Technical Report Overview

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Teck

Report: Line Creek Local Aquatic Effects Monitoring Program (LAEMP), 2016

Overview: This report presents the 2016 results of the local aquatic effects monitoring program developed for Teck's Line Creek Operations. The report presents the second year of data collection for the program, which monitors potential effects of the West Line Creek Active Water Treatment Facility on biological productivity and tissue selenium accumulation downstream of the facility.

This report was prepared for Teck by Minnow Environmental Inc.

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Future studies will be made available at **teck.com/elkvalley**

Line Creek Local Aquatic Effects Monitoring Program (LAEMP) Report, 2016

Prepared for:
Teck Coal Limited
Sparwood, British Columbia

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Line Creek Local Aquatic Effects Monitoring Program (LAEMP), 2016

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EXECUTIVE SUMMARY

A local aquatic effects monitoring program (LAEMP) for Teck's Line Creek Operation (LCO) was developed to monitor potential aquatic effects of the West Line Creek Active Water Treatment Facility (WLC AWTF), which became fully operational in February 2016. The LAEMP was designed to evaluate potential influences of the WLC AWTF on biological productivity, tissue selenium accumulation, and/or other receiving environment characteristics (e.g., water temperatures) downstream from the WLC AWTF discharge. This report presents the third year of data (2016) collection for the Line Creek LAEMP, and the first year reflecting full operation.

The aqueous phosphorus Site Performance Objective (SPO) in Permit 107517 was based on projections for effluent and receiving water phosphorus concentrations, and the periphyton chlorophyll-a SPO was based on limited available baseline data prior to WLC AWTF operation. Data collected in 2016 allowed for evaluation of conditions relative to projections and the SPO under full WLC AWTF operation. Total phosphorus concentrations in WLC AWTF effluent averaged only 0.04 mg/L in 2016 compared to the average of 0.3 mg/L projected prior to WLC AWTF operation. Consequently, concentrations of total phosphorus in Line Creek at the Compliance Point (LC_LCDSSLCC) have usually been below the projected range, and always below the SPO of 0.02 mg/L since the WLC AWTF began operating. The various indicators of primary and secondary productivity (i.e., periphyton chlorophyll-*a* and AFDM, benthic invertebrate biomass, density, and sample abundance) indicated a pattern of highest productivity at LILC3, immediately downstream from the WLC AWTF outfall, and lower productivity with increasing distance downstream, but this pattern was evident prior to WLC AWTF operation. Local and regional data showed that aqueous total phosphorus concentrations and periphyton chlorophyll-*a* levels can approach or exceed the SPO values of 0.02 mg/L and 100 mg/m^2, respectively, even at areas undisturbed by mining. Teck will be applying to amend Permit 107517 to retain the total phosphorus SPO of 0.02 mg/L, but remove the requirement for chlorophyll-a measurements. Monitoring of biological productivity will continue in the Line Creek LAEMP based on benthic invertebrate endpoints. A before-after/control-impact (BACI) analysis showed that of benthic invertebrate biomass and density (Hess samples) at areas downstream from the WLC AWTF were not any more different from the South Line Creek reference area in 2016 (full WLC AWTF operation) than prior to full WLC AWTF operation. BACI analysis also showed no effects on benthic invertebrate community structure except potentially reduced family richness at the downstream areas in 2016 relative to the reference area in previous years. Potential reduction in family-level invertebrate richness at LILC3 and LIDSL was also suggested by kick sample data collected in 2016, compared to data collected in 2014 and 2015, but not in comparison to earlier data from 2012. No adverse effect of WLC AWTF operation was evident for other community endpoints evaluated for Hess or kick samples collected in 2016 compared to previous years.

Tissue selenium data collected in 2016 and early 2017 indicate that, although the WLC AWTF has successfully reduced total selenium loads to the receiving environment, some of the residual effluent load may have shifted from being in the form of selenate, which has relatively low bioavailability (and is the dominant form in AWTF influent and in other areas of the watershed), to other selenium forms that may be more bioavailable. Tissue selenium concentrations in periphyton and benthic invertebrates were increased immediately downstream from the WLC AWTF outfall during the sampling campaigns to historical and upstream levels. Additional monitoring is required to fully understand these results, including potential effects of selenium speciation on the receiving environment.

There do not appear to be other potential influences associated with WLC AWTF operation that are not already being addressed through sampling for Key Questions #1 (productivity) and #2 (tissue selenium accumulation).The LAEMP will be repeated annually for at least two more years to allow for three years of sampling during full operation of the WLC AWTF to monitor potential changes in the receiving environment. In light of the results of the 2016 Line Creek LAEMP the sampling design will be modified for the 2017 Line Creek LAEMP study design, allowing greater resolution of spatial differences along Line Creek (i.e., additional sampling areas) and measurement of within-area variability in biological endpoints (i.e., more replicates) to improve understanding of the local aquatic effects on Line Creek associated with WLC AWTF operation.

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1 INTRODUCTION

1.1 Background

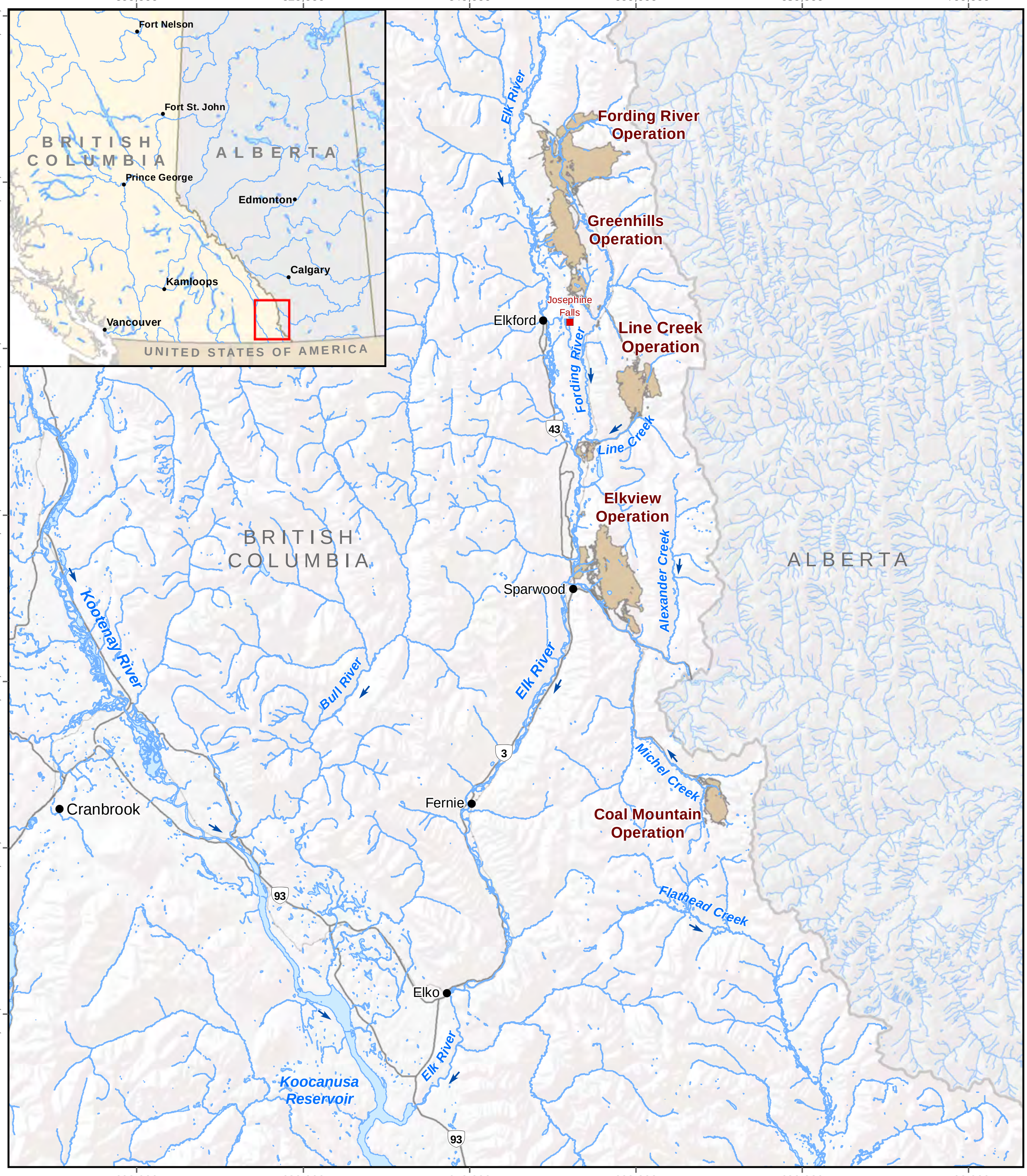
Teck Resources Limited (Teck) operates five, open pit, steelmaking coal mines in the Elk River watershed, which are the Fording River Operation (FRO), Greenhills Operation (GHO), Line Creek Operation (LCO), Elkview Operation (EVO), and Coal Mountain Operation (CMO; Figure 1.1). Discharges from the mines to the Elk River watershed are authorized by the British Columbia Ministry of Environment (MOE) through permits that are issued under provisions of the *Environmental Management Act*. Permit 107517, issued November 14, 2015, and recently amended March 1, 2017, specifies the terms and conditions associated with discharges from Teck's five Elk Valley coal mine operations.

Teck's Regional Aquatic Effects Monitoring Program (RAEMP) is a requirement under Permit 107517, and provides comprehensive routine monitoring and assessment of potential mine-related effects on the aquatic environment downstream from Teck's coal mines in the Elk Valley (i.e., every three years, with the most recent cycle of sampling completed in 2015). Teck conducts a variety of additional programs to monitor, evaluate, and/or manage the aquatic effects of mining operations within the Elk Valley at local and regional scales:

- Regional Water Quality Monitoring Program
- Regional Flow Monitoring Plan
- Regional Calcite Monitoring Program
- Chronic Toxicity Testing Program
- Regional Fish and Fish Habitat Management Program (RFFHMP)
- Tributary Evaluation and Management Plan

Permit 107517 also required that Teck develop a local aquatic effects monitoring program (LAEMP) related to commissioning of the West Line Creek Active Water Treatment Facility (WLC AWTF) as indicated in Section 9.3.1:

> *"The Permittee must develop and implement a Local Aquatic Effects Monitoring program to determine the effects of the Line Creek discharge on the receiving environment. An*



LEGEND

Teck Coal Mine Operation

Teck's Coal Mine Operations within the Elk River Watershed, Southeast British Columbia

0 10 20 40 km

Projection: North American Datum 1983 UTM Zone 11

Date: May 2017

Project 167202.0074

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Figure 1.1

Document Path: S:\Projects\167202\167202.0074 - Teck Line Creek 2016 LAEMP\GIS Mapping\LAEMP Report Maps\16-74 Fig 1.1 Teck Coal Limited Operation.mxd *annual study design for the program must be prepared in consultation with the EMC[1] and submitted to the Director for approval by May 31 each year."*

Also, Section 10.5 of Permit 107517 states:

The LAEMP Annual Reports must be reported on in accordance with generally accepted standards of good scientific practice in a written report and submitted to the Director by May 31 of each year following the data collection calendar year.

The goal of the Line Creek LAEMP is to assess site-specific issues (e.g., potential effects of active water treatment) on a more frequent and localized basis, as required until sufficient data have been collected, concerns no longer exist, or relevant monitoring can be incorporated into the RAEMP.

1.2 Key Questions (Study Objectives)

The Line Creek LAEMP was designed to evaluate effects related to the commissioning of the WLC AWTF at LCO. After a brief period of operation in late 2014 (July to October), the WLC AWTF was recommissioned starting on October 24, 2015 and has been operating at full capacity since February 2016. The fluidized bed reactor technology used at the WLC AWTF for selenium and nitrate removal requires the addition of phosphorus to the treatment process. Although the WLC AWTF is managed to minimize the amount of residual phosphorus in treated effluent, there is potential for phosphorus concentrations to increase in Line Creek downstream from the WLC AWTF discharge and potentially cause increased algal growth and change the trophic status and biotic community structure in Line Creek downstream from the WLC AWTF. Consequently, as part of the approval for WLC AWTF operation at LCO, the MOE specified Site Performance Objectives (SPOs) in Section 3.4 of Permit 107517 for a new monitoring station in Line Creek downstream from the WLC AWTF discharge and the confluence with South Line Creek (identified by Teck as LC_LCDSSLCC and in the Permit as E297110). In addition to an average total phosphorus limit of 0.02 mg/L over the growing season (June 15 to September 30), the SPO specified a limit of 100 mg/m^2 for periphyton chlorophyll-a measured as an average of at least five sub-samples collected during each of three sampling events during the growing season (Appendix C).

Another concern that was expressed prior to commissioning of the WLC AWTF was potential change in the form of selenium that would be released into Line Creek from the WLC AWTF.

[1] EMC refers to the Environmental Monitoring Committee, which Teck was required to form as a requirement of Permit 107517. The EMC consists of representatives from the MOE, the Ministry of Energy and Mines, Environment Canada, the Ktunaxa Nation, Interior Health Authority, and the Permittee. The EMC reviews submissions and provides technical advice to Teck and the MOE Director regarding monitoring programs.

Selenate has been the dominant form of selenium in surface waters downstream from Teck's coal mines, as would be expected in the well-oxygenated flowing stream habitats that dominate the Elk River watershed. At the WLC AWTF, selenium is removed via uptake into microorganisms within the treatment system. There is potential for some of the residual selenium in treated water to be in the form of selenite or other chemically-reduced forms of selenium (e.g., organoselenium), which are accumulated into the base of the food web more readily than selenate (Ogle et al. 1988; Riedel et al. 1996; Stewart et al. 2010). Therefore, although the WLC AWTF is designed to reduce total selenium loads to Line Creek there is potential that selenium concentrations in tissues of biota may not show a similar reduction. Therefore, the Line Creek LAEMP, was designed to evaluate biological productivity and tissue selenium accumulation downstream from the WLC AWTF discharge (Minnow 2014), beginning with collection of baseline data in 2014 prior to commissioning of the WLC AWTF (Minnow 2015a), and continued monitoring in 2015 (Minnow 2015b, 2016a). Another concern raised subsequently was potential effects on aquatic biota of changes to instream temperatures or dissolved oxygen, as well as effects related to constituents other than selenium or nutrients related to operation of the WLC AWTF.

Based on the information described above, and consultation with the EMC beginning in 2015, the objectives for the Line Creek LAEMP were updated and re-stated as key questions in 2016:

1. Is active water treatment affecting biological productivity downstream in Line Creek?
2. Are tissue selenium concentrations reduced downstream from the WLC AWTF?
3. Is WLC AWTF operation affecting aquatic biota through thermal effects, effects on dissolved oxygen concentrations, or concentrations of treatment-related constituents other than nutrients or selenium?

1.3 Linkages to the Adaptive Management Plan for Teck Coal in the Elk Valley

As required in Permit 107517 Section 11, Teck has developed an Adaptive Management Plan (AMP) to support implementation of the Elk Valley Water Quality Plan (EVWQP), to achieve water quality and calcite targets, ensure that human health and the environment are protected, and where necessary, restored, and to facilitate continual improvement of water quality management in the Elk Valley. The AMP was submitted to the EMC and MOE Director July 31, 2016 as required by the Permit. Study designs for many programs were established before the AMP was submitted. The AMP is currently under review and Teck is working to incorporate input received from the EMC. Teck will work to embed elements of the AMP within each program through reviews of monitoring programs at the study design and annual report stages through implementation of the AMP. Data from the RAEMP and the various LAEMPs will feed into the adaptive management process to specifically address Big Questions #5 (Does monitoring for mine-related effects indicate that the aquatic ecosystem is healthy?) and #2 (Will aquatic ecosystem health be protected by meeting the long-term site performance objectives?). Following an adaptive management framework, evaluation of data collected in 2016 was used to inform adjustments to the 2017 Line Creek LAEMP study design.

2 METHODS

2.1 Overview

The general approach for the Line Creek LAEMP is summarized in Table 2.1, which explains the data that were collected and evaluated in relation to each of the key study questions. Monitoring locations listed in Table 2.2 are shown in Figure 2.1. These represent the same locations that were sampled for the LAEMP in 2014 and 2015 with the addition of LCUT for 2016. In response to the key questions described in Section 1.2, the 2016 LCO LAEMP includes evaluation of the following components, as described in more detail in Table 2.1:

- Periphyton chlorophyll-a concentrations, ash free dry mass (AFDM), and tissue selenium concentrations;
- Benthic invertebrate biomass, community and tissue selenium concentrations;
- Concentrations of nutrients, total selenium, and selenium species in water (based on LCO's routine water monitoring program);
- Water temperature downstream and upstream of the WLC AWTF;
- Water toxicity at the outlet of the WLC AWTF and at the Compliance Point (LC_LCDSSLCC / LIDSL); and
- *In situ* water quality (including temperature and dissolved oxygen) at routine water quality monitoring locations, and the influent and effluent of the WLC AWTF.

Water sampling associated with LCO and the WLC AWTF was completed annually, as required under Permit 107517 (Table 2.3).

Biological samples associated with the 2016 LAEMP (i.e., benthic invertebrates) were collected from September 7th to 10th, 2016 and February 28th to March 2nd 2017.

2.2 Water Quality

2.2.1 Routine Water Quality

Routine water quality monitoring data collected by Teck were downloaded from Teck's EQuIS^{TM} database for the monitoring stations that correspond to biological sampling areas, for assessment as part of the LAEMP (Table 2.3 and Figure 2.1):

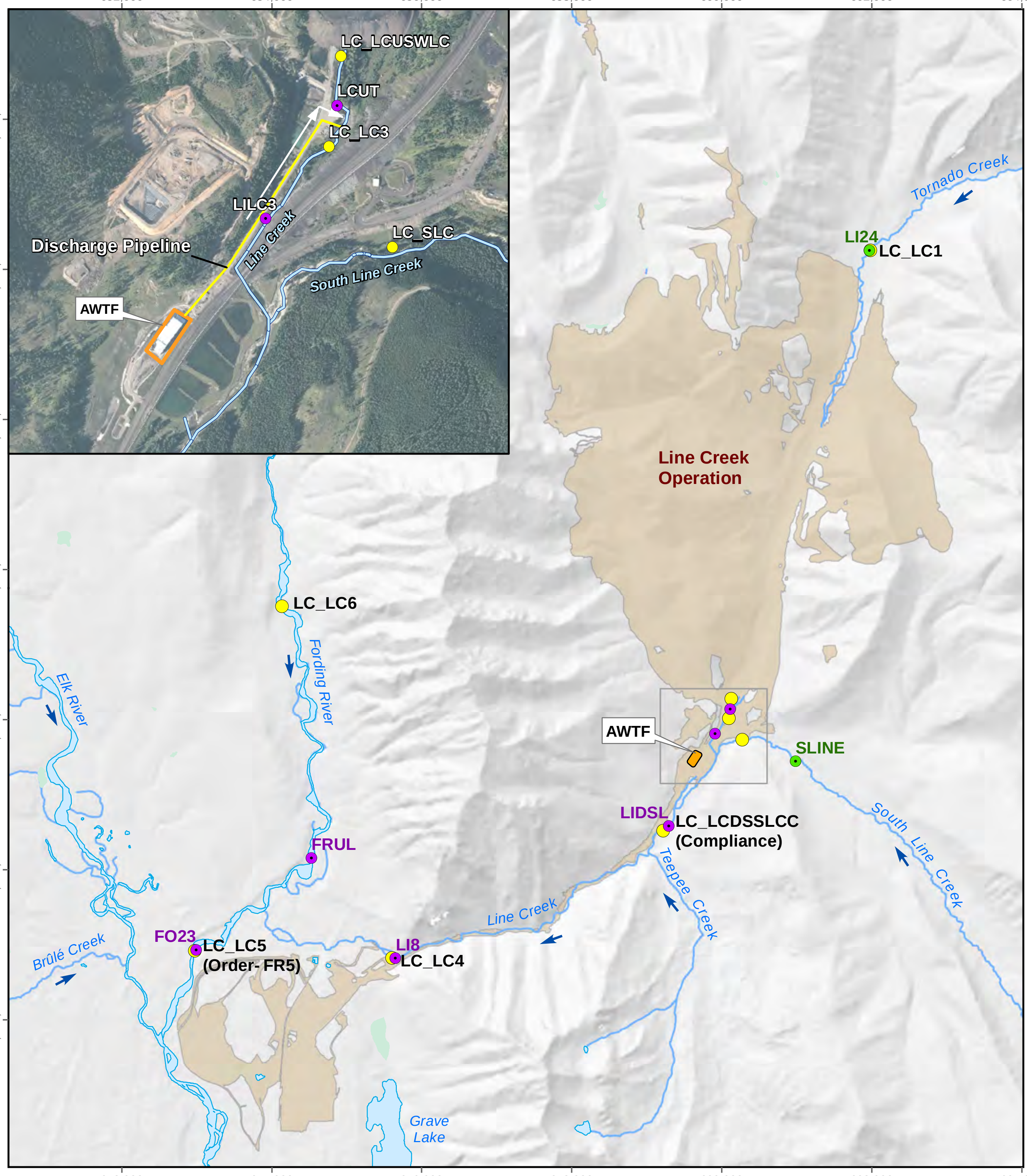
- Nutrient concentrations (i.e., nitrate, nitrite, ammonia, total Kjeldahl nitrogen [TKN], total phosphorus, and ortho-phosphate);

Table 2.1: Summary of 2016 LAEMP for Line Creek

Key Questions	Assessment Endpoints	Measurement Endpoints				How Data was Evaluated to Address Key Question
		Water	Sampling Areas	Biological	Sampling Areas	
Is active water treatment affecting biological productivity downstream in Line Creek?	Biological productivity downstream from the AWTF discharge post- compared to pre-AWTF commissioning and relative to productivity observed upstream from the discharge	Nutrient concentrations	LC_LC1 (LI24), LC_SLC (SLINE), LC_LC3 (LILC3), LC_LCDSSLCC (LIDSL), LC_LC4 (LI8), LC_LC6 (FRUL), LC_LC5 (FO23) (see Table 2.2 for timing)	Benthic invertebrate biomass, Benthic invertebrate community structure	Biomass - SLINE, LILC3, LIDSL Community - LI24, SLINE, LCUT, LILC3, LIDSL, LI8, FRUL, FO23 (annually)	Determine if there is an increase in benthic invertebrate biomass, or shift in community structure, that corresponds with other measures of productivity (e.g., periphyton chlorophyll-a, AFDM), over time.
Are tissue selenium concentrations reduced downstream from the AWTF?	Tissue selenium concentrations downstream from the AWTF discharge post- compared to pre-AWTF commissioning and relative to concentrations observed upstream from the discharge	Total and dissolved selenium concentrations	LC_LC1 (LI24), LC_SLC (SLINE), LC_LC3 (LILC3), LC_LCDSSLCC (LIDSL), LC_LC4 (LI8), LC_LC6 (FRUL), LC_LC5 (FO23) (see Table 2.2 for timing)	Periphyton tissue selenium, Benthic invertebrate tissue selenium (composite and single taxon samples)	Periphyton - LCUT, LILC3, LIDSL, LI8 (September 2016 and February 2017) Benthic Invertebrates - LI24, SLINE, LCUT, LILC3, LIDSL, LI8, FRUL, FO23 (annually and February 2017)	Determine if there is a change in periphyton and benthic invertebrate tissue selenium concentrations over time that corresponds to changes in total selenium concentrations or selenium speciation in water. Benthic invertebrate community data being collected for other purposes can be used as supporting evidence of ecosystem health status downstream from the AWTF.
		Selenium speciation	WL_WLCI_SP01, WL_LCI_SP02, WL_BFBW_SP21, LC_LC3 (LILC3), LC_LCDSSLCC (LIDSL), LC_LC4 (LI8) (see Table 2.2 for timing)			
Is AWTF operation affecting aquatic biota through thermal effects, effects on dissolved oxygen concentrations or concentrations of treatment-related constituents other than nutrients or selenium?	Biological community structure downstream from the AWTF discharge post-compared to pre-AWTF commissioning and relative to community structure observed upstream from the discharge	Temperature (data loggers)	Not completed in 2016	Benthic invertebrate community structure	LILC3, LIDSL, LI8 (annually)	Evaluate effects of AWTF discharge on water temperature and oxygen concentrations relative to BC guidelines for the protection of aquatic health. Benthic invertebrate community data being collected for other purposes can be used as supporting evidence of ecosystem health status downstream from the AWTF.
		Dissolved oxygen	WL_LCI_SP02, WL_WLCI_SP01, WL_BFWB_OUT_SP21, LC_LC3 (LILC3), LC_LCDSSLCC (LIDSL), LC_LC4 (LI8) (see Table 2.2 for timing)	Benthic invertebrate community structure	LILC3, LIDSL, LI8 (annually)	
		Toxicity	WL_BFWB_OUT_SP21, LC_LCDSSLCC (LIDSL) (see Table 2.2 for timing)	Benthic invertebrate community structure	LI24, SLINE, LILC3, LIDSL, LI8, FRUL, FO23 (annually)	Evaluate effluent and receiving water toxicity test results. Determine if there is a change in benthic invertebrate community endpoints away from the reference condition that does not correspond to observed changes in nutrient or selenium concentrations.

Table 2.2: **Monitoring Areas Associated with the 2016 Line Creek LAEMP**

Location Description		Biological Sampling			Teck Water Quality		
		Station ID (Teck water	UTM (11U)		Area Code	UTM (11U)	
			Easting	Northing		Easting	Northing
Reference	Tornado Creek (south fork of upper Line Creek)	LI24	662214	5538393	LC_LC1	661979	5538254
	South Line Creek	SLINE	661122	5531374	LC_SLC	660271	5531737
Mine-Exposed Line Creek	Line Creek upstream of the AWTF	LCUT	660114	5532140	LC_LCUSWLC	660114	5532140
	Line Creek upstream South Line Creek and downstream AWTF discharge	LILC3	659947	5531859	LC_LC3	660090	5532023
	Line Creek downstream South Line Creek and AWTF discharge	LIDSL	659293	5530590	LC_LCDSSLCC	659218	5530522
	Line Creek near mouth	LI8	655421	5528967	LC_LC4	655604	5528824
Mine-Exposed Fording River	Fording River upstream Line Creek	FRUL	654549	5530179	LC_LC6	654140	5533513
	Fording River downstream Line Creek	FO23	652962	5528825	LC_LC5	652977	5528919



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- Exposed Biological Monitoring Area
- Reference Biological Monitoring Area
- Teck Water Quality Station
- Active Water Treatment Facility (AWTF)
- Teck Coal Mine Operation

Line Creek LAEMP Biological Monitoring Areas and Teck Water Quality Stations, 2016

0 1.25 2.5 5 km

Map Projection: UTM Zone 11N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada. All rights reserved.

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Figure 2.1

Document Path: S:\Projects\167202\167202.0074 - Teck Line Creek 2016 LAEMP\GIS Mapping\LAEMP Report Maps\16-74 Fig 2.1 LAEMP Monitoring Areas.mxd

Table 2.3: **Summary of Water Quality Monitoring Associated with the LAEMP**

Location Description	Water Station ID (associated biological Station ID in brackets)	EMS Number	UTM (11U)		Water Quality Samples				
			Easting	Northing	Designation	Field parameters[a]	Selenium speciation[b]	Toxicity[c]	All other parameters required under mine permits[d]
Line Creek upstream of LCO	LC_LC1 (LI24)	E216142	661979	5538254	Reference	T	-	-	W/M
South Line Creek	LC_SLC (SLINE)	E282149	660271	5531737	Reference	T	-	-	M
Line Creek AWTF Influent	WL_LCI_SP02	E293371	660138	5532109	Exposed	D	M	-	M
West Line Creek AWTF Influent	WL_WLCI_SP01	E293370	660011	5532218	Exposed	D	M	-	M
AWTF Effluent (buffer pond discharge)	WL_BFBW_OUT_SP21	E291569	660050	5532070	Exposed	D	M	W	M[e]
Line Creek ~200 m downstream of the AWTF	LC_LC3 (LILC3)	200337	660090	5532023	Exposed	T	M	-	W/M
Line Creek downstream South Line Creek	LC_LCDSSLCC (LIDSL)	E297110	659218	5530522	Exposed	T	M	Q/SA[f]	W/M[g]
Line Creek upstream of the process plant and ~5,550 m downstream of the AWTF	LC_LC4 (LI8)	200044	655604	5528824	Exposed	T	M	-	W/M
Fording River upstream Line Creek	LC_LC6 (FRUL)	200338	654140	5533513	Exposed	M	-	-	M
Fording River downstream Line Creek	LC_LC5 (FO23)	200028	652977	5528919	Exposed	M	-	-	W/M

D - Daily; T - twice monthly; M - monthly; W - weekly during freshet (March 15 to July 15); Q - quarterly. Sampling frequency is currently managed through the permit, and after one year of data collection during sustained operation of the AWTF, sampling frequency may be adjusted.

[a] Dissolved oxygen, water temperature, specific conductance, pH.

[b] Selenate, selenite, organoselenium.

[c] Acute and chronic as per Permit 107517 requirements.

[d] Total and dissolved metals, total and dissolved organic carbon, nutrients, major ions, etc. as per Table 18 of Permit 107517 or Table 3 of Permit 5353.

[e] Three times weekly for selenium and nitrate.

[f] Q = 7 day *C. Dubia* and 72 hr Subcapitatpa and SA = 30 day early life stage rainbow trout.

[g] Total phosphorus every two weeks from June 15 - September 30th.

- Total and dissolved selenium concentrations and selenium speciation data (i.e., concentrations of selenate, selenite, dimethylselenoxide, selenocyanate, selenosulfate, methylseleninic acid, and selenomethionine).
- *In situ* water quality data (i.e., temperature, pH, conductivity, and dissolved oxygen).

Quality assurance and quality control (QA/QC) associated with water sampling were presented by Teck in the annual water quality report for Permit 107517 (e.g., Teck 2017).

2.2.2 Toxicity Testing

Water samples were collected three times at LC_LCDSSLCC in 2016 for acute toxicity testing, as stipulated in Permit 106970 (Table 2.1; Figure 2.1). The following acute toxicity tests were conducted on the water at LC_LCDSSLCC:

- Acute Lethality Test using Rainbow Trout (*Oncorhynchus mykiss*); Report EPS 1/RM/9 July 1990 (with May 1996 and May 2007 amendments; Environment Canada 2007a); and
- Acute Lethality Test using *Daphnia* spp.; Report EPS 1/RM/11 July 1990 (with May 1996 amendments; Environment Canada 1996).

The following waterborne chronic toxicity tests were completed at the Compliance Point (LC_LCDSSLCC based on requirements of Permit 107517) on a quarterly basis:

- 72-hour growth/inhibition test using a freshwater alga (*Pseudokirchneriella subcapitata*) (EPS1/RM/25; Environment Canada 2007b);
- 7-day test of reproduction and survival using the cladoceran, *Ceriodaphnia dubia* (EPS1/RM/21; Environment Canada 2007c);
- 30-day test of larval survival and growth using the fathead minnow, *Pimephales promelas* (U.S.EPA Method 1000.0); and
- A modified 28-day water-only test with the amphipod, *Hyalella azteca*. This test is not a standard test but rather has been modified from “Methods for measuring the toxicity and bioaccumulation of sediment-associated contaminants with freshwater invertebrates (second edition)”, EPA/600/R-99/064.

Also, 30-day early life stage toxicity tests using rainbow trout, *Oncorhynchus mykiss* (EPS 1/RM/28-1E) are conducted semi-annually (once in spring, once in fall).

Toxicity tests and associated QA/QC measures were completed and reported by the biological testing laboratory contracted by Teck in accordance with the above listed methods. The results were summarized by Teck in reports completed in accordance with Permit 107517 (Teck 2016, 2017) and applicable results (i.e., for stations in Line Creek) are summarized in this report.

2.3 Primary Productivity

Periphyton samples were collected for analysis of chlorophyll-a and AFDM at seven areas in September 2016 (Table 2.4). Three areas were situated downstream from the WLC AWTF on Line Creek: LILC3 (LC_LC3), LIDSL (LC_LDCSSLCC), and LI8 (LC_LC4). Two reference areas on Line Creek were also sampled: LI24 (LC_LC1) and SLINE (LC_SLC), as were two areas in the Fording River upstream (FRUL/LC_LC6) and downstream (FO23/LC_LC5) of Line Creek (Table 2.4; Figure 2.1). All productivity endpoints were measured in September, however periphyton chlorophyll-a was also evaluated four additional times (2 with n=1 and 2 with n=5) at LIDSL (LC_LCDSSLCC) during the growing season (July to Sept) in accordance with the SPO in Permit 107517, which stipulates a minimum of three sampling events between July 15 and September 30.

Periphyton samples were collected from riffle habitats with a water depth of at least 10 cm and uniform substrate characteristics. When a sampling area with such characteristics was identified, a relatively flat rock of at least 12 cm in length was sampled. If a rock chosen by this method was judged unsuitable for sampling (e.g., highly angular, or uncharacteristic surface texture), an alternative rock in close proximity, having visibly similar periphyton coverage, was sampled instead. This approach was used to try and minimize the variability in chlorophyll-a and AFDM that is attributable to variations in natural habitat.

For each periphyton chlorophyll-a sample, a total of five suitable rocks were selected and taken to shore for sampling. A thin acetate template with a 4 cm^2 opening was placed on the rock, and all periphyton within the opening was removed from the rock using a scalpel. This process was repeated on each of the five rocks, and all five scrapings were placed on a wetted Whatman® GF/F glass fiber filter (e.g., 90 mm diameter, 0.7 µm pore size) to provide a single, composite sample per station. The filter paper containing the sample was then folded in half twice and tightly wrapped in aluminum foil. The foil wrapped samples were placed in a labelled Whirl-Pak® bag and stored in a cooler with freezer packs (in the field) until transfer to a freezer later in the day. Samples can be stored frozen for up to 30 days as long as they are not exposed to light (APHA et al. 1998).

The same rocks sampled for chlorophyll-a analysis were also used to collect separate scrapings for analysis of AFDM (Table 2.4). Each composite sample for AFDM analysis was placed in a small sealed container and kept cool until transfer to a freezer later in the day.

Samples for AFDM and chlorophyll-a analysis were shipped frozen to ALS Environmental (Calgary, AB or Burnaby, BC). Analysis of chlorophyll-a was completed using procedures adapted from EPA Method 445.0; involving routine acetone extraction followed by fluorescence detection using a non-acidification procedure (a method that is not subject to interferences from

Table 2.4: Biological Monitoring Associated with the 2016 Line Creek LAEMP

Location Description		Teck Water Quality Station	EMS Number	Biological Sampling			Periphyton			Benthic Invertebrates			Periphyton		Benthic Invertebrates						
				Station ID	UTM (11U)					Hess		Kick and Sweep			Composite		Rhyacophilidae		Ephemeroptera	Chironomidae	*Parapsyche sp.*
					Easting	Northing	Productivity				Community		Tissue Selenium								
							Chlorophyll-*a*		AFDM	Biomass											
							September						September	February	September	February	September	February	September	February	
Reference	Tornado Creek (south fork of upper Line Creek)	LC_LC1	E216142	LI24	662214	5538393	-	n=1	n=1	-	-	n=1	n=1	-	n=1	-	n=1	-	n=1	-	-
Reference	South Line Creek	LC_SLC	E282149	SLINE	661122	5531374	-	n=1	n=1	n=10	n=10	n=1	n=1	-	n=1	-	n=1	-	n=1	-	-
Mine-exposed Line Creek	Line Creek upstream of the AWTF	LC_LCUSWLC	-	LCUT	660114	5532140	-	-	-	-	-	n=1	n=1	n=10	n=1	n=5	n=1	n=1	n=1	n=1	n=1
Mine-exposed Line Creek	Line Creek upstream South Line Creek and downstream AWTF discharge	LC_LC3	200337	LILC3	659947	5531859	-	n=1	n=1	n=10	n=10	n=1	n=1	n=10	n=1	n=5	n=1	n=1	n=1	n=1	n=1
Mine-exposed Line Creek	Line Creek downstream South Line Creek and AWTF discharge	LC_LCDSSLCC	E297110	LIDSL	659293	5530590	n=5[a]	n=5	n=1	n=10	n=10	n=1	n=1	n=10	n=1	n=5	n=1	n=1	n=1	n=1	n=1
Mine-exposed Line Creek	Line Creek near mouth	LC_LC4	200044	LI8	655421	5528967	-	n=1	n=1	-	-	n=1	n=1	n=10	n=1	n=5	n=1	n=1	n=1	-	n=1
Mine-exposed Fording River	Fording River upstream Line Creek	LC_LC6	200338	FRUL	654549	5530179	-	n=1	n=1	-	-	n=1	n=1	-	n=1	-	n=1	-	n=1	-	-
Mine-exposed Fording River	Fording River downstream Line Creek	LC_LC5	200028	FO23	652962	5528825	-	n=1	n=1	-	-	n=1	n=1	-	n=1	-	n=1	-	n=1	-	-

Notes: All sampling was conducted by Minnow during the September sampling period unless otherwise noted.

[a] Periphyton chlorophyll-a sampled by Teck a minimum of 3 times per growing season (July 15 to Sept 30), sample dates: 14-Jul-16 (n=1), 27-Jul-16 (n=1), 23-Aug-16, 7-Sept-16, and 21-Sept-16 (n=5)

chlorophyll-b). Analysis of AFDM followed procedures modified from American Public Health Association (APHA) Method 10300 C. Total AFDM was calculated as the difference between the dried sample weight and the ash weight, both of which were determined gravimetrically. Dry weight was determined by drying the sample at 105°C, and the ash weight was subsequently determined by ashing the dried sample at 500°C.

Periphyton coverage was also visually scored at each station in September based on the categories stipulated by the Canadian Aquatic Biomonitoring Network (CABIN) protocol (Environment Canada 2012):

1. Rocks not slippery, no obvious color (<0.5 mm thick)
2. Rocks slightly slippery, yellow-brown to light green color (0.5 - 1 mm thick)
3. Rocks have noticeable slippery feel, patches of thicker green to brown algae (1-5 mm thick)
4. Rocks are very slippery, numerous clumps (5-20 mm thick)
5. Rocks mostly obscured by algae mat, may have long strands (>20 mm thick)

2.4 Secondary Productivity and Community (Hess Sampling)

Ten stations were sampled at three of the Line Creek areas (SLINE, LILC3, and LIDSL) in September for analysis of benthic invertebrate biomass and community structure (Table 2.4; Figure 2.1). Benthic invertebrates were collected using a Hess sampler with 500 µm mesh, for measurement of biomass and community endpoints relative to the area sampled. Stations were located a minimum of 5 m apart to ensure they were representative of the overall area. A single sample was collected at each station by carefully inserting the base of the Hess sampler into the substrate to a depth of approximately 5 to 10 cm. Any gravel or cobble enclosed within the Hess sampler was carefully washed while allowing the current to carry dislodged organisms into the mesh collection net. All organisms collected into the net were rinsed into the bottom of the net, and then into a labelled wide-mouth plastic jar. Samples were preserved to a level of 10% buffered formalin in ambient water within approximately 6 hours of collection to ensure that biomass was not lost through predation or decomposition of tissues before the samples were sorted at the laboratory.

Benthic invertebrate biomass samples were sent to ZEAS Inc. (lead taxonomist Danuta Zaranko) in Nobleton, ON, for sorting and taxonomic identification. All preserved organisms in each sample were sorted from the sample debris into groups separated at the family-level of taxonomy for weighing. Each family group of organisms was placed onto a fine cloth to drain excess surface moisture (preservative) before being weighed to the nearest 0.0001 g. Total and family-level biomass were reported for each sample (preserved wet weight).

2.5 Benthic Invertebrate Community Structure (Kick Sampling)

A single sample was collected in each of eight areas during the September sampling event (Table 2.4). Benthic invertebrate community sampling followed the CABIN protocol, which involves a 3-minute travelling kick into a net with a triangular aperture measuring 36 cm per side and mesh having 400-µm openings (Environment Canada 2012). During sampling, the field technician moved across the stream channel (from bank to bank, depending on stream depth and width) in an upstream direction. With the net being held immediately downstream of the technician's feet; the detritus and invertebrates disturbed from the substrate were passively collected in the kick-net by the stream current. After three minutes of sampling time, the sampler returned to the stream bank with the sample. The kick-net was rinsed with water to move all debris and invertebrates into the collection cup at the bottom of the net. The collection cup was then removed and the contents poured into a labelled plastic jar and preserved in a 10% buffered formalin solution.

