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Addendum 2 to

Quality Assurance Project Plan

Little Spokane River Watershed Dissolved Oxygen and pH Total Maximum Daily Load Study: Water Quality Study Design

March 2015

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Addendum

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See "Study area" and "Impairments addressed by this TMDL" sections.

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Little Spokane River Watershed Dissolved Oxygen and pH Total Maximum Daily Load Study: Water Quality Study Design

March 2015

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1.0 Title Page and Table of Contents

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2.0 Abstract

Several areas of the Little Spokane River are on Washington State's list of polluted waters (303(d) list) and require a cleanup plan, or total maximum daily load (TMDL). TMDL assessments have been completed for temperature, bacteria, and turbidity. Data and modeling have been completed to assess dissolved oxygen and pH in the mid and lower mainstem of the Little Spokane River.

To complete the TMDL analysis for dissolved oxygen (DO) and pH, two key tasks remain. First, a watershed modeling analysis needs to be completed to assess landscape contributions of nutrients and carbonaceous biochemical oxygen demand (CBOD) to water bodies in the Little Spokane River watershed and their transport to Lake Spokane. Second, DO and pH listings in the upper Little Spokane River and in the tributaries need to be assessed.

This Quality Assurance Project Plan addendum describes the data collection and modeling needed to complete these two tasks, so that the DO and pH TMDL for the Little Spokane River can be completed.

3.0 Background

This study includes data collection and modeling needed to provide the technical basis for determining the total maximum daily loads (TMDLs) of pollutants that cause all dissolved oxygen and pH impairments to flowing streams in the Little Spokane River watershed.

This Quality Assurance Project Plan (QAPP) Addendum builds on the previous QAPP developed for the Little Spokane River dissolved oxygen and pH TMDL (Joy and Tarbutton, 2010).

3.1 Study area and surroundings

Geographic setting

The Little Spokane River basin consists of a 700-square mile drainage area that includes regions located in north-central Spokane County, south Pend Oreille County, and southeast Stevens County in northeast Washington, as well as Bonner County in the state of Idaho (Figure 1). The Little Spokane River 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 Little Spokane River watershed has been designated as Water Resource Inventory Area 55 (WRIA 55).

The Little Spokane River watershed is a broad basin surrounded by the Okanogan foothills 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 at an elevation of 3,998 feet west of Dragoon Creek. To the north, the West Branch Little Spokane River tributaries form on Boyer Mountain at an elevation of 5,256 feet (Figure 1).

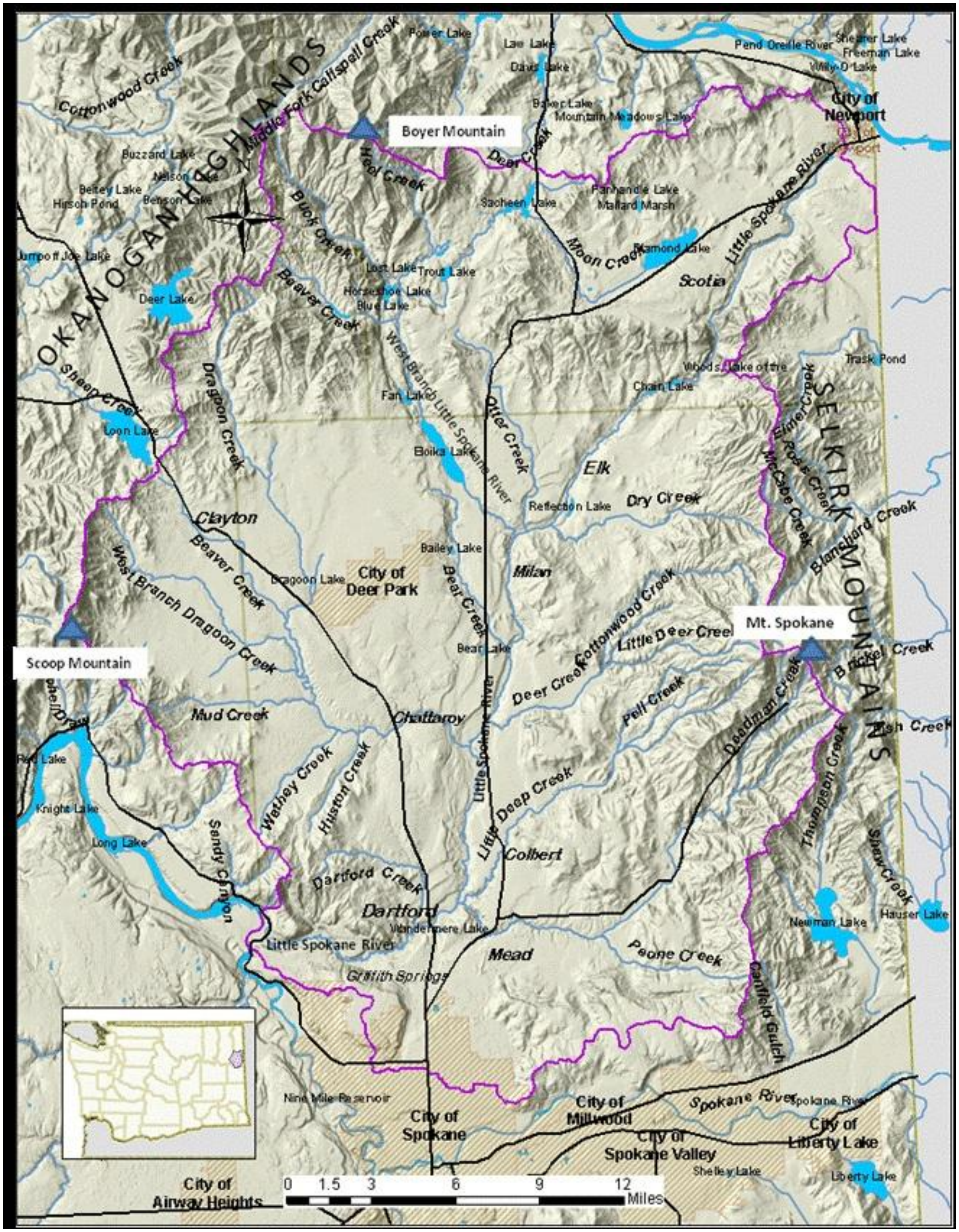

Figure 1. Study area for the Little Spokane River dissolved oxygen and pH Total Maximum Daily Load study.

Climate

The basin climate ranges from semi-arid to sub-humid, with precipitation increasing northerly and easterly with altitude. In the lower part of the Little Spokane River 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 1 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, Table 1 shows the considerable temporal variations in precipitation amounts.

Table 1. Average monthly precipitation (inches), 1971-2000.

Station	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

Air temperatures tend to be warmer in the summer and colder in winter from southwest to northeast (Table 2). A more complete description of the climate is presented in the WSU/WWRC Quality Assurance Project Plan (Cichosz et al., 2005).

Table 2. Average mean and maximum air temperature (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 east of the Little Spokane River basin, a great amount of surface water is available on an annual basin-wide basis. However, the temporal variations in precipitation previously discussed produce large fluctuations in monthly runoff volumes. Precipitation in the high mountains, largely in the form of snowfall during the winter, 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, causing seasonal problems related to water temperature.

Little Spokane River sub-watersheds

The Little Spokane River watershed corresponds to a USGS HUC-8 catchment.

At the HUC-10 level, the Little Spokane River divides into 3 catchments, and subdivides into several sub-catchments at the HUC-12 level:

- The upper Little Spokane River and tributaries from the mouth of the West Branch upstream
    - Little Spokane River headwaters
    - Little Spokane River – Chain Lake
    - Deer Valley
    - Dry Creek
    - Otter Creek
    - Buck Creek
    - West Branch Little Spokane River – Horseshoe Lake
    - West Branch Little Spokane River – Eloika Lake
- Dragoon Creek
    - Upper Dragoon Creek
    - West Branch Dragoon Creek
    - Lower Dragoon Creek
- The lower Little Spokane River and tributaries below the West Branch, excepting Dragoon Creek
    - Deer Creek
    - Little Deep Creek
    - Upper Deadman Creek
    - Lower Deadman Creek
    - Little Spokane River – Bear Creek
    - Little Spokane River – Dartford Creek

To describe the basin, the watershed can be divided into the four major sub-watersheds:

- Upper Little Spokane River, the East Branch Little Spokane River, and tributaries above the confluence with the West Branch Little Spokane River.
- West Branch Little Spokane River from the confluence below Eloika Lake to Diamond Lake.
- Middle Little Spokane River and tributaries from the confluence of the two branches to Dartford.
- Lower Little Spokane River below Dartford to the mouth at Lake Spokane (Long Lake).

The mainstem of the two upper branches have several associated lakes and wetlands. The largest lakes are in the West Branch sub-watershed and include Eloika, Sacheen, Horseshoe, and Diamond Lakes. These are linked by sections of the West Branch or Moon Creek. Chain Lake, an enlargement of the Little Spokane River, is a similar feature in the eastern branch.

The area is forested and is sparsely populated except for residences around the lakes, in the valleys, and along the highways. A rough comparison of available streamflow records indicates the Upper and West Branch sub-watersheds contribute 40% - 50% of the annual streamflow through the Middle sub-watershed to the U.S. Geological Survey (USGS) gage at Dartford.

These major tributaries are located in the Middle sub-watershed: Dragoon, Deer, Deadman, and Little Deep Creeks. Tributaries in the Middle watershed contribute approximately 30% - 40% of the annual Little Spokane River streamflow above the Dartford gage. The middle Little Spokane River flows through an area that has more agricultural land uses up the tributaries and more densely placed residences along the banks of the river. Dairies and larger livestock operations are located in the Dragoon Creek and Deadman Creek sub-watersheds. Deer Park along Dragoon Creek and Mead along Deadman Creek are the largest incorporated areas in the Little Spokane River watershed outside of Spokane.

The Lower sub-watershed is on the urban fringe of Spokane and is beginning to see more residential and commercial development activity. The riparian area of the mainstem Little Spokane River is somewhat protected here because of major wetlands and springs associated with the high groundwater input from the Hillyard Trough and Little Spokane Arm of the Spokane Valley-Rathdrum Prairie (SVRP) aquifer. The groundwater input accounts for more than 56% of the Little Spokane River outflow to Lake Spokane during the low-flow periods of July, August, and September (Joy and Tarbutton, 2010). So SVRP inflows more than double the flow in this reach during critical periods, and produce significant changes in temperature and other quality parameters. Much of the riparian land in the lower reaches has been set aside as part of Riverside State Park, Spokane County's Lower Little Spokane Natural Area, and the Washington Department of Fish and Wildlife Spokane Fish Hatchery. Development is growing on the uplands draining to the river and tributaries.

Groundwater

Groundwater is important throughout the watershed as a source of surface water baseflows during the low-flow season and domestic drinking water supply and as a source of high-quality water in the lower watershed. Groundwater from the SVRP aquifer Hillyard Trough and Little Spokane Arm is an important feature of the Little Spokane River below Dartford. The Deer Park, Green Bluff, Peone Prairie, Orchard Prairie, and Five Mile Prairie aquifers provide considerably less water; nevertheless, they are 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 Little Spokane River. In low-flow periods (especially August and September), discharge volumes at the Dartford gage average approximately 150 cfs and consist primarily of groundwater inflows (Chung, 1975). During summer drought periods, the entire discharge in the mainstem of the river is contributed by groundwater baseflow. The mainstem of the Little Spokane River upstream of the confluence with the West Branch Little Spokane River is groundwater flow (Chung, 1975). The discharge record for the Little Spokane River at Scotia also suggests that most of the water is derived from groundwater rather than surface runoff (SCCD, 2003).

The significance of groundwater input to the lower Little Spokane River watershed below Dartford can be seen in Figure 2. The two USGS gage stations, 12431000 and 12431500, are only 7.5 miles apart with no significant tributary input. The substantial increase in streamflow every month is due primarily to springs and groundwater discharge from the SVRP aquifer. On average, approximately 240 cfs - 250 cfs of groundwater inflow enters this short reach.

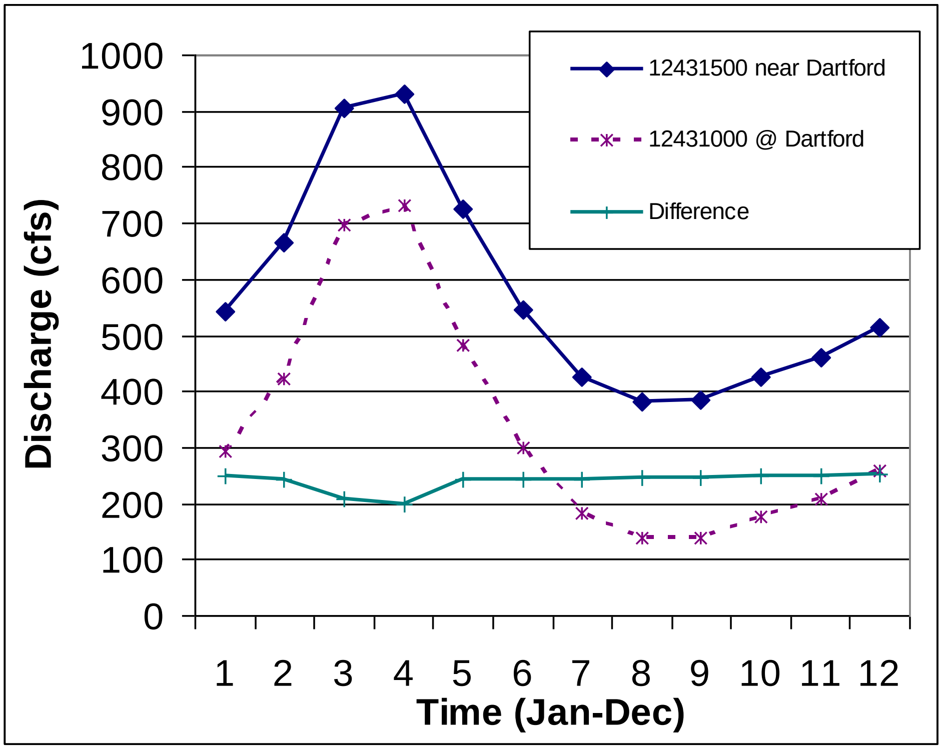

Figure 2. Comparison of flow between Little Spokane River at Dartford and near Dartford gaging stations for 12-year overlapping period of record through water year 2005 (Barber et al., 2007).

