



DEPARTMENT OF
ECOLOGY
State of Washington

Quality Assurance Project Plan

Evaluation of Groundwater Quality and Discharge Conditions at the Terminus of Deep and Coulee Creeks (Spokane County)

June 2016

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Quality Assurance Project Plan

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June 2016

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EAP: Environmental Assessment Program

EIM: Environmental Information Management database

WQP: Water Quality Program

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2.0 Abstract

To help reduce nuisance algal blooms, the 2010 Spokane River Dissolved Oxygen Total Maximum Daily Load (DO TMDL) report required reductions, of up to 50%, in the nutrient load the Spokane River receives from the Deep and Coulee Creek drainages which are tributary to the Spokane River. When developing the water quality model that was constructed to support the Spokane River DO TMDL report, Ecology assumed the water quality of Deep and Coulee Creeks was similar to that of Hangman Creek, which joins the Spokane River a few miles upstream of Deep Creek. However, ambient water quality data collected for Deep and Coulee Creek since the model was developed indicates that this assumption was incorrect. Another confounding factor is that both Deep and Coulee Creek go subsurface (dry up) in their lower reaches before reaching the Spokane River. Deep Creek only has surface flow to the Spokane River during infrequent rain-on-frozen ground conditions.

To better understand the nutrient load that potentially enters the Spokane River from the Deep/Coulee Creek watershed, Ecology's Water Quality Program in the Eastern Regional Office proposed a project to sample groundwater for nutrients near the mouth of Deep Creek. This Quality Assurance Project Plan describes the approach and design for that study. For this project, we will use a combination of physical measurements and groundwater quality information collected from instream piezometers to define local scale surface water/groundwater interactions and water quality conditions at the terminus of Deep Creek.

3.0 Background

Since 1998, the Washington State Department of Ecology (Ecology) has partnered with other government agencies, tribes, industries, and the local community to improve dissolved oxygen conditions in the Spokane River and Lake Spokane. Having sufficient dissolved oxygen in surface water is critical for fish, invertebrates, and other aquatic life. Excess nutrients in water can deplete dissolved oxygen and contribute to harmful toxic algae blooms.

Portions of the Spokane River and Lake Spokane have excessive algae blooms during the summer low flow period. Reducing nutrients is key to improving area water quality conditions. To this end, the [2010 Spokane River Dissolved Oxygen Total Maximum Daily Load report](#) (DO TMDL) required the following water quality improvements:

- Remove more than 90% of total phosphorus from point sources in Washington.
- Reduce up to half of the nutrients from nonpoint sources in Hangman and Coulee Creeks, the Little Spokane River, and surrounding Lake Spokane.

Deep Creek and its primary tributary Coulee Creek, are tributaries to the Spokane River (Figure 1). Deep Creek enters the Spokane River about a mile upstream of the Nine Mile Dam. When developing the water quality model that preceded and supported the Spokane River DO TMDL report, Ecology assumed the water quality of Deep and Coulee Creeks was similar to Hangman Creek, which joins the Spokane River a few miles upstream of Deep Creek. However, ambient water quality data collected since the model was developed indicates this assumption was incorrect. Another confounding factor is that both Deep and Coulee Creek go subsurface (dry up) a few miles above their confluence with the Spokane River. Deep Creek only has surface flow to the Spokane River during infrequent rain-on-frozen ground conditions.

To better understand the nutrient load that potentially enters the Spokane River from the Deep/Coulee Creek watershed, Eastern Regional Office's Water Quality Program proposed a project to sample discharging groundwater for nutrients near the mouth of Deep Creek. This Quality Assurance Project Plan describes the study's approach and design.

3.1 Study area and surroundings

The project study area encompasses a short segment of the Spokane River proper adjacent to its confluence with Deep Creek (Figure 1).

