**Supervisor Approval and First Sampling Date Form**

**for QAPP Addendums**

Title of QAPP Addendum: **Addendum 3 to the Spokane River Toxics Reduction Strategy Study: Groundwater Survey**

Lead author’s name: Adriane Borgias

This addendum is an addition to an original Quality Assurance Project Plan. It is not a correction (errata) to the original plan. Addendum 3 represents a minor addition to the existing “Spokane River Toxics Reduction Strategy” project. The project uses an Ecology approved QAPP (dated July 11, 2014) that was prepared by LimnoTech and approved by the Spokane River Regional Toxics Task Force.

This Addendum adds 20 groundwater/spring water samples, with associated quality assurance samples, to the study. The Addendum also includes a new procedure: groundwater sampling for low level PCBs.

The first set of samples were collected in August and September, 2015 following development and technical review of the Addendum. The second and third sets were collected February 17, 2016 and May 17, 2016, respectively. The following people provided comments on the preliminary draft:

Pam Marti, Peer reviewer

Bill Kammin, QA Officer

Mike Hermanson, Spokane County

The significant concerns of the reviewers have been addressed in the draft Addendum. Ecology’s Quality Assurance officer provided email approval for the sampling activities on August 10, 2015.

Supervisor’s approval of first date of sampling confirms the following:

* Supervisor has verified that the appropriate reviewers had the opportunity to comment and that their significant concerns will be addressed in the sampling work and final QAPP Addendum.
* Supervisor will ensure that the QAPP Addendum is approved, finalized, and posted to the Internet within 8 weeks of the date of supervisor’s signature below. Otherwise, work on the project will cease until the QAPP Addendum is completed.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Supervisor’s signature

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date of supervisor’s signature

\_\_Email approval\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Bill Kammin’s (Quality Assurance Officer) signature

\_\_August 10, 2015 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date of Quality Assurance Officer’s signature

**Distribution List for QAPP Addendums**

QAPP title: Addendum 3 to the Spokane River Toxics Reduction Strategy Study: Groundwater Survey

Author(s): Adriane Borgias

EAP peer reviewer: Pam Marti

Links to: *Spokane River Toxics Reduction Strategy, June 2014. Prepared by LimnoTech, Inc., approved by Ecology:*

[*http://srrttf.org/wp-content/uploads/2013/05/QAPP\_FINAL\_081114.pdf*](http://srrttf.org/wp-content/uploads/2013/05/QAPP_FINAL_081114.pdf)

*Approval Checklist:* [*http://srrttf.org/wp-content/uploads/2013/05/SRRTTF-QAPP-Checklist-FINAL-08122014.pdf*](http://srrttf.org/wp-content/uploads/2013/05/SRRTTF-QAPP-Checklist-FINAL-08122014.pdf)

Key words: Spokane River, Toxics Reduction, Polychlorinated biphenyl, PCB, Groundwater, Spring water

**Send email notice to:**

Everyone listed on the QAPP and Addendum 3 signature pages:

Bud Leber, Kaiser Aluminum

David Dilks, LimnoTech

Jim Bellatty, Ecology

Robert Steed, Idaho DEQ\*

Cathy Whiting, LimnoTech\*

Carrie Turner, LimnoTech\*

Shea Hewage, Axyx

Dale Hoover, Axyx

John Kern, SVL\*

Michael Desmaris, SVL\*

Shawn Hinz, Gravity

Adriane Borgias, Ecology

Mike Hermanson, Spokane County

Ted Hamlin, Ecology

The review email notice will also go to

Randy Marshall, WQ QA Coordinator

Pam Marti, Peer reviewer

Bill Kammin, QA Officer

The Spokane River Regional Toxics Task Force web notice and email distribution list

Affected tribes (Natural Resource Directors) Brian Crossley, Spokane Tribe of Indians

Rebecca Stevens, Coeur d’Alene Tribe

Rob Lindsay, Spokane County

Ben Brattebo, Spokane County

Jeremy Ryf, Ecology

Lisa Brown, Ecology

Martha Maggi

Joel Bird (MEL Director)