The U.S. Geological Survey published a major study of the hydrogeology of the Little Spokane River in 2013 (Kahle et al., 2013). The report provides detailed mapping of bedrock and surficial aquifers, and groundwater elevations and flow directions. Key features identified in this study include:

- Bedrock is at or near the surface in the higher elevation areas in the east, north, and west margins of the watershed.
- Extensive alluvial deposits in the valleys grow deeper towards the basin mouth.
- Streams on the east side tend to be “sinking;” in other words, as they leave the shallow bedrock areas, they tend to drop into the alluvial deposits and then reappear farther downstream as springs.
- Streams on the west side cross the plateau in the Deer Park area without sinking. However, base flows on the west side tend to be lower.
- As described above, the SVRP aquifer dominates the hydrology of the basin below Dartford.

Surface water

Three USGS gages are currently in operation:
- 12431000 – Little Spokane River at Dartford
- 12431500 – Little Spokane River near Dartford
- 12427000 – Little Spokane River at Elk

The first two are located in the two lower sections of the Little Spokane River. The Little Spokane River at Elk is located in the Upper Little Spokane River sub-watershed.

The Little Spokane River at Elk was in operation from 1948-1971 and was reactivated in October 2008. It is located upstream of the West Branch confluence at river mile (RM) 37.5, and represents a drainage area of 115 square miles. The Little Spokane River at Dartford is located at RM 11.4 and has a drainage area of 665 square miles. The Little Spokane River near Dartford is located at RM 3.9 and has a drainage are of 698 square miles.

The Spokane Conservation District (SCD) operated gages at two sites through 2014:
- Dragoon Creek near mouth
- Deadman Creek near mouth

SCD has also measured flow at two Little Spokane River sites:
- Little Spokane River at Scotia Road
- Little Spokane River at Milan

Only recently has the West Branch sub-watershed been gaged. SCD established gages in 2007 at the following locations; however, these are now inactive:

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

SCD also conducted seepage runs in 2009 and 2010.

The Spokane Community College has maintained a gage in the Little Spokane River at Chattaroy.

Potential pollutant sources

Nutrients and biochemical oxygen demand can reach streams from a variety of sources. Residents and businesses in small towns in the watershed use individual on-site septic tanks. Deer Park, the community at Diamond Lake, and Mountainside Middle School have wastewater treatment plants (WWTPs) that discharge to on-site land disposal instead of directly to waterways (Table 3), and a new community on-site system is planned for Sacheen Lake. Several sand and gravel operations and dairies are permitted or registered in the Middle and Upper sub-watersheds. The Spokane Fish Hatchery at Griffith Springs discharges raceway water and other effluents to the lower reaches of the Little Spokane River. Groundwater is pumped from wells around the former Colbert Landfill, stripped of volatile organics, and discharged to the Little Spokane River.

Table 3. Wastewater, stormwater, and livestock facilities with permits in the Little Spokane River watershed. (Ecology, 2009)

WQ Permit No.	Facility Site Name	Permitted Receiving Water (Surface)	Facility type
WAG137007D	WA DFW Spokane Hatchery	LSR	Fish Hatchery GP
	Colbert Landfill	LSR	Landfill
	Peone Pines STP	none	Biosolids
	Walker Septic Service	none	Biosolids
ST0008016D	Deer Park STP	none	Biosolids; Const SW GP; Muni to ground SWDP
	Clayton Sewer District	none	Biosolids; Muni to ground SWDP
ST0008029D	Diamond Lake STP	none	Biosolids; Muni to ground SWDP
ST0008111A	Mountainside Middle School	none	Muni to ground SWDP
WAR046505	Spokane City Sewer Maintenance Dept	LSR, Deadman Creek, Little Deep Creek	Muni SW GP
WAR046506	Spokane County Muni SW	unknown	Muni SW GP
WAR043000	WSDOT SW GP	LSR, Deadman Creek, Little Deep Creek, Dragoon Creek	Muni SW GP
WA0000876	CDC Mead LLC	Deadman Ck	Ind NPDES IP; Biosolids; Landfill
WAR127295	Durham School Services Newport	none although may discharge to LSR headwaters during significant rainfall or snowmelt	Ind SW GP
WAR301800	Darigold (Inland NW Dairies LCC)	To Spokane MS4 which discharges outside basin to Spokane River	Ind SW GP
ST0008047	Chevron Pipe Line Co Spokane	none	Ind to ground SWDP
WAG507067	Central Pre Mix Crestline	none	Landfill; Recycling; Sand & Gravel GP
WAG500062	CPM Development Corp Recycle Crush	none	Sand & Gravel GP
WAG507178	CPM Development Crestline	none	Sand & Gravel GP
WAG507067	Interstate Concrete & Asphalt Co Elk	none	Sand & Gravel GP
WAG507211	Pend Oreille County District 1 Sand Pit	none	Sand & Gravel GP
WAG507161	SemMaterials LP Spokane	none	Sand & Gravel GP
WAG507022	Spokane County PWD Dalton	none	Sand & Gravel GP
WAG507027	Spokane Rock Products ELK	none	Sand & Gravel GP
WAG507008	Toners Excavating	none	Sand & Gravel GP
WAG507175	WA DOT Blystone Quarry QS-C-331	none	Sand & Gravel GP
WAG507065	WA DOT Denison Chat	none	Sand & Gravel GP
WAG507095	WA DOT PS-C-313 Elk	none	Sand & Gravel GP
WAG507184	WA DOT QS-C-140 Burroughs Quarry	none	Sand & Gravel GP
9160	Kimebert Farm	none	CAFO GP; Dairy
9191	Betty Don Jersey Farm	none	Dairy
	Borges Dairy	none	Dairy

WQ Permit No.	Facility Site Name	Permitted Receiving Water (Surface)	Facility type
4204	Darilane Farms	none	Dairy
9120	Dunrenton Ranch	none	Dairy
4244	Hutchinson Dairy	none	Dairy
	Lindale Dairy	none	Dairy
9536	Reiters Holstein Dairy LLC	none	Dairy
6004	Schmidt Dairy	none	Dairy
	Selkirk Jerseys	none	Dairy
	T & D Dairy	none	Dairy

WWTP: Wastewater treatment plant
PWD: Public Works Department
WDOT: Washington State Department of Transportation
LLC: Limited Liability Corporation
WDFW: Washington Department of Fish & Wildlife
STP: Sewage treatment plant
SW: Stormwater
GP: General permit
SWDP: Stormwater discharge permit
CAFO: Concentrated animal feeding operation

Christian (2003) estimated the Little Spokane River and its tributaries have lost 56% - 93% of their historical riparian vegetation. Residential and commercial uses, roads, railroads, crop fields, and pastures have replaced natural vegetation. Bank and field erosion, reduced shade, fertilizers, road right-of-way chemicals, stormwater runoff, water withdrawals, and livestock associated with uses in the riparian area potentially negatively influence DO and pH in the Little Spokane River and its tributaries, as follows:

- Erosion and sedimentation can widen stream channels and reduce hyporheic exchange. This can result in warmer water temperatures. Warmer water holds less dissolved oxygen, and algae can grow more quickly in warmer water, altering DO and pH.
- Erosion can release nutrients adsorbed to soil particles.
- Reduced shade results in warmer water, reducing DO capacity. Also, increased light reaching the stream can stimulate algal photosynthesis.
- Fertilizer can run off to streams, adding nitrogen and/or phosphorus, which can stimulate algae growth.
- Road right-of-way chemicals can kill riparian vegetation, further reducing shade.
- Stormwater runoff can deliver nutrients to streams, stimulating algal photosynthesis.
- Water withdrawals can reduce streamflows, reducing the stream's ability to assimilate DO and pH changes resulting from algal growth.
- Livestock can trample streambanks, decreasing vegetation and increasing erosion and sedimentation. Livestock excrement can be a source of nutrients including nitrogen and phosphorus, which can stimulate algae growth.
- Loss of riparian vegetation can increase pollutant transport into the stream by reducing the ability of the riparian zone to filter pollutants.

The Little Spokane River watershed becomes more urbanized as it approaches the City of Spokane. Spokane and surrounding suburbs in Spokane County have stormwater treatment systems, and the city and county have municipal stormwater permits within the urban growth area (UGA) (Table 3). Some residential and urbanized areas distant from the Little Spokane River require protection from stormwater effects (Figure 3). The Washington State Department of Transportation (WSDOT) also is required to manage stormwater within the UGA in Spokane County, under its municipal stormwater permit (Table 3).

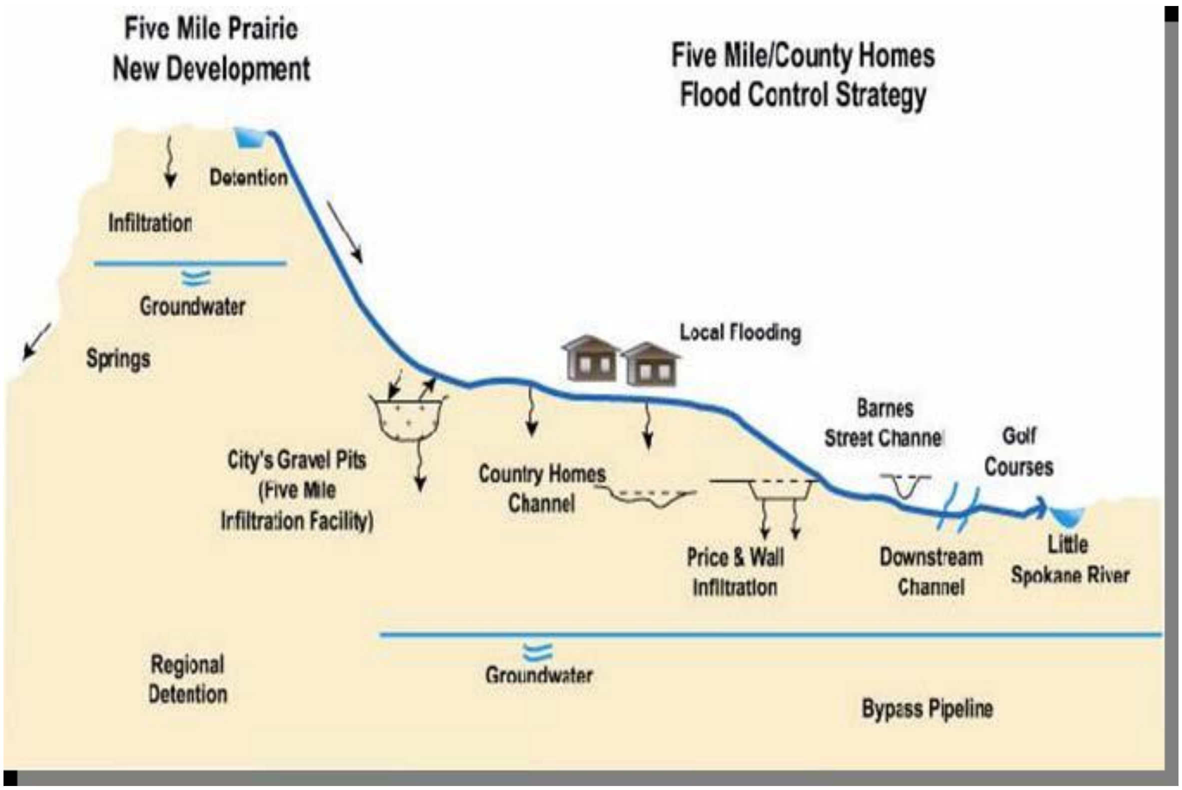

Figure 3. An example of stormwater treatment methods used in the urbanizing areas of Little Spokane River.

3.1.1 Logistical problems

Logistical issues could occur. These potential problems and solutions are described here:

- Denial of access to private property. At most sampling locations, samples can be collected from a bridge at a public road crossing if permission to access private property is denied. However, this would interfere with collection of streamflow, channel survey, and diel hydrolab data. If this occurs, an attempt will be made to find a nearby alternate sampling location.
- Difficulty timing sampling with adequate storm events. This project includes storm event/rain-on-snow event sampling. This can be difficult, as these events can occur any time, including weekends, days late in the week when shipping samples to the lab is problematic,

and other obstacles. Staff will make every effort to capture two such events; but if they can not, it will not be detrimental to the project goals.

- Inability to measure high flows. Some streams will not be wadeable at high flows. Personnel safety will always be the first consideration. It may be possible to get high-flow measurements at some locations using a bridge-board or other non-wading method. If this cannot be done, then gaging station data will be used, as available.

3.1.2 History of study area

The Little Spokane River watershed was originally inhabited by Native Americans who now make up the Spokane, Kalispel, and Coeur d'Alene Tribes. As settlers arrived, they began to use the area for agriculture, timber harvest, and recreation. Mining claims to the north opened up transportation corridors through the basin. The growth of the Spokane metropolitan area increased the residential and urban areas of the south of the basin and increased access to the entire basin for homes and recreation.

3.1.3 Parameters of interest

The parameters of interest for this study with water quality criteria are dissolved oxygen (DO) and pH. The pollutants that are most likely to affect these two parameters are nutrients − primarily various forms of phosphorus and nitrogen − and carbon, or carbonaceous biochemical oxygen demand (CBOD). Physical parameters affecting DO and pH include stream morphology and substrate conditions, flow and turbulence, geochemistry, and water temperature. Suspended sediment is also of interest, because of its effects on morphology and its association with certain forms of phosphorus.