2.6 Tissue Selenium Concentrations

2.6.1 Periphyton

A single periphyton tissue sample was collected in September, 2016, from all areas in Line Creek, except LCUT/LC_LCUSWLC, by collecting periphyton remaining from the rocks sampled for analysis of chlorophyll-a and AFDM. Ten periphyton tissue samples were also collected in February, 2017, from each of four areas in Line Creek upstream (LCUT/LC_LCUSWLC) and downstream from the WLC AWTF (LILC3/LC_LC3, LIDSL/LC_LCDSSLCC, and LI8/LC_LC4; Table 2.4). Each sample was a composite of scrapings from five rocks.

After a suitable rock was selected, it was taken to shore and the periphyton was scraped from the surface of the rock using a scalpel until sufficient sample volume (a minimum of 0.5 g wet weight) was attained. Larger samples (2 g wet weight) were collected in February, 2017, to allow for analysis of additional analytes (total organic carbon and metals). This process was repeated with four additional rocks and all five scrapings were placed in a scintillation vial to provide a single, composite sample per station. Vials were stored in a cooler with freezer packs (in the field) until transferred to a freezer later in the day

Tissue samples were transported by courier in coolers with ice packs to the Saskatchewan Research Council (SRC) laboratory in Saskatoon, Saskatchewan, where they were freeze-dried and a subsample was analyzed for total organic carbon, remainder of the sample was subsequently shipped to ALS Environmental to be analyzed for full metal scan including selenium using Inductively Coupled Plasma Mass Spectrometry analysis (ICP-MS). Results were reported on a dry weight (dw) basis.

2.6.2 Benthic Invertebrates

Benthic invertebrate tissue samples were collected for selenium analysis in September and February (Table 2.4; Figure 2.1) using the CABIN kick and sweep sampling method as described in Section 2.4, except that sampling was not timed. The following sub-samples were taken for selenium analysis:

- A composite sample of a variety of benthic invertebrate taxa. These samples are useful for comparison to baseline data, and as an estimate of dietary selenium exposure for consumer organisms (e.g., fish, birds).
- Separate samples of four representative benthic invertebrate taxa, where available (i.e., Chironomidae, Ephemeroptera, *Parapsyche* sp., and Rhyacophilidae). Analysis of representative taxa was anticipated to minimize variability relative to composite samples, thereby facilitating detection of potential trends in selenium concentrations over time.

Up to four single-taxon samples, plus one composite sample, were collected from the six sampling areas on Line Creek and two areas on the Fording River (Table 2.4). For composite samples, as many organisms as possible were carefully removed from the sample using tweezers until about 2 g of wet tissue was obtained. For representative taxa samples, 2 g of wet tissue was targeted, but samples were often smaller due to difficulty in obtaining the desired taxa in a given area.

Invertebrate tissue samples were placed into labelled scintillation vials and stored in a cooler with ice packs until transfer to a freezer later in the day. Tissue samples were kept in a freezer until they were transported by courier in coolers with ice packs to the Saskatchewan Research Council (SRC) laboratory in Saskatoon, Saskatchewan, where they were freeze-dried and subsequently shipped to ALS Environmental to be analyzed for selenium using Inductively Coupled Plasma Mass Spectrometry analysis (ICP-MS). Results were reported on a dry weight (dw) basis.

2.7 Data Analysis

2.7.1 Secondary Production

Benthic invertebrate biomass data (preserved wet weight) were standardized by area sampled (i.e., per m^2). Individual value plots showing benthic invertebrate biomass values were prepared for each of the three Line Creek areas (two mine-exposed and one reference areas, n=10 samples per area). Biomass data from 2014 and 2015 were also shown for comparison to 2016 data. Benthic invertebrate biomass and community endpoints from Hess samples were analyzed among areas and years using a before-after/control-impact (BACI) ANOVA model

(Underwood 1992) as outlined in the 2015 study report (i.e., Appendix B of Minnow 2016a). The BACI model assesses changes in the relative differences between control (i.e., reference) and impact (i.e., mine-exposed) areas over time. Data for the "before" period were available in 2014[2] and 2015 for two reference areas (SLINE and LI24) and three mine-exposed areas (LIDSL, LILC3, and LI8). Data for the "after" period were available in 2016 for one reference area (SLINE) and two mine-exposed areas (LIDSL and LILC3). Therefore, the BACI was performed using data for SLINE, LIDSL and LILC3, from which 10 samples were collected in each area in each time period.

The BACI model that was fit to the data (with two years of before data and two mine-exposed areas) was:

$$Y = BA + CI + BA \times CI + Area(CI) + Year(BA) + CI \times Year(BA) + BA \times Area(CI) + Area \times Year(BA \times CI) + \epsilon$$

where:

- Y = response variable;
- BA = a fixed factor for time period with two levels (before and after);
- CI = a fixed factor for area type with two levels (control and impact);
- $BA \times CI$ = the interaction between BA and CI;
- $Area(CI)$ = a fixed factor for area when there are more than two areas (nested in CI because each area can only be assigned to one level of CI);
- $Year(BA)$ = a fixed categorical factor for year when there are more than two years in the before period or more than two years in the after period (nested in BA because each year can only be assigned to one level of BA);
- $CI \times Year(BA)$ = the interaction between CI and $Year$;
- $BA \times Area(CI)$ = the interaction between BA and $Area$;
- $Area(CI) \times Year(BA)$ = the interaction between $Area$ and $Year$; and

[2] Commissioning-phase discharge from the AWTF began August 27, 2014, and the facility was shut down on October 17, 2014. Biological sampling in 2014 was conducted between September 2nd and 8th. Due to the brief period of exposure to less-than-capacity AWTF effluent, biological data from 2014 are not considered representative of steady-state AWTF operation. Recommissioning of the AWTF occurred in October 2015, after the periphyton growing season; therefore, biological data from 2013 and 2015 are considered baseline. In the BACI analysis, in the event that different results were obtained for 2016 and 2014 versus 2016 and 2015, the latter comparison was considered more relevant because the WLC AWTF did not operate prior to biological sampling in 2015, whereas it did operate briefly prior to sampling in 2014.

- ϵ = the error term.

The BACI model was used to test for BACI effects (i.e., changes in the relative differences among areas over time). The BACI effects were assessed by testing the significance of the interaction terms containing the BA and CI terms. Interpretation of the ANOVA table began by assessing the significance of the interaction between $Area(CI)$ and $Year(BA)$. If the interaction was significant then the relative differences among areas were significantly different over time (i.e., a BACI effect), but it depended on which years and areas were compared (see Figure A.1a). In that case, contrasts were conducted to determine the areas and years that caused the significant difference. If the interaction term was not significant, then the interpretation of the ANOVA table continued by assessing the significance of the interaction between CI and $Year(BA)$ and the interaction between BA and $Area(CI)$. These terms in the model assess whether the relative differences among areas depended on which year and group (control or impact) were compared (i.e., there was a BACI effect that depended on which years were compared; see Figure A.1b) and whether the relative differences among areas depended on which area and period (before or after) were compared (i.e., there was a BACI effect that depended on which areas were compared; see Figure A.1c). If these interaction terms were significant, then contrasts were conducted to determine where the interaction was occurring. If these interaction terms were not significant, then the interaction between BA and CI was assessed for significance. If it was significant, then the relative differences between the control and impact areas depended on the time period (before or after), indicating that the impact areas are responding in a similar manner in the after period but differently from the control areas (i.e., there is a consistent BACI effect that does not depend on which year and group are compared; see Figure A.1d). Testing the significance of the interaction terms is the key hypothesis of interest in the BACI model as it tests for changes in the relative differences among areas over time. If all interaction terms are not significant (i.e., there are no BACI effects) then the remaining main effect terms were assessed for significance. For example, the BA term can be assessed to test whether there is an overall difference from the before period to the after period.

A BACI effect was considered to be relevant if it detected a difference in the same direction between an exposed and reference area in 2016 compared to both the before years (e.g., the relative difference between LILC3 [and/or LIDSL] and SLINE was significant between 2016 and 2014 as well as between 2016 and 2015). In the event that different results were obtained for 2016 and 2014 versus 2016 and 2015, the latter comparison was considered more relevant because the WLC AWTF did not operate prior to biological sampling in 2015, whereas it did operate briefly prior to sampling in 2014.

Data were transformed (log_{10}-, square root, or fourth root) as required to meet the assumption of normality for the residuals of the BACI model. Outliers with Studentized residuals with magnitude greater than four were removed from the analysis. The BACI models and contrasts were conducted in R (R Core Team 2015) using the linear model (*lm* function) and the *contrast* and *lsmeans* packages.

The magnitude of difference for a significant BACI effect was expressed in terms of the number of standard deviations and as a percentage change and was calculated as follows:

Magnitude of Difference = $\frac{(\bar{X}_{AI}-\bar{X}_{AC})-(\bar{X}_{BI}-\bar{X}_{BC})}{S_r}$

where:

- $\bar{X}_{AI}$ = the mean for the mine-exposed area in the after period;
- $\bar{X}_{AC}$ = the mean for the reference area in the after period;
- $\bar{X}_{BI}$ = the mean for the mine-exposed area in the before period;
- $\bar{X}_{BC}$ = the mean for in reference area in the before period; and
- S_r= the standard deviation of the residuals in the BACI model (i.e., the pooled within area/year standard deviation).

Magnitude of Difference = $\frac{(\bar{X}_{AI}-\bar{X}_{AIpred})}{\bar{X}_{AIpred}} \cdot 100\%$

where $\bar{X}_{AIpred}$ = the predicted mean for the mine-exposed area in the after period if there was no BACI effect (i.e., $\bar{X}_{AIpred}$ = $(\bar{X}_{BI} - \bar{X}_{BC}) + \bar{X}_{AC}$. The $\bar{X}_{AI}$ and $\bar{X}_{AIpred}$ means were back transformed to original data units when the data were transformed for analysis.

2.7.2 Tissue Selenium Concentrations

Tissue selenium concentrations in different sample types of benthic invertebrates (i.e., composite, Chironomidae, *Parapsyche* sp., Ephemeroptera and Rhyacophilidae) and periphyton were compared among the six sampling areas of Line Creek and two sampling areas on the Fording River through visual inspection of data tables and plots. Composite-taxa benthic invertebrate tissue samples were also evaluated relative to the Level 1 benchmark of 11.0 mg/kg dw for potential dietary effects to juvenile fish (Windward 2014) and the Level 1 benchmark of 13.0 mg/kg dw for effects to benthic invertebrates (EVWQP; Teck 2014). Data from 2012, 2014, and 2015 were also shown for comparison to 2016 and 2017 results.

3 PRODUCTIVITY

3.1 Overview

Data evaluated in this section pertain to Key Question #1: Is active water treatment affecting biological productivity downstream in Line Creek?

3.2 Primary Productivity Indictors

Fewer periphyton samples were collected per area compared to previous years based on recommendations in the 2015 Line Creek LAEMP Report and 2016 Line Creek LAEMP Study Design (Minnow 2016a,b); however, five samples were collected at the Compliance Point (LC_LCDSSLCC/LIDSL) three times over the growing season and two additional single composite samples were collected in July (Table 2.4).

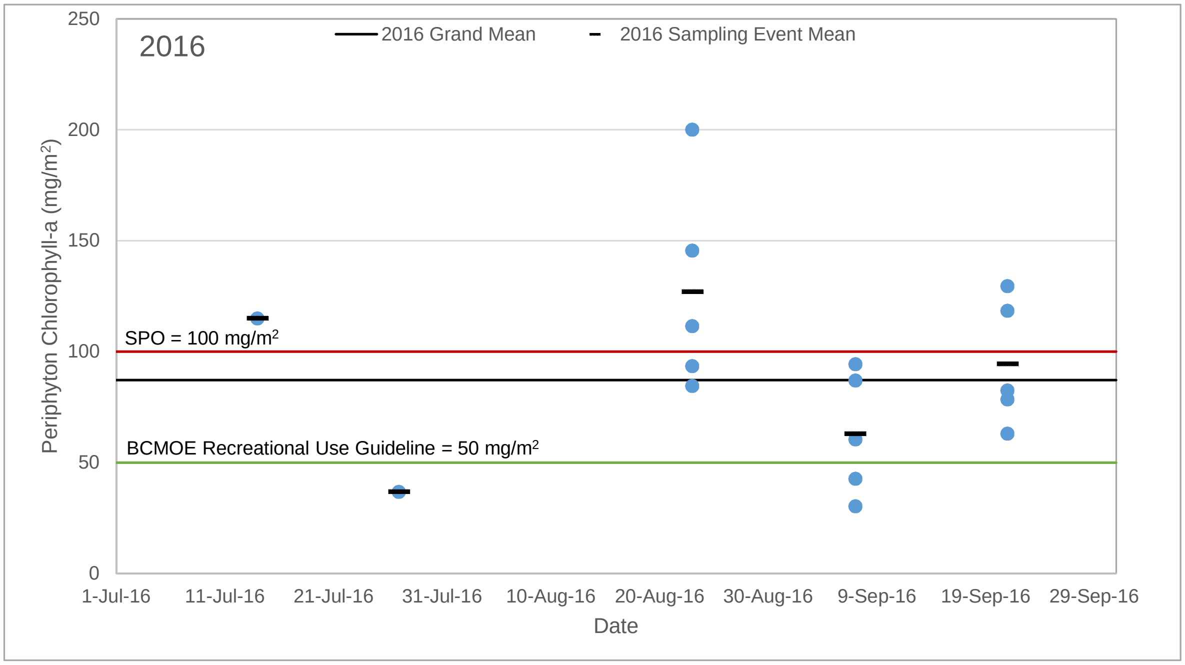
Periphyton chlorophyll-a concentrations at the Compliance Point varied over the 2016 growing season, and were generally higher than concentrations observed in 2015 (Figure 3.1). Mean periphyton chlorophyll-a concentrations ranged from 37 mg/m^2 to 127 mg/m^2 among sampling events in 2016 with one sampling event exceeding the SPO on August 23, 2016 with a mean of 127 mg/m^2 (Figure 3.1). Periphyton chlorophyll-a and AFDM were both highest at LILC3 (LC_LC3) in 2016, and lower at sampling areas farther downstream, where values were comparable to those at reference areas (Figure 3.2). A similar spatial pattern was observed in previous years (Figures 3.3 and 3.4).

Visual scores of periphyton coverage were similar among reference and mine-exposed areas, with all receiving scores of 2 or 3 (of a maximum of 5; Appendix Table A.1).

3.3 Secondary Productivity Indicators

Benthic invertebrate biomass and density in 2016 also followed a similar pattern to previous years (Figures 3.5 and 3.6). Highest biomass and density were observed at LILC3 (LC_LC3), immediately downstream from the WLC AWTF discharge, although levels were comparable in 2016 (while the WLC AWTF was operating) to those observed in 2015 (no WLC AWTF operation).

BACI analysis (Section 2.7) was used to statistically compare benthic invertebrate endpoints for downstream areas LIDSL (LC_LCDSSLCC) and LILC3 (LC_LC3) relative to the reference area SLINE (LC_SLC) over the period 2014 to 2016. Although there was a significant BACI effect for biomass that depended on which years were compared, the individual contrasts for 2016 versus 2014, and 2016 versus 2015, were not significant (i.e., no effect of WLC AWTF operation in 2016 on invertebrate biomass) (Figure 3.7; Appendix Table A.10). A BACI effect was observed for density in 2016 compared to 2014, but not between 2016 and 2015 (Figure 3.7; Appendix



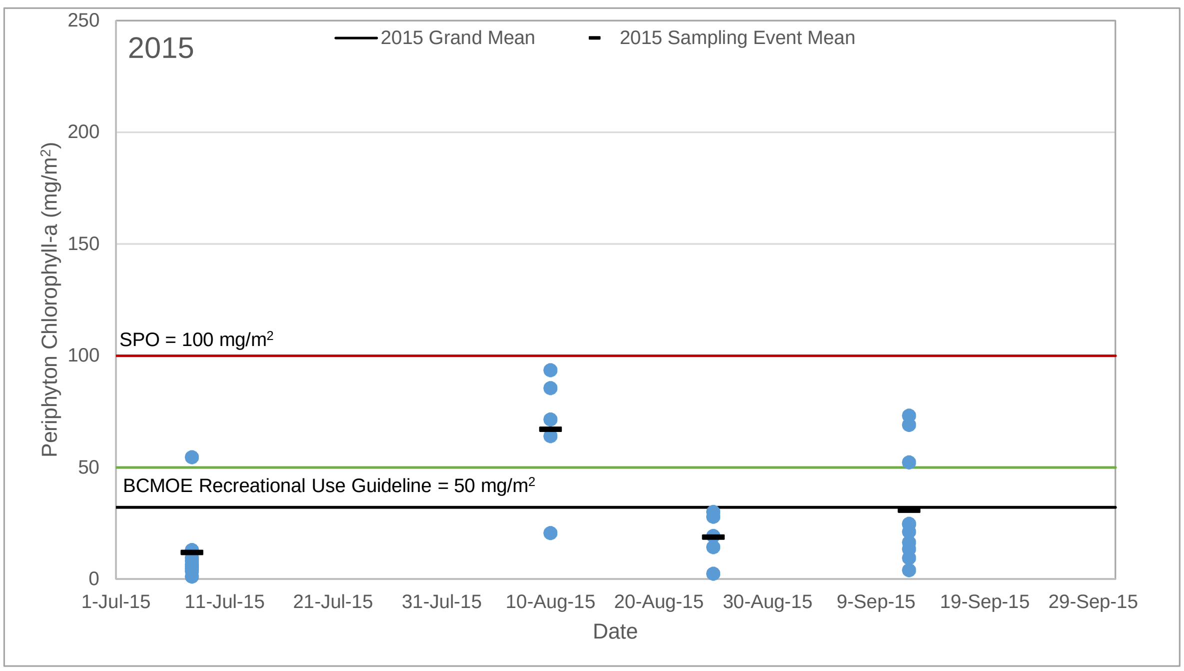


Figure 3.1: Seasonal Periphyton Chlorophyll-a Concentrations at LIDSL (LC_LCDSSLCC) in 2016 Compared to 2015

Notes: September July 8, 2015 (n = 10), August 10 and 25, 2015 (n = 5), September 12, 2015 (n = 10), July 14, 2016 (n =1), July 27, 2016 (n = 1), August 23, 2016 (n = 5), September 7 and 21, 2016 (n = 5)

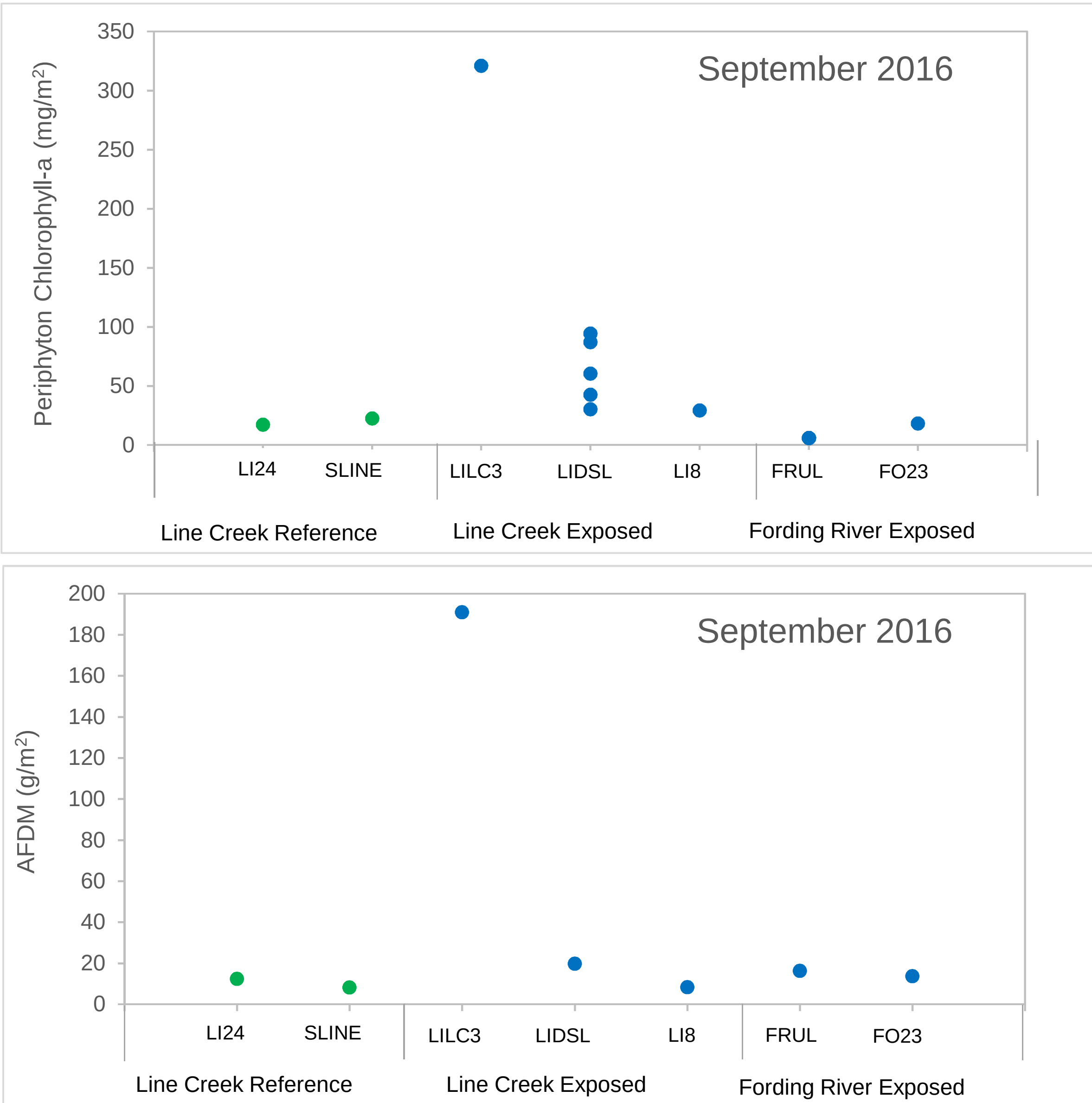


Figure 3.2: Periphyton Chlorophyll-a and AFDM Measurements in Line Creek and Fording River in September 2016

Notes: n = 1 per area except n = 5 at LIDSL. LI24=LC_LC1, SLINE=LC_SLC, LILC3=LC_LC3, LIDSL=LC_LCSDSSLCD (Compliance Point), LI8=LC_LC4, FRUL=LC_LC6, and FO23=LC_LC5.

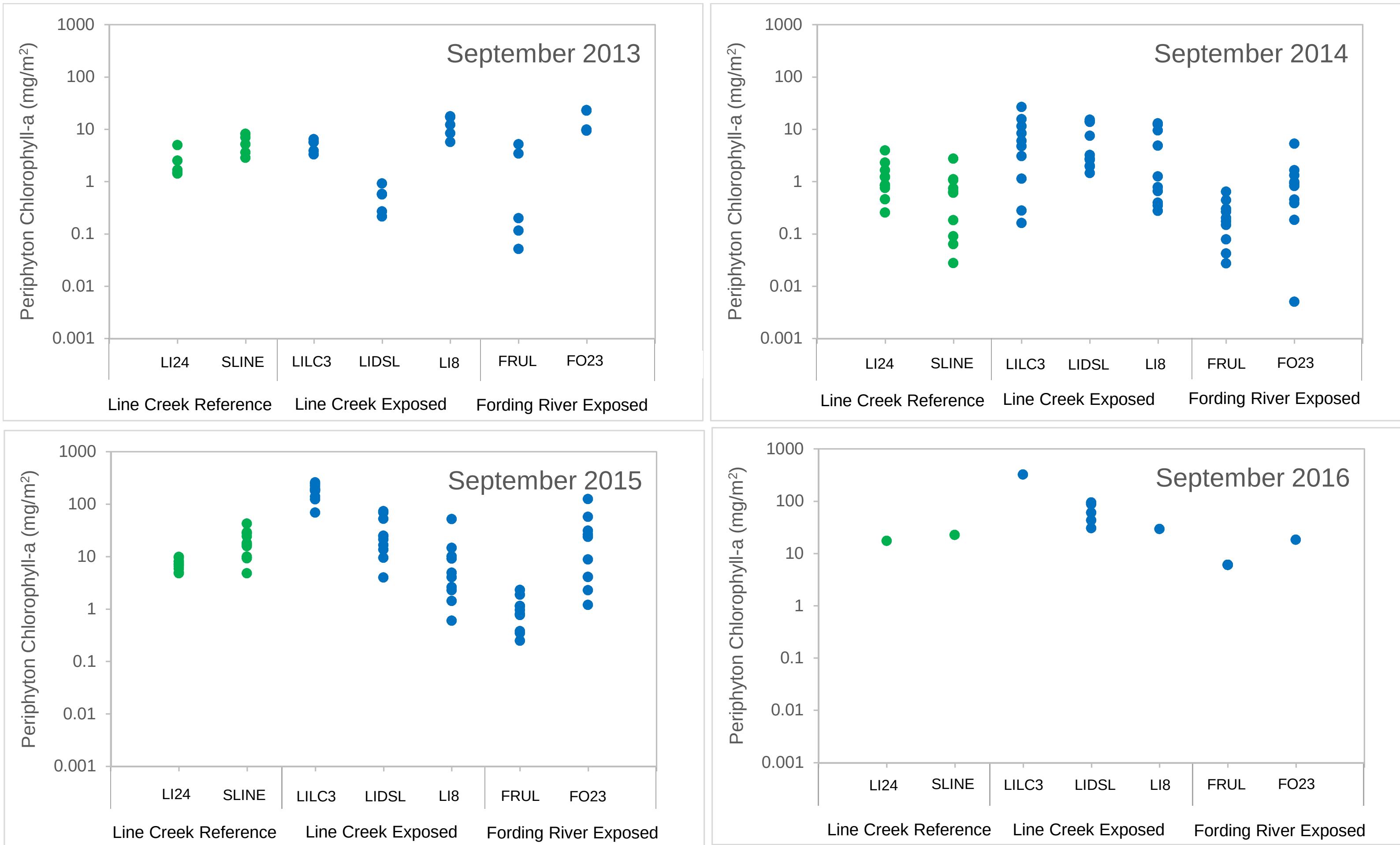


Figure 3.3: Periphyton Chlorophyll-a Concentrations in Line Creek and Fording River, 2013 to 2016

Notes: September 2013 (n = 5), September 2014 (n = 10), September 2015 (n = 10) and September 2016 (n = 5 [LIDSL], n = 1 [Other Areas]).
LI24=LC_LC1, SLINE=LC_SLC, LILC3=LC_LC3, LIDSL=LC_LCSDSSLCD (Compliance Point), LI8=LC_LC4, FRUL=LC_LC6, and FO23=LC_LC5.

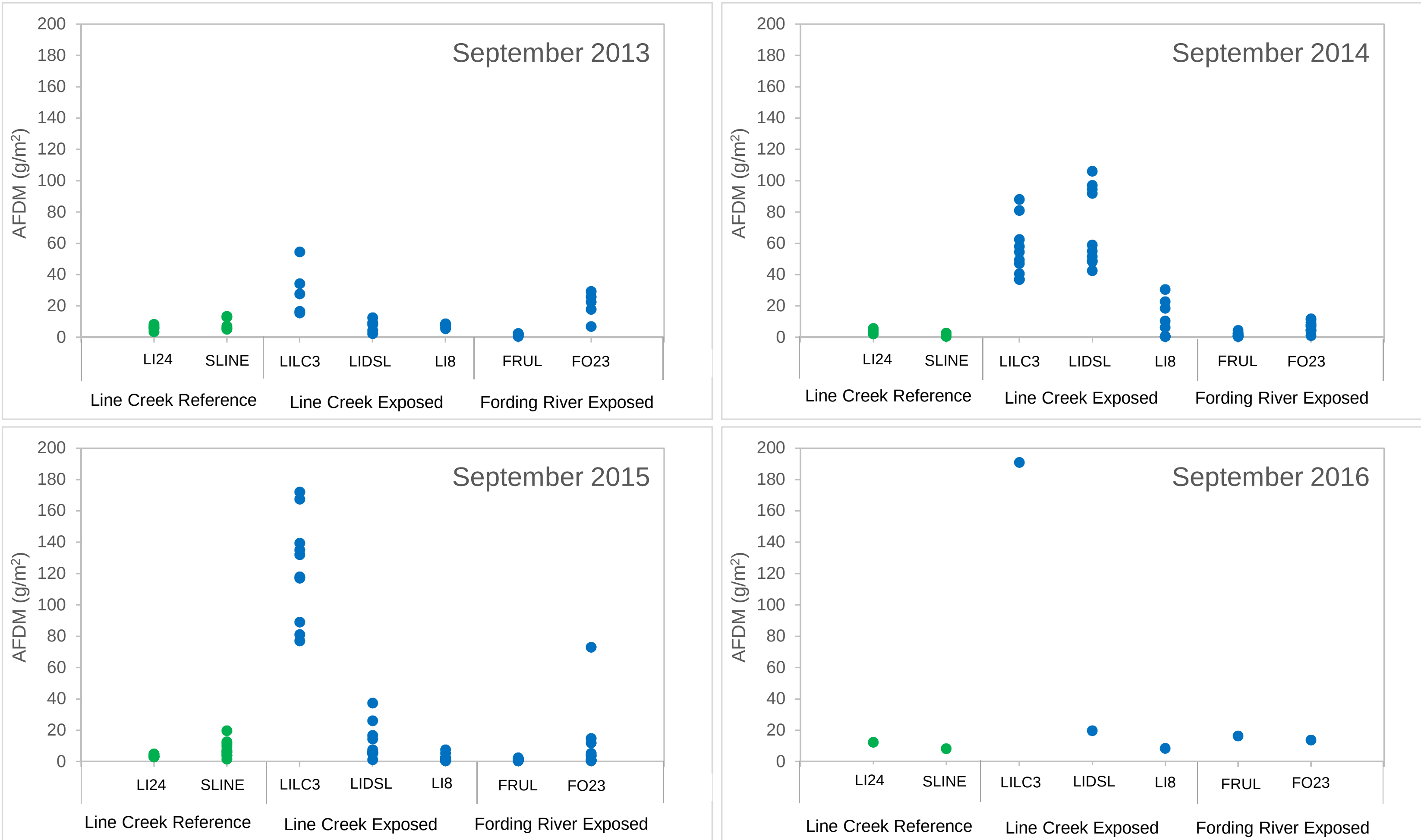


Figure 3.4: Periphyton AFDM Values in Line Creek and Fording River, 2013 to 2016

Notes: September 2013 (n = 5), September 2014 (n = 10), September 2015 (n = 10), and September 2016 (n = 1). LI24=LC_LC1, SLINE=LC_SLC, LILC3=LC_LC3, LIDSL=LC_LCSDSSLCD (Compliance Point), LI8=LC_LC4, FRUL=LC_LC6, and FO23=LC_LC5.

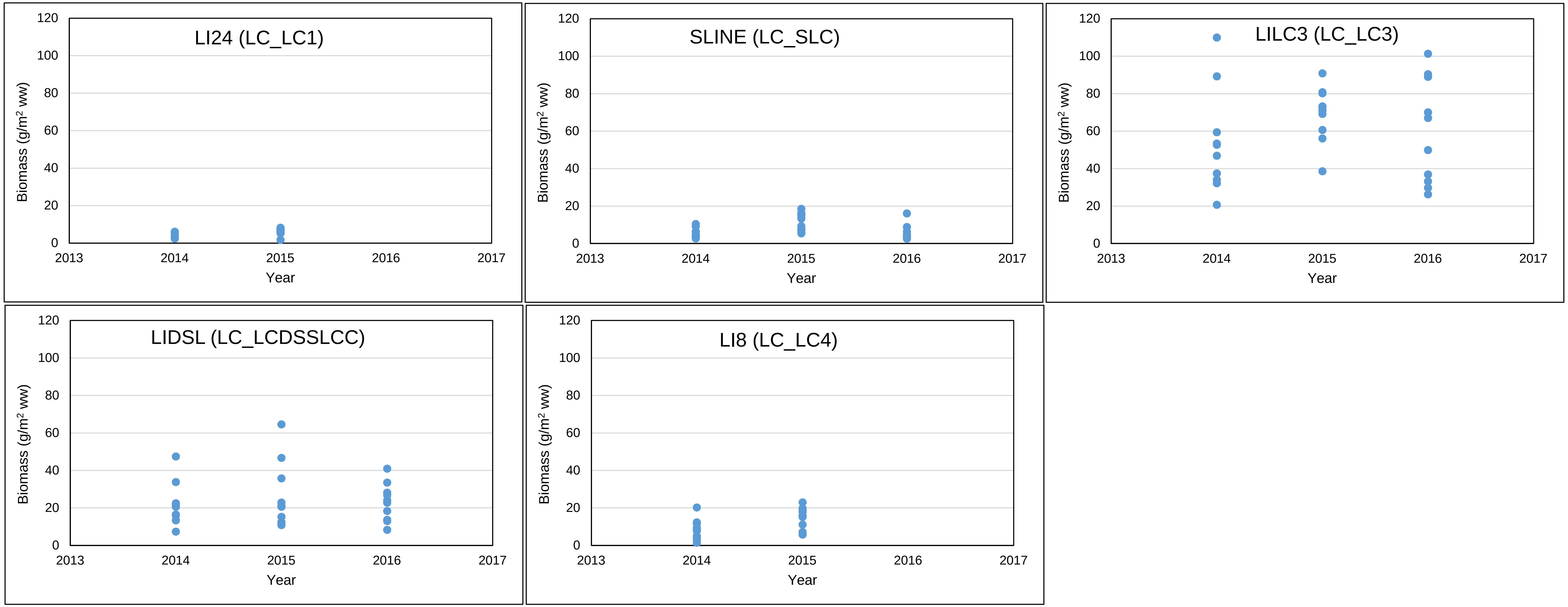


Figure 3.5: Benthic Invertebrate Biomass Observed During the Line Creek LAEMP from 2014 to 2016

Note: n = 5 per area per year.

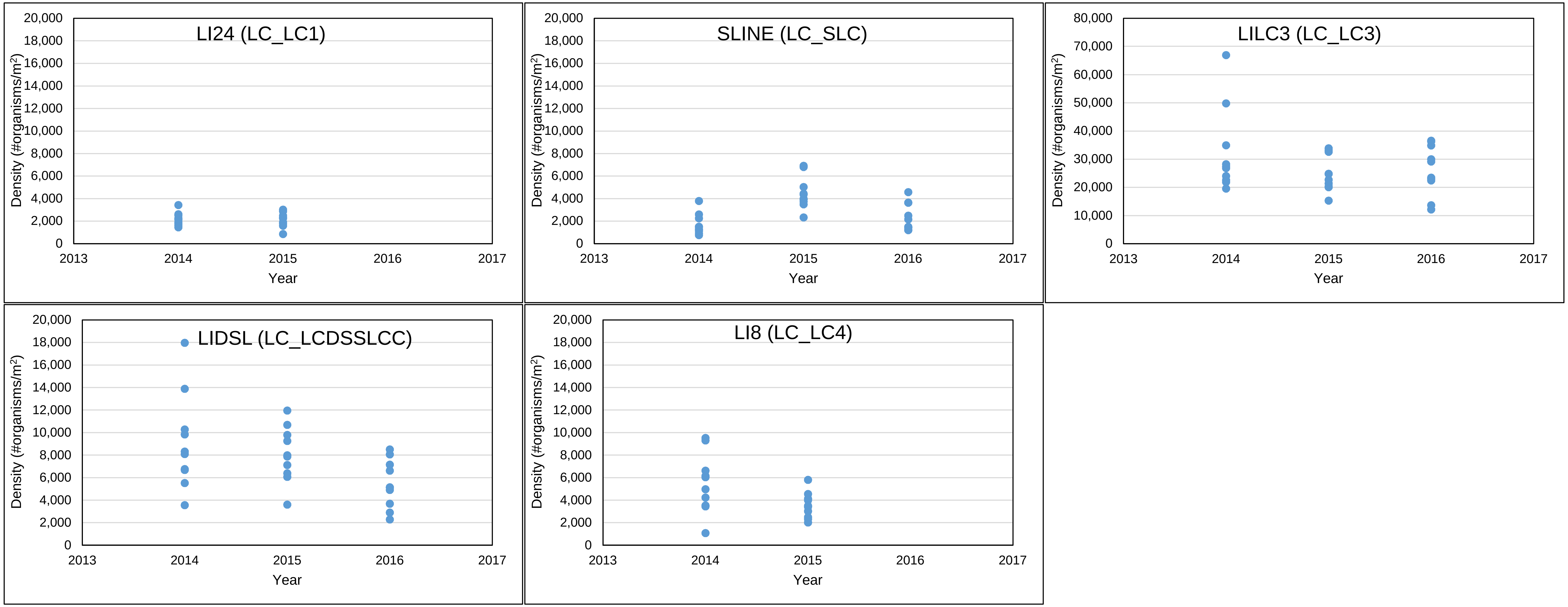


Figure 3.6: Benthic Invertebrate Density Observed During the Line Creek LAEMP from 2014 to 2016

Note: Different abundance y-axis scale for LILC3. n = 5 per area per year.

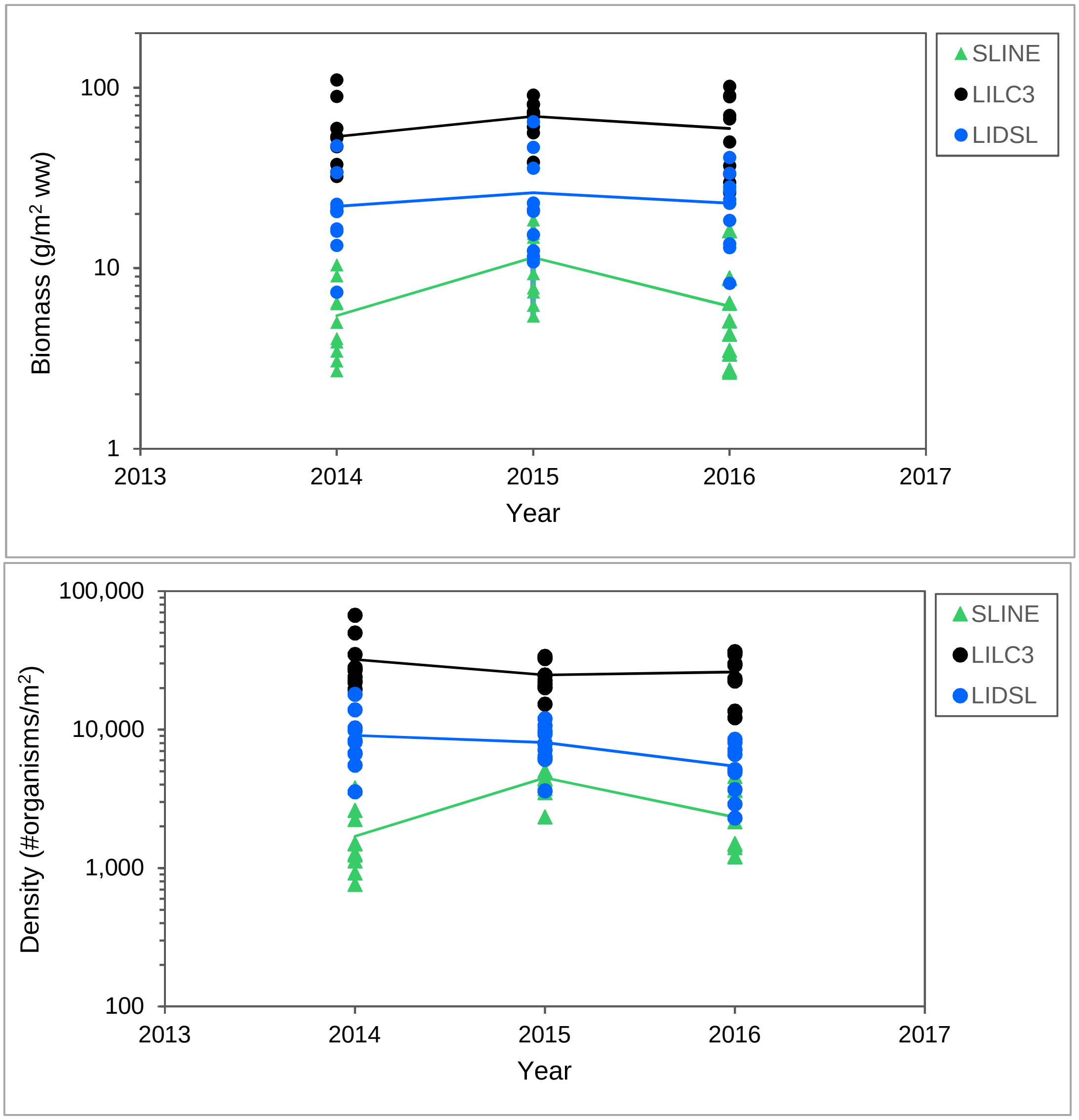


Figure 3.7: BACI Plots for Benthic Invertebrate Biomass and Density in Line Creek from 2014 to 2016

Note: Y-axes are on a log scale

Table A.10), which also indicated no effect of WLC AWTF operation in 2016 on invertebrate productivity.