Bill Kammin (QA Officer)

Jim Bellatty, ERO

Cc for information:

Chris Page/Kara Whitman Ruckleshaus Center

Lisa Dally Wilson, representing SRSP

#### EIM Study ID\_\_SRUW-Spokane\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

ECOLOGO_W-C

*Draft 5 –**September 6, 2016*

Addendum 3 to

Quality Assurance Project Plan

Spokane River Toxics Reduction Strategy Study

August 2015

Revision Date: September 6, 2016

Data for this project will be available on Ecology’s Environmental Information Management (EIM) website at [www.ecy.wa.gov/eim/index.htm](http://www.ecy.wa.gov/eim/index.htm). Search Study ID xxxx

#### Original Publication

Quality Assurance Project Plan: *Spokane River Toxics Reduction Strategy Study, Prepared by LimnoTech, Inc, for the Spokane River Regional Toxics Task Force, July 2014.* <http://srrttf.org/wp-content/uploads/2013/05/QAPP_FINAL_081114.pdf>

*Addendum 1, August 1, 2015:* <http://srrttf.org/wp-content/uploads/2015/08/Spokane_River_QAPP_Addendum1_signed_081715.pdf>

*Addendum 2, February 29, 2016:* <http://srrttf.org/wp-content/uploads/2016/06/QAPP_addendum2_final_022916.pdf>

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Washington State Department of Ecology

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*Accommodation Requests: To request ADA accommodation including materials in a format for the visually impaired, call Ecology at 360-407-6834. Persons with impaired hearing may call Washington Relay Service at 711. Persons with speech disability may call TTY at 877-833-6341.*

Addendum to Quality Assurance Project Plan

Spokane River Toxics Reduction Strategy

Groundwater Survey

August 2015

**Approved by:**

|  |  |  |
| --- | --- | --- |
| Signature: |  | Date: |
| Bud Leber, SRRTTF-ACE, Client Technical Coordinator |  |  |
| Signature: |  | Date: |
| Adriane P. Borgias Author / Project Manager, Water Quality Program, Eastern Regional Office |  |  |
| Signature: |  | Date: |
| David Dilks, LimnoTech, Advisor |  |  |
| Signature: |  | Date: |
| Mike Hermanson, Spokane County, Advisor |  |  |
| Signature: |  | Date: |
| Ted Hamlin, Field Coordinator, Water Quality Program, Eastern Regional Office |  |  |
| Signature: |  | Date: |
| Richard Grace, Laboratory, AXYS Analytical Services |  |  |
| Signature: |  | Date: |
| Jim Bellatty, Section Manager, Water Quality Program, Eastern Regional Office |  |  |
|  |  |  |
| Signature: |  | Date: |
| Bill Kammin, Ecology Quality Assurance Officer  EAP: Environmental Assessment Program |  |  |

Signatures are not available on the Internet version.

# Abstract

Washington State Department of Ecology, Urban Waters, in collaboration with Spokane County proposes to collect groundwater data from a select set of Spokane Valley-Rathdrum Prairie aquifer wells and springs located adjacent to the Spokane River. The objectives of the study are to 1) characterize PCB concentrations in groundwater at the Idaho-Washington state line, and groundwater inputs to the river upstream of Kaiser Aluminum in Spokane Valley, 2) evaluate groundwater concentrations of PCB in the aquifer near gaining reaches, 3) correlate groundwater measurements with 2015 in-river synoptic studies and mass balance determinations, 4) check for potential sources of PCB contamination in groundwater that might reach the river, and 5) characterize PCB concentrations of source water for the Spokane Fish Hatchery, which discharges to the Little Spokane River.

Up to 20 environmental samples will be collected in three sampling periods, representative of the Spokane River’s three major flow regimes. Samples, consisting of groundwater and spring water, will be collected using Ecology’s Standard Operating Procedure for Purging and Sampling Monitoring Wells Plus Guidance on Collecting Samples for Volatiles and other Organic Compounds (EAP SOP 078) and analyzed for PCB congeners using EPA Method 1668C.