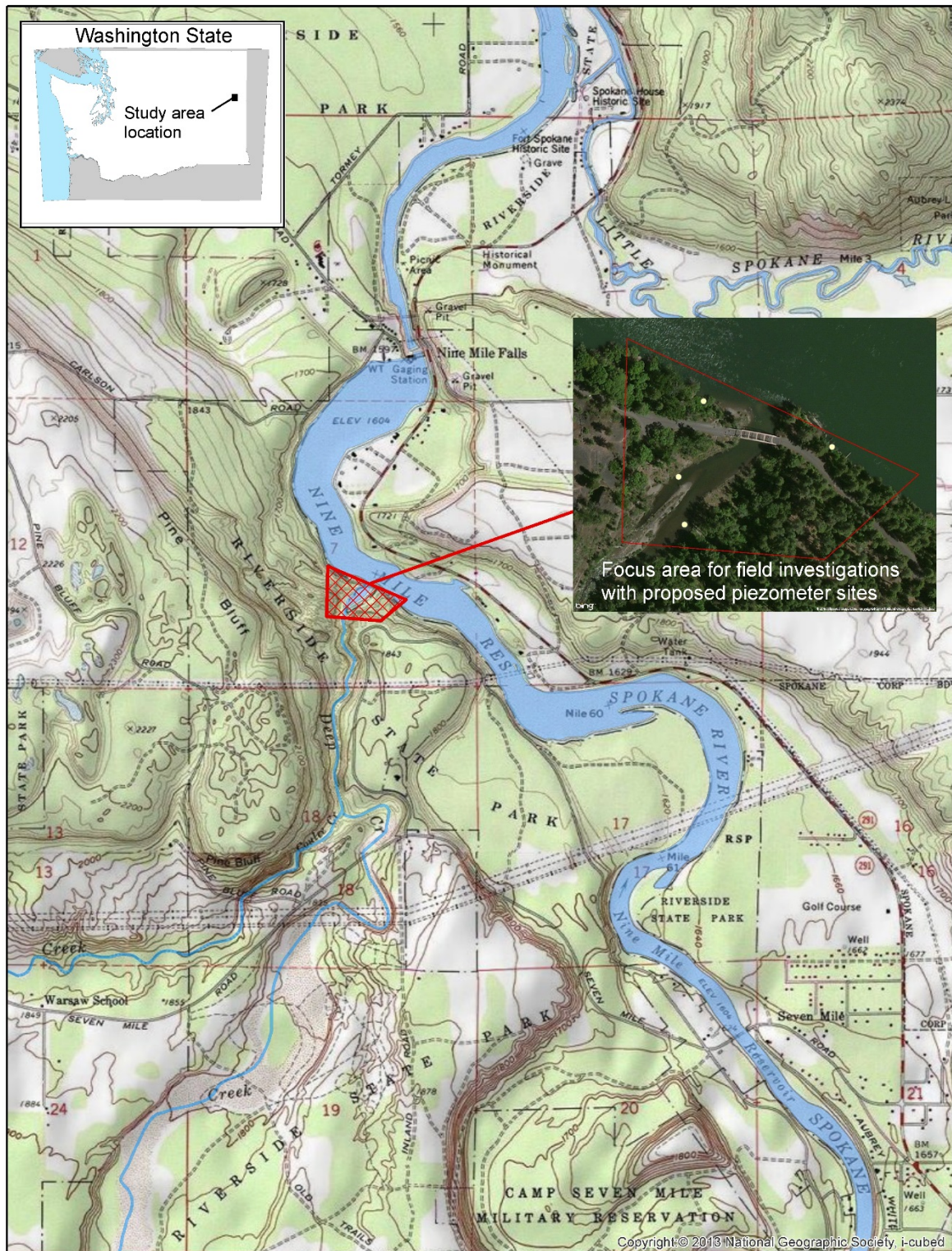


Figure 1. Study area location and detail.

3.1.1 Logistical problems

See Section 4.7.

3.1.2 History of study area

The study area for this project lies within Riverside State Park which is managed by Washington State Parks. The park was established in the early 1930s and encompasses over 10,000 acres of land adjacent to the Spokane River. The park is a recreation hub (e.g., fishing, hiking, rafting, mountain biking, and snowmobiling) for residents of Spokane and other surrounding communities. The area encompassed by the park has a long history of flooding, sometimes catastrophically (Bretz, 1959).

3.1.3 Parameters of interest

The parameters of interest for this project are primarily phosphorus- and nitrogen-based nutrients (i.e., total phosphorus, orthophosphate, Ammonia, Nitrate+Nitrite-N, and total persulfate nitrogen) that can enter the Spokane River as groundwater discharge from the Deep/Coulee Creek drainage. When these compounds are present at elevated concentrations in discharging groundwater, they can contribute to problematic instream aquatic plant growth and impaired surface water quality.

To determine whether groundwater discharges into the Spokane River at the study site, water temperatures and streambed vertical hydraulic gradients will be monitored in a small network of instream piezometers. This information will be used to determine if and when groundwater quality samples should be collected from the piezometers.

The goal is to collect samples when the Spokane River is gaining water from the unconsolidated sediments that border the river at the study site. If groundwater is discharging to the river, we will sample for the above nutrients, field parameters (i.e., temperature, pH, specific conductance, and dissolved oxygen) plus dissolved organic carbon, chloride, and total alkalinity.

3.1.4 Results of previous studies

Several recent studies and investigations involving the greater Deep and Coulee Creek area are relevant to this evaluation.

Kahle et al. (2005) summarized previous streamflow gain and loss estimates for the Spokane River between Seven Mile Road and the Nine Mile Dam (see Figure 1). The streamflow gain/loss estimates provided by Kahle et al are highly variable and were derived via physical streamflow measurements or from groundwater modeling exercises. Estimated streamflow gains from groundwater within this reach ranged from 5 to 653 ft³/s while estimated streamflow losses to groundwater ranged from 1.1 to 1,028 ft³/s depending on the period evaluated.

During summer 2010, GeoEngineers (2011) measured streamflows and phosphorus concentrations at several points along Deep and Coulee Creeks and in 4 area domestic wells, to

estimate surface water and groundwater phosphorus loads to the Spokane River from the Deep/Coulee Creek drainages. Although they were able to define surface water phosphorus concentrations, the report authors could not directly estimate surface water loads since both creeks infiltrated into the ground before joining the Spokane River. Using a number of simplifying assumptions about area surface water and groundwater conditions, the study authors subsequently conducted a Darcy flux evaluation to estimate groundwater (and infiltrated surface water) phosphorus loads to the Spokane River from the Deep/Coulee watershed. Based on this evaluation, estimated total phosphorus loading to the river from infiltrated surface water and groundwater ranged from 0.25 to 1.85 lbs/day with a median value of 0.95 lbs/day for the May-July 2010 period. Groundwater was estimated to contribute 0.05 lbs/day of the overall load along this reach.

Spokane County (2013) used existing streamflow information and seepage runs to evaluate surface water/groundwater interactions along Deep and Coulee Creeks. Based on these evaluations, both creeks gained water from groundwater discharge in their upper to middle reaches and lost water to groundwater in their lower reaches before going dry a few miles above their confluence with the Spokane River.

It is unclear from the above studies how infiltrated surface water and groundwater from the Deep and Coulee Creek watersheds eventually enter the Spokane River. Conceivably they could enter the river as direct groundwater discharge from the unconsolidated sediments and mass-wasting deposits that border the river near its confluence with Deep Creek (Figure 2). Alternatively, water that leaves the creeks through infiltration may recharge deeper basalt aquifers and discharge to the river either locally or elsewhere.

3.1.5 Regulatory criteria or standards

The results of this study will be used to help guide future implementation activities for the Spokane River DO TMDL.