3.4 Community Endpoints

A BACI effect was observed for density and %EPT between 2016 compared to 2014, but not between 2016 and 2015 (Figures 3.7 and 3.8; Appendix Table A.5), indicating that full operation of the WLC AWTF in 2016 did not affect these benthic invertebrate community characteristics at the two areas downstream from the WLC AWTF outfall (LILC3/LC_LC3; LIDLS/LC_LCDSSLCC). Family richness at LILC3 and LIDSL was 11% and 36% lower than expected in 2016, based on the relationship between these areas and reference area SLINE (LC_SLC) in 2014 and 2015, which suggests an effect related to WLC AWTF operation. A BACI effect was also observed for % Ephemeroptera between the reference area (SLINE/LC_SLC) and the Compliance Point (LIDSL/LC_LCDSSLCC), indicating an 81% increase in 2016 compared to the value expected based on area differences in the before period (Figure 3.8 and Appendix Table A.5). The direction of change for % Ephemeroptera is opposite to what would be expected if the WLC AWTF was having an adverse effect on the aquatic environment.

Benthic community structure based on CABIN kick and sweep samples was also evaluated relative to normal (regional reference area) ranges defined in the 2015 RAEMP (Figures 3.9 to 3.12). Similar to biomass and density results for Hess samples (Figures 3.5 and 3.6), benthic invertebrate organism abundance based on kick samples was highest at LILC3, immediately downstream from the WLC AWTF (Figure 3.9). Potential reduction in family-level invertebrate richness at LILC3, compared to data collected in 2014 and 2015 , however, family richness at LILC3 in 2016 was comparable to that measured in 2012 (Figure 3.10). Also, LPL-level richness was within normal ranges at all areas in 2016 and was not noticeably different from values observed in 2015 at the two downstream areas closest to the WLC AWTF (LILC3 and LIDSL) (Appendix Figure A.5). Percent EPT and % Ephemeroptera at LILC3 were below the normal range, but comparable to values reported prior to WLC AWTF operation (Figures 3.11 and 3.12). Community endpoints at the other mine-exposed areas were within normal ranges in 2016, except that sample abundance at LI8, in lower Line Creek, was slightly above the normal range and historical observations at that area (Figures 3.9 to 3.12).

Overall, WLC AWTF operation does not appear to have adversely affected benthic invertebrate communities downstream, other than a potential reduction in family richness, which will be evaluated again in the 2017 cycle of the Line Creek LAEMP.

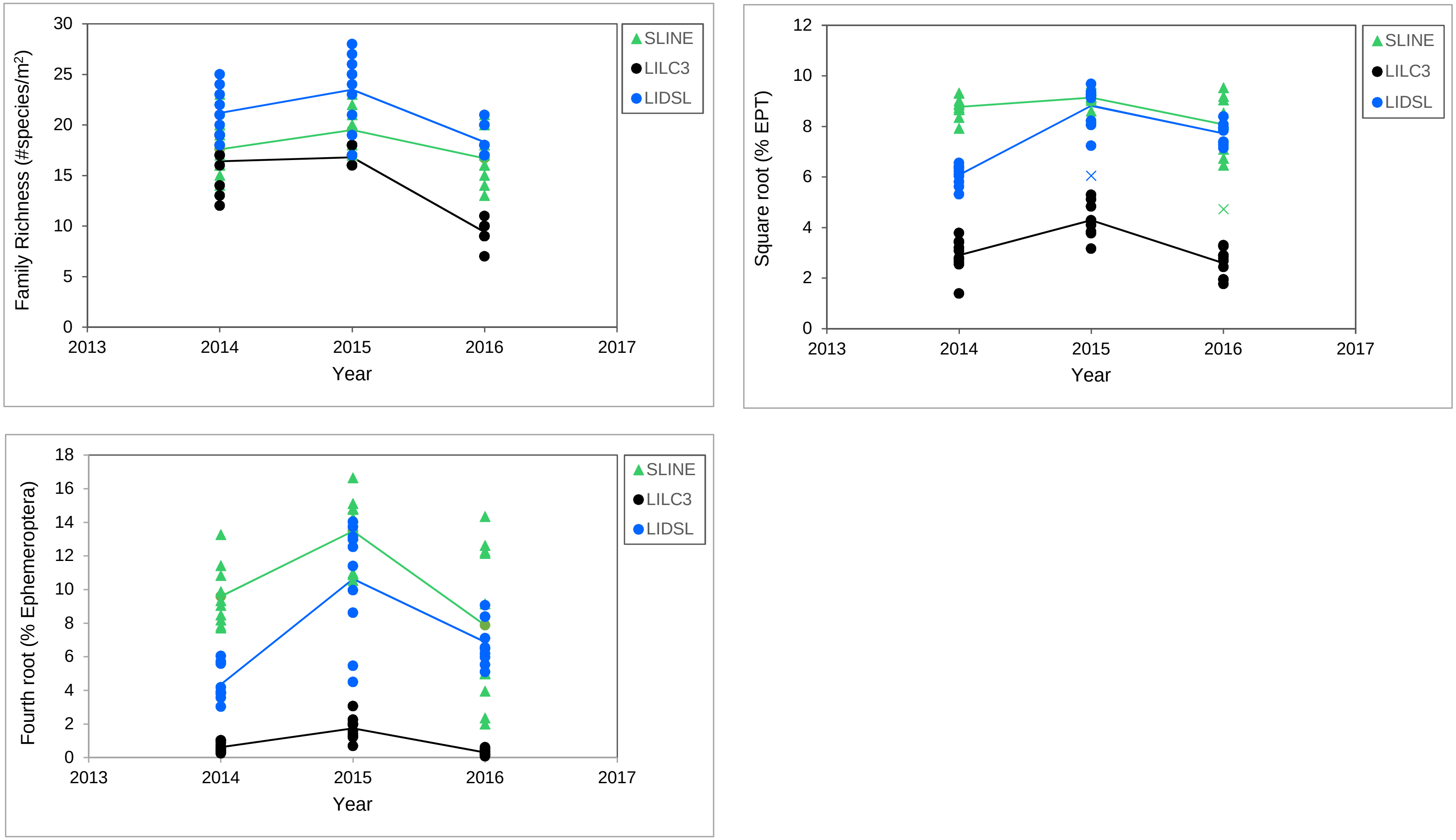


Figure 3.8: BACI Plots for Benthic Invertebrate Richness, %EPT, and %Ephemeroptera in Line Creek from 2014 to 2016

Note: Family Richness is not transformed, %EPT is square root transformed, and %Ephemeroptera is fourth root transformed. X denotes outlier removed from analysis.

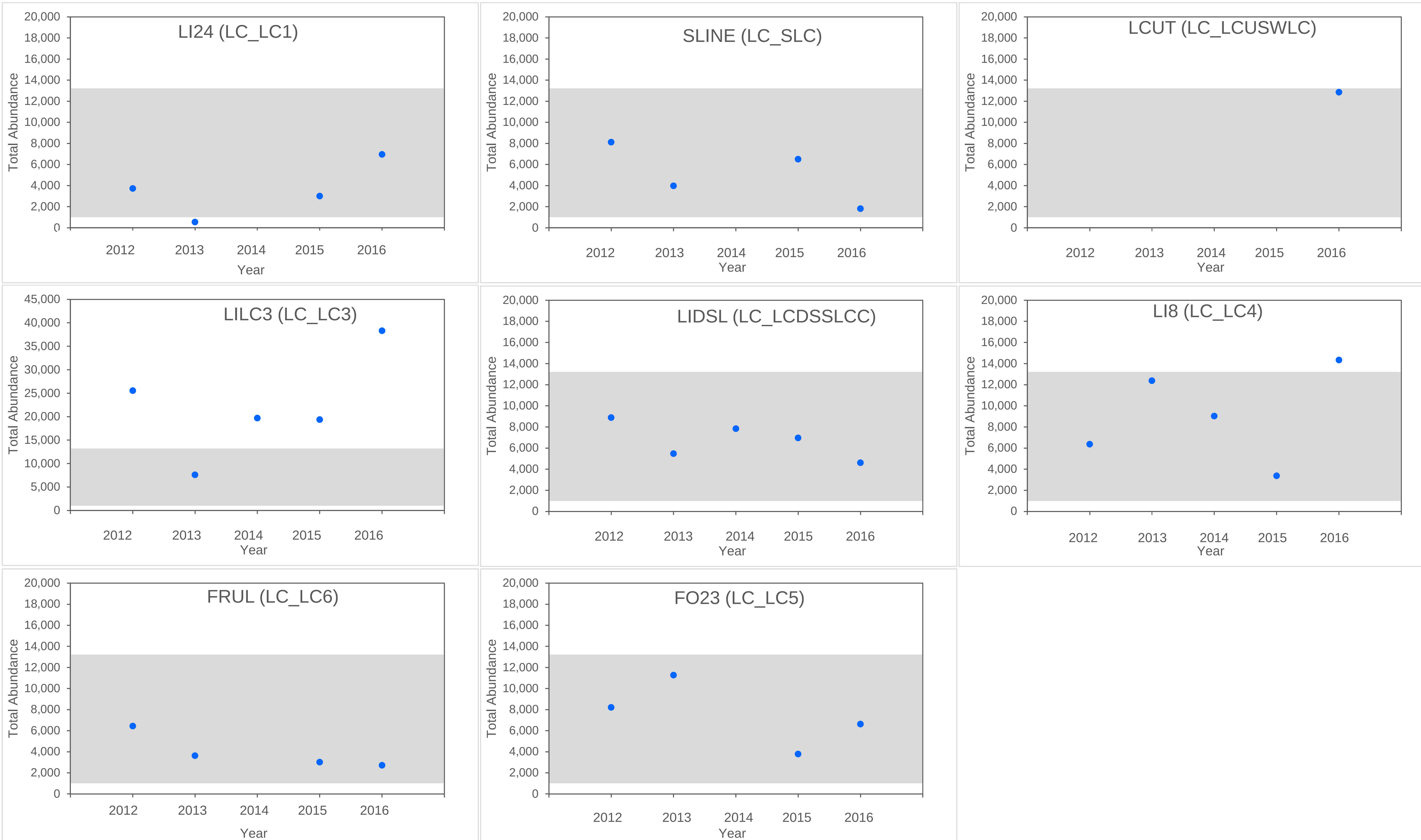


Figure 3.9: Benthic Invertebrate Community Abundance from 2012 to 2016

Notes: Gray shading represents the normal range defined as the 2.5th and 97.5th percentiles of values for reference areas sampled in 2012 and 2015 (n=50) for the RAEMP.

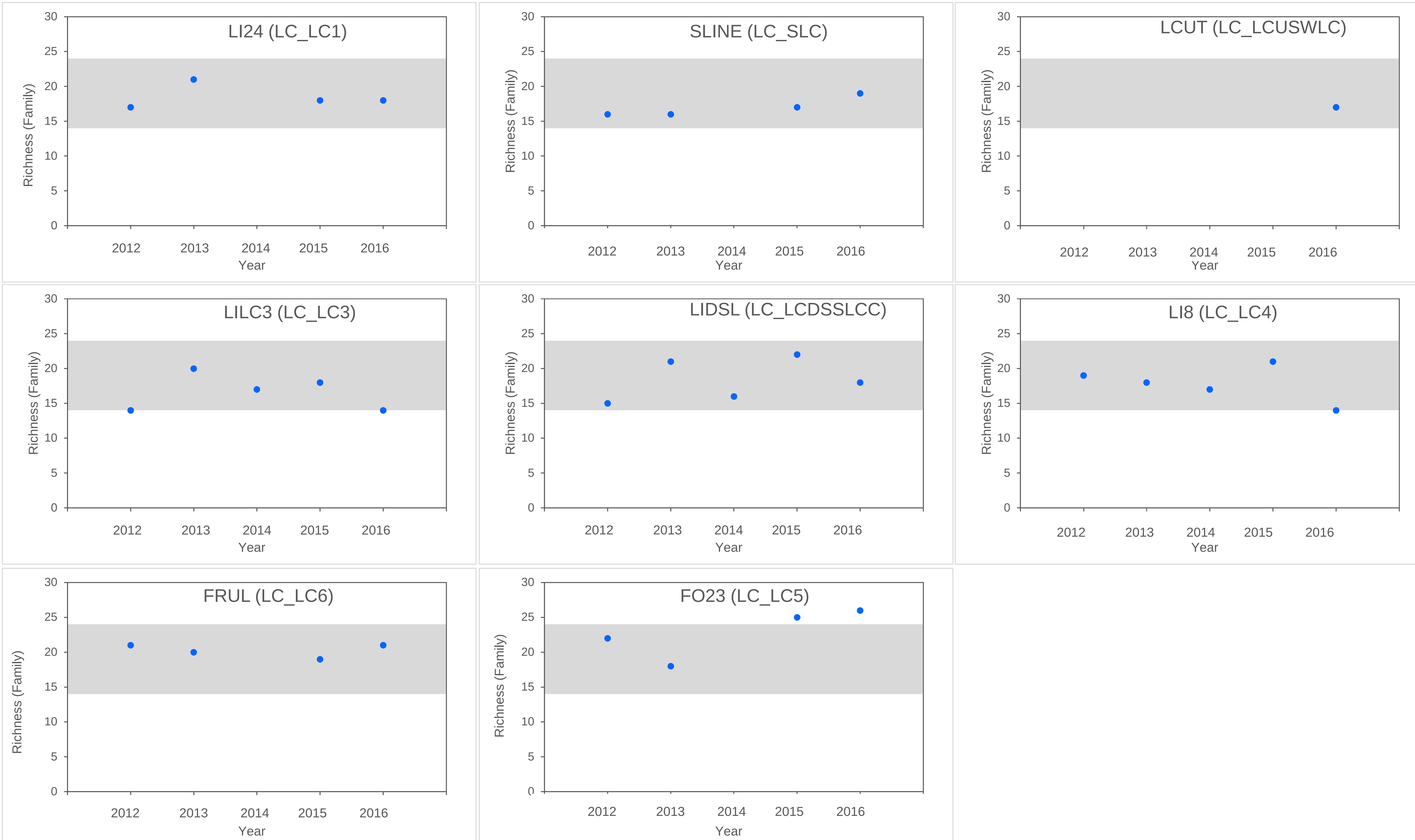


Figure 3.10: Benthic Invertebrate Community Family Richness from 2012 to 2016

Notes: Gray shading represents the normal range defined as the 2.5th and 97.5th percentiles of values for reference areas sampled in 2012 and 2015 for the RAEMP (n=75).

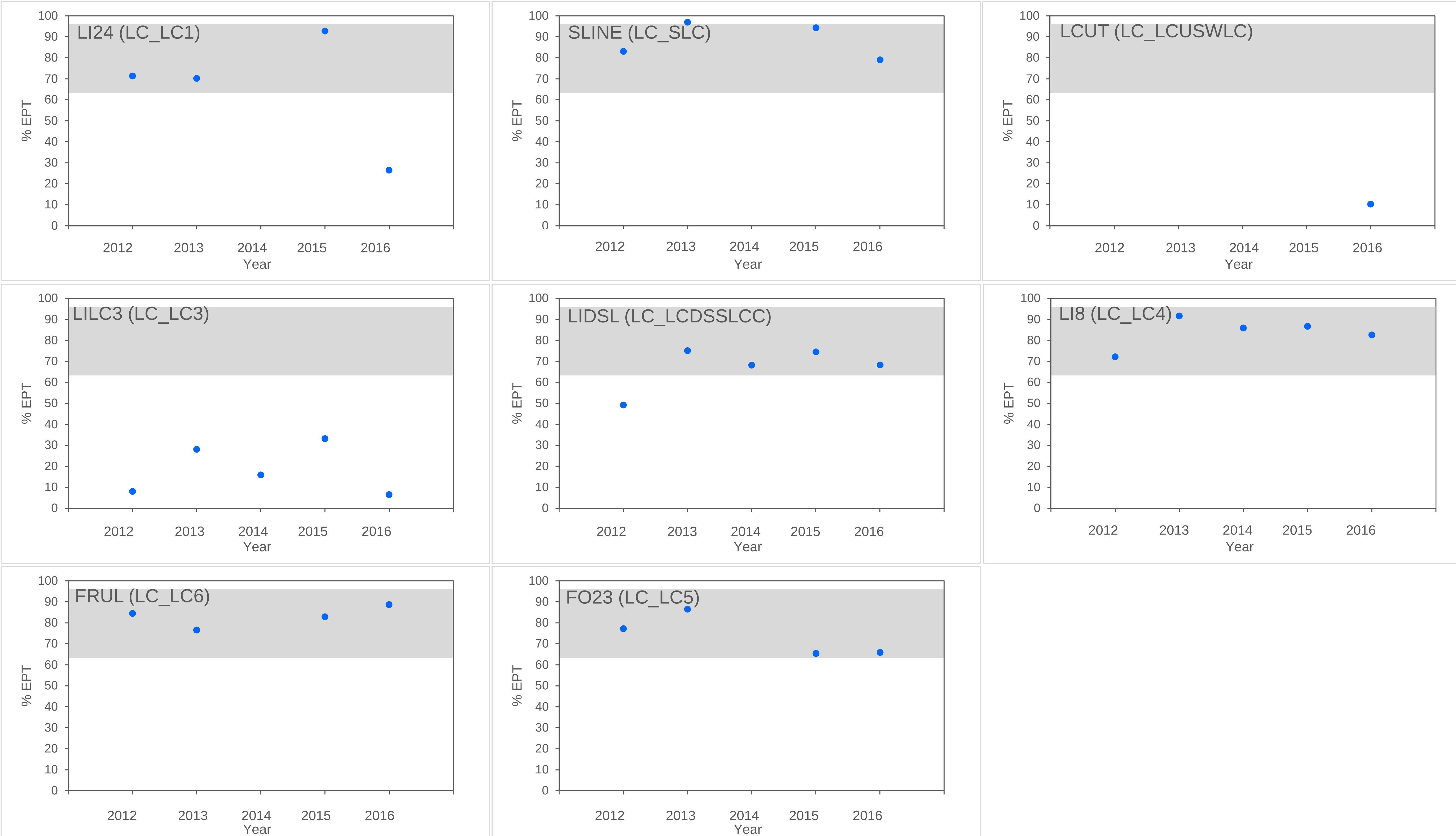


Figure 3.11: Plots of Benthic Invertebrate Community Percent Relative Abundance EPT from 2012 to 2016

Notes: Gray shading represents the normal range defined as the 2.5th and 97.5th percentiles of the distribution of values for reference areas sampled in 2012 and 2015 for the RAEMP (n=72).

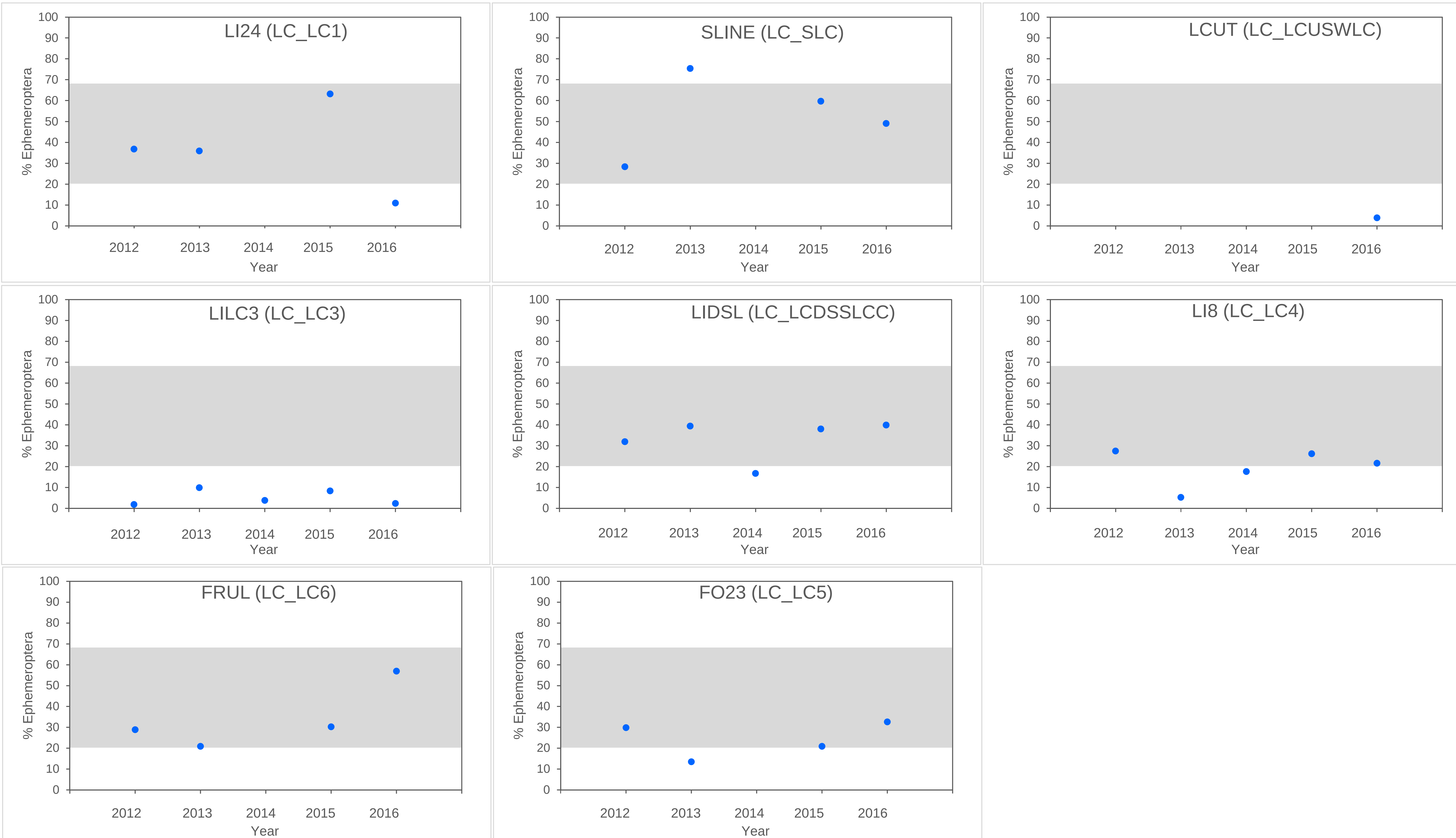


Figure 3.12: Benthic Invertebrate Community Percent Relative Abundance Ephemeroptera from 2012 to 2016

Notes: Gray shading represents the normal range defined as the 2.5th and 97.5th percentiles of values for reference areas sampled in 2012 and 2015 (n=73) for the RAEMP.

3.5 Phosphorus and Chlorophyll-a SPO

The aqueous phosphorus SPO in Permit 107517 was based on projections for effluent and receiving water phosphorus concentrations, and the periphyton chlorophyll-a SPO was based on limited available baseline data prior to WLC AWTF operation (Appendix C). More data are now available, allowing for re-assessment of the SPOs. Total phosphorus concentrations in WLC AWTF effluent averaged only 0.04 mg/L in 2016 compared to a projected average of 0.3 mg/L (Appendix C). Consequently, concentrations of total phosphorus in Line Creek at the Compliance Point (LC_LCDSSLCC) have usually been below the projected range, and always below the SPO of 0.02 mg/L since the WLC AWTF began operating (Figure 3.13). Also, biological indicators of productivity in Line Creek and elsewhere in the watershed have not correlated with total phosphorus or orthophosphate concentrations (i.e., biological variability among areas is associated with factors other than nutrient concentrations) (Appendix C). Aqueous total phosphorus concentrations and periphyton chlorophyll-a levels can approach or exceed the SPO values of 0.02 mg/L and 100 mg/m^2, respectively, even at areas undisturbed by mining (Figure 3.14). These results were discussed with the EMC during several meetings since October, 2016. Based on more recent information and an improved understanding of existing conditions, (see detailed evaluation presented in Appendix C), Teck will be submitting a request to amend Permit 107517 to remove the SPO requirement for periphyton chlorophyll-a measurements. However, monitoring of potential changes in productivity will continue in the Line Creek LAEMP based on benthic invertebrate productivity indicators. Monitoring of periphyton chlorophyll-a will also continue in 2017 (Minnow 2017) to ensure compliance with the Permit.

3.6 Summary

Total phosphorus concentrations in WLC AWTF effluent averaged only 0.04 mg/L in 2016 compared to the average of 0.3 mg/L projected prior to WLC AWTF operation. Consequently, concentrations of total phosphorus in Line Creek at the Compliance Point (LC_LCDSSLCC) have usually been below the projected range, and always below the SPO of 0.02 mg/L since the WLC AWTF began operating. The various indicators of primary and secondary productivity (i.e., periphyton chlorophyll-a and AFDM, benthic invertebrate biomass, density, and sample abundance in the kick samples) indicated a pattern of highest productivity at LILC3, immediately downstream from the WLC AWTF outfall, and lower productivity with increasing distance downstream (similar to the pattern observed prior to WLC AWTF operation). Local and regional data showed that aqueous total phosphorus concentrations and periphyton chlorophyll-a levels can approach or exceed the SPO values of 0.02 mg/L and 100 mg/m^2, respectively, even at areas undisturbed by mining. Teck will be applying to amend Permit 107517 to retain the total

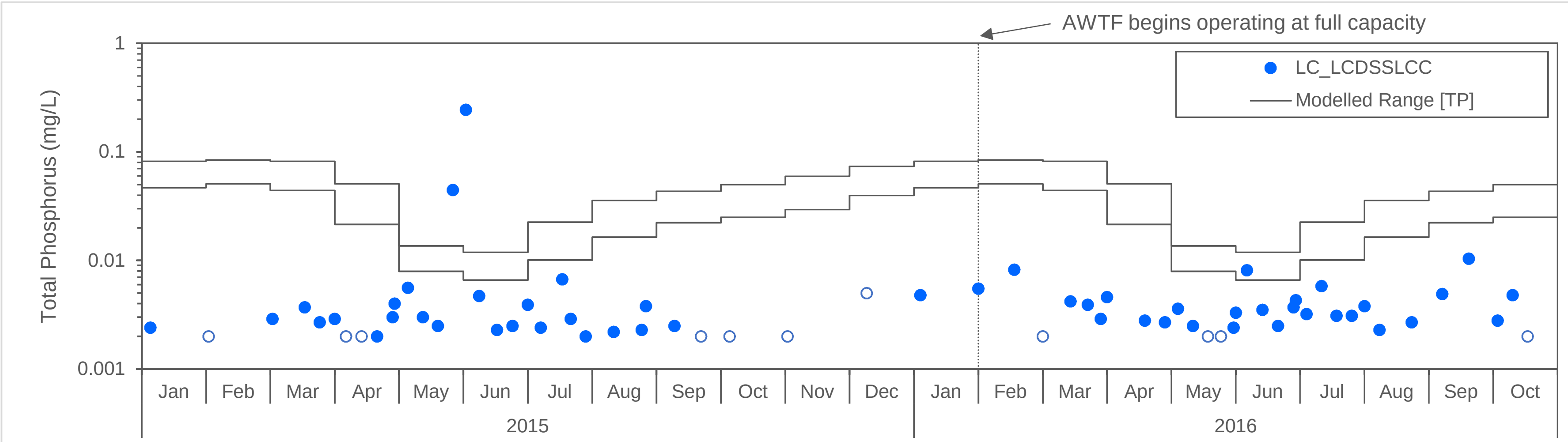


Figure 3.13: Observed Concentrations of Total Phosphorus at LC_LCDSSLCC versus Modelled Monthly Concentration Range (from Low Flow to High Flow)

Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL

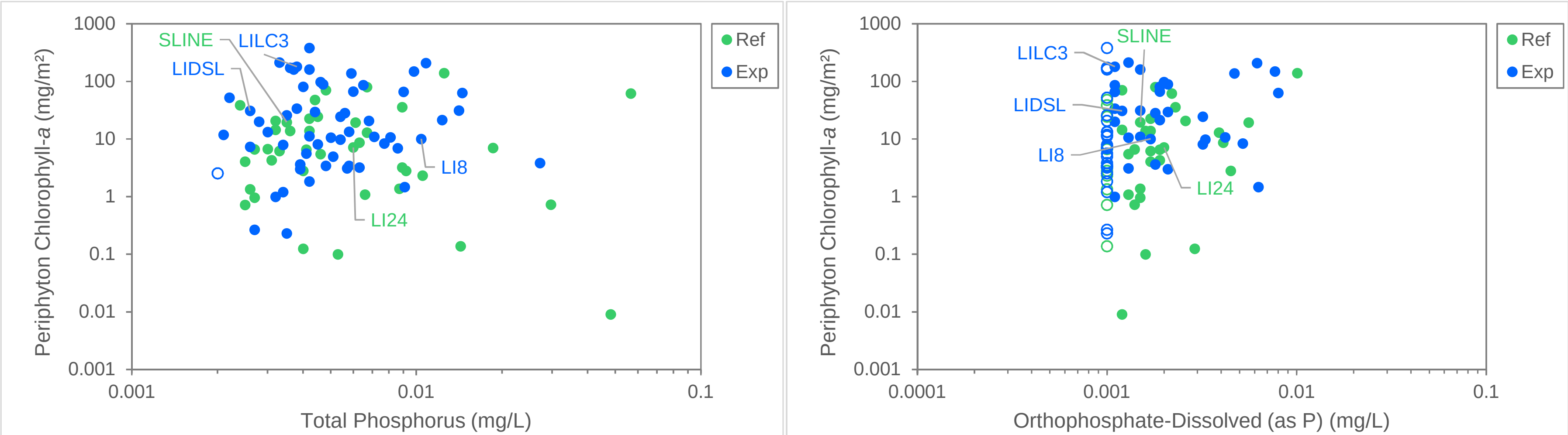


Figure 3.14: Periphyton Chlorophyll-a Concentrations Versus Aqueous Total Phosphorus and Orthophosphate Concentrations

Note: Water samples were collected at the same time as periphyton among 40 reference and 58 mine-exposed areas sampled in the RAEMP, September 2015. Line Creek sampling areas are specifically identified (LIDSL is the Compliance Point LC_LCDSSLCC, see Figure 2.1). Phosphorus concentrations below the detection limit (DL) are plotted as open symbols at the DL.

phosphorus SPO of 0.02 mg/L, but remove the requirement for chlorophyll-a measurements. Monitoring of biological productivity will continue in the Line Creek LAEMP based on benthic invertebrate endpoints. A BACI analysis showed that benthic invertebrate biomass and density (Hess samples) at areas downstream from the WLC AWTF were not any more different from the South Line Creek reference area in 2016 (full WLC AWTF operation) than prior to full WLC AWTF operation. BACI analysis also showed no effects on benthic invertebrate community structure, except reduced family richness at the downstream areas in 2016 relative to the reference area in previous years (2014, 2015). Potential reduction in family-level invertebrate richness at LILC3 was also suggested by kick sample data collected in 2016, compared to data collected in 2014 and 2015, but not in comparison to earlier data from 2012. No adverse effects of associated with operation of the WLC AWTF operation were evident for other community endpoints evaluated for kick samples collected in 2016 compared to previous years.

4 SELENIUM SPECIATION AND TISSUE ACCUMULATION

4.1 Overview

Data evaluated in this section are related to addressing Key Question #2: Are tissue selenium concentrations reduced downstream from the WLC AWTF?

4.2 Initial Investigations

The composite-taxa benthic invertebrate sample collected at LILC3 (LC_LC3) in September 2016 had a higher tissue selenium concentration than was previously observed at that location, and it was also much higher than was observed at the area immediately upstream from the WLC AWTF outfall (LCUT; Table 4.1). Also in mid-to-late 2016, Teck was investigating challenges respecting the performance of the WLC AWTF with respect to selenium removal. Although treatment was successfully reducing total selenium concentrations in Line Creek (Figure 4.1), it had become apparent that some of the remaining selenium in effluent was in chemical forms (e.g., selenite; Figure 4.2) having potentially greater bioavailability to aquatic biota than selenate, which is the dominant form in the influent (Figure 4.3) and other areas of the watershed (Figures 4.4 to 4.6). Although concentrations in the receiving environment continued to be dominated by selenate, there were slightly elevated concentrations of the other forms observed in effluent (Figures 4.4 to 4.6). As of October 2016, previous issues associated with selenium speciation analysis were being resolved, resulting in better analytical resolution and identification of selenium species and improved method detection limits. Detection limits of 0.015 to 0.300 µg/L are now being consistently achieved for all selenium species. The recent analyses have resolved that concentrations formerly reported as selenomethione (a highly bioavailable form) were likely methylseleninic acid (having uncertain, but likely lower, bioavailability compared to selenomethionine). Also, concentrations previously reported as an “unknown” species appear to be, at least in part, dimethylselenoxide (Figure 4.2).

Based on the elevated tissue selenium concentrations observed immediately downstream from the WLC AWTF in September, 2016, and concurrent concerns about selenium species other than selenate being observed in effluent and receiving water samples, additional sampling was undertaken in the winter of 2017 to determine if tissue selenium concentrations were still elevated downstream from the WLC AWTF. The sampling design involved more replication per area for both periphyton and benthic invertebrates, to reduce uncertainties regarding selenium enrichment at the base of the food web (sampling design presented in Appendix B). Further sampling was undertaken in April, 2017, (sampling design in Appendix B), but only the results from February were available for inclusion in this report.

Table 4.1: Selenium Concentrations (mg/kg dw) in Composite-Taxa Benthic Invertebrate Samples (2006 to 2016) n = 1 Per Year

Water Body	Biological Monitoring Area	Teck Water Quality Station	Location Description	2006	2009		2010	2011	2012	2013	2014		2015	2016
				Aug	May/June	Aug/ Sept	Aug	Aug	Sept	July	July	Sept	Sept	Sept
Line Creek	LI24	LC_LC1	Tornado Creek (south fork of upper Line Creek)	1.4	4.4	-	-	-	5.1	-	-	4.0	5.3	3.8
Line Creek	SLINE	LC_SLC	South Line Creek	-	-	-	-	-	4.8	-	-	6.0	3.9	4.1
Line Creek	LCUT	LC_LCUSWLC	Line Creek upstream of the AWTF	-	-	-	-	-	-	-	-	-	-	6.2
Line Creek	LILC3	LC_LC3	Line Creek upstream South Line Creek and downstream of AWTF discharge	-	-	-	-	-	7.0	-	-	17	14	35
Line Creek	-	LC_LCCPL	Line Creek contingency pond	-	-	-	-	-	-	36	42	-	-	-
Line Creek	LIDSL	LC_LCDSSLCC (Compliance Point)	Line Creek downstream South Line Creek and AWTF discharge	-	-	-	-	-	7.7	4.3	5.6	14	8.9	16
Line Creek	LI8	LC_LC4	Line Creek near mouth of Fording	7.8	11	8	6.3	8.4	7.8	-	-	8.4	9.3	12
Fording River	FRUL	FR_FR6	Fording River upstream of Line Creek	-	-	-	-	-	8.0	-	-	-	-	-
Fording River	FO23	FR_FR5	Fording River downstream Line Creek	10	5.8	9.7	5	8.8	7.5	11	8.8	-	6.4	6.7

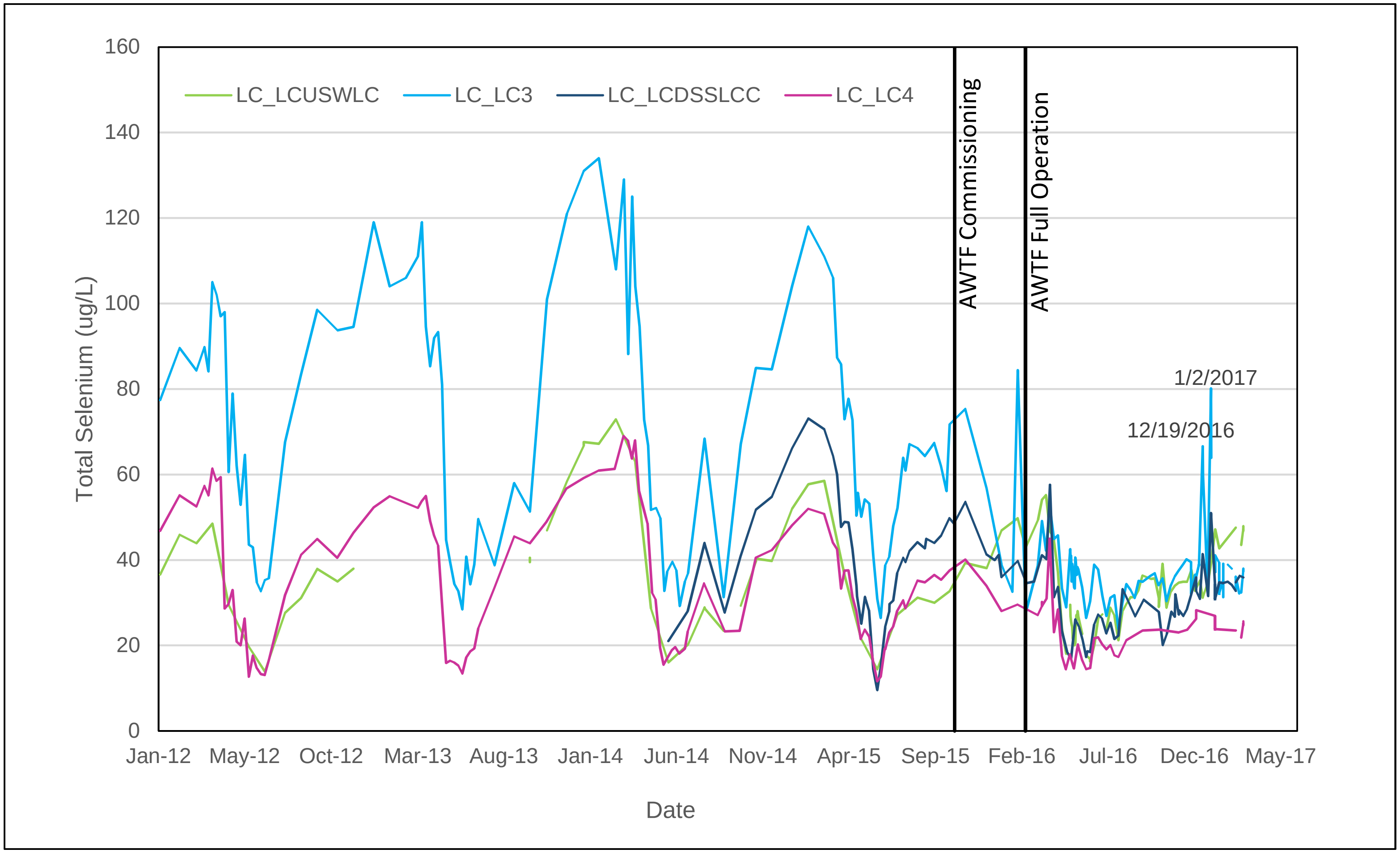


Figure 4.1: Total Concentrations of Selenium in Water in Line Creek, January 2012 to February 2017

Notes: Plant was in recirculation on December 19 and January 2, due to blasted sand clarifier cleaning on December 19, and high phosphorus alarm on January 2.