This project is proposed as Addendum 3 to the Ecology-approved *Quality Assurance Project Plan (QAPP), Spokane River Toxics Reduction Strategy Study*, prepared by LimnoTech, Inc. in July 2014 and published at: http://srrttf.org/wp-content/uploads/2013/05/QAPP\_FINAL\_081114.pdf.

*Addendum 1, August 1, 2015:* <http://srrttf.org/wp-content/uploads/2015/08/Spokane_River_QAPP_Addendum1_signed_081715.pdf>

*Addendum 2, February 29, 2016:* <http://srrttf.org/wp-content/uploads/2016/06/QAPP_addendum2_final_022916.pdf>

This project follows all aspects of the 2014 Spokane River Toxics Reduction Strategy QAPP, except for the noted changes and additions in this Addendum. The headings below refer to the 2014 QAPP.

# Section 1.0 Project Management

Spokane River Regional Toxics Task Force (SRRTTF) is Ecology’s client for this study. Funding for this project is provided by Ecology through the Urban Waters Initiative. Spokane County is assisting with the sampling activities. To ensure consistency with other sampling efforts, quality assurance activities will be aligned with the 2014 Spokane River Toxics Reduction Strategy QAPP, with data quality assurance and review performed by LimnoTech.

Ecology will coordinate with LimnoTech as Technical Advisor and AXYS Analytical to ensure consistency of data and methods.

Washington State Department of Ecology is responsible for the preparation of Addendum 3 of the QAPP and the proposed activities. Table 1 contains the Project Team Responsibilities uniquely assigned to Addendum 3.

## Section 1.1 Project Organization

**Table 1. Project Team and Responsibilities**

| Name/Affiliation | Project Title | Responsibilities |
| --- | --- | --- |
| SRRTTF | Ecology Client | Advises and provides direction  Reviews and uses project results |
| Bud Leber – SRRTTF-ACE  Kaiser Aluminum  Spokane Valley, WA  (509) 927-6445 | Coordinator | **Technical Coordination**  Manages work associated with concurrent Addendums 1 and 2 of QAPP.  Coordinates LimnoTech contract activities.  Communicates with Ecology and the SRRTTF. |
| Adriane Borgias  Department of Ecology  Water Quality Section  Eastern Regional Office  Spokane, WA  Phone: 509-329-3515 | Project Manager | **Coordinates project**  Writes Addendum 3 of the QAPP  Conducts QA review of data, analyzes and interprets data, and ensures data is entered into EIM  Assists with draft and final report. |
| Spokane County Utilities  Mike Hermanson  Ben Brattebo  Rob Lindsay  Spokane, WA  Phone: 509-477-7576 | Advisor  Field Assistance | Provides technical direction  Provides access to County resource wells and spring sampling locations.  Collects samples and field data.  Assists with the draft report and final report. |
| David Dilks  LimnoTech Staff  Ann Arbor, MI  734-332-1200 | Advisors | Project Manager for concurrent Addendums 1 and 2 activities.  Advises Ecology on technical matters for Addendum 3  Provides Data Quality Assurance  Reviews data for consistence with the 2014 QAPP and Addendum 3. |
| Ted Hamlin  Department of Ecology  Water Quality Section  Eastern Regional Office  Spokane, WA  Phone: 509-329-3573 | Field Coordinator | Conducts Sample Collection  Collects samples and field data  Documents sampling activities  Coordinates and manages sample delivery to laboratory |
| Richard Grace  Director - Sales, Marketing, and Service  AXYS Analytical Services Ltd.  2045 Mills Road West  Sidney, British Columbia  V8L 5X2  Toll Free - 1-888-373-0881  e-mail - [rgrace@axys.com](mailto:rgrace@axys.com) | Laboratory | Provides chemical analysis services and data packages.  Coordinates with MEL QA Coordinator. |
| Bill Kammin  Department of Ecology  Environmental Assessment Program  Lacy, WA  360-407-6964 | Ecology Quality Assurance  Officer | Reviews and approves the QAPP Addendum 3. |
| Pam Marti  Department of Ecology  Environmental Assessment Program | Hydrogeologist | Reviews draft and final report.  Enters data into EIM. |