3.1.4 Results of previous studies

Flow monitoring

Figure 4 shows streamflows for the last six years for the three USGS gages. Several patterns are of interest:

- The gage at Elk shows the flows from the headwaters.
- The difference between the Elk gage and the gage "at Dartford" shows the contributions of tributaries in the lower basin.
- Increased flows for the gage "near Dartford" show the contribution of groundwater inflow.

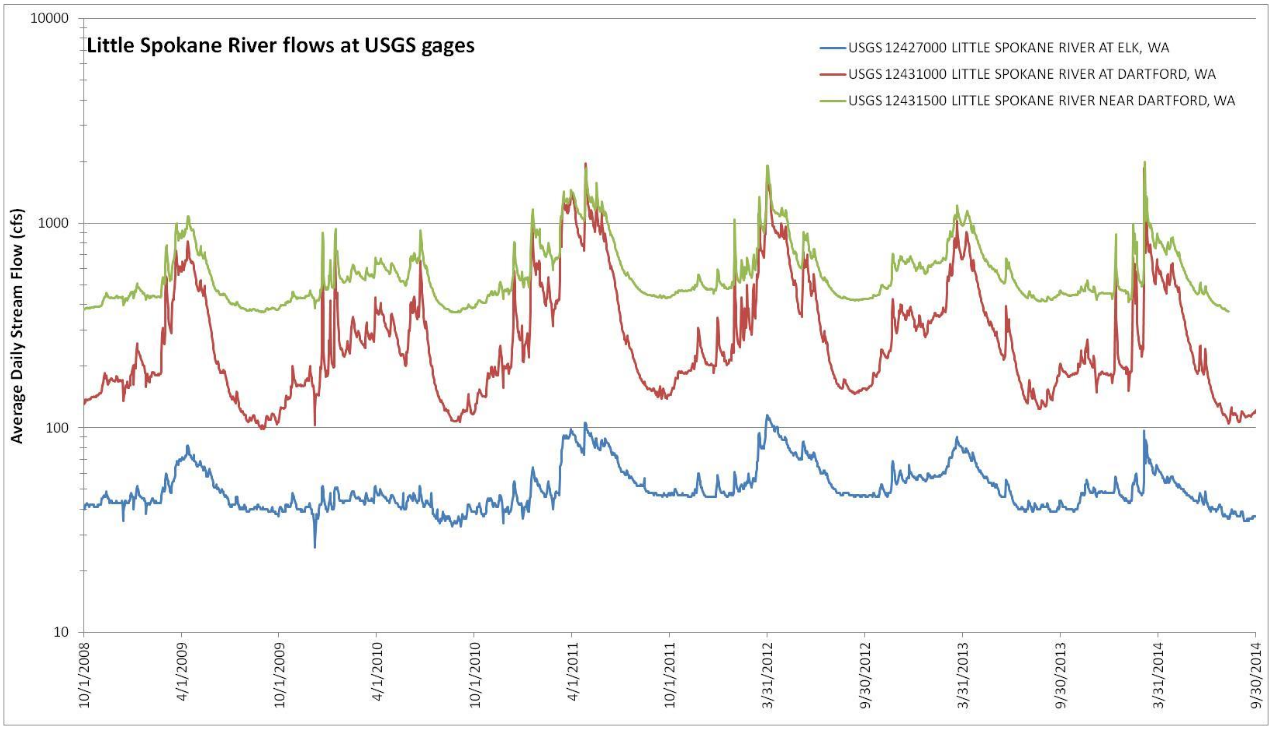

Figure 4. Little Spokane River flows at USGS gages.

Flows in tributaries during low-flow conditions are illustrated by the results of the SCD seepage runs shown in Table 4.

Table 4. Results of SCD seepage runs

River Mile	Description	Discharge (cfs)	
		2009	2010
34.6	Dry Creek at mouth	1.72	1.65
33.5	Otter Creek at mouth	6.89	5.72
33.2	Little Spokane River upstream of West Branch	54.7	54.8
32.8	West Branch Little Spokane River at mouth	11.5	11.0
29.7	Little Spokane River upstream of Bear Creek	69.2	65.6
27.8	Bear Creek at mouth	3.00	3.12
23.1	SCC Chattaroy gage – rated discharge	76.0	69.0
23	Deer Creek at mouth	0.767	1.13
21.4	Dragoon Creek at mouth	20.0	18.7
19.4	Little Spokane River downstream of Dragoon Creek	99.8	99.9
13.5	Little Spokane River upstream of Deadman Creek	114	110

Streamflows in the Little Spokane River have declined since the 1950s (Joy and Jones, 2012). However, flows vary considerably on an annual and seasonal basis. Streamflow declines are the result of increased water use as well as lower than average precipitation (Ecology, 1995).

TMDL Studies

Total maximum daily load assessments of the Little Spokane River watershed have been in progress since 2003 (McBride and Butler, 2003) to address 303(d) listings for temperature, bacteria, turbidity, DO, and pH. Washington State Department of Ecology (Ecology) awarded a contract to Washington State University's (WSU) Washington Water Research Center (WWRC) in 2004 to conduct a comprehensive water quality study addressing the first three parameters and to characterize DO, pH, and nutrients, especially phosphorus (Cichosz et.al., 2005; Barber et al., 2007). Nitrogen, phosphorus, and carbon are essential nutrients for aquatic biomass growth. Excessive biomass can cause problems with DO and pH concentrations.

Ecology used the results of the WSU/WWRC study and previous studies by the Spokane County CD and the Pend Oreille CD to complete TMDL assessments for fecal coliform, turbidity, and temperature (Joy and Jones, 2012).

Ecology began work on TMDL assessments for dissolved oxygen and pH in 2010. Two synoptic surveys were completed on the mid and lower Little Spokane River and tributary mouths in 2010 (Joy and Tarbutton, 2010) and a time-of-travel study was completed for the same reach in 2013 (Tarbutton, 2013). When this QAPP was drafted, a QUAL2Kw model had been built and calibrated from this data, and it is possible to assess impacts of nutrient inputs to dissolved oxygen and pH in the Little Spokane River during summertime low-flow conditions. The 2010 study was not designed to address listings in the upper portion of the Little Spokane River upstream of Chain Lake or in tributaries. Studies to address these listings were deferred at that time.

Because the Little Spokane River is a tributary to Lake Spokane, the Little Spokane TMDL for dissolved oxygen and pH will need to not only address impairments in the Little Spokane watershed but also will need to address nutrient loading to Lake Spokane. The Spokane River and Lake Spokane TMDL set load allocations for phosphorus, ammonia, and CBOD at the mouth of the Little Spokane River, to protect dissolved oxygen and prevent algae blooms in Lake Spokane (Moore and Ross, 2010).

Currently available data indicate that the vast majority of nutrient loading to the Little Spokane watershed comes from either groundwater or nonpoint pollutant sources. Therefore, assessing nutrient loading in the Little Spokane watershed will require a watershed-level analysis, using a watershed model designed to simulate landscape contributions of flow, sediment, and nutrients from land surfaces to waterways.

A number of developments have occurred since data on the Little Spokane dissolved oxygen and pH TMDL were collected in 2010:

- The Washington Department of Fish and Wildlife (WDFW) has proposed expansion of the Little Spokane Fish Hatchery. To plan for this expansion, WDFW needs to know what the wasteload allocations for the hatchery are going to be. This means that there is a need for Ecology to be able to complete this wasteload allocation as soon as possible.

- Modeling work using the QUAL2Kw calibrated to 2010 data indicates that point source wasteload allocations in the Little Spokane watershed, and in particular for the hatchery, will be limited not by impacts to the Little Spokane River itself, but by impacts to Lake Spokane via phosphorus transport through the Little Spokane River. This means that the watershed-level assessment must be complete to set these wasteload allocations.
- Ecology's plan was to use nutrient data from the WSU/WWRC study, which was collected at an appropriate spatial distribution and sampling frequency, to calibrate the watershed model. However, a detailed review of data quality from the WSU/WWRC study has shown that the data quality of nutrient and total suspended solids is poor, with all of these parameters failing to meet their precision targets (%RSD). Unfortunately, the data for total phosphorus and total suspended solids, which are the two most important parameters for this watershed analysis, had the lowest precision. (See section 7.5) It would not be appropriate to use these data for regulatory purposes such as TMDL development. Additional data of an acceptable quality will need to be collected.
- Ecology has developed a simplified water quality model, River Metabolism Analyzer (RMA) (Pelletier, 2013) which is far simpler and quicker to use, with fewer data requirements than water quality models like QUAL2Kw. The RMA model is appropriate for developing allocations for small streams like those that were deferred in 2010.

The Little Spokane River Watershed Fecal Coliform Bacteria, Temperature, and Turbidity Total Maximum Daily Load study (Joy and Jones, 2012) found that improvements were needed for all three parameters included in the study. The TMDL set load and wasteload allocations for fecal coliform bacteria, for shade (to control temperature) and for total suspended solids (to control turbidity). This report is available at the following link: https://fortress.wa.gov/ecy/publications/SummaryPages/1110075.html.

3.1.5 Regulatory criteria or standards

See section 3.2, under subheading "Water Quality Standards and Numeric Targets."

3.2 Total Maximum Daily Load (TMDL) studies

What is a TMDL?

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.

Federal Clean Water Act requirements

The Clean Water Act (CWA) established a process to identify and clean up polluted waters. The CWA requires each state to develop and maintain water quality standards that protect, restore, and preserve water quality. Water quality standards consist of (1) a set of designated uses for all water bodies, such as salmon spawning, swimming, and fish and shellfish harvesting; (2) numeric and narrative criteria to achieve those uses; and (3) an antidegradation policy to protect high quality waters that surpass these conditions.

The Water Quality Assessment (WQA) 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, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, 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 WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list].

Category 1 – Waters that meet standards for parameter(s) for which they have 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.

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 it 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).

Ecology submits the WQIR to the U.S. Environmental Protection Agency (EPA) for approval. Once EPA approves the WQIR, Ecology develops a *Water Quality Implementation Plan* (WQIP) 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 will be set in the resulting TMDL. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices to reduce impacts to water quality. The area that will be subject to the TMDL is shown in Figure 1 and is the same as the study area.

Similarly, all point source dischargers in the watershed must also comply with the TMDL. Little Spokane Fish Hatchery effluent and treated groundwater from the Colbert Landfill will be evaluated, as will stormwater from various dischargers.

Ecology will be working with the Little Spokane River Watershed Committee, Spokane Conservation District (CD), Pend Oreille CD, Spokane County, the City of Spokane, Washington Department of Fish and Wildlife, Washington State Department of Transportation, and others to recommend and implement actions that improve water quality 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 (nonpoint) 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.

Why is Ecology conducting a TMDL study in this watershed?

Background

Data collected by the Pend Oreille Conservation District, the Spokane Conservation District, WSU/WWRC, and Ecology's ambient monitoring program formed the basis for listing the Little Spokane River and 11 tributary or subtributary streams for dissolved oxygen and pH on the 2012 303(d) list.

See section 3.0 for a description of the history of TMDLs in the Little Spokane watershed up to this time.

Impairments addressed by this TMDL

The main beneficial use to be protected by this TMDL is aquatic life in the Little Spokane River watershed and the Spokane River. The Little Spokane River and its tributaries have not been identified as having special populations of salmon to protect (Table 602 of WAC 173-201A-602) However, several salmonid communities are present, and other aquatic life and critical aquatic habitats have been described (McLellan, 2003a; 2003b; 2005).

The surviving native species most sensitive to water quantity and quality are redband trout and mountain whitefish. Sections of the Little Spokane River mainstem and Little Deep, Deadman, Dragoon, and Dartford Creeks have remnant populations of redband trout (Western Native Trout Initiative, 2007; McLellan, 2005). Based on the 2001 and 2002 surveys conducted by the Washington Department of Fish & Wildlife (WDFW), mountain whitefish are currently present in the Little Spokane River drainage encompassing Bear Creek, Dry Creek, Little Spokane River, Otter Creek, West Branch Little Spokane River, Wethey Creek, Horseshoe Lake, and Chain Lakes (McLellan, 2003a; 2003b).

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 goes on to say:

> *On-going Washington Department of Fish & Wildlife (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.*

However, there is no major effort to re-establish anadromous (sea-run) salmon or steelhead in the Little Spokane River watershed because of downstream barriers in the Spokane River system. But improving water quality conditions would be a necessary step for enhancing and protecting all aquatic communities, including cold water fisheries. Proper levels of DO and pH are essential for healthy fish and macroinvertebrate populations.

The uses will be protected by ensuring that the dissolved oxygen and pH meet water quality standards in the water body.

Table 5 lists water bodies that are on the 2012 303(d) list for these parameters.

Table 5. Study area water bodies on the 2012 303(d) list for dissolved oxygen and pH.

Water body	Parameter	Listing ID	WBID code	NHD reachcode	Township	Range	Section
Little Spokane River	DO	42597	WA-55-1010	17010216000280	26N	42E	05
	DO	47875		17010308000083	30N	45E	08
	pH	50434		17010308001158	27N	43E	33
	pH	50436		17010308000077	29N	43E	35
Dartford Creek	pH	50416	(none)	17010308000151	26N	43E	06
Deadman Creek	DO	41981	WA-55-1011	17010216001680	26N	43E	01
	pH	50410		17010308000031	26N	43E	01
	pH	50411		17010308000038	27N	44E	33
	pH	11388		17010308000025	27N	43E	33
Little Deep Creek	pH	50401	(none)	17010308000052	27N	43E	33
Peone Creek	DO	47055	(none)	17010308000018	26N	44E	08
Dragoon Creek	DO	47094	WA-55-1012	17010308000085	29N	42E	34
	pH	50397		17010308000107	28N	43E	33
Unnamed Spring at Kaiser	DO	42359	(none)	(none)	26N	43E	03
Dry Creek	pH	50373	(none)	17010308000156	29N	44E	30
West Branch Little Spokane	pH	50379	(none)	17010308000085	29N	43E	15
	DO	47073		17010308000056	29N	43E	15
	DO	47862		17010308000088	30N	43E	32
	DO	47863		17010308006689	31N	43E	34
Beaver Creek	DO	47869	(none)	17010308000101	30N	43E	18
Buck Creek	DO	47872	(none)	17010308000142	30N	43E	06
Moon Creek	DO	47861	(none)	17010308000099	30N	44E	08

WBID: Water-body Identification
NHD: National Hydrography Dataset

In addition, the synoptic surveys conducted by Ecology in 2010 found that dissolved oxygen and pH criteria were exceeded at many of the sites monitored (Table 6).