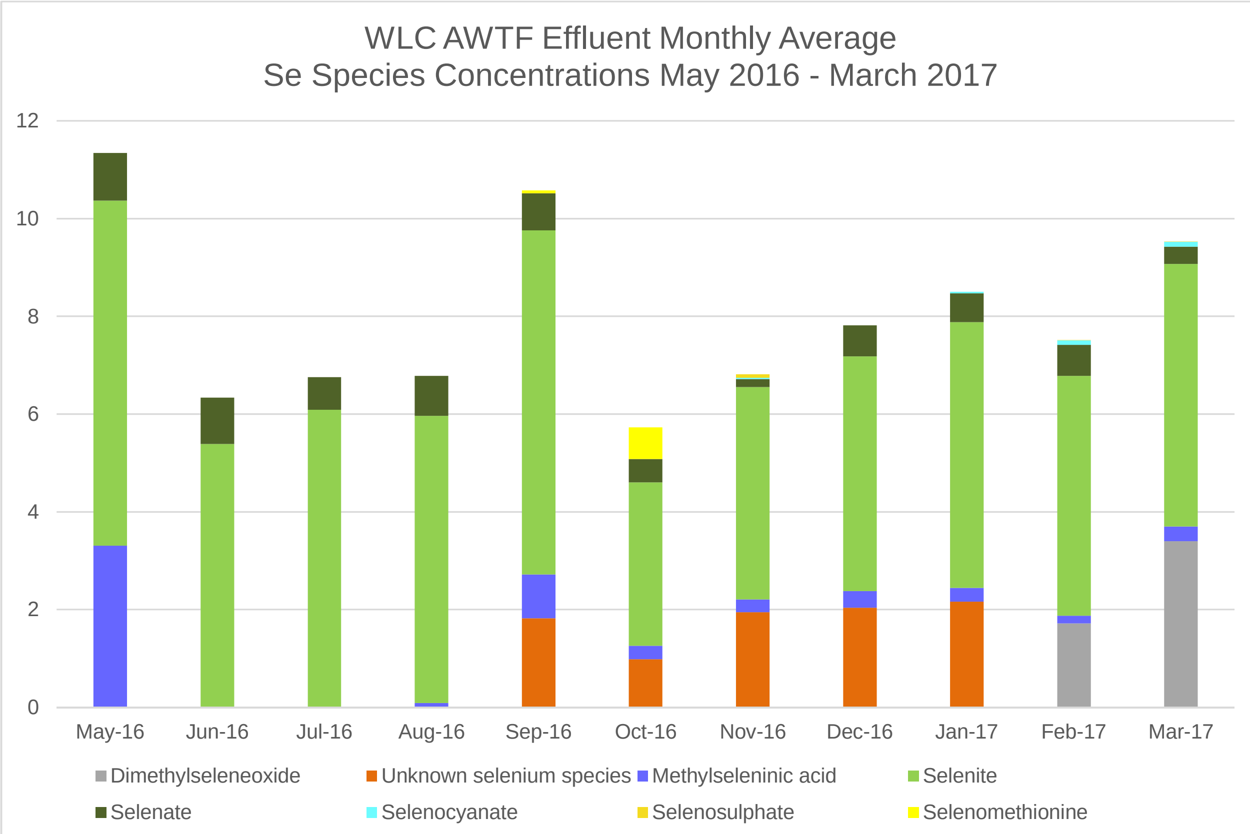


Figure 4.2: **Selenium Species in WLC AWTF Effluent**

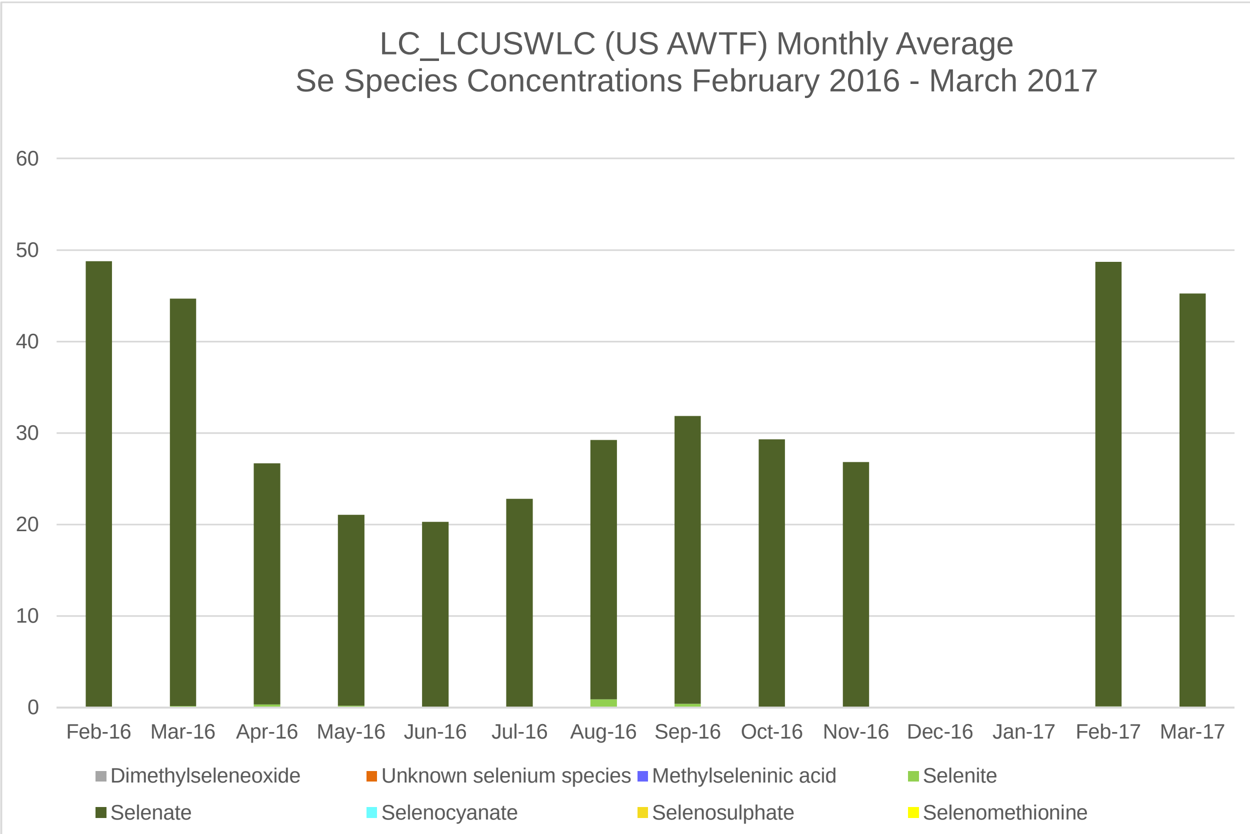


Figure 4.3: **Selenium Species Upstream of AWTF**

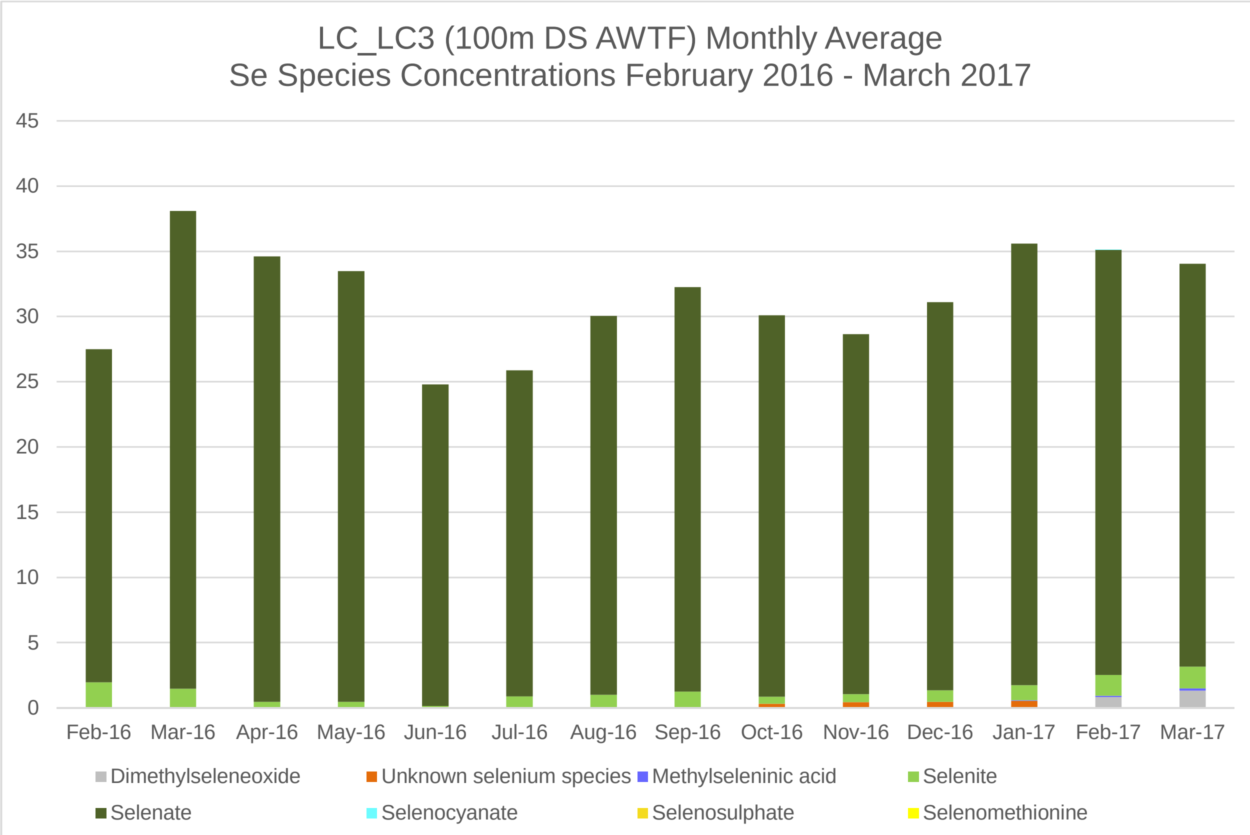


Figure 4.4: **Selenium Species 100m Downstream of AWTF**

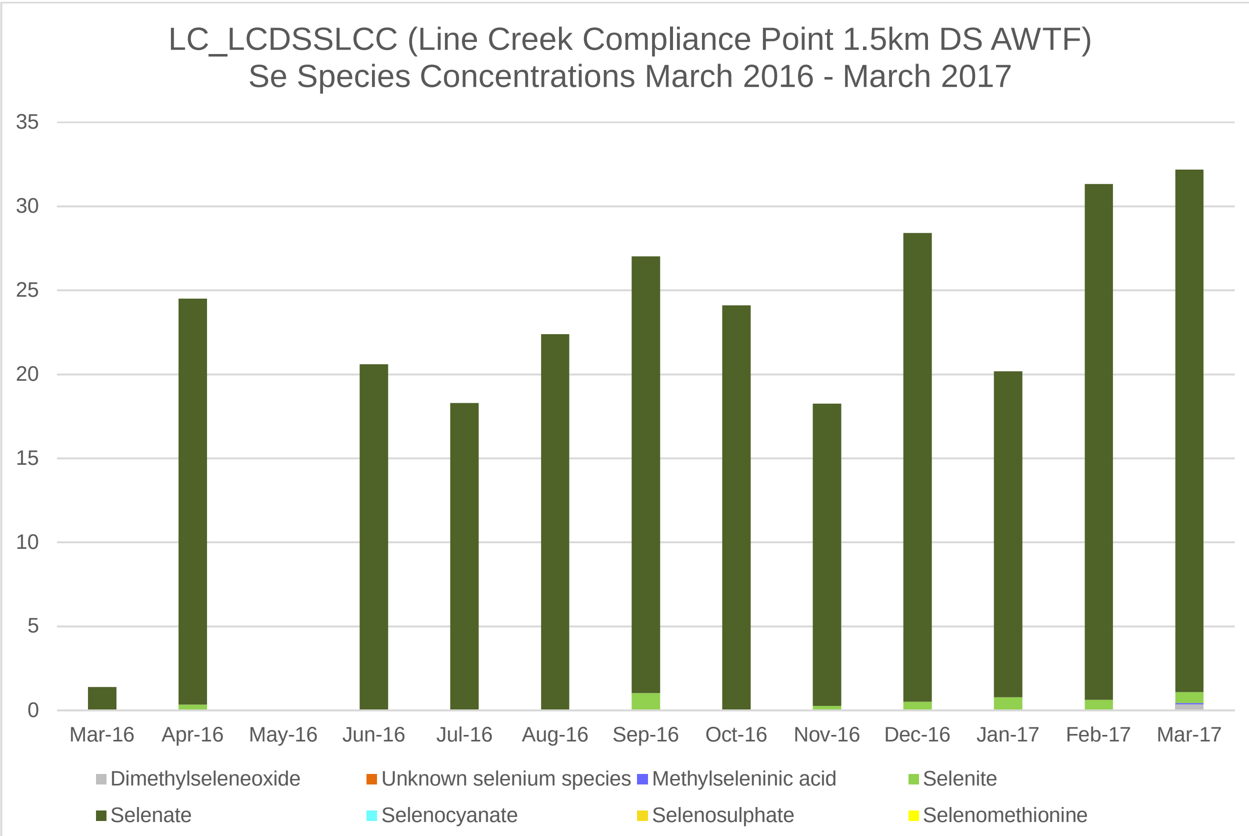


Figure 4.5: **Selenium Species ~1.5km Downstream of AWTF**

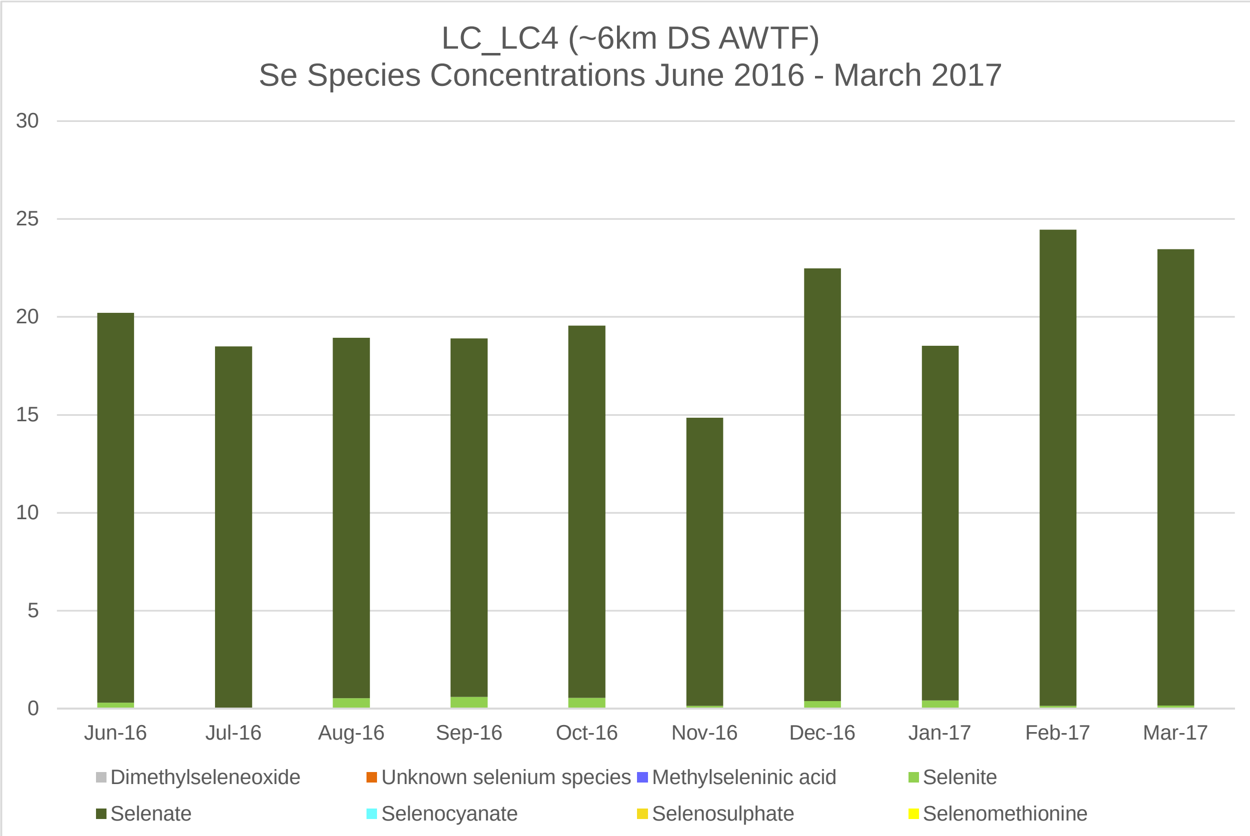


Figure 4.6: **Selenium Species ~6km Downstream of AWTF**

4.3 Additional Sampling in 2017 Compared to Historical Results

4.3.1 Periphyton Tissue Selenium Concentrations

The samples collected in the winter of 2017 indicated that tissue selenium concentrations continued to be elevated immediately downstream from the AWTF compared to previous years (Table 4.2). Although the selenium concentration in periphyton samples collected in September 2016 were not substantially different from previous samples collected in the same areas, the concentrations observed at the areas both upstream and downstream from the WLC AWTF in the winter of 2017 were substantially elevated. Field technicians reported in the winter that sampling was confounded by the presence of calcite and other gritty material that was suspected to be sediment particles that had settled into the calcite-periphyton matrix (Appendix Table A.13). There was also abundant bryophyte growth at LILC3 (as there has been since before WLC AWTF operation), which technicians tried to avoid by sampling on the sides of rocks, where bryophytes were less abundant or absent, and also by collecting the filamentous algae that was also present there. Chemical analysis of periphyton samples included measurement of total organic carbon content and selected metals in an effort to distinguish the proportion of selenium associated with abiotic (e.g., calcite, sediment deposition) versus organic (periphyton) components (Appendix Table D.2). The results suggested that at least some of the selenium reported for samples collected at LCUT (LC_LCUSWLC) and LILC3 (LC_LC3) was associated with inorganic material, but the amount of selenium in periphyton tissue alone could not be confirmed from the available data (but also see section 4.3.2). In spite of the confounding influences, concentrations of selenium in periphyton at LILC3 (downstream from the WLC AWTF) were clearly elevated compared to those at LCUT (upstream from the WLC AWTF). Periphyton selenium concentrations at the two areas sampled further downstream were much lower and, at LI8 (LC_LC4), were comparable to levels observed previously (Table 4.2).

4.3.2 Benthic Invertebrate Tissue Selenium Concentrations

Concentrations of selenium measured in composite-taxa benthic invertebrate samples appeared to be slightly lower in February 2017 at LILC3 (LC_LC3), than in September 2016, but were still higher than historical observations (Table 4.3; Appendix Table A.14). Also, as observed for periphyton, the concentrations at LILC3 were higher than at the area upstream from the WLC AWTF outfall (LCUT/LC_LCUSWLC). Relatively lower benthic invertebrate tissue selenium concentrations compared to periphyton selenium concentrations at both LCUT and LILC3 in February 2017 provided evidence that the concentrations reported for periphyton were confounded by selenium associated with inorganic material (e.g., sediment particles and calcite). This is because concentrations of selenium in invertebrate consumers are typically 1 to 3 times dietary exposure concentrations (Presser and Luoma 2010) and, in the Elk Valley, have typically

Table 4.2: Selenium Concentrations in Periphyton Samples, 2012 to 2017

Water Body	Biological Monitoring Area	Teck Water Quality Station	Location Description	2012 September (mg/kg dw)	2015 September (mg/kg dw)	2016 September (mg/kg dw)	2017 February /March (mg/kg dw)
Line Creek	LI24	LC_LC1	Tornado Creek (south fork of upper Line Creek)	2.1	2.9	5.5	-
	SLINE	LC_SLC	South Line Creek	-	1.5	4.1	-
	LCUT	LC_LCUSWLC	Line Creek upstream of the AWTF	-	-	-	26 (mean)[a]
	LILC3	LC_LC3	Line Creek upstream South Line Creek and downstream of AWTF discharge	18.1	3.8	16	45 (mean)[a]
	LIDSL	LC_LCDSSLCC (Compliance Point)	Line Creek downstream South Line Creek and AWTF discharge	-	1.4	2	5.2 (mean)[a]
	LI8	LC_LC4	Line Creek near mouth of Fording	-	5.3	2.6	3.1 (mean)[a]
Fording River	FRUL	FR_FR6	Fording River upstream of Line Creek	-	3.7	7.1	-
	FO23	FR_FR5	Fording River downstream Line Creek	1.6	9.1	13	-

[a] n=10 per area (Appendix Table A.12).

Table 4.3: **Selenium Concentrations (mg/kg dw) in Composite-Taxa Benthic Invertebrate Samples, 2006 to 2017**

Water Body	Biological Monitoring Area	Teck Water Quality Station	Location Description	2006	2009		2010	2011	2012	2013	2014		2015	2016	2017
				Aug	May/June	Aug/ Sept	Aug	Aug	Sept	July	July	Sept	Sept	Sept	Feb/ Mar
Line Creek	LI24	LC_LC1	Tornado Creek (south fork of upper Line Creek)	1.4	4.4	-	-	-	5.1	-	-	4.0	5.3	3.8	-
	SLINE	LC_SLC	South Line Creek	-	-	-	-	-	4.8	-	-	6.0	3.9	4.1	-
	LCUT	LC_LCUSWLC	Line Creek upstream of the AWTF	-	-	-	-	-	-	-	-	-	-	6.2	5 (mean)[a]
	LILC3	LC_LC3	Line Creek upstream South Line Creek and downstream of AWTF discharge	-	-	-	-	-	7.0	-	-	17	14	35	27 (mean)[a]
	-	LC_LCCPL	Line Creek contingency pond	-	-	-	-	-	-	36	42	-	-	-	-
	LIDSL	LC_LCDSSLCC (Compliance Point)	Line Creek downstream South Line Creek and AWTF discharge	-	-	-	-	-	7.7	4.3	5.6	14	8.9	16	12 (mean)[a]
	LI8	LC_LC4	Line Creek near mouth of Fording	7.8	11	8	6.3	8.4	7.8	-	-	8.4	9.3	12	8.9 (mean)[a]
Fording River	FRUL	FR_FR6	Fording River upstream of Line Creek	-	-	-	-	-	8.0	-	-	-	-	-	-
	FO23	FR_FR5	Fording River downstream Line Creek	10	5.8	9.7	5.9 (mean)	8.8	7.5	11	8.8	-	6.4	6.7 (mean)	-

[a] n= 5 per area in 2017 (Appendix Table A.14).

been about 2.5 times dietary (periphyton) concentrations (Minnow et al. 2011). It is estimated that selenium concentrations reported for periphyton samples from both areas were about five times actual tissue concentrations. Nevertheless, both periphyton and benthic invertebrate data indicated higher selenium concentrations immediately downstream from the WLC AWTF outfall compared to upstream during the February sampling. Concentrations were lower at monitoring areas farther downstream at LIDSL (LC_LCDSSLCC) and LI8 (LC_LC4) (Tables 4.2 and 4.3). Water samples collected in late February and early March for analysis of selenium species identified higher concentrations of non-selenate forms of selenium at stations downstream from the WLC AWTF compared to upstream (Table 4.4).

Individual taxon samples (i.e., Ephemeroptera, *Parapsyche* sp., Rhyacophilidae, Chironomidae) showed a similar pattern of tissue selenium concentrations to the composite-taxa invertebrate tissue samples (Appendix Table A.15), with elevated concentrations immediately downstream of the outfall (LILC3/LC_LC3), but tissue selenium concentrations observed in 2016 and the winter of 2017 at areas farther downstream were lower and comparable to concentrations observed in previous years for the same taxa (Table 4.5).

4.3.3 Evaluation Relative to Tissue Benchmarks and Community Characteristics

Except at LILC3/LC_LC3 and LIDSL/LC_LCDSSLCC, composite-taxa invertebrate tissue selenium concentrations were below Level 1 benchmarks developed in the EVWQP (Figure 4.7). As noted in Section 3.4, BACI analysis based on Hess samples showed that benthic invertebrate biomass and density at areas downstream from the WLC AWTF were not any more different from the South Line Creek reference area in 2016 (full WLC AWTF operation) than prior to full WLC AWTF operation (i.e., no AWTF effect on productivity). The BACI analysis showed lower family richness at the downstream areas in 2016 compared to 2014-2015 (relative to the reference area), but this was not corroborated by kick sample data nor were effects indicated by evaluation of the other community endpoints reported for Hess and kick samples. These data suggest that elevated tissue selenium concentrations observed in 2016 have not influenced benthic invertebrate productivity or community structure (other than conflicting evidence of potential reduction in family richness) at the two areas immediately downstream from the WLC AWTF (LILC3/LC_LC3 and LIDSL/LC_LCDSSLCC). Further monitoring in 2017 will be important for verifying if there has been a change in benthic invertebrate community structure related to WLC AWTF operation and/or elevated tissue selenium concentrations.

4.3.4 Estimated Selenium Concentrations in Fish Tissues

Tissue selenium concentrations were also estimated for cutthroat trout ovaries assuming long-term dietary exposure (e.g., a period of months) within the same areas in which benthic

Table 4.4: Selenium Concentrations Measured in Water, Late February to Early March 2017

Biological Monitoring Area	Water Sample Code	Sample Date	Selenium (ug/L)		Selenium Species (ug/L)								
			Total	Dissolved	Selenate	Selenite	Selenomethionine	Methylseleninic Acid	Selenocyanate	Selenosulfate	Dimethylselenoxide	Unknown Concentrations	Sum of Species
LCUT	LC_LCUSWLC	2/24/2017	41.3	42.5	49.5	0.089	0.0	0.0	0.0	0.0	0.0	0.0	49.6
	LC_LCUSWLC	3/6/2017	45.9	45.5	45.2	0.078	0.0	0.0	0.0	0.0	0.0	0.0	45.3
LILC3	LC_LC3	2/7/2017	33.8	36.4	32	1.68	0.0	0.135	0.004	0.0	-	0.016	33.8
	LC_LC3	2/20/2017	32.2	32.0	32.4	1.66	0.0	0.109	0.0	0.007	-	0.0	34.2
	LC_LC3	2/24/2017	29.9	30.3	33	1.65	0.0	0.153	0.024	0.01	0.944	0.0	35.8
	LC_LC3	3/6/2017	34.6	32.9	30.9	1.66	0.0	0.179	0.0	0.007	1.32	0.007	34.1
LIDSL	LC_LCDSSLCC	2/24/2017	29.0	28.5	33.8	0.632	0.0	0.078	0.0	0.01	0.262	0.012	34.8
	LC_LCDSSLCC	3/6/2017	30.2	31.4	31.1	0.657	0.0	0.076	0.0	0.0	0.365	0.0	32.2
LI8	LC_LC4	2/24/2017	21.3	21.0	25.2	0.075	0.0	0.023	0.007	0.005	0.0	0.0	25.3
	LC_LC4	3/6/2017	23.4	23.3	23.3	0.1	0.0	0.032	0.0	0.01	0.032	0.0	23.5

"-" not reported

Table 4.5: Mean Selenium Concentrations Measured in Specific Invertebrate Taxa (mg/kg dw), 2009 to 2017

Water Body	Biological Monitoring Area	Teck Water Quality Station	Year	Month	Ephemeroptera (Mayflies)	Trichoptera (Caddisflies)		Midges
						Parapsyche sp.[a]	Rhyacophilidae	Chironomidae
Line Creek	(LI24)	LC_LC1	2014	Sept	8.6	-	4.1	-
			2015	Sept	7.5	-	0.74	-
			2016	Sept	7.1	-	4	-
	(SLINE)	LC_SLC	2014	Sept	11	-	3.9	-
			2015	Sept	7.7	-	6.7	-
			2016	Sept	6.7	-	5.2	-
			2017	Feb/Mar	-	-	-	-
	(LCUT)	LC_LCUSWLC	2016	Sept	6.1	-	5.4	-
			2017	Feb/Mar	-	7.6 (mean)	6.3	4.1
	(LILC3)	LC_LC3	2014	Sept	33	-	22	-
			2015	Sept	6.9	-	19	-
			2016	Sept	31	-	42	-
			2017	Feb/Mar	-	50 (mean)	(none found)	17
	LIDSL)	LC_LCDSSLCC	2014	Sept	17	-	21	-
			2015	Sept	7.5	-	29	-
			2016	Sept	14	-	24	-
			2017	Feb/Mar	-	18 (mean)	23	12
	(LI8)	LC_LC4	2009	Sept	-	-	14	-
			2014	Sept	11	-	11	-
			2015	Sept	7.4	-	13	-
			2016	Sept	-	-	12	-
			2017	Feb/Mar	-	12 (mean)	12	(none found)
Fording River	FO23 (downstream from Line Creek)	LC_LC5	2015	Sept	7.3	-	-	-
			2016	Sept	11 (mean)	-	-	-

"-" not sampled
[a] n= 5 per area in 2017 (Appendix Table A.15).

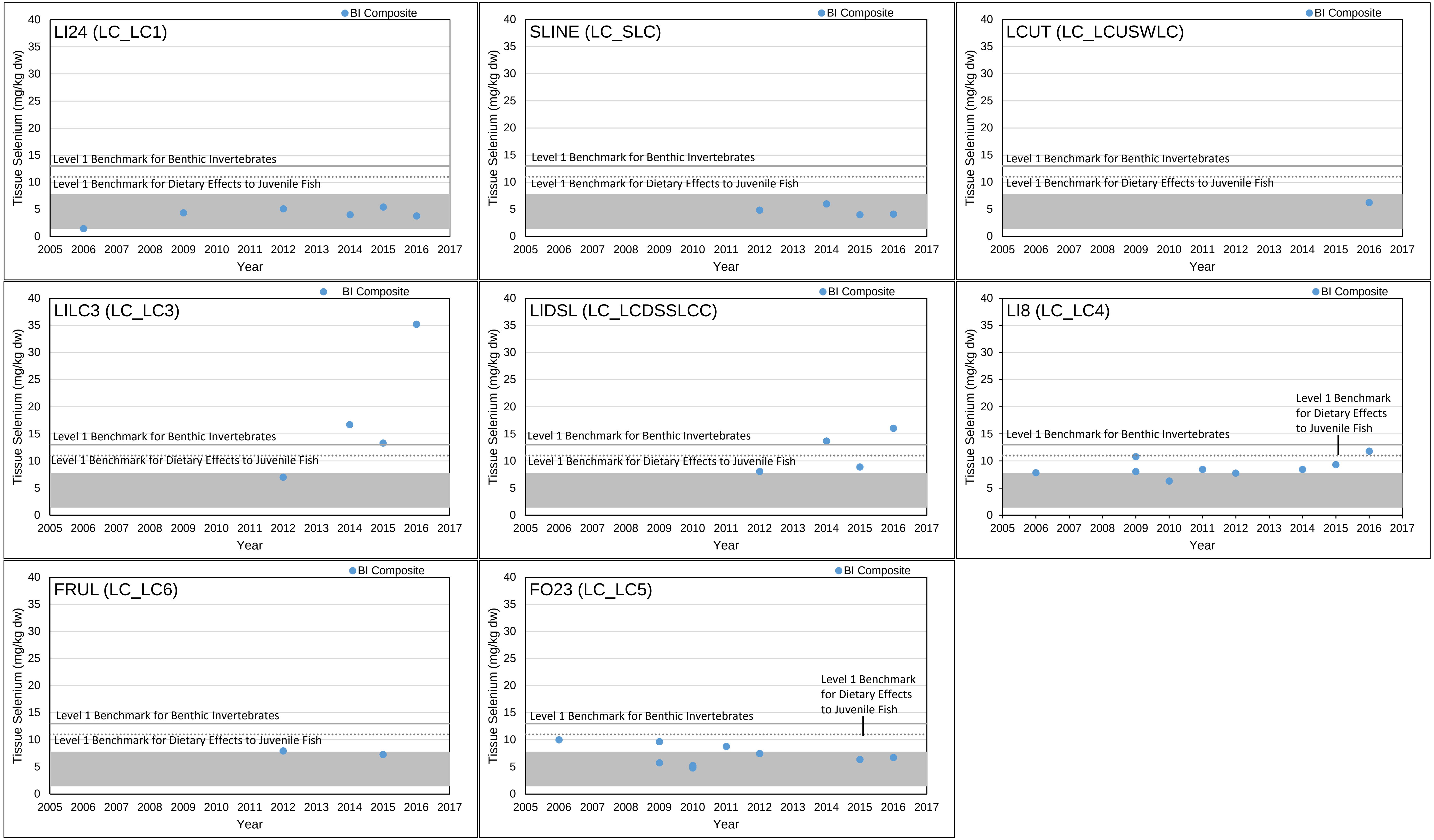


Figure 4.7: Tissue Selenium Concentrations Observed in Benthic Invertebrate (BI) Composite-Taxa Samples Collected in Line Creek and Fording River from 2006 to 2016

Notes: Gray shading represents the normal range defined as the 2.5 th and 97.5th percentiles of values for reference areas sampled in historical studies in the Elk Valley. n = 176.

invertebrates were sampled[3]. The estimates also assumed a dietary selenium exposure (benthic invertebrate)-to-muscle concentration relationship of 1:1 for fish (Presser and Luoma 2010) and a westslope cutthroat trout ovary-to-muscle selenium concentration relationship of 2:1 (Nautilus and Environmental and Interior Reforestation Co. Ltd. 2011). Except at LILC3 (LC_LC3) and LIDSL (LC_LCDSSLCC), estimated ovary selenium concentrations were less than the EVWQP Level 1 selenium benchmark (Figure 4.8). Historical cutthroat trout muscle selenium concentrations observed in fish captured in lower Line Creek are presented in Figure 4.9 for further context; however, no recent tissue data are available. Two cutthroat trout and one bull trout were captured in sampling completed in April, 2017, along with collection of additional periphyton and benthic invertebrate samples. The results will be presented to the EMC once available. Further sampling of fish tissues is planned for September 2017 and winter 2018 (Minnow 2017).

4.4 Management Responses

Teck is continuing to advance work to address the challenge in plant performance related to selenium speciation, consistent with an adaptive management approach. It has been determined that timely and successful testing and implementation of a solution to this challenge requires continued operation of the facility. On-going operation will also have the benefit of continued removal of 99% of the nitrate from mine-affected water (i.e., 3,500 kg of nitrates that are not being released to the receiving environment each month).

- Activities and advancement related to the selenium speciation issue include:
- Collecting selenium speciation samples within the plant process
- Maintaining plant stability and establishing a baseline of selenium speciation
- Analyzing plant data to determine how operational changes correlate with a change in selenium speciation in the WLC AWTF
- Identifying a number of potential pilot scale options including continued bench-scale testing
- Expect to begin pilot-scale testing in the summer on prioritized options (Advanced Oxidation Process)

[3] An assumption of high dietary fidelity within areas of limited size is not realistic, but provides an indication of the fish tissue selenium concentrations that could be expected under a worst-case dietary exposure scenario (e.g., dietary exposure at LILC3/LC_LC3).

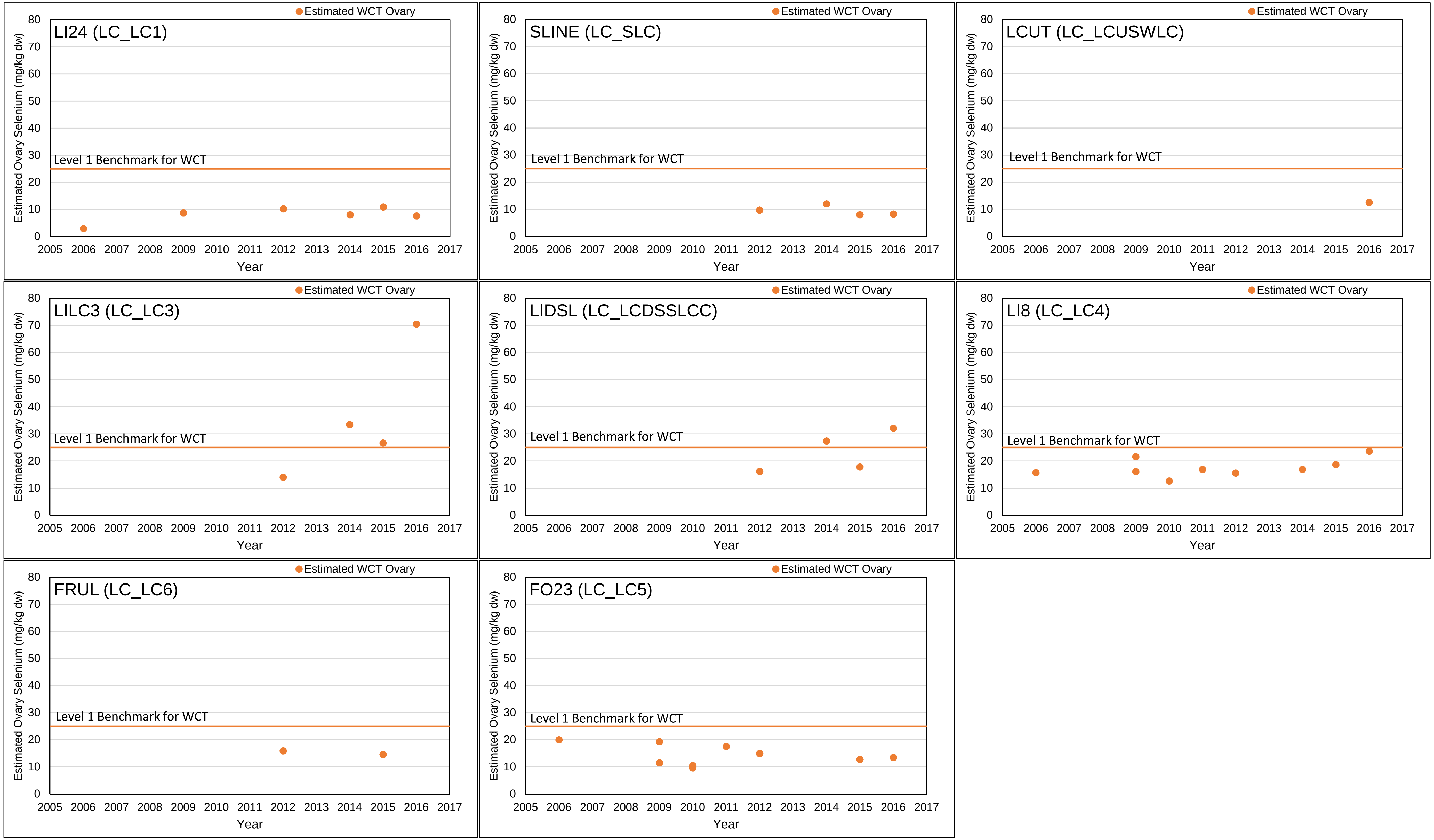


Figure 4.8: Estimated Westslope Cutthroat Trout Ovary Selenium Concentrations

Notes: Estimated based on a dietary exposure (benthic invertebrate-to-muscle) concentration relationship of 1:1 (Presser and Luoma 2010) and an ovary-to-muscle concentration relationship of 2:1 (Nautilus and Environmental and Interior Reforestation Co. Ltd. 2011).

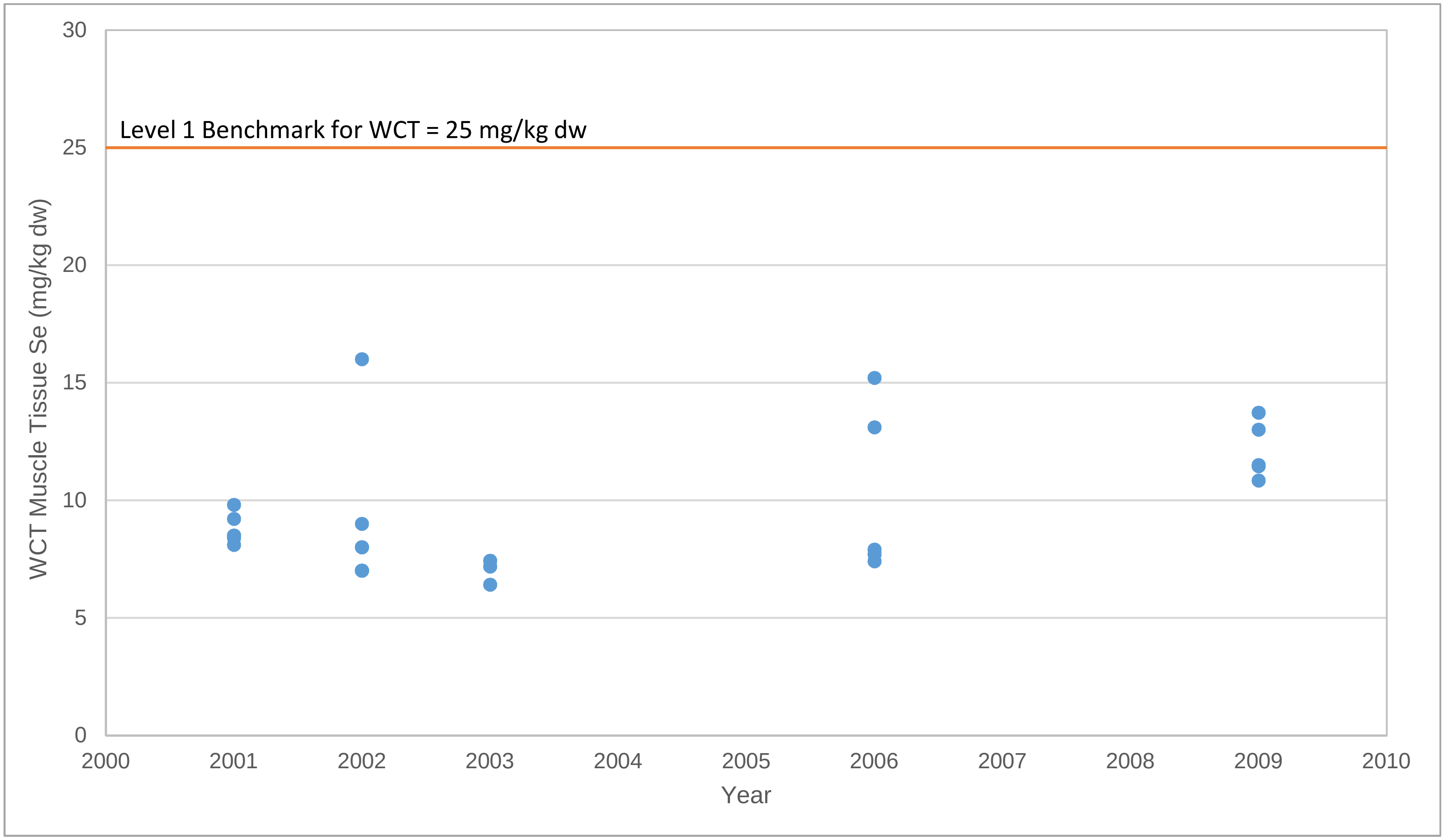


Figure 4.9: Westslope Cutthroat Trout (WCT) Muscle Selenium Concentrations at LI8 (LC_LC4), 2001 to 2009

- Assessing the implications for the design and flowsheet for the planned FRO-S WLC AWTF so the regulatory application for FRO-S WLC AWTF can be submitted
- Continued research and development of alternative treatment methods such as the Saturated Rock Fill full scale trial project at Elkview Operation

Receiving environment monitoring is continuing throughout 2017, with routine measurement of selenium species in effluent and receiving water, along with biological sampling campaigns in February-March, April, and September as part of the Line Creek LAEMP.