Figure . Organization Chart

## Section 1.2 Project Background

In August 2014, the Spokane River Regional Toxics Task Force (Task Force) conducted dry weather synoptic sampling in the Spokane River. The “Synoptic Survey” provided information about in-stream PCB concentrations and groundwater contributions, and identified the potential for PCB loading to the river from up-gradient sources. The Task Force conducted additional in-stream studies during Spokane River’s low-flow conditions in August 2015. The August 2015 dry weather sampling (Addendum 1 to the Spokane River Toxics Reduction Strategy Study) will result in a refined understanding of in-stream PCB concentrations and potential groundwater loading.

This study, conducted by the Department of Ecology, Urban Waters Initiative, and Spokane County, proposes to collect groundwater and spring water samples from seven locations in the Spokane Valley Aquifer. The selected locations provide a more complete understanding of the relationship of PCBs in groundwater and impacts to the Spokane River.

The Project Objectives for Addendum 3 are:

1. Characterize PCB concentrations in groundwater at the Idaho-Washington state line, and groundwater inputs to the river upstream of Kaiser Aluminum in Spokane Valley.
2. Evaluate groundwater concentrations in the aquifer in gaining reaches at locations close to the river.
3. Correlate groundwater data with the in-stream concentrations from the synoptic surveys.
4. Check for groundwater sources of PCB that potentially discharge to the river.
5. Characterize the PCB concentrations of source water for the Spokane Fish Hatchery, which discharges to the Little Spokane River.

## Section 1.3 Project/Task Description and Schedule

### 1.3.1 Confidence Interval Testing

The confidence interval testing performed in 2014 provides a general estimate of the confidence limits for this data set.[[1]](#footnote-1)

### 1.3.2 Sampling Approach

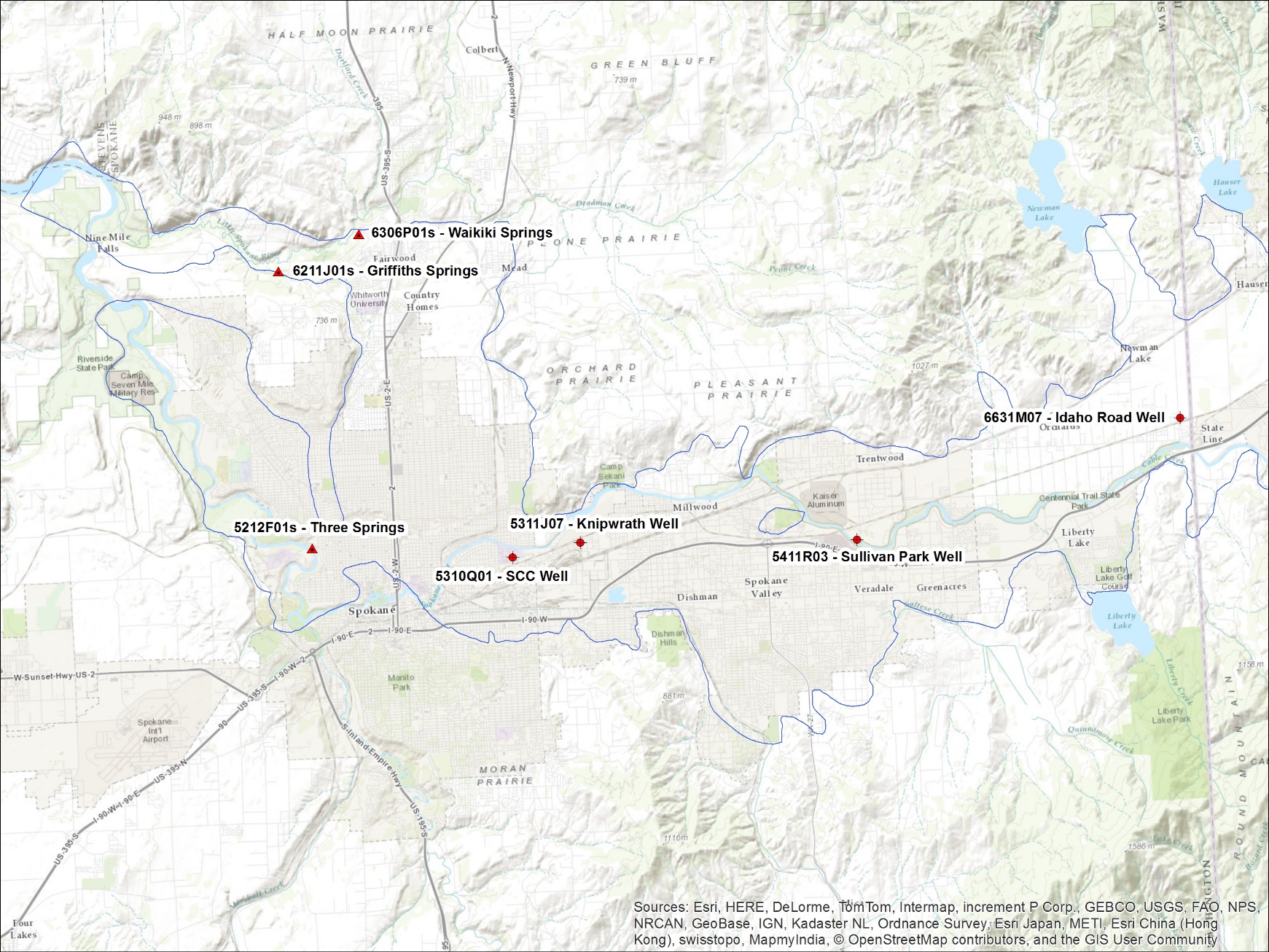
The sampling approach consists of:

1. Sample select wells (4) and springs (up to 3) between the Idaho-Washington state line and the Little Spokane River. See Figure 2 for location of sampling points.
2. Wells will be sampled using the Ecology’s “Standard Operating Procedure for Purging and Sampling Monitoring Wells Plus Guidance on Collecting Samples for Volatiles and other Organic Compounds (EAP SOP 078) (See Appendix A of this Addendum.) This SOP provides direction for a variety of sampling scenarios and analytes. The following are the specific equipment and protocols used in this sampling effort:
   1. A Grundfos Redi-Flo2 stainless steel submersible pump will be used.
   2. Laboratory pre-cleaned Teflon tubing will be used. New tubing will be used for every sample collected.
   3. Low-flow sampling techniques will be used. Samples will be collected when three consecutive readings taken 3 minutes apart are within the following, as suggested by ASTM Practice D 6771:
      1. pH: ± 0.2 pH units
      2. Conductivity: ± 3% of reading
      3. Dissolved Oxygen: ± 10% of reading or ± 0.2 mg/l, whichever is greater.
      4. Turbidity: Turbidity readings will not be collected because the SVRP aquifer produces turbidity close or at 0.0 NTU consistently.
   4. Clean hands-dirty hands sampling protocol will be used.
   5. The pump will be cleaned prior to sampling the first well and between each subsequent well. Cleaning will include a deionized water with liquinox rinse followed by a deionized water rinse. Deionized water will be supplied by the laboratory.
   6. At least one field blank will be collected during each sampling event. The field blank will be a laboratory provided sample collection bottle with laboratory provided deionized water. The field blank will be opened to the atmosphere during the time that the environmental sample is collected.
   7. An equipment rinsate blank will be collected during the first sampling event. The rinsate blank will be laboratory provided deionized water run through the pump and tubing. The pump will be cleaned prior to collection of the rinsate blank.
   8. The samples will be approximately 2 L.
   9. The pump will be placed such that it is collecting samples from the top of the water table as allowed by well construction. The pump will be placed just below the top of screen, and when the screen extends above the static water level the pump will be placed just below the static water level.
   10. A gas powered generator is necessary for pump operation. The generator will be positioned down wind and as far away as possible from the well.
3. Springs will be sampled using the “Spokane River Toxics Reduction Strategy Study, Sampling and Analysis Plan” dated July 31, 2014.[[2]](#footnote-2)
4. Collect 3 sets of data representative of the major flow regimes in the Spokane River:
   1. summer/fall low flow;
   2. winter mid flow; and
   3. spring high flow.
5. If possible, coordinate low flow sampling with the 2015-6 in-stream synoptic sampling event in order to better correlate groundwater data with in-stream PCB concentrations.