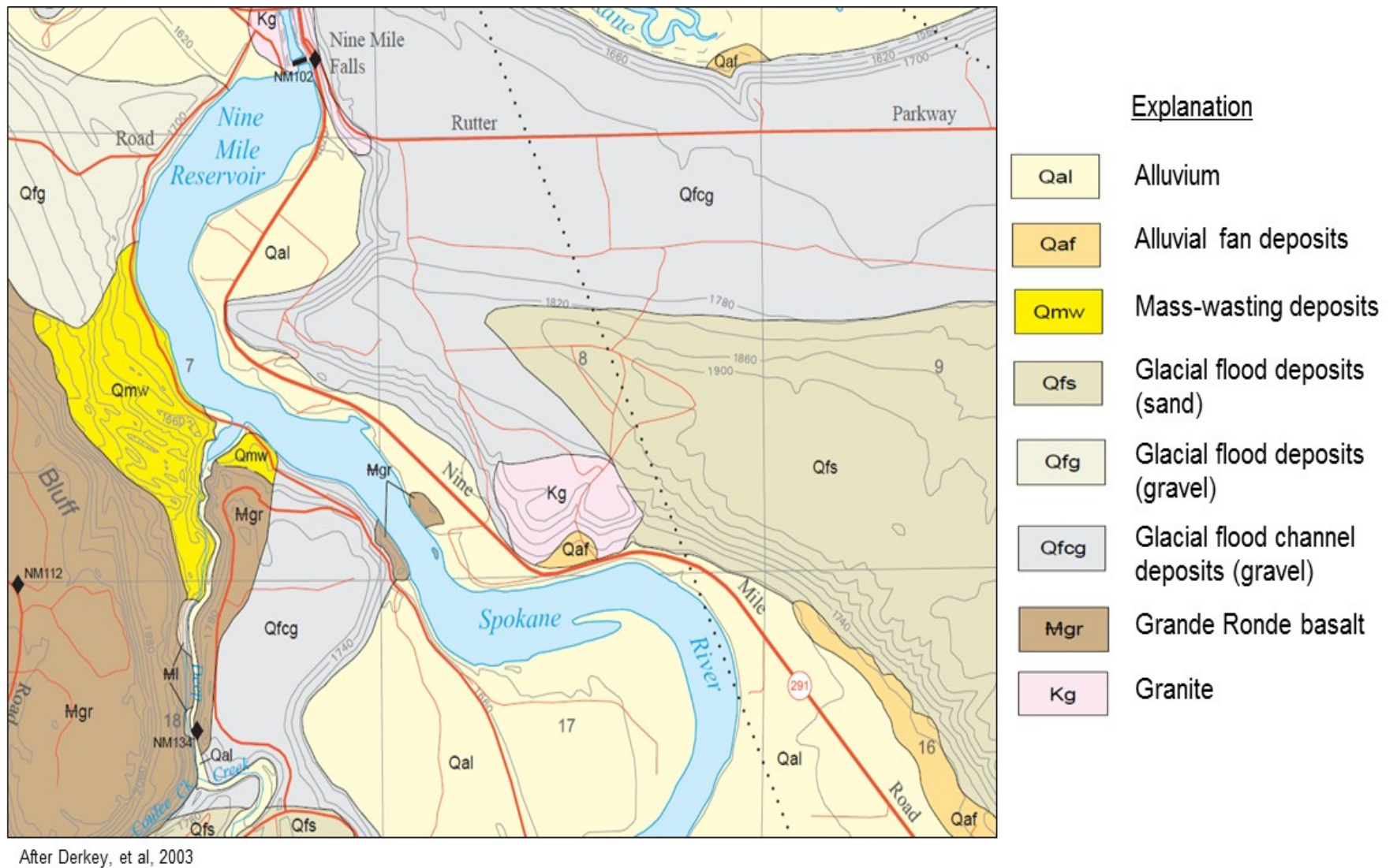


Figure 2. Study area surficial geology.

4.0 Project Description

This project will build on the previous studies described in Section 3.1.4. The principal purpose of this project is to determine whether the unconsolidated sediments that border the Spokane River near the terminus of Deep and Coulee Creek provide a discharge pathway for groundwater and infiltrated surface water from these drainages to enter the Spokane River. This will be accomplished using a combination of instream piezometers, thermistors, and transducers. These instruments will be deployed within the unconsolidated sediments and monitored to define local scale surface water/groundwater interactions. If groundwater is found to be discharging into the Spokane River at this location, we will sample the piezometers to define ambient groundwater quality conditions at the study site. The water quality data will be combined with hydraulic information from the instream piezometers to estimate groundwater fluxes and nutrient loads to the river at the study site. Additional details on the study goals, objectives, and tasks are described below.

4.1 Project goals

The goals of this project are:

- To define groundwater/surface water interactions (gain/loss conditions) along the Spokane River near its confluence with Deep Creek.
- If shallow groundwater is discharging into the Spokane River, characterize groundwater nutrient concentrations (e.g., phosphorus and nitrogen compounds) and estimate groundwater nutrient loads to the river from the Deep Creek unconsolidated sediments.

4.2 Project objectives

The project objectives are to:

- Install in-water piezometers, thermistors, and potentially transducers, to characterize groundwater flow direction(s) and volumetric exchanges between the Spokane River and the unconsolidated sediments near the terminus of Deep Creek.
- For those piezometers where groundwater is found to be discharging to the river, sample groundwater quality per applicable SOPs for the parameters described in Section 3.1.3. Sample quarterly for one year – if appropriate.
- Conduct constant head injection tests of the project piezometers to determine the hydraulic conductivity of the unconsolidated sediments underlying the river locally.
- If appropriate, combine groundwater flux estimates and water quality information to estimate groundwater nutrient loads to the river from the Deep/Coulee Creek unconsolidated sediments.
- Prepare a report of the study findings, QA assessment, and conclusions.

4.3 Information needed and sources

Most of the data needed to complete the project will be generated during this study. Pertinent information on the location and construction of other wells near the terminus of Deep and Coulee Creeks will be obtained from the Ecology Water Resources Program Well log system, <http://ecyapps7/waterresources/Map/wclswebmap/default.aspx>.

4.4 Target population

The target population for this project includes streambed vertical hydraulic gradients, near surface groundwater quality, and other environmental conditions related to the potential discharge of groundwater into the Spokane River from unconsolidated sediments near the terminus of Deep/Coulee Creek.

4.5 Study boundaries

See Figure 1 Section 3.1 for a map of the study area location and approximate boundary.

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

- WRIA - 54
- HUC - 17010307

4.6 Tasks required

A general overview of the tasks required to meet the project goals for this effort are discussed below and in Section 4.2. Additional details on the technical approach and field and lab tasks are described in Section 7.

- Install instream piezometers within the unconsolidated sediments that border the Spokane River near the terminus of Deep Creek.
- Calibrate and install thermistors/pressure transducers in each piezometer to track near real time water temperatures and groundwater levels.
- Conduct monthly manual water level measurements and perform periodic downloads of thermistors and transducers.
- Collect quarterly water quality samples from gaining piezometers for 1 year.
- Conduct constant head injection tests of the instream piezometers to characterize aquifer hydraulic properties (after Pitz, 2006).
- If appropriate, combine water quality data and hydraulic information from the project instream piezometers to derive groundwater nutrient loading estimates for the Spokane River at the study site.