4.5 Summary

Tissue selenium concentrations observed in 2016 and early 2017 indicate that, although the WLC AWTF has successfully reduced total selenium loads to the receiving environment, some of the residual effluent load may have shifted from selenate, which has relatively low bioavailability (and is the dominant form in AWTF influent and in other areas of the watershed), to other selenium forms that may be more bioavailable. Tissue selenium concentrations in periphyton and benthic invertebrates were increased immediately downstream from the WLC AWTF outfall during the 2016 and early 2017 sampling campaigns compared to historical levels. Additional monitoring is required to fully understand the potential effects of selenium speciation on the receiving environment, including:

- Ongoing water quality data including selenium speciation analysis; and
- Further biological sampling in April and September, 2017 as well as February 2018, to evaluate tissue selenium concentrations and potential effects on benthic invertebrate community structure.

5 OTHER POTENTIAL INFLUENCES OF THE WLC AWTF

5.1 Overview

Data evaluated in this section are related to addressing Key Question #3: Is WLC AWTF operation affecting aquatic biota through thermal effects, effects on dissolved oxygen concentrations, or concentrations of treatment-related constituents other than nutrients or selenium?

5.2 Temperature

Water temperature data for the period 2013 to 2016 are presented for the Compliance Point (LIDSL/LC_LCDSSLCC) and upstream reference areas (Figure 5.1). No temporal trends in water temperatures in the receiving environment from 2013 to 2016 were observed for annual water temperature, water temperature measured over the periphyton growing season (June 15-September 30, as defined in Permit 107517), or in the month prior to biological sampling completed in early September at LC_LCDSSLCC (see Appendix C of the Proposed SPO Update, in Appendix C of this report). Monthly mean water temperature measurements downstream of the WLC AWTF discharge in 2016 were minimally elevated compared to upstream water temperatures (Table 5.1), with the differences ranging from 0.4 to 1.1 °C among months. BC water temperature guidelines for bull trout and westslope cutthroat trout specify a maximum ± 1 °C change from the optimum temperature range for different life stages of these species (Table 5.2). Line Creek water temperatures were lower than the optimum temperature ranges for the different life stages of westslope cutthroat prior to AWTF operation but were slightly warmer after the AWTF was commissioned (Table 5.2; BCMOE 2017). Therefore, WLC AWTF operation has not adversely affected water temperatures in Line Creek with respect to fish.

5.3 Dissolved Oxygen

Line Creek immediately downstream of the WLC AWTF discharge remains well oxygenated with concentrations above the most conservative MOE guideline for the protection of the most sensitive fish (embryo/alevin) life stages (Figure 5.2; BCMOE 2017).

5.4 Toxicity Results

Most samples of WLC AWTF effluent caused no mortalities in 48-hour *Daphnia magna* and 96-hour rainbow trout (*Oncorhynchus mykiss)* toxicity tests (Table 5.3). Only two of 90 *Daphnia magna* tests and none of the 57 rainbow trout tests failed (i.e., ≥ 50% mortality). No mortalities were observed in acute toxicity tests of samples collected at the Compliance Point (LC_LCDSSLCC) (Table 5.4).

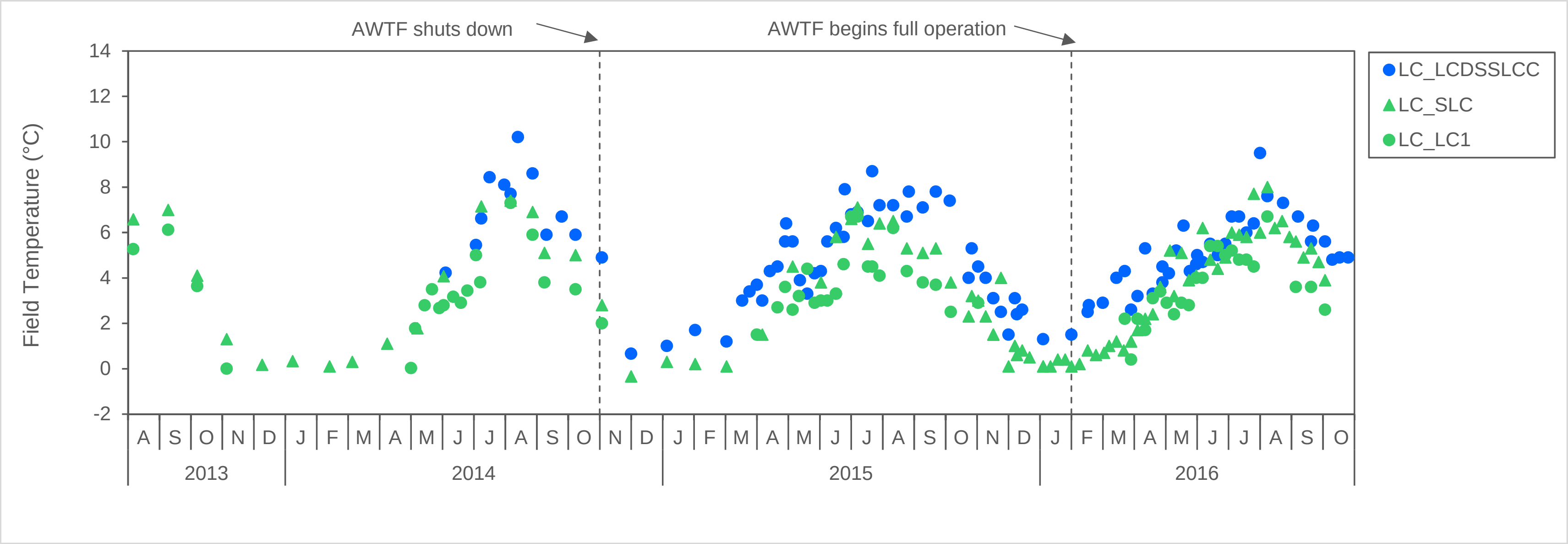


Figure 5.1: **Scatterplot of field temperature at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016**

Table 5.1: Mean Monthly Temperature Measurements at WLC AWTF in 2016

Month	AWTF (LC_WTF_OUT)	Upstream AWTF (LC_LCUSWLC)	Downstream AWTF (LC_LC3)	Downstream-Upstream (Difference)
Feb-16	5.6	3.7	4.5	0.7
Mar-16	5.2	3.5	4.3	0.8
Apr-16	7.7	4.2	4.9	0.7
May-16	9.3	4.3	4.9	0.6
Jun-16	9.7	5.1	6.1	1.0
Jul-16	8.2	5.7	6.8	1.1
Aug-16	8.3	6.1	7.2	1.1
Sep-16	7.3	6.1	7.2	1.1
Oct-16	6.8	5.1	5.8	0.7
Nov-16	7.3	4.7	5.1	0.4
Dec-16	5.0	3.4	3.4	0.0

Table 5.2: Summary of MOE Optimum Temperature Ranges for Aquatic Life

Species	Life Stage[a]		
	Incubation	Rearing	Spawning
Westslope Cutthroat Trout	9.0 - 12.0	7.0 - 16.0	9.0 - 12.0
Bull Trout[b]	2.0 - 6.0	6.0 - 14.0	5.0 - 9.0

[a] Recommended guideline of ± 1 degree Celsius change beyond optimum temperature range.
[b] Maximum daily temperature 15 °C, maximum incubation temperature is 10 °C, minimum incubation temperature is 2 °C, and maximum spawning temperature is 10 °C.

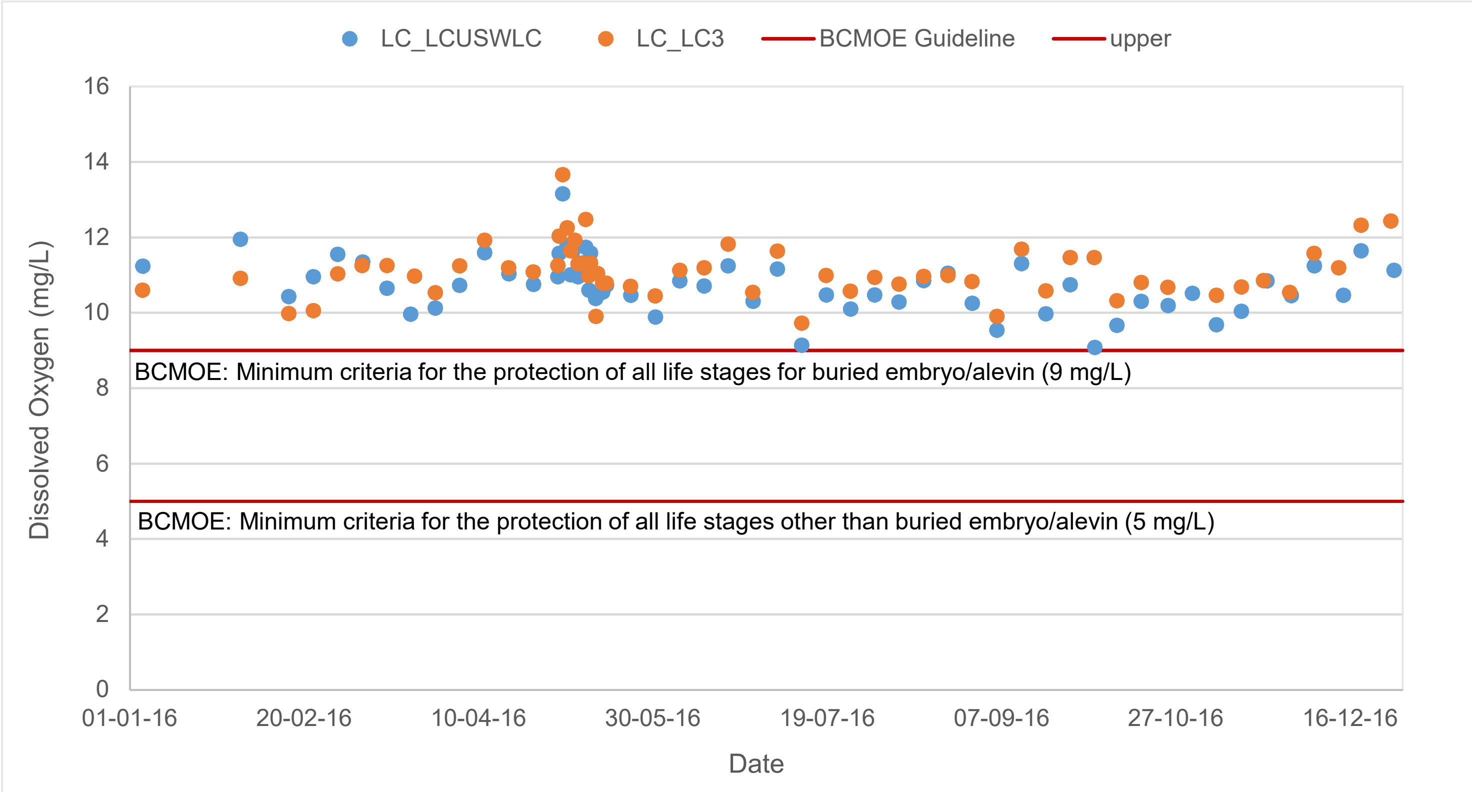


Figure 5.2: Dissolved Oxygen Concentrations in Line Creek Immediately Upstream (LC_LCUSWLC) and Downstream (LC_LC3) of the WLC AWTF in 2016

Table 5.3: Acute Toxicity Results for WLC AWTF Effluent for 2016

Daphnia magna				*Oncorhynchus mykiss*	
Date	**Percent Mortality**	**Date**	**Percent Mortality**	**Date**	**Percent Mortality**
4-Jan-16	0	29-Aug-16	17	4-Jan-16	0
18-Jan-16	0	6-Sep-16	0	18-Jan-16	0
18-Jan-16	0	6-Sep-16	23	2-Feb-16	0
26-Jan-16	0	12-Sep-16	26	8-Feb-16	0
2-Feb-16	0	17-Sep-16	0	16-Feb-16	0
8-Feb-16	0	19-Sep-16	0	22-Feb-16	0
22-Feb-16	0	19-Sep-16	0	29-Feb-16	0
29-Feb-16	0	26-Sep-16	0	7-Mar-16	0
21-Mar-16	0	26-Sep-16	0	21-Mar-16	0
28-Mar-16	80	3-Oct-16	0	28-Mar-16	0
4-Apr-16	13	3-Oct-16	0	31-Mar-16	10
11-Apr-16	3	3-Oct-16	7	4-Apr-16	0
18-Apr-16	3	11-Oct-16	0	11-Apr-16	0
25-Apr-16	10	11-Oct-16	0	18-Apr-16	0
2-May-16	0	11-Oct-16	10	25-Apr-16	0
9-May-16	27	17-Oct-16	0	2-May-16	0
16-May-16	3	17-Oct-16	0	9-May-16	0
16-May-16	47	17-Oct-16	0	16-May-16	0
25-May-16	0	24-Oct-16	0	25-May-16	0
25-May-16	0	24-Oct-16	0	30-May-16	0
30-May-16	0	31-Oct-16	0	6-Jun-16	0
30-May-16	0	31-Oct-16	0	13-Jun-16	0
6-Jun-16	0	7-Nov-16	0	20-Jun-16	0
6-Jun-16	0	7-Nov-16	0	27-Jun-16	0
8-Jun-16	20	14-Nov-16	0	4-Jul-16	0
13-Jun-16	0	14-Nov-16	0	11-Jul-16	0
13-Jun-16	0	21-Nov-16	0	18-Jul-16	0
20-Jun-16	0	21-Nov-16	0	25-Jul-16	0
20-Jun-16	0	28-Nov-16	0	25-Jul-16	20
27-Jun-16	0	28-Nov-16	0	1-Aug-16	0
27-Jun-16	10	5-Dec-16	0	8-Aug-16	0
4-Jul-16	7	5-Dec-16	0	15-Aug-16	0
4-Jul-16	0	12-Dec-16	0	19-Aug-16	0
11-Jul-16	0	12-Dec-16	0	22-Aug-16	0
11-Jul-16	0	19-Dec-16	0	29-Aug-16	0
18-Jul-16	0	19-Dec-16	0	6-Sep-16	10
18-Jul-16	0	27-Dec-16	0	17-Sep-16	0
25-Jul-16	0	27-Dec-16	0	19-Sep-16	0
25-Jul-16	0			26-Sep-16	0
1-Aug-16	0			3-Oct-16	0
1-Aug-16	0			11-Oct-16	0
8-Aug-16	0			17-Oct-16	0
8-Aug-16	0			24-Oct-16	0
15-Aug-16	0			31-Oct-16	0
15-Aug-16	27			7-Nov-16	0
15-Aug-16	90			14-Nov-16	0
18-Aug-16	0			21-Nov-16	0
19-Aug-16	0			28-Nov-16	0
19-Aug-16	0			5-Dec-16	0
22-Aug-16	0			12-Dec-16	0
22-Aug-16	43			19-Dec-16	0
29-Aug-16	0			27-Dec-16	0

Table 5.4: Results for Acute Toxicity Tests Measured at LC_LCDSSLCC in 2016

Date	Percent Survival	
	Daphnia magna	*Oncorhynchus mykiss*
31-Oct-16	100	100
15-Nov-16	100	100
19-Dec-16	100	100

Table 5.5: Results of Quarterly and Semi-Annual Toxicity Tests at LC_LCDSSLCC in 2016[a,b] (Golder 2017)

Quarter	*C. dubia*		*P. subcapitata*	*O. mykiss*			
	% Survival	Reproduction (%control-normalized)	Cell Yield ($x10^4$ cells/ml)	Survival (%control-normalized)	Viability (%control-normalized)	Length (%control-normalized)	Wet Weight (%control-normalized)
Q1	100	109 ± 16	129.5 ± 5.3	-	-	-	-
Q2	100	**67 ± 39**	**<u>91.0 ± 4.8</u>**	<u>88 ± 16</u>	<u>78 ± 6</u>	104 ± 2	97 ± 2
Q3	100	83 ± 21	119.5 ± 5.5	-	-	-	-
Q4	100	94 ± 18	156.0 ± 4.5	**<u>69 ± 8</u>**	**<u>70 ± 10</u>**	104 ± 1	116 ± 11

Notes: **Bold values** = result siginificantly lower than Fording River reference
<u>Underlined values</u> = result significantly lower than Elk River reference.

[a] Results presented as percent survival or endpoint ± standard deviation.

[b] For any endpoint that was determined to be influenced by organism performance, results are expressed as percent control normalized units.

Ceriodaphnia dubia (C. dubia) reproduction was significantly reduced at LC_LCDSSLCC relative to reference samples in Q2 (Table 5.5). Golder (2017) reported that the concentration of nitrate in the Line Creek sample (6.33 mg/L NO_3-N) was slightly lower than the EVWQP Level 2 benchmark (7.4 mg/L NO_3 at hardness 203 mg/L as $CaCO_3$; Golder 2014), indicating that nitrate may have contributed to the observed response in this test.; however, evidence for adverse effects was equivocal because reproduction was significantly reduced relative to one but not both reference samples. *P. subcapitata* cell yield was significantly reduced relative to both reference samples in Q2 which indicated a possible adverse response to the test water. *O. mykiss* survival was significantly reduced in Q2 and Q4 compared to both reference samples. The viability endpoint for *O. mykiss* was also significant relative to only one reference sample in Q2 but for both in Q4, indicating a possible adverse response to the test water during the latter quarter. Concentrations of all parameters in these tests were equal to or lower than concentrations in reference waters and/or test site waters with non-significant results, and were lower than the chronic BC water quality guidelines, so no water quality parameter was identified as a potential cause of the statistically significant result in these tests (Golder 2017).

5.5 Calcite

Calcite indices measured as part of the regional calcite monitoring program and in association with benthic invertebrate sampling (using kick nets) in the LAEMP are summarized in Table 5.6 as further supporting information. A small increase in calcite index was observed at benthic invertebrate monitoring areas downstream (CI=1.1) compared to upstream (CI=0.89) of the AWTF in 2016 (Table 5.6).

5.6 Summary

There do not appear to be other potential influences associated with WLC AWTF operation (i.e. temperature, dissolved oxygen, or precipitation of calcite) that are not already being addressed through monitoring related to for Key Questions #1 (productivity) and #2 (tissue selenium accumulation).

Table 5.6: Calcite Index Values in Line Creek from 2013 to 2016

Biological Monitoring Area	Teck Water Station	Calcite Reach*	Teck Regional Calcite Monitoring (Calcite Index)				Calcite Index at Benthic Invertebrate Monitoring Areas	
			2013	2014	2015	2016	2015	2016
LI24	LC_LC1	LINE7	0.00	0.00	0.00	0.00	0.00	0.00
SLINE	LC_SLC	SLIN2	0.00	0.00	0.00	0.00	0.00	0.32
LCUT	LC_LCUSWLC	-	-	-	-	-	-	0.89
LILC3	LC_LC3	LINE4	0.40	0.27	0.68	0.65	1.00	1.06
LIDSL	LC_LCDSSLCC	LINE3-75	0.00	0.00	0.00	-	0.60	0.78
LI8	LC_LC4	LINE1-75	0.40	0.00	0.00	0.00	0.04	0.48
FRUL	LC_LC6	FORD2-25	0.00	0.00	0.00	0.00	0.00	0.01
FO23	LC_LC5	FORD1-50	0.00	0.00	0.00	0.20	0.93	0.37

6 SUMMARY

The various indicators of primary and secondary productivity (i.e., periphyton chlorophyll-a and AFDM, benthic invertebrate biomass, density, and sample abundance) indicated a pattern of highest productivity at LILC3, immediately downstream from the WLC AWTF outfall, and lower productivity with increasing distance downstream, but this pattern was evident prior to WLC AWTF operation. A before-after/control-impact (BACI) analysis showed that of benthic invertebrate biomass and density (Hess samples) at areas downstream from the WLC AWTF were not any more different from the South Line Creek reference area in 2016 (full WLC AWTF operation) than prior to full WLC AWTF operation (2014, 2015). BACI analysis also showed no effects on benthic invertebrate community structure, except reduced family richness at the downstream areas in 2016 relative to the reference area in previous years. Potential reduction in family-level invertebrate richness at LILC3 and LIDSL was also suggested by kick sample data collected in 2016, compared to data collected in 2014 and 2015, but not in comparison to earlier data from 2012. No adverse effect of WLC AWTF operation was evident for other community endpoints evaluated for kick samples collected in 2016 compared to previous years.

Tissue selenium data collected in 2016 and early 2017 indicate that, although the WLC AWTF has successfully reduced total selenium loads to the receiving environment, some of the residual effluent load may have shifted from being in the form of selenate, which has relatively low bioavailability (the dominant form in AWTF influent and in other areas of the watershed), to other selenium forms that may be more bioavailable. Tissue selenium concentrations in periphyton and benthic invertebrates were increased immediately downstream from the WLC AWTF outfall during the sampling campaigns to historical and upstream levels. Additional monitoring is required to fully understand these results, including potential effects of selenium speciation on the receiving environment.

There do not appear to be other potential influences associated with WLC AWTF operation that are not already being addressed through sampling for Key Questions #1 (productivity) and #2 (tissue selenium accumulation).

The LAEMP will be repeated annually for at least two more years to allow for three years of sampling during full operation of the WLC AWTF to monitor potential changes in the receiving environment. In light of the results of the 2016 Line Creek LAEMP the sampling design will be modified for the 2017 Line Creek LAEMP study design, allowing greater resolution of spatial differences along Line Creek (i.e., additional sampling areas) and measurement of within-area variability in biological endpoints (i.e., more replicates) to improve understanding of the local aquatic effects on Line Creek associated with WLC AWTF operation (Minnow 2017).

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APPENDIX A

DETAILED DATA

Habitat Data

Table A.1: Habitat Information Associated with Mine-Exposed and Reference Areas Sampled During the Benthic Invertebrate Survey, September 2016

Station ID	Reference		Mine-Exposed					
	LI24	SLINE	LCUT	LILC3	LIDSL	LI8	FO23	FRUL
Waterbody	Tornado Creek	Line Creek	Line Creek	Line Creek	Line Creek	Line Creek	Fording River	Fording River
Date Sampled	8-Sep-16	8-Sep-16	9-Sep-16	9-Sep-16	7-Sep-16	9-Sep-16	9-Sep-16	10-Sep-16
Zone 11 UTMs - E	662214	661122	660114	659931	659293	655421	652962	654549
Zone 11 UTMs - N	5538393	5531374	5532140	5531841	5530590	5528967	5528825	5530179
Elevation	1,659	1,503	1,448	1,637	1,393	1,281	1,216	1,248
Samplers' Initials	CR-DH-JG	CR-DH-JG	CR-DH-JG	CR-DH-JG	CR-DH-JG	CR-DH-JG	CR-DH-JG	SW-DH
Habitat Characteristics								
Surrounding Land Use	Mining	Mining	Mining	Mining	Mining	Mining	Mining	Forest
Anthropogenic Influences	Upstream of Line Creek	Upstream of Line Creek Operations	Line Creek down of spoils	Line Creek Operations	Downstream of Line Creek treatment	Line Creek Operations upstream	Downstream of Fording	Mining upstream
Length of Reach Assessed (m)	50	50	-	50	100	50-100	-	100
% Riffle	90	50	90	100	100	40	65	100
% Run	0	0	0	0	0	40	0	0
% Rapids	0	50	10	0	0	20	35	0
% Pool/Back Eddy	10	0	0	0	0	0	0	0
Streamside Vegetation (most dominant first)	Coniferous trees, shrubs, ferns/grass	Coniferous trees, deciduous trees, shrubs, ferns/grass	Coniferous trees, deciduous trees, shrubs, ferns/grass	Coniferous trees, shrubs, ferns/grass	Coniferous trees, shrubs, ferns/grass	Coniferous trees, deciduous trees, shrubs, ferns/grass	Coniferous trees, deciduous trees, shrubs, ferns/grass	Coniferous trees, shrubs
% Bedrock	0	0	0	0	0	0	0	0
% Boulder	trace	30	10	10	5	5	5	trace
% Cobble	60	30	50	30	60	40	40	60
% Pebble	30	20	30	50	20	40	40	30
% Gravel	5	15	10	10	15	10	10	10
% Sand/Finer	5	5	0	0	0	5	5	trace
% Organic	0	0	0	0	0	0	0	0
Canopy Coverage (%)	1 - 25	1 - 25	1 - 25	0	0	26 - 50	1 - 25	1 - 25
Macrophyte Coverage (%)	0	0	0	0	0	0	0	0
Periphyton Coverage	3	2	3	3	2	2	2	-
Bank Stability	unstable, substantial erosion	unstable, substantial erosion	stable, no erosion	stable, no erosion	stable, no erosion	moderate	moderate	moderate
Water Colour & Clarity	colourless/clear	colourless/clear	colourless/clear	colourless/clear	colourless/clear	colourless/clear	colourless/clear	colourless/clear
Bankfull Width (m)	9	13	22	33	15	22	28	33
Wetted Width (m)	5	7	5.4	5	11	11	19	13.2
Bankfull-Wetted Depth (cm)	120	150	21	3-4	69	3.5	150	150
Gradient (%)	2.0	3.0 - 4.0	1.5 - 2.0	3.0	1.5	1.5 - 2.0	0.5	2.0
Comments/Notes	Lots of algae on rocks.	Very difficult to Hess due to large size of rocks. Where rocks were cobble size water depth was too low to Hess. Productivity samples appear low in number of organisms relative to kick and sweep samples.	Small mayfly sample.	-	-	Lots of mayflies at this location.	No Rhyacophilidae	-
Benthic								
Number of Samples	3	-	3	-	3	2	2	-
Approx. weight of sample (grams)	>1	>1	>1	>1	>1	>0.5	>0.5	-
Time spent sampling (Hours)	1	1	1.5	1.5	5 - 7	1	1	-
Dominant Taxa	Plecoptera	Plecoptera Rhyacophilidae Hydropsychidae	Hydropsychidae Rhyacophilidae Plecoptera	Hydropsychidae Ephemoptera	Trichoptera Plecoptera Ephemoptera	Ephemoptera Hydropsychidae Rhyacophilidae Plecoptera	Perlidae Ephemoptera	-
Macrophyte Samples	No	No	No	No	No	No	No	No
CABIN								
Samplers' Initials	DH	CR	CR	DH	CR	DH	CR	DH
Equipment	Triangle Net	Triangle Net	Triangle Net	Triangle Net	Triangle Net	Triangle Net	Triangle Net	Triangle Net
Sieve Size (um)	400	400	400	400	400	400	400	400
100 pebble count completed?	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Sampling Time (min)	3	3	3	3	3	3	3	-
Total Kick Distance (m)	20	16	21	20	13	30	25	-
Number of Jars	1	1	1	1	1	1	1	1
Number of transects	4	2.5	4	4	1.3	3	2.5	2.5
Distance from shore (m)	-	-	-	-	-	-	10	6

Table A.2: ***In Situ* Water Quality Measurements LCO LAEMP, September 2016**

Characteristics	Reference		Mine-Exposed					
	LI24	**SLINE**	**LCUT**	**LILC3**	**LIDSL**	**LI8**	**FRUL**	**FO23**
Date	8-Sep-16	8-Sep-16	9-Sep-16	9-Sep-16	7-Sep-16	9-Sep-16	10-Sep-16	9-Sep-16
Temperature (°C)	3.82	4.87	5.78	5.25	7.68	7.30	6.89	10.20
Conductivity (uS/cm)	344	229	596	648	535	473	453	494
Specific Conductivity (uS/cm)	205	371	941	1041	799	715	692	689
pH	7.00	7.21	7.43	6.89	7.14	7.59	8.23	7.67
Dissolved Oxygen (mg/L)	11.62	11.95	12.17	11.74	13.17	11.19	12.02	10.34
Dissolved Oxygen (%)	88.5	93.4	97.5	92.7	110.6	93.1	99	92.2

Table A.3: Mean Pebble Measurements for 2016 Line Creek LAEMP

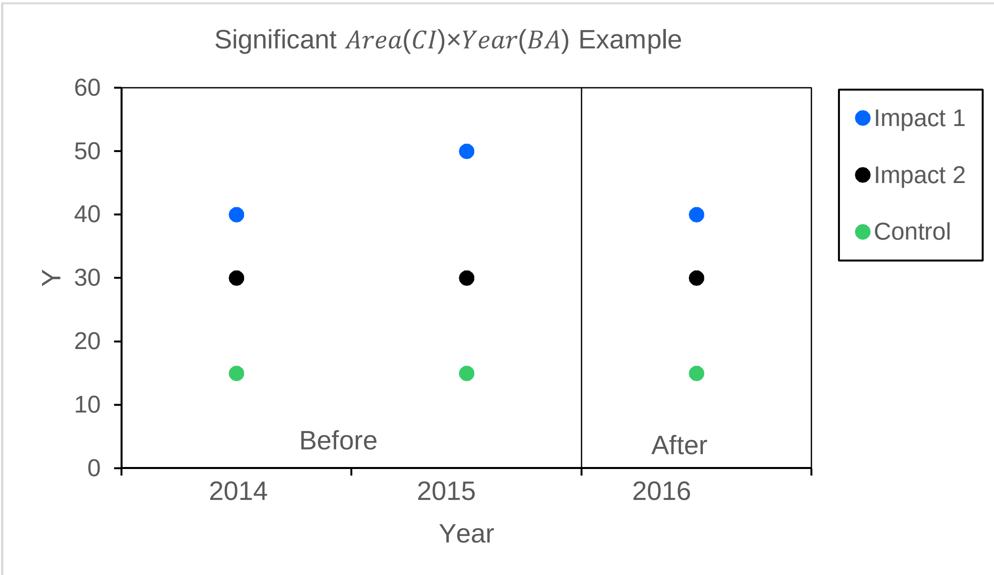
Station ID		Intermediate Axis (cm)		Embeddedness (%)	
		Mean	Standard Deviation	Mean	Standard Deviation
Reference	LI24	9.0	7.9	32.5	31.3
	SLINE	11.7	8.6	22.5	27.5
Mine-Exposed	LCUT	8.9	7.6	45.0	30.7
	LILC3	7.0	5.1	22.5	18.4
	LIDSL	8.9	6.6	30.0	28.4
	LI8	6.4	4.4	17.5	23.7
	FRUL	5.8	3.5	40.0	29.3
	FO23	5.7	4.3	42.5	26.5

Table A.4: Calcite Measurements for 2016 Line Creek LAEMP

Station ID		Concreted Status	Calcite Presence	Calcite Index
Reference	LI24	0.00	0.00	0.00
	SLINE	0.00	0.32	0.32
Mine-Exposed	LCUT	0.00	0.89	0.89
	LILC3	0.07	0.99	1.06
	LIDSL	0.00	0.78	0.78
	LI8	0.00	0.48	0.48
	FRUL	0.00	0.01	0.01
	FO23	0.00	0.37	0.37

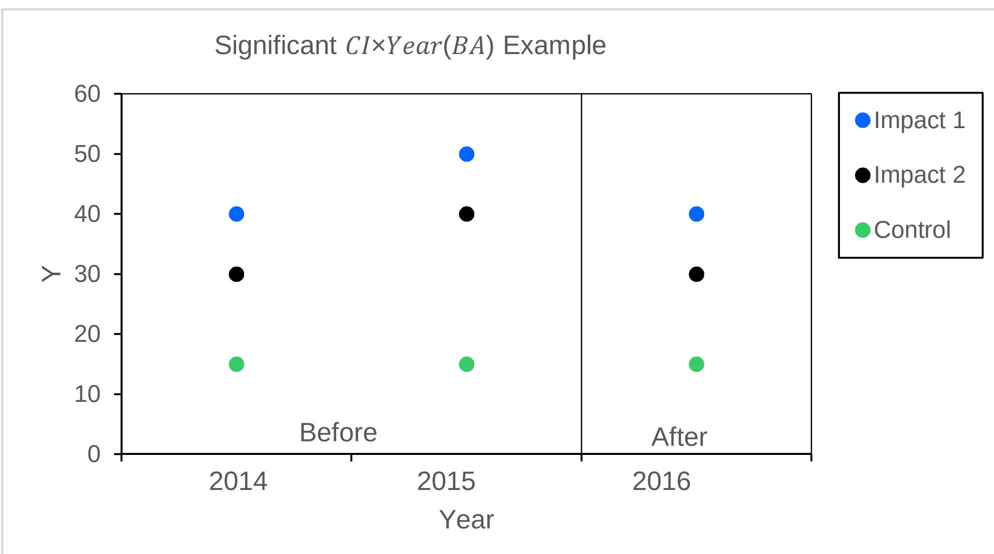
Hess Sampling / BACI Data

a)



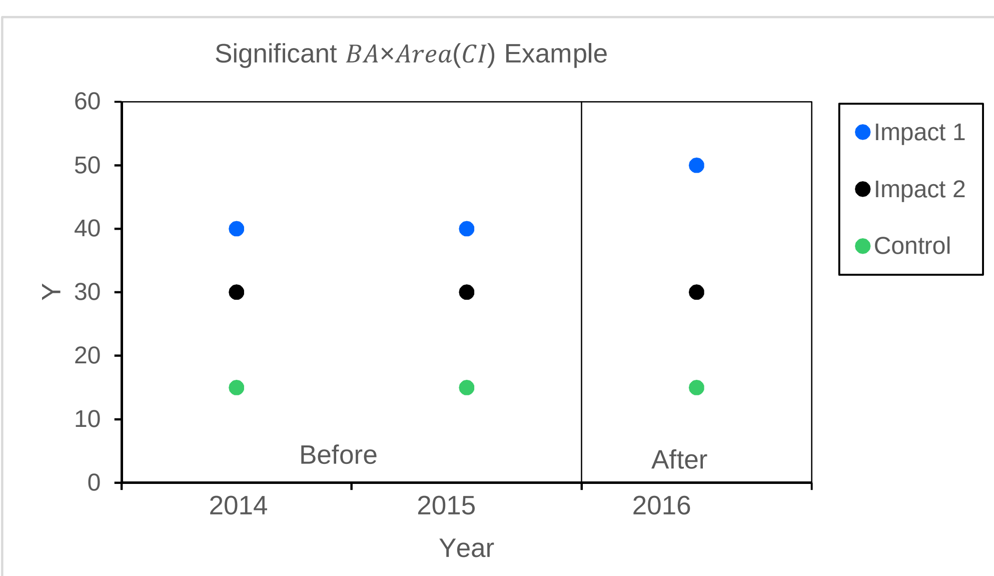
Note: The relative differences among areas over time are significant but depend on the year and area compared (Effect at Impact 1 in year 2015 compared to 2016).

b)



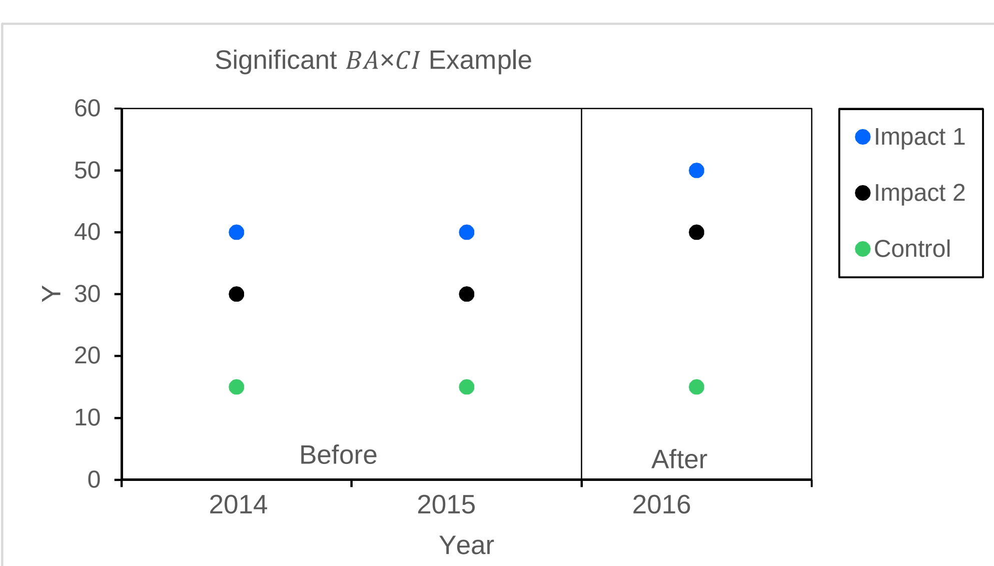
Note: The relative differences among areas over time are significant but depend on the level of CI and area compared (Effect at Impact areas in year 2015 compared tc

c)



Note: The relative differences among areas over time are significant but depend on the level of BA and area compared (Effect at Impact 1 in After period).

d)



Note: The relative difference among areas over time are significant but depend on the level of BA and level of CI compared (Effect at Impact areas in After period).