**Table 2. Sampling Location and Justification**

| Identification Number | Type | Location | Justification |
| --- | --- | --- | --- |
| 6631M07 | Well | Idaho Road | Well location characterizes groundwater PCB concentrations at stateline. |
| 5411R03 | Well | Sullivan Park | Well location upriver from Kaiser Aluminum Trentwood property. |
| 5311J07 | Well | Knipwrath | Well location characterizes groundwater PCB concentrations downgradient of the operating pool for Upriver Dam, a losing reach of the river, and up-gradient of a significant gaining reach. |
| 531Q01 | Well | Spokane Community College | Located downgradient of known toxics cleanup sites with PCB contaminated groundwater, and characterizes aquifer PCB concentrations prior to discharge to the Spokane River. The river reach between Upriver Dam and Greene Street gains over 200 cfs during low flow periods. |
| 5212F01S | Spring | Three Springs | Captures groundwater inputs into the Spokane River from Western Arm of the Spokane Valley Rathdrum Prairie aquifer. |
| 6306P01S | Spring | Waikiki Springs | Captures groundwater inputs into the Little Spokane River from the Hillyard Trough (north fork of aquifer) |
| 6211J01S | Spring | Griffiths Springs | Source water for the Little Spokane Fish Hatchery |

**Figure 2. Sample Locations**



### 1.3.4 Parameters

The study parameters for Addendum 3 include PCB congeners, temperature, conductivity, pH, dissolved oxygen, and depth to groundwater. The parameters are summarized in Table 2.

**Table 3. Sample Parameters**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Parameter | Matrix | Number of Samples | Expected Range of Results | Analytical  Method | Instrument Range | Sensitivity/Method Detection Limit |
| PCB Congeners (pg/L) | Water | 20 | 10-10,000 | EPA 1668C: AXYS MLA 010 with specific DLs and blank criteria per the original QAPP. | NA | 1-20 |
| Temperature (o C) | Water | 20 | 7-15 | YSI 556[[3]](#footnote-3) | -5 to 50 oC/  -5 to 45 oC/ | ±0.10 oC |
| Conductivity (mS/cm) | Water | 20 | 40-305 | YSI 556 | 0-100 mS/cm | ±0.5%/±1% of range |
| pH | Water | 20 | 6-9 | YSI 556 | 0-14 | ±0.2 |
| Dissolved Oxygen | Water | 20 | 5-11 | YSI 556 | 0 to 50 mg/L | 0 to 50 mg/L |
| Depth to Groundwater | Water | 20 |  | Direct measurement |  |  |

### 1.3.5 Schedule

The schedule for Addendum 3 is in Table 3

|  |  |  |
| --- | --- | --- |
| QAPP Addendum 3 |  |  |
| QAPP Addendum 3 approved for sampling  Final QAPP Approval | August 10, 2015  September xx, 2016 |  |
| Field and laboratory work | Due date | Lead staff |
| Low Flow conditions  Field work completed | August 24, 2015  September 14-15, 2015 | Ted Hamlin |
| Low Flow conditions  Laboratory analyses completed | November 2015 | Adriane Borgias |
| Mid Winter conditions  Field work completed | February 16-17, 2016 | Ted Hamlin |
| Mid Winter conditions  Laboratory analyses completed | May 2016 | Adriane Borgias |
| Spring Flow conditions  Field work completed | May 2016 | Ted Hamlin |
| High Flow conditions  Laboratory analyses completed | August 2016 | Adriane Borgias |
| Environmental Information System (EIM) database | |  |
| EIM Study ID | ID number | |
| Product | Due date | Name |
| EIM data loaded | October 2016 | Pam Marti |
| EIM QA | December 2016 | name |
| EIM complete (\*\*\*see below) | January 2017 | name |
| Progress reports | | |
| Author lead | Mike Hermanson, Spokane County  David Dilks, LimnoTech (QA Summary)  Adriane Borgias, Department of Ecology | |
| Schedule | | |
| 1st laboratory report | November, 2015 | |
| 2nd laboratory report | May, 2016 | |
| 3rd laboratory report | June, 2016 | |
| Final report | |  |
| Author lead / support staff | Adriane Borgias / Mike Hermanson, Ben Brattebo (Spokane County), LimnoTech (QA summary) | |
| 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 (Joan) | January, 2017 | |
| Final report due on web | February, 2017 | |

