenance costs.
Pet waste management	Nutrients, Fecal	Keeps neighbors happy.	Need to have bags along when walking pets, need a place to put waste.
Proper household chemical use and disposal	Chemicals, Nutrients	Saves money on chemical purchases and prevents contamination around the house.	Need to take to local recycle centers where hazardous household waste can be taken.
Proper pesticide/herbicide use and disposal	Chemicals, Nutrients	Saves money on chemical purchases and prevents contamination around the house.	Need to take to local recycle centers where hazardous household waste can be taken.
No lawn clipping dumping in streams	Chemicals, Nutrients	Can be used in compost pile and used on garden.	Need another way to compost or dispose of yard waste.
Follow shoreline management	Sediment, Chemicals, Nutrients	Stays compliant with all current regulations.	May limit (remove "Less") access to the water, limit (remove "loss") of view, weed problems.
Riparian buffers	Sediment, Nutrients, Temperature, Dissolved Oxygen	Increases local water quality, better stream side habitat, reduces erosion, reduces solar heating of water, and helps reduce flood damage.	Loss of backyards and views, weeds, cost in time and money to establish, potential wildlife fecal inputs.
Storm water	Sediment, Nutrients, Temperature, Dissolved Oxygen, chemicals	Stays compliant with all current regulations	Increased cost, increase land use near roads, maintenance of ditches

Issue 4: Nutrients/fecal from Septic Systems

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Educate on the negative effects of garbage disposals	Fecal, Chemicals, Nutrients	Prolongs septic system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	Desired in kitchens, may already exist.
Have system inspections every 1-3 year	Fecal, Chemicals, Nutrients	Prolongs system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	Cost of inspection/pumping done on a regular basis. Need to target older systems near streams.
Take roof drains out of system/away from drain field	Fecal, Chemicals, Nutrients	Prolongs septic system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	May not have a good area to drain roof system to.
Educate about proper items to go into systems	Fecal, Chemicals, Nutrients	Prolongs system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	Reaching people with septic systems, not enough places for disposal of household hazardous wastes.
Comment on new developments through SEPA	Fecal, Chemicals, Nutrients	Prolongs septic system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	The Spokane County Conservation District may not be on all lists for review. Public may not be aware of opportunity to comment.
Replace or repair failing systems	Fecal, Chemicals, Nutrients	Prolongs system life, reduces maintenance costs, could prevent contamination around drain field. Reduces health hazards.	High cost, many people may not know systems need to be replaced.
Gray water systems for new development		Add capacity for new const, may be able to re-use gray water	Cost more to build, hard to retrofit existing systems, water may not be useable in all garden areas.

Issue 5: Sediment/Chemical from Gravel and Summer Roads

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Pave roads	Sediment	Reduces soil erosion and windblown dust.	Initial cost to pave and maintenance. Chemical de-icers and oil runoff.
Close roads in winter	Sediment	No winter runoff or sediment.	Less access, may require gates on roads, more maintenance.
Increased grading and graveling	Sediment	Better road conditions, better drainage.	Increased costs for the county.
Vegetative buffers	Sediments, Chemicals	Traps sediment and reduces erosion along road.	Need larger right of ways, weeds, cost in time and money to establish. Utilities may be impacted
Reduce speed limits	Sediment	Reduce damage to roads.	Hard to enforce.
Rock controls to reduce flow velocity in ditches	Sediment	Reduces ditch erosion and maintenance.	May collect debris.

Issue 6: Sediment from Storm Water

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Road/impervious surfaces direct runoff to basin/settling ponds	Sediment, Chemicals	Reduces sediment to streams, helps recharge local groundwater.	Increased cost, increase land use near roads, maintenance of ditches.
Vegetative buffers	Sediments, Nutrients, Chemicals	Increases local water quality, better habitat, and reduces solar heating of water.	Need larger right of ways, weeds, cost in time and money to establish. Need to design swales and drainage ways.
Direct Stormwater to treatment facilities	Sediments, Nutrients, Chemicals	Allows for better storm water handling in high density housing areas.	High cost and maintenance. Need infrastructure from roads. Will probably only work in high-density areas.

Issue 7: Forestry Management

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Selective harvest	**Sediment**	Healthier forest, better harvest over time, higher resale value, higher production.	Less income, need skilled logger, may be topography dependent.
Stream crossings	Sediment	Better water quality, less erosion.	Cost more, may have to remove after completion.
Streamside management zones	Sediment Temperature	Higher resale value and reduced fire hazard.	Less trees available for logging, harder to remove logs.
Proper road planning & construction	Sediment	Healthier forest, better harvest over time, higher resale value, higher production.	May take longer to plan, could increase road costs.
Identification signage of logger or company; DNR keeps list	Sediment, Temperature, Forest Condition	Allows public to rate logging jobs done in the area. Highlights skilled loggers and provides better future trees.	Require sign be maintained for a period of time, possible up to five years.
Education of landowner; Understand Forest Practices Act	Sediment, Temperature, Forest Condition	Healthier forest, better harvest over time, higher resale value, higher production.	May be hard to keep an up to date list of contractors. Difficult to get out to new landowners.
Replant trees, reseed grasses	Sediment, Forest Condition	Healthier forest, better harvest over time, higher resale value, higher production.	Requires more post-harvest time. Cost more to replant than to let reseed naturally.

Issue 8: Recreational Impacts

BMP	Parameters Addressed	Potential Benefits to Implement BMP	Potential Problems to Implement BMP
Boat cleaning station	Milfoil distribution, Chemical	Reduces aquatic weed problems. Allows boat owners to easily clean boats and trailers.	High cost to install and maintain. Need some way to handle wash water. Needs to be easy and fast, no waiting. Space could be a problem.
Dump stations	Fecal, Chemicals, Nutrients	Keeps the lakes healthier, provides a convenient location for dumping waste.	High cost to install and maintain. Need some way to handle waste. Need to be convenient for boat operators.
Parks bathroom/ changing stations	Fecal, Chemicals, Nutrients	Keeps park trails and streams healthier and cleaner. Provides convenient location for going to the bathroom.	High cost to install and maintain. Need daily cleaning/care.
Pet waste Station	Fecal, Nutrients	Keeps the trails clean for walking.	Need some way to handle waste. Need to be convenient to trails and kept stocked.
Design access for parks	Sediment	Allows park users easy access to water and aesthetic areas.	Higher cost to install and maintain. May put hard structures in a more natural area.
Proper carrying capacity	Fecal, Chemicals, Nutrients	Prevents overcrowding of facilities. Better for wildlife and habitat.	May have to turn people away when parks are full. Need full time attendant at gate.
Proper boat speed	Shoreline erosion, Sediment	Prevents shore erosion, keeps lakes and streams safer. Saves money on gasoline, noise is reduced	Hard to enforce. Need more education about why boat speed is important.

Implementation activities

Implementation activities will generally involve the agencies responsible for the development of the implementation strategy, namely the Spokane County Conservation District, Pend Oreille Conservation District, the Washington Department of Ecology, Spokane County, Pend Oreille County, the city of Spokane, Washington Department of Transportation, and the Spokane and Tri-County Regional Health Districts. The implementation activities will also involve other agencies and groups, such as the Pacific Northwest Direct Seed Association, Washington State University Extension, seed and fertilizer companies, local producer based cooperatives, the Natural Resources Conservation Service, Washington Department of Transportation, and the Farm Service Agency.

The ability to meet specific interim targets and milestones will depend on the funds available, the personnel and resources available, and the producers in the watershed. The Little Spokane watershed lies within the boundaries of three conservation districts: Spokane County Conservation District, Pend Oreille Conservation District, and Stevens County Conservation District. Each district has an interest in improving water quality. Based on their collective expertise in obtaining, leveraging, and utilizing grant type funding for getting conservation on the ground, the following interim targets are proposed (after the final TMDL plan is approved):

Year	Interim Targets
2	Initial grants applied for and BMP programs setup
3	Ongoing watershed wide education/information program setup
5	20% of target areas in BMP program
7	25% improvement in water quality at 90% confidence level
11	75% improvement in water quality at 90% confidence level
13	Meets water quality standards 90% of the water year.
15	Meets Spokane River TMDL phosphate load requirements at confluence

The intent of this water quality improvement report (WQIR) is to install all measures that benefit water quality within a ten-year timetable. We recognize that even after measures are implemented, there will be a lag time before water quality standards are met. Streambank planting projects, for example, will take time for vegetation to mature before maximum water quality benefit will be realized.

These targets will require significant commitment from all stakeholders. Without watershed wide commitment the targets may not be met.

A detailed plan called a water quality improvement plan (WQIP) will be developed following EPA's approval of this plan. The WQIP will outline specifics on who will commit to implementation, what they will implement, where they will be implementing, and a timetable for completion.

The state's forest practices regulations will be relied upon to bring waters into compliance with the load allocations established in this TMDL on private and state forest lands. This strategy, referred to as the Clean Water Act Assurances, was established as a formal agreement to the 1999 Forests and Fish Report (www.dnr.wa.gov/Publications/fp_rules_forestsandfish.pdf).

The state's forest practices rules were developed with the expectation that the stream buffers and harvest management prescriptions were stringent enough to meet state water quality standards for temperature and turbidity, and provide protection equal to what would be required under a TMDL. As part of the 1999 agreement, new forest practices rules for roads were also established. These new road construction and maintenance standards are intended to provide better control of road-related sediments, provide better streambank stability protection, and meet current BMPs.

To ensure the rules are as effective as assumed, a formal adaptive management program was established to assess and revise the forest practices rules, as needed. The agreement to rely on the forest practices rules in lieu of developing separate TMDL load allocations or implementation requirements for forestry is conditioned on maintaining an effective adaptive management program.

Consistent with the directives of the 1999 Forests and Fish agreement, Ecology conducted a formal ten-year review of the forest practices and adaptive management programs in 2009:

www.ecy.wa.gov/programs/wq/nonpoint/ForestPractices/CWAassurances-FinalRevPaper071509-W97.pdf

Ecology noted numerous areas where improvements were needed, but also recognized the state's forest practices program provides a substantial framework for bringing the forest practices rules and activities into full compliance with the water quality standards. Therefore, Ecology decided to conditionally extend the CWA assurances with the intent to stimulate the needed improvements. Ecology, in consultation with key stakeholders, established specific milestones for program accomplishment and improvement. These milestones were designed to provide Ecology and the public with confidence that forest practices in the state will be conducted in a manner that does not cause or contribute to a violation of the state water quality standards.

The success of this TMDL project will be assessed using monitoring data from streams in the watershed.

SEPA/Planning

Land use planning activities must consider TMDLs during State Environmental Policy Act (SEPA) and other local land use planning reviews. If the land use action under review is known to potentially impact temperature, fecal coliform bacteria, and turbidity as addressed by this TMDL, then the project may have a significant adverse environmental impact. SEPA lead agencies and reviewers are required to look at potentially significant environmental impacts and alternatives and to document that the necessary environmental analyses have been made. Land use planners and project managers should consider findings and actions in this TMDL to help prevent new land uses from violating water quality standards. Ecology recently published a focus sheet on how TMDLs play a role in SEPA impact analysis, threshold determinations, and mitigation (www.ecy.wa.gov/biblio/0806008.html). Additionally, the TMDL should be considered in the issuance of land use permits by local authorities.

Who needs to participate?

Washington Department of Ecology

Ecology has authority under the federal Clean Water Act by the U.S. EPA to establish water quality standards, administer the NPDES wastewater permitting program, and enforce water quality regulations under Chapter 90.48 RCW. Ecology responds to complaints, conducts inspections, and issues NPDES permits as part of its responsibilities under state and federal laws and regulations. In cooperation with conservation districts, Ecology will pursue implementation of BMPs for agricultural and other land uses and may use formal enforcement, including fines, if voluntary compliance is unsuccessful.

Spokane County Conservation District and Pend Oreille Conservation District

The conservation districts have authority under Chapter 89.08 RCW to develop farm plans, protect water quality, and to provide animal waste management information, education and technical assistance to residents on a voluntary basis. Farmers receiving a Notice of Correction from Ecology or local health jurisdictions will normally be referred to the local conservation district for assistance. When developing farm plans, the districts use guidance and specifications from the U.S. Natural Resources Conservation Service.

In addition, the conservation districts seek and receive grant funds that will assist landowners to implement BMPs that improve riparian health and protect water quality to the LSR and its associated tributaries.

Natural Resources Conservation Service (NRCS)

NRCS works closely with conservation districts to implement farm plans and agricultural BMP programs. NRCS is one of the primary entities for technical assistance and financial support to assist in the implementation of agricultural and livestock BMPs throughout the watershed.

Spokane and Tri-County Health Departments

The health departments regulate on-site sewage systems in the watershed in accordance with Chapter 246-272 WAC. When the department receives a complaint about a failing system, the department verifies the failure and assists the landowner with coming into compliance with Chapter 246-272 WAC. In addition, the health departments are often involved in the investigation of complaints about agricultural animal waste.

Spokane County, Pend Oreille County, Stevens County, and City of Spokane

The LSR falls under the requirements of the Shoreline Management Act (SMA) (RCW 90.58). The SMA is administered principally by local governments through locally developed Shoreline

Master Programs (SMPs), and Ecology provides technical and financial assistance for the development and implementation of the SMPs.

Ecology reviews and approves the SMPs, and with the local governments has the authority for compliance and enforcement of the SMA and SMPs. Local governments review projects in their jurisdiction for compliance with local SMPs and the SMA through a permit process. The SMA specifically lists protecting water quality as a purpose of the SMA (RCW 90.58.020). Local governments must periodically update their SMPs and must integrate them with their Growth Management Act provisions, including critical area ordinances. As of June 2011, the plan was still being developed.

Other organizations for participation:
Pacific Northwest Direct Seed Association
WDNR
WA State Department of Fish and Wildlife
Lake associations
Friends of the Little Spokane River
County Commissioner Representative
Small communities
Washington State University Extension
WSDOT

What is the schedule for achieving water quality standards?

Implementation activities will involve the agencies noted in the Reasonable Assurances section of this report. The schedule of achieving water quality goals can be found on Table 41 of this WQIR.

Monitoring progress

A monitoring program for evaluating progress is an important component of any implementation strategy. Monitoring is needed to keep track of what activities have or have not been done, measure the success or failure of target pursuit actions, and evaluate improvements in water quality. Monitoring should also be done after water quality standards are achieved (compliance monitoring) to ensure that standards continue to be met.

Monitoring implementation actions and how they will be maintained

A TMDL must include monitoring to measure achievement of targets and water quality standards. Monitoring also provides evidence that BMPs are having the desired results.

Depending on resources, Ecology will be responsible to ensure appropriate monitoring is conducted. Likewise, dependent on resources, conservation districts will be encouraged to partner in monitoring efforts. Where appropriate, photo monitoring will be utilized.

A quality assurance project plan (QAPP) project plan should be prepared for all monitoring conducted. The QAPP should follow Ecology guidelines (Lombard and Kirchmer, 2004), paying particular attention to consistency in sampling and analytical methods.

Effectiveness monitoring

The purpose of effectiveness monitoring is to discover if management activities and BMPs are improving water quality. Effectiveness monitoring results are used to determine if the interim targets and/or water quality standards are being achieved. Ecology usually performs this monitoring five years after the *water quality implementation plan* is finished. The ability of Ecology to conduct the monitoring in five years depends on the availability of resources. If the streams are found to not meet the interim targets and/or water quality criteria, an adaptive management strategy will be adopted and future effectiveness monitoring will need to be scheduled.

BMP monitoring

During the next phase of this TMDL effort, Ecology will develop a water quality implementation plan (WQIP). The plan will include a monitoring strategy that will incorporate monitoring recommendations made in the TMDL Analyses sections of this report. Ecology will monitor the progress made towards implementing the actions outlined in this TMDL and the implementation strategy.

As BMP projects are put into place, progress will be tracked as required by the granting or funding agency. Progress will be tracked using numeric criteria to the extent possible, e.g. feet or acres of planting, feet or miles of fencing, number of off-site watering facilities, etc.

Water quality monitoring for watershed improvements will be scheduled at five-year intervals, depending on funding availability. The monitoring plan will be changed if necessary as an element of adaptive management.

To determine the effectiveness of the pollutant reduction effort, fish population and habitat condition assessments may be necessary.

Stormwater permit holders are responsible for meeting the monitoring requirements of their permits. Organizations conducting restoration projects or installing BMPs are responsible for monitoring plant survival rates and maintenance of improvements, structures and fencing.

Adaptive management

Natural systems are complex and dynamic. The way a system will respond to human management activities is often unknown and can only be described as probabilities or possibilities. Adaptive management involves testing, monitoring, evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings. In the case of TMDLs, Ecology uses adaptive management to assess whether the actions identified as necessary to solve the identified pollution problems are the correct ones and whether they are working. As we implement these actions, the system will respond, and it will also change. Adaptive management allows us to fine-tune our actions to make them more effective, and to try new strategies if we have evidence that a new approach could help us to achieve compliance.

Full TMDL reductions should be achieved by 2036 (Table 41). These targets will be described in terms of percent reductions, concentrations, and implementation activities. Partners will work together to monitor progress towards these goals, evaluate successes, obstacles, and changing needs, and make adjustments to the implementation strategy as needed.

Ecology will use adaptive management when water monitoring data show that the TMDL targets are not being met or implementation activities are not producing the desired result. A feedback loop (Figure 38) consisting of the following steps will be implemented:

Step 1. The activities in the *water quality implementation* plan are put into practice.

Step 2. Programs and BMPs are evaluated for technical adequacy of design and installation. Evaluation will be made by agencies with appropriate expertise with Ecology acting as a facilitator as well as a contributor.

Step 3. Ecology evaluates effectiveness of the activities by assessing new monitoring data and comparing it to the data used to set the TMDL targets.

> Step 3a. If the goals and objectives are achieved, the implementation efforts are adequate as designed, installed, and maintained. Project success and accomplishments should be publicized and reported to continue project implementation and increase public support.
>
> Step 3b. If not, then BMPs and the Implementation Plan will be modified or new actions identified. The new or modified activities are then applied as in Step 1.

Additional monitoring may be necessary to better isolate the bacteria sources so that new BMPs can be designed and implemented to address all sources of bacteria to the streams.

It is ultimately Ecology's responsibility to assure that implementation is being actively pursued and water standards are achieved.

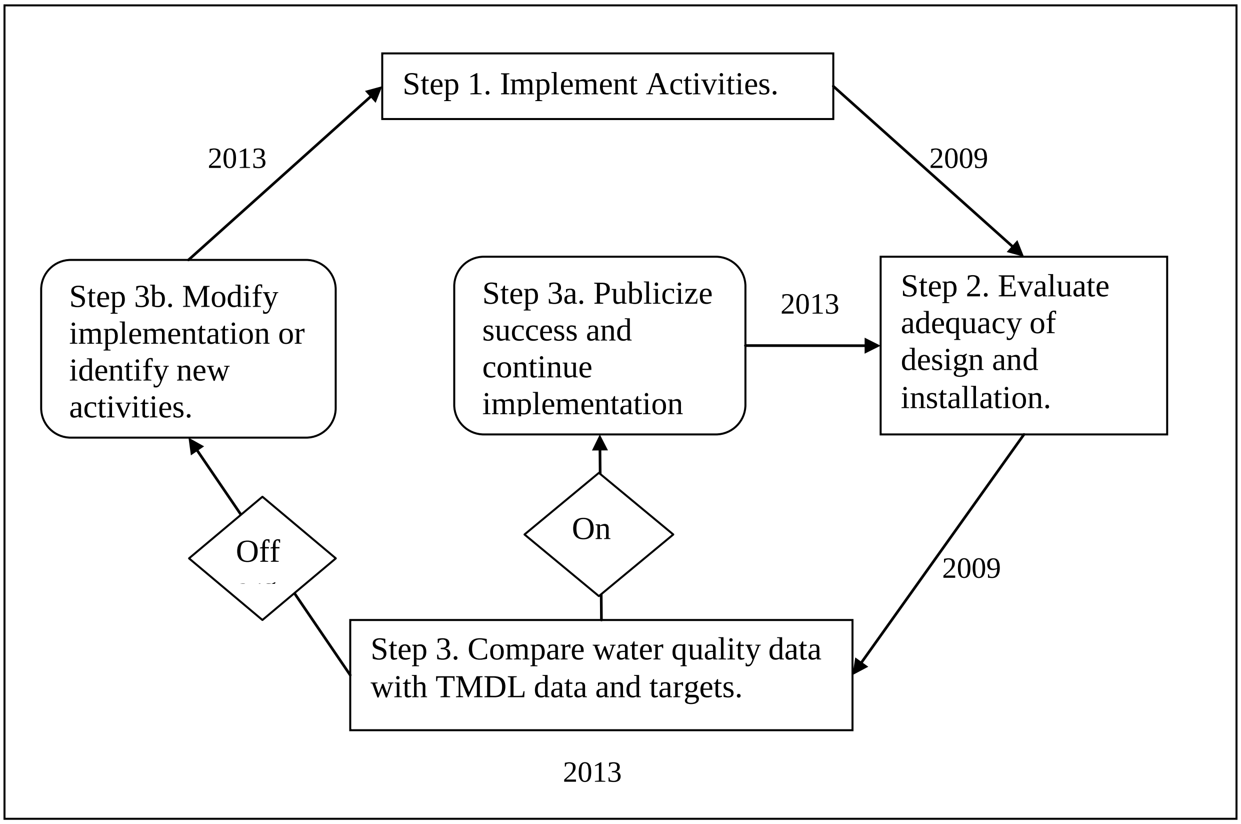

Figure 38. Feedback loop for determining need for adaptive management. Dates are estimates and may change depending on resources and implementation status.

See the *Monitoring Plan* section in this report.

Potential funding sources

Natural Resources Conservation Service	Conservation Programs www.nrcs.usda.gov/programs	These programs "....help people reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other natural disasters."
	Emergency Watershed Protection www.nrcs.usda.gov/programs/ewp/index.html	NRCS purchases land vulnerable to flooding to ease flooding impacts.
	Wetland Reserve Program www.wa.nrcs.usda.gov/programs/wrp/wrp.html	Landowners may receive incentives to enhance wetlands in exchange for retiring marginal agricultural land.
Washington State Conservation Commission	www.scc.wa.gov/index.php/contact/Conservation-Districts Potential Grants List	Various environmental program grants.