Table 6. Study area water bodies not meeting dissolved oxygen and/or pH criteria during 2010.

Water body	Location	Parameter(s) not meeting criteria
Little Spokane River	Little Spokane R. at Frideger Rd.	DO
	Little Spokane R. at Elk-to-Hwy Rd. in Elk	DO, pH
	Little Spokane R. at E. Eloika Rd.	DO
	Little Spokane R. at Deer Park-Milan Rd.	DO, pH
	Little Spokane R. at Riverway Rd.	DO, pH
	Little Spokane R. at Chattaroy	DO, pH
	Little Spokane R. at Little Spokane Dr. in Buckeye	DO
	Little Spokane R. at E. Colbert Rd.	DO
	Little Spokane R. at N. Little Spokane Dr.	DO, pH
	Little Spokane R. at Dartford USGS gage	DO
	Little Spokane R. at N. Dartford Dr.	DO, pH
	Little Spokane R. at W. Waikiki Rd.	DO
	Little Spokane R. at Rutter Pkwy.	DO, pH
	Little Spokane R. at Hwy 291	DO
Dry Creek	Dry Creek at Milan-Elk Road	DO
	Dry Creek at North Dunn Rd	DO
Otter Creek	Otter Creek at Elk to Hwy Rd	DO
West Branch Little Spokane River	West Branch at Eloika outlet	DO, pH
Bear Creek	Bear Creek at Milan Road	DO
Deer Creek	Deer Creek at Hwy 2	DO
Dragoon Creek	Dragoon Creek at Crescent Rd	DO, pH
Little Deep Creek	Little Deep Creek at mouth at landowner property	DO, pH
	Little Deep Creek at Colbert Road	DO
Deadman Creek	Deadman Creek near mouth at landowner property	DO
	Deadman Creek at private owner below Market St bridge	DO
Dartford Creek	Dartford Creek at Hazard Rd	pH

How will the results of this study be used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve clean water. This is done by assessing the situation, recommending practices to reduce pollution, and establishing limits for facilities that have permits. Since the study may also identify the main sources or source areas of pollution, Ecology and local partners use these results to figure out where to focus water quality improvement activities. Sometimes the study suggests areas for follow-up sampling to further pinpoint sources for cleanup.

Water Quality Standards and Numeric Targets

Dissolved oxygen

Aquatic organisms are very sensitive to reductions in the level of DO in the water. The health of fish and other aquatic species depends on maintaining an adequate supply of oxygen dissolved in the water. Oxygen levels affect growth rates, swimming ability, susceptibility to disease, and the relative ability to endure other environmental stressors and pollutants. While direct mortality due to inadequate oxygen can occur, Washington State designed the criteria to maintain conditions that support healthy populations of fish and other aquatic life.

Oxygen levels can fluctuate over the day and night in response to changes in climatic conditions as well as the respiratory requirements of aquatic plants and algae. Since the health of aquatic species is tied predominantly to the pattern of daily minimum oxygen concentrations, the criterion is based on the lowest 1-day minimum oxygen concentrations that occur in a water body.

In the Washington State water quality standards, freshwater aquatic life use categories are described using key species (salmonid versus warm-water species) and life-stage conditions (spawning versus rearing). Minimum concentrations of DO are used as criteria to protect different categories of aquatic communities, some of which are specified for individual rivers, lakes, and streams.

The Little Spokane River watershed has not been designated for protection of any special population of fish. However, since the Little Spokane River is a tributary to Lake Spokane which has a core summer salmonid habitat designation, it must comply with the criteria of the lake [WAC 173-201A-600(1)(a)(iii)]. The DO criterion for core summer salmon protection criteria states [WAC 173-201A-200(1)(d)]:

> *The one-day minimum dissolved oxygen concentration shall not fall below 9.5 mg/L more than once every ten years on average. When DO is lower than the criterion (or are within 0.2 mg/L of the criterion) due to natural conditions, then cumulative human-caused activities will not decrease the dissolved oxygen more than 0.2 mg/L.*

The criterion above is used to maintain conditions where a water body is naturally capable of providing full support for its designated aquatic life uses. The standards recognize, however, that not all waters are naturally capable of staying above the fully protective DO criteria. When a water body is naturally lower in oxygen than the criteria, the state provides an additional allowance for further depression of oxygen conditions due to human activities. In this case, the combined effects of all human activities must not cause more than a 0.2 mg/l decrease below that naturally lower (inferior) oxygen condition.

The DO criterion may be quite restrictive for the Little Spokane River, especially during summer low-flows in July and August. Data are necessary to define or estimate DO conditions in the Little Spokane River that would seasonally occur without impacts from anthropogenic sources. For example, naturally low DO concentrations in groundwater are known to affect specific reaches of the watershed. Also, temperature and barometric pressure conditions can result in DO concentrations at 100% saturation that are below 9.5 mg/L. However, the role of nutrients and eutrophication in creating DO concentrations out of compliance during critical summer conditions is likely occurring in open reaches of the mainstem and tributaries as well.

While the numeric criteria generally apply throughout a water body, the criteria are 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. For this reason, the standards direct that samplers take measurements from well-mixed portions of rivers and streams.

pH

The pH of natural waters is a measure of acid-base equilibrium achieved by the various dissolved compounds, salts, and gases. pH is an important factor in the chemical and biological systems of natural waters. pH both directly and indirectly affects the ability of waters to have healthy populations of fish and other aquatic species. Changes in pH affect the degree of dissociation of weak acids or bases. This effect is important because the toxicity of many compounds is affected by the degree of dissociation.

While some compounds (e.g., cyanide) increase in toxicity at lower pH, others (e.g., ammonia) increase in toxicity at higher pH. While there is no definite pH range within which aquatic life is unharmed and outside which it is damaged, there is a gradual deterioration as the pH values are further removed from the normal range. However, at the extremes of pH, lethal conditions can develop. For example, extremely low pH values (<5.0) may liberate sufficient carbon dioxide from bicarbonate in the water to be directly lethal to fish.

The state established pH criteria in the Washington State water quality standards primarily to protect aquatic life. The criteria also serve to protect waters as a source for domestic water supply. Water supplies with either extreme pH or that experience significant changes of pH even within otherwise acceptable ranges are more difficult and costly to treat for domestic water purposes. pH also directly affects the longevity of water collection and treatment systems, and low pH waters may cause compounds of human health concern to be released from the metal pipes of the distribution system.

In the state's water quality standards, two pH criteria are established to protect six different categories of aquatic communities. Since the Little Spokane River watershed has not been designated with a special category but does need to comply with core summer salmonid protection, the pH criterion is [WAC 173-201A-200(1)(g)]:

pH must be kept within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units.

The criteria above are used to maintain conditions where a water body is naturally capable of providing full support for its designated aquatic life uses. The standards recognize, however, that not all waters are naturally capable of staying within the fully protective pH criteria. When a water body is naturally lower or higher than the criteria, this natural pH level becomes the local criteria. However, the state does not provide an additional allowance for further changes due to human activities. Only when the pH is within the criteria range can the combined effects of all human activities cause not more than a 0.2 units change.

Phosphorus, Ammonia, and CBOD

The Spokane River Dissolved Oxygen TMDL (Moore and Ross, 2010) identified Load Allocations for the mouth of the Little Spokane River. Table 7 summarizes the relevant allocations as reported in the TMDL, while Table 8 summarizes the load reductions for total phosphorus.

Table 7. Spokane River TMDL Load Allocations for the Little Spokane River.

Season	2001 Flow (cfs)	Total Phosphorus		Ammonia (NH3-N)		CBOD	
		Allocation Concentration (mg/L)[1]	2001 Load Allocation (lbs/day)	Allocation Concentration (mg/L)	2001 Load Allocation (lbs/day)	Allocation Concentration (mg/L)	2001 Load Allocation (lbs/day)
March – May Average	565	0.034	102.5	0.035	106.2	2.1	6409.3
June	426	0.023	53.9	0.005	11.5	2.1	4828.2
July – October Average	364	0.016	32.2	0.006	11.0	1.5	2867.8

Table 8. Spokane River TMDL total phosphorus load reductions for the Little Spokane River.

Month	Loads (lbs/day)			Load Reduction (lbs/day)	% Reduction	
	Natural (lbs/day)	2001 (lbs/day)	TMDL (lbs/day)		of 2001 Load (%)	of Human Load (%)
Mar-May	35.9	139.9	102.5	37.4	27	36
June	18.1	74.0	53.9	20.1	27	36
Jul - Oct	16.2	41.1	32.2	9.0	22	36

4.0 Project Description

4.1 Project goals

The goals specified in the original QAPP remain in effect and are summarized as follows:

- Complete TMDL assessments to address all dissolved oxygen and pH impairments in the Little Spokane watershed.
- Meet the load allocation for phosphorus at the mouth of the Little Spokane River, established in the Spokane River TMDL.

4.2 Project objectives

The goals will be accomplished by (1) completing a technical analysis for DO and pH TMDLs in the Little Spokane River and its tributaries, and (2) completing an analysis of pollutant loading and transport through the Little Spokane River watershed, in light of established allocations for the Spokane River TMDL.

To achieve the project goals and objectives this QAPP outlines, the field and analytical tasks that will be completed are:

- We will collect one year of nutrient, suspended sediment, streamflow, and other related data at approximately one-month intervals and for storm events from a network of sites designed to provide the information necessary to build and calibrate a watershed model for the Little Spokane River watershed.
- In locations where there is some question about the ability of the modeling framework to accurately simulate the nutrient dynamics (e.g., lakes), we will collect data twice per month, so that, if needed, a "hard-wired" boundary condition can be defined in the model at those locations.
- To assist in understanding the role of lakes in nutrient transport, especially in the West Branch Little Spokane River, we will sample each of five lakes once during late summer for epilimnion and hypolimnion nutrients, and we will collect temperature, dissolved oxygen, and pH profiles.
- A modeling framework will be selected that meets the project objectives and other criteria such as usability and the ability to capture critical environmental processes. Frameworks to be considered include Watershed Analysis Risk Management Framework (WARMF), Soil and Water Assessment Tool (SWAT), or Hydrologic Simulation Program-Fortran (HSPF).
- The watershed model will be built and calibrated to observed flow, sediment, and nutrient data.
- The watershed model will be used to evaluate the nutrient reductions that can be expected from implementation of best management practices (BMPs) for various land uses, including agricultural and urban.

- Diel dissolved oxygen and pH data, as well as alkalinity data, will be collected at tributary locations and at locations in the upper portion of the Little Spokane River to address tributary impairments. We will use a model framework such as the River Metabolism Analyzer (RMA) model.
- RMA models will be built to assess nutrient impacts to dissolved oxygen and pH in tributaries and in the upper portion of the Little Spokane River.
- Nutrient impacts to dissolved oxygen and pH in the middle and lower Little Spokane River will be assessed, using the existing calibrated QUAL2Kw model based on 2010 data.
- Load and wasteload allocations throughout the watershed will be calculated from the more restrictive of: (1) allowable impacts to dissolved oxygen and pH in streams within the Little Spokane watershed or (2) the load allocations for phosphorus, ammonia, and CBOD set for the mouth of the Little Spokane River in the Spokane River and Lake Spokane Dissolved Oxygen and Phosphorus TMDL.

4.3 Information needed and sources

Watershed Model

Mechanistic watershed model frameworks that could meet project objectives are available in the public domain. These include WARMF, SWAT, and HSPF. This project will review these frameworks for suitability based on several criteria:

- The ability to model subwatersheds at a scale roughly between the HUC-10 and HUC-12 basin scale.
- The ability to model seasonal, daily, and diurnal timeframes adequately to inform the mainstem Little Spokane River model and the allocations to the Spokane River TMDL.
- The ability to capture relevant effects of groundwater, wetlands, and lakes.
- The ability to realistically simulate the effects of BMPs such as vegetated buffer strips, tillage practices, and others.
- The ability to capture instream processes of nutrient and carbon uptake and release.
- The ease of model development and support for the model framework.
- The ability of the model to provide results that can be communicated to stakeholders and the public.

Input data for all these model frameworks are similar, so the selection of the specific model is not expected to affect the proposed data collection. Sufficient flexibility is being included in this QAPP to address specific needs as they emerge.

Model development will rely on many sources of existing data. This will include:

- Historical water quality data from the sources described above.
- Flow data from the sources described in the sections above.

- Regional meteorologic data from sources such as National Weather Service, AgWeatherNet, and SnoTEL.
- GIS data layers for relevant information such as topography, hydrography, elevation, soils, geology.

RMA Model

RMA (River Metabolism Analyzer) is a simplified modeling tool developed by Ecology (Pelletier, 2013). RMA analyzes algal productivity, ecosystem respiration, reaeration, dissolved oxygen, and pH. Required data include:

- Diel dissolved oxygen, pH, and temperature data
- Alkalinity data
- Concentration of the limiting nutrient

Where available, Ecology data from 2010 will be used. At other locations, this data will be collected as described in this QAPP.

4.4 Target population

Nutrients, CBOD, dissolved oxygen and pH in the Little Spokane River watershed.

4.5 Study boundaries

The study area for this project consists of WRIA 55, the Little Spokane River watershed (Figure 1).

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area:

WRIAs

- 55 (Little Spokane)

HUC numbers

- 17010308 (Little Spokane)

4.6 Tasks required

The following is a very brief summary of the tasks required to complete this project. These tasks will be described in more detail in later sections.