- Prepare a report that summarizes the project methods, results, and conclusions.

4.7 Practical constraints

Logistical conditions that could interfere with sampling include:

- The study area is underlain by basalts of the Columbia River basalt group. In some areas the inferred unconsolidated sediments (Figure 2) that overlie the basalt may not be thick enough to install effective instream piezometers.
- Scheduling conflicts, sample bottle delivery errors, vehicle or equipment problems, or limited availability of personnel or equipment. This can be mitigated to some extent by having backup equipment on hand and giving clear instructions to field teams on what to do if equipment fails.
- Site access issues. If there are unforeseen site access issues, we will attempt to find alternate sampling locations that will enable us to meet the project objectives.
- High streamflow. Sampling events may be rescheduled if flows are too high to safely sample.
- Reservoir management practices may complicate groundwater flow conditions at the project site. Transducers that record measurements continually (i.e., every 15 minutes) will allow us to observe changes that might occur over shorter timeframes than would be observed by quarterly sampling/monthly field visits.

4.8 Systematic planning process

Preparing this QAPP satisfied the project systematic planning needs.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities.

Staff (all are EAP staff except client)	Title	Responsibilities
Karin Baldwin Water Quality Program Eastern Regional Office Phone: 509-329-3601	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Kirk Sinclair GFFU SC Section Phone: 360-407-6557	Project Manager, Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft and final project reports.
Martha Maggi GFFU SC Section Phone: 306-407-6453	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Jessica Archer SC Section Phone: 360-407-6698	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Jim Ross Eastern Operations Section Phone: 509-329-3425	Unit Supervisor for the Study Area	Provides internal review of the QAPP, and approves the final QAPP
Tom Mackie Eastern Operations Section Phone: 509-454-4244	Section Manager for the 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

GFFU: Groundwater, Forests and Fish Unit

QAPP: Quality Assurance Project Plan

MEL: Manchester Environmental Laboratory

SC: Statewide Coordination

5.2 Special training and certifications

All field staff involved with this project either already have relevant experience following SOPs or will be trained by senior staff who do. Field staff who lack the necessary skills and experience to work independently will be paired with staff mentors who will oversee and verify their work and provide the necessary training to enable them to work proficiently and independently.

See Section 8.1 for a list of the standard procedures and practices that will be followed during this project.

5.3 Organization chart

See Table 1, Section 5.1.

5.4 Project schedule

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Install piezometers and instrumentation	Aug-Sept 2016	Kirk Sinclair
Field work completed	Sept 2016-Oct 2017	Kirk Sinclair
Laboratory analyses completed	Dec 2017	
Environmental Information System (EIM) database		
EIM Study ID	KSIN0009	
Product	Due date	Lead staff
EIM data loaded	Feb 2018	Kirk Sinclair
EIM data entry review	Mar 2018	To be determined
EIM complete	Apr 2018	Kirk Sinclair
Final report		
Author lead / Support staff	Kirk Sinclair	
Schedule		
Draft due to supervisor	Apr 2018	
Draft due to client/peer reviewer	Apr 2018	
Draft due to external reviewer(s)	NA	
Final (all reviews done) due to publications coordinator	Jun 2018	
Final report due on web	Jul 2018	

5.5 Limitations on schedule

Potential field-related constraints are addressed in Section 4.7. Any unforeseen limitations that would affect the project schedule will be discussed with the project manager's supervisor as needed.

5.6 Budget and funding

The project budget assumes we will sample 4-6 instream piezometers and the Spokane River near the terminus of Deep Creek, quarterly for one year. Excluding vehicle expenses, the total estimated cost for equipment, travel, and laboratory work to support this project is approximately \$8,230. See details below (Table 3).

Table 3. Anticipated laboratory analytical costs.

Parameter	Number of Field Samples	Number of Field Duplicates	Number of Field Blanks	Total Sample Count	Cost per Sample	Subtotal
Alkalinity	28	4	4	36	\$18.43	\$663
Ammonia (NH ₃)	28	4	4	36	\$14.09	\$507
Nitrate + Nitrite - N	28	4	4	36	\$14.09	\$507
Total Persulfate Nitrogen (TPN)	28	4	4	36	\$18.43	\$663
Orthophosphate (OP)	28	4	4	36	\$16.26	\$585
Total Phosphorus (TP)	28	4	4	36	\$19.50	\$702
Chloride	28	4	4	36	\$14.09	\$507
DOC	28	4	4	36	\$38.98	\$1439
Total						\$5573

- Equipment: \$400 for construction of instream piezometers
- Travel: \$2,260 (5 trips from Olympia to Spokane and return anticipated. Includes a total of 4 days for equipment installation, and 4 quarterly sample visits of 3 days each. The final quarterly sample visit will include an extra day for equipment removal).

6.0 Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to other analysis methods used in this study.

6.1 Decision Quality Objectives (DQOs)

This study will provide background information and analysis of groundwater conditions at the terminus of Deep and Coulee Creeks. This information may be used to help implement the Spokane River DO TMDL.

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 field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Tables 4 and 5.

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 and bias will be addressed by submitting replicate samples. Ecology's Manchester Environmental Laboratory (MEL) will assess precision and bias in the laboratory through the use of duplicates and blanks.

Tables 4 and 5 outline expected precision of sample duplicates and method reporting limits. 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 4. Measurement quality objectives for field measurements and equipment.

Parameter	Equipment/ method	Precision- Field duplicates (median)	Equipment Accuracy	Equipment Resolution	Equipment Range	Expected Range
Field Water Quality Measurements						
Water Temperature	Hydrolab®	± 0.2°C	± 0.1°C	0.01°C	-5 to 50°C	0 to 30°C
Specific Conductance	Hydrolab®	5% RSD	± 5% of reading	1 uS/cm	0-100,000 uS/cm	50-1000 uS/cm
pH	Hydrolab®	± 0.2 s.u.	± 0.2 units	0.01 s.u.	0 to 14 s.u.	6 to 10 s.u.
Dissolved Oxygen – Luminescent (LDO)	Hydrolab®	5% RSD	± 0.1 mg/L at <8 mg/L; ± 0.2 mg/L at 8 to <20 mg/L	0.01 mg/L	0 to 60 mg/L	0 to 10 mg/L
Water Level Measurements						
Groundwater Level	Electric/ Steel Tape	± 0.01 ft	± 0.01ft	± 0.01ft	0 to 300 ft	0 to 5 ft
Continuous Temperature Monitoring						
Water Temperature	Hobo Water Temp Pro v2	n/a	± 0.2°C at 0° to 50°C	0.02°C at 25°C	-40° to +50°C	0° to 30°C

RSD: Relative Standard Deviation

Table 5. Measurement quality objectives for field duplicates and laboratory samples.