Washington State Department of Ecology: Water Quality Program (WQP) Shorelands and Environmental Assistance Program	Centennial Clean Water Fund, Section 319, and State Revolving Fund www.ecy.wa.gov/programs/wq/funding/funding.html	Facilities and water pollution control-related activities; implementation, design, acquisition, construction, and improvement of water pollution control. Priorities include: implementing water cleanup plans; keeping pollution out of streams and aquifers; modernizing aging wastewater treatment facilities; reclaiming and reusing waste water.
	Coastal Zone Protection Fund Watershed Planning www.ecy.wa.gov/watershed/index.html	Some funding is available through a program that taps into penalty monies collected by the WQP. Development of watershed plans to manage water resources and protect existing water rights.
Washington State Public Works Board	Public Works Trust Fund http://pwb.wa.gov/programInfor1.aspx?ActiveView=0	Administered by the Public Works board, this funding provides financial assistance to local government and private water systems. It supports public works projects and encourages independence at the local level.
U.S. Department of Agriculture	Farm Service Agency (FSA): Conservation Reservation Program (CRP) Rural Development: Rural Housing Repair and Rehabilitation	CRP helps agricultural producers protect environmentally-sensitive land. Loans to low-income rural residents to repair, improve, or modernize a home or remove health and safety hazards (e.g. failing on-site septic systems).
U.S. Environmental Protection Agency	Watershed Funding: www.epa.gov/owow/funding.html	Provides tools, databases, and information on funding sources that can be used to protect watersheds.

Summary of public involvement methods

The LSR TMDL work group was formed after two public meetings held in the watershed on April 30 and May 1, 2003. Announcements were posted throughout the watershed, and 1,411 postcard announcements were sent to local businesses, towns, and residences that indicated they were interested in LSR water quality. The first public meeting was held at Colbert Elementary School in the lower part of the watershed, and represented the small acreage and urban land uses. The second public meeting was held at Newport High School in the upper part of the watershed that is representative of more rural, agricultural, and livestock land. An organizational meeting was held at the Spokane County Conservation District on July 24, 2003 with people from the public meetings who indicated they were interested on working on the TMDL. Workgroup meetings have since been held approximately monthly in Riverside, Washington.

Several agencies and organizations were represented at the meetings:

- Ecology
- Audubon Society
- Friends of Little Spokane River
- Eloika Lake Association

- Sierra Club
- City of Spokane
- Spokane County Planning
- Agricultural operators
- Small acreage landowners
- Small community representatives

Spokane and Pend Oreille County Conservation Districts, local citizens, and agency personnel worked collaboratively to identify the water quality issues throughout the watershed and to propose workable best management practices (BMPs) and other solutions. Both the local citizens and agency personnel need to be commended for their patience throughout the TMDL process. Although the process was initiated in 2003, challenges in gathering data, processing data, and analyzing data created a lag time longer than what was anticipated. The group needs to be commended for their perseverance, dedication and patience in seeing this process through.

In addition to a press release that went to area media, a public comment period was held from October 24, 2011 through November 24, 2011. Ads were placed in three local newspapers: The *Elk Sentinel*, November, 2011 issue (which was published in October), the October 26, 2011 issue of the *Newport Miner*, and the October 24, 2011 issue of the *Spokesman-Review*.

References

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer, 1976. Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey Professional Paper 964, Reston, VA. http://landcover.usgs.gov/pdf/anderson.pdf

Aroner, E., 2007. WQHydro - Water Quality/ Hydrology/ Graphics/ Analysis Package. Portland, OR.

Casola, J.H., J.E. Kay, A.K. Snover, R.A. Norheim, L.C. Whitely Binder, and the Climate Impacts Group, 2005. Climate Impacts on Washington's Hydropower, Water Supply, Forests, Fish, and Agriculture. A report prepared for King County (Washington) by the Climate Impacts Group (Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle).

Barber, M., T. Cichosz, S. Chen, Y. Luo, G. Fu, and A. Al-Omari, 2007. Total Maximum Daily Load Technical Report for the Little Spokane River: Data Collection, Analysis, and Recommendations. November 16, 2007. Report to the Washington State Department of Ecology Environmental Assessment Program, Olympia, WA.

Barnes, Harry H., Jr. 1967. Roughness Characteristics of Natural Channels. U.S. Geological Survey Water-Supply Paper 1849, U.S. Government Printing Office, Washington, DC.

Canwell, S., 2003. Macroinvertebrate study of the Little Spokane River and its tributaries. Master of Science thesis, Biology Department, Eastern Washington University, Cheney, WA.

Chapra, S.C. and G.J. Pelletier, 2003. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality (Beta Version): Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Christian, P.A., 2003. A riparian study of the Little Spokane River and its tributaries using a geographic information system (GIS). Master of Science thesis, Biology Department, Eastern Washington University, Cheney, WA.

Chulos, J., 2011. Personal communication with Washington State Department of Ecology, Eastern Regional Office, Water Quality Program, Sand & Gravel permit manager. February 25, 2011.

Chung, S.K., 1975. Little Spokane River Basin (Water Resources Inventory Area No. 55). Washington State Department of Ecology, Water Resources Program, Olympia, WA. 68 pgs.

Cichosz, T., G. Fu, S. Chen, and M. Barber, 2005. Little Spokane River Watershed Total Maximum Daily Load Study: Revised Quality Assurance Project Plan. Publication SWWRC-04-006. State of Washington Water Research Center, Pullman, WA.

Cohn, T., 2002. Estimator 2002, A Beta Release by Tim Cohn. January 30, 2002, Updated June 4, 2002. www159.pair.com/cohns/TimCohn/TAC_Software/Estimator/e2002/

Coots, R., 2002. Colville River Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication 02-03-036. www.ecy.wa.gov/biblio/0203036.html

Cusimano, R. and D. Giglio, 1995. Salmon Creek Nonpoint Source Pollution TMDL. Washington State Department of Ecology, Olympia, WA. Publication No. 95-355. www.ecy.wa.gov/biblio/95355.html

Dolan, D.M., A.K. Yui, and R.D. Geist, 1981. Evaluation of river load estimation methods for total phosphorus. J. Great Lakes Research, 7(3): 207-214.

Ecology, 1995. Little Spokane River Watershed Draft Initial Assessment. May 1995. Washington State Department of Ecology, Water Resources Program, Spokane, WA. 8 pgs. www.ecy.wa.gov/biblio/95163.html

Ecology, 2006. Surface Water Criteria. Washington State Department of Ecology, Water Quality Program website. www.ecy.wa.gov/programs/wq/swqs/criteria.html

Ecology, 2009. Washington State Department of Ecology, River and Stream Water Quality Monitoring website. Little Spokane River watershed (WRIA 55) historical station network. Accessed June 2009. www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html.

Ecology, 2010. Permit and Reporting Information System (PARIS) retrieval of WDFW Spokane Hatchery discharge monitoring report data. Washington State Department of Ecology, Olympia, WA.

EPA, 2000. Ambient Water Quality Criteria Recommendations Rivers and Streams in Nutrient Ecoregion II. EPA 88-B-00-015. Office of Water, U.S. Environmental Protection Agency, Washington, DC.

EPA, 2007. Level III Ecoregions of the continental United States. U.S. Environmental Protection Agency. National Health and Environmental Effects Research Laboratory, Corvallis, OR. www.epa.gov/wed/pages/ecoregions/level_iii_iv.htm

Golder Associates, 2003. Little Spokane Watershed Instream Flow Needs Assessment Report. Submitted to the Middle and Little Spokane Watershed Planning Unit. Spokane, WA. www.spokanecounty.org/wqmp/projects/PDF/Instream_Flow_Report-Text.pdf

Hallinan, P., 2011. Personal communication with Eastern Regional Office Water Quality Program permit manager. Spokane, WA.

Hallock, D., 1991. Little Spokane River Study, Final Report. Washington State Department of Ecology, Olympia, WA. Publication No. 91-e15, 20pgs. www.ecy.wa.gov/biblio/91e15.html

Hallock, D., 1996. Spokane Basin Data Analysis Report – Little Spokane Sub-Basin. Washington State Department of Ecology, Olympia, WA. 12 pages. Publication No. 96-329. www.ecy.wa.gov/biblio/96329.html

Hallock, D., 2002. A Water Quality Index for Ecology's Stream Monitoring Program. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-052. 17 pgs + app. www.ecy.wa.gov/biblio/0203052.html

Hamlet A.F. and D.P. Lettenmaier, 1999. Effects of climate change on hydrology and water resources in the Columbia River Basin. Journal of the American Water Resources Association, 35(6):1597-1623.

Hamlet, A.F., P.W. Mote, M. Clark, and D.P. Lettenmaier, 2005. Effects of temperature and precipitation variability on snowpack trends in the western U.S. Journal of Climate, 18 (21): 4545-4561.

Hanlon, J.A. and D. Keehner, 2010. Revisions to the November 22, 2002 Memorandum: Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs. U.S. Environmental Protection Agency, Office of Wastewater Management and Office of Wetlands, Oceans, and Watersheds, Washington, DC. 7 pgs.

Hillman, T.W., M.D. Miller, and B.A. Nishitani, 1999. Evaluation of Seasonal-Cold-Water Temperature Criteria. BioAnalysts, Inc. Prepared for: Idaho Division of Environmental Quality, Boise, ID. 48 pgs.

Joy, J., 1981. Dragoon Creek receiving water study/Deer Park STP. Memorandum to Carl Nuechterlein. Washington State Department of Ecology. Spokane, WA. Publication No. 81-e18. 28 pgs. www.ecy.wa.gov/biblio/81e18.html

Joy, J., 2000. Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-006. 60 pgs + app. www.ecy.wa.gov/biblio/0003006.html

Joy, J. and T. Swanson, 2005. Walla Walla River Basin Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington Department of Ecology, Olympia, WA. Publication No. 05-03-041. 76 pgs + app. www.ecy.wa.gov/biblio/0503041.html

Joy, J. and S. Tarbutton, 2010. Little Spokane River Watershed Dissolved Oxygen and pH Total Maximum Daily Load Study: Water Quality Study Design (Quality Assurance Project Plan). August 2010. Washington State Department of Ecology, Olympia, WA. Publication No. 10-03-113. www.ecy.wa.gov/biblio/1003113.html

Kahle, S.C., R.R. Caldwell, and J.R. Bartolino, 2005. Compilation of Geologic, Hydrologic, and Ground-Water Flow Modeling Information for the Spokane Valley – Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. Scientific Investigations Report 2005-5227. U.S. Department of Interior, U.S. Geological Survey, Reston, VA.

Kraege, C., 2003. Letter to Mr. Greg Gordon, Kaiser Aluminum and Chemical Co. from Washington State Department of Ecology, Solid Waste and Financial Assurance Program regarding Kaiser Aluminum Mead Works – NPDES Permit No. WA-000876. March 6, 2003. Olympia, WA.

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. www.ecy.wa.gov/biblio/0403030.html.

Lundgren, M., 1998. Dragoon Creek Watershed Management Plan. For the Spokane County and Stevens County Conservation Districts. November 1998. Spokane, WA.

Luo, Yuzhou, 2007. Shade.xls: a tool for estimating shade from riparian vegetation: shade_Mature-New worksheet. In Little Spokane River TMDL model files from Washington State University, Pullman, WA.

MacCoy, D., 2006. Fish Communities and Related Environmental Conditions of the Lower Boise River, Southwestern Idaho, 1974–2004: U.S. Geological Survey Scientific Investigations Report 2006-5111

McLellan, J.G., 2002. Section 2, Part I. Baseline Assessment of Fish Species Distribution and Densities in the Little Spokane River Drainage, Year 1. In: Connor, J., J. McLellan, D. O'Connor, and B. Crossley. Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams. Project No. 1997-00400, (BPA Report DOE/BP-00004619-2).

McLellan, J.G., 2003. Section 2, Part I. Baseline Assessment of Fish Species Distribution and Densities in the Little Spokane River Drainage, Year 2, and the Spokane River between Spokane Falls and Nine Mile Falls Dam. In: Connor, J., J. McLellan, C. Butler, B. Crossley, J. Arterburn, A. Hammond, A. Black, J. Smith, J. Stegan, and D. O'Connor. Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams. Project No. 1997-00400, (BPA Report DOE/BP-00004619-3).

McLellan, J.G., 2005. Section 2, Part I. Baseline Assessment of Fish Species Distribution and Densities in the Little Spokane River Drainage, Year 3, and the Spokane River below Spokane Falls. In: Connor, J., J. McLellan, C. Butler, and B. Crossley. Resident Fish Stock Status above Chief Joseph and Grand Coulee Dams, 2002 – 2003 Annual Report. Project No. 199700400, (BPA Report DOE/BP-00004619-5).

Moore, R.D., D.L. Spittlehouse, and A. Story, 2005. Riparian microclimate and stream temperature response to forest harvesting: a review. Journal of the American Water Resources Association. 41(4):813-834.

Mote, P.W., E. Salathé, and C. Peacock, 2005. Scenarios of future climate for the Pacific Northwest, Climate Impacts Group, University of Washington, Seattle, WA. 13 pp.

Newcombe, C.P. and J.O.T. Jensen, 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management, 16(4):693-727.

Noll, R., J. Joy, and E. Snouwaert, 2009. Hangman (Latah) Creek Watershed Fecal Coliform, Temperature, and Turbidity Total Maximum Daily Load: Water Quality Improvement Report. Washington Department of Ecology, Olympia, WA. Publication No. 09-10-030. www.ecy.wa.gov/biblio/0910030.html

O'Connor, S., 2009. Little Spokane River. Electronic-mail message to S. Braley, June 5, 2009. Water Quality Program, Washington State Department of Ecology, Olympia, WA.

ODEQ, 2001. Ttools 3.0 User Manual. Oregon Department of Environmental Quality, Portland, OR. www.deq.state.or.us/wq/TMDLs/tools.htm

Ott, W.R., 1995. Environmental Statistics and Data Analysis. CRC Lewis Publishers, Boca Raton, FL. 296 pgs.

Plotnikoff, R.W., 1994. Stream Bioassessment for: Little Spokane River at Pine River Park. Washington State Department of Ecology. Unpublished data. Reported in: SCCD, 2003. The Little Spokane Watershed Plan Development: A Compilation of Project Results (2001 – 2002). Water Resources Public Data File 03-01. Spokane County Conservation District, Spokane, WA.

Ross, J., 2004. Total Maximum Daily Load Effectiveness Monitoring Study: Dragoon Creek Quality Assurance Project Plan. Draft March 2004. Environmental Assessment Program, Eastern Regional Office, Washington State Department of Ecology, Spokane, WA.

Ross, J., 2008a. Dragoon Creek Ammonia Nitrogen, Chlorine, and Phosphorus Total Maximum Daily Load Study: Water Quality Effectiveness Monitoring Report. Draft January 2008. Environmental Assessment Program, Eastern Regional Office, Washington State Department of Ecology, Spokane, WA.

Ross, J., 2008b. Quality Assurance Project Plan: Little Spokane River Fish Hatchery Water Quality Monitoring for Nutrients. Washington State Department of Ecology, Spokane, WA. Publication No. 08-03-120. www.ecy.wa.gov/biblio/0803120.html

Ross, J., 2009 unpublished data. Little Spokane River Fish Hatchery Water Quality Monitoring for Nutrients project. Washington State Department of Ecology, Eastern Regional Office, Spokane, WA.

SCCD (Spokane County Conservation District), 2003. The Little Spokane Watershed Plan Development: A Compilation of Project Results (2001 – 2002). Water Resources Public Data File 03-01. Spokane County Conservation District, Spokane, WA.

SCCD (Spokane County Conservation District), 2005a. The Hangman (Latah) Creek Water Sampling Data Summary. Spokane County Conservation District. Spokane, WA. March 2005.

SCCD (Spokane County Conservation District), 2005b. Spokane County Proper Functioning Condition Stream Inventory. Spokane County Conservation District. Spokane, WA. June 2005.

SCCD (Spokane County Conservation District), 2009. Little Spokane River watershed gaging network daily average streamflow data. Spokane, WA.

Scholz, A.T., K. O'Laughlin, D. Geist, D. Peone, J. Uehara, L. Fields, T. Kleist, I. Zozaya, T. Peone and K. Teesatuskie, 1985. Compilation of information on salmon and steelhead total run size, catch and hydropower related losses in the Upper Columbia River Basin, above Grand Coulee Dam. Upper Columbia United Tribes Fisheries Center Fisheries Technical Report No 2. Eastern Washington University, Cheney, WA.

Shrestha, R., G. Fu, S. Chen, and M.E. Barber, 2004. Little Spokane River Watershed Total Maximum Daily Load Study: Draft Quality Assurance Project Plan: July 2004. State of Washington Water Research Center and Washington State University, Pullman, WA.

Soltero, R.A., D.T. Knight, L.M. Sexton, B.L Siegmund, L.L. Wargo, M.L. Wainwright, D.S. Lamb, 1991. Water Quality Assessment and Restoration Alternatives for Sacheen Lake, WA. Sacheen Lake Sewer District, Eastern Washington University and Kennedy Engineers for Washington State Department of Ecology Grant No. TAX 90045. Spokane, WA.

Spokane County, 2005. Watershed Management Plan: Water Resource Inventory Area 55 - Little Spokane River & Water Resource Inventory Area 57 - Middle Spokane River. Draft 03 prepared by: Little Spokane River and Middle Spokane River Planning Unit. Spokane, WA. June 2005. www.spokanecounty.org/wqmp/projects/ASP/WatershedPlan.asp

Spokane County, 2008. Detailed Implementation Plan Little and Middle Spokane River Basins, Water Resource Inventory Area 55/57. Prepared by the WRIA 55/57 Watershed Implementation Team with the assistance of Sound Resolutions and Cascadia Consulting Group Approved on February 20, 2008. Spokane, WA. www.spokanecounty.org/wqmp/projects/PDF/WRIA%2055%2057%20FINAL%20DIP.pdf

Spokane County, 2009. Five Mile Watershed (North Spokane) Virtual Tour. Spokane County Stormwater Utility. North Spokane (Five Mile) Watershed. Spokane, WA. www.spokanecounty.org/data/stormwater/watersheds_miscinfo/fivemile/FiveMileVirtualTour_FINAL_LowRes2.pdf

Spokane County, 2010. Unpublished Colbert Landfill effluent data files. Spokane, WA.

USGS, 1994. 1:250,000 Scale Quadrangles of Land Use/Land Cover GIRAS Spatial Data in the Conterminous U.S. U.S. Geological Survey, Reston, VA. http://gcmd.nasa.gov/records/GCMD_EPA_GIRAS.html

USGS, 2005. 1:100,000 scale National Hydrography Dataset. U.S. Geological Survey, Reston, VA. http://nhd.usgs.gov/data.html

U.S. Census Bureau, 1980. Census of Population, Volume I. Issued Feb 1982; and U.S. Census Bureau 1990 Census of Population and Housing, Summary. www.census.gov

WDFW Region 1 lake management file, 1956. Washington Department of Fish and Wildlife. Eastern Regional Office, Spokane Valley, WA.

Western Native Trout Initiative, 2010. Western Native Trout Status Report: Redband Trout. www.westernnativetrout.org/sites/default/files/Redband-Trout-Assessment.pdf

WRCC, 2009. Washington Climate Summaries. Western Regional Climate Center, Reno, NV. www.wrcc.dri.edu/summary/climsmwa.html

Wydoski, R.S. and R.R. Whitney. 2003. Inland fishes of Washington. University of Washington Press, Seattle, WA.

Zaroban, D.W., M.P. Mulvey, T.R. Maret, R.M. Hughes, and G.D. Merritt, 1999. Classification of Species Attributes for Pacific Northwest Freshwater Fishes. Northwest Science 73(2): 81-93.

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Appendices

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Appendix A. Glossary, acronyms, and abbreviations

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 water bodies (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.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum and minimum thermometers or continuous monitoring probes having sampling intervals of 30 minutes or less.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days prior and the three days after that date.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every 10 years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

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

Anadromous: Types of fish, such as salmon, that go from the sea to freshwater to spawn.

Angular canopy density (ACD): The percentage of time that a given point on a stream will be shaded from direct beam solar radiation between 10 a.m. to 2 p.m. local solar time. For example, if a point on a stream is always shaded from 10 a.m. to 2 p.m. in August, then August ACD at that point is 100%. If that point is never shaded between 10 a.m. to 2 p.m., then ACD at that point is zero. Average ACD of a stream reach is estimated by sampling it over the width and length of the reach. Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80 to 90%

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels" (Dunne and Leopold, 1978).

Baseflow: Groundwater discharge. The component of total streamflow that originates from direct groundwater discharges to a stream.

Benthic: Bottom-dwelling organisms.

Benthic index of biological integrity (B-IBI): A multi-metric index that reflects benthic aquatic community richness and composition, number and abundance of indicator species, trophic organization and function, reproductive behavior, species abundance, and condition of individual aquatic organisms.

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

Biota: Flora (plants) and fauna (animals).

Chronic critical effluent concentration: The maximum concentration of effluent during critical conditions at the boundary of the mixing zone assigned in accordance with WAC 173-201A-100. The boundary may be based on distance or a percentage of flow. Where no mixing zone is allowed, the chronic critical effluent concentration shall be 100% effluent.

Clean Water Act: A 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.

Critical condition: When the physical, chemical, and biological characteristics of the receiving water environment interact with the effluent to produce the greatest potential adverse impact on aquatic biota and existing or designated water uses. For steady-state discharges to riverine systems, the critical condition may be assumed to be equal to the 7Q10 (see definition) flow event unless determined otherwise by the department.

Critical period: For fecal coliform – May through September at the majority of sites; for temperature – July and August high seasonal temperatures; for turbidity and TSS – March through May and December and January trout and whitefish spawning periods.

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

Diel: Of, or pertaining to, a 24-hour period.