- Collection of monthly nutrient, suspended sediment, flow, and other related field measurements at a network of sites throughout the watershed
- Collection of biweekly measurements of these same parameters at certain lake outlets

- Collection of channel morphology data in tributaries and the upper portion of the Little Spokane River watershed
- Collection of stage measurements during non-sampling weeks to provide flow estimates for those weeks
- Collection of continuous flow data at the mouths of the three largest tributaries. This gaging will be performed in conjunction with Ecology's Freshwater Monitoring Unit (SHU).
- Collection of snow depth and snow coverage data at selected locations during the winter months
- Collection of nutrient samples and hydrolab profiles at five lakes, once each during late summer
- Collection of diel hydrolab data and alkalinity data at locations in tributaries and the upper Little Spokane River
- Collection of continuous water temperature data at six locations in watershed
- Construction and calibration of a watershed model to assess sediment and nutrient contributions from the landscape to water bodies throughout the watershed
- Construction and calibration of simple RMA models at tributary and upper watershed locations to assess impact of nutrient concentrations on dissolved oxygen and pH
- Calculation of load and wasteload allocations using the watershed model, the RMA models, and the existing calibrated QUAL2Kw model.

4.7 Practical constraints

See section 3.1.1

4.8 Systematic planning process

This addendum, along with the original QAPP and first addendum, represents the systematic planning process.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 9. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Elaine Snouwaert Water Quality Program Eastern Regional Office Phone: 509-329-3503	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Tighe Stuart Eastern Regional Office Eastern Operations Section Phone: 509-329-3476	Project Manager	Writes the QAPP. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Paul Pickett Headquarters Office Eastern Operations Section Phone: 360-407-6882	Co-Project Manager	Co-writes the QAPP. Assists with QA review. Analyzes and interprets data. Co-writes the draft report and final report.
Andrew Albrecht Eastern Regional Office Eastern Operations Section Phone: 509-329-3417	Principal Investigator	Oversees field sampling and transportation of samples to the laboratory.
Phillip Lefler Eastern Regional Office Eastern Operations Section Phone: 509-329-3420	Field Assistant	Helps collect samples and records field information.
Jim Ross Eastern Regional Office Eastern Operations Section Phone: 509-329-3425	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Tom Mackie Central Regional Office Eastern Operations Section Phone: 509-454-4244	Section Manager for the Project Manager and Study Area	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

The field lead for each survey will be trained in and experienced with the SOPs being used. Laboratory staff are trained and certified for the analytical methods being used.

5.3 Organization chart

See Table 9.

5.4 Project schedule

Table 10 shows schedule details.

Table 10. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work completed	February 2016	Andy Albrecht
Laboratory analyses completed	March 2016	
Environmental Information System (EIM) database		
EIM Study ID	jjoy0007	
Product	Due date	Lead staff
EIM data loaded	May 2016	Andy Albrecht
EIM data entry review	June 2016	Tighe Stuart
EIM complete	July 2016	Andy Albrecht
Final technical report		
Author lead / Support staff	Tighe Stuart / Paul Pickett	
Schedule		
Draft due to supervisor	October 2016	
Draft due to client/peer reviewer	November 2016	
Draft due to external reviewer(s)	December 2016	
Final (all reviews done) due to publications coordinator	January 2017	
Final report due on web	February 2017	

5.5 Limitations on schedule

Field-related logistical issues are addressed in section 3.1.1.

Model development using historical data will begin concurrent with the proposed monitoring. Model calibration will be completed after the collection and QA assessment of data is completed.

5.6 Budget and funding

The estimated laboratory budget and number of lab samples are shown in Table 11. All samples for this project will be analyzed by Ecology's Manchester Environmental Laboratory (MEL).

Table 11. Laboratory budget.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample	MEL Subtotal
Total suspended solids	500	63	563	$12	$6,756
Chloride	500	63	563	$15	$8,445
Total persulfate nitrogen	510	64	574	$19	$10,906
Ammonia nitrogen	510	64	574	$15	$8,610
Nitrate-nitrite nitrogen	510	64	574	$15	$8,610
Total phosphorus	510	64	574	$20	$11,480
Orthophosphate	510	64	574	$17	$9,758
Total organic carbon	136	17	153	$36	$5,508
Dissolved organic carbon	136	17	153	$40	$6,120
Chlorophyll *a*	68	9	77	$60	$4,620
Alkalinity	38	5	43	$19	$817
				Total for study:	$81,630

6.0 Quality Objectives

6.1 Decision Quality Objectives (DQOs)

DQOs are not necessary for this project. The TMDL process includes the assessment of uncertainty and assignment of a Margin of Safety.

6.2 Measurement Quality Objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty, which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with MQOs. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs (Tables 12-13).

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols.

Field sampling precision will be addressed by submitting replicate samples. MEL will assess precision and bias in the laboratory through the use of duplicates and blanks.

Tables 12 and 13 summarize the MQOs for field and laboratory parameters. The required reporting limits are also included. Continuous or instantaneous Hydrolab meter measurements collected at each sampling event will conform to the quality control parameters in Table 14. The targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by Ecology's Environmental Assessment Program (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's MQOs and QC procedures are documented in the MEL Lab Users Manual (MEL, 2008).

Table 12. Measurement quality objectives for field measurements.

Parameter	Method	Expected Range of Values	Precision (replicate median RSD)	Reporting Limits and Resolution
Secchi depth	Manual	1 – 20 m	10% RSD	0.1 m
Velocity[1]	Marsh McBirney Flowmeter	<0.1 – 10 ft/s	—	0.01 ft/s
Water Temperature[1]	Hydrolab®	1.0 - 35° C	+/- 0.1° C	0.01° C
	Onset TidBit®	1.0 - 30° C	+/- 0.2° C	0.01° C
Specific Conductivity[2]	Hydrolab®	50 – 500 umhos/cm	+/- 0.5%	0.1 umhos/cm
pH[1]	Hydrolab®	6.0 – 9.0 s.u.	0.20 s.u.	1 to 14 s.u.
Dissolved Oxygen[1]	Hydrolab®	1.0 – 12 mg/L	5% RSD	0.1 - 15 mg/L
	Winkler Titration	1.0 – 12 mg/L	—	0.1 mg/L

[1] as units of measurement, not percentages.
[2] as percentage of reading, not RSD.

Table 13. Measurement quality objectives for laboratory analyses.

Precision replicate error values include laboratory and field variability.

Parameter	Method	Expected Range of Concentrations	Precision (replicate median RSD)	Bias (% deviation from true value)	Reporting Limits and Resolution
Total Suspended Solids	SM 2130	<1 – 2000 mg/L	15% RSD[1]	n/a	1 mg/L
Chloride	EPA 300.0	0.3 – 100 mg/L	5% RSD[1]	n/a	0.1 mg/L
Alkalinity	SM 2320B	20 – 200 mg/L as $CaCO_3$	10% RSD[1]	n/a	5 mg/L
Ammonia	SM 4500-NH_3H	<0.01 – 30 mg/L	10% RSD[1]	5	0.01 mg/L
Dissolved Organic Carbon	EPA 415.1	<1 – 20 mg/L	10% RSD[1]	10	1 mg/L
Nitrate/Nitrite	4500-NO_3 I	<0.01 – 30 mg/L	10% RSD[1]	5	0.01 mg/L
Total Persulfate Nitrogen	SM 4500-NB	0.5 – 50 mg/L	10% RSD[1]	10	0.025 mg/L
Orthophosphate	SM 4500-P G	0.01 – 5.0 mg/L	10% RSD[1]	5	0.003 mg/L
Total Phosphorous	SM 4500-P F	0.01 – 10 mg/L	10% RSD[1]	5	0.005 mg/L
Total Organic Carbon	EPA 415.1	<1 – 20 mg/L	10% RSD[1]	10	1 mg/L
Chlorophyll-a	SM 10200H3M	1 – 1000 mg/m^2	20% RSD[1]	n/a	0.1 µg/L

[1] Replicate results with a mean of less than or equal to 5 times the reporting limit will be evaluated separately.
TNVSS: Total non-volatile suspended solids.
SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA, AWWA and WEF, 1998).
EPA: EPA Method Code.

Table 14. Hydrolab® equipment individual probe quality control requirements.

Parameter	Replicate Samples	Calibration Drift End Check
Dissolved Oxygen	RPD ≤ 20%	± 4 %
pH	± 0.2 pH units	± 0.2 pH units
Temperature	± 0.3 °C	n/a
Conductivity	RPD ≤ 10%	± 10 %

6.2.1 Targets for Precision, Bias, and Sensitivity

6.2.1.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs (Table 13).

6.2.1.2 Bias

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of QC procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicate samples (Table 13). MEL will assess bias in the laboratory through the use of duplicates and blanks.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. Targets for field and lab measurement sensitivity required for the project are listed in Table 13.

6.2.2 Targets for Comparability, Representativeness, and Completeness

6.2.2.1 Comparability

To insure comparability, field measurements will follow approved Environmental Assessment Program SOPs. These are listed in section 8.1.

6.2.2.2 Representativeness

The study is designed to have enough sampling sites at sufficient sampling frequency to meet study objectives. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting QC samples, but natural spatial and temporal variability can contribute greatly to the overall variability in sample and measurement values. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled; thus, a completeness of 95% is acceptable. Potential problems are flooding, site access problems, or sample container shortages.

6.3 Model Quality Evaluation

To meet the objectives of this project, model quality results should be comparable to other models used in TMDL studies. A summary of results for comparison is available in *A Synopsis of Model Quality from the Department of Ecology's Total Maximum Daily Load Technical Studies* (Sanderson and Pickett, 2014).

6.3.1 Goodness-of-fit

This study will use the following calibration and corroboration methods to assess goodness-of-fit. The methods described below will use appropriate spatial and temporal pooling of data to help provide a more comprehensive understanding of model uncertainty.

6.3.1.1 Precision

Precision is a measure of the variability in the model results relative to measured values. This study will evaluate Precision through use of standard metrics such as Relative Standard Deviation, Root Mean Square Error, or the Nash-Sutcliffe Coefficient.

6.3.1.2 Bias

Bias is the average difference between modeled and observed values. This study will evaluate Bias through use of standard metrics such as the mean error or relative percent difference.

6.3.1.3 Qualitative assessment

Graphical assessment and spatial assessments with GIS will be all used to provide a qualitative assessment of the goodness-of-fit to supplement the quantitative methods.

7.0 Sampling Process Design (Experimental Design)

7.1 Study Design

The project objectives will be met as follows:

- To complete TMDL analyses in the Little Spokane River and its tributaries, the existing calibrated QUAL2Kw model will be used for mid and lower Little Spokane River. For the upper Little Spokane River (above Chain Lake) and tributaries, RMA models will be built and calibrated. This is a simple model appropriate for evaluating DO and pH in small streams.
- To complete the assessment of pollutant loading and transport in Little Spokane River watershed, a watershed model such as WARMF, HSPF, or SWAT will be used. These are examples of modeling frameworks that are commonly used for watershed-scale flow, sediment, and nutrient loading analyses.

The following sections detail the data that will need to be collected. The data being collected for this project was determined as follows:

[data to be collected] = [data needed for the modeling frameworks selected] – [existing data]

7.1.1 Field measurements

See section 7.1.2 for a description of all measurements that will take place during sampling events.

In addition, the following measurements will be taken:

Channel measurements

Measurements of channel geometry will be taken at tributary locations and locations in the upper portion of the Little Spokane River. Existing data are sufficient to characterize channel geometry in the middle and lower parts of the Little Spokane River. Channel measurements will be taken during medium flow conditions during late spring or early summer. Table 15 presents a list of sites where channel measurements *may* be taken. However, because the exact location of channel measurements is not critically important and because the ability to conduct channel surveys is heavily dependent on landowner permissions, it is likely that many of these sites will change. If measurements are only performed at a subset of these sites, it will not be detrimental to project success.

Table 15. Possible locations for channel measurements

Stream	Location
Little Spokane River	Scotia
	Grahams
Dry Ck	Dunn Rd
	Milan-Elk Rd
Otter Ck	Oregon Rd
	Valley Rd (upper crossing)
	Valley Rd (lower crossing)
Moon Ck	Hwy 211
West Branch Little Spokane River	Below Horseshoe Lk
	Fan Lk Rd
	Eloika Lk Rd
	West Branch Rd
	Along E Eloika Rd
Buck Ck	Horseshoe Lk Rd
Beaver Ck	Horseshoe Lk Rd
Bear Ck	Deer Park-Milan Rd
	Hwy 2
Deer Ck	Jackson Rd
	MSSP land near Dunn Rd
	Tallman Rd
	Elk-Chattaroy Rd
Little Deer Ck	MSSP land along Deer Ck Rd
Dragoon Ck	Monroe Rd nr Hwy 395
	Burroughs Rd
	Staley Rd
	Hwy 395
	Crescent Rd
West Branch Dragoon Ck	Parker Rd
	Monroe Rd
Deadman Ck	MSSP boundary
	Elliot Rd
	Holcomb Rd
	Heglar Rd
	Market St
	Shady Slope Rd
SF Deadman Ck	Along Elliot Rd
NF Little Deep Ck	Madison Rd
SF Little Deep Ck	Day-Mt Spokane Rd
Little Deep Ck	Dunn Rd
	Colbert Rd
	Shady Slope Rd
Dartford Ck	Ballard Rd
	Hazard Rd

MSSP = Mt. Spokane State Park

Snow depth and coverage measurements

WARMF, HSPF and SWAT predict snow depth and coverage as state variables in the model simulation, albeit in slightly different ways. To provide a comparison point for these model predictions, measurements of snow depth and snow water equivalent (SWE), as well as landscape photographs to provide estimates of snow coverage, will be taken at least twice per month during the winter while snow is on the ground at four locations in the watershed. The sites for these measurements need to meet the following criteria:

- Snow depth measurement locations will be readily accessible throughout the winter, fairly flat (<10% slope), not covered by heavy forest canopy, not covered by heavy grass or weeds, and not disturbed by regular foot or animal traffic.
- Snow coverage photo locations will generally be along public roads, at locations near the top of a hill where a good vista is provided of at least a square mile of landscape, such that it is easy to see from that location how much of the landscape is covered by snow.