Parameter	Verification Standards (LCS, CRM, CCV)	Field/Lab Duplicate Samples	Matrix Spikes	Matrix Spike-Duplicates	Lowest Concentrations of Interest
	% Recovery Limits	Relative Percent Difference (RPD)	% Recovery Limits	Relative Percent Difference (RPD)	Units of Concentration (mg/L)
Laboratory analyses					
Alkalinity	20	10	20	20	5.0
Ammonia-N	20	10	20	20	0.010
Nitrate-nitrite-N	20	10	20	20	0.010
Total persulfate nitrogen-N	20	10	20	20	0.025
Ortho-phosphate	20	10	20	20	0.003
Total phosphorus	20	10	20	20	0.001
Chloride	20	10	20	20	0.10
DOC	20	10	20	20	1.0

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 field and laboratory duplicate samples will be expressed as relative percent difference (RPD) as shown in Table 5.

Duplicate field samples will be collected by filling two bottles for each laboratory analysis, one after the other for each group of constituents in each bottle, i.e., filling one bottle for alkalinity, then the 2nd bottle for alkalinity followed by one bottle for nutrients followed by the 2nd bottle for nutrients, etc.

6.2.1.2 Bias

Bias is defined as the difference between the sample value and the 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 8, Section 10.1). 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 Tables 4 and 5.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

The SOPs we plan to follow during this study are listed in Section 8.1. Relatively few details are available regarding previous groundwater data collection and analysis methods for this study area. Therefore it may be difficult to directly compare the data collected during this study with previous data.

6.2.2.2 Representativeness

Groundwater level and water quality conditions are relatively slow to change compared with surface water. Therefore quarterly sampling should be sufficient to characterize groundwater quality conditions at the study site. However, reservoir management practices may complicate groundwater flow conditions at the project site. Transducers that record measurements

continually (i.e., every 15 minutes) will allow us to observe changes that might occur over shorter timeframes than would be observed by quarterly sampling/monthly field visits.

Water quality samples collected from properly-constructed-gaining-instream piezometers are representative of groundwater conditions just prior to its discharge into a river or other surface water body – which is the central focus of this investigation.

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 project is to correctly collect and analyze 100% of the planned measurements and samples. However, since problems occasionally arise during sample collection that cannot be controlled, a completeness of 95% is acceptable. Potential problems are flooding, site access problems, equipment failure, or sample container shortages.

7.0 Sampling Process Design (Experimental Design)

7.1 Study design

The principal purpose of this study is to determine whether the unconsolidated sediments that border the Spokane River near the terminus of Deep and Coulee Creek provide a discharge pathway for groundwater from these drainages to enter the Spokane River.

Field measurements will be made monthly for water levels and approximately quarterly for groundwater quality for 1 year. Field measurements will begin approximately 4-6 weeks after successful installation of the instream piezometers. Recording thermistors will be installed at 3 depths within each successfully completed piezometer to monitor streambed thermal profiles at 30 minute intervals. The thermal data will provide secondary confirmation of the groundwater flow directions inferred from piezometer water level measurements. If site conditions allow, water level transducers may be installed in one or more piezometers to monitor groundwater levels at 30-minute intervals.

Other field measurements (temperature, pH, conductivity, dissolved oxygen) will also be collected for the Spokane River and instream piezometers during each sampling event.

7.1.1 Field measurements

The field measurements that will be made during this project are listed in Table 4 in Section 6.2.

7.1.2 Sampling location and frequency

The proposed sampling sites are shown in Figure 1. Piezometer water levels will be measured monthly. Samples for laboratory analysis will be collected quarterly (a relatively high frequency for groundwater) to observe potential groundwater quality effects related to seasonal streamflow patterns.

7.1.3 Parameters to be determined

See Tables 4 and 5 (Section 6.2) for a summary of field and laboratory parameters of interest. In addition, we hope to estimate groundwater flow directions and streambed hydraulic characteristics.

7.2 Maps or diagram

See Figure 1.

7.3 Assumptions underlying design

Assumptions underlying the study design include:

- When properly installed, instream piezometers provide representative information about local groundwater level and water quality conditions.
- The proposed number and position of instream piezometers will be adequate to establish local groundwater quality conditions and groundwater fluxes – including direction and volume of water movement.
- The proposed frequency of water quality sampling is sufficient to document the potential variability and average value of area groundwater nutrient concentrations.

7.4 Relation to objectives and site characteristics

The study is designed to account for potential complicating factors such as:

- Periodic reversals in surface water/groundwater flow direction due to seasonal differences in streamflow volume or reservoir operations.
- Seasonal differences in local groundwater quality conditions due to changes in surface water/groundwater interactions.
- The potential for upward groundwater flow at the site (i.e., from deeper basalt to shallower unconsolidated aquifers).

7.5 Characteristics of existing data

Existing relevant data for the study area is discussed in Section 3.1.4.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Groundwater samples and procedures for the study will follow Ecology SOPs:

- EAP033 Hydrolab use and maintenance (Swanson, 2010).
- EAP052 for depth to water measurements (Marti, 2009).
- EAP074 for use of pressure transducers as part of groundwater studies (Sinclair and Pitz, 2010).
- EAP078 for purging and sampling monitoring wells (Marti, 2011).
- EAP061 for installing, monitoring, and decommissioning hand-driven in-water piezometers (Sinclair and Pitz, 2013).
- EAP013 for determining coordinates via hand-held GPS receivers (Janisch, 2006).

Field measurements will be made at all sampling sites and recorded in a notebook.

Measurements for Specific conductance, pH, dissolved oxygen, and water temperature will be collected using a calibrated Hydrolab MiniSonde® following Ecology's SOP EAP033 (Swanson, 2010) and manufacturer's recommendations.