Dilution factor: The relative proportion of effluent to stream (receiving water) flows occurring at the edge of a mixing zone during critical discharge conditions as authorized in accordance with the state's mixing zone regulations at WAC 173-201A-100.
http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A-020

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (for example, diurnal temperature rises during the day and falls during the night.)

Ecoregion: A system of environmental classification used by EPA (Omernik and Gallant, 1986) and others that uses geology, vegetation, climate and other natural factors to create areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources.

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of non-self-replicating introduced native species, do not need to receive full support as an existing use.

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

Fecal coliform (FC): 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 plus or minus 0.2 degrees Celsius. FC bacteria 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 (average) of multiple sample values. A geometric mean, is usually less than the arithmetic mean, or commonly understood average, and tends to dampen the effect of few very high or low values, which might bias the arithmetic mean. 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.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

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.

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

Lower LSR: Lower Spokane River below Dartford to the mouth at Lake Spokane (Long Lake).

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

Middle LSR: Lower Spokane River from the confluence of the two branches to Dartford.

Morphology: Shape (e.g., channel morphology).

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

National Pollutant Discharge Elimination System (NPDES): National program for issuing and revising permits, as well as imposing and enforcing pretreatment requirements, under the Clean Water Act. The NPDES permit program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

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

Parameter: Water quality constituent being measured (analyte). A physical, chemical, or biological property whose values determine environmental characteristics or behavior.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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.

Riparian: Relating to the banks along a natural course of water.

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.

Surrogate measures: To provide more meaningful and measurable pollutant loading targets, EPA regulations [40 CFR 130.2(i)] allow other appropriate measures, or surrogate measures in a TMDL. The Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program (EPA, 1998) includes the following guidance on the use of surrogate measures for TMDL development:

When the impairment is tied to a pollutant for which a numeric criterion is not possible, or where the impairment is identified but cannot be attributed to a single traditional "pollutant," the state should try to identify another (surrogate) environmental indicator that can be used to develop a quantified TMDL, using numeric analytical techniques where they are available, and best professional judgment (BPJ) where they are not.

System-potential mature riparian vegetation: Vegetation that can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

System-potential riparian microclimate: The best estimate of air temperature reductions that are expected under mature riparian vegetation. System-potential riparian microclimate can also include expected changes to wind speed and relative humidity.

System-potential temperature: An approximation of the temperatures that would occur under natural conditions. System-potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system-potential condition uses best estimates of *mature riparian vegetation, system-potential channel morphology, and system-potential riparian microclimate* that would occur absent any human alteration.

Thalweg: The deepest and fastest moving portion of a stream.

Total maximum daily load (TMDL): A distribution of a substance in a water body designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations 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.

Total suspended solids (TSS): The suspended particulate matter in a water sample as retained by a filter.

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.

Upper LSR: The East Branch Lower Spokane River above the confluence with the West Branch Lower Spokane River.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute 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.

Water year: October 1 through September 30. For example, WY 2005 is October 1, 2004 through September 30, 2005.

Acronyms and Abbreviations

B-IBI	Benthic index of biological integrity
BMPs	Best management practices
BOD	Biological oxygen demand
DEM	Digital elevation model data for GIS software
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
EPT	*Ephemeroptera, Plecoptera, Trichoptera* macroinvertebrate species
EWU	Eastern Washington University
FC	Fecal coliform bacteria
GIRAS	Geographical information retrieval and analysis system
GIS	Geographic Information System software
LSR	Little Spokane River
NPDES	National Pollutant Discharge Elimination System
NSDZ	Near-stream disturbance zones
NTU	Nephelometric turbidity units
ODEQ	Oregon Department of Environmental Quality
PCB	Polychlorinated biphenyl
POCD	Pend Oreille Conservation District
QA	Quality assurance
QC	Quality control
QUAL2K	A particular EPA-supported water quality model

RCW	Revised Code of Washington
RKM	River kilometer
RM	River mile
SCCD	Spokane County Conservation District
SVRP	Spokane Valley-Rathdrum Prairie aquifer
TMDL	Total maximum daily load (water cleanup plan)
TSS	Total suspended solids
USGS	United States Geological Survey
WAC	Washington (State) Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WQI	Water Quality Index
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation
WSU	Washington State University
WWRC	Washington Water Research Center
WWTP	Wastewater treatment plant

Units of measurement

cfu/100 mL	coliform forming units per 100 milliliters
cfs	cubic feet per second
km	kilometer
log_e or ln	natural logarithm
m	meters
mg/L	milligrams per liter
$W/m^2/d$	watts/meter squared/day
°C	degrees Celsius or centigrade

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Appendix B. Supplemental information on temperature

Overview of stream heating processes

The temperature of a stream reflects the amount of heat energy in the water. Changes in water temperature within a particular segment of a stream are induced by the balance of the heat exchange between the water and the surrounding environment during transport through the segment. If there is more heat energy entering the water in a stream segment than there is leaving, the temperature will increase. If there is less heat energy entering the water in a stream segment than there is leaving, then the temperature will decrease.

The general relationships between stream parameters, thermodynamic processes (heat and mass transfer), and stream temperature change are outlined in Figure B-1.

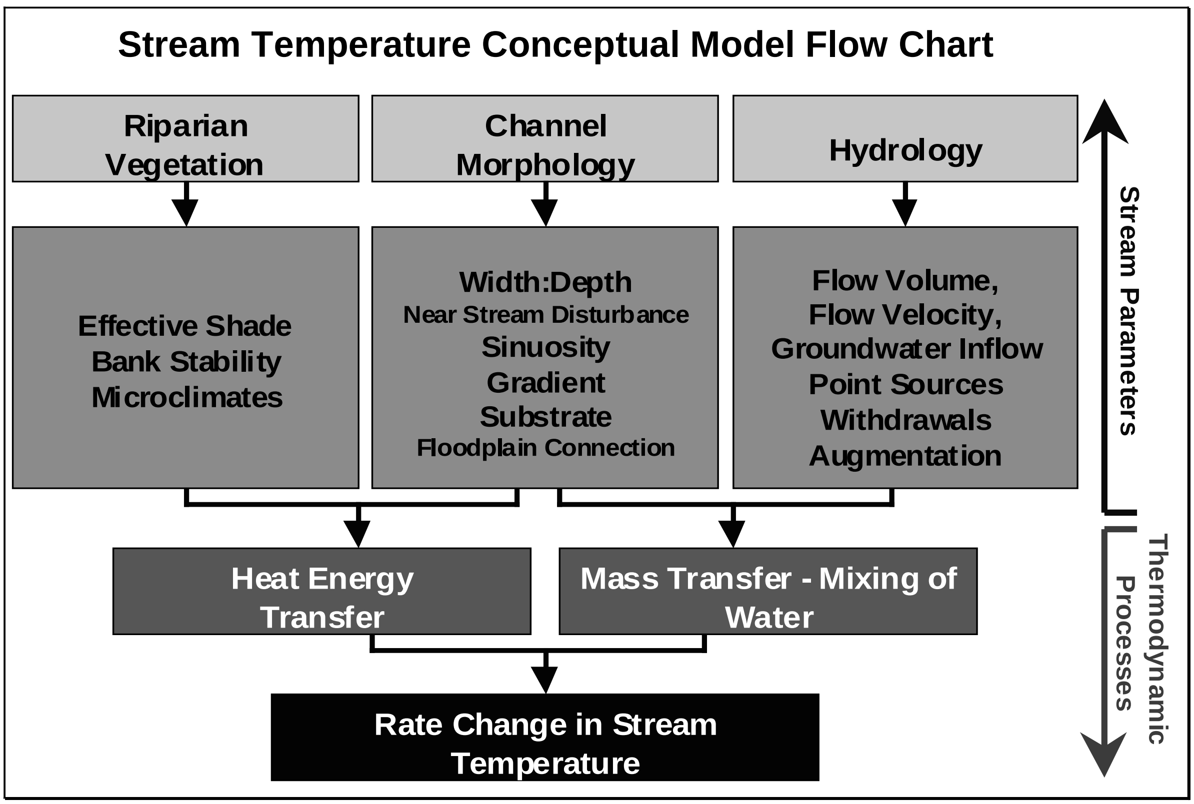

Figure B-1. Conceptual model of factors that affect stream temperature.

Adams and Sullivan (1989) reported that the following environmental variables were the most important drivers of water temperature in forested streams:

- **Stream depth.** Stream depth affects both the magnitude of the stream temperature fluctuations and the response time of the stream to changes in environmental conditions.
- **Air temperature.** Daily average stream temperatures and daily average air temperatures are both highly influenced by incoming solar radiation (Johnson, 2004). When the sun is not shining, the water temperature in a volume of water tends toward the dew-point temperature (Edinger et al., 1974).
- **Solar radiation and riparian vegetation.** The daily maximum temperatures in a stream are strongly influenced by removal of riparian vegetation because of diurnal patterns of solar heat flux. Daily average temperatures are less affected by removal of riparian vegetation.
- **Groundwater.** Inflows of groundwater can have an important cooling effect on stream temperature. This effect will depend on the rate of groundwater inflow relative to the flow in the stream and the difference in temperatures between the groundwater and the stream.

Heat budgets and temperature prediction

Heat exchange processes occur between the water body and the surrounding environment, and control stream temperature. Edinger et al. (1974) and Chapra (1997) provide thorough descriptions of the physical processes involved. Figure B-2 shows the major heat energy processes or fluxes across the water surface or streambed.

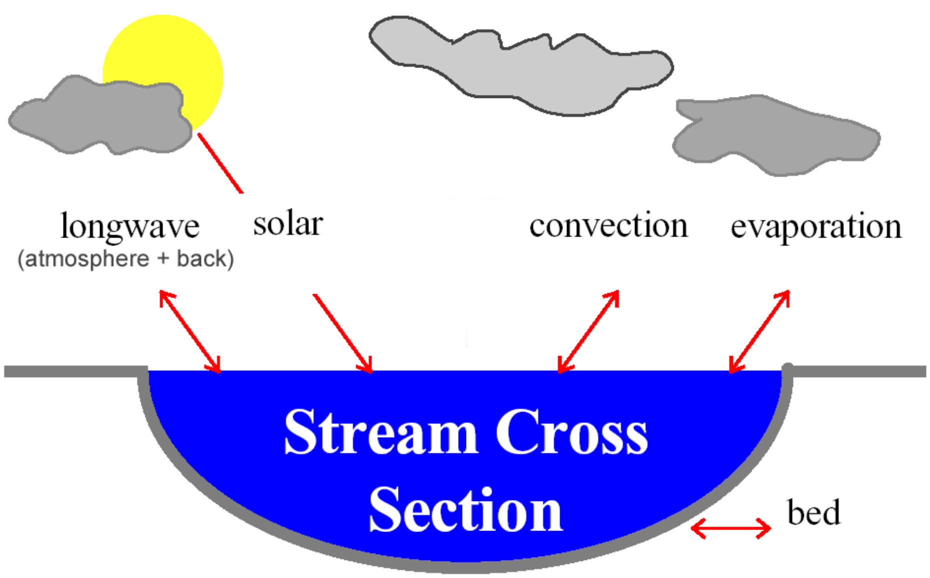

Figure B-2. Surface heat exchange processes that affect water temperature.

Net heat flux = solar + longwave atmosphere + longwave back + convection + evaporation + bed. Heat flux between the water and streambed occurs through conduction and hyporheic exchange.

The heat exchange processes with the greatest magnitude are as follows (Edinger et al., 1974):

- **Shortwave solar radiation**. Shortwave solar radiation is the radiant energy that passes directly from the sun to the earth. Shortwave solar radiation is contained in a wavelength range between 0.14 µm and about 4 µm. The peak values during daylight hours are typically about 3 times higher than the daily average. Shortwave solar radiation constitutes the major thermal input to an unshaded body of water during the day when the sky is clear.

- **Longwave atmospheric radiation.** Longwave radiation from the atmosphere ranges in wavelength from about 4 to 120 µm. Longwave atmospheric radiation depends primarily on air temperature and humidity and increases as both of those increase. It constitutes the major thermal input to a body of water at night and on warm cloudy days. The daily average heat flux from longwave atmospheric radiation typically ranges from about 300 to 450 W/m^2 at mid latitudes (Edinger et al., 1974).

- **Longwave back radiation from the water to the atmosphere.** Water sends heat energy back to the atmosphere in the form of longwave radiation in the wavelength range from about 4 to 120 µm. Back radiation accounts for a major portion of the heat loss from a body of water. Back radiation increases as water temperature increases. The daily average heat flux out of the water from longwave back radiation typically ranges from about 300 to 500 W/m^2 (Edinger et al., 1974).

The remaining heat exchange processes generally have less magnitude and are as follows:

- **Evaporation flux at the air-water interface** is influenced mostly by the wind speed and the vapor pressure gradient between the water surface and the air. When the air is saturated, the evaporation stops. When the gradient is negative (vapor pressure at the water surface is less than the vapor pressure of the air), condensation, the reversal of evaporation, takes place. This term then becomes a gain component in the heat balance.

- **Convection flux at the air-water interface** is driven by the temperature difference between water and air and by the wind speed. Heat is transferred in the direction of decreasing temperature.

- **The bed conduction flux and hyporheic exchange** component of the heat budget represents the heat exchange through conduction between the bed and the water body and the influence of hyporheic exchange. The magnitude of bed conduction is driven by the size and conductance properties of the substrate. The heat transfer through conduction is more pronounced when thermal differences between the substrate and water column are higher and usually affects the temperature diel profile, rather than affecting the magnitude of the maximum daily water temperature.

Hyporheic exchange recently received increased attention as a possible important mechanism for stream cooling (Johnson and Jones, 2000, Poole and Berman, 2000, Johnson, 2004). The hyporheic zone is defined as the region located beneath the channel characterized by complex hydrodynamic processes that combine stream water and groundwater. The resulting fluxes can have significant implications for stream temperature at different spatial and temporal scales.

The bulk temperature of a vertically mixed volume of water in a stream segment under natural conditions tends to increase or decrease with time during the day according to whether the net heat flux is positive or negative. When the sun is not shining, the water temperature tends toward the dew-point temperature (Edinger et al., 1974; Brady et al., 1969). The equilibrium temperature of a natural body of water is defined as the temperature at which the water is in equilibrium with its surrounding environment and the net rate of surface heat exchange would be zero (Edinger et al., 1968; 1974).

The dominant contribution to the seasonal variations in the equilibrium temperature of water is from seasonal variations in the dew-point temperature (Edinger et al., 1974). The main source of hourly fluctuations in water temperature during the day is solar radiation. Solar radiation generally reaches a maximum during the day when the sun is highest in the sky unless cloud cover or shade from vegetation interferes.

The complete heat budget for a stream also accounts for the mass transfer processes, which depend on the amount of flow and the temperature of water flowing into and out of a particular volume of water in a segment of a stream. Mass transfer processes in open channel systems can occur through advection, dispersion, and mixing with tributaries and groundwater inflows and outflows. Mass transfer relates to transport of flow volume downstream, instream mixing, and the introduction or removal of water from a stream. For instance, flow from a tributary will cause a temperature change if the temperature is different from the receiving water.

Thermal role of riparian vegetation

The role of riparian vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in the scientific literature. Summer stream temperature increases due to the removal of riparian vegetation is well documented (e.g., Holtby, 1988; Lynch et al., 1984; Rishel et al., 1982; Patric, 1980; Swift and Messer, 1971; Brown et al., 1971; and Levno and Rothacher, 1967). These studies generally support the findings of Brown and Krygier (1970) that loss of riparian vegetation results in larger daily temperature variations and elevated monthly and annual temperatures. Adams and Sullivan (1989) also concluded that daily maximum temperatures are strongly influenced by the removal of riparian vegetation because of the effect of diurnal fluctuations in solar heat flux.

Summaries of the scientific literature on the thermal role of riparian vegetation in forested and agricultural areas are provided by Belt et al., 1992; Beschta et al., 1987; Bolton and Monahan, 2001; Castelle and Johnson, 2000; CH2M Hill, 2000; GEI, 2002; Ice, 2001; and Wenger, 1999. All of these summaries recognize that the scientific literature indicates that riparian vegetation plays an important role in controlling stream temperature.

The list of important benefits that riparian vegetation has on the stream temperature includes:

- Near-stream vegetation height, width, and density combine to produce shadows that can reduce solar heat flux to the surface of the water.

- Riparian vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity, lower wind speeds, and cooler ground temperatures along stream corridors.
- Bank stability is largely a function of near-stream vegetation. Specifically, channel morphology is often highly influenced by land-cover type and condition by affecting flood plain and instream roughness, contributing coarse woody debris, and influencing sedimentation, stream substrate compositions, and streambank stability.

The warming of water temperatures as a stream flows downstream is a natural process. However, the rates of heating can be dramatically reduced when high levels of shade exist and heat flux from solar radiation is minimized. The overriding justification for increases in shade from riparian vegetation is to minimize the contribution of solar heat flux in stream heating. There is a natural maximum level of shade that a given stream is capable of attaining, and the importance of shade decreases as the width of a stream increases.

The distinction between reduced heating of streams and actual cooling is important. Shade can significantly reduce the amount of heat flux that enters a stream. Whether there is a reduction in the amount of warming of the stream, maintenance of inflowing temperatures, or cooling of a stream as it flows downstream depends on the balance of all of the heat exchange and mass transfer processes in the stream.

Effective shade

Shade is an important parameter that controls the stream heating derived from solar radiation. Solar radiation has the potential to be one of the largest heat-transfer mechanisms in a stream system. Human activities can degrade near-stream vegetation and/or channel morphology, and in turn, decrease shade. Reductions in stream surface shade have the potential to cause significant increases in heat delivery to a stream system. Stream shade is an important factor in describing the heat budget for the present analysis. Stream shade may be measured or calculated using a variety of methods (Chen, 1996; Chen et al., 1998a,b; Ice, 2001; OWEB, 1999; Teti, 2001; Teti and Pike, 2005).

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography, above a stream. Effective shade is defined as the fraction or percentage of the total possible solar radiation heat energy that is prevented from reaching the surface of the water:

$$\text{effective shade} = (J_1 - J_2)/J_1$$

where J_1 is the potential solar heat flux above the influence of riparian vegetation and topography, and J_2 is the solar heat flux at the stream surface.

In the Northern Hemisphere, the earth tilts on its axis toward the sun during summer months, allowing longer day length and higher solar altitude, both of which are functions of solar declination (i.e., a measure of the earth's tilt toward the sun) (Figure B-3). Geographic position (i.e., latitude and longitude) fixes the stream to a position on the globe, while aspect provides the stream/riparian orientation (direction of streamflow). Near-stream vegetation height, width, and density describe the physical barriers between the stream and sun that can attenuate and scatter incoming solar radiation (i.e., produce shade) (Table B-1). The solar position has a vertical component (i.e., solar altitude) and a horizontal component (i.e., solar azimuth) that are both functions of time/date (i.e., solar declination) and the earth's rotation.

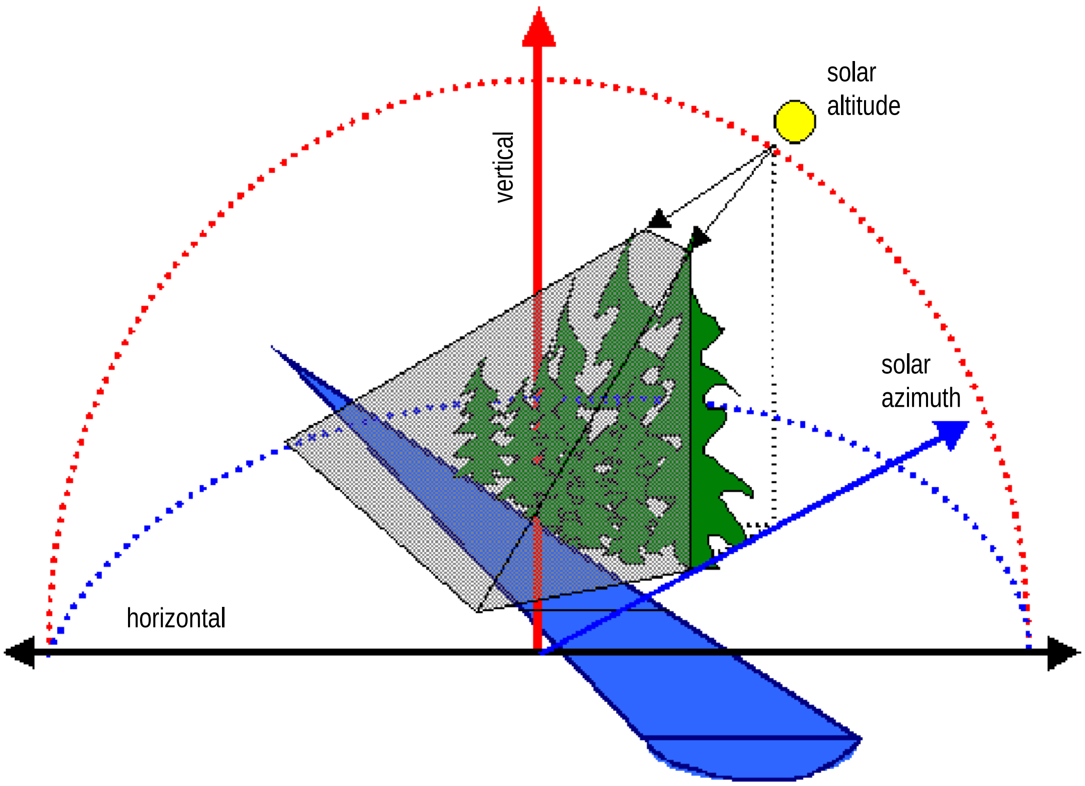

Figure B-3. Parameters that affect shade and geometric relationships.

Solar altitude is a measure of the vertical angle of the sun's position relative to the horizon. Solar azimuth is a measure of the horizontal angle of the sun's position relative to north.