Table 16 gives a preliminary list of locations for these measurements.

Snow depth, SWE, and coverage are secondary parameters in the watershed model, and it is acceptable for data to be approximate and/or qualitative in nature.

Table 16. Possible locations for snow depth measurements and snow coverage photos

Measurement type	Location
Snow depth measurements	Meadow along Little Spokane trail near painted rocks, just west of Rutter Parkway
	Open field north of Deer Park Airport
	Meadow southeast of Horseshoe Lk Rd crossing of Beaver Ck
	DNR land along Blanchard Rd., just southwest of Blanchard Hump
	Feryn Ranch natural area, near parking area
Snow coverage photo points	Prufer Crosscut Rd., looking N into Williams Valley
	Walbridge Rd., looking SE into Wild Rose Prairie
	Horseshoe Lk. Rd. on descent toward Beaver Ck., looking E
	Summit of Blanchard Rd., looking S toward Mt. Spokane
	Orchard Bluff Rd., looking NW toward Deer Ck.
	Dunn Rd., looking S into Big Meadows
	Day-Mt. Spokane Rd. on Green Bluff, looking E toward Madison Rd. Valley
	Day-Mt. Spokane Rd. at foot of Green Bluff, looking S toward Peone Prairie

In addition, one or more Ecology employees or volunteers residing in the watershed area may be enlisted to take daily measurements of snow depth (new snow depth and cumulative snow depth), using a snow measurement board.

Continuous streamflow measurement

Continuous streamflow will be gaged for the three largest tributaries to the Little Spokane River:

- West Branch Little Spokane River at Eloika Lake outlet
- Dragoon Creek at mouth
- Deadman Creek at mouth

This gaging work will be done in conjunction with Ecology's Freshwater Monitoring Unit (FMU). FMU stream gaging activities are performed under a Quality Assurance Monitoring Plan (Butkus, 2005).

Continuous temperature measurement

The watershed model for the Little Spokane River does not require extremely accurate temperature predictions, such as would be needed for a Temperature TMDL for example. However, temperature predictions need to be in a reasonable "ballpark" range, because many of the processes simulated by the model are temperature-dependent. Therefore, continuous temperature data from six locations in the watershed will be adequate. Temperature data will be collected throughout the study period, regardless of season.

- Little Spokane River at Scotia
- Little Spokane River at E. Eloika Rd.
- Little Spokane River at N. Little Spokane Dr.
- West Branch Little Spokane River at Eloika Lake outlet

- Dragoon Creek at mouth
- Deadman Creek at mouth

7.1.2 Sampling location and frequency

Stream sampling

Stream sampling locations are shown in Table 17. Sampling locations are located at the downstream end of probable stream segments in the watershed model (such as reaches in SWAT or REACHRES in HSPF). These are generally:

- Sites just upstream of a tributary or sub-tributary
- Mouths of tributaries of sub-tributaries
- Inlets and outlets of lakes or swamps
- Natural break points in streams, such as geology or soil changes

The following activities will be performed at some or all of the stream sampling locations, as shown in Table 17.

- **Monthly sampling** – At all locations, samples will be collected monthly for total suspended solids, chloride, total persulfate nitrogen, ammonia, nitrate-nitrite, total phosphorus, and orthophosphate. Measurements of streamflow, temperature, conductivity, pH, and dissolved oxygen will be taken concurrently with sampling. Total organic carbon and dissolved organic carbon samples will be collected quarterly, during February, May, August, and November.
- **Chlorophyll *a*** – At selected locations, chlorophyll *a* samples will be collected during monthly sampling, during May through November.
- **Additional mid-monthly sampling** – At two locations, additional samples and measurements will be collected midway between monthly sampling events. This will include only total suspended solids, chloride, total persulfate nitrogen, ammonia, nitrate-nitrite, total phosphorus, orthophosphate, streamflow, temperature, conductivity, pH, and dissolved oxygen.
- **Storm event sampling** – Two storm event sampling runs will be conducted between February and May. The storm sampling run will include all the same locations as the normal monthly sampling run, as well as the same parameters. (Dissolved organic carbon, total organic carbon, and chlorophyll *a* will not be collected during storm sampling events.) An attempt will be made to time the storm events during flow spike events, where the streamflow of the Little Spokane River at the Dartford USGS gage at least doubles from its previous level. National Oceanic and Atmospheric Administration (NOAA) river forecasts will be used to plan these sampling events. http://water.weather.gov/ahps/
- **Diel hydrolab and alkalinity** – At selected locations, diel (24 to 48 hour) records of temperature, conductivity, pH, and dissolved oxygen will be collected twice during stable warm weather conditions, once during July and once during August. At these locations, alkalinity samples will be collected during the July and August monthly sampling runs.

Table 17. Stream sampling locations and activities.

Sampling Location	Purpose	Monthly sampling	Chlorophyll a	Additional mid-month	Diel Hlab + Alkalinity
LSR @ Scotia	Characterize beginning of stream	X			
LSR @ Frideger Rd.	Outlet of Chain Lake	X	X	X	
LSR @ Elk	US of Sheets, Dry, Otter and WBLSR	X	X		
LSR @ Chattaroy	US of Deer and Dragoon confluences	X	X		
LSR @ N. LSR Dr.	US of Deadman confluence	X	X		
LSR @ Mouth	Endpoint of watershed	X			
Reflection Lake outlet	Outlet of lake, mouth of tributary	X	X		
Dry Ck @ Mouth	Mouth of tributary	X			
Otter Ck @ Mouth	Mouth of tributary	X			
Moon Ck @ Hwy 211	Upper portion of WBLSR watershed	X			X
WBLSR @ Harworth Rd.	Outlet of Sacheen + swamps DS of lake	X	X		X
Buck Ck @ Mouth	Mouth of sub-tributary/Lake inlet	X			X
Beaver Ck @ Mouth	Mouth of sub-tributary	X			X
WBLSR blw Horseshoe Lk	Outlet of Horseshoe Lk	X	X		
WBLSR @ Fan Lk Rd	Inlet to Eloika Lk	X	X		X
WBLSR @ Eloika Lk Rd	Outlet of Eloika Lk	X	X	X	X
Bear Ck @ Mouth	Mouth of tributary	X			X
Deer Ck abv Little Deer Ck	US of Little Deer confluence; break point between bedrock geology and glacial fill	X			X
Little Deer Ck @ Mouth	Mouth of sub-tributary	X			X
Deer Ck @ Mouth	Mouth of tributary	X			
Dragoon Ck @ Dahl Rd	Above Deer Park	X			X
Dragoon Ck @ Monroe Rd nr Hwy 395	Below Deer Park	X			X
Dragoon Ck abv WB Dragoon Ck	US of WB Dragoon confluence	X			X
WB Dragoon Ck @ Mouth	Mouth of sub-tributary	X			X
Dragoon Ck @ North Rd	Break point in channel morphology	X			X
Dragoon Ck @ Mouth	Mouth of tributary	X			
NF Little Deep Ck @ Madison Rd	Mouth of upper branch; break point between bedrock geology and glacial fill	X			X
SF Little Deep Ck @ Day-Mt Spokane Rd	Mouth of upper branch; break point between bedrock geology and glacial fill	X			X
Little Deep Ck @ Mouth	Mouth of sub-tributary	X			
Deadman Ck @ Park Bdy	"Clean" water coming off Mt Spokane	X			
Deadman Ck @ Holcomb Rd	Break point between bedrock geology and glacial fill	X			X
Deadman Ck @ Bruce Rd	Outlet of Feryn Ranch wetland	X			X
Deadman Ck @ Shady Slope Rd	US of Little Deep Ck	X			
Dartford Ck @ Mouth	Mouth of tributary	X			

LSR = Little Spokane River WBLSR = West Branch Little Spokane River US = Upstream DS = Downstream

Late summer lake sampling

Data collected at lake outlets during the summer of 2010 suggest that lakes in the Little Spokane watershed have a strong impact on nutrient transport, acting as nutrient sinks during the summer. It is possible that these lakes then release nutrients during and after fall turnover, but that is unknown. To better understand the role of lakes in regulating nutrient transport, very limited sampling will be done at five lakes in the watershed.

Each lake will be visited once, during August or early September. At each lake, two composite samples will be taken, one from the epilimnion and one from the hypolimnion. Parameters collected will include total persulfate nitrogen, ammonia, nitrate-nitrite, total phosphorus, and orthophosphate. Chlorophyll *a* samples will be collected from the epilimnion only. Profiles of temperature, conductivity, pH, and dissolved oxygen will be collected from one or two locations in each lake, and secchi depth will be measured at each profile point. Table 18 summarizes lake sampling locations.

Table 18. Late summer lake sampling locations and activities.

Lake	Location	Approximate depth	Composite nutrient samples	Profiles and secchi measurements
Diamond Lake	Deep location near east end of lake	55 ft	X	X
Sacheen Lake	Deep location in northeast portion of lake	40 ft		X
	Deep location/hole near outlet at west end of lake	70 ft	X	X
Horseshoe Lake	Deep location in west arm of lake	140 ft		X
	Deep location in east arm of lake	40 ft	X	X
Eloika Lake	Deepest location near center of lake	15 ft	X	X
Chain Lake	Deep location near east end of lake	60 ft		X
	Deep location near west end of lake	125 ft	X	X

7.1.3 Parameters to be determined

See section 7.1.2

7.2 Maps or diagram

Figure 5 shows the sampling locations for this project.

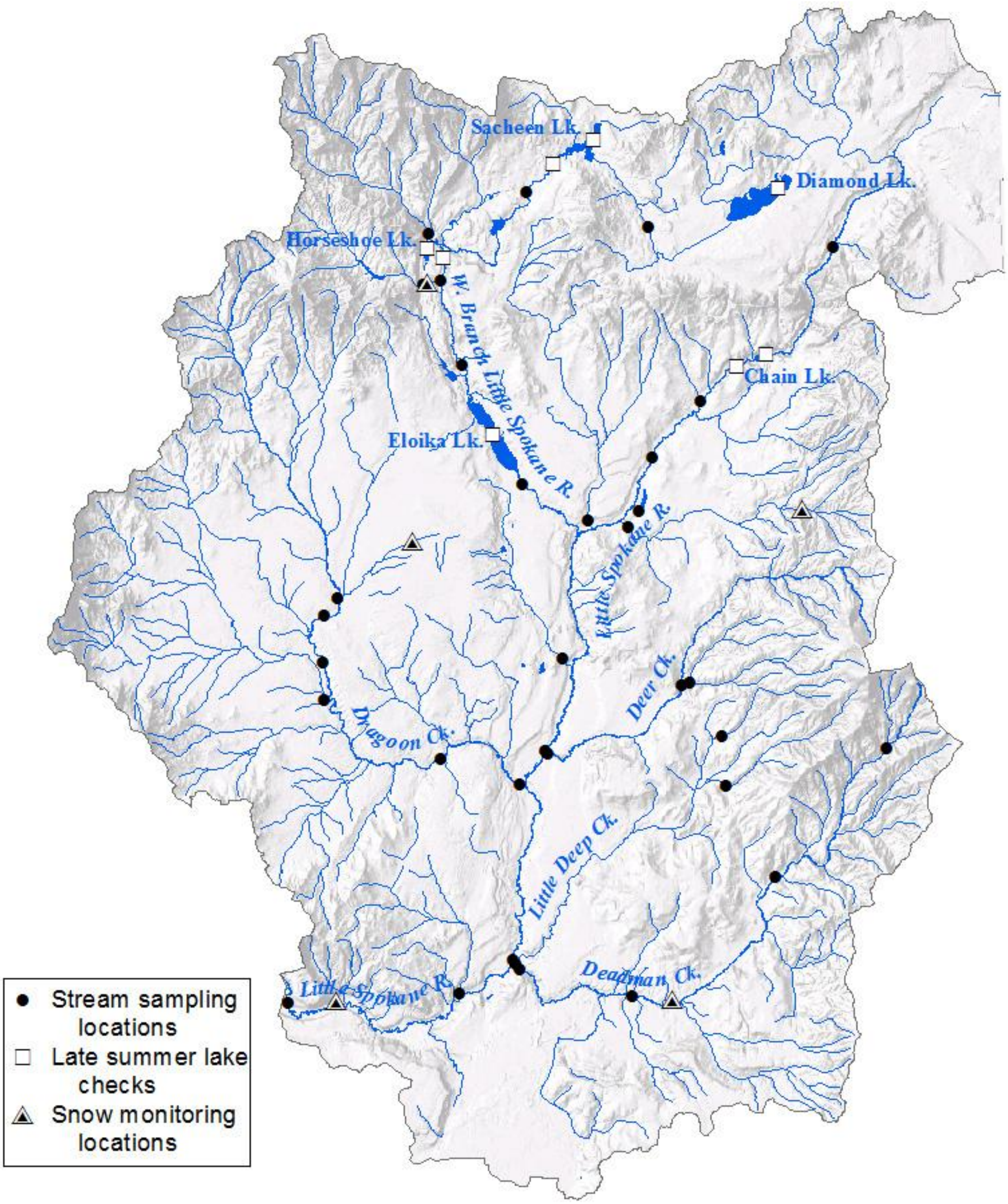

Figure 5. Sampling locations for the Little Spokane River during 2015 through 2016.

7.3 Assumptions underlying design

Not applicable.

7.4 Relation to objectives and site characteristics

Not Applicable.

7.5 Characteristics of existing data

Ambient Data

Ecology's ambient monitoring program has a long term monitoring station at the mouth of the Little Spokane River (Station ID 55B070). Monthly data from this site are available from 1977 through the present, except for 1992-1993. A variety of parameters have been sampled at this location, including nutrient parameters, dissolved oxygen, pH, and continuous temperature. These data will be extremely useful for calculating long-term statistics for nutrient loading, and for extending watershed model runs for years beyond the one year of watershed-wide data that is being collected in this study. Ambient data is considered to be of high quality, and any data quality issues well-documented in data qualifiers. A Quality Assurance Monitoring Plan for this sampling program is available online (Hallock and Ehinger, 2003).