If site conditions allow, continuous (15 minute) water level measurements may be made using calibrated water level transducers (SOP EAP074). These measurements will be compared and checked against manual water level measurements made during field sampling using a calibrated E-tape or steel tape (SOP EAP052).

Groundwater samples will be collected using a peristaltic pump. The pump will be fitted with new silastic tubing at the start of each sampling event. Each monitoring well and instream piezometer will have a dedicated, 1/4-inch diameter polypropylene tube for purging and sample collection. The tubing will be stored in individual clean Ziploc bag between sample events.

All piezometers will be purged using standard low-flow techniques (e.g., < 0.5 L/min) until field parameters measured in an airtight flow-through chamber are stable. Samples that do not require filtering will be collected first. The remaining samples will then be collected using disposable in-line filters (0.45 µm). Additional groundwater quality sampling details are specified in SOP EAP078 and EAP061.

Constant head injection tests (or equivalent) will be conducted at each piezometer to estimate hydraulic conductivity values for the adjacent streambed sediments (see Pitz, 2006).

The latitude/longitude coordinates of all monitoring locations will be recorded with a GPS receiver using protocols detailed by Janisch, 2006.

8.2 Containers, preservation methods, holding times

Table 6. Sample containers, preservation, and holding times

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Alkalinity, chloride	Water	500 mL– NO headspace	500 mL poly	Cool to < 6°C	14 days
Ammonia-N, Nitrate-Nitrite-N, Total persulfate nitrogen - N	Water	125 mL	125 mL poly, clear	H2SO4 to pH <2; Cool to < 6°C	28 days
Ortho Phosphate	Water	125 mL	125 mL poly, amber	Cool to < 6°C	48 hours
Total Phosphate	Water	125 mL	125 mL poly, clear	1:1 HCL to pH <2; Cool to < 6°C	28 days
Dissolved organic carbon	Water	125 mL	125 mL poly, clear	1:1 HCL to pH <2; Cool to < 6°C	28 days

8.3 Invasive species evaluation

Field staff will follow EAP's SOP EAP070 to minimize the spread of invasive species (Parsons et al., 2012). The Spokane River basin is not in an area of Extreme Concern. Still, staff will follow the decontamination procedures in place for areas of Moderate Concern, to minimize the potential for invasive species transport between sites.

For more information, please see Ecology's website on minimizing the spread of invasive species at <http://www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html>.

8.4 Equipment decontamination

New, clean dedicated sample tubing and filters will be used to gather and prepare any groundwater quality samples that are collected for this project. New, clean silastic tubing (~ 1.5 foot length) will be used in the peristaltic pump at the start of each sampling event to collect samples. The silastic tubing will be decontaminated between wells and piezometers with a brief deionized water rinse followed by several minutes of pre-sample purging at each site prior to collecting samples for laboratory analysis. A single field blank will be collected during each sampling event to confirm that purging offers adequate decontamination of the silastic tubing between sampling sites.

The E-tape used to measure water levels in the piezometers will be rinsed with deionized water between wells.

Since sample tubing and filters will not be shared among the sampled wells, no equipment decontamination beyond the above is needed or warranted for this effort.

After conducting field work, field staff will:

- Inspect and clean all equipment by removing any visible soil, vegetation, vertebrates, invertebrates, plants, algae, or sediment. If necessary, a scrub brush will be used to clean equipment which will then be rinsed with clean water either from the site or brought for that purpose.
- Drain all water from samplers or other equipment that may harbor water from the site. This step will take place before leaving the sampling site or at an interim upland site.

8.5 Sample ID

Sample ID's will be obtained from MEL prior to each sampling event. MEL will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number. The combination of work order number and field ID constitute the sample ID. For tracking purposes, all sample IDs will be recorded in the field logs.

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 Ecology's Operations Center, the sample coolers will be kept in a secure walk-in-cooler until picked up by the laboratory courier and transported to MEL. Chain-of-custody will be maintained and documented on the Laboratory Analysis Required (LARs) sheet.

8.7 Field log requirements

For this project we will use EAP's standard field data sheets. Example field sheets are provided in Appendix A, of SOP EAP061 (Sinclair and Pitz, 2013).

The following information will be recorded during visits to each site:

- Name and location of project
- Field staff
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, sample ID, samples collected, identity of QC samples
- Field measurement results
- Pertinent observations
- Any problems with sampling

8.8 Other activities

Field staff who are unfamiliar with instream piezometer installation, measurement, and sampling will be trained by the project manager per relevant Ecology SOPs. Maintenance of the Hydrolab MS-5 MiniSonde® and other equipment will follow EAP033 SOP protocols and manufacturer instructions/recommendations.

The field lead will notify MEL about proposed sampling events a few weeks before sampling. If possible, all samples will be collected between Monday and Wednesday to ensure holding times are met for all samples. The field lead will keep the laboratory apprised of necessary updates to scheduled sampling dates or other unforeseen changes. The field lead will coordinate with the laboratory courier to ensure the appropriate number and type of containers are available for each sample event and that samples arrive at the laboratory on time and in good condition.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Table 7. Field and laboratory measurement methods

Parameter	Matrix	Expected Range of Results	Method	Method Detection Limit
Field procedures				
Water level	Water	0-5 feet	E-tape, steel tape, or transducer	0.01 feet
Temperature	Water	0-30°C	Hydrolab MS-5 / Hobo Water Temperature Pro V2	0.2 / 0.25°C respectively
pH	Water	4-9 S.U.	Hydrolab MS-5	NA
Specific conductance	Water	50-1000 umhos/cm	Hydrolab MS-5	5 umhos/cm
Dissolved oxygen	Water	0-10 mg/L	Hydrolab MS-5	0.1 mg/L
Laboratory procedures				
Alkalinity	Water	5-500 mg/L	EPA 310.2	5 mg/L
Ammonia-N	Water	0.010-10 mg/L	SM4500 NH3 H	0.010 mg/L
Nitrate-Nitrite-N	Water	0.010-10 mg/L	SM4500 NO3 I	0.010 mg/L
Total persulfate nitrogen-N	Water	0.010-10 mg/L	SM4500 NO3 B	0.025 mg/L
Ortho-phosphate	Water	0.005–5 mg/l	SM4500 PG	0.005 mg/L
Total phosphorus	Water	0.005–5 mg/l	SM4500 PF	0.005 mg/L
Chloride	Water	1-20 mg/L	EPA 300.0	0.10 mg/L
DOC	Water	1-10 mg/L	SM5310 B	1.0 mg/L

9.2 Lab procedures table

See Table 7, Section 9.1. All laboratory bound water samples will be field-filtered using a new in-line 0.45 micron capsule filter.