While the interaction of these shade variables may seem complex, the mathematics that describes them is relatively straightforward geometry. Using solar tables or mathematical simulations, the potential daily solar load can be quantified. The shade from riparian vegetation can be measured with a variety of methods, including: Ice, 2001; OWEB, 1999; Boyd, 1996; Teti, 2001; Teti and Pike, 2005:

- Hemispherical photography
- Angular canopy densiometer
- Solar pathfinder

Hemispherical photography is generally regarded as the most accurate method for measuring shade, although the equipment that is required is significantly more expensive compared with other methods. Angular canopy densiometers (ACD) and Solar pathfinders provide a good balance of cost and accuracy for measuring the importance of riparian vegetation for preventing increases in stream temperature (Teti, 2001; Beschta et al., 1987; Teti, 2005). Whereas canopy density is usually expressed as a vertical projection of the canopy onto a horizontal surface, the ACD is a projection of the canopy measured at an angle above the horizon at which direct beam solar radiation passes through the canopy. This angle is typically determined by the position of the sun above the horizon during that portion of the day (usually between 10 a.m. and 2 p.m. in mid-to-late summer) when the potential solar heat flux is most significant.

Typical values of the ACD for old-growth stands in western Oregon have been reported to range from 80% to 90%.

Computer programs for the mathematical simulation of shade may also be used to estimate shade from measurements or estimates of the key parameters listed in Table B-1 (Ecology, 2003; Chen, 1996; Chen et al., 1998a,b; Boyd, 1996; Boyd and Park, 1998).

Table B-1. Factors that influence stream shade.

Description	Parameter
Season/time	Date/time
Stream characteristics	Aspect, channel width
Geographic position	Latitude, longitude
Vegetative characteristics	Riparian vegetation height, width, and density
Solar position	Solar altitude, solar azimuth

Riparian buffers and effective shade

Trees in riparian areas provide shade to streams and minimize undesirable water temperature changes (Brazier and Brown 1973; Steinblums et al., 1984). The shading effectiveness of riparian vegetation is correlated to riparian area width (Figure B-4).

The shade as represented by angular canopy density (ACD) for a given riparian buffer width varies over space and time because of differences among site-potential vegetation, forest development stages (e.g., height and density), and stream width. For example, a 50-foot-wide riparian area with fully developed trees could provide from 45 to 72% of the potential shade in the two studies shown in Figure B-4.

The Brazier and Brown (1973) shade data show a stronger relationship between ACD and buffer strip width than the Steinblums et al. (1984) data: the r^2 correlation for ACD and buffer width was 0.87 and 0.61 in Brazier and Brown (1973) and Steinblums et al. (1984), respectively. This difference supports the use of the Brazier and Brown curve as a base for measuring shade effectiveness under various riparian buffer proposals. These results reflect the natural variation among old-growth sites studied and show a possible range of potential shade.

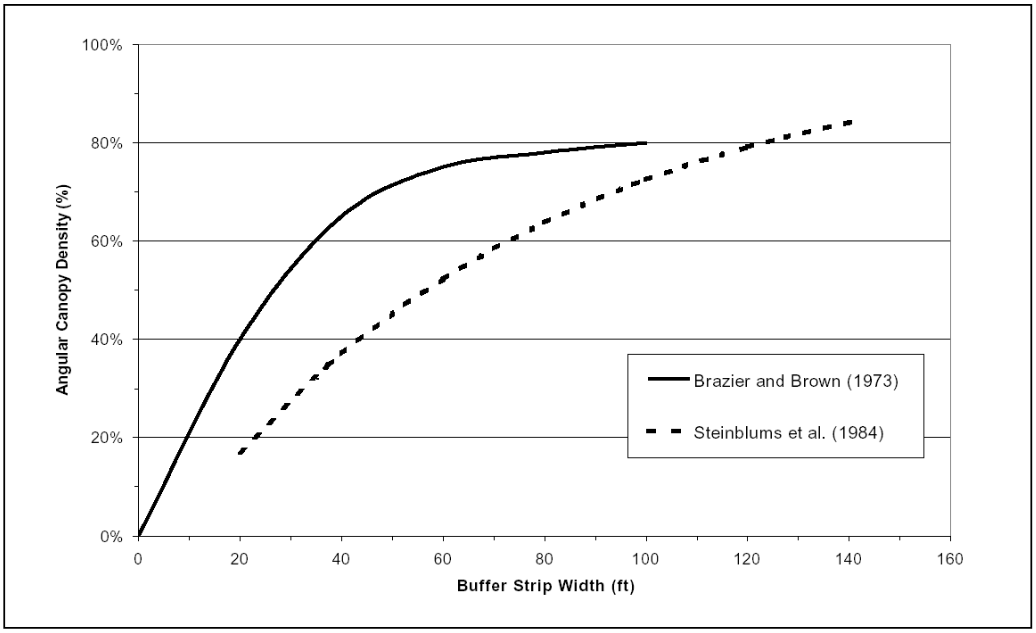

Figure B-4. Relationship between angular canopy density and riparian buffer width for small streams in old-growth riparian stands. (after Beschta et al., 1987 and CH2M Hill, 2000).

Several studies of stream shading report that most of the potential shade comes from the riparian area within about 75 feet (23 meters) of the channel (CH2M Hill, 2000; Castelle and Johnson, 2000):

- Beschta et al. (1987) report that a 98-foot (30-meter) buffer provides the same level of shading as that of an old-growth stand.
- Brazier and Brown (1973) found that a 79-foot (24-meter) buffer would provide maximum shade to streams.
- Steinblums et al. (1984) concluded that a 56-foot (17-meter) buffer provides 90% of the maximum ACD.
- Corbett and Lynch (1985) concluded that a 39-foot (12-meter) buffer should adequately protect small streams from large temperature changes following logging.
- Broderson (1973) reported that a 49-foot (15-meter) buffer provides 85% of the maximum shade for small streams.
- Lynch et al. (1984) found that a 98-foot (30-meter) buffer maintains water temperatures within 2 °F (1 °C) of their former average temperature in small streams (channel width less than 3 meters).

GEI (2002) reviewed the scientific literature related to the effectiveness of buffers for shade protection in agricultural areas in Washington. They concluded that buffer widths of 10 meters (33 feet) provide nearly 80% of the system-potential shade in agricultural areas. Wenger (1999) concluded that a minimum continuous buffer width of 10-30 meters should be preserved or restored along each side of all streams on a municipal or county-wide scale to provide stream temperature control and maintain aquatic habitat. GEI (2002) considered the recommendations of Wenger (1999) to be relevant for agricultural areas in Washington.

Steinblums et al. (1984) concluded that shade could be delivered to forest streams from beyond 75 feet (22 meters) and potentially out to 140 feet (43 meters). In some site-specific cases, forest practices between 75 and 140 feet from the channel have the potential to reduce shade delivery by up to 25% of maximum. However, any reduction in shade beyond 75 feet would probably be relatively low on the horizon, and the impact on stream heating would be relatively low. This is because the potential solar radiation decreases significantly as solar elevation decreases.

Microclimate - surrounding thermal environment

A secondary consequence of near-stream vegetation is its effect on the riparian microclimate. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity, and lower wind speeds are characteristic. Riparian microclimates tend to moderate daily air temperatures. Relative humidity increases result from the evapotranspiration that is occurring by riparian plant communities. Wind speed is reduced by the physical blockage produced by riparian vegetation.

Riparian buffers commonly occur on both sides of the stream, compounding the edge influence on the microclimate. Brosofske et al. (1997) reported that a buffer width of at least 150 feet (45 meters) on each side of the stream was required to maintain a natural riparian microclimate environment in small forest streams (channel width less than 4 meters) in the foothills of the western slope of the Cascade Mountains in western Washington with predominantly Douglas Fir and Western Hemlock.

Bartholow (2000) provided a thorough summary of literature of documented changes to the environment of streams and watersheds associated with extensive forest clearing. Changes summarized by Bartholow (2000) are representative of hot summer days and indicate the mean daily effect unless otherwise indicated:

- **Air temperature**. Edgerton and McConnell (1976) showed that removing all or a portion of the tree canopy resulted in cooler terrestrial air temperatures at night and warmer temperatures during the day, enough to influence thermal cover sought by elk (*Cervus canadensis*) on their eastern Oregon summer range. Increases in maximum air temperature varied from 5 to 7 ºC for the hottest days (estimate). However, the mean daily air temperature did not appear to have changed substantially since the maximum temperatures were offset by almost equal changes to the minima.

  Similar temperatures have been commonly reported (Childs and Flint, 1987; Fowler et al., 1987), even with extensive clearcuts (Holtby, 1988). In an evaluation of buffer strip width, Brosofske et al. (1997) found that air temperatures immediately adjacent to the ground increased 4.5 ºC during the day and about 0.5 ºC at night (estimate). Fowler and Anderson (1987) measured a 0.9 ºC air temperature increase in clearcut areas, but temperatures were also 3 ºC higher in the adjacent forest. Chen et al. (1993) found similar (2.1 ºC) increases.

All measurements reported here were made over land instead of water, but in aggregate support about a 2 ºC increase in ambient mean daily air temperature resulting from extensive clearcutting.

- **Relative humidity**. Brosofske et al. (1997) examined changes in relative humidity within 17- to 72-meter buffer strips. The focus of their study was to document changes along the gradient from forested to clearcut areas, so they did not explicitly report pre- to post-harvest changes at the stream. However, there appeared to be a reduction in relative humidity at the stream of 7% during the day and 6% at night (estimate). Relative humidity at stream sites increased exponentially with buffer width. Similarly, a study by Chen et al. (1993) showed a decrease of about 11% in mean daily relative humidity on clear days at the edges of clearcuts.

- **Wind speed**. Brosofske et al. (1997) reported almost no change in wind speed at stream locations within buffer strips adjacent to clearcuts. Speeds quickly approached upland conditions toward the edges of the buffers, with an indication that wind actually increased substantially at distances of about 15 meters from the edge of the strip, and then declined farther upslope to pre-harvest conditions. Chen et al. (1993) documented increases in both peak and steady winds in clearcut areas; increments ranged from 0.7 to 1.2 meter/s (estimated).

Thermal role of channel morphology

Changes in channel morphology (widening) impact stream temperatures. As a stream widens, the surface area exposed to heat flux increases, resulting in increased energy exchange between a stream and its environment (Chapra, 1997). Further, wide channels are likely to have decreased levels of shade due to the increased distance created between vegetation and the wetted channel, and the decreased fraction of the stream width that could potentially be covered by shadows from riparian vegetation. Conversely, narrow channels are more likely to experience higher levels of shade.

Channel widening is often related to degraded riparian conditions that allow increased streambank erosion and sedimentation of the streambed, both of which correlate strongly with riparian vegetation type and condition (Rosgen, 1996). Channel morphology is not solely dependent on riparian conditions. Sedimentation can deposit material in the channel, fill pools, and aggrade the streambed, reducing channel depth and increasing channel width.

Channel modification usually occurs during high-flow events. Land uses that affect the magnitude and timing of high-flow events may negatively impact channel width and depth. Riparian vegetation conditions will affect the resilience of the streambanks/flood plain during periods of sediment introduction and high flow. Disturbance processes may have differing results depending on the ability of riparian vegetation to shape and protect channels. Channel morphology is related to riparian vegetation composition and condition by:

- **Building streambanks**. Traps suspended sediments, encourages deposition of sediment in the flood plain, and reduces incoming sources of sediment.

- **Maintaining stable streambanks**. High rooting strength and high streambank and flood plain roughness prevent streambank erosion.
- **Reducing flow velocity** (erosive kinetic energy). Supplies large woody debris to the active channel, provides a high pool-to-riffle ratio, and adds channel complexity that reduces shear stress exposure to streambank soil particles.

Temperature references

Adams, T.N. and K Sullivan, 1989. The physics of forest stream heating: a simple model. Timber, Fish, and Wildlife, Report No TFW-WQ3-90-007. Washington State Department of Natural Resources, Olympia, WA.

Bartholow, J.M., 2000. Estimating cumulative effects of clearcutting on stream temperatures. Rivers, 7(4), 284-297.

Belt, G.H., J. O'Laughlin, and W.T. Merrill, 1992. Design of Forest Riparian Buffer Strips for the Protection of Water Quality: Analysis of Scientific Literature. Report No. 8. Idaho Forest, Wildlife, and Range Policy Analysis Group, University of Idaho, Moscow, ID.

Beschta, R.L., R.E. Bilby, G.W.Brown, L.B. Holtby, and T.D. Hofstra, 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. In: Streamside management: forestry and fisher interactions, E.O. Salo and T.W. Cundy, editors, pp 192-232. Proceedings of a conference sponsored by the College of Forest Resources, University of Washington, Seattle WA. Contribution No. 57 – 1987.

Bolton, S. and C. Monohan, 2001. A review of the literature and assessment of research needs in agricultural streams in the Pacific Northwest as it pertains to freshwater habitat for salmonids. Prepared for: Snohomish County, King County, Skagit County, and Whatcom County. Prepared by: Center for Streamside Studies, University of Washington, Seattle, WA.

Boyd, M.S., 1996. Heat source: stream, river, and open channel temperature prediction. Oregon State University. M.S. Thesis. October 1996.

Boyd, M. and C. Park, 1998. Sucker-Grayback Total Daily Maximum Load. Oregon Department of Environmental Quality and U.S. Forest Service.

Brady, D.K., W.L. Graves, and J.C. Geyer, 1969. Surface heat exchange at power plant cooling lakes. Cooling water discharge project report No. 5. Edison Electric Institute, New York, NY. Publication No. 69-901.

Brazier, J.R. and G.W. Brown, 1973. Buffer strips for stream temperature control. Res. Pap. 15. Forest Research Laboratory, Oregon State University. 9 p.

Brock, S. and A. Stohr, 2002. Little Klickitat River Watershed Temperature Total Maximum Daily Load. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-031. www.ecy.wa.gov/biblio/0203031.html

Broderson, J.M., 1973. Sizing buffer strips to maintain water quality. M.S. Thesis, University of Washington, Seattle, WA.

Brosofske, K.D., J. Chen, R.J. Naiman, and J.F. Franklin, 1997. Harvesting effects on microclimate gradients from small streams to uplands in western Washington. Ecol. Appl. 7(4): 1188-1200.

Brown, G.W. and J.T. Krygier, 1970. Effects of clear-cutting on stream temperature. Water Resources Research 6(4):1133-1140.

Brown, G.W., G.W. Swank, and J. Rothacher, 1971. Water temperature in the Steamboat drainage. USDA Forest Service Research Paper PNW-119, Portland, OR. 17 p.

Castelle, A.J. and A.W. Johnson, 2000. Riparian vegetation effectiveness. Technical Bulletin No. 799. National Council for Air and Stream Improvement, Research Triangle Park, NC. February 2000.

CH2M Hill, 2000. Review of the scientific foundations of the forests and fish plan. Prepared for the Washington Forest Protection Association. www.wfpa.org/

Chapra, S.C., 1997. Surface water quality modeling. McGraw-Hill Companies, Inc.

Chen, Y.D., 1996. Hydrologic and water quality modeling for aquatic ecosystem protection and restoration in forest watersheds: a case study of stream temperature in the Upper Grande Ronde River, Oregon. PhD dissertation. University of Georgia, Athens, GA.

Chen, J., J.F. Franklin, and T.A. Spies, 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. Agricultural and Forest Meteorology 63, 219-237.

Chen, Y.D., R.F. Carsel, S.C. McCutcheon, and W.L Nutter, 1998a. Stream temperature simulation of forested riparian areas: I. watershed-scale model development. Journal of Environmental Engineering. April 1998. pp 304-315.

Chen, Y.D., R.F. Carsel, S.C. McCutcheon, and W.L. Nutter, 1998b. Stream temperature simulation of forested riparian areas: II. model application. Journal of Environmental Engineering. April 1998. pp 316-328.

Childs, S.W. and L.E. Flint, 1987. Effect of shadecards, shelterwoods, and clearcuts on temperature and moisture environments. Forest Ecology and Management, 18, 205-217.

Cohn, T., 1988. Adjusted Maximum Likelihood Estimation of the Moments of Lognormal Populations from Type I Censored Samples. U.S. Geological Survey Open File Report No. 88-350. 34 p.

Corbett, E.S. and J.A. Lynch, 1985. Management of streamside zones on municipal watersheds. P. 187-190 In: R.R. Johnson, C.D. Ziebell, D.R. Patton, P.F. Folliott, and R.H. Hamre (eds.). Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, April 16-18, 1985. Tucson, AZ.

Ecology, 2003. Shade.xls - a tool for estimating shade from riparian vegetation. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/models/.

Edgerton, P.J. and B.R. McConnell, 1976. Diurnal temperature regimes of logged and unlogged mixed conifer stands on elk summer range. Station Research Note PNW-277. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 6 p.

Edinger, J.E., D.W. Duttweiler, and J.C. Geyer, 1968. The response of water temperatures to meteorological conditions. Water Resources Research, Vol. 4, No. 5.

Edinger, J.E., D.K. Brady, and J.C. Geyer, 1974. Heat exchange and transport in the environment. EPRI Publication No. 74-049-00-3, Electric Power Research Institute, Palo Alto, CA.

Fowler, W.B. and T.D. Anderson, 1987. Illustrating harvest effects on site microclimate in a high-elevation forest stand. Research Note PNW-RN-466. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 10 pp.

Fowler, W.B., J.D. Helvey, and E.N. Felix, 1987. Hydrologic and climatic changes in three small watersheds after timber harvest. Res. Pap. PNW-RP-379. Portland, OR. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 13 p.

GEI, 2002. Efficacy and economics of riparian buffers on agricultural lands, State of Washington. Prepared for the Washington Hop Growers Association. Prepared by GEI Consultants, Englewood, CO.

Holtby, L.B., 1988. Effects of logging on stream temperatures in Carnation Creek, B.C., and associated impacts on the coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 45:502-515.

Howard, D. and G. Pelletier, 2002. Wind River Watershed Temperature Total Maximum Daily Load: Submittal Report. Washington State Department of Ecology, Olympia, WA. Publication No. 02-10-029. www.ecy.wa.gov/biblio/0210029.html

Ice, G., 2001. How direct solar radiation and shade influences temperatures in forest streams and relaxation of changes in stream temperature. In: Cooperative Monitoring, Evaluation, and Research (CMER) workshop: heat transfer processes in forested watershed and their effects on surface water temperature, Lacey, WA. February 2001.

Johnson, S.L., 2004. Factors influencing stream temperatures in small streams: substrate effects and a shading experiment. Canadian Journal of Fisheries and Aquatic Sciences 61:913-923.

Johnson, S.L. and J.A. Jones, 2000. Stream temperature response to forest harvest and debris flows in western Cascades, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 57 (supplement 2): 30-39.

Levno, A. and J. Rothacher, 1967. Increases in maximum stream temperatures after logging in old growth Douglas-fir watersheds. USDA Forest Service PNW-65, Portland, OR. 12 p.

Lynch, J.A., G.B. Rishel, and E.S. Corbett, 1984. Thermal alterations of streams draining clearcut watersheds: quantification and biological implications. Hydrobiologia 111:161-169.

OWEB, 1999. Water quality monitoring technical guidebook: chapter 14, stream shade and canopy cover monitoring methods. Oregon Watershed Enhancement Board. www.oregon.gov/OWEB/docs/pubs/wq_mon_guide.pdf?ga=t

Patric, J.H., 1980. Effects of wood products harvest on forest soil and water relations. Journal of Environmental Quality 9(1):73-79.

Poole, G.C. and C.H. Berman, 2000. Pathways of human influence on water temperature dynamics in stream channels. Environmental Protection Agency, Region 10, Seattle, WA. 20 p.

Rishel, G.B., J.A. Lynch, and E.S. Corbett, 1982. Seasonal stream temperature changes following forest harvesting. Journal of Environmental Quality 11(1):112-116.

Rosgen, D., 1996. Applied river morphology. Wildland Hydrology publishers. Pagosa Springs, CO.

Steinblums, I., H. Froehlich, and J. Lyons, 1984. Designing stable buffer strips for stream protection. Journal of Forestry 821(1): 49-52.

Swift, L.W. and J.B. Messer, 1971. Forest cuttings raise water temperatures of a small stream in the southern Appalachians. Journal of Soil and Water Conservation 26:11-15.

Teti, P., 2001. A new instrument for measuring shade provided by overhead vegetation. Cariboo Forest Region Research Section, British Columbia Ministry of Forests, Extension note No. 34. www.for.gov.bc.ca/rsi/research/cextnotes/extnot34.pdf

Teti, P.A. and R.G. Pike, 2005. Selecting and testing an instrument for surveying stream shade. BC Journal of Ecosystems and Management 6(2):1-16. www.forrex.org/jem/2005/vol6_no2_art1.pdf

Thomann, R.V. and J.A. Mueller, 1987. Principles of Surface Water Quality Modeling and Control. Harper & Row, New York, NY.

Teti, P.A. and R.G. Pike, 2005. Selecting and testing an instrument for surveying stream shade. BC Journal of Ecosystems and Management 6(2):1-16. www.forrex.org/jem/2005/vol6_no2_art1.pdf

Wenger, S., 1999. A review of the scientific literature on riparian buffer width, extent, and vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia, Athens, GA.

Zar, J.H., 1984. Biostatistical Analysis, 2nd Edition. Prentice-Hall. Englewood Cliffs, NJ.

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Appendix C. Ancillary temperature model data, shade curve data, and temperature load allocations

Table C-1. Climate data at Deer Park (DEW) and Spokane Airport (GEG) for the August 9, 2005 temperature model calibration.