Ecology 2010 Data

Ecology data collected on the Little Spokane River in 2010 consist of two synoptic nutrient surveys with diel dissolved oxygen and pH data. Data were collected at sites on the Little Spokane River downstream of Chain Lake, and the mouths of tributaries. These data were used to calibrate the QUAL2Kw model which will be used to evaluate DO and pH in the mid and lower Little Spokane River mainstem. However, the temporal and spatial scale of these data is not appropriate for a watershed-scale modeling analysis. The quality of these data is assessed in detail in a data summary report and is generally good (Stuart, 2012).

WSU/WWRC Data

WSU/WWRC collected certain nutrient parameters for a little over a year at a network of sites distributed throughout the watershed. While the temporal and spatial scale of these data is good for watershed modeling, the data quality of the nutrient parameters is poor. The total phosphorus and total suspended solids data, which are the two most important parameters for this analysis, were the least precise (Figure 6). It would not be appropriate to use these data for regulatory purposes such as TMDL development.

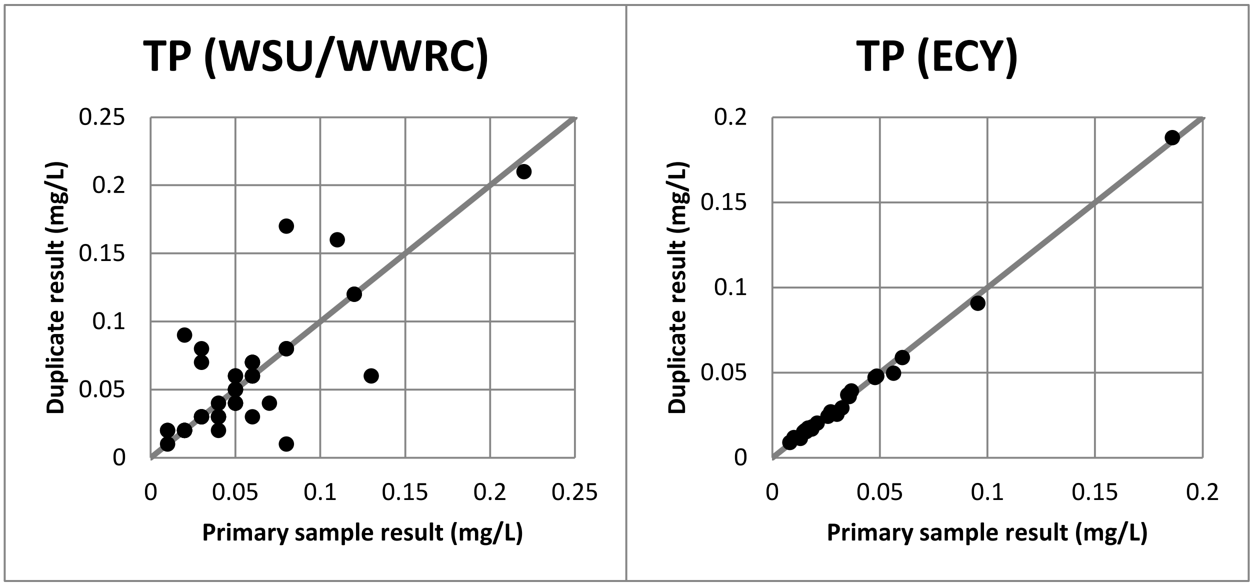

Figure 6. Total phosphorus duplicate precision for WSU/WWRC data set, with corresponding precision from Ecology's 2010 data set shown at right for comparison.

Ideally, primary sample results and duplicate results should be similar. A data set with high precision is represented by dots falling near the diagonal gray line. Dots scattered far from the gray line indicate low precision.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

To ensure comparability, field measurements will follow approved Environmental Assessment Program SOPs (Ecology, 2014):

- EAP011 - Instantaneous Measurement of Temperature in Water
- EAP015 - Manually Obtaining Surface Water Samples
- EAP023 - Collection and Analysis of Dissolved Oxygen (Winkler Method)
- EAP024 - Estimating Streamflow
- EAP033 - Hydrolab®, DataSonde®, and MiniSonde® Multiprobes
- EAP044 – Continuous Temperature Monitoring of Fresh Water Rivers and Streams Conducted in a TMDL Study
- EAP084 - Conducting Riparian Vegetation and Stream Channel Surveys in Wadeable Streams for Temperature TMDL Studies

Channel geometry measurements will be performed using EAP084 at medium-sized streams, but an alternate method will be used for small streams, as EAP084 becomes cumbersome and inaccurate for very shallow and/or narrow tributary streams. The alternate method is described in Appendix A. The procedures for snow measurement and snow coverage photography are provided in Appendix A.

8.2 Containers, preservation methods, holding times

Table 19 details laboratory parameters included in this project.

Table 19. Containers, preservation methods, and holding times for laboratory samples (MEL, 2008).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Chlorophyll-a	Surface water	1000 mL amber poly	Cool to 4 °C; 24 hrs to filtration	28 days after filtration
Total Organic Carbon	Surface water	125 mL clear poly	1:1 HCl to ph<2; Cool to 4 °C	28 days
Dissolved Organic Carbon	Surface water	125 mL poly with Whatman Puradisc™ 25PP 0.45 µm pore size filters	Filter in field with 0.45 µm pore size filter; 1:1 HCl to ph<2; Cool to 4 °C	28 days
Total Suspended Solids	Surface water	1000 mL poly	Cool to 4 °C	7 days
Alkalinity	Surface water	500 mL poly - no headspace	Cool to 4 °C; Fill bottle completely; Don't agitate sample	14 days
Chloride	Surface water	500 mL poly	Cool to 4 °C	28 days
Total Persulfate Nitrogen	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Ammonia	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Nitrate/Nitrite	Surface water	125 mL clear poly	H_2SO_4 to pH<2; Cool to 4 °C	28 days
Orthophosphate	Surface water	125 mL amber poly with Whatman Puradisc™ 25PP 0.45 µm pore size filters	Filter in field with 0.45 µm pore size filter; Cool to 4 °C	48 hours
Total Phosphorus	Surface water	60 mL clear poly	1:1 HCl to ph<2; Cool to 4 °C	28 days

8.3 Invasive species evaluation

The Little Spokane River watershed is in an area of moderate concern. This means that invasive species such as New Zealand mud snails, which are particularly hard to clean off equipment and are especially disruptive to native ecological communities, have not been found in this area. Sampling crews will follow SOP EAP070, Minimizing the Spread of Aquatic Invasive Species.

8.4 Equipment decontamination

Not applicable.

8.5 Sample ID

Sample ID numbers will follow the standard convention established by MEL, YYMMWWW-SS, where YY is the two digit year, MM is the two digit month, WWW is the three digit work order identifier assigned by MEL, and SS is the sample ID number within the work order.

8.6 Chain-of-custody, if required

Once collected, samples will be stored in coolers in the sampling vehicle. When field staff are not in the sampling vehicle, it will be locked to maintain chain-of-custody. Upon return to the Eastern Region Operations Center, the chain-of-custody portion of the Laboratory Analysis Required sheet will be filled out. Samples will be shipped to MEL via Alaska Air Cargo and MEL courier.

8.7 Field log requirements

A field log will be maintained by the field lead and used during each sampling event. The field log will be kept in either (1) a Rite-in-the-Rain® waterproof notebook; or (2) electronic form, using a Trimble Yuma® or similar device for notekeeping. The following information, as applicable, will be recorded during each visit to each site:

- Name of location
- Field staff
- Weather conditions
- Date, Time, Location ID, samples collected, identity of QC samples
- Field measurement results
- Instrument ID of hydrolabs and flow meters used
- Pertinent observations
- Any problems with sampling
- Datalogger deployment date/time, instrument ID

8.8 Other activities

Any field staff new to the type of sampling required for this study will be trained by senior field staff or the project manager, following relevant Ecology SOPs. Any maintenance needed for Hydrolab MiniSonde® or Marsh-McBirney FlowMate® equipment will be performed by trained field staff, following Ecology's SOP EAP033, or by the equipment manufacturer. Before sampling begins, staff will send MEL a schedule of sampling events. This will allow the lab to plan for the arrival of samples. All samples will be collected between Monday and Wednesday so that holding times will be met for all orthophosphate and Chlorophyll *a* samples. However, sampling at the storm events may be performed on different days of the week, if the lab indicates that this is acceptable. The lab will be notified immediately if there will be any deviations from the scheduled date of sampling. To ensure that the appropriate number and type of required sample containers are available, the field lead will work with the laboratory courier to develop a schedule for delivery of sampling containers.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Table 20 shows the field and laboratory measurement methods required to meet the goals and objectives of this project.

Table 20. Measurement Methods (field and laboratory)

Analyte	Sample Matrix	# of samples[1]	Expected Range of Results	Method	Method Detection Limit
Field Procedures					
Secchi depth	water	8	1 – 20 m	Manual	0.1 m
Velocity	water	≤ 542 flow measurements	<0.1 – 10 ft/s	Marsh-McBirney FlowMate®	0.01 ft/s
Water Temperature	water	542 instantaneous measurements + 8 lake profiles + 32 diel deployments	1.0 - 35° C	Hydrolab MiniSonde®	N/A
Specific Conductivity	water		50 – 500 umhos/cm	Hydrolab MiniSonde®	0.1 umhos
pH	water		6.0 – 9.0 s.u.	Hydrolab MiniSonde®	N/A
Dissolved Oxygen	water		1.0 – 12 mg/L	Hydrolab MiniSonde®	0.01 mg/L
Dissolved Oxygen	water	~280 [2]	1.0 – 12 mg/L	Winkler titration	1 mg/L
Laboratory Procedures					
Total Suspended Solids	water	563	<1 – 2000 mg/L	SM 2130	1 mg/L
Chloride	water	563	0.3 – 100 mg/L	EPA 300.0	0.1 mg/L
Alkalinity	water	43	20 – 200 mg/L as $CaCO_3$	SM 2320B	5 mg/L
Ammonia	water	574	<0.01 – 30 mg/L	SM 4500-NH_3H	0.01 mg/L
Dissolved Organic Carbon	water	153	<1 – 20 mg/L	EPA 415.1	1 mg/L
Nitrate/Nitrite	water	574	<0.01 – 30 mg/L	4500-NO_3 I	0.01 mg/L
Total Persulfate Nitrogen	water	574	0.5 – 50 mg/L	SM 4500-NB	0.025 mg/L
Orthophosphate	water	574	0.01 – 5.0 mg/L	SM 4500-P G	0.003 mg/L
Total Phosphorous	water	574	0.01 – 10 mg/L	SM 4500-P F	0.005 mg/L
Total Organic Carbon	water	153	<1 – 20 mg/L	EPA 415.1	1 mg/L
Chlorophyll-a	water	77	1 – 1000 mg/m^2	SM 10200H3M	0.1 µg/L

[1]Includes field QC and field blank samples.
[2]Winkler dissolved oxygen samples are collected as a quality check on Hydrolab MiniSonde® dissolved oxygen data and are collected on an as-needed basis. 280 samples is an estimate.

9.2 Lab procedures table

See Table 20.

9.3 Sample preparation method(s)

Not applicable. Chlorophyll *a* samples will be filtered by MEL rather than in the field.

9.4 Special method requirements

No special methods will be used for this study.

9.5 Lab(s) accredited for method(s)

All chemical analysis will be performed at MEL, which is accredited for all methods (Table 20).

10.0 Quality Control (QC) Procedures

10.1 Table of field and lab QC required

Table 21 shows the QC requirements for this project.

Table 21. Summary of field and laboratory quality control samples and intervals.

Parameter	Field Blanks	Field Replicates	Lab Check Standard	Lab Method Blanks	Lab Replicates	Matrix Spikes
Field						
Velocity	n/a	10%	n/a	n/a	n/a	n/a
pH	n/a	10%	n/a	n/a	n/a	n/a
Temperature	n/a	10%	n/a	n/a	n/a	n/a
Dissolved Oxygen	n/a	10%	n/a	n/a	n/a	n/a
Specific Conductivity	n/a	10%	n/a	n/a	n/a	n/a
Laboratory						
Chlorophyll-a	1/project	10%	n/a	n/a	1/20 samples	n/a
Total Organic Carbon	1/project	10%	1/run	1/run	1/20 samples	1/20 samples
Dissolved Organic Carbon	1/project	10%	1/run	1/run	1/20 samples	1/20 samples
Total Suspended Solids	4/project	10%	1/run	1/run	1/20 samples	n/a
Alkalinity	4/project	10%	1/run	1/run	1/20 samples	n/a
Chloride	4/project	10%	1/run	1/run	1/20 samples	n/a
Total Persulfate Nitrogen	4/project	10%	1/run	1/run	1/20 samples	1/20 samples
Ammonia Nitrogen	4/project	10%	1/run	1/run	1/20 samples	1/20 samples
Nitrate & Nitrite Nitrogen	4/project	10%	1/run	1/run	1/20 samples	1/20 samples
Orthophosphate P	4/project	10%	1/run	1/run	1/20 samples	1/20 samples
Total Phosphorus	4/project	10%	1/run	1/run	1/20 samples	1/20 samples

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. The lab will follow prescribed procedures to resolve the problems. Options for corrective actions might include:

- Retrieving missing information.
- Re-calibrating the measurement system.
- Re-analyzing samples within holding time requirements.
- Modifying the analytical procedures.
- Requesting additional sample collection or additional field measurements.
- Qualifying results.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

Staff will record all field data in a field notebook or an equivalent electronic collection platform. Before leaving each site, staff will check field notebooks or electronic data forms for missing or improbable measurements. Staff will enter field-generated data into Microsoft (MS) Excel® spreadsheets as soon as practical after they return from the field. If data were collected electronically, data will be backed up on Ecology servers when staff return from the field. The field assistant will check data entry against the field notebook data for errors and omissions. The field assistant will notify the field lead or project manager of missing or unusual data.