9.2.1 Analyte

See Table 7, Section 9.1.

9.2.2 Matrix

See Table 7 Section 9.1. Groundwater is the matrix of interest to this study.

9.2.3 Number of samples

See Table 3, Section 5.6.

9.2.4 Expected range of results

See Table 7, Section 9.1.

9.2.5 Analytical method

See Table 7, Section 9.1.

9.2.6 Sensitivity/Method Detection Limit (MDL)

See Table 7, Section 9.1.

9.3 Sample preparation method(s)

There are no special or unusual sample preparation methods envisioned or needed for this project. All samples will be field filtered into clean-analyte-specific-sample containers at the time of collection per EAP SOP's EAP061 and EAP078. MEL will provide pre-cleaned sample bottles for this project and will include acid preservative for those analyses that require field preservation of samples.

9.4 Special method requirements

There are no special method requirements anticipated for this project.

9.5 Lab(s) accredited for method(s)

All water quality samples collected during this project will be submitted to MEL. MEL is fully accredited and certified to perform the laboratory analyses proposed for this project.

10.0 Quality Control Procedures

10.1 Table of field and lab quality control (QC) required

Table 8. Quality control samples, types, and frequency

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Temperature	NA	NA	NA	NA	NA	NA
pH	NA	NA	NA	NA	NA	NA
Specific conductance	NA	NA	NA	NA	NA	NA
Dissolved oxygen	NA	NA	NA	NA	NA	NA
Alkalinity	10%	10%	1/batch	1/batch	1/batch	1/batch
Ammonia-N	10%	10%	1/batch	1/batch	1/batch	1/batch
Nitrite+Nitrate-N	10%	10%	1/batch	1/batch	1/batch	1/batch
Total persulfate N	10%	10%	1/batch	1/batch	1/batch	1/batch
Ortho-phosphate	10%	10%	1/batch	1/batch	1/batch	1/batch
Total phosphorus	10%	10%	1/batch	1/batch	1/batch	1/batch
Chloride	10%	10%	1/batch	1/batch	1/batch	1/batch
Dissolved organic carbon (DOC)	10%	10%	1/batch	1/batch	1/batch	1/batch

The QC samples all will have MQOs (evaluation criteria) associated with them. These are described in Section 6.2. These criteria must be met to obtain fully usable data.

As a QC check for all installed transducers, monthly-manual-water-level measurements will be made at each instrumented well during the study. The check measurements will be made with a calibrated electronic well probe or steel tape using EAP's standard protocols (Marti, 2009).

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. A corrective action may need to be taken as a result of sampling as well as lab issues. Prescribed procedures will be followed 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 collection of additional samples or taking additional field measurements.
- Qualifying results.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

All field data will be recorded using standard EAP field data sheets (Sinclair and Pitz, 2013). Staff will check field sheets for missing or improbable measurements before leaving a site. Field-generated data will be entered into Microsoft (MS) Excel® spreadsheets as soon possible after returning from the field. The project manager will check data entry for errors and omissions. Missing or unusual data will be flagged for follow-up QA review and corrective action if necessary.

Lab results will be checked for missing or improbable data. Data received from MEL through Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the initial "Request for Analysis" forms submitted by the project lead. The project manager will flag for follow-up review any 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 User's Manual (MEL, 2008). Variability in lab duplicates will be quantified using the procedures outlined in the MEL User's 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's standard electronic data transfer to the EIM holding area is appropriate for this project. No unusual electronic data transfer requirements are envisioned or required. MEL will electronically transfer all laboratory-generated data 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

Existing data will be accepted if they were collected with standardized sampling, analytical, and quality assurance methods that can be documented and that are comparable to those outlined in this study.

11.5 EIM/STORET data upload procedures

MEL's standard internal electronic data transfer to the EIM holding area from the MEL LIMS database is appropriate for this project. No unusual electronic data transfer, storage, or other requirements are envisioned or needed. All field and laboratory data will be entered into EIM following existing Ecology business rules and the EIM User's Manual.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Field audits are always appropriate for a project involving either field measurements or sampling. Insufficient QA resources are currently available for auditing activities. However, there could be a field consistency review by another experienced EAP hydrogeologist. The aim of such reviews is to improve field work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthening our data quality assurance program.

12.2 Responsible personnel

See Section 12.1.

12.3 Frequency and distribution of report

No interim reports or data summaries are anticipated or needed for this project. However, draft copies of field data sheets and project case narratives will be provided to the client, if requested, prior to completion of the draft project report. A final report will be published according to the project schedule shown in Section 5.4.

12.4 Responsibility for reports

The project manager is responsible for drafting and finalizing the study completion report.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

After completing field measurements and sample collection at a site, the project manager will perform an initial data verification before departing the site. This includes checking the data sheet for omissions or outliers. If measurements were missed or a measurement is determined to be an outlier, the measurement will be completed or repeated, as needed.

After each sampling event, the project manager will evaluate field data to determine compliance with project MQOs. Values that exceed the MQOs will be noted. At the conclusion of the study, all out-of-compliance values (if any) will be compiled and assessed for usability by the project lead.

13.2 Lab data verification

MEL staff will perform laboratory data verification following standard laboratory practices. After the laboratory verification, a secondary verification of each data package will be performed by the project manager. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention being paid to laboratory QC results. If any issues are discovered, the project manager will contact the laboratory to reach resolution.

13.3 Validation requirements, if necessary

Data validation is not performed by the EAP project manager. Instead, once all laboratory data have been verified by MEL staff, the EAP project manager will complete a detailed quality review of the data set as part of the verification process. Field measurements data that are verified by the project manager will be verified by second EAP staff member from the Groundwater, Forests and Fish Unit.