QUAL2K time (hrs)	Climate Data at DEW			Climate Data at GEG		
	Air Temp (ºC)	Dew Point (ºC)	Cloud Cover	Air Temp (ºC)	Dew Point (ºC)	Cloud Cover
0	12.78	5.56	0.00	19.44	5.56	0.00
1	12.22	6.11	0.00	21.11	6.11	0.00
2	11.67	6.67	0.00	18.89	5.00	0.00
3	12.22	6.67	0.00	17.78	4.44	0.00
4	11.11	6.67	0.00	17.22	5.00	0.13
5	11.11	6.67	0.00	16.11	5.00	0.13
6	15.00	8.89	0.00	17.78	6.11	0.13
7	20.56	8.33	0.00	20.00	7.22	0.00
8	22.22	7.22	0.00	21.67	9.44	0.00
9	23.89	7.78	0.00	24.44	10.56	0.00
10	26.11	8.33	0.00	26.11	11.11	0.00
11	28.33	9.44	0.00	27.78	10.00	0.00
12	29.44	8.33	0.00	29.44	10.00	0.13
13	31.11	8.06	0.00	31.11	8.33	0.13
14	32.78	7.78	0.00	32.22	7.22	0.13
15	33.33	6.11	0.44	32.78	6.11	0.13
16	33.33	5.00	0.44	32.78	5.00	0.13
17	32.78	3.33	0.00	32.78	3.33	0.13
18	31.67	2.22	0.00	31.67	2.22	0.13
19	26.11	5.00	0.00	29.44	1.67	0.13
20	17.78	5.00	0.00	27.22	3.33	0.13
21	16.11	3.89	0.00	23.33	3.89	0.00
22	14.44	3.89	0.00	23.33	5.00	0.00
23	17.22	5.00	0.00	21.67	5.56	0.00
Mean	21.81	6.33	0.04	24.84	6.13	0.07

Table C-2. Climate data at Deer Park (DEW) and Spokane Airport (GEG) for the July 8, 2006 temperature model verification run.

QUAL2K time (hrs)	Climate Data at DEW			Climate Data at GEG		
	Air Temp (ºC)	Dew Point (ºC)	Wind (m/sec)	Air Temp (ºC)	Dew Point (ºC)	Wind (m/sec)
0	16.81	9.58	2.19	17.22	3.89	2.6
1	15.83	8.75	2.31	15.00	4.44	0.0
2	12.78	8.89	2.44	13.89	4.44	0.0
3	13.06	9.17	2.31	14.44	6.11	1.5
4	11.94	8.61	2.57	13.33	5.56	0.0
5	13.06	9.58	1.93	13.33	7.22	2.6
6	16.39	10.69	1.93	15.00	7.78	2.6
7	18.61	10.83	3.09	16.67	8.33	3.6
8	20.69	11.39	1.93	18.89	7.78	3.1
9	21.67	10.56	3.09	21.67	6.67	2.6
10	23.06	10.83	2.44	24.44	5.00	2.6
11	24.58	10.69	1.67	26.11	2.78	1.5
12	25.42	10.14	1.41	27.22	2.22	2.6
13	26.11	10.42	2.70	27.78	1.67	1.5
14	26.39	10.00	0.64	28.89	2.22	4.1
15	27.08	10.00	1.29	29.44	0.00	2.1
16	27.08	10.14	0.77	29.44	-1.67	2.6
17	26.67	10.00	1.41	29.44	-1.11	3.1
18	26.39	10.14	2.83	29.44	-0.56	3.1
19	25.00	10.42	2.70	28.33	0.56	2.1
20	19.86	11.25	1.67	26.11	3.89	2.1
21	17.64	11.11	1.29	23.89	4.44	0.0
22	15.56	10.69	0.39	21.11	5.56	0.0
23	14.58	10.42	2.19	20.00	5.56	0.0
Mean	20.26	10.18	1.97	22.13	3.87	1.91

Table C-3. Little Spokane River (LSR) water balance for the July 8, 2006 QUAL2K model verification simulation.

Site ID	Mainstem reach/turbidity	Distance from mouth (km)	Calibration (ft^3/s)		Observed (ft^3/s)
			Tributary source	Diffusive source	
1	LSR at site #1	75.1	28.8	35	28.8
15	Dry Creek	55.7	3.5		
18	Otter Creek	53.9	3.7		
23	WB LSR	52.9	15		
2	LSR at site #2	51.4		17	86.9
4	Bear Creek	44.7	1.1		
10	Deer Creek	37.0	0.35		
13	Dragoon Creek	34.3	14.9		
3	LSR at site #3	21.5			160
8	Deadman Creek	21.1	17.9		
	USGS at Dartford	17.5		262	180
17	Dartford Creek	17.3	2.1		
21	USGS near Dartford	6.3			444
26	55B070	1.8		21	465

Table C-4. Climate data at Deer Park (DEW) and Spokane Airport (GEG) for the August 13, 2003 average conditions for the 7-day, 2-year (7Q2) temperature model run.

QUAL2K time (hrs)	Climate Data at DEW			Climate Data at GEG		
	Air Temp (ºC)	Dew Point (ºC)	Wind (m/sec)	Air Temp (ºC)	Dew Point (ºC)	Wind (m/sec)
0	10.00	3.33	0.00	15.00	4.44	1.54
1	7.78	2.78	0.00	15.00	4.44	0.00
2	7.78	3.33	0.00	12.78	3.89	2.57
3	7.22	3.89	0.00	12.78	3.89	0.00
4	6.67	3.89	2.57	10.00	3.89	1.54
5	5.56	2.78	0.00	11.67	3.89	1.54
6	10.00	5.00	1.54	13.89	5.00	2.06
7	14.44	6.11	0.00	18.33	6.11	0.00
8	19.44	6.67	0.00	21.67	4.44	1.54
9	21.11	6.67	1.54	22.78	5.00	0.00
10	24.44	5.00	2.57	25.00	3.33	3.09
11	26.67	5.00	4.63	25.56	2.78	3.09
12	27.78	3.33	3.09	27.78	1.67	3.60
13	29.44	4.44	4.63	28.33	0.56	2.57
14	28.89	4.44	5.14	28.89	2.22	7.20
15	30.00	4.44	4.63	29.44	3.33	6.17
16	30.56	3.89	4.63	28.89	2.22	6.17
17	29.44	3.33	4.12	28.89	1.67	5.14
18	28.89	2.78	4.12	27.78	0.00	4.12
19	25.00	2.22	3.09	25.00	0.56	3.09
20	16.67	1.67	0.00	21.67	0.56	2.57
21	14.44	1.11	1.54	18.89	1.11	3.09
22	12.22	0.56	2.57	17.22	2.22	2.06
23	10.00	0.00	0.00	17.78	1.11	3.09
Mean	18.52	3.61	2.10	21.04	2.85	2.74

Table C-5. Climate data at Deer Park (DEW) and Geiger Field (GEG) for the July 31, 2003 critical condition (90th percentile highest temperature) scenario.

Time (hr)	Climate Data at DEW			Climate Data at GEG		
	Air Temp (^oC)	Dew Point (^oC)	Wind (m/sec)	Air Temp (^oC)	Dew Point (^oC)	Wind (m/sec)
0	16.11	2.22	2.06	22.22	0.00	4.12
1	13.89	1.67	0.00	21.67	0.00	4.12
2	13.33	2.22	2.57	19.44	-1.11	5.14
3	12.22	1.67	0.00	18.89	-0.56	4.63
4	12.78	3.33	0.00	18.33	0.00	4.12
5	12.78	3.33	0.00	17.78	1.11	4.12
6	16.67	5.00	1.54	19.44	3.89	4.63
7	21.11	7.22	0.00	22.22	6.67	4.12
8	23.33	6.67	0.00	23.89	7.78	3.60
9	25.56	8.89	3.09	26.67	8.33	2.57
10	27.78	9.44	3.60	28.89	8.89	4.63
11	30.00	8.89	1.54	31.67	8.89	5.66
12	31.11	8.89	2.06	32.22	8.33	2.57
13	32.78	8.33	2.06	33.33	7.78	1.54
14	34.44	8.33	2.06	34.44	8.33	4.12
15	35.00	8.33	2.06	35.56	7.78	4.63
16	35.00	7.78	2.06	35.56	7.22	3.60
17	35.56	8.89	1.54	35.00	7.22	4.12
18	35.00	13.33	0.00	34.44	6.67	4.63
19	31.11	15.56	0.00	31.67	5.00	3.09
20	25.56	7.22	0.00	27.22	3.33	4.12
21	21.11	6.11	0.00	27.22	3.33	4.12
22	17.78	5.56	0.00	22.22	3.33	3.09
23	16.11	5.56	0.00	21.11	3.89	3.09
Mean	24.00	6.85	1.09	26.71	4.84	3.92

Table C-6. Little Spokane River (LSR) water balances for 7-day, 10-year (7Q10) low flow and 7-day, 2-year (7Q2) low flow used for critical and typical condition simulations with the QUAL2K model.

Mainstem reach/turbidity	Distance from mouth (km)	7Q10 Critical Condition (ft^3/s)		Estimated 7Q10	7Q2 Average Condition (ft^3/s)		Estimated 7Q2
		Tributary source	Diffusive source	(ft^3/s)	Tributary source	Diffusive source	(ft^3/s)
LSR at Scotia	75.1	17.4		17.4	26.4		26.4
LSR at Elk				34.9			40
Dry Creek	55.7	1.4	35		2.0	35	
Otter Creek	53.9	0.2			0.32		
West Branch LSR	52.9	4.6			7.1		
Bear Creek	44.7	1.1			1.6		
Deer Creek	37.0	0.35	17		0.53	17	
Dragoon Creek	34.3	11.8			18.5		
Deadman Creek	21.1	6.4			10.0		
USGS at Dartford	17.5		220	91.9		240	131.3
Dartford Creek	17.3	2.1			3.14		
USGS near Dartford	6.3			312			371
55B070	1.8		17.7			19.3	

Table C-7. Shade curve data to determine system-potential effective shade and heat load allocations for miscellaneous non-modeled tributaries in the Little Spokane River (LSR) watershed (Barber et al., 2007).

Bankfull width (m)	Effective shade from vegetation (%) at the stream center for various stream aspects (degrees from North)			Daily average global solar short-wave radiation ($W/m^2/d$) at the stream center for various stream aspects (degrees from North)		
	0 and 180 deg. aspect	45, 135, 225 and 315 deg. aspect	90 and 270 deg. aspect	0 and 180 deg. aspect	45, 135, 225 and 315 deg. aspect	90 and 270 deg. aspect
1	95.05%	95.02%	95.33%	15.50	15.60	14.63
2	94.14%	94.14%	95.06%	18.37	18.37	15.49
3	93.23%	93.45%	94.65%	21.22	20.52	16.76
4	91.56%	91.68%	93.80%	26.44	26.08	19.45
5	87.29%	87.24%	90.98%	39.84	39.98	28.27
6	79.69%	79.16%	81.75%	63.65	65.31	57.19
7	73.52%	72.76%	74.26%	83.00	85.38	80.67
8	68.51%	67.58%	67.96%	98.70	101.60	100.41
9	64.35%	63.28%	62.62%	111.72	115.10	117.14
10	60.83%	59.60%	57.81%	122.78	126.63	132.24
11	57.76%	56.38%	53.50%	132.40	136.70	145.73
12	55.04%	53.70%	49.50%	140.91	145.12	158.28
13	52.79%	51.14%	45.80%	147.95	153.13	169.86
14	50.61%	48.98%	42.36%	154.81	159.90	180.65
15	48.78%	46.85%	39.25%	160.52	166.57	190.39
16	46.95%	44.90%	36.43%	166.26	172.69	199.22

Table C-8. Average shade and heat load allocations for the mainstem Little Spokane River LSR from Scotia to the mouth (Barber et al., 2007).

Distance from headwater (km)	Current effective shade condition (%)	Current solar load ($W/m^2/d$)	Target effective shade (%)	Required shade increase (%)	Load allocation for shortwave solar radiation ($W/m^2/d$)
0	45.40%	171.12	95.74%	50.34%	13.36
0.96	43.17%	178.11	95.72%	52.55%	13.40
1.9	40.90%	185.23	95.91%	55.01%	12.82
2.9	41.74%	182.59	95.52%	53.78%	14.04
3.8	43.14%	178.20	95.15%	52.01%	15.20
4.8	38.51%	192.71	95.33%	56.81%	14.65
5.8	36.96%	197.59	95.14%	58.19%	15.23
6.7	10.04%	281.94	10.04%	0.00%	281.94
7.7	7.43%	290.11	7.43%	0.00%	290.11
8.6	8.06%	288.16	8.06%	0.00%	288.16
9.6	26.44%	230.56	94.84%	68.41%	16.16
10.6	28.37%	224.50	93.58%	65.21%	20.12
11.5	28.14%	225.21	92.16%	64.01%	24.59
12.5	22.33%	243.42	93.95%	71.62%	18.95
13.4	25.64%	233.07	91.33%	65.70%	27.16
14.4	23.85%	238.66	91.58%	67.73%	26.39
15.4	7.44%	290.10	89.51%	82.08%	32.87
16.3	7.47%	290.01	88.26%	80.80%	36.78
17.3	23.66%	239.26	87.79%	64.13%	38.28
18.2	23.86%	238.65	86.60%	62.75%	41.99
19.2	22.73%	242.18	85.52%	62.79%	45.39
20.2	9.07%	285.00	87.56%	78.50%	38.97
21.1	16.84%	260.64	85.42%	68.59%	45.68
22.1	19.29%	252.96	82.10%	62.81%	56.11
23.0	22.38%	243.28	72.72%	50.35%	85.49
24.0	20.55%	249.02	67.57%	47.03%	101.63
25. 0	19.65%	251.82	65.53%	45.88%	108.03
25.9	20.34%	249.66	65.66%	45.32%	107.63
26.9	20.16%	250.23	64.25%	44.09%	112.03
27.8	19.39%	252.64	63.52%	44.13%	114.32
28.8	15.98%	263.33	60.37%	44.39%	124.22
29.8	8.47%	286.88	60.86%	52.39%	122.67
30.7	7.51%	289.87	60.80%	53.28%	122.87
31.7	7.60%	289.60	58.74%	51.14%	129.32
32.6	8.39%	287.11	56.90%	48.51%	135.09
33.6	8.48%	286.85	58.24%	49.76%	130.88
34.6	7.41%	290.18	54.43%	47.02%	142.83
35.5	8.32%	287.33	55.99%	47.67%	137.93
36.5	8.27%	287.50	54.08%	45.81%	143.91
37.4	8.70%	286.14	58.92%	50.22%	128.74
38.4	8.46%	286.91	59.12%	50.67%	128.12
39.4	37.95%	194.49	54.59%	16.64%	142.32
40.3	44.50%	173.95	61.65%	17.15%	120.20
41.3	43.76%	176.27	60.94%	17.19%	122.40
42.2	7.46%	290.03	62.09%	54.63%	118.81
43.2	43.94%	175.70	60.87%	16.93%	122.63

Distance from headwater (km)	Current effective shade condition (%)	Current solar load ($W/m^2/d$)	Target effective shade (%)	Required shade increase (%)	Load allocation for shortwave solar radiation ($W/m^2/d$)
44.2	42.80%	179.29	59.19%	16.40%	127.89
45.1	41.06%	184.74	57.04%	15.98%	134.65
46.1	23.23%	240.59	57.35%	34.12%	133.66
47.0	7.47%	289.99	55.01%	47.54%	140.99
48.0	7.46%	290.05	54.60%	47.14%	142.30
49. 0	7.42%	290.17	51.31%	43.90%	152.59
49.9	7.40%	290.23	42.85%	35.46%	179.10
50.9	7.41%	290.18	49.06%	41.64%	159.66
51.8	7.44%	290.10	45.00%	37.56%	172.39
52.8	20.37%	249.56	49.82%	29.45%	157.27
53.8	8.05%	288.20	8.05%	0.00%	288.20
54.7	13.28%	271.80	36.96%	23.68%	197.57
55.7	8.05%	288.20	8.05%	0.00%	288.20
56.6	8.02%	288.26	8.02%	0.00%	288.26
57.6	8.00%	288.33	8.00%	0.00%	288.33
58.6	30.02%	219.33	43.69%	13.67%	176.48
59.5	34.52%	205.22	47.15%	12.63%	165.63
60.5	8.26%	287.52	8.26%	0.00%	287.52
61.4	8.13%	287.95	8.13%	0.00%	287.95
62.4	8.05%	288.19	8.05%	0.00%	288.19
63.4	7.95%	288.48	7.95%	0.00%	288.48
64.3	7.96%	288.47	7.96%	0.00%	288.47
65.3	8.08%	288.10	8.08%	0.00%	288.10
66.2	8.03%	288.25	8.03%	0.00%	288.25
67.2	8.22%	287.66	8.22%	0.00%	287.66
68.2	9.84%	282.57	9.84%	0.00%	282.57

Appendix D. Supplemental information on models

Statistical theory of rollback

The statistical rollback method proposed by Ott (1995) describes a way to use a numeric distribution of a water quality parameter to estimate the distribution after abatement processes are applied to sources. The method relies on basic dispersion and dilution assumptions and their effect on the distribution of a chemical or a bacterial population at a monitoring site downstream from a source. It then provides a statistical estimate of the new population after a chosen reduction factor is applied to the existing pollutant source. In the case of the TMDL, compliance with the most restrictive of the dual FC criteria will determine the reduction factor needed.

As with many water quality parameters, FC counts collected over time at an individual site usually follow a lognormal distribution. That is, over the course of sampling for a year, or multiple years, most of the counts are low, but a few are much higher. When monthly FC data are plotted on a logarithmic-probability graph (the open diamonds in Figure D-1), they appear to form nearly a straight line.

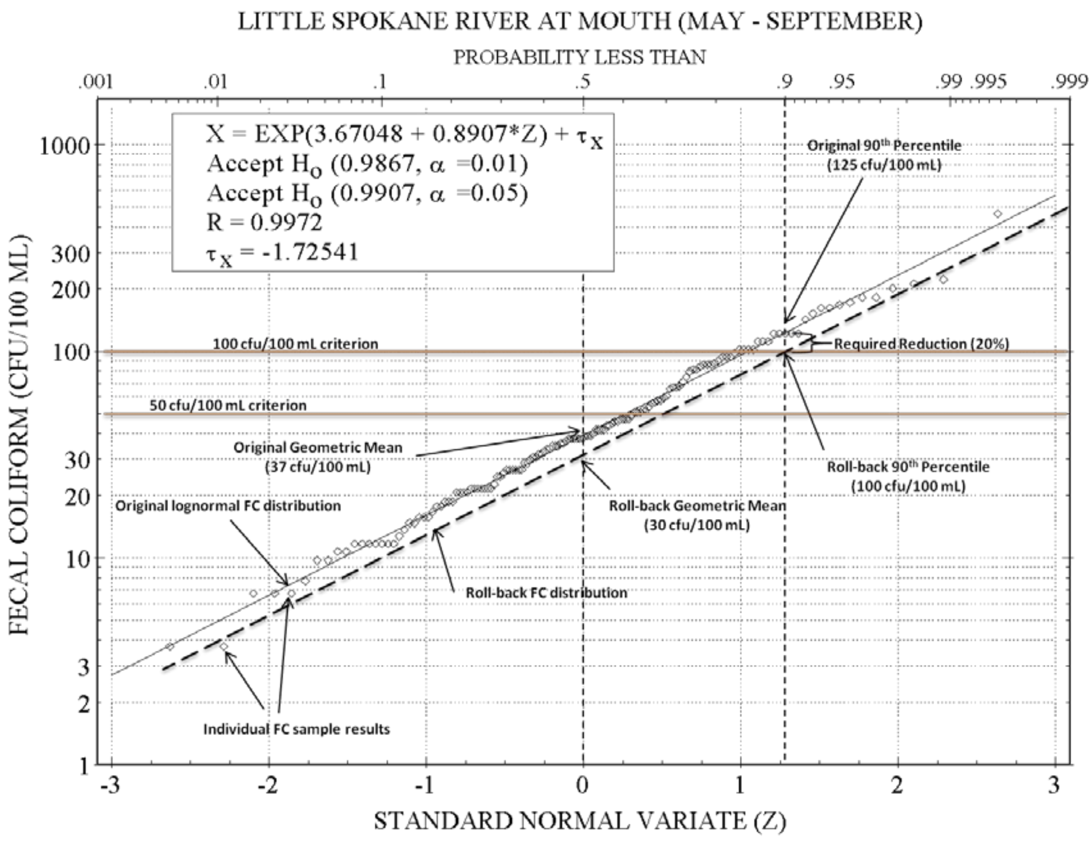

Figure D-1. Graphical depiction of the statistical rollback method for fecal coliform (FC) targets.

The 50^{th} percentile (an estimate of the geometric mean) and the 90^{th} percentile (a representation of the level over which 10% of the samples lie) can be located along a line plotted from an equation estimating the original monthly FC data distribution.

In Figure D-1, these numbers are 37 cfu/100 mL and 125 cfu/100 mL, respectively. Using the statistical rollback method, the 90^{th} percentile value is then reduced to 100 cfu/100 mL (*extraordinary primary contact recreation* 90^{th} percentile criterion), since 37 cfu/100 mL meets the geometric mean criterion. The new distribution is plotted parallel to the original. The estimate of the geometric mean for this new distribution, located at the 50^{th} percentile, is 30 cfu/100 mL. The result is a geometric mean target of a sample distribution that would likely have less than 10% of its samples over 100 cfu/100 mL. A 20% FC reduction is required from combined sources to meet this target distribution from the simple calculation:

(125 - 100) / 125 = 0.2 * 100 = 20%.

The following is a summary of the major theorems and corollaries for the Statistical Theory of Rollback (STR) from *Environmental Statistics and Data Analysis* by Ott (1995).

1. If Q = the concentration of a contaminant at a source, and D = the dilution-diffusion factor, and X = the concentration of the contaminant at the monitoring site, then X = Q*D.
2. Successive random dilution and diffusion of a contaminant Q in the environment often result in a lognormal distribution of the contaminant X at a distant monitoring site.
3. The coefficient of variation (CV) of Q is the same before and after applying a "rollback" (i.e., the CV in the post-control state will be the same as the CV in the pre-control state). The rollback factor = r, a reduction factor expressed as a decimal (a 70% reduction would be a rollback factor of 0.3). The random variable Q represents a pre-control source output state, and rQ represents the post-control state.
4. If D remains consistent in the pre-control and post-control states (long-term hydrological and climatic conditions remain unchanged), then CV(Q)*CV(D)=CV(X), and CV(X) will be the same before and after the rollback is applied.
5. If X is multiplied by the rollback factor, then the variance in the post-control state will be multiplied by r^2, and the post-control standard deviation will be multiplied by r.
6. If X is multiplied by the rollback factor, the quantiles of the concentration distribution will be scaled geometrically.
7. If any random variable is multiplied by r, then its expected value and standard deviation also will be multiplied by r, and its CV will be unchanged. (Ott uses "expected value" for the mean.)