Lab results will be checked for missing and/or improbable data. MEL will send data through Ecology's Laboratory Information Management System (LIMS). The field lead will check MEL's data for omissions against the "Request for Analysis" forms. The project manager will review data requiring additional qualifiers.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2008). Variability in lab duplicates will be quantified, using the procedures outlined in the MEL Users Manual. Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

11.3 Electronic transfer requirements

MEL will provide all data electronically to the project manager through the LIMS to EIM data feed. There is already a protocol in place for how and what MEL transfers to EIM through LIMS.

11.4 Acceptance criteria for existing data

See section 7.5

11.5 EIM/STORET data upload procedures

All field measurement data will be entered into EIM, following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Not applicable. There is not a need for audits for this study. However, there could be a field consistency review by another experienced EAP field staff during the period of this project. The aim of this review is to improve field work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen our data QA program.

12.2 Responsible personnel

See Section 12.1

12.3 Frequency and distribution of report

The data collection and analysis performed under this project will be used to complete the Little Spokane River Dissolved Oxygen and pH TMDL. The final TMDL report will be published according to the project schedule in Section 5.4.

12.4 Responsibility for reports

Tighe Stuart will be the lead on the final report. Paul Pickett will co-write the report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The field lead will verify initial field data before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

Once quarterly, the field assistant will compare all field data to determine compliance with MQOs. The field assistant will note values that are out of compliance with the MQOs and will notify the field lead. At the conclusion of the study, the field lead will compile a summary of all out of compliance values (if any) and provide it to the project manager for a decision on usability.

13.2 Lab data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, the field lead will perform a secondary verification of each data package. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention to laboratory QC results. The field lead will bring any discovered issues to the project manager for resolution.

13.3 Validation requirements, if necessary

All laboratory data that have been verified by MEL staff will be validated by a project staff member. Field measurement data that was verified by a project staff member will be validated by a different staff member.

After data entry and data validation tasks are completed, all field, laboratory, and flow data will be entered into the EIM system. EIM data will be independently reviewed by another field assistant for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

After all laboratory and field data are verified, the field lead or project manager will thoroughly examine the data package, using statistics and professional judgment, to determine if MQOs have been met. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the field lead and project manager will decide if affected data should be qualified or rejected based upon the decision criteria from the QAPP. The project manager will decide how any qualified data will be used in the technical analysis.

14.2 Data analysis and presentation methods

The technical analysis will include an evaluation of model quality to assess model uncertainty and ensure that the development of TMDL allocations and targets are appropriately supported by the quality of the model results.

14.3 Treatment of non-detects

Any non-detects will be included in the study analysis. Depending on the circumstances, non-detects will be treated in one of two ways:

- Non-detect may be replaced with half the detection limit
- Non-detect may be treated as an indeterminate value between zero and the detection limit. For example when comparing model predictions to observed data where the observed data is a non-detect, any predicted value less than the detection limit would be considered an exact match.
- For summary statistics, methods such as ROS or Kaplan-Meier may be used.

14.4 Sampling design evaluation

The sampling design is based on the data needs of the modeling and analytical tools that will be used to complete the TMDL analysis. These primarily include input and calibration data to feed the watershed model (WARMF, HSPF or SWAT) as well as data to feed the RMA modeling tool. It is expected that these modeling tools, used with the data collected during this project and existing data, will be sufficient to meet project goals and objectives.

14.5 Documentation of assessment

In the technical report, the project manager will include a summary of the data quality assessment and model quality evaluation findings. This summary is usually included in the data quality section of reports.

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16.0 Figures

See Table of Contents for list of figures in the report.

17.0 Tables

See Table of Contents for list of tables in the report.

18.0 Appendices

Appendix A. Additional Field Protocols

There are four sets of field protocols required for this study that are not covered by existing EAP SOPs. This appendix contains descriptions of these protocols. These protocols are preliminary and may need to be changed, depending on experience in the field.

Channel geometry measurements for very narrow streams

Unlike many previous TMDL studies, this project requires measurements of channel geometry on tributary streams, including small headwater streams, and does not require these measurements on wide mainstem river sites. Streams requiring channel geometry measurements in this study will range in width from extremely narrow to moderate width.

For streams with bankfull widths greater than ~25 ft, EAP SOP 084, Conducting Riparian Vegetation and Stream Channel Surveys in Wadeable Streams for Temperature TMDL Studies, will be used. Sections 7.1 – 7.5.6 will be followed. Later sections, which are intended for temperature TMDLs, will not be used.

For streams with bankfull widths less than ~25 ft, the cross-section survey procedure in EAP SOP 084 becomes overly time-consuming and somewhat inaccurate. For such streams, the following procedure will be used.

Equipment required

- Standard nylon measure tape graduated in tenths of feet, same as used for flow measurements
- Stadia rod
- Carpenter's level

Procedure

- Follow EAP SOP 084 sections 7.1 – 7.3.3 to select site, measure streamflow, and measure incision.
- Stretch a standard nylon measure tape, such as is used during flow measurements, from one bankfull edge to the other. The tape should be at the bankfull height. This may require two crew members, one to hold either end of the tape. Hold the tape completely taut. If the distance across the channel is too far to hold the tape taut without it sagging, then use EAP SOP 084.
- The third crew member uses a carpenter's level to check that the tape is stretched flat across the stream. If it is not, have the two crew members on the banks adjust the location of their ends of the tape until everyone is satisfied that the tape is level, and represents the bankfull height.
- The third crew member proceeds across the stream from one bankfull edge to the other, taking measurements at 12-20 increments. At each location, the crew member will record the tape distance, and use a stadia rod to record bankfull depth (i.e., vertical distance from streambed to tape) and wetted depth if the measurement falls within the wetted width.

- Make sure to record the tape distances of both bankfull edges and both wetted edges.

Daily snow depth measurements

The following procedure will be used by Ecology staff or volunteers who live in the Little Spokane watershed and are taking daily snow depth measurements at their private residences. This procedure is adapted from NOAA procedures, and some of the language is taken from those procedures (NOAA, 2013).

Equipment required

- Two snow measurement boards. These each consist of a piece of heavy-duty plywood approximately 4 ft x 4 ft, spray-painted white.
- Yardstick or ruler
- Snow shovel

Procedure

- Site the snow measurement boards (SMBs) during a period of time when there is no snow on the ground. Put the SMBs in a flat, open location. Find an area where wind effects and drifting are minimized and far enough away from buildings or trees where snow blowing off of higher structures is unlikely to fall onto the SMBs. If there seems to be a risk of the SMBs blowing away in windstorms, it might be good so secure them to the ground, perhaps with rebar stakes.
- One of the SMBs is for measuring new snowfall each day. This SMB is cleared off daily. The other SMB is for measuring accumulated snow depth. This SMB is not ever cleared off.
- Measurements should be taken daily, at about the same time of day.
- To measure daily snow accumulation, simply use the yardstick to measure snow depth on the board that is cleared daily. If snow depths on the board vary, pick an average spot so as not to bias the measurement high or low. If no snow has fallen since the previous day, mark “0”. Then, shovel the SMB clear.
- To measure accumulated snow depth, use the yardstick to measure snow depth on the board that is not ever cleared. If snow depths on the board vary, pick an average spot, so as not to bias the measurement high or low. If there is no snow on this board, mark “0”. Do not clear the SMB.
- A trace of snow (snow present but too shallow to accurately measure) should be recorded as “T”.
- For days when measurements are missed, record “NM”. If the person measuring has been away (say, on vacation) for a period of time, then on the first day back they should measure accumulated snow depth as normal. However, they should *not* measure daily snowfall unless they are absolutely sure that all the snow on the daily SMB fell within the previous 24 hours. Instead, they should clear the daily SMB, and mark “NM” for daily snowfall for that day. The next day all measurements should be taken as normal.
- Record qualitative comments about the condition of snow, such as “powder,” “wet,” “wet with crust.”

Field snow depth and snow water equivalent measurements

The following procedure will be used by field crews when measuring snow depth and snow water equivalent (SWE) at sites located throughout the study area. Some of the language in these procedures is taken from NOAA procedures (NOAA, 2013).

Equipment required

- Yardstick
- Snow core tube. This does not need to be an official snow core sampling device (which is usually very long, designed for high mountain applications). This can be a piece of single-wall stovepipe with an end cap on one end, a thin-walled piece of PVC pipe with an end cap on one end, or something similar. The device should have a hole drilled in the side of the tube near the open end, for hanging from the scale.
- Spatula large enough to cover open end of snow core tube
- Digital hanging scale, with resolution down to at least 0.02 lbs
- Hanging post for scale. This is a post ~6 ft tall with a ~1-foot horizontal extension at the top and a hook at the end of the horizontal extension, for hanging the scale. This may not be needed at all sites, if a tree branch or other convenient place to hang the scale is available.

Procedure for snow depth

- Measure depth of snow at snow measurement site using the yardstick. Choose a spot where snow is undisturbed by human or animal traffic, or snow falling from trees. Try to find a typical or representative depth so as not to bias the measurement high or low. This may mean taking measurements in a few locations and using the average measurement.
- When no snow or ice is on the ground in exposed areas within 100 yards (300 feet) of your normal observing location, record a "0".
- A trace of snow (snow present but too shallow to accurately measure) should be recorded as "T".
- When, in your judgment, less than 50% of the exposed ground is covered by snow, even though the covered areas have a significant depth, the snow depth should be recorded as a trace (T). Make a note of the range of depths of the remaining snow in the comments.
- When strong winds have blown the snow, take several measurements where the snow was least affected by drifting and average them. If exposed areas are blown free of snow while others have drifts, again try to combine visual averaging with measurements to record your representative value for snow depth. (Note that if more than half of the ground is snow-free, only a trace should be reported.)

Procedure for snow water equivalent (SWE)

- If at least 2 inches of snow are present on the ground, a snow core should be taken to measure snow water equivalent (SWE).
- Choose an undisturbed location with representative snow depth.
- Make sure the snow core tube is clean and clear of snow.
- One crew member holds the post vertical. Hang the scale from the post.
- Hang the snow core tube from the scale and tare the scale. The scale should now read zero. Remove the snow core tube from the scale. The scale should now read a negative value.
- Place the open end of the snow core tube on the top of the snow and push it to the ground.

- Slide the spatula under the bottom of the snow core tube. Lift the tube and spatula together, and turn the snow core tube over, so the open end is facing sideways or slightly up. Slowly remove the spatula, scraping it into the tube. Try to avoid letting snow fall to the bottom of the tube yet, and avoid letting any fall out the open end.
- If dirt, grass, weeds, or other debris have gotten in the tube, carefully remove them as best you can.
- If there is still a layer of snow on the ground where the core was taken, carefully spatula that snow into the tube.
- Now turn the tube so the open end is facing up, and let the snow fall to the bottom of the tube.
- Hang the tube with the snow in it from the scale. The value displayed by the scale should represent the weight of the snow in the tube. Record this value.
- Snow water equivalent is calculated as:

$$S = \frac{W}{\pi\left(\frac{d}{2}\right)^2 \times K}$$

Where:
S = snow water equivalent (in)
W = measured weight of snow core (lbs)
d = inside diameter of snow core tube (in)
K = the density of water = 0.0361 lbs/in^3

- Remove the tube from scale, empty the tube, and scrape it clean as much as possible.

Snow coverage photography

Equipment required
- Digital camera

Procedure
- Navigate to the snow coverage photo location using a GPS or known landmarks.
- Face the direction specified in the instructions for the photo location, using view-finder or digital screen to orient picture frame to landmarks as specified in photo location instructions
- Take photo. Record location and photo file number.
- Upon returning to office, download photo and give it a name that includes location and date.
- Analyze photo to determine what fraction of the ground in the landscape is covered by snow, to the nearest 10%. Often this will be either 0% or 100% in which case the task is simple. However in situations of partial or patchy snow coverage, more care will be needed. Make sure to only consider the fraction of the ground that is covered. Do not consider the presence or absence of snow on trees. Also, do not consider plowed roads, roofs, etc.

Appendix B. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

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

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.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

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 flow event unless determined otherwise by the department.

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.

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

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 (e.g., diurnal temperature rises during the day, and falls during the night).

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

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.

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.

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

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, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES 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.

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 NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

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: Source of pollution that discharges 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 5 acres of land.

Pollution: 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.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Snow Water Equivalent: The amount of liquid water that would result if snowpack were entirely melted.

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.

Streamflow: Discharge of water in a surface stream (river or creek).

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

Synoptic survey: Data collected simultaneously or over a short period of time.

System potential: The design condition used for TMDL analysis.

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 not meeting (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): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload 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.

Watershed model: A computer modeling framework that can predict streamflow in a network of streams in a watershed based on meterological input data, can predict non-point pollutant loading to streams from the landscape, and can predict fate and transport of those pollutants once they reach the stream.

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

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 ten 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.

90^{th} percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90^{th} percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

BMP	Best management practice
CBOD	Carbonaceous biochemical oxygen demand
CD	Conservation District
CWA	Clean Water Act
DO	Dissolved oxygen
DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
LIMS	Laboratory Information Management System
LSR	Little Spokane River
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
NOAA	National Oceanic and Atmospheric Administration
NPDES	(See Glossary above)
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SCD	Spokane Conservation District
SMB	Snow measurement board
SOP	Standard operating procedures
SVRP	Spokane Valley-Rathdrum Prairie Aquifer
SWE	Snow Water Equivalent
TMDL	(See Glossary above)
TOC	Total organic carbon
TSS	(See Glossary above)
USGS	United States Geological Survey
WAC	Washington Administrative Code
WBLSR	West Branch Little Spokane River
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WQIR	Water Quality Improvement Report
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

°C	degrees centigrade
cfs	cubic feet per second
°F	degrees Fahrenheit
ft	feet
ft/s	feet per second
in	inch
in^3	cubic inches
lbs	pounds
m	meter
mi^2	square mile
mg/L	milligrams per liter (parts per million)
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
um	micrometer
umhos/cm	micromhos per centimeter

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split Sample: The term split sample denotes when a discrete sample is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

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