After all data entry and data verification tasks are complete, field and laboratory data will be entered into the Ecology EIM system by the project manager. The EIM data will be independently reviewed by another staff member from the Groundwater, Forests and Fish Unit. Approximately 10 percent of the EIM results for the project will be checked. The check will include data for all of the project parameters. 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, a detailed examination of the project data will be performed by the project manager to determine if the study 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 project manager will decide if affected data should be qualified or rejected based on the decision criteria detailed in the QA Project Plan. The project manager will decide how qualified data are ultimately used in subsequent analysis.

14.2 Data analysis and presentation methods

The data collected during this project will be summarized in tabular and graphic form in a formal published study report. Where possible, field measurements of groundwater and surface water levels, streambed hydraulic parameters, and groundwater quality information will be used to evaluate potential fluxes and nutrient loading from groundwater to the Spokane River at the study site. The results of this evaluation will be included and discussed in the study report.

14.3 Treatment of non-detects

Laboratory non-detect values, if present, will be included in the study analysis. When preparing statistical data summaries, non-detect will be replaced by half the reported detection limit. If a significant number of non-detects occur, another assessment method may be used (Singh et al., 2006).

14.4 Sampling design evaluation

The sampling design is based on existing information, and the actual conditions at the site may be more complex than thought. If we identify deficiencies in our sampling design, we will evaluate the potential consequences on the project. We may recommend additional work or activities to resolve such problems.

14.5 Documentation of assessment

The project manager will include a data quality assessment section in the formal study report; where field and laboratory data quality will be evaluated and discussed.

15.0 References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Bretz, J.H., 1959. Washington's channeled Scabland. Division of Mines and Geology, State of Washington. Bulletin No. 45. 57 p.

Derkey, R.E., Hamilton, M.M., and Stradling, D.F., 2003. Geologic map of the Nine Mile Falls 7.5-minute Quadrangle, Spokane and Stevens County, Washington. Washington Division of Geology and Earth Resources. Open File Report 2003-8.

GeoEngineers, 2011. Technical memorandum field data collection and phosphorus loading summary – Deep Creek field data collection area bi-state nonpoint source phosphorus study, Spokane County, WA. Prepared for Spokane County Department of Utilities. 66 p.
<http://www.spokanecounty.org/ArchiveCenter/ViewFile/Item/2429>

Janisch, J., 2006. Standard Operating Procedure for Determining Global Position System Coordinates, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP013. www.ecy.wa.gov/programs/eap/quality.html

Kahle, S.C., Caldwell, R.R., and Bartolino, J.R., 2005. Compilation of geologic, hydrologic, and ground-water flow modeling information for the Spokane Valley—Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho: U.S. Geological Survey Scientific Investigations Report 2005-5227, 64 p.

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

Marti, P., 2011. Standard Operating Procedure for Purging and Sampling Monitoring Wells. Washington State Department of Ecology SOP EAP078. 34 p.
www.ecy.wa.gov/programs/eap/quality.html

Marti, P., 2009. Standard Operating Procedure for Manual Well-Depth and Depth-to-Water Measurements. Washington State Department of Ecology SOP EAP052. 31 p.
www.ecy.wa.gov/programs/eap/quality.html

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA.

Parsons, J. et al., 2012, Standard operating procedures to minimize the spread of invasive species. Version 2.1. Washington State Department of Ecology EAP070. 31 p.
www.ecy.wa.gov/programs/eap/quality.html

Pitz, C.F., 2006. An evaluation of a piezometer-based constant head injection test (CHIT) for use in groundwater/surface water interaction studies. Washington State Department of Ecology, Environmental Assessment Program, publication No. 06-03-042. 31 p.
<https://fortress.wa.gov/ecy/publications/documents/0603042.pdf>

Sinclair, K. and C. Pitz, 2013. Standard operating procedure for installing, monitoring, and decommissioning hand-driven in-water piezometers. Version 2.0. Washington State Department of Ecology EAP061. 77 p. www.ecy.wa.gov/programs/eap/quality.html

Sinclair, K. and C. Pitz, 2010. Standard operating procedure for the use of submersible pressure transducers during groundwater studies. Washington State Department of Ecology EAP074, 56.
www.ecy.wa.gov/programs/eap/quality.html

Singh, A., R. Maichle, and L. E. Sanghee, 2006. On the computation of a 95% upper confidence limit of the unknown population mean based upon data sets with below detection limit observations. U.S. EPA Report EPA 600/R-06/022.
<http://www.epa.gov/osp/hstl/tsc/Singh2006.pdf>

Spokane County Water Resources, 2013. West plains hydrogeology: Deep Creek and Coulee Creek groundwater/surface water interaction. 8 p.

Swanson, T., 2010. Standard Operating Procedure for Hydrolab® DataSonde® and MiniSonde® Multiprobes, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP033. www.ecy.wa.gov/programs/eap/quality.html

16.0 Figures

The figures in this QAPP are inserted after they're first mentioned in the text.

17.0 Tables

The tables in this QAPP are inserted after they're first mentioned in the text.

18.0 Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

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

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

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, 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.

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 where more than 5 acres of land have been cleared.

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.

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

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

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.

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.

Acronyms and Abbreviations

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
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
SRM	Standard reference materials
TMDL	(See Glossary above)
USGS	United States Geological Survey
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
ft	feet

g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/L	milligrams per liter (parts per million)
mL	milliliter
s.u.	standard units
ug/L	micrograms per liter (parts per billion)
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity

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:

$$[\text{Abs}(a-b)/((a + b)/2)] * 100$$

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: A discrete sample that 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)

References for QA Glossary

Ecology, 2004. Guidance for the Preparation of Quality Assurance Project Plans for Environmental Studies. <https://fortress.wa.gov/ecy/publications/SummaryPages/0403030.html>

Kammin, B., 2010. Definition developed or extensively edited by William Kammin, 2010. Washington State Department of Ecology, Olympia, WA.

USEPA, 1997. Glossary of Quality Assurance Terms and Related Acronyms. U.S. Environmental Protection Agency. <http://www.ecy.wa.gov/programs/eap/quality.html>

USEPA, 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4. U.S. Environmental Protection Agency. <http://www.epa.gov/quality/qs-docs/g4-final.pdf>

USGS, 1998. Principles and Practices for Quality Assurance and Quality Control. Open-File Report 98-636. U.S. Geological Survey. <http://ma.water.usgs.gov/fhwa/products/ofr98-636.pdf>