Statistical formulae for deriving percentile values

The 90^{th} percentile value for a population can be derived in several ways. The set of FC counts collected at a site were subjected to a statistically-based formula (Zar, 1984). The estimated 90th percentile is calculated by:

(a) Calculating the arithmetic mean and standard deviation of the sample result logarithms (base 10);

(b) Multiplying the standard deviation in (a) by 1.28;
(c) Adding the product from (b) to the arithmetic mean;
(d) Taking the antilog (base 10) of the results in (c) to get the estimated 90th percentile.

The 90th percentile derived using this formula assumes a lognormal distribution of the FC data. Several sites were checked to verify lognormal distributions. The variability in the data is expressed by the standard deviation, and with some data sets it is possible to calculate a 90th percentile greater than any of the measured data.

Water quality index (WQI)

To evaluate ambient water quality data, Ecology (Hallock, 2002) developed a ecoregional WQI for turbidity, TSS, and other parameters that do not have specific Washington State water quality criteria. The TSS critical season for trout and whitefish spawning is within the high-flow period. Data collected from LSR watershed sites were set to the following quadratic equations for high-flow turbidity and TSS in the Northern Rockies ecoregion:

–

Little Deep Creek provides an example of how the WQI scores were used to develop a loading capacity for sites with small data sets. The eight Little Deep Creek TSS concentrations were well correlated with turbidity during the critical period (Figure D-2). The seasonal WQI scores for these data were 61 for TSS and 55 for turbidity (Table D-1). Iterative calculations found that Little Deep Creek required an 80% reduction to bring the critical period average WQI scores of TSS to 87 and turbidity to 80.

Table D-1. Total suspended solids (TSS) and turbidity (NTU) data from Little Deep Creek used to determine acceptable Water Quality Index (WQI) scores.

	LSRTMDL-16			Little Deep Creek					
	TSS	**WQI**	Q	NTU	**WQI**	**80% red**	**WQI**	80% NTU	**WQI**
12/16/2004	12	62	3.62	10	57	**2.4**	88	2.5	80
1/11/2005	5.4	74	1.45	4.2	71	**1.1**	100	1.2	93
3/8/2005	22	53	2.53	12	54	**4.4**	78	4.3	71
4/12/2005	34	47	13.19	20	46	**6.8**	71	6.3	64
5/19/2005	5.2	75	4.47	9.4	58	**1.0**	100	1.2	93
12/13/2005	4	79	0.63	2.6	79	**0.8**	100	0.9	97
3/14/2006	15	59	18.88	17	49	**3.0**	84	3.0	77
4/11/2006	35	46	48.23	39.1	36	**7.0**	70	6.4	64
		62			**56**		**86**		**80**

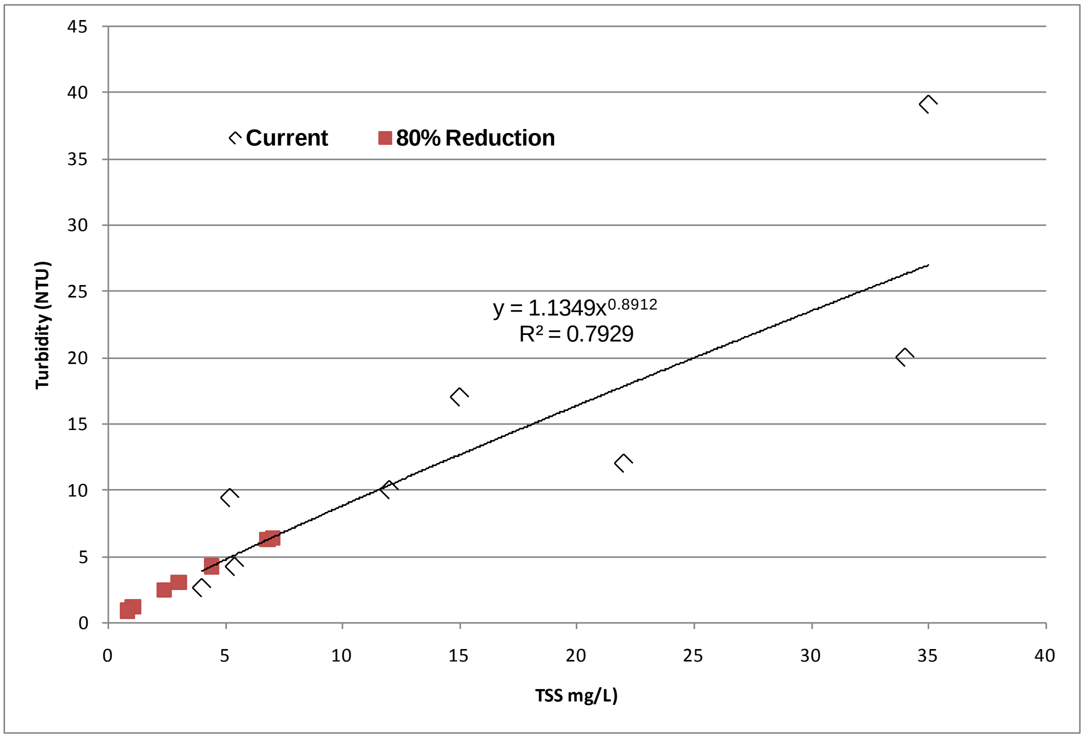

Figure D-2. The total suspended solids (TSS) and turbidity regression equation used to estimate the effect of reducing TSS loading and turbidity to meet the loading capacity at Little Deep Creek during critical trout and whitefish spawning seasons.

Beales ratio equation

The Beales ratio estimator from *Principles of Surface Water Quality Modeling and Control* by Thomann and Mueller (1987) provides a mass loading rate estimate of a pollutant. The formula for the unbiased stratified ratio estimator is used when continuous flow data are available for sites with less frequent pollutant sample data. The average load is then:

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

where,

$\overline{W}_p$ is the estimated average load for the period,

p is the period,

$\overline{Q}_p$ is the mean flow for the period,

$\overline{W}_c$ is the mean daily loading for the days on which pollutant samples were collected,

$\overline{Q}_c$ is the mean daily flow for days when samples were collected,

n is the number of days when pollutant samples were collected.

Also,

$$S_{QW} = [1 / (n-1)]* \left[\left(\sum_{i=1}^{n} Q_{ci} * W_{ci} \right) - n * \overline{W_c}\,\overline{Q_c} \right]$$

and

$$S^2_Q = [1/ (n-1)]* \left[\left(\sum_{i=1}^{n} Q_{ci}^2 \right) - n * \overline{Q_c^2} \right]$$

where,
Q_{ci} are the individually measured flows,
W_{ci} is the daily loading for the day the pollutant samples were collected.

An example of how the Beales ratio equation is used to estimate the annual average TSS at a site (Little Deep Creek) is demonstrated in Table D-2. The 80% source reduction is applied to estimate the TSS load after implementing best management practices (Table D-3).

Table D-2. Beales ratio equation applied to total suspended solids (TSS) and streamflow data collected at Little Deep Creek.

16-WSU	Little Deep Creek						
Date	TSS	QA	Daily Q	tons/d		Q x Ld	Q2
12/16/2004	12		3.62	0.12		0.4	13
1/11/2005	5		1.45	0.02		0.0	2
2/15/2005	8		2.7	0.06		0.2	7
3/8/2005	22		2.53	0.15		0.4	6
4/12/2005	34		13.19	1.21		15.9	174
5/19/2005	5		4.47	0.06		0.3	20
6/14/2005	6		2.8	0.05		0.1	8
7/12/2005	2		1.54	0.01		0.0	2
8/9/2005	2		0.68	0.00		0.0	0
9/13/2005	11		0.73	0.02		0.0	1
10/11/2005	1		0.91	0.00		0.0	1
11/8/2005	2		1.22	0.01		0.0	1
12/13/2005	4		0.63	0.01		0.0	0
2/14/2006	9		6.05	0.15		0.9	37
3/14/2006	15		18.88	0.76		14.4	356
4/11/2006	35		48.23	4.55		219.4	2326
	count =	16	Q DailAvg.	Avg. Ld.	Sea.AvgQ	Sum Q Ld	Sum Q2
515	days		**6.9**	**0.45**	**7.5**	**252**	**2956**
			Sqw=	13.53134	->>>>	**0.52**	tons/day
			S2q=	146.9863			
Drainage area	37.9					269	tons/survey period
						7.1	tons/mi2

Table D-3. Total suspended solids (TSS) load reduction estimate applied to the data in Table D-2.

16-WSU	Little Deep Creek 80% reduction						
Date	TSS	QA	Daily Q	tons/d		Q x Ld	Q2
12/16/2004	2.4		3.62	0.02		0.1	13
1/11/2005	1		1.45	0.00		0.0	2
2/15/2005	1.6		2.7	0.01		0.0	7
3/8/2005	4.4		2.53	0.03		0.1	6
4/12/2005	6.8		13.19	0.24		3.2	174
5/19/2005	1		4.47	0.01		0.1	20
6/14/2005	1.2		2.8	0.01		0.0	8
7/12/2005	0.4		1.54	0.00		0.0	2
8/9/2005	0.4		0.68	0.00		0.0	0
9/13/2005	2.2		0.73	0.00		0.0	1
10/11/2005	0.2		0.91	0.00		0.0	1
11/8/2005	0.4		1.22	0.00		0.0	1
12/13/2005	0.8		0.63	0.00		0.0	0
2/14/2006	1.8		6.05	0.03		0.2	37
3/14/2006	3		18.88	0.15		2.9	356
4/11/2006	7		48.23	0.91		43.9	2326
	count =	16	Q DailAvg.	Avg. Ld.	Sea.AvgQ	Sum QxLd	Sum Q2
515	days		**6.9**	**0.09**	**7.5**	**50**	**2956**
			Sqw=	2.706269	->>>>	**0.10**	tons/day
			S2q=	146.9863			
Drainage area	37.9					54	tons/survey period
						1.4	tons/mi2

Multiple regression model by Cohn (1988)

The method employs a statistical regression model, where the constituent concentrations are estimated based on streamflow and time/season. The application requires daily value streamflow records and unit values of constituent concentrations.

$$\ln[L] = \beta_0 + \beta_1 \ln[Q] + \beta_2 \ln[Q]^2 + \beta_3 T + \beta_4 T^2 + \beta_5 \sin[2*\pi T] + \beta_6 \cos[2*\pi T] + \varepsilon$$

where,

L is the water quality constituent concentration (e.g., phosphorus, TSS).

Q is the daily discharge.

T is time, expressed in fraction of a year

The parameters β_1 and β_2 in the equation correspond to variability related to flow dependence, the next pair correspond to time trends, and the third pair are used to fit a first-order Fourier series to the seasonal component of variability.

Load duration curve analysis

A comparison of flow volumes to FC criteria violations at the mouth of the LSR can be graphically shown using a load duration graph (Figure D-3). The horizontal axis shows the frequency at which flows at the site were exceeded. Based on long-term USGS gaging records (1971–2006), 90% of the flows exceeded 378 cfs, 50% of the flows exceeded 466 cfs, and 10% of the flows exceeded 881 cfs. The FC loads (flow volume x FC count x 24.6 x 10^6) for individual monthly samples (open boxes) collected at Ecology site 55B070 over the same period are compared to FC loads compliant with the 50 cfu/100 mL and 100 cfu/100 mL criteria (green and red lines) along a frequency flow graph.

The graph shows that most of the FC samples collected during all flow volumes met the criteria; they were below the two criteria lines. The site easily meets the geometric mean criteria of 50 cfu/100 mL under all flow conditions. However, statistical analysis showed the site fails the recreational water quality standard because more than 10% of the samples collected between May and September were greater than 100 cfu/100 ml. Flows most common in those months also have most of the FC loads above the 50 cfu/100 mL criterion line. They tend to be evenly distributed between the 20% and 100% flow exceeded values. Interestingly, fewer samples from the highest flows (greater than 881 cfs) are over the criteria. These flows would be more common in the winter and early spring melt times.

By reducing the FC loads upstream by 20%, the analysis estimates that enough of the individual FC loads (solid diamonds in Figure D-3) between May and September will comply with the 100 cfu/100 mL criterion (i.e., fewer than 10% will exceed 100 cfu/100 mL) to meet the recreational water quality standard.

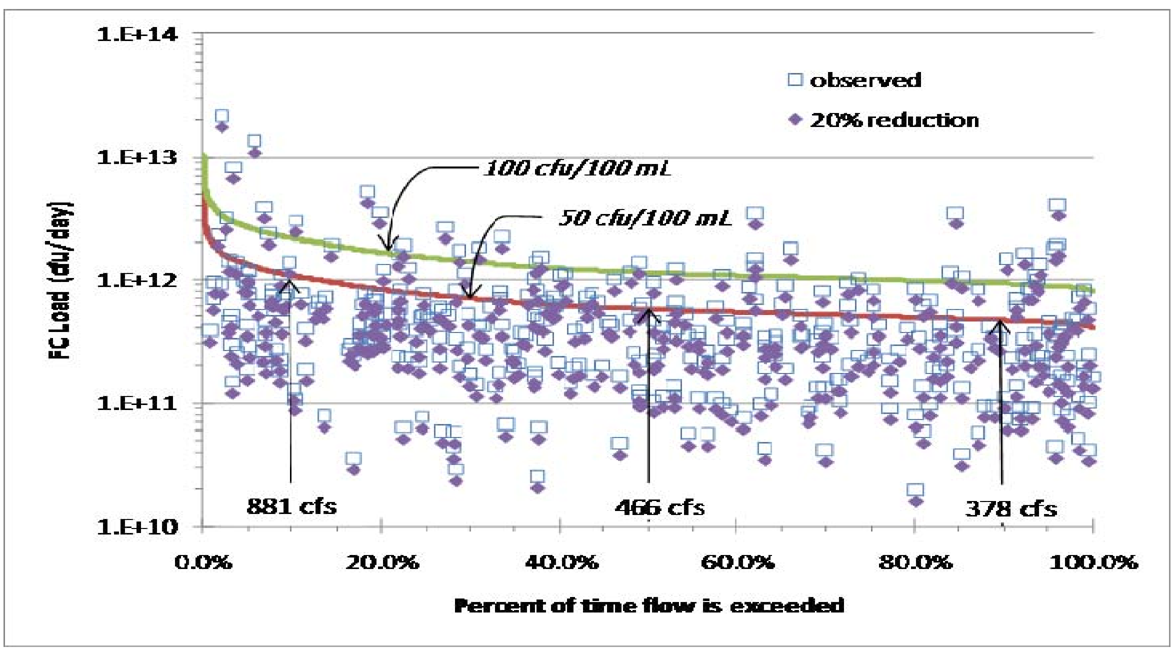

Figure D-3. Fecal coliform (FC) criteria (red and green lines) load duration curves compared to monthly samples collected at the mouth of the LSR. □The resulting loads from a 20% FC load reduction are also shown ♦.

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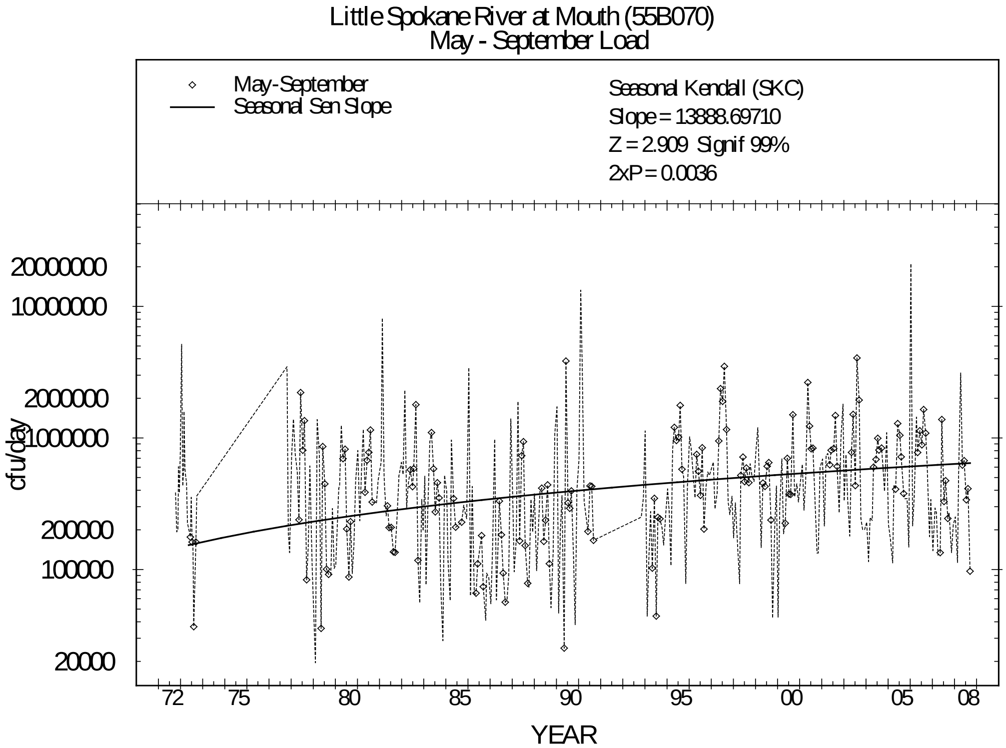
Appendix E. Supplemental technical data

Table E-1. Monthly discharge statistics for the USGS gage, Little Spokane River at Dartford (1947-2008), and monthly average discharge occurring during two major surveys (POCD, 2000; Barber et al., 2007).

Statistic	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Minimum	115	143	204	169	139	117	84	70	81	94	119	114
10th	175	205	308	312	202	153	111	96	105	124	151	171
25th	201	266	406	427	298	178	132	111	119	135	164	188
50th	238	380	547	565	399	248	163	134	138	155	182	222
Mean	300	413	586	630	424	267	167	133	138	157	192	241
75th	328	515	667	837	534	327	187	151	155	176	215	276
90th	448	676	966	963	649	376	228	174	170	188	247	322
Maximum	1204	1108	1629	1469	1176	711	331	217	227	244	357	824
Surveys												
1998										176	225	361
1999	448	694	1156	847	563	329	228	167	159			
2004												202
2005	199	212	233	308	202	153	113	85	93	121	152	172
2006	813	529	628	751								



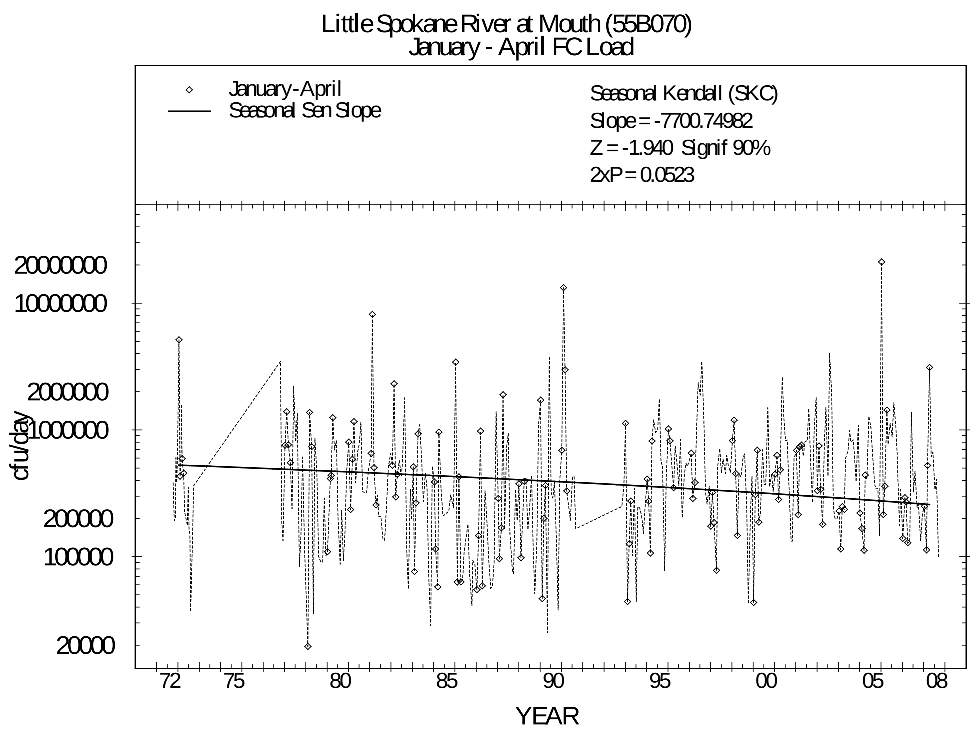


Figure E-1. Seasonal fecal coliform (FC) load trends at the mouth of the Little Spokane River at Ecology station 55B070.

Appendix F. Fish species data and calculations

Fish species reported in the Little Spokane River watershed in:

McLellan, J.G., 2005. 2003 WDFW Annual Report for the Project Resident Fish Stock Status Above Chief Joseph and Grand Coulee Dams Part I. Baseline Assessment of Fish Species Distribution and Densities in the Little Spokane River Drainage, Year 3, and the Spokane River below Spokane Falls. March 2005 Washington Department of Fish and Wildlife, Spokane, WA

Table F-1. Updated list of fish species reported to occur within the Little Spokane River system.