Figure A.1: Examples of Significant Interactions in the BACI Model with two Impact Areas, One Control Area, Two Before Periods, and One After Period

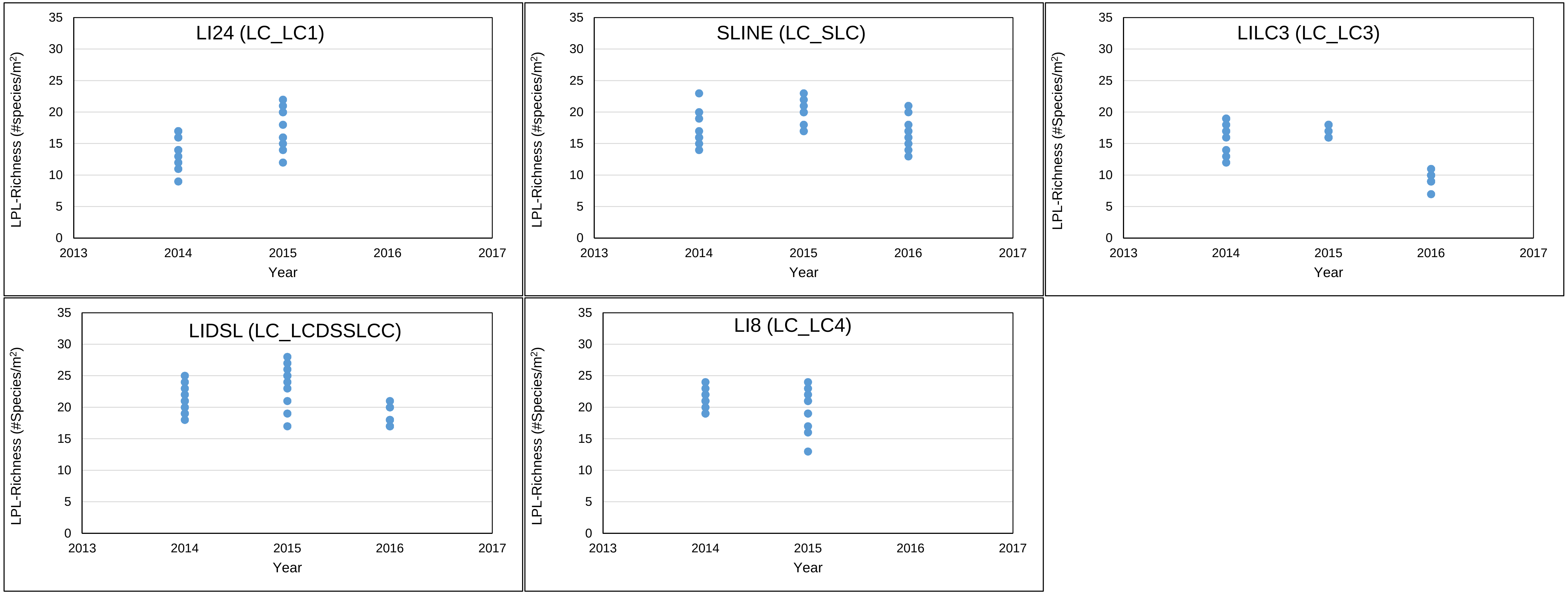


Figure A.2: **Benthic Invertebrate LPL-Richness Observed During the Line Creek LAEMP from 2014 to 2016**

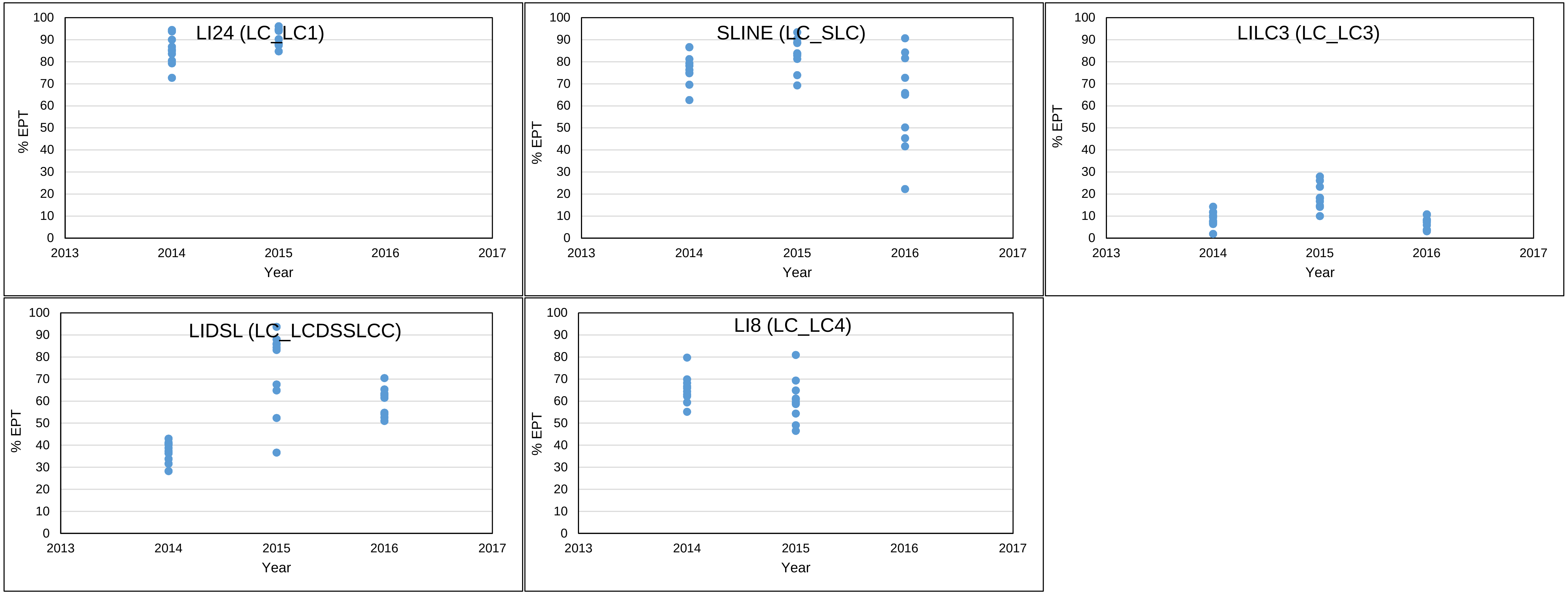


Figure A.3: **Benthic Invertebrate Percent Ephemeroptera-Plecoptera-Tricoptera (EPT) Observed During the Line Creek LAEMP from 2014 to 2016**

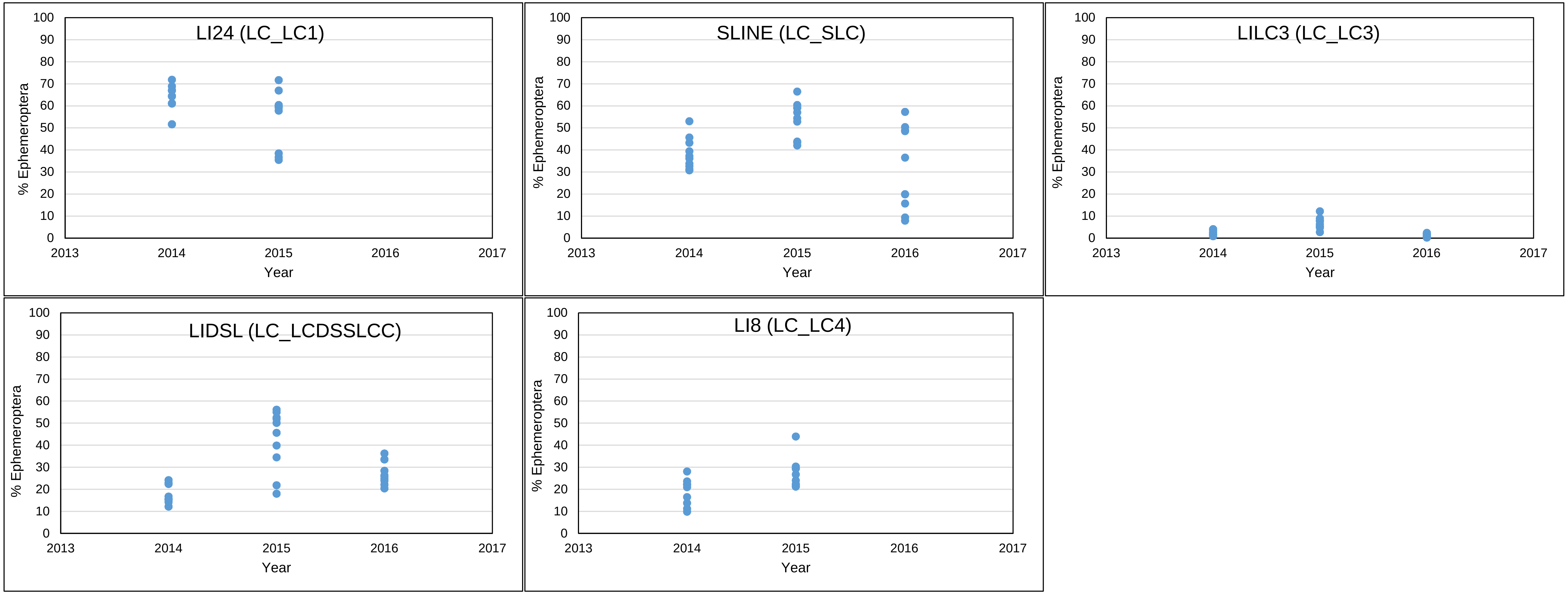


Figure A.4: **Benthic Invertebrate Percent Ephemeroptera Observed During the Line Creek LAEMP from 2014 to 2016**

Table A.5: ANOVA Table for BACI Models and p-value for Contrasts

Model						Contrasts (P-value and Magnitude of Difference[a])							
						Year(BA)×CI		Area(CI)×BA		Year(BA)×Area(CI)			
										LIDSL vs SLINE		LILC3 vs SLINE	
Response	Transformation	Term	DF	F	P-Value	2014 vs 2016	2015 vs 2016	LIDSL vs SLINE	LILC3 vs SLINE	2014 vs 2016	2015 vs 2016	2014 vs 2016	2015 vs 2016
Biomass	log	BA	1	1.44	0.233	-	-	-	-	-	-	-	-
		CI	1	228.06	<0.001	-	-	-	-	-	-	-	-
		BA×CI	1	1.60	0.209	-	-	-	-	-	-	-	-
		Year(BA)	1	10.04	0.002	-	-	-	-	-	-	-	-
		Area(CI)	1	60.56	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×CI	1	3.88	0.052	0.932	0.114	-	-	-	-	-	-
		Area(CI)×BA	1	0.07	0.796	-	-	-	-	-	-	-	-
		Year(BA)×Area(CI)	1	0.57	0.453	-	-	-	-	-	-	-	-
		Error	81	-	-	-	-	-	-	-	-	-	-
Density	log	BA	1	7.72	0.007	-	-	-	-	-	-	-	-
		CI	1	361.16	<0.001	-	-	-	-	-	-	-	-
		BA×CI	1	0.13	0.721	-	-	-	-	-	-	-	-
		Year(BA)	1	5.89	0.017	-	-	-	-	-	-	-	-
		Area(CI)	1	162.75	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×CI	1	28.65	<0.001	0.085 (-1.6 SD/-49%)	0.171	-	-	-	-	-	-
		Area(CI)×BA	1	2.84	0.096	-	-	0.329	0.652	-	-	-	-
		Year(BA)×Area(CI)	1	0.29	0.594	-	-	-	-	-	-	-	-
		Error	81	-	-	-	-	-	-	-	-	-	-
Family Richness	-	BA	1	72.24	<0.001	-	-	-	-	-	-	-	-
		CI	1	0.42	0.518	-	-	-	-	-	-	-	-
		BA×CI	1	12.00	0.001	-	-	-	-	-	-	-	-
		Year(BA)	1	6.68	0.012	-	-	-	-	-	-	-	-
		Area(CI)	1	131.39	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×CI	1	0.19	0.663	-	-	-	-	-	-	-	-
		Area(CI)×BA	1	6.27	0.014	-	-	0.094 (-0.96 SD/-11%)	<0.001 (-2.3 SD/-36%)	-	-	-	-
		Year(BA)×Area(CI)	1	1.71	0.195	-	-	-	-	-	-	-	-
		Error	81	-	-	-	-	-	-	-	-	-	-
% EPT	Square root[b]	BA	1	12.54	0.001	-	-	-	-	-	-	-	-
		CI	1	534.64	<0.001	-	-	-	-	-	-	-	-
		BA×CI	1	2.82	0.097	-	-	-	-	-	-	-	-
		Year(BA)	1	80.46	<0.001	-	-	-	-	-	-	-	-
		Area(CI)	1	675.24	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×CI	1	23.33	<0.001	-	-	-	-	-	-	-	-
		Area(CI)×BA	1	14.06	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×Area(CI)	1	11.23	0.001	-	-	-	-	<0.001 (3.7 SD/105%)	0.923	<0.001 (0.59 SD/36%)	0.138
		Error	79[b]	-	-	-	-	-	-	-	-	-	-
% Ephemeroptera	Fourth root	BA	1	29.09	<0.001	-	-	-	-	-	-	-	-
		CI	1	262.80	<0.001	-	-	-	-	-	-	-	-
		BA×CI	1	1.56	0.215	-	-	-	-	-	-	-	-
		Year(BA)	1	51.99	<0.001	-	-	-	-	-	-	-	-
		Area(CI)	1	391.24	<0.001	-	-	-	-	-	-	-	-
		Year(BA)×CI	1	3.89	0.052	0.393	0.968	-	-	-	-	-	-
		Area(CI)×BA	1	14.06	<0.001	-	-	0.023 (1.6 SD/81%)	0.538	-	-	-	-
		Year(BA)×Area(CI)	1	0.92	0.340	-	-	-	-	-	-	-	-
		Error	81	-	-	-	-	-	-	-	-	-	-

P-value < 0.1

[a] Magnitude of difference reported as 1) the change in the relative difference in means between mine-exposed and reference in the after period relative to the before period, expressed in terms of the number of pooled within-area/year standard deviations and 2) the difference between the observed mean in the after period for the impact area relative to the predicted mean (assuming no BACI effect) in the after period for the impact area, expressed as a percentage.

[b] Two outliers (LIDSL-10 in 2015 with %EPT = 37% and SLINE-4 in 2016 with %EPT = 22%) were removed with Studentized residuals > 4 in magnitude

Table A.6: Benthic Macroinvertebrates Hess Samples Collected from Line Creek, 2016

Station	LILC3																				LIDSL									
Replicate	1		2		3		4		5		6		7		8		9		10		1		2		3		4		5	
ROUNDWORMS																														
P. Nemata	64	0.0480	48	0.0008	64	0.1240	8	0.0008	16	0.0008	16	0.0008	24	0.0496	16	0.0004	48	0.0056	72	0.0136	3	0.0001	-	-	-	-	8	0.0052	2	0.0006
FLATWORMS																														
P. Platyhelminthes																														
Cl. Turbellaria																														
F. Planariidae	88	0.1848	104	0.1360	48	0.0712	-	-	48	0.1344	48	0.1208	72	0.0984	16	0.0128	72	0.0424	8	0.0080	3	0.0008	4	0.0111	14	0.0248	14	0.0352	3	0.0008
ANNELIDS																														
P. Annelida																														
WORMS																														
Cl. Oligochaeta																														
F. Enchytraeidae	-	-	-	-	24	0.0008	-	-	-	-	-	-	-	-	-	-	-	-	8	0.0008	-	-	-	-	-	-	-	-	-	-
F. Naididae	-	-	-	-	8	0.0008	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Lumbriculidae	24	0.1104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0020	-	-	-	-	6	0.0090	-	-
ARTHROPODS																														
MITES																														
Cl. Arachnida																														
Subcl. Acari	32	0.0160	16	0.0008	24	0.0120	36	0.0168	80	0.0640	32	0.0256	56	0.0256	12	0.0088	8	0.0040	40	0.0264	4	0.0023	4	0.0030	10	0.0018	14	0.0026	18	0.0064
SEED SHRIMPS																														
Cl. Ostracoda	56	0.0120	88	0.0768	-	-	16	0.0040	56	0.0328	24	0.0136	128	0.1208	4	0.0004	96	0.0248	-	-	10	0.0080	7	0.0029	2	0.0024	4	0.0032	2	0.0008
INSECTS																														
Cl. Insecta																														
BEETLES																														
O. Coleoptera																														
F. Elmidae	-	-	-	-	-	-	-	-	-	-	8	0.0280	-	-	-	-	-	-	-	-	1	0.0014	-	-	-	-	-	-	-	-
MAYFLIES																														
O. Ephemeroptera																														
F. Ameletidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.003	-	-	1	0.0035
F. Baetidae	8	0.0312	48	0.0784	32	0.1528	4	0.0144	16	0.0608	-	-	32	0.0640	-	-	24	0.0232	16	0.0264	8	0.0149	11	0.0232	64	0.1436	62	0.1716	15	0.0364
F. Ephemerellidae	-	-	-	-	8	0.0096	-	-	-	-	-	-	8	0.2296	-	-	8	0.0136	-	-	14	0.0080	8	0.0114	26	0.0504	14	0.0204	13	0.0344
F. Heptageniidae	40	0.0616	40	0.0088	8	0.0056	4	0.0008	8	0.0040	8	0.0088	8	0.0176	8	0.0032	8	0.0032	8	0.0048	53	0.9780	45	0.1373	130	0.3768	144	0.4974	88	0.2792
STONEFLIES																														
O. Plecoptera																														
F. Capniidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.0002	-	-	-	-
F. Chloroperlidae	56	0.1504	40	0.0504	8	0.0432	4	0.0056	48	0.0808	-	-	48	0.2024	12	0.0200	-	-	24	0.0296	39	0.0795	19	0.0404	24	0.0466	40	0.0772	12	0.0298
F. Leuctridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.0069	2	0.0012	-	-	2	0.0044	2	0.0060
F. Nemouridae	144	1.0784	184	1.4688	56	0.3504	8	0.1016	120	0.5512	32	0.2840	80	0.6776	28	0.3136	-	-	48	0.3120	28	0.1070	40	0.2263	68	0.2478	98	0.6542	58	0.3231
F. Perlodidae	-	-	-	-	-	-	4	0.0072	-	-	-	-	8	0.0240	4	0.0040	-	-	8	0.0008	2	0.0460	2	0.0008	4	0.0688	4	0.0238	2	0.0124
F. Peltoperlidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Taeniopterygidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.0028	3	0.0010	22	0.0064	20	0.0126	6	0.0120
CADDISFLIES																														
O. Trichoptera																														
pupae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**2**	0.0372	-	-	-	-
F. Apataniidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0003	2	0.0002	2	0.0002	-	-
F. Brachycentridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	0.0016	-	-	-	-	-	-	-	-	-	-	-	-
F. Glossosomatidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.0148	8	0.0394	14	0.0578	22	0.0934	9	0.0446
F. Hydropsychidae	72	2.8612	35	3.0842	83	4.3158	10	0.2726	32	1.5704	53	4.3441	85	4.5668	19	1.3035	28	1.4772	50	1.2743	12	0.3915	10	0.6076	64	1.1463	63	1.8352	42	1.1652
F. Limnephilidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Rhyacophilidae	59	2.1736	40	1.4684	1	0.0569	-	-	28	0.3880	17	0.2658	13	0.9735	10	0.3116	11	0.1885	7	0.4875	6	0.0334	4	0.0907	4	0.0054	11	0.1801	5	0.1401
F. Uenoidae	-	-	-	-	-	-	4	0.0008	-	-	-	-	-	-	-	-	-	-	-	-	25	0.0008	30	0.0012	38	0.0012	56	0.0018	15	0.0006
TRUE FLIES																														
O. Diptera																														
indeterminate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0017	-	-	-	-	-	-	-	-
F. Ceratopogonidae	8	0.0080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.0150	2	0.0102	-	-	-	-	-	-
F. Chironomidae	2824	2.1072	3001	2.6122	1976	1.5568	1116	2.1968	2536	2.0544	2672	1.9104	3064	3.0816	1228	1.3292	1976	1.1656	1944	1.4856	103	0.3760	78	0.1374	160	0.1468	248	0.4272	61	0.1256
F. Empididae	-	-	8	0.0176	-	-	-	-	8	0.0448	-	-	-	-	4	0.0128	8	0.0256	8	0.0208	2	0.0051	2	0.0051	-	-	6	0.015	2	0.0120
F. Muscidae	-	-	1	0.0313	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Pelecorhyncidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Psychodidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	12	0.0044	2	0.0012	-	-	2	0.0022	-	-
F. Simuliidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	22	0.0229	7	0.0074	10	0.0298	6	0.0142	134	0.4468
F. Tipulidae	8	0.0488	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	0.1575	1	0.0007	-	-	4	0.0028	-	-
TOTAL NUMBER OF ORGANISMS	3483		3653		2340		1214		2996		2910		3626		1361		2295		2241		368		290		662		850		490	
TOTAL NUMBER OF TAXA [a]	14		13		13		11		12		10		13		12		12		13		25		22		19		23		20	
TOTAL BIOMASS (g)		8.8916		9.0345		6.6999		2.6214		4.9864		7.0019		10.1315		3.3203		2.9753		3.6906		2.2808		1.3598		2.3973		4.0889		2.6803

Table A.6: Benthic Macroinvertebrates Hess Samples Collected from Line Creek, 2016

Station											SLINE																			
Replicate	6		7		8		9		10		1		2		3		4		5		6		7		8		9		10	
ROUNDWORMS																														
P. Nemata	1	0.0001	2	0.0002	1	0.0001	-	-	-	-	-	-	-	-	2	0.0002	1	0.0001	1	0.0001	1	0.0001	-	-	-	-	-	-	-	-
FLATWORMS																														
P. Platyhelminthes																														
Cl. Turbellaria																														
F. Planariidae	2	0.0032	6	0.0048	5	0.0045	4	0.0022	8	0.0048	-	-	-	-	-	-	1	0.0005	-	-	-	-	-	-	-	-	-	-	-	-
ANNELIDS																														
P. Annelida																														
WORMS																														
Cl. Oligochaeta																														
F. Enchytraeidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	0.0002	-	-	-	-	-	-	1	0.0001	-	-	-	-	-	-
F. Naididae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Lumbriculidae	-	-	4	0.0102	5	0.0176	-	-	-	-	-	-	4	0.0100	4	0.0058	-	-	2	0.0026	1	0.0013	-	-	1	0.0020	3	0.0043	-	-
ARTHROPODS																														
MITES																														
Cl. Arachnida																														
Subcl. Acari	2	0.0007	16	0.0116	5	0.0011	8	0.0024	4	0.0014	-	-	-	-	-	-	1	0.0006	7	0.0019	1	0.0009	1	0.0003	-	-	-	-	1	0.0004
SEED SHRIMPS																														
Cl. Ostracoda	3	0.0004	10	0.0100	-	-	6	0.0018	-	-	2	0.0001	2	0.0001	8	0.0014	2	0.0001	22	0.0124	2	0.0001	4	0.0001	5	0.0008	53	0.0171	2	0.0001
INSECTS																														
Cl. Insecta																														
BEETLES																														
O. Coleoptera																														
F. Elmidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MAYFLIES																														
O. Ephemeroptera																														
F. Ameletidae	-	-	6	0.0052	-	-	2	0.0098	4	0.0028	3	0.0057	1	0.0007	-	-	-	-	3	0.0014	-	-	-	-	-	-	13	0.0176	2	0.0310
F. Baetidae	15	0.0331	62	0.1542	65	0.1335	66	0.1442	28	0.0664	-	-	1	0.0078	10	0.0486	3	0.0265	1	0.0034	-	-	1	0.0084	1	0.0005	3	0.0255	-	-
F. Ephemerellidae	9	0.0042	22	0.0166	7	0.0111	4	0.0062	16	0.0212	34	0.0848	8	0.0336	22	0.0924	14	0.0340	11	0.0718	11	0.0164	27	0.0497	23	0.0536	23	0.1269	2	0.0018
F. Heptageniidae	36	0.0748	180	0.4112	105	0.2395	74	0.2700	138	0.2912	49	0.0832	51	0.1505	40	0.1046	26	0.0677	14	0.0103	23	0.0933	40	0.0551	48	0.2678	52	0.0503	20	0.0520
STONEFLIES																														
O. Plecoptera																														
F. Capniidae	1	0.0009	-	-	1	0.0001	2	0.0020	-	-	-	-	-	-	-	-	-	-	1	0.0004	-	-	-	-	-	-	1	0.0001	-	-
F. Chloroperlidae	9	0.0156	52	0.0972	16	0.0395	20	0.0434	20	0.0438	6	0.0066	3	0.0042	6	0.0066	1	0.0033	16	0.0317	11	0.0314	4	0.0128	3	0.0011	20	0.0315	4	0.0108
F. Leuctridae	2	0.0005	-	-	2	0.0015	-	-	6	0.0028	1	0.0007	-	-	8	0.0078	-	-	1	0.0021	2	0.0033	-	-	1	0.0004	15	0.0071	1	0.0017
F. Nemouridae	27	0.1008	90	0.4322	89	0.3995	42	0.2250	40	0.0186	4	0.0040	11	0.0264	32	0.0448	9	0.0350	9	0.0297	6	0.0106	4	0.0023	9	0.0120	7	0.0110	4	0.0152
F. Perlodidae	2	0.0192	12	0.3142	3	0.0383	-	-	4	0.0384	-	-	3	0.0205	21	0.4133	10	0.1992	3	0.1522	6	0.1297	6	0.0911	9	0.1934	1	0.0021	3	0.0245
F. Peltoperlidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.0206	-	-	1	0.0014	-	-	-	-	-	-	1	0.0019	-	-
F. Taeniopterygidae	20	0.0038	14	0.0102	17	0.0077	2	0.0016	4	0.0028	12	0.0027	-	-	6	0.0010	-	-	-	-	4	0.0017	5	0.0026	2	0.0001	1	0.0003	3	0.0038
CADDISFLIES																														
O. Trichoptera																														
pupae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Apataniidae	-	-	-	-	-	-	2	0.0006	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Brachycentridae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Glossosomatidae	6	0.0200	44	0.2614	13	0.0667	20	0.1026	8	0.0380	1	0.0047	3	0.0237	6	0.0492	14	0.1140	2	0.0127	12	0.0920	4	0.0436	9	0.0811	-	-	4	0.0322
F. Hydropsychidae	8	0.4348	24	1.1568	47	0.9192	23	0.5884	28	0.3899	-	-	4	0.0017	8	0.4334	3	0.0014	3	0.1176	3	0.0022	2	0.0013	5	0.2082	-	-	4	0.0316
F. Limnephilidae	-	-	-	-	-	-	-	-	-	-	1	0.0613	-	-	1	0.0645	-	-	-	-	-	-	-	-	-	-	2	0.0006	1	0.0002
F. Rhyacophilidae	2	0.0019	4	0.01	5	0.0425	3	0.0535	5	0.2176	2	0.0038	3	0.0287	12	0.1610	6	0.0794	8	0.0082	7	0.0528	5	0.0644	10	0.0451	7	0.0268	3	0.0149
F. Uenoidae	6	0.0003	16	0.0004	6	0.0004	2	0.0002	14	0.0006	23	0.0008	-	-	8	0.0026	16	0.0006	79	0.0027	13	0.0004	20	0.0007	-	-	16	0.0004	28	0.0008
TRUE FLIES																														
O. Diptera																														
indeterminate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0007
F. Ceratopogonidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Chironomidae	73	0.1000	232	0.358	154	0.3567	144	0.1998	168	0.1242	12	0.0068	22	0.0112	140	0.0846	345	0.2983	175	0.1452	110	0.0688	14	0.0135	17	0.0059	19	0.0262	36	0.0410
F. Empididae	2	0.0036	4	0.0182	4	0.0176	4	0.0060	2	0.0080	-	-	2	0.0099	18	0.0648	2	0.0039	6	0.0293	-	-	1	0.0028	3	0.0076	6	0.0141	1	0.0100
F. Muscidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
F. Pelecorhyncidae	-	-	2	0.0446	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0001	-	-	-	-	1	0.0026	-	-
F. Psychodidae	-	-	-	-	-	-	-	-	4	0.0012	-	-	-	-	-	-	-	-	-	-	1	0.0021	-	-	-	-	-	-	-	-
F. Simuliidae	3	0.0058	4	0.018	164	0.5038	84	0.1726	12	0.0212	-	-	3	0.0037	4	0.0008	3	0.0080	-	-	-	-	1	0.0004	1	0.0001	3	0.0017	-	-
F. Tipulidae	-	-	-	-	1	0.0080	2	0.0028	-	-	-	-	-	-	-	-	-	-	-	-	1	0.0020	-	-	-	-	2	0.0612	-	-
TOTAL NUMBER OF ORGANISMS	229		806		715		514		513		150		121		362		457		365		216		140		147		249		120	
TOTAL NUMBER OF TAXA [a]	20		21		21		20		19		13		15		21		17		20		19		17		16		21		18	
TOTAL BIOMASS (g)		0.8237		3.3452		2.8089		1.8351		1.2949		0.2652		0.3327		1.6082		0.8726		0.6371		0.5092		0.3492		0.8797		0.4293		0.2727

Table A.7: **Percent Recovery of Benthic Macroinvertebrates for Hess Samples from Line Creek 2016**

Station	Number of Organisms Recovered (initial sort)	Number of Organisms in Re-sort	Percent Recovery
LIDSL-BIO-10	257	259	99.2%
LILC3-BIO-3	299	310	96.5%
SLINE-BIO-6	212	216	98.1%
		Average % Recovery	97.9%

Kick and Sweep Sampling Data

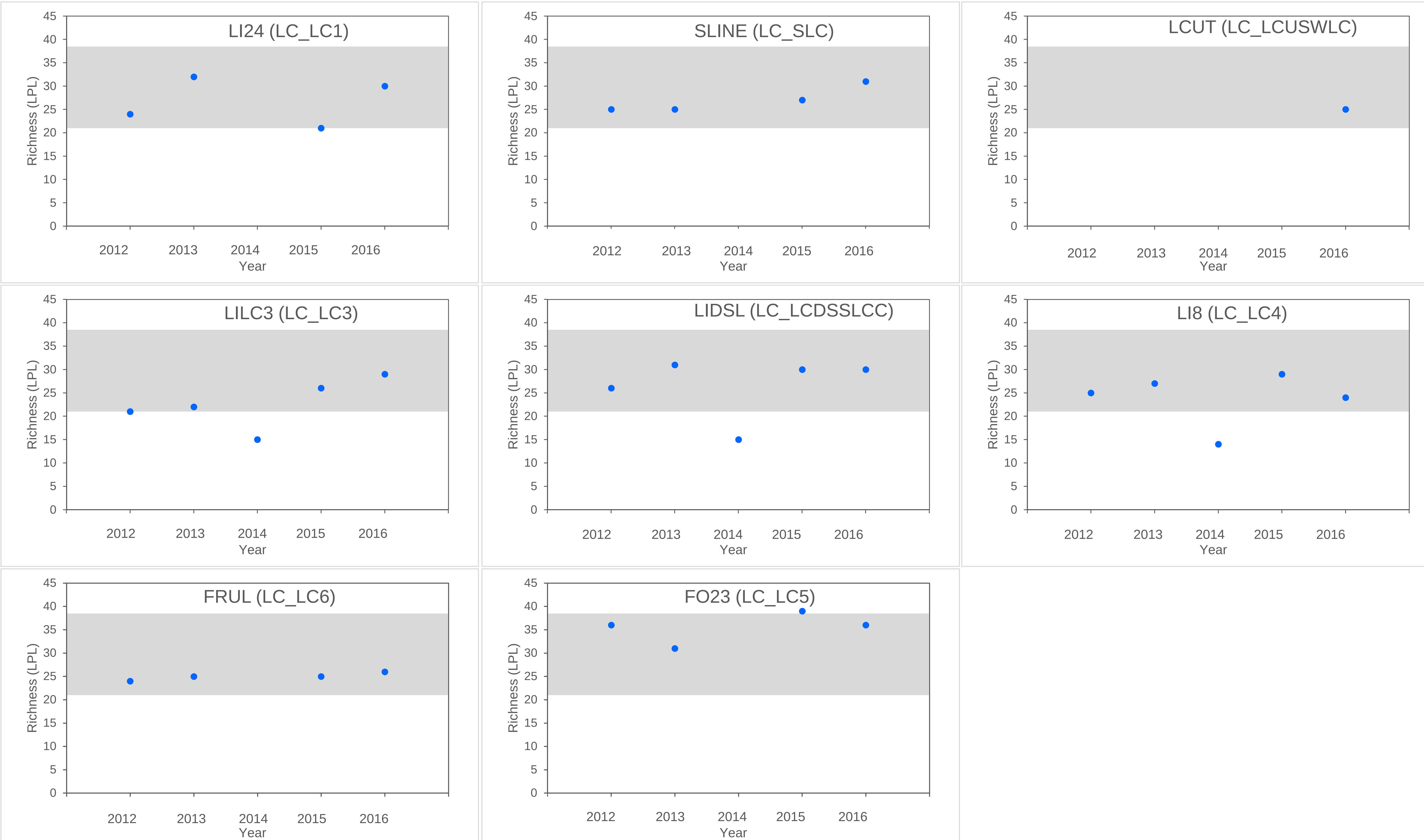


Figure A.5: Plots of Benthic Invertebrate Community LPL Richness from 2012 to 2016

Notes: Gray shading represents the normal range defined as the 2.5th and 97.5th percentiles of values for reference areas sampled in 2012 and 2015 for the RAEMP (n=75).

Table A.8: Whole Sample Counts for CABIN 3-Minute Kick Samples

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter
suesalter@cordilleraconsulting.ca
250-494-7553

Site:	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN
Sample:	SLINE-BIC	LI24-BIC	LCUT-BIC	LILC3-BIC	LIDSL-BIC	LI8-BIC	FRUL-BIC	FO23-BIC
Sample Collection Date:	08-Sep-16	08-Sep-16	09-Sep-16	09-Sep-16	07-Sep-16	09-Sep-16	10-Sep-16	09-Sep-16
CC#:	CC171295	CC171294	CC171302	CC171283	CC171296	CC171303	CC171311	CC171299
Phylum: Arthropoda	0	0	0	0	0	0	0	0
| Order: Collembola	0	0	0	0	0	0	0	0
Subphylum: Hexapoda	0	0	0	0	0	0	0	0
| Class: Insecta	0	0	0	0	0	0	0	0
| Order: Ephemeroptera	0	0	0	0	0	0	0	0
| Family: Ameletidae	0	0	0	0	0	0	0	0
Ameletus	70	160	0	0	10	260	0	0
| Family: Baetidae	0	0	0	100	0	0	0	0
Acentrella	0	0	0	0	0	0	0	0
Acentrella turbida	0	0	0	0	0	0	0	0
Baetis	15	60	120	220	620	320	683	380
Baetis tricaudatus group	10	0	280	60	340	540	492	260
Baetis bicaudatus	10	20	0	0	0	0	0	0
| Family: Ephemerellidae	145	100	0	100	140	220	25	200
Drunella	30	0	0	0	0	0	0	0
Drunella coloradensis	20	20	0	0	0	0	0	0
Drunella doddsii	45	160	40	0	50	520	125	780
Drunella spinifera	0	0	0	20	0	0	0	0
Ephemerella	0	0	0	20	0	0	0	0
| Family: Heptageniidae	525	140	60	400	590	940	167	480
Cinygmula	0	0	0	0	10	0	0	0
Epeorus	10	100	0	0	90	40	0	0
Rhithrogena	10	0	0	0	0	280	50	60
| Family: Leptophlebiidae	0	0	0	0	0	0	0	0
Neoleptophlebia	0	0	0	0	0	0	0	0
Paraleptophlebia	0	0	0	0	0	0	0	0
| Order: Plecoptera	0	0	0	0	0	0	0	0
| Family: Capniidae	0	0	0	0	0	40	25	60
| Family: Chloroperlidae	10	140	40	20	10	0	67	80
Suwallia	15	0	0	0	0	0	0	0
Sweltsa	45	140	20	220	120	20	92	720
| Family: Leuctridae	10	0	0	0	0	0	8	0
Despaxia augusta	0	0	0	0	0	0	0	0
| Family: Nemouridae	0	0	0	0	20	0	0	0
Visoka cataractae	0	20	0	0	0	0	0	0
Zapada	50	100	40	180	200	800	17	140
Zapada oregonensis group	15	100	280	460	270	440	0	0
Zapada cinctipes	0	0	0	0	40	40	142	220
Zapada columbiana	65	140	0	140	150	20	0	0
| Family: Peltoperlidae	0	0	0	0	0	0	0	0
Yoraperla	5	0	20	0	0	0	0	0
| Family: Perlidae	0	0	20	0	0	0	133	20
Calineuria californica	0	0	0	0	0	0	0	0
Hesperoperla	0	0	0	0	0	0	100	120
Hesperoperla pacifica	0	0	0	0	0	0	0	0
| Family: Perlodidae	15	40	40	40	30	60	50	140
Isoperla	0	0	0	0	0	0	0	0
Megarcys	30	240	20	0	10	40	0	20
Skwala	0	0	0	0	0	0	0	0
| Family: Pteronarcyidae	0	0	0	0	0	0	0	0
Pteronarcella	0	0	0	0	0	0	0	0
| Family: Taeniopterygidae	0	0	20	0	0	5880	67	160
Taenionema	50	40	0	0	60	0	0	0
| Order: Trichoptera	0	0	20	40	0	20	0	0
| Family: Apataniidae	0	0	0	0	60	0	0	0
Allomyia	0	0	0	0	0	0	0	0
Apatania	0	0	0	0	0	880	0	0
Pedomoecus sierra	0	0	0	0	0	0	0	20
| Family: Brachycentridae	0	0	0	0	0	0	8	0
Brachycentrus	0	0	0	0	0	0	0	0
Brachycentrus americanus	0	0	0	0	0	0	0	0
| Family: Glossosomatidae	0	0	0	0	10	0	0	60
Anagapetus	0	0	0	0	0	160	0	0
Glossosoma	10	0	0	0	0	0	42	160
| Family: Hydropsychidae	50	20	80	140	260	0	0	0
Arctopsyche	0	0	0	0	0	0	0	0
Arctopsyche grandis	0	0	0	0	0	0	8	20
Arctopsyche ladogensis	0	0	0	0	0	0	0	0
Hydropsyche	0	0	0	0	0	0	0	0
Parapsyche	5	0	160	300	40	0	0	0
| Family: Hydroptilidae	0	0	0	0	0	0	0	0
Hydroptila	0	0	0	0	0	0	0	0
| Family: Lepidostomatidae	0	0	0	0	0	0	0	0
Lepidostoma	0	0	0	0	0	0	8	20
| Family: Leptoceridae	0	0	0	0	0	0	0	0
| Family: Limnephilidae	0	0	20	0	0	0	0	0
Ecclisomyia	0	80	0	0	0	0	0	0
| Family: Rhyacophilidae	0	0	0	0	0	0	0	0
Rhyacophila	20	20	20	20	20	0	67	0
Rhyacophila betteni group	0	0	0	0	0	0	25	40
Rhyacophila brunnea/vemna grou	15	0	0	0	10	0	0	20
Rhyacophila hyalinata group	10	0	20	0	0	0	0	0
Rhyacophila vofixa group	5	0	0	0	0	0	0	0
Rhyacophila atrata complex	0	0	0	0	0	0	0	160
Rhyacophila narvae	0	0	0	0	0	0	0	0
| Family: Uenoidae	0	0	0	0	0	0	0	0
Neothremma	0	0	0	0	0	0	0	0
Oligophlebodes	120	0	0	0	0	340	0	20
| Order: Coleoptera	0	0	0	0	0	0	0	0
| Family: Dytiscidae	0	0	0	0	0	0	0	0
Stictotarsus	0	0	0	0	0	0	0	0
| Family: Elmidae	0	0	0	0	0	0	0	0
Heterlimnius	0	0	0	0	0	0	0	20

Table A.8: Whole Sample Counts for CABIN 3-Minute Kick Samples

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561) Taxonomist: Sue Salter 250-494-7553
Minnow (Georgetown), Shari Weech suesalter@cordilleraconsulting.ca

Site:	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN
Sample:	SLINE-BIC	LI24-BIC	LCUT-BIC	LILC3-BIC	LIDSL-BIC	LI8-BIC	FRUL-BIC	FO23-BIC
Sample Collection Date:	08-Sep-16	08-Sep-16	09-Sep-16	09-Sep-16	07-Sep-16	09-Sep-16	10-Sep-16	09-Sep-16
CC#:	CC171295	CC171294	CC171302	CC171283	CC171296	CC171303	CC171311	CC171299
| Order: Diptera	0	0	0	0	0	0	0	0
| Family: Athericidae	0	0	0	0	0	0	0	0
Atherix	0	0	0	0	0	0	0	0
| Family: Ceratopogonidae	0	0	0	0	0	0	0	0
Bezzia/ Palpomyia	0	0	0	0	0	0	0	0
Probezzia	0	0	0	0	0	0	0	0
| Family: Chironomidae	50	540	1080	3980	290	320	25	100
| Subfamily: Chironominae	0	0	0	0	0	0	0	0
| Tribe: Chironomini	0	0	0	0	0	0	0	0
Microtendipes	0	0	0	0	0	0	0	0
Microtendipes pedellus group	0	0	0	0	0	0	0	0
Pagastiella	0	0	0	0	0	0	0	0
Polypedilum	0	0	20	40	0	0	0	0
| Tribe: Tanytarsini	0	0	0	0	0	0	0	0
Constempellina sp. C	0	0	0	0	0	0	17	0
Micropsectra	0	40	0	1900	230	1300	75	840
Paratanytarsus	0	0	0	0	0	0	0	0
Rheotanytarsus	0	0	0	80	10	0	0	0
Stempellinella	0	0	0	0	0	0	0	0
Sublettea coffmani	0	0	0	0	0	0	0	0
Tanytarsus	0	0	0	0	0	0	0	0
| Subfamily: Diamesinae	0	0	0	0	0	0	0	0
| Tribe: Diamesini	0	0	0	0	0	0	0	0
Diamesa	10	620	160	520	30	0	0	0
Pagastia	0	20	700	1460	60	20	17	40
Potthastia	0	0	0	0	0	0	0	0
Potthastia longimana group	0	0	0	0	0	0	0	0
Pseudodiamesa	0	0	20	80	0	60	0	0
| Subfamily: Orthocladiinae	0	0	0	0	0	0	0	0
Brillia	0	0	0	0	0	0	0	0
Corynoneura	0	0	0	0	10	20	0	0
Cricotopus (Nostococladius)	0	0	0	40	0	0	0	0
Diplocladius cultriger	0	0	0	80	0	0	0	0
Eukiefferiella	55	400	940	1060	10	0	0	20
Heleniella	0	0	0	0	0	0	0	0
Hydrobaenus	5	120	20	200	270	540	0	0
Limnophyes	0	0	0	0	0	0	0	0
Metriocnemus	0	0	0	0	0	0	0	0
Orthocladiinae RAI 004 (Like Helen	0	0	0	0	0	0	0	0
Orthocladius complex	195	3060	7360	20080	90	100	8	180
Parakiefferiella	0	0	0	0	0	0	0	0
Paraphaenocladius	0	0	0	0	0	0	0	0
Parorthocladius	0	0	0	0	0	0	0	0
Rheocricotopus	0	60	280	3260	180	20	0	40
Synorthocladius	10	0	0	0	0	0	0	0
Thienemanniella	0	0	0	0	0	0	0	0
Tvetenia	20	80	300	2280	140	100	8	40
| Subfamily: Tanypodinae	0	0	0	0	0	0	0	0
Zavrelimyia	0	0	0	0	0	0	0	0
| Tribe: Pentaneurini	0	0	0	0	0	0	0	0
Pentaneura	0	0	0	0	0	0	0	0
Thienemannimyia group	0	0	0	0	0	0	0	0
| Family: Dixidae	0	0	0	0	0	0	0	0
| Family: Empididae	0	0	0	40	10	0	0	0
Chelifera/ Metachela	0	0	0	20	0	0	33	40
Clinocera	0	0	0	40	0	0	0	40
Neoplasta	0	0	0	0	0	0	0	0
Oreogeton	10	0	0	0	10	0	0	0
Trichoclinocera	0	0	0	0	0	0	0	0
Wiedemannia	0	0	0	0	0	0	33	20
| Family: Muscidae	0	0	0	0	0	0	0	0
Limnophora	0	0	0	0	0	0	0	0
| Family: Psychodidae	0	0	0	0	0	0	0	0
Pericoma/Telmatoscopus	0	0	20	0	0	0	58	220
| Family: Simuliidae	0	0	0	0	0	0	0	0
Prosimulium	0	0	0	0	0	0	0	0
Prosimulium/Helodon	0	0	0	0	0	0	0	0
Simulium	0	0	0	0	20	0	0	0
| Family: Stratiomyidae	0	0	0	0	0	0	0	0
Euparyphus	0	0	0	0	0	0	0	0
| Family: Syrphidae	0	0	0	0	0	0	0	0
| Family: Tipulidae	0	0	0	0	0	0	0	0
Antocha	0	20	0	0	0	0	0	0
Dicranota	5	0	0	0	0	0	17	0
Gonomyodes	0	40	0	0	0	0	0	0
Hesperoconopa	0	0	0	0	0	0	0	0
Hexatoma	0	0	0	0	0	0	0	40
Tipula	0	20	0	0	0	0	0	20
Subphylum: Chelicerata	0	0	0	0	0	0	0	0
| Class: Arachnida	0	0	0	0	0	0	0	0
| Order: Trombidiformes	0	0	0	0	0	0	0	20
| Family: Aturidae	0	0	0	0	0	0	0	0
Aturus	0	0	0	0	0	0	0	0
| Family: Feltriidae	0	0	0	0	0	0	0	0
Feltria	0	0	140	140	10	0	0	0
| Family: Hydryphantidae	0	0	0	0	0	0	0	0
Protzia	0	20	0	0	0	0	0	0
| Family: Hygrobatidae	0	0	0	0	0	0	0	0
Atractides	0	20	0	0	0	0	0	0
Hygrobates	0	0	0	0	0	0	0	0
| Family: Lebertiidae	0	0	0	0	0	0	0	0
Lebertia	15	20	100	240	40	0	0	320
| Family: Sperchontidae	0	0	0	0	0	0	0	0
Sperchon	0	20	400	280	60	20	0	40
Sperchonopsis	5	0	0	0	0	0	0	0