### 

### 1.3.6 Budget

The analytical costs for this project are $24,000 and total project cost, including supplies and shipping is $26,424. PCB Congener analysis will be performed by AXYS, Analytical using EPA Method 1668C. The Quality Assurance evaluation will be performed by LimnoTech. The budget breakdown is in Table 4.

**Table 4. Project Budget**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Location | Sampling Events | | | | Cost per Sample |
| 8/24/2015 | 9/14-15/2015 | 2/16-17/2016 | 5/17/2016 |  |
| Idaho Road (well) |  | S, B | S | S | $750 |
| Sullivan Park (well) |  | S, B, D | S | S | $750 |
| Knipwrath Cellars (well) |  | S, B, RB | S | S, D | $750 |
| Spokane Community College (well) |  | S, B | S | S | $750 |
| Three Springs | S, D |  | S | S, B | $750 |
| Waikiki Springs | S |  | S | S, TB | $750 |
| Griffith Springs |  |  | S, TB, D | S |  |
| **Total Number of Analyses** | **3** | **10** | **9** | **10** | **32** |
| Total Cost for Analysis |  |  |  |  | **$24,000** |
| Supplies and Shipping |  |  |  |  | $2624 |
| **Total Urban Waters Project Cost** |  |  |  |  | **$26,624** |

S = Sample

B = Blank (clean water shipped from lab, cap opened during sampling, then closed)

TB = Trip Blank (clean water shipped from lab to site and returned unopened)

RB = Rinsate Blank (clean equipment rinsed with clean water and tested)

D = Duplicate analysis

### 1.4 Quality Objectives and Criteria

Refer to 2014 Spokane River Toxics Reduction Strategy QAPP.

### 1.5 Documents and Records

The approved Addendum 3 will be distributed to the list of project personnel identified in the 2014 Spokane River Toxics Reduction Strategy QAPP, the Addendum 3 signature page and posted on the Spokane River Regional Toxics Task Force at srrttf.org.

The Project Manager maintains the project files and records for this project, including data generated by the project.

## Section 2. Data Generation and Acquisition

Refer to 2014 Spokane River Toxics Reduction Strategy QAPP.

Attachment A to this Addendum contains an additional sampling procedures for collection of groundwater samples.

## Section 3. Assessment and Oversight.

Refer to 2014 Spokane River Toxics Reduction Strategy QAPP.

For the purposes of Addendum 3, the Washington State Department of Ecology serves as Project Manager.

## Section 4. Data Validation and Usability.

Refer to 2014 Spokane River Toxics Reduction Strategy QAPP.

For the purposes of Addendum 3, Washington State Department of Ecology manages the Quality Assurance aspects of the field activities and LimnoTech manages the data Quality Assurance activities.

# Attachment A

## Standard Operating Procedure for Sampling Groundwater Wells for Low Level PCB Analysis

1. LimnoTech, 2014. Confidence Testing Results from Spokane River PCB Sampling, http://srrttf.org/wp-content/uploads/2015/08/SRRTTF\_Phase\_2\_AppendixE.pdf.pdf [↑](#footnote-ref-1)
2. http://srrttf.org/wp-content/uploads/2013/05/Spokane\_SAP\_Final-080814.pdf [↑](#footnote-ref-2)
3. Operation of the YSI 556 conducted by Spokane County in accordance with the instrument operating manual. [↑](#footnote-ref-3)