Example:
Common Name, *Species Name*
Location Source

Salmonidae

Brown Trout *Salmo trutta*
Beaver Creek$_2$
Dragoon Creek
Dry Creek
Eloika Lake
Little Spokane River
Otter Creek
Sacheen Lake
Spring Creek
WB Dragoon Creek
WB Little Spokane River
Wethey Creek

Eastern Brook Trout *Salvelinus fontinalis*
Bear Creek
Beaver Creek$_1$
Beaver Creek$_2$
Buck Creek
Deer Creek
Dragoon Creek
Dry Creek
Heel Creek
Little Deer Creek
Little Spokane River
Mud Creek
Otter Creek
Sacheen Lake
S. Fork Deadman Creek
Spring Creek
Spring Heel Creek
Trout Lake
WB Dragoon Creek
Wethey Creek

Lake Trout *Salvelinus namaycush*
Horseshoe Lake

Kokanee *Oncorhynchus nerka*
Buck Creek
Chain Lake
Horseshoe Lake
Little Spokane River

Rainbow Trout *Oncorhynchus mykiss*
Bear Creek
Beaver Creek$_1$
Beaver Creek$_2$
Buck Creek
Chain Lake
Dartford Creek
Deadman Creek
Deer Creek
Diamond Lake
Dragoon Creek
Dry Creek
Eloika Lake
Fan Lake
Horseshoe Lake
Little Deep Creek
Little Deer Creek
Little Spokane River
Otter Creek
Spring Creek
Trout Lake
WB Dragoon Creek
WB Little Spokane River
Wethey Creek

Mountain Whitefish *Prosopium williamsoni*
Bear Creek
Chain Lake
Dragoon Creek
Dry Creek
Horseshoe Lake
Little Spokane River
Otter Creek
WB Little Spokane River
Wethey Creek

Pygmy Whitefish *Prosopium coulteri*
Horseshoe Lake
Little Spokane River

Esocidae

Grass Pickerel *Esox americanus vermiculatus*
Buck Creek
Eloika Lake
Fan Lake
Little Spokane River
WB Little Spokane River

Cyprinidae

Carp *Cyprinus carpio*
Little Spokane River

Chiselmouth *Acrocheilus alutaceus*
Chain Lake
Dragoon Creek
Little Spokane River
WB Dragoon Creek

Longnose Dace *Rhinichthys cataractae*
Bear Creek
Deadman Creek
Deer Creek
Dragoon Creek
Dry Creek
Little Deep Creek
Little Spokane River
WB Dragoon Creek
WB Little Spokane River

Northern Pikeminnow *Ptychocheilus oregonensis*
Chain Lake
Dragoon Creek
Dry Creek
Little Spokane River

Redside Shiner *Richardsonius balteatus*
Beaver Creek$_2$
Chain Lake
Deadman Creek
Dragoon Creek
Little Deep Creek
Little Spokane River
WB Dragoon Creek

Speckled Dace *Rhinichthys osculus*
Bear Creek
Beaver Creek$_2$
Deadman Creek
Dragoon Creek
Little Deep Creek
Little Spokane River
Otter Creek
WB Dragoon Creek

Tench *Tinca tinca*
Chain Lake
Eloika Lake
Fan Lake
Little Spokane River
Sacheen Lake
Trout Lake
WB Little Spokane River

Catostomidae

Bridgelip Sucker *Catostomus columbianus*
Bear Creek
Beaver Creek$_2$
Deadman Creek
Dragoon Creek
Little Deep Creek
Little Spokane River
WB Dragoon Creek

Largescale Sucker *Catostomus macrocheilus*
Chain Lake
Dragoon Creek
Little Spokane River

Longnose Sucker *Catostomus catostomus*
Horseshoe Lake
Little Spokane River
Little Spokane River
Trout Lake

White Sucker *Catostomus commersi*
Little Spokane River

Centrarchidae

Black Crappie *Pomoxis nigromaculatus*
Chain Lakes
Diamond Lake
Eloika Lake
Fan Lake
Little Spokane River
Sacheen Lake

Bluegill *Lepomis macrochirus*
Horseshoe Lake

Little Spokane River
WB Little Spokane River

Green Sunfish *Lepomis cyanellus*
Bear Creek
Diamond Lake
Eloika Lake
Fan Lake
Horseshoe Lake
Sacheen Lake
Trout Lake

Largemouth Bass *Micropterus salmoides*
Diamond Lake
Dry Creek
Eloika Lake
Fan Lake
Little Spokane River
Sacheen Lake
Spring Heel Creek
Trout Lake
WB Little Spokane River

Pumpkinseed *Lepomis gibbosus*
Diamond Lake
Eloika Lake
Fan Lake
Horseshoe Lake
Little Spokane River
Sacheen Lake
WB Little Spokane River

Smallmouth Bass *Micropterus dolomieui*
Eloika Lake

Percidae

Yellow Perch *Perca flavescens*
Chain Lake
Diamond Lake
Eloika Lake
Fan Lake
Horseshoe Lake
Little Spokane River
Sacheen Lake
Trout Lake
WB Little Spokane River

Ameiurus

Black Bullhead *Ameiurus melas*
Eloika Lake

Brown Bullhead *Ameiurus nebulosus*
Diamond Lake
Dragoon Creek
Eloika Lake
Little Spokane River
Sacheen Lake
Trout Lake

Yellow Bullhead *Ameiurus natalis*
Eloika Lake
Fan Lake
Horseshoe Lake
Spring Heel Creek
WB Little Spokane River

Cottidae

Sculpin *Cottus* spp.
Buck Creek
Dragoon Creek
Little Spokane River
Wethey Creek

Mottled Sculpin *Cottus bairdi*
Beaver Creek[2]
Deer Creek
Dragoon Creek
Dry Creek
Little Spokane River
Otter Creek
Spring Creek
WB Dragoon Creek
WB Little Spokane River

Slimy Sculpin *Cottus cognatus*
Bear Creek
Buck Creek

Torrent Sculpin *Cottus rotheus*
Dragoon Creek
Dry Creek
WB Dragoon Creek

[1] Beaver Creek; tributary to the West Branch Little Spokane River (LSR).
[2] Beaver Creek; tributary to Dragoon Creek.
WB: West Branch.

Fish assemblage score

This is a description of the steps used to calculate a rough Fish Assemblage Score to reflect thermal tolerance. A score based on species thermal tolerance and other attributes were taken from Table 1 of Zaroban et al. (1999). These were applied to fish species identified by WDFW in summer 2003 collections along the Little Spokane River (McLellan, 2005).

Table F-2. Fish species attribute classification.

Class	Fish Species attributes[1]
1	native, cold water, sensitive
2	native, cold water, intermediate
3	alien, cold water, intermediate
4	native, cool water, intermediate
5	alien, cool water, intermediate
6	native, cool, tolerant
7	alien, cool, tolerant
8	alien, warm, intermediate
9	alien, warm, tolerant

[1] Attributes taken from Table 1 of Zaroban et al., 1999.

Table F-3. Classification applied to species identified in WDFW fish surveys in 2003 (McLellan, 2005).

Abbreviation	Common Name	Attribute class[1]
EBT	Eastern brook trout	3
RBT	Rainbow trout	1
MWF	Mountain whitefish	2
BT	Brown trout	3
Sculpin	Sculpin species	4
Chiselmouth	Chiselmouth	4
N Pikeminnow	Northern pikeminnow	6
Longnose dace	Longnose dace	4
Red shiner	Red shiner	4
Speckled dace	Speckled dace	4
Tench	Tench	8
BL sucker	Bridgelip sucker	6
LS sucker	Largescale sucker	6
G Pickerel	Grass Pickerel	5
Pumpkinseed	Pumpkinseed	7
LM Bass	Largemouth bass	9
Bluegill	Bluegill	9
Yellow perch	Yellow perch	5
Y. Bullhead	Yellow bullhead	9

[1] Attributes taken from Table 1 of Zaroban et al., 1999.

Table F-4. Fish sample site location information (McLellan, 2005).

Site Number	Latitude start	Longitude start	Latitude finish	Longitude finish	Length (m)
3	48.1325	117.112	48.1286	117.128	1266
4	48.1286	117.128	48.1279	117.133	388
5	48.1279	117.133	48.1253	117.139	569
6	48.1253	117.139	48.1187	117.143	794
7	48.1187	117.143	48.1079	117.153	1278
10	48.0922	117.172	48.0804	117.168	1396
11	48.0804	117.168	48.0617	117.183	2468
16	48.0359	117.248	48.022	117.273	2747
18	48.0166	117.277	47.9893	117.301	3752
21	47.9849	117.325	47.9824	117.329	457
22	47.9824	117.329	47.9695	117.334	5412
23	47.9695	117.334	47.9376	117.327	1473
26	47.9263	117.336	47.9039	117.344	1925
27	47.9039	117.344	47.8916	117.354	441
29	47.8883	117.356	47.8798	117.367	690
31	47.876	117.369	47.8558	117.367	1748
32	47.8558	117.367	47.8425	117.375	2242
33	47.8425	117.375	47.8261	117.376	3174
36	47.7955	117.384	47.7912	117.398	951
37	47.7912	117.398	47.7846	117.405	918
38	47.7846	117.405	47.7826	117.416	4441

Table F-5. The percentage of each fish species collected by WDFW at sites and the final fish assemblage score calculated for the site.

Site Number	Final Score	EBT	RBT	MWF	BT	Sculpin	Chiselmouth	N Pikeminnow	Longnose Dace	Red Shiner	Speckled dace	Tench	BL sucker	LS Sucker	G Pickerel	Pumpkinseed	LM Bass	Bluegill	Yellow Perch	Y. Bullhead
3	**3.2**	77				23														
4	**3.1**	79	2			18												1		
5	**3.3**	72				13					14							1		
6	**3.2**	76				3					22									
7	**3.1**	86				6					8									
10	**2.3**	47	40			5					8									
11	**2.4**	44	38			6					12									
16	**4.0**	1	15	1		19	6	6		35	2		12	6						
18	**4.2**		22	3		27	5	3	3	8		2	13	7			7			
21	**4.3**					71					7			7					14	
22	**5.5**					23		11			3		20	14	14	3			6	6
23	**4.1**	1	18	5		22	2	12	8	5			16	5					6	
26	**5.0**					35	15	45						5						
27	**5.7**			2		19						12	38	21	2	2			2	
29	**4.2**		7			54	7	4	7	4			7	11						
31	**4.1**					71			18	6				6						
32	**4.6**		7			43		7	4	7			21	7		4				
33	**4.8**					60		25					15							
36	**4.3**		6	4		4	9			51			6	22						
37	**4.0**		10		1	17	36	4	4	16			10	1						
38	**2.5**		43	21		24			3				3	6						

The score was calculated as follows:

Score = [(Fish Class Species 1 x percentage Species 1 at site) + (Fish Class Species 2 x percentage Species 1 at site) +… (Fish Class Species n x percentage Species n at site)] / 100

For example, at site 38, the species identified and their percentages and species class score were as shown in Table F-6.

Table F-6. Fish class species, percentage, and class score at site 38.

Species	Percentage at Site	Classification Score
Rainbow trout	42.5%	1
Mountain whitefish	21.2%	2
Sculpins	24.2%	4
Longnose dace	3.0%	4
Bridgelip sucker	3.0%	6
Largescale sucker	6.1%	6

Calculating the site score:

[(1 x 42.5) + (2 x 21.2) + (4 x 24.2) + (4 x 3) + (6 x 3) + (6 x 6.1)] / 100 =
[248.2] / 100 = **2.48**

Lower scores have a higher percentage of cold or cool water, native, thermo-sensitive fish species. Higher scores have a higher percentage of cool or warm water, thermo-tolerant fish species. The fish assemblage score at Site 38 reflects a population of primarily thermo-sensitive, cool or cold water native fish.

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Appendix G. Record of public participation

Introduction

Public involvement is vital in any TMDL. TMDLs are successful only when the watershed landowners and other residents are involved. They are the closest to and most knowledgeable of the watershed resources. Many private landowners in the Little Spokane River (LSR) watershed are intimately involved with local, state and federal agencies.

Summary of comments and responses

Two private citizens and three public entities provided comments to the document. Public comments and Ecology's responses are included in Appendix H of this document.

Public meetings

The LSR TMDL work group was formed after two public meetings held in the watershed on April 30 and May 1, 2003. Announcements were posted throughout the watershed, and 1,411 postcard announcements were sent to local businesses, towns, and residences that have indicated they were interested in LSR water quality. The first public meeting was held at Colbert Elementary School in the lower part of the watershed and represented the small acreage and urban land uses. The second public meeting was held at Newport High School in the upper part of the watershed that is representative of more rural, agricultural and livestock land. An organizational meeting was held at the Spokane County Conservation District on July 24, 2003 with people from the public meetings who indicated they were interested on working on the TMDL. Since then, workgroup meetings have been held approximately monthly in Riverside, Washington.

Outreach and announcements

A 30-day public comment period for this report was held from October 24, 2011 through November 23, 2011.

A news release was sent to all local media in the LSR watershed area.

Advertisements were placed in the following publications:
The Spokesman Review, October 24, 2011 edition
The Elk Sentinel, November edition (published in October)
The Newport Miner, October 26, 2011 edition

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Appendix H. Response to public comments

Please note the page numbers referred to in the comments refer to the original draft publication published in October 2011; however, due to possible formatting change, they may not match the pages numbers in this final publication.

To: Jon Jones,

Subject: Public Comment on Publication #11-10-075
Little Spokane River Water Quality Management Plan

Comment: The Department of Ecology has not taken a stand against the expansion of the Mount Spokane Ski Area. The west side expansion will increase the water temperature and sedimentation of spring-time runoff into Deadman Creek, Little Deep Creek, Deep Creek and Deer Creek. The impact on the TMDL's will begin at the very source of these major tributaries for the Little Spokane River. The reduced watershed capacity of Mount Spokane due to rapid Spring runoff from the clear cut ski expansion will cause lower summer water flows in the Little Spokane River. This not only adversely impacts ground water and domestic exempt well users, potentially could reduce agricultural output, and it impacts TMDL's. One of your committee members even stated, "to involve the Washington State Parks and Recreation Commission would just make things to complicated."

The Department of Ecology has also ignored the issue of adverse impacts to Little Spokane River water quality by recreational activities. Recreational sites like public parks and canoe put-in and take-out areas contribute to sedimentation and increased human fecal coliform levels. By calling these, "soft" recreational activities is misleading. The golf courses along the Little Spokane River also reduce water quality from fertilizers, herbicides, and pesticides. However, no TMDL's have been set for these pollutants. The reason given is that testing for these pollutants is to expensive, or maybe the reason is the Spokane Country Club members would become upset if the TMDL"s were exceeded and cutbacks in these pollutants would impact the quality of their greens. It seems to be the intent of the Department of Ecology to go after private property owners with lawns to the river edge and domestic exempt well owners, but golf courses that use tons of water and pollutants are off limits.

Dale C. Gill
2614 W. Grace
Spokane, WA. 99205
November 23,2011

Responses to Dale C. Gill's comments:

Response concerning the Mount Spokane Ski Area:
The state's forest practices regulations will be relied upon to bring waters into compliance with the load allocations established in this TMDL on private and state forest lands. This strategy, referred to as the Clean Water Act Assurances, was established as a formal agreement to the 1999 Forests and Fish Report (www.dnr.wa.gov/Publications/fp_rules_forestsandfish.pdf). It is important to acknowledge that these objectives apply to all land owners in the forest areas. Pages 138 and 139 of the draft report discuss the role of the state forest practices act in more detail. Once there has been a conversion from forest land to another use, the land will no longer be covered under the Forestry regulations. Ecology will then work with the State Parks Department or other appropriate agency or agencies to address the issue.

Response to comment concerning recreational activities: The advisory group understood the potential impacts of recreation and agreed that recreation should be addressed. Issue 8 of the Implementation Strategy (page 137 of the Draft TMDL) addresses the issue. As we develop the Implementation Plan for this TMDL, we will continue to work with land uses, such as parks and golf courses, to include implementation activities to reduce pollutants from these areas.

Response to testing for other pollutants: Ecology recognizes other pollutants can have adverse impacts on water quality. Recommended implementation activities, such as riparian buffers, serve to reduce a number of pollutants, including fertilizers and pesticides; but if water quality monitoring confirms that pollution problems persist, Ecology will take additional action up to and including enforcement. The normal action for addressing pollutants through the TMDL process is described in the Executive Summary portion of this report and can be found on page xiii.

Response to focus on private landowners: The purpose of this TMDL, as well as all TMDLs, is to provide a water cleanup plan that applies to all users of the watershed. The intent of these TMDLs is to work with all watershed users, regardless of ownership, to meet state clean water standards. The development of the implementation plan for this TMDL will bring additional participants into the process.

Comments about the Little Spokane River TMDL.

Submitted by Thomas Wimpy, a member of WRIA 55/57 and the West Branch of the Little Spokane River group.

The following comments are my personal opinion.

Comments on Phosphorus:

The TMDL does mention phosphorus, which was part of the reason for conducting the TMDL on the Little Spokane River. Since the Little Spokane River (LSR) will be considered a point source of phosphorus for the Spokane River, it would have been nice to see some phosphorus levels measured during the TMDL process. Of course, new technology can do this via satellite images but there can be no quantitative statements made in the future concerning the reduction of phosphorus levels when there are no baseline measurements to compare it with. I agree that the fecal coliform and suspended sediment data may parallel the phosphorus levels and the proposed actions will probably reduce some of that phosphorus loading from the "non-point sources" along the Little Spokane River. It's too bad that the opportunity was missed to get an accurate picture of phosphorus levels at various points along the LSR.

Comments on Temperature:

Someone should challenge the temperature recommendations since the model indicates that the requirement cannot be met when there is low flow in the LSR. It's funny that the low flow years have prompted other requirements to be implemented in the past. These requirements were for conservation of water, not temperature. Maybe this is one area where water quality and water quantity can overlap.

Though riparian shade and buffering is better for the water quality, I personally do not think that the effects will be seen in the 10 to 15 years of this implementation. Most of the shrubs and trees do not grow that fast. These changes also depend upon the education of the landowners. Presently, there is more concern about the environment that 20 years ago but 20 years from now, the development may again be more important than the environment and fish within the LSR. I also did not see where any mention was made to the numerous "farm ponds" that are used to raise fish, water livestock and alter the temperature of the surface water.

An additional Comment:

Since one of the highlights of this and other TMDL's is the red band trout, it should be emphasized that the red band trout is a subspecies of rainbow trout, not a separate species. Development may have isolated this subspecies by the placement of dams along the Spokane River (the last 100 years) and modified the gene pool by supplementing the population for at least 50 years. Not to mention how many places and times that the LSR and the lakes within it have been "rehabilitated". Care should be taken not to elevate a subspecies to a species without proper scientific evidence and consensus.

Responses to Thomas Wimpy's comments

Response to lack of phosphorous monitoring: Ecology is sampling for phosphorous on a monthly basis at the mouth of the Little Spokane. The Spokane Conservation District is also planning phosphorous monitoring in the Bear Creek watershed, a subwatershed of the Little Spokane. A dissolved oxygen and pH study is being planned by Ecology for later this year. Availability of resources will dictate the need for and how much future monitoring will be done.

Response to low flow issue comment: Although these TMDLs do not address flow, Ecology recognizes the importance of adequate flows. Maintaining adequate flows will take a combined effort of private citizens, agencies and groups to craft and implement a successful strategy. Although the modeling indicated that numeric temperature criteria may not be able to be met at all times during low flow, the water quality standards state the stream must meet the numeric criteria or natural conditions. The modeling provides a numeric target that would be expected under natural conditions.

Response to riparian shade comment: It is estimated the LSR has lost 61% of its natural riparian area and its tributaries have fared worse. Riparian vegetation losses range from 70% in Dragoon Creek to 93% in Little Deep Creek. A goal of this project is to restore the stream to its natural condition to the greatest extent possible. We will try to reach the goals of this TMDL, and if after 15 years standards are not met, the TMDL will be reevaluated.

Response to "farm pond" comment: If surface pond water is not allowed to re-enter the stream, the pond water has the opportunity to slowly infiltrate back into the stream. This not only has a water cooling effect, but also the effect of removing some nutrients. Ponds also are a way of holding water and releasing slowly to help even the water flow.

Response to Redband Trout comment: On page 14 of the LSR TMDLs we quote the watershed plan stating redband trout are a sub-species of rainbow trout. Pages 13 and 14 also explain why we focus on rainbow trout and mountain whitefish, and how the environmental requirements for redband trout are slightly different from those commonly attributed to rainbow trout. Additional information about genetically distinct populations of native redband trout, *not interbred with planted rainbow trout*, documented in the Little Spokane River watershed are discussed in "Fine-scale population structure of rainbow trout in the Spokane River drainage in relation to hatchery stocking and barriers" by M.P. Small, J.G. McLellan, J.Loxterman, J. Von Bargen, A. Frye, and C. Bowman. Transactions of the American Fisheries Society 2007 volume 136, pages 301-317.

November 22, 2011

Mr. Jon Jones
Washington State Department of Ecology
Eastern Regional Office
4601 N. Monroe Street
Spokane, Washington 99205

RE: WSDOT Review Comments for Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load Water Quality Improvement Report Draft

Dear Mr. Jones:

The Washington State Department of Transportation (WSDOT) Environmental Services Office has reviewed the Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load (TMDL) Water Quality Improvement Report Draft – October 2011 (Washington State Department of Ecology Publication No. 11-10-075).

We appreciate the opportunity to provide comments on this TMDL document. WSDOT is committed to working collaboratively with Ecology and others to address the fecal coliform, heating, and sediment contributions of stormwater discharges from state highways in the Lower Spokane River Watershed.

Before we provide our specific comments, we have one general comment that we request be given serious consideration (more detail is provided in comment #5 below). We question why WSDOT stormwater is required to receive wasteload allocations (WLAs), given that our discharges were not sampled during the TMDL study and are merely assumed to contain bacteria, turbidity and are a source of heating. No data or other justification is provided in the report. We request that WSDOT be removed from the WLA assignments in this TMDL.

We would like to provide the following specific comments, which include the page number and wording in question/of concern:

1) Page xvi, fifth bullet: "Bacteria from stormwater discharges under Spokane County, city of Spokane, Washington Department of Transportation, construction, and one industrial permit will require controls through wasteload allocations (Table ES-4)."

   Comment: WSDOT stormwater was not sampled during the TMDL study, therefore, the percent reductions assigned to WSDOT (contained in Table ES-4) are presumptuous and without basis. This is supported by the statement on page 106, "Monitoring data were not collected to adequately provide numeric FC loads from MS4 and WSDOT stormwater sources." See comment #5.

2) Page xviii, last bullet: "Excessive heat from stormwater discharges under Spokane County, city of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls to prevent impairment of aquatic life if stormwater is discharged directly to surface water instead of through infiltration (Table ES-4)."