Table A.8: **Whole Sample Counts for CABIN 3-Minute Kick Samples**

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter
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Site:	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN
Sample:	SLINE-BIC	LI24-BIC	LCUT-BIC	LILC3-BIC	LIDSL-BIC	LI8-BIC	FRUL-BIC	FO23-BIC
Sample Collection Date:	08-Sep-16	08-Sep-16	09-Sep-16	09-Sep-16	07-Sep-16	09-Sep-16	10-Sep-16	09-Sep-16
CC#:	CC171295	CC171294	CC171302	CC171283	CC171296	CC171303	CC171311	CC171299
| Family: Torrenticolidae	0	0	0	0	0	0	0	0
Testudacarus	0	0	0	0	0	0	8	0
Torrenticola	0	0	0	20	0	0	0	0
| Order: Sarcoptiformes	0	0	0	0	0	0	0	0
| Order: Oribatida	0	0	0	0	0	0	0	0
| Family: Hydrozetidae	0	0	0	0	0	0	0	20
Phylum: Mollusca	0	0	0	0	0	0	0	0
| Class: Bivalvia	0	0	0	0	0	0	0	0
| Order: Veneroida	0	0	0	0	0	0	0	0
| Family: Pisidiidae	0	0	0	0	0	0	0	0
Phylum: Annelida	0	0	0	0	0	0	0	0
Subphylum: Clitellata	0	0	0	0	0	0	0	0
| Class: Oligochaeta	0	0	0	0	0	0	0	0
| Order: Lumbriculida	0	0	0	0	0	0	0	0
| Family: Lumbriculidae	0	0	0	0	0	0	0	20
| Order: Tubificida	0	0	0	0	0	0	0	0
| Family: Enchytraeidae	0	0	0	0	0	0	0	0
Enchytraeus	0	20	0	0	0	0	0	60
| Family: Naididae	0	0	0	0	0	0	0	0
Chaetogaster	0	0	0	0	0	0	0	0
Nais	0	0	0	0	0	0	8	120
Pristina	0	0	0	0	0	0	0	0
Tubifex	0	0	0	0	0	0	0	0
Phylum: Cnidaria	0	0	0	0	0	0	0	0
| Class: Hydrozoa	0	0	0	0	0	0	0	0
| Order: Anthoathecatae	0	0	0	0	0	0	0	0
| Family: Hydridae	0	0	0	0	0	0	0	0
Hydra	0	0	0	0	0	0	0	0
Totals:	**1815**	**6960**	**12860**	**38320**	**4630**	**14360**	**2708**	**6620**

Table A.8: Whole Sample Counts for CABIN 3-Minute Kick Samples

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter
suesalter@cordilleraconsulting.ca

250-494-7553

Site:	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN	CABIN
Sample:	SLINE-BIC	LI24-BIC	LCUT-BIC	LILC3-BIC	LIDSL-BIC	LI8-BIC	FRUL-BIC	FO23-BIC
Sample Collection Date:	08-Sep-16	08-Sep-16	09-Sep-16	09-Sep-16	07-Sep-16	09-Sep-16	10-Sep-16	09-Sep-16
CC#:	CC171295	CC171294	CC171302	CC171283	CC171296	CC171303	CC171311	CC171299
Taxa present but not included:								
Terrestrials	0	0	0	0	0	0	0	0
Phylum: Arthropoda	0	0	0	0	0	0	0	0
Subphylum: Crustacea	0	0	0	0	0	0	0	0
| Class: Ostracoda	25	140	620	3660	200	160	25	620
| Class: Maxillipoda	0	0	0	0	0	0	0	0
| Class: Copepoda	0	0	0	0	0	0	0	0
Phylum: Annelida	0	0	0	0	0	0	0	0
Subphylum: Clitellata	0	0	0	0	0	0	0	0
| Class: Oligochaeta	0	0	0	0	0	0	0	0
| Order: Tubificida	0	0	0	0	0	0	0	0
| Family: Lumbricidae	0	0	0	0	0	0	0	0
Phylum: Nemata	5	0	20	20	10	0	0	0
Phylum: Platyhelminthes	0	0	0	0	0	0	0	0
| Class: Turbellaria	5	0	20	20	10	20	0	20
Totals:	**35**	**140**	**660**	**3700**	**220**	**180**	**25**	**640**

Table A.9: Sorting Efficiency for CABIN 3-Minute Kick Samples

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter
suesalter@cordilleraconsulting.ca
250-494-7553

	Total Recovered	Total from Sample	Percent Efficiency
Site - QC, Sample - QC 1, CC# - CC171277, Percent sampled = 5%, Sieve size = 400			
Plecoptera	3		
Oligochaeta	1		
Total:	**4**	**338**	**99%**
Site - QC, Sample - QC 2, CC# - CC171286, Percent sampled = 5%, Sieve size = 400			
Diptera	2		
Ephemeroptera	1		
Plecoptera	4		
Trichoptera	1		
Oligochaeta	3		
Total:	**11**	**375**	**97%**
Site - QC, Sample - QC 3, CC# - CC171298, Percent sampled = 8%, Sieve size = 400			
Ephemeroptera	2		
Trichoptera	1		
Total:	**3**	**353**	**99%**
Site - QC, Sample - QC 4, CC# - CC171310, Percent sampled = 7%, Sieve size = 400			
Plecoptera	1		
Oligochaeta	2		
Total:	**3**	**387**	**99%**

Table A.10: Taxonomic QC for CABIN 3-Minute Kick Samples

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter
suesalter@cordilleraconsulting.ca

2

Site - CABIN, Sample - HENUP-BIC, CC# - CC171282, Percent sampled = 10%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Rhyacophila hyalinata group	2	2						
Lebertia	1	1						
Sperchon	2	2						
Parapsyche	2	2						
Hydropsychidae	2	2						
Glossosoma	2	2						
Taeniopterygidae	1	1						
Taenionema	38	37	No			X		
Megarcys	2	2						
Visoka cataractae	1	1						
Zapada	1	1						
Zapada columbiana	5	5						
Zapada oregonensis group	2	2						
Heptageniidae	255	255						
Rhithrogena	31	31						
Epeorus	9	9						
Sweltsa	4	4						
Drunella doddsii	5	5						
Ephemerellidae	77	77						
Ameletus	1	1						
Oreogeton	4	4						
Empididae	1	1						
Tvetenia	3	3						
Eukiefferiella	6	6						
Orthocladius complex	18	18						
Micropsectra	5	5						
Chironomidae	2	2						
Probezzia	2	2						
Total:	**484**	**483**						
					0	1	0	
% Total Misidentification Rate =	misidentifications / total number		x100 =		0.00	**Pass**		

Table A.10: Taxonomic QC for CABIN 3-Minute Kick Samples

Project: Teck Elk Valley 2016 (2561) | Taxonomist: Sue Salter | 2
Minnow (Georgetown), Shari Weech | suesalter@cordilleraconsulting.ca

Site - CABIN, Sample - HENUP-BIC, CC# - CC171282, Percent sampled = 10%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Site - CABIN, Sample - CORCK-BIC, CC# - CC171288, Percent sampled = 5%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Chaetogaster	20	20						
Aturus	25	23	No			X		
Pisidiidae	1	1						
Enchytraeus	56	56						
Nais	1	1						
Rhyacophila brunnea/vemna group	5	5						
Sperchon	1	1						
Feltria	4	4						
Lebertia	3	3						
Hydroptila	68	68						
Rhyacophila	25	25						
Hydropsychidae	1	1						
Perlodidae	1	1						
Zapada	62	62						
Sweltsa	1	1						
Zapada cinctipes	62	62						
Zapada columbiana	1	1						
Chloroperlidae	1	1						
Heptageniidae	2	2						
Drunella	1	1						
Ephemerellidae	1	1						
Dicranota	9	9						
Antocha	1	1						
Simuliidae	3	3						
Limnophora	1	1						
Pericoma/Telmatoscopus	103	103						
Chelifera/ Metachela	2	2						
Empididae	22	22						
Thienemannimyia group	1	1						
Thienemanniella	1	1						
Tanypodinae	1	1						
Orthocladius complex	90	90						
Tvetenia	16	16						
Cricotopus (Nostococladius)	1	1						
Pagastia	88	88						
Eukiefferiella	11	11						
Heleniella	3	3						
Hydrobaenus	1	1						
Micropsectra	89	89						
Chironomidae	16	16						
Heterlimnius	3	3						
Elmidae	7	7						
Total:	**811**	**809**						
					0	1	0	
% Total Misidentification Rate =	misidentifications / total number		x100 =		0.00	**Pass**		

Table A.10: Taxonomic QC for CABIN 3-Minute Kick Samples

Project: Teck Elk Valley 2016 (2561) Taxonomist: Sue Salter 2
Minnow (Georgetown), Shari Weech suesalter@cordilleraconsulting.ca

Site - CABIN, Sample - HENUP-BIC, CC# - CC171282, Percent sampled = 10%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Site - CABIN, Sample - SLINE-BIC, CC# - CC171295, Percent sampled = 20%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Diamesa	2	2						
Chironomidae	10	10						
Eukiefferiella	11	11						
Hydrobaenus	1	1						
Orthocladius complex	39	39						
Synorthocladius	2	2						
Tvetenia	4	4						
Dicranota	1	1						
Ameletus	14	14						
Baetis	3	3						
Oreogeton	2	2						
Baetis bicaudatus	2	2						
Ephemerellidae	26	29	No			X		
Drunella	6	6						
Drunella coloradensis	4	4						
Drunella doddsii	9	9						
Heptageniidae	107	105	No			X		
Epeorus	2	2						
Rhithrogena	2	2						
Suwallia	3	3						
Sweltsa	9	9						
Chloroperlidae	2	2						
Zapada columbiana	13	13						
Zapada	10	10						
Leuctridae	2	2						
Perlodidae	3	3						
Zapada oregonensis group	3	3						
Yoraperla	1	1						
Megarcys	6	6						
Taenionema	10	10						
Rhyacophila	4	4						
Parapsyche	1	1						
Hydropsychidae	10	10						
Glossosoma	2	2						
Lebertia	3	3						
Rhyacophila brunnea/vemna group	3	3						
Oligophlebodes	24	24						
Rhyacophila vofixa group	1	1						
Rhyacophila hyalinata group	2	2						
Baetis tricaudatus group	2	2						
Sperchonopsis	1	1						
Total:	**362**	**363**						

			0	2	0	
% Total Misidentification Rate =	misidentifications / total number	x100 =	0.00	**Pass**		

Table A.10: **Taxonomic QC for CABIN 3-Minute Kick Samples**

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter 2
suesalter@cordilleraconsulting.ca

Site - CABIN, Sample - HENUP-BIC, CC# - CC171282, Percent sampled = 10%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Site - CABIN, Sample - FO23-BIC, CC# - CC171299, Percent sampled = 5%, Sieve size = 400	Laboratory Count	QC Audit Count	Agreement	Misidentification	Questionable Taxonomic Resolution	Enumeration	Insufficent Taxonomic Resolution	Comments
Micropsectra	42	42						
Chironomidae	5	5						
Heterlimnius	1	1						
Eukiefferiella	1	1						
Orthocladius complex	9	9						
Pagastia	2	2						
Tvetenia	2	2						
Rheocricotopus	2	2						
Chelifera/ Metachela	2	2						
Clinocera	2	2						
Pericoma/Telmatoscopus	11	11						
Wiedemannia	1	1						
Hexatoma	2	2						
Tipula	1	1						
Drunella doddsii	39	39						
Ephemerellidae	10	10						
Baetis	19	19						
Heptageniidae	24	26	No			X		
Rhithrogena	3	3						
Chloroperlidae	4	4						
Sweltsa	36	36						
Capniidae	3	3						
Perlidae	1	1						
Zapada	7	7						
Zapada cinctipes	11	11						
Megarcys	1	1						
Perlodidae	7	7						
Hesperoperla	6	6						
Taeniopterygidae	8	8						
Pedomoecus sierra	1	1						
Hydrozetidae	1	1						
Rhyacophila atrata complex	8	8						
Baetis tricaudatus group	13	12	No			X		
Enchytraeus	3	3						
Nais	6	6						
Arctopsyche grandis	1	1						
Glossosomatidae	3	3						
Glossosoma	8	8						
Rhyacophila betteni group	2	2						
Lepidostoma	1	1						
Oligophlebodes	1	1						
Trombidiformes	1	1						
Rhyacophila brunnea/vemna group	1	1						
Lebertia	16	16						
Sperchon	2	2						
Lumbriculidae	1	1						
Total:	**331**	**332**						
					0	2	0	
% Total Misidentification Rate =	misidentifications / total number			x100 =	0.00	**Pass**		

Table A.11: **Sub-Sample QC for CABIN 3-Minute Kick Samples**

Cordillera Consulting

Project: Teck Elk Valley 2016 (2561)
Minnow (Georgetown), Shari Weech

Taxonomist: Sue Salter 250-494-7553
suesalter@cordilleraconsulting.ca

Station ID		Organisms in Subsample																				Actual Total	Precision Error		Accuracy Error	
CC#	Sample Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		Min (%)	Max (%)	Min (%)	Max (%)
171279	FOUKI-BIC	358	368	378	338																	1442	2.65	10.58	0.69	6.24
171280	MI3-BIC	382	306	307	303	333	331	320	306	360	345	311	313	338	333	315	305	310	346	345	309	6518	0.00	20.68	1.56	17.21
171282	HENUP-BIC	490	457	470	487	498	534	566	518	496	545											5061	0.40	19.26	1.60	11.84
171295	SLINE-BIC	400	411	437	426	461																2135	2.52	13.23	0.23	7.96

Tissue Selenium Sampling Data

Photo A.1: Looking upstream at LC_LCUSWLC, Feb 2017.

Photo A.2: Close up of substrate at LC_LCUSWLC, Feb 2017.

Photo A.3: Close up of station 4 rocks (typical) sampled for periphyton at LC_LCUSWLC, Feb 2017.

Photo A.4: Looking upstream at LC_LC3, Feb 2017.

Photo A.5: Close up of substrate at LC_LC3, Feb 2017.

Photo A.6: Close up of station 1 rocks (typical) sampled for periphyton at LC_LC3, Feb 2017.

Photo A.7: Looking upstream at LC_LCDSSLCC, Feb 2017.

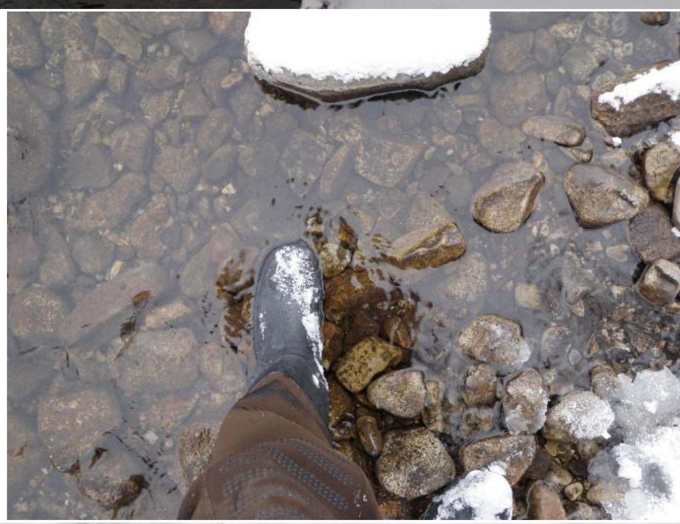


Photo A.8: Close up of substrate at LC_LCDSSLCC, Feb 2017.

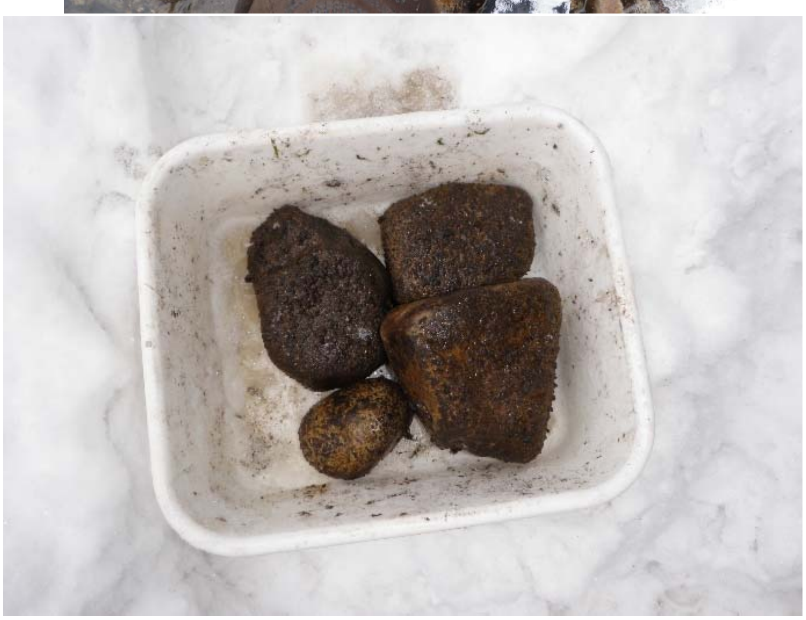


Photo A.9: Close up of station 1 rocks (typical) sampled for periphyton at LC_LCDSSLCC, Feb 2017.

Photo A.10: Close up of station 4 rocks (typical) sampled for periphyton at LC LC4. Feb 2017.

Photo A.11: Close up of substrate at LC_LC4, Feb 2017.

Photo A.12: Looking upstream at LC_LC4, Feb 2017.

Table A.12: Periphyton Selenium Concentrations and Summary Statistics for Samples Collected February 28 to March 2, 2017

Area	Sample Code	Sample Date	Selenium Concentration (mg/kg dw)							95% Confidence Interval	
			Sample	Mean of Replicate Rocks within Station	Area Median	Area Minimum	Area Maximum	Area Mean	Area Standard Deviation	Lower	Upper
LC_LCUSWLC (LCUT) (upstream from AWTF outfall)	LCUT-PERT-01	28-Feb-2017	25	-	26	11	37	26	6.9	22	30
	LCUT-PERT-02	28-Feb-2017	21	-							
	LCUT-PERT-03	28-Feb-2017	37	-							
	LCUT-PERT-04	28-Feb-2017	27	-							
	LCUT-PERT-05A	28-Feb-2017	26	29							
	LCUT-PERT-05B	28-Feb-2017	27								
	LCUT-PERT-05C	28-Feb-2017	31								
	LCUT-PERT-05D	28-Feb-2017	33								
	LCUT-PERT-05E	28-Feb-2017	27								
	LCUT-PERT-06	28-Feb-2017	26	-							
	LCUT-PERT-07	28-Feb-2017	28	-							
	LCUT-PERT-08	28-Feb-2017	34	-							
	LCUT-PERT-09	28-Feb-2017	11	-							
	LCUT-PERT-10	28-Feb-2017	24	-							
LC_LC3 (LILC3)	LILC3-PERT-01	28-Feb-2017	46	-	44	37	61	45	7.6	41	49
	LILC3-PERT-02	28-Feb-2017	40	-							
	LILC3-PERT-03	28-Feb-2017	37	-							
	LILC3-PERT-04	28-Feb-2017	38	-							
	LILC3-PERT-05A	28-Feb-2017	45	46							
	LILC3-PERT-05B	28-Feb-2017	51								
	LILC3-PERT-05C	28-Feb-2017	47								
	LILC3-PERT-05D	28-Feb-2017	45								
	LILC3-PERT-05E	28-Feb-2017	44								
	LILC3-PERT-06	28-Feb-2017	53	-							
	LILC3-PERT-07	28-Feb-2017	39	-							
	LILC3-PERT-08	28-Feb-2017	61	-							
	LILC3-PERT-09	28-Feb-2017	47	-							
	LILC3-PERT-10	28-Feb-2017	42	-							
LC_LCDSSLCC (LIDSL)	LIDSL-PERT-01	1-Mar-2017	4.5	-	5.3	3.4	6.7	5.2	1.0	5	6
	LIDSL-PERT-02	1-Mar-2017	4.7	-							
	LIDSL-PERT-03	1-Mar-2017	3.4	-							
	LIDSL-PERT-04	1-Mar-2017	5.7	-							
	LIDSL-PERT-05A	1-Mar-2017	5.9	6.7							
	LIDSL-PERT-05B	1-Mar-2017	9.2								
	LIDSL-PERT-05C	1-Mar-2017	4.0								
	LIDSL-PERT-05D	1-Mar-2017	6.2								
	LIDSL-PERT-05E	1-Mar-2017	8.4								
	LIDSL-PERT-06	1-Mar-2017	6.0	-							
	LIDSL-PERT-07	1-Mar-2017	4.5	-							
	LIDSL-PERT-08	1-Mar-2017	5.1	-							
	LIDSL-PERT-09	1-Mar-2017	5.8	-							
	LIDSL-PERT-10	1-Mar-2017	5.6	-							
LC_LC4 (LI8)	LI8-PERT-01	2-Mar-2017	2.6	-	3.2	2.6	3.6	3.1	0.32	3	3
	LI8-PERT-02	2-Mar-2017	3.0	-							
	LI8-PERT-03	2-Mar-2017	3.3	-							
	LI8-PERT-04	2-Mar-2017	2.8	-							
	LI8-PERT-05A	2-Mar-2017	2.4	3.4							
	LI8-PERT-05B	2-Mar-2017	2.9								
	LI8-PERT-05C	2-Mar-2017	3.8								
	LI8-PERT-05D	2-Mar-2017	4.2								
	LI8-PERT-05E	2-Mar-2017	3.9								
	LI8-PERT-06	2-Mar-2017	2.9	-							
	LI8-PERT-07	2-Mar-2017	3.1	-							
	LI8-PERT-08	2-Mar-2017	3.4	-							
	LI8-PERT-09	2-Mar-2017	3.3	-							
	LI8-PERT-10	2-Mar-2017	3.6	-							

Table A.13: Concentrations of Selenium, TOC, and Selected Metals in Periphyton Samples Collected in February / March, 2017 and Associated Field Observations

Area	Sample Code	Total Selenium (Se; mg/kg dw)		Total Organic Carbon (TOC; % dw)		Total Aluminum (Al; mg/kg dw)		Total Iron (Fe; mg/kg dw)		Total Titanium (Ti; mg/kg dw)		Calcium (Ca; mg/kg dw)		Field Observations
		Sample Concentration	Area Mean	Sample Concentration	Area Mean	Sample Concentration	Area Mean	Sample Concentration	Area Mean	Sample Concentration	Area Mean	Sample Concentration	Area Mean	
LC_LCUSWLC / LCUT (Line Creek Upstream AWTF Outfall)	LCUT-PERT-01	25	26	7.9	8.3	644	809	588	753	3.6	3.6	252,000	249,340	See Photos A.1 to A.3. Brown/green periphyton present (less abundant than at LC_LC3) and no filamentous periphyton seen. Bryophytes present, but not as abundant as at LC_LC3. Calcite present in chalky form mixed with deposited sediment (grit). Also calcite concretion following a non-linear gradient of very high concretion at the two most upstream stations closest to spoils (90%+ at station 10, to less at the other stations (~25% at station 1 farthest downstream). Chironomids found burrowed throughout calcite/periphyton matrix.
	LCUT-PERT-02	21		8.7		648		717		2.8		248,000		
	LCUT-PERT-03	37		8.4		515		433		< 2.5		261,000		
	LCUT-PERT-04	27		8.3		1,260		1,500		4.8		212,000		
	LCUT-PERT-05A	26		7.7		746		498		3.5		249,000		
	LCUT-PERT-05B	27		8.4		699		551		3		276,000		
	LCUT-PERT-05C	31		6.4		418		372		< 2.5		306,000		
	LCUT-PERT-05D	33		7.5		766		665		3.3		274,000		
	LCUT-PERT-05E	27		7.9		780		642		3.4		257,000		
	LCUT-PERT-06	26		8.7		746		674		3.8		252,000		
	LCUT-PERT-07	28		7.5		798		738		3.8		253,000		
	LCUT-PERT-08	34		6.1		1,160		788		4.0		282,000		
	LCUT-PERT-09	11		8.7		824		823		3.4		241,000		
	LCUT-PERT-10	24		11		813		725		3.7		220,000		
LC_LC3 / LILC3 (Line Creek downstream AWTF outfall)	LILC3-PERT-01	46	45	20	24	3,850	3,748	18,400	16,906	26.70	22	36,900	37,972	See Photos A.4 to A.6. Very abundant dark green filamentous periphyton associated with bryophytes. Similar brown/green periphyton biofilm (scum) associated with calcite to that seen at LC_LCUSWLC. Bryophytes very abundant, growing on the calcite. Calcite present in chalky form mixed with deposited sediment (grit). Chironomids found burrowed throughout calcite/periphyton matrix.
	LILC3-PERT-02	40		23		3,620		15,500		27.40		41,600		
	LILC3-PERT-03	37		22		3,890		14,800		23.60		49,000		
	LILC3-PERT-04	38		24		3,570		14,300		22.50		39,300		
	LILC3-PERT-05A	45		27		2,840		15,600		22.30		24,400		
	LILC3-PERT-05B	51		25		3,110		15,200		22.30		27,700		
	LILC3-PERT-05C	47		25		3,730		17,100		20.80		28,500		
	LILC3-PERT-05D	45		23		3,550		14,900		22.90		28,400		
	LILC3-PERT-05E	44		25		2,900		15,000		21.10		24,100		
	LILC3-PERT-06	53		27		3,930		20,300		22.80		31,300		
	LILC3-PERT-07	39		27		3,480		13,800		20.50		27,600		
	LILC3-PERT-08	61		25		3,770		21,500		20.30		38,400		
	LILC3-PERT-09	47		23		4,060		18,300		18.60		34,900		
	LILC3-PERT-10	42		24		4,080		16,600		18.80		54,100		
LC_LCDSSLCC / LIDSL (Line Creek downstream South Line Creek)	LIDSL-PERT-01	4.5	5.2	7.7	9.2	1,700	1,294	4,430	1,756	5.2	5.3	239,000	253,000	See Photos A.7 to A.9. Similar brown/green periphyton biofilm (scum) associated with chalky calcite and grit (but much less calcite than at LC_LC3 or LC_LCUSWL and more gritty material than at any other station). No bryophytes present. Cutthroat trout observed.
	LIDSL-PERT-02	4.7		9.2		1,180		1,420		5.4		270,000		
	LIDSL-PERT-03	3.4		9.7		1,230		1,430		5.4		248,000		
	LIDSL-PERT-04	5.7		8.7		1,080		1,220		5.2		273,000		
	LIDSL-PERT-05A	5.9		9.9		958		1,060		3.7		245,000		
	LIDSL-PERT-05B	9.2		7.0		1,020		1,230		4.7		270,000		
	LIDSL-PERT-05C	4.0		8.5		1,330		1,740		4.8		238,000		
	LIDSL-PERT-05D	6.2		10		1,150		1,380		4.5		258,000		
	LIDSL-PERT-05E	8.4		11		854		854		4.1		299,000		
	LIDSL-PERT-06	6.0		9.9		1,260		1,350		5.1		270,000		
	LIDSL-PERT-07	4.5		9.6		1,550		1,950		5.6		229,000		
	LIDSL-PERT-08	5.1		9.0		1,430		1,580		6.2		254,000		
	LIDSL-PERT-09	5.8		9.4		1,160		1,370		5.3		245,000		
	LIDSL-PERT-10	5.6		9.2		1,290		1,560		5.6		240,000		
LC_LC4 / LI8 (lower Line Creek)	LI8-PERT-01	2.6	3.1	11	10	587	784	610	947	4.1	6.0	276,000	256,180	See Photos A.10 to A.12. Dark brown periphyton biofilm (scum). No bryophytes present. No calcite present.
	LI8-PERT-02	3.0		10		798		848		5.6		260,000		
	LI8-PERT-03	3.3		10		918		1,100		6.7		256,000		
	LI8-PERT-04	2.8		10		728		720		5.4		223,000		
	LI8-PERT-05A	2.4		9.5		714		995		5.3		224,000		
	LI8-PERT-05B	2.9		12		1,090		1,280		8.5		238,000		
	LI8-PERT-05C	3.8		11		582		741		5.5		258,000		
	LI8-PERT-05D	4.2		7.5		842		1,370		7.9		265,000		
	LI8-PERT-05E	3.9		12		678		904		5.6		239,000		
	LI8-PERT-06	2.9		8.9		1,340		1,880		10.6		221,000		
	LI8-PERT-07	3.1		9.2		688		1,020		4.7		286,000		
	LI8-PERT-08	3.4		12		577		581		4.6		261,000		
	LI8-PERT-09	3.3		9.7		676		806		5.9		283,000		
	LI8-PERT-10	3.6		11		748		851		6.3		251,000		

Table A.14: Selenium Concentrations in Composite Benthic Invertebrate Samples Collected February 28 to March 2, 2017

Area	Sample Code	Sample Date	Selenium Concentration (mg/kg dw)						95% Confidence Interval	
			Sample	Area Median	Area Minimum	Area Maximum	Area Mean	Area Standard Deviation	Lower	Upper
LC_LCUSWLC (LCUT) (upstream from AWTF outfall)	LCUT-BIC-01	28-Feb-2017	5.25	5.2	4.3	5.3	5.0	0.42	4.6	5.3
	LCUT-BIC-02	28-Feb-2017	5.22							
	LCUT-BIC-03	28-Feb-2017	4.32							
	LCUT-BIC-04	28-Feb-2017	5.28							
	LCUT-BIC-05	28-Feb-2017	4.75							
LC_LC3 (LILC3)	LILC3-BIC-01	28-Feb-2017	20.1	25	19	41	27	9.1	19.3	35.2
	LILC3-BIC-02	28-Feb-2017	31.2							
	LILC3-BIC-03	28-Feb-2017	19.0							
	LILC3-BIC-04	28-Feb-2017	24.9							
	LILC3-BIC-05	28-Feb-2017	41.1							
LC_LCDSSLCC (LIDSL)	LIDSL-BIC-01	1-Mar-2017	10.7	11	11	14	12	1.7	10.6	13.7
	LIDSL-BIC-02	1-Mar-2017	10.8							
	LIDSL-BIC-03	1-Mar-2017	14.0							
	LIDSL-BIC-04	1-Mar-2017	11.2							
	LIDSL-BIC-05	1-Mar-2017	14.1							
LC_LC4 (LI8)	LI8-BIC-01	2-Mar-2017	6.84	9.3	6.8	11	8.9	1.6	7.5	10.2
	LI8-BIC-02	2-Mar-2017	7.67							
	LI8-BIC-03	2-Mar-2017	9.31							
	LI8-BIC-04	2-Mar-2017	10.7							
	LI8-BIC-05	2-Mar-2017	9.75							

Table A.15: **Selenium Concentrations Measured in Individual *Parapsyche* sp., February 28, 2017 to March 2, 2017**

Area	Sample Code	Sample Date	Selenium Concentration (mg/kg dw)						95% Confidence Interval	
			Sample	Area Median	Area Minimum	Area Maximium	Area Mean	Area Standard Deviation	Lower	Upper
LC_LCUSWLC (LCUT) (upstream from AWTF outfall)	LCUT-PAR-01	1-Mar-2017	5.96	7.7	5.1	9.8	7.6	2.1	5.8	9.4
	LCUT-PAR-02	1-Mar-2017	9.79							
	LCUT-PAR-03	1-Mar-2017	9.48							
	LCUT-PAR-04	1-Mar-2017	7.71							
	LCUT-PAR-05	1-Mar-2017	5.11							
LC_LC3 (LILC3)	LILC3-PAR-01	28-Feb-2017	43.3	52.0	43.3	53.0	49.7	4.0	46.2	53.3
	LILC3-PAR-02	28-Feb-2017	52.1							
	LILC3-PAR-03	28-Feb-2017	53.0							
	LILC3-PAR-04	28-Feb-2017	52.0							
	LILC3-PAR-05	28-Feb-2017	48.3							
LC_LCDSSLCC (LIDSL)	LIDSL-PAR-01	1-Mar-2017	17.0	17.7	16.5	19.5	17.7	1.1	16.7	18.7
	LIDSL-PAR-02	1-Mar-2017	16.5							
	LIDSL-PAR-03	1-Mar-2017	17.7							
	LIDSL-PAR-04	1-Mar-2017	17.8							
	LIDSL-PAR-05	1-Mar-2017	19.5							
LC_LC4 (LI8)	LI8-PAR-01	2-Mar-2017	11.7	11.7	11.1	12.9	11.9	0.7	11.3	12.6
	LI8-PAR-02	2-Mar-2017	11.1							
	LI8-PAR-03	2-Mar-2017	12.9							
	LI8-PAR-04	2-Mar-2017	12.4							
	LI8-PAR-05	2-Mar-2017	11.5							

APPENDIX B

2017 FEBRUARY AND APRIL SAMPLING STUDY DESIGNS

Memo

To: Chris Stroich and Carla Fraser, Teck Coal Ltd.

From: Patti Orr, Minnow Environmental Inc.

Date: 2/23/2017

Re: Line Creek Winter Field Sampling

Sampling completed in September 2016 for the Line Creek local effects monitoring program (LAEMP) gave evidence that bioaccumulation of selenium downstream from the West Line Creek (WLC) Active Water Treatment Facility (AWTF) has increased since the AWTF was commissioned in late 2015. Additional tissue selenium sampling is proposed in February 2017 to:

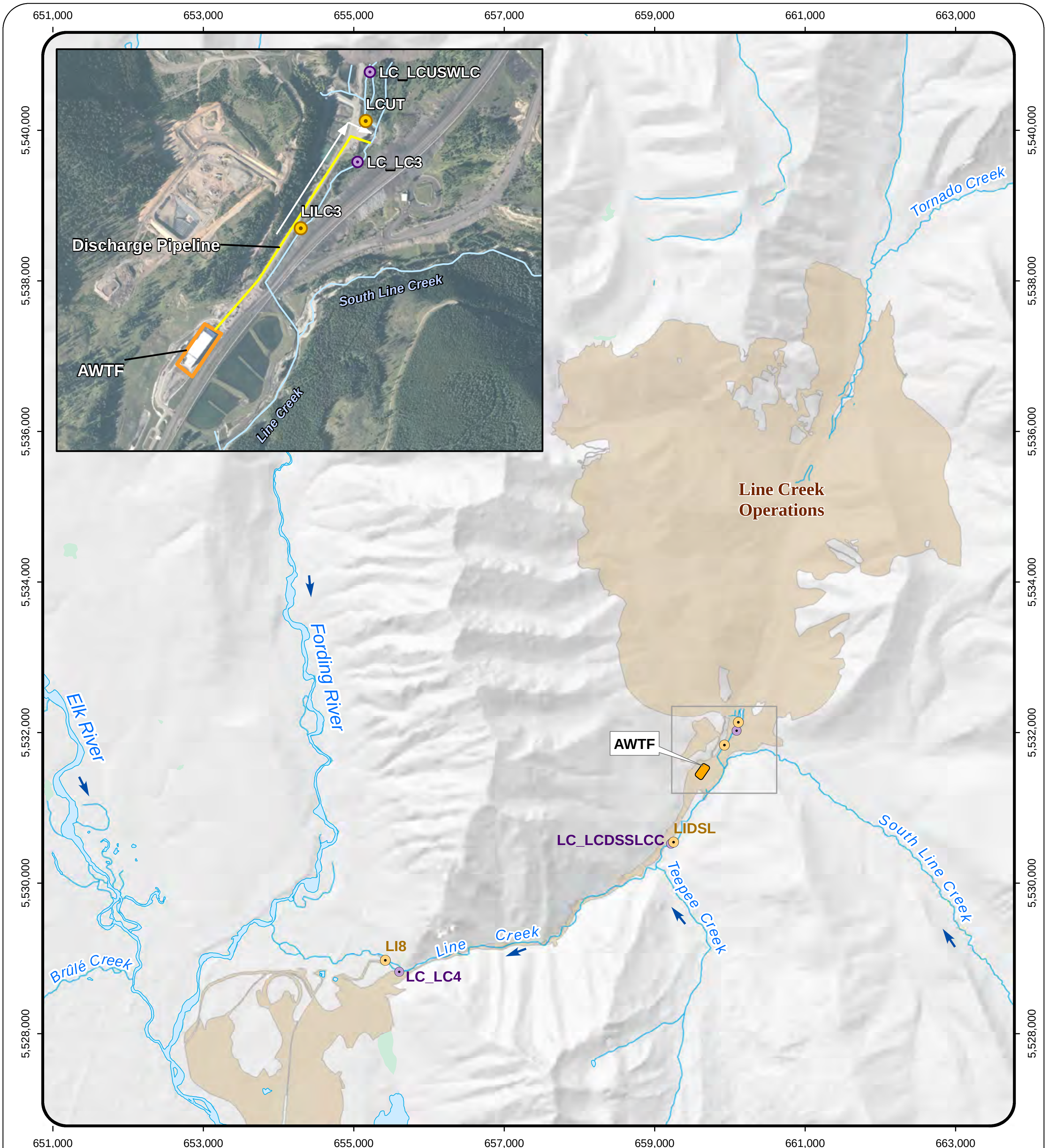
- determine if tissue selenium concentrations remain elevated downstream from the AWTF. Even if results do not show the apparent pattern observed in September (perhaps due to periphyton dormancy), the results will still provide some insight into seasonal variability in selenium bioaccumulation (which Teck has a requirement to address as a condition of MOE's approval of the Regional Aquatic Effects Monitoring Program design via a letter dated November 14, 2014).

- provide more information about within-area variability of periphyton and invertebrate selenium concentrations that may reduce some uncertainties regarding enrichment at the base of the food web. This information will inform estimates of Kds (which describe the relationship between water and periphyton selenium concentrations to support bioaccumulation modelling) and future sample size requirements (for future field sampling).

The sampling program will be completed using a phased approach, with the first sampling event starting on February 28, 2017. The primary goal of this initial sampling event is to determine if selenium concentrations in biota are still elevated relative to past observations. Any additional sampling requirements for the next phase of investigation (and appropriate sample sizes) will be determined following evaluation of data from the first phase.

Monitoring will focus on the three areas in Line Creek that represent a gradient in selenium exposure downstream of the AWTF (i.e., LC_LC3/LILC3, LC_LCDSSLCC/LIDSL and LC_LC4/LI8), as well as the area immediately upstream of the AWTF (LC_LCUSWLC/LCUT; Figure 1; Table 1). These represent the same locations sampled as part of the 2016 LAEMP.

Methods for sampling and analysis of each component are described in more detail below.



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Meters

MAP INFORMATION
Map Projection: UTM Zone 11N NAD 1983
Data Source: Reproduced under licence from Her Majesty the Queen in Right of Canada, Department of Natural Resources Canada.

Creation Date: February 2017
Project No.: 167202.0074

Legend

- Exposed Biological Sampling Station
- Teck Water Quality Station
- Teck Coal Mine Operations
- Active Water Treatment Facility (AWTF)
- Waterbody
- Wetland
- Watercourse
- Water Flow Direction

Figure 1: Line Creek Selenium Monitoring Areas and Corresponding Teck Water Monitoring Stations, 2017

minnow environmental inc.

Table 1: Summary of proposed selenium sampling, February 2017.

Location Description	Biological Sampling			2017 February 28 - March 3				
	Biological Sampling Area ID (Teck water quality Station ID in brackets)	UTM (11U) Easting	UTM (11U) Northing	Periphyton[1]	Benthic Invertebrate Composite	*Parapsyche* sp. (individual)	*Rhyacophila* sp. (composite)	Chironomidae (composite)
Line Creek upstream of the AWTF	LCUT (LC_LCUSWLC)	660114	5532140	10	5	5	1	If sufficiently abundant
Line Creek downstream AWTF discharge and upstream South Line Creek	LILC3 (LC_LC3)	659947	5531859	10	5	5	1	1
Line Creek downstream AWTF discharge and South Line Creek	LIDSL (LC_LCDSSLCC)	659320	5530619	10	5	5	1	If sufficiently abundant
Line Creek near mouth	LI8 (LC_LC4)	655421	5528971	10	5	5	1	If sufficiently abundant

[1] Aluminum, iron, and titanium will be analyzed in addition to selenium. TOC will also be analyzed on a minimum of three samples per area.

1. Periphyton Selenium

Periphyton samples will be collected from 10 stations located a minimum of 5 m apart in each sampling area (i.e., one sample at each of 10 stations per area), with sampling progressing from downstream to upstream within each area (Table 1). Each sample will be a composite of scrapings from five rocks selected randomly. Once a rock is selected for sampling, the rock will be placed in a plastic bin and taken to shore. An equal amount of surface area will be scraped from each of the five rocks with a scalpel to collect at least 2 g wet weight of periphyton. Scrapings will be transferred directly into a pre-labelled cryovial (without rinsing) to minimize the amount of water in each sample. If periphyton coverage is very low due to winter die-back, it may be necessary to scrape more than five rocks to obtain a sufficient mass of sample. If this is the case, additional periphyton will be collected from rocks located immediately adjacent to the five rocks initially selected for sampling.

Periphyton tissue samples will be placed into labelled cryovials and stored in a cooler with ice packs until transferred to a freezer later in the day. Frozen samples will be shipped to the laboratory for analysis of dry weight selenium concentration and percent moisture.

2. Benthic Invertebrate Selenium

Benthic invertebrate samples for selenium analysis will be collected using the kick and sweep sampling method. Four types of samples will be collected for analysis of tissue selenium:

- A composite sample of *Rhyacophila* sp. *Rhyacophila* sp. have been sampled as part of the Line Creek LAEMP since 2014. Analysis of this single genus will facilitate detection of potential changes in tissue selenium over time.

- Individual *Parapsyche* sp.. *Parapsyche* sp. is a genus of large net-spinning caddisflies that tend to congregate on the undersides of large rocks. It is also the largest and most common caddisfly genus found in Line Creek (i.e., tissue from a single individual should be sufficient for accurate determination of selenium content). Although not specifically targeted in the past, it will contribute in the future (along with *Rhyacophila* sp.) to understanding changes in tissue selenium concentrations over time. Collection and analysis of individuals will also contribute to the understanding of variation in selenium accumulation among individuals within areas.

- One composite sample of chironomids at LC_LC3/LILC3, if sufficient mass can be obtained, because this taxon dominates the invertebrate community at this location. Additional chironomid samples may be collected at the other sampling areas, if chironomids are sufficiently abundant.

- Composite samples of benthic invertebrates. These samples will be useful for comparison to previous results, and as an estimate of dietary selenium concentrations of consumer organisms (e.g., fish, birds). A total of five samples will be collected in each area to determine within-area variability. Samples within areas will be collected a minimum of 5 meters apart, moving from downstream to upstream. Each sample will be composed of the most common organisms found in the kick sample (based on abundance and biomass).

Invertebrate tissue samples will be placed into labelled cryovials and stored in a cooler with ice packs until transferred to a freezer later in the day. Frozen samples will be shipped to the laboratory for analysis of dry weight selenium concentration and percent moisture.

3. Supporting Information and Measurements

All field observations and measurements will be recorded on standardized field data collection forms copied on waterproof paper. Sample collection stations will be recorded as UTMs (Universal Transverse Mercator) using the North American Datum of 1983, so the same stations can be visited in the future, if necessary. Water temperature, dissolved oxygen (DO), pH, and specific conductance will be measured in each area using a field meter that has been appropriately calibrated. Photographs will also be taken of samples and sample stations.

Teck should ensure that corresponding water samples are also collected for selenium analysis (total, dissolved and speciation) at the same time as the field program is being implemented.

4. Laboratory and Data Analysis

Tissue samples will initially be sent to the Saskatchewan Research Council (SRC) laboratory in Saskatoon, SK, for freeze-drying. A sufficient portion of each freeze-dried sample be sent to ALS Environmental in Burnaby, BC, for analysis of selenium, aluminum (Al), iron (Fe), and titanium (Ti). SRC will measure total organic carbon (TOC) content on any samples for which a sufficient dried mass of sample remains. Minnow will ensure that sufficient sample amounts are collected at a minimum of three periphyton samples per area (but possibly up to all 10 samples per area if each sample contains sufficient dried mass) to measure TOC. The analyses of Al, Fe, Ti, and TOC will assist in determining if deposition of fine inorganic material confounds estimates of periphyton tissue selenium accumulation at the base of the food web. A "rush" turnaround time will be requested to ensure results are reported as quickly as possible. Following receipt of analytical data, results will be compiled into appropriate tables and figures, and provided to Teck as a data package for review.

Technical Memorandum

To: Carla Fraser, Teck Coal Ltd.

From: Patti Orr, Tyrell Worrall, Justin Wilson, Minnow Environmental Inc.

Date: 4/20/2017

Re: Line Creek Field Sampling in April 2017, Including Fish

Sampling completed in September 2016 for the Line Creek local effects monitoring program (LAEMP) gave evidence that bioaccumulation of selenium downstream from the West Line Creek (WLC) Active Water Treatment Facility (AWTF) has increased since the AWTF was commissioned in late 2015. The sampling is proposed to begin the week of 24 April, 2017. This will allow for collection of additional periphyton and benthic invertebrate samples for analysis of tissue selenium concentrations to assess seasonal variability and potential influence of the AWTF on tissue selenium accumulation of biota in Line Creek. Sampling of westslope cutthroat trout (WCT; *Oncorhynchus clarkii lewisi*) is also proposed, as explained below.

Westslope Cutthroat Trout

<u>Timing of Sampling</u>

Ovarian recrudescence is typically indicated by a gonadosomatic index (GSI) of at least 1% (Pilgrim 2009; Environment Canada 2012). Coastal cutthroat trout (*Oncorhynchus clarkii clarkii)* sampled in Alaska that are believed to spawn in late April or in May had sufficient gonad development in October to differentiate immature (GSI<1.8%) and mature (GSI>1.8%) individuals. Ovarian development of WCT in the Elk River watershed is also usually evident by October, but progresses slowly until late winter or early spring (S. Cope, Westslope Fisheries, pers. comm.). Ovary weights of WCT collected in the Elk Valley in 1996, 2002, 2003, and 2006 showed substantial ovary development by April (Figure 1). Peak spawning typically occurs around mid-June.

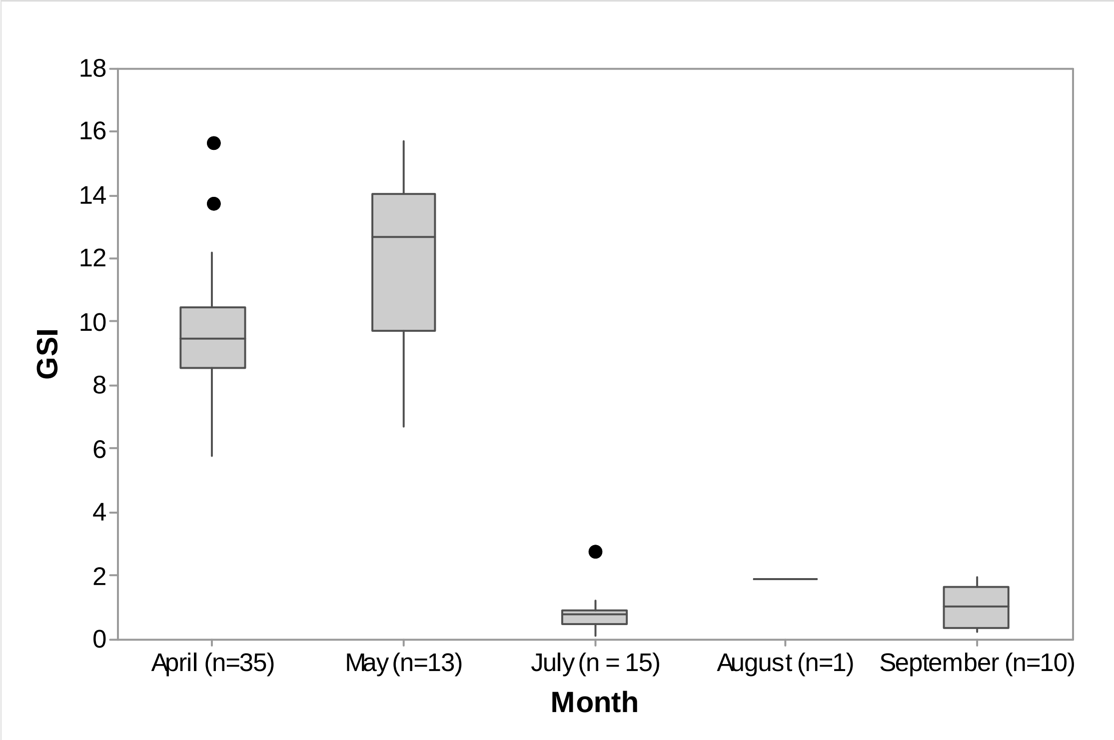

Figure 1. Boxplot of GSI by sampling month for female WCT collected in the Elk Valley in 1996, 2002, 2003, and 2006. The GSI was calculated as the ratio of ovary weight to total body weight, expressed as a percentage.

Although data presented in Figure 1 represented only five months of the year, the pattern is consistent with that described by Barrett and Munkittrick (2010) for a variety of fish species that show maximal gonad development in the 3 to 4 months immediately prior to spawning (Figure 2).

Collection of WCT ovaries for evaluation of potential reproductive effects related to selenium would ideally occur in late May or in June, close to or during spawning. However, this timing coincides with peak freshet, when water levels, velocity, and turbidity are typically all high and preclude safe and efficient fish collection. Therefore, sampling is proposed to be completed in late April, when streams will be ice-free and in only the early stages of freshet (i.e., low flows and good water clarity). Also, Line Creek is used for spawning by both resident and migrant WCT populations, with the former group being of greatest interest with respect to understanding food web transfer of selenium associated with the West Line Creek AWTF. It is expected that fish captured in April will be more likely to be part of the resident Line Creek population than if fishing were delayed until May or June[1]. Figure 1 shows that WCT ovaries will be substantially developed in April.

[1] It is hoped that spawners that overwinter in other parts of the watershed do not migrate into Line Creek until closer to spawning (May-June). If so, fish captured in Line Creek in April are more likely to be ones that overwintered there, in which case, tissue selenium concentrations will be more likely to reflect local dietary exposure than fish captured in May or June.

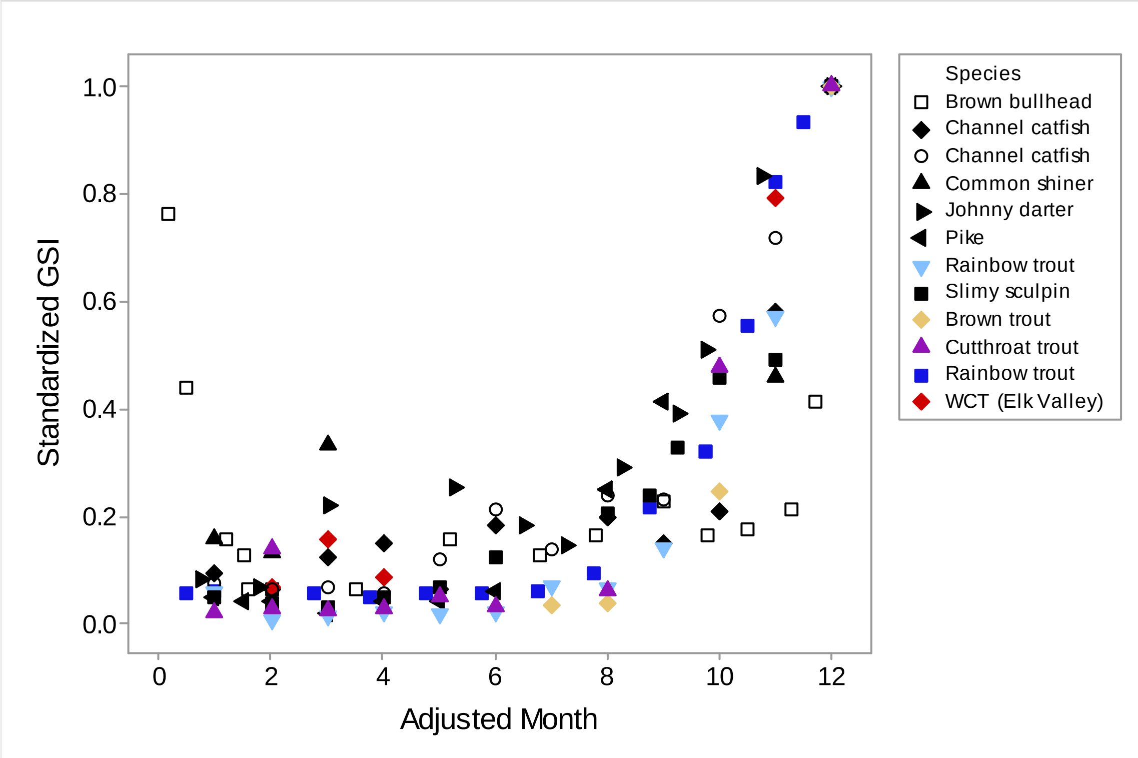

Figure 2. Scatterplot of standardized GSI (monthly mean GSI divided by maximum monthly mean GSI) versus adjusted month (adjusted so that the maximum monthly GSI occurs in month 12) for single spawners that show maximal gonad development in the few months just prior to spawning (copied from Barrett and Munkittrick 2010). Black symbols and blue triangle are from Barrett and Munkittrick (2010). Additional data were added for brown trout (Crim and Idler, 1978), cutthroat trout (Mushurobira et al. 2013), rainbow trout (Bon et al. 1978), and for WCT in the Elk Valley in 1996, 2002, 2003, and 2006.

<u>Sampling Areas</u>

WCT will be sampled in two areas of Line Creek: (1) between South Line Creek and Teepee Creek, roughly bounded by two of the areas sampled in February for analysis of periphyton and benthic invertebrate selenium concentrations (i.e., LC_LC3/LILC3 and LC_LCDSSLCC/LIDSL); and (2) in lower Line Creek in the vicinity of LC_LC4/LI8 (Figure 1). WCT representing various life stages have been captured in these areas in past studies for estimation of population density (Arnett and Berdusco 2009). WCT were also sampled at the most downstream area for analysis of tissue selenium concentrations in 2006 (Minnow et al. 2007).

<u>Sample Sizes and Capture Methods</u>

Angling with fly fishing rods and spinning rods has been the most frequently used and successful capture method in the lotic areas (rivers) sampled. Two to four anglers will fish simultaneously at each area. A diverse range of habitat, including deep pools, glides, side channels, and large woody debris, will be angled to collect the target sample size. Efforts will be concentrated as close to target locations as possible (typically locations where samples were obtained in past studies), and expanded outward, if needed, until the required numbers of fish are captured.

Five mature female WCT will be targeted in both areas (Figure 1). To the extent possible, fish gender will be determined prior to fish sacrifice using secondary sexual characteristics (i.e., shape of jaw, colour, condition of vent/ovipositor). Individual fish will be targeted based on size (i.e., WCT from 200mm to 450mm) to maximize the likelihood of obtaining adult, ripe females.

Non-target species that are captured will be sampled opportunistically. Muscle plugs will be sampled non-lethally from any adult bull trout that are captured and then the fish will be released near the site of capture. Adult mountain whitefish that are captured will be processed as described for cutthroat trout (up to five individuals per area). Any incidental mortalities will be recorded, and the samples will be retained, kept frozen, and given an individual sample code. Undersized target or non-target species will be recorded and released.

Sample Processing

All fish and corresponding tissues will be assigned unique sample codes. Body mass (in grams) and fork length (in millimetres) will be measured using Pesola™ spring scales (accurate to 0.3%) and a metre stick (± 1 mm), respectively. In the case of fish that are sacrified, two otoliths will be extracted from each fish and stored in small, labelled paper envelopes: one otolith to be used for age analysis and the other for selenium analysis. The body cavity of each fish will be opened using round-nosed scissors. The gender of the fish will be recorded and the gonads will be extracted, weighed to the nearest 0.1 g using a top-loading digital scale, and placed into a sterile, labelled, Whirl-Pak® bag. The liver will be similarly extracted, weighed, and stored in a labelled Whirl-Pak® bag. A muscle sample (minimum of 5 g) will be taken from behind the dorsal fin on the dorsal side of the fish using a clean fillet knife. The muscle will be filleted from the bones and the skin removed so that the sample is composed of only muscle. Each muscle sample will be weighed to the nearest 0.1 g, packaged in a sterile, labelled, Whirl-Pak® bag and frozen

For fish sampled non-lethally, a muscle sample will be taken by inserting a 4 mm biopsy punch into the dorsal musculature and applying light pressure while turning (twisting) the punch. The tissue sample will be removed from the biopsy punch using a clean pair of forceps, removing the skin and storing the remaining tissue in a sterile, labelled, vial or Whirl-Pak® bag.

Soft tissue samples will be stored in a cooler with ice packs until transferred to a freezer later in the day. Frozen samples will be shipped to the laboratory. As with the February sampling, the samples will be sent to SRC in Saskatoon for freeze-drying and then to ALS in Burnaby for analysis of tissue selenium concentrations. Otoliths collected for age analysis will be sent to North Shore Environmental, in Thunder Bay, ON. Otoliths collected for selenium analysis will be sent to the laboratory of Dr. Norman Halden at the University of Manitoba in Winnipeg.

Periphyton and Benthic Invertebrates

Periphyton and benthic invertebrates will be collected again from the same four areas that were sampled in February: LC_LC3/LILC3, LC_LCDSSLCC/LIDSL and LC_LC4/LI8 downstream from the AWTF, as well as the area immediately upstream of the AWTF (LC_LCUSWLC/LCUT; Figure 1). Samples will also be collected from the reference area LC_SLC. The data from the samples collected in February were analyzed to determine sample size requirements (Table 1). Compositing periphyton scrapings from five rocks at each station did not reduce the margin of error associated with estimates of mean tissue concentration in each area (first set of results in Table 1) compared to analyzing scrapings from individual rocks (second set of results in Table 1). Therefore, sampling in April will shift the effort from 10 stations, each being a composite of scrapings from five rocks (i.e., scraping a total of 50 rocks per area), to 15 stations, each being a scraping from a single rock (i.e., scraping a total of 15 rocks per area[2]. For composite-taxa benthic invertebrate samples, the number of stations will be increased from 5 (in February-March) to 10 (in April) to reduce the margin of error on estimates of area mean tissue selenium

[2] Unless this yields too little tissue to meet analytical laboratory requirements in which case scrapings will be added from one or more additional rocks at that station.

Table 1. Margins of error for estimating the area mean concentration of selenium in periphyton and benthic invertebrates based on coefficients of variation (COV) from samples collected February 28 to March 2, 2017.

Sample Size	Margin of Error (% of mean concentration) for Two-sided 95% Confidence Interval								
	Periphyton						Benthic Invertebrates		
	Estimates based on within area variability (one sample per station = composite of 5 scrapings from a rock)			Estimates based on within area variability (one sample per station = one scraping on a rock)			Estimates based on within area variability (one sample per station = one composite sample)		
	Pooled COV based on 4 areas (17.0%)	Max COV (26.6%) (LCUT)	Min COV (10.3%) (LI8)	Pooled COV based on 4 areas (17.9%)	Max COV (31.0%) (LIDSL)	Min COV (5.88%) (LILC3)	Pooled COV based on 4 areas (20.7%)	Max COV (33.4%) (LILC3)	Min COV (8.47%) (LCUT)
2	152	239	93	160	279	53	186	300	76
3	42	66	26	44	77	15	51	83	21
4	27	42	16	28	49	9.4	33	53	13
5	21	33	13	22	39	7.3	26	42	11
6	18	28	11	19	33	6.2	22	35	8.9
7	16	25	9.5	17	29	5.4	19	31	7.8
8	14	22	8.6	15	26	4.9	17	28	7.1
9	13	20	7.9	14	24	4.5	16	26	6.5
10	12	19	7.4	13	22	4.2	15	24	6.1
11	11	18	6.9	12	21	4.0	14	22	5.7
12	11	17	6.5	11	20	3.7	13	21	5.4
13	10	16	6.2	11	19	3.6	12	20	5.1
14	9.8	15	6.0	10	18	3.4	12	19	4.9
15	9.4	15	5.7	9.9	17	3.3	11	19	4.7

Margin of error associated with the sample sizes recommended for the April sampling program concentrations by about 10%. Sample sizes for single-taxon samples will be the same as for the February-March program.

Supporting Information and Measurements

All field observations and measurements will be recorded on standardized field data collection forms copied on waterproof paper. Sample collection stations will be recorded as UTMs (Universal Transverse Mercator) using the North American Datum of 1983, so the same stations can be visited in the future, if necessary. Water temperature, dissolved oxygen (DO), pH, and specific conductance will be measured in each area using a field meter that has been appropriately calibrated. Photographs will also be taken of samples and sample stations.

Teck should ensure that corresponding water samples are also collected for selenium analysis (total, dissolved and speciation) at the same time as the field program is being implemented.

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APPENDIX C

SITE PERFORMANCE OBJECTIVE EVALUATION

Proposal to Update the Site Performance Objective for Phosphorus Management in Line Creek

Prepared for:
Teck Coal Limited
Sparwood, British Columbia

Prepared by:
Minnow Environmental Inc.
Georgetown, Ontario

May 2017

Proposal to Update the Site Performance Objective for Phosphorus Management in Line Creek

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1 INTRODUCTION

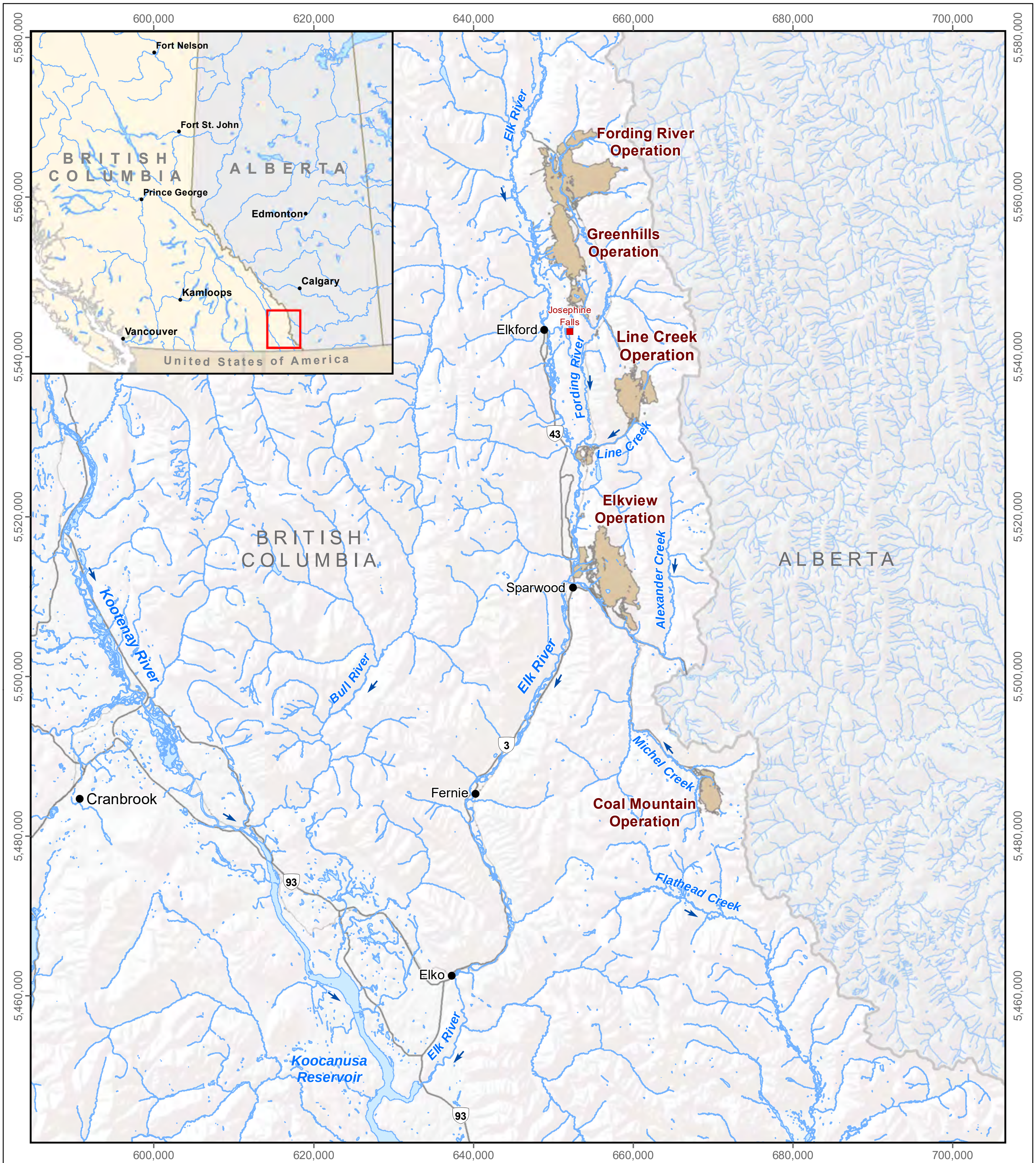
1.1 Background

Teck Resources Limited (Teck) operates five, open pit, steelmaking coal mines in the Elk River watershed, which are the Fording River Operation (FRO), Greenhills Operation (GHO), Line Creek Operation (LCO), Elkview Operation (EVO), and Coal Mountain Operation (CMO; Figure 1.1). In May 2012, an application was submitted to the British Columbia Ministry of Environment (MOE) and Ministry of Energy and Mines (MEM) seeking approval to construct and operate an active water treatment facility (AWTF) at LCO. The application explained that a Fluidized Bed Reactor would be used to decrease selenium concentrations in water from West Line Creek and that the technology requires addition of phosphorus. During review and discussion of the application, the MOE expressed concern that predicted residual phosphorus concentrations in the discharge have potential to elevate phosphorus in Line Creek above naturally occurring concentrations. If phosphorus concentrations increase, algal growth may also increase and affect overall aquatic ecosystem health downstream from the AWTF.

Discharges from Teck's mines to the Elk River watershed are authorized by the MOE through permits that are periodically issued under provisions of the *Environmental Management Act*. Permit 107517, issued November 14, 2015 and amended and March 1, 2017, specifies the terms and conditions associated with discharges from Teck's five Elk Valley coal mine operations. As part of the approval for AWTF operation at LCO, the MOE specified Site Performance Objectives (SPOs) in Section 3.4 of Permit 107517 for a new monitoring station in Line Creek downstream from the AWTF discharge and the confluence with South Line Creek (identified by Teck as LC_LCDSSLCC and in the Permit as E297110;Table 1.1; Figure 1.2). Section 3.4 of Permit 107517 also stipulates that in the event that any of the SPOs specific to AWTF operation are exceeded, Teck must review the discharge concentration limits for total phosphorus in Section 2.6.1.2 and submit an application to amend the limit such that the SPOs are met.

Table 1.1: SPOs for Monitoring Station LC_LCDSSLCC in Permit 107517

Parameter	Objective	Method/Notes
Chlorophyll-a	≤ 100 mg/m^2	Average calculated each sampling date, based upon at least 5 sub-samples collected randomly from each stream reach. Minimum of three sampling events between July 15th and September 30th. Detailed methodology must be included in the Local Aquatic Effects Monitoring Program.
Total Phosphorus	≤ 0.02 mg/L	Growing season average calculated from measurements collected every two weeks between June 15 and September 30 annually.



LEGEND

Teck Coal Mine Operation

Teck's Coal Mine Operation within the Elk River Watershed, Southeast British Columbia

0 10 20 40 km

Projection: North American Datum 1983 UTM Zone 11
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Date: May 2017
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Figure 1.1

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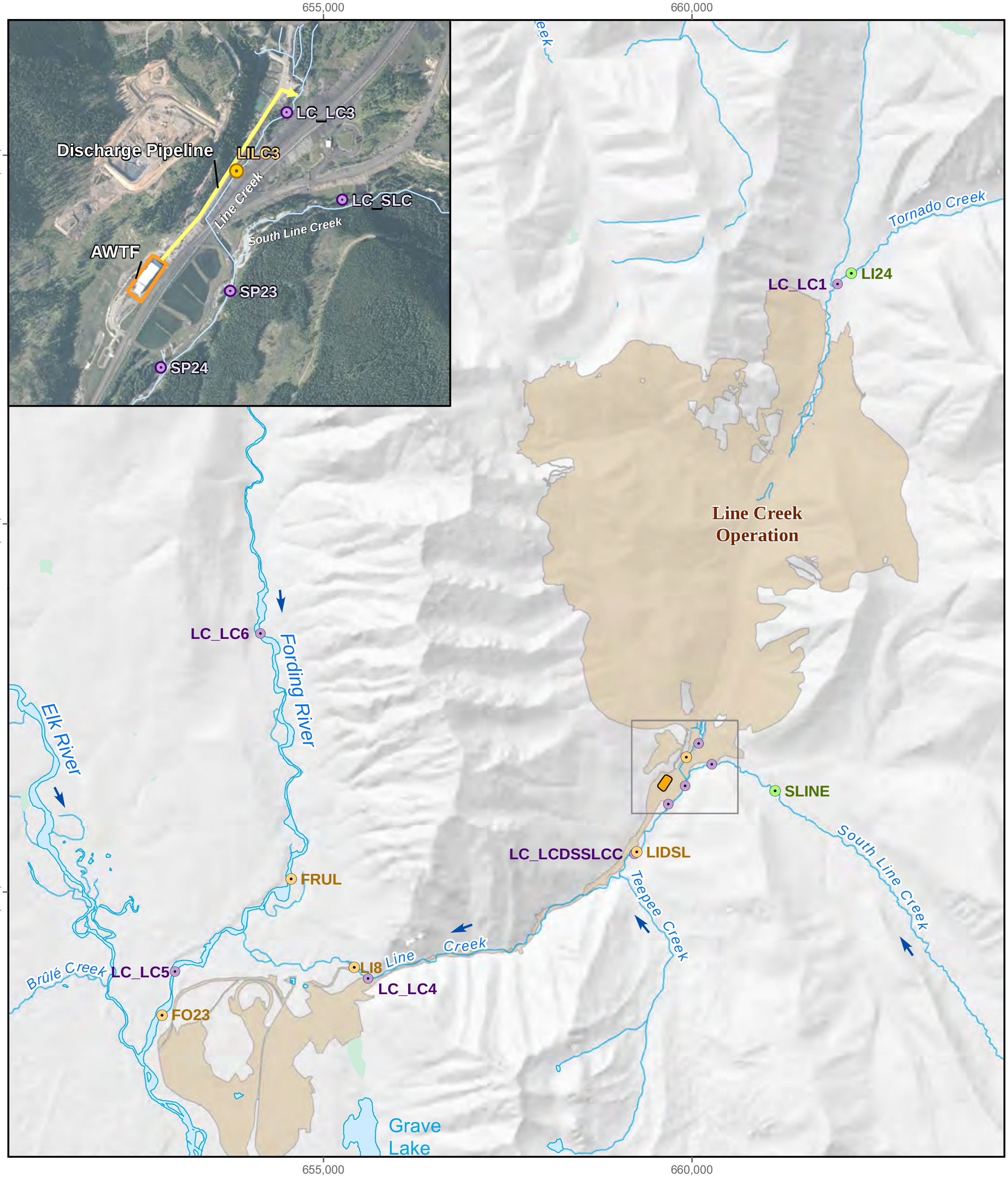

LEGEND

- Exposed Biological Sampling Station
- Reference Biological Sampling Station
- Teck Water Quality Station
- Active Water Treatment Facility (AWTF)
- Teck Coal Mine Operation

Line Creek LAEMP Biological Monitoring Areas and Teck Water Monitoring Stations

0 1.25 2.5 5 km

Map Projection: UTM Zone 11N NAD 1983

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Figure 1.2

Document Path: S:\GIS Library\Map Templates\Maps\16.0074 Figure 1.2 Line Creek LAEMP.mxd

In advance of MOE's issuance of Permit 107517 and the associated requirements in Table 1.1, a phosphorus management framework was developed by Teck and approved by the MOE (Appendix A). The framework explained how Teck would respond if phosphorus loads from the AWTF increased receiving water concentrations and resulted in increased biological productivity. The management response levels (Table 1.2) were based on projections for effluent and receiving water phosphorus concentrations, and limited available baseline periphyton productivity data. The response framework applies to the compliance station LC_LCDSSLCC (Figure 1.2) and the associated periphyton data that have been collected as part of the Line Creek local aquatic effects monitoring program (LAEMP).

Table 1.2: Initial Framework for Phosphorus Management at LC_LCDSSLCC

Average Periphyton Chlorophyll-a Concentration [a]	Action Level	Management Response [b]
<25 mg/m^2	No action	None, other than routine LAEMP reporting
25-50 mg/m^2	Low	Determine if the increase in primary productivity is mainly attributable to AWTF nutrient loads (i.e., corroborated by other monitoring results). Provide update to MOE on mitigation options being considered (with rationale), as well as steps and schedule for implementation, should future annual monitoring cycle identify a moderate or high action level.
50-75 mg/m^2	Moderate	Provided LAEMP results verify that increased productivity is occurring and is mainly attributable to the AWTF[a], confirm mitigation plans with MOE, and initiate management and regulatory steps for implementation.
>75 mg/m^2	High	Provided LAEMP results verify that increased productivity is occurring and is mainly attributable to the AWTF[a], implement mitigation.

[a] At LC_LCDSSLCC. Average chlorophyll-a concentration must be evaluated relative to reference conditions. If reference conditions are similar to conditions at the assessment point in Line Creek, then no action is required.
[b] Management responses are initiated before the next annual monitoring cycle.

After a brief period of operation in late 2014 (July to October), the AWTF was recommissioned in starting in October, 2015, and has been in full operation since February, 2016. Data are now available to compare phosphorus concentrations in effluent and receiving water to predictions. Biological productivity data that have been collected in Line Creek and other areas of the watershed are also available to assess relationships between nutrient concentrations in water and biological productivity. This document proposes to update the SPOs in Permit 107517 related to phosphorus management based on data collected since AWTF operations began. The results presented herein are also relevant to addressing concerns about potential influence of mining on aquatic productivity through the LAEMPs for Teck's other mine operations, as well as in the regional aquatic effects monitoring program (RAEMP)[1].

1.2 Objectives

The objectives of this document are to:

- Re-evaluate the phosphorus management framework developed in April, 2014, by assessing water quality and biological monitoring data collected since the original framework was developed and AWTF operation commenced;
- Update the SPO for phosphorus in Line Creek to address the requirements of Section 3.4 of Permit 107517;
- Determine the most effective indicator(s) of nutrient enrichment in the Elk River watershed associated with mining- and AWTF-related nutrient loads as input to the scope of Teck's LAEMPs and the RAEMP; and
- Contribute to a condition in the MOE's approval of the RAEMP study design (in a letter to Teck from MOE dated November 14, 2014) for "Additional studies to address nutrient loading in the Fording and Elk Rivers from mine-related sources."

[1] One of the conditions of MOE's approval of the RAEMP design was to conduct "Additional studies to assess nutrient loading in the Fording and Elk Rivers from mine-related sources." (letter to Teck dated November 14, 2014).

2 AQUEOUS PHOSPHORUS CONCENTRATIONS

Teck's application to the MOE for approval to operate the AWTF estimated the use of 53,000 L/year of phosphoric acid, but actual usage was only 10,400 L during the first full year of operation. As a result of lower usage and other efforts to minimize phosphorus loss to the downstream environment (e.g., construction of the buffer pond), total phosphorus concentrations in AWTF effluent averaged only 0.04 mg/L over 2016 compared to a projected average of 0.3 mg/L. Consequently, concentrations of total phosphorus in Line Creek at the Compliance Point (LC_LCDSSLCC) have usually been below the projected range[2], and always below the maximum of 0.02 mg/L stipulated in Permit 107517 during AWTF operation (Figure 2.1).

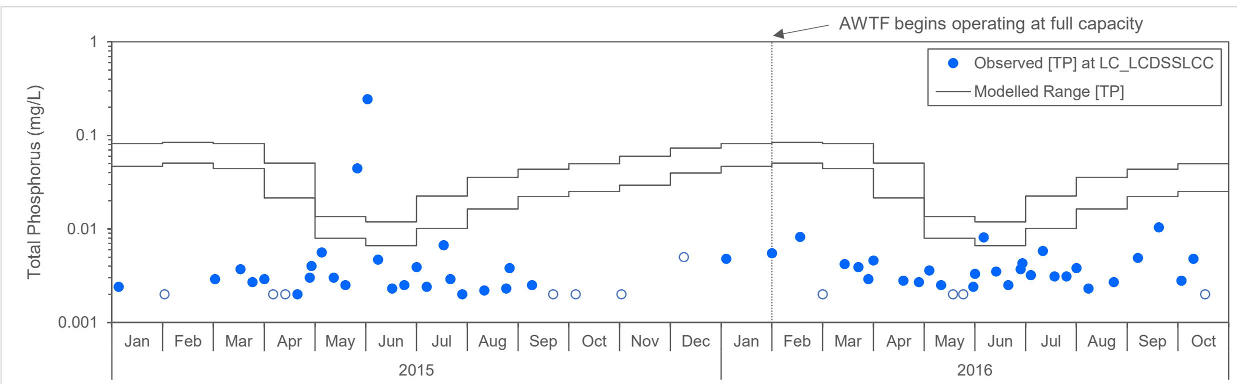


Figure 2.1: Observed Concentrations of Total Phosphorus versus Modelled Monthly Concentration Range at LC_LCDSSLCC (E297110)

Note: Modelled monthly concentration range from low flow to high flow of total phosphorus in Line Creek at the Compliance Point. Concentrations below the detection limit (DL) are plotted as open symbols at the DL

Concentrations of total phosphorus and orthophosphate in water at the Compliance Point (LC_LCDSSLCC) have also been within the range of concentrations observed at reference stations, even since the AWTF came into full-capacity operation (Figure 2.2).

Monthly mean concentrations of total phosphorus and orthophosphate (log_{10}-transformed to meet statistical assumptions of normality) were compared among areas (Table 2.1; Figure 2.3). There was no difference in mean concentrations of total phosphorus and orthophosphate between the reference areas (LC_LC1 and LC_SLC; Table 2.1), so concentrations at stations downstream

[2] The range of total phosphorus concentrations in receiving water reflected projected effluent loads under a range of flow conditions.