   Comment: WSDOT stormwater was not sampled during the TMDL study, therefore, the assumption that WSDOT discharges exhibit "excessive heat" is presumptuous and without basis. This is supported by the statement on page 109 (emphasis added), "Thermal loading from direct MS4 stormwater discharges can increase the temperature of small receiving waters at certain times of the year…this presumption must be verified after identifying any direct MS4 discharges to surface waters and by then monitoring temperature in the receiving water and the stormwater discharges." See comment #5.

3) Page xx, fifth bullet: "Turbidity and TSS loads from stormwater discharges under Spokane County, City of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls (Table ES-4)."

   Comment: WSDOT stormwater was not sampled during the TMDL study, therefore, the assumption that WSDOT discharges require additional controls is presumptuous and without basis. This is supported by the statement on page 112, "As with FC and temperature, point sources in the LSR watershed may not be large contributors to the current turbidity and TSS load…" See comment #5.

4) Page xxii, Table ES-4 and page 107, Table 35:

   Comment: Suggest replacing the text in Table ES-4 describing WSDOT's fecal coliform WLA with the text in Table 35 for consistency. The WLAs described in these tables are worded differently and can be interpreted differently. Table ES-4 states WSDOT's WLA equals, "Geometric mean 50 cfu/100 mL & not more than 10%>100 cfu/100 mL," which is the water quality standard. Water quality standards by definition are a measure applied to receiving waters rather than stormwater outfalls. Table 35 states WSDOT's WLA is to, "Maintain *extraordinary primary contact* criteria in receiving waters." WSDOT recommends this wording be used in Table ES-4 as it requires our discharges not cause an exceedance of water quality standards in the receiving water rather than establishing a numeric effluent limit equal to water quality standards.

5) Page xxii, Table ES-4; page 107, Table 35; page 111, Table 36; page 114, Table 37. Wasteload allocations for NPDES dischargers in the Little Spokane River watershed:

   Comment: Ecology's policy, *Ensuring Credible Data for Water Quality Management, WQP Policy 1-11***,** September 2006, states that credible data must be used to establish TMDLs and does not include the use of data-free assumptions.

   To be consistent with regulations and guidelines used to establish TMDLs, we feel it is Ecology's responsibility to characterize the sources of pollution and assign numeric WLAs only when there is credible, site specific data or information indicating that WSDOT facilities are a significant source or contributor of the pollutants of concern. In the absence of site specific stormwater outfall data, numeric WLAs assigned to WSDOT are presumptuous and without just cause.

Based on the fact that WSDOT stormwater was not sampled during the study and/or identified as a significant source of these pollutants within the TMDL area, we do not feel numeric WLAs are warranted. However, in the event new data or other actionable information should later reveal that WSDOT is a significant source or contributor, it would be appropriate to assign WSDOT actions, or a numeric WLA at that time if supported by site-specific, scientifically credible data, under the TMDL via the adaptive management process.

6) Page 106, third paragraph, last sentence: "The Washington State Department of Transportation (WSDOT) is responsible for stormwater in the urbanized area and any other TMDL water body potentially affected by runoff from highways, rest areas, or any other WSDOT facility."

<u>Comment</u>: Suggest revising this sentence to be more consistent with the permit coverage language, S1.B.1 and 2, "Washington State Department of Transportation's (WSDOT's) permit regulates stormwater discharges from municipal separate storm sewer systems (MS4s) owned or operated by WSDOT within the Phase I and II designated boundaries. Also, this permit covers stormwater discharges to any water body in Washington State for which there is a U.S. Environmental Protection Agency (EPA) approved Total Maximum Daily Load (TMDL) with load allocations and associated implementation documents specifying actions for WSDOT stormwater discharges."

7) Page 106, last paragraph: "Monitoring data were not collected to adequately provide numeric FC loads from MS4 and WSDOT stormwater sources. When data are available, EPA guidance requires numeric loads to be established in the stormwater permits (Hanlon and Keehner, 2010)."

<u>Comment</u>: Suggest deleting the last sentence. WSDOT feels it is inappropriate to reference this memo when EPA has not formally decided whether to retain the memorandum without change, reissue it with revisions, or to withdraw it based on stakeholder comments in May 2011. As you are aware, "A key issue addressed in the 2010 memorandum is the feasibility of including numeric effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges."[i]

8) Page 106, last paragraph, last sentence: "In the interim, the three jurisdictions will be required to monitor effectiveness and implement best management practices (BMPs) that reduce FC counts in stormwater to achieve *extraordinary primary recreation* criteria in these receiving waters."

<u>Comment</u>: Suggest the following revision: "In the interim, the three jurisdictions will be required to ~~monitor effectiveness and~~ implement the requirements of their permits. ~~best management practices (BMPs) that reduce FC counts in stormwater~~ Compliance with permit

requirements is presumed to achieve *extraordinary primary recreation* criteria in these receiving waters." As stated in the draft document, this could be interpreted to mean that WSDOT must perform sampling and install BMPs specifically for this TMDL, which is not reflected in the assigned action items or warranted based on the lack of data identifying WSDOT as a source.

9) Page 111, Table 36, Temperature WLA: "Continue with permit-directed BMPs which infiltrate stormwater and prevent direct discharges to surface water. Where surface discharges are present, verify that volumes are <1% of receiving water volume from May through October, and temperatures do not exceed 7-DADMax criteria at a probability of once in 10 years."

   Comment: Suggest deleting the last sentence. To comply with the last sentence of the WLA, WSDOT would have to monitor the flow of all surface water discharges and the receiving waters, and continuously monitor temperature. This onerous WLA is not warranted based on the lack of data identifying WSDOT as a source.

   Further, WSDOT questions the likelihood of an event that would produce 7 days of discharge exceeding 16 degrees C, which is supported by the statements on page 109, "Stormwater is also not a likely heat source during October to April," and "May and September are the most likely months for stormwater to have an impact on water temperatures that could potentially exceed water quality criteria…but it is unlikely that prolonged rainfall will occur during these times to cause the applicable 7-day average daily maximum criteria to be exceeded."

10) Page 113, second paragraph under Stormwater heading: "However, permit holders are required to inventory their systems and treat any stormwater for turbidity and TSS that directly discharges to surface waters. According to stormwater treatment manuals, 80% removal of TSS is easily achievable. Considering the magnitude of TSS removal and turbidity improvement needed in the affected water bodies, all MS4 stormwater must be treated to remove >80% of the TSS."

    Comment: 1) Suggest making this paragraph specific to the city of Spokane and Spokane County, and 2) Suggest adding the following paragraph to address WSDOT's requirements, "WSDOT is required to inventory stormwater discharge locations within Phase II permit coverage areas and treat any stormwater for turbidity and TSS that directly discharges to surface waters when triggered during new construction per the NPDES Municipal Stormwater Permit and General Construction Permit requirements."

11) Page 114, Table 37, Turbidity/TSS WLA: ">80% removal of TSS."

    Comment: Suggest adding the following footnote pertaining to WSDOT's WLA, "when triggered during new construction."

12) Page 125, "WSDOT will follow provisions of their municipal stormwater permit."

Comment: Suggest the following revision, “Compliance with WSDOT’s ~~will follow provisions of their~~ municipal stormwater permit, in all Phase II coverage areas, constitutes compliance with the goals of this TMDL.”

In general:

- If a numeric WLAs will remain for WSDOT (which we strongly disagree with), the following sentence should be added to this TMDL document: “Compliance with assigned action items constitutes compliance with assigned WLAs.”

- WSDOT has not performed a QA/QC check on the water quality or flow data presented in this report, nor have we re-computed the math behind derived values, and reserve the right to make corrections if errors are found at a later date.

Thank you for considering our comments. If you have questions or wish to discuss, please contact WSDOT’s TMDL Lead, Jana Ratcliff, at 360-570-6649 (office), 360-701-6353 (cell), or ratclij@wsdot.wa.gov.

Sincerely,

Kenneth M. Stone
Resource Programs Branch Manager
Environmental Services Office

KMS:jr

Cc: Ken Stone
Jana Ratcliff
Tammie Williams
Greg Lahti

United States Environmental Protection Agency. Office of Water. March 17, 2011. Web. http://www.epa.gov/npdes/pubs/sw_tmdlwla_comments.pdf

Response to Washington State Department of Transportation comments 1, 2, 3, 5 and “General Comment”

The Department of Ecology (Ecology) recognizes that stormwater was not directly sampled in the Little Spokane River watershed, as we openly stated on page 106 of the report. Two stormwater sampling sites were established in 2004 – 2006 study (Table 17, sites 24 and 25 in the report), but a runoff event did not occur.

Following current USEPA guidance, Ecology is required to establish wasteload allocations (WLA) for stormwater loads from all jurisdictions holding discharge permits. The guidance allows the use of best available data to make a WLA determination. We believe we made a defensible and credible determination based on the following assumptions and facts:

- The city of Spokane and Spokane County rely on infiltration to treat stormwater in suburban areas of the Little Spokane River watershed (example Figure 10 in the report).
- Washington State Department of Transportation (WSDOT) presumably follows local methods like infiltration that are effective in treating stormwater.
- Stormwater loads of fecal coliform bacteria, heat (temperature), and suspended solids (turbidity) are significantly reduced by infiltration.
- However, WSDOT has not inventoried its stormwater system in the Little Spokane River watershed. Therefore, WSDOT cannot yet say if all of their stormwater is treated by infiltration and avoids direct discharge to surface waters in the watershed.
- Under its 2009 NPDES MS4 permit WAR043000A, WSDOT is required to “Inventory and document all known municipal separate storm sewer outfalls and structural stormwater treatment and flow control BMPs WSDOT owns, operates, or maintains” by 2014.

That is why the note in Table ES-4 and narrative texts in the Load and Wasteload Allocations section of the report specifically state the numeric WLAs are for stormwater directly discharged surface water and not treated by infiltration. If WSDOT identifies a direct stormwater discharge during the inventory process, retrofit the discharge with infiltration or monitor compliance with the WLAs.

Response to comment 4:
We will change the wording in Table ES-4 to read “Maintain a geometric mean 50 cfu/100 mL and not more than 10% > 100 cfu/100 mL in the receiving water.”

Response to comment 6:
The expanded definition of the WSDOT permit will be included in the final report.

Response to comment 7:
Ecology believes the current guidance from USEPA concerning requirements of WLAs in stormwater permits is found in the memorandum referenced in the report (Hanlon and Keehner, 2010). The guidance has been challenged, but it has not been revised or rescinded.

Response to comment 8:

The last paragraph on page 106 will be changed to:

> “Monitoring data were not collected to adequately provide numeric FC loads from MS4 and WSDOT stormwater sources. When data are available, EPA guidance requires numeric loads to be established in the stormwater permits (Hanlon and Keehner, 2010). Also as noted earlier, these jurisdictions commonly use infiltration treatment, a method very effective in reducing fecal coliform loads. In the interim, the three jurisdictions will be required to identify surface discharges of stormwater directly to receiving waters and

implement best management practices (BMPs) that reduce FC counts in stormwater to achieve extraordinary primary recreation criteria in these receiving waters."

Response to comment 9:
This task should not be "onerous" since Ecology assumed: 1) WSDOT needs to inventory "…outfalls and structural stormwater treatment and flow control BMPs WSDOT owns, operates, or maintains' by 2014", 2) most of the stormwater is already treated through infiltration, and 3) very few of the surface water stormwater discharges are expected be greater than 1% of the receiving water volume for May through October. Stormwater volumes for stormwater systems identified with surface discharges can be estimated using various hydrologic models common to other work WSDOT performs. Continuous temperature monitoring recorders are inexpensive, easily installed and reliable.

Response to comments 10 & 11:
In WSDOT's next MS4 permit (2015), the Little Spokane River TMDL will be included among the TMDL areas in Section S6. By then, the WSDOT stormwater system inventory should be complete and the surface discharges of stormwater causing concern should be identified. WSDOT will need to comply with the >80% TSS removal requirement for all of them, not just in areas of new construction.

Response to comment 12:
The revised language is acceptable.

SPOKANE COUNTY

DIVISION OF ENGINEERING AND ROADS
A DIVISION OF THE PUBLIC WORKS DEPARTMENT

November 30, 2011

Washington State Department of Ecology
Water Quality Program
Attn. Jon Jones
Eastern Regional Office
4601 N. Monroe Street
Spokane, WA 99205

Re: Written Comments on Little Spokane River Watershed TMDL

Dear Mr. Jones,

Thank you for keeping us informed as the Little Spokane River Watershed Fecal Coliform Bacteria, Temperature and Turbidity TMDL moves towards a final document. Below are our comments on the October 2011 draft:

- On ***page xvi***, The "Fecal Coliform Bacteria" paragraph references an "evaluation of 30 sites", however, Table ES-1 doesn't provide a summary of findings for the 30 sites. To provide clarity and an upfront look at monitoring results that form the overall basis for the fecal coliform recommendations, we proposed the following:
  - within the 3rd paragraph revise the 1st sentence as follows, "A total of 30 sites with fecal coliform data were ~~evaluated~~ analyzed (Table ES-~~1~~ 21)." (Table ES-21 is the same as Table 21, adapted for the Executive Summary.)
  - on ***page xvi***, after 6th bullet, add paragraph as follows, "The recommended fecal coliform load reductions, load allocations, and average daily load capacity for sites in the Little Spokane River watershed are summarized in Table ES-1."
- Provide a GIS map showing the physical locations (for fecal coliform) referenced in Table 21 that are Water Quality Category 5.
- On **page 30**, under "Current Land Use and Potential Pollutant Sources", 1st paragraph, it would be beneficial to have a GIS map that shows the land uses throughout the watershed, rather than just a reference to *Figure 2* that only

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indicates (relating to this paragraph) the location of "dairies". The Spokane County "Comprehensive Plan Map" prepared by Spokane County Building and Planning would provide current land use information and provide the opportunity to illustrate the relationship between land use and the watershed. We recommend that this map be utilized within this TMDL.

- It would provide a good reference to have a "River Mile (RM) Map" to use as a reference for **Tables 22 and 23,** elsewhere within the TMDL. Also, **Page xxiii**, under Conclusions and Recommendations, the first paragraph references RM 10.1 and RM 31.8. In addition, a river mile column, that references the "River Mile Map", would be beneficial in **Table ES-1**.

- **Page xviii**, 8th bullet, states that "Excessive heat from stormwater discharges under Spokane County…..will require controls to prevent impairment of aquatic life if stormwater is discharged directly to surface water instead of through infiltration (Table ES-4)." We believe that this sentence is misleading. Since there doesn't appear to be any direct monitoring and water quality data supporting this TMDL relating to temperature, we would request that the word "Potentially" be placed at the beginning of the above referenced sentence.

- **Page 106**, last paragraph states, "Monitoring data was not collected to adequately provide numeric FC loads from MS4 and WSDOT stormwater sources." This sentence is accurate. However, if the same is true for temperature and turbidity, this statement should be repeated within those sections as well.

- **Page 108**, under Point Sources, 1st paragraph, last sentence, that states, "Dairies in the watershed have not been identified as having discharges to surface waters.", is misleading. This sentence appears to contradict page 106 second paragraph that states, "Waste management operations at dairies in the Dragoon Creek, Deadman Creek, and Upper LSR sub-watersheds should be given priority to annual inspections." Also, agriculture and livestock operation have the potential to impact surface water temperature. A solution may be to rewrite the first sentence to state, "Dairies within the watershed will require further investigation to identify any discharges to surface waters."

- **Page 110**, 1st paragraph, 2nd sentence, that states, "They are locating…..and outfalls, and are conducting water quality and flow monitoring.", is not completely accurate. To date, Spokane County has located drywells, swales and outfalls. However, the Phase II Permit does not currently require nor have we yet to conduct water quality monitoring or flow monitoring. The second Phase II Permit cycle is proposed to contain monitoring requirements. Although at this time, the revised Phase II Permit is in a draft form and available for public comment. The above sentence (and other sections within the TMDL if necessary) should be revised accordingly.

- **Page 110**, if possible, it would be beneficial to create a map indicating known temperature impaired locations.

- **Page 113**, under Stormwater, 1st paragraph, 2nd sentence, states "The City of Spokane, Spokane County, and WSDOT are responsible for stormwater controls in urban jurisdictions within the Lower LSR and Deadman Creek areas." This sentence should also recognize that the "NPDES Construction Permit" process is currently managed by Ecology. Therefore, Ecology is also responsible for stormwater controls within this watershed.

- The implication throughout the TMDL document is that the implementation of the Eastern Washington Phase II Municipal Stormwater Permit (Permit) held by Spokane County will reduce the concerns about stormwater runoff impacts to the Little Spokane River. In fact, the Permit is only oriented toward municipal *point source* discharges of stormwater to surface waters (and ground waters outside of the UIC Program) from the defined municipal separate storm sewer system (MS4) within the Phase II Permit boundary. Nonpoint source stormwater runoff is not covered under the Phase II Permit.

Thank you for the opportunity to submit comments on the draft Little Spokane River Watershed TMDL. Please let me know if you have any questions.

Sincerely,

Russ Connole
Project Manager

cc: Matt Zarecor, Development Services/Stormwater Utility
Ben Brattebo, Water Resource Specialist

3

Responses to comments from Spokane County Division of Engineering and Roads

Response to comment 1:
Ecology will strike the reference to Table ES-1 in the first sentence of the 3rd paragraph on page xvi. As recommended by the comment, we will add a modified 7th bullet: "The recommended fecal coliform load reductions, load allocations, reserve allocations and loading capacities for the 30 sites evaluated in the Little Spokane River watershed are summarized in Table ES-1."

Response to comment 2:
The Category 5 sites referenced in Table 21 can be generally identified by the red color (5-Impaired Waters) in Figure 2 and the description in Table 1 (pages 7 and 8). The watershed is too big to adequately display a detailed map of each site. Details can be found on the Ecology web page: www.ecy.wa.gov/programs/wq/303d/2008/index.html.

Response to comment 3:
Thank you for offering Spokane County's land use map. We will provide the following link to it in the report in the Current land use and potential pollutant sources section (www.spokanecounty.org/bp/data/Documents/CompPlan/Maps/cp.pdf). As you may understand, the 11" by 17" print of the map would only cover part of the watershed and would be difficult to read for some of the public. That, and additional print costs, is why Ecology chose not to produce a land use map in the report. However, the use of the county's land use map will be reevaluated during the implementation phase of this TMDL.

Response to comment 4:
Tables 22 and 23 have the river miles associated with the sites. The sites in Table ES-1 summarize these data by referencing "LSR at Scotia Road", "LSR at Chattaroy" etc. An additional RM designation in the summary would tend to emphasize a particular "point", rather than a broader "reach" that has been evaluated. The purpose of a TMDL is to address water quality in a broader sense; for example, by reaches, and not concentrate on individual monitoring sites.

Response to comment 5:
Ecology will change the bullet to read:

> Infiltration is the common practice for jurisdictions in the watershed with stormwater permits, so heat loads regulated by these permits are not considered significant. Excessive heat from any surface stormwater discharges directly to receiving waters in the watershed regulated under Spokane County, city of Spokane, Washington Department of Transportation, construction, and industrial permits will require controls to prevent impairment of aquatic life (Table ES-4).

Response to comment 6:
The sentences will be repeated in all three WLA discussions in the final report.

Response to comment 7:
Ecology has no record of dairies in the watershed having permits to discharge directly to surface water. Ecology is recommending that annual inspections by the Washington Department of Agriculture focus on dairies in certain areas of the watershed to ensure proper best waste management practices (BMPs) are maintained. Note that in Table ES-4, dairies are given fecal coliform, temperature, and turbidity allocations of zero.

Response to comment 8:
The corrections will be made in the final report.

Response to comment 9:
A map of temperature impairments would include anywhere significant stretches of riparian areas are without site potential shade. Figure ES-2 and Table C-8 provide locations of temperature impairment along the mainstem Little Spokane River. Table 1 can be used to locate some impaired areas on tributary streams in the watershed.

Response to comment 10:
Comment noted. Ecology's responsibility for construction permits is mentioned on page 2, but a sentence will be added to the final report on page 113. Ecology will also highlight the issue in the Implementation Section of the report.

Response to comment 11:
Comment noted. If stormwater-related water quality issues are identified from nonpoint sources not under the control of jurisdictions with permits, Ecology will need to work with others in the watershed to control these sources.

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DIRECTOR

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DEPARTMENT OF ECOLOGY
EASTERN REGIONAL OFFICE

November 22, 2011

Jon Jones
Water Quality Program
Washington Department of Ecology
4601 N. Monroe St., Suite 202
Spokane, WA 99205

Re: Draft Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load / Water Quality Improvement Plan (October 2011)

Dear Jon:

Thank you for the opportunity to review the referenced Draft Little Spokane River TMDL. The City of Spokane offers the following comments:

City of Spokane Stormwater

Stormwater discharges from the City of Spokane are referenced numerous times throughout the document. See, e.g., pp. xvi, xviii and xx, and Table ES-4. The City has no known point source discharges to the Little Spokane River or its tributaries. This should be noted in the TMDL.

Spokane River DO TMDL Requirements

The City of Spokane acknowledges that reductions in phosphorus, ammonia, and CBOD required in the Spokane River Dissolved Oxygen TMDL are mentioned in the draft Little Spokane River (LSR) TMDL document at pages 124 and 127. Ecology established load allocations for phosphorus, ammonia and CBOD for the LSR in the Spokane River DO TMDL at Tables 6a and 6b, but these specific load allocations and the measures necessary to attain them are not addressed in the draft LSR TMDL. It is critical that phosphorous, ammonia and CBOD in the LSR be controlled consistent with the Spokane River Dissolved Oxygen TMDL, and that progress be monitored, if the dissolved oxygen standards are going to be attained in the Spokane River.

Thank you in advance for your consideration of these comments. Please call me at 625-7900 if you have questions or would like more information.

Sincerely,

Lars H. Hendron

FOR Dale E. Arnold, Director
Wastewater Management

dea

cc: Lars Hendron; Principal Engineer – Wastewater Management

Responses to City of Spokane

Response to comment 1:
The Ecology author was unaware that the City had completed its inventory of stormwater infrastructures and outfalls. Corrections to the narrative will be made in the final report. The WLAs will be still valid for future annexation areas.

Response to comment 2:
These pollutants and pollution issues will be evaluated in the next Little Spokane River TMDL study to address dissolved oxygen and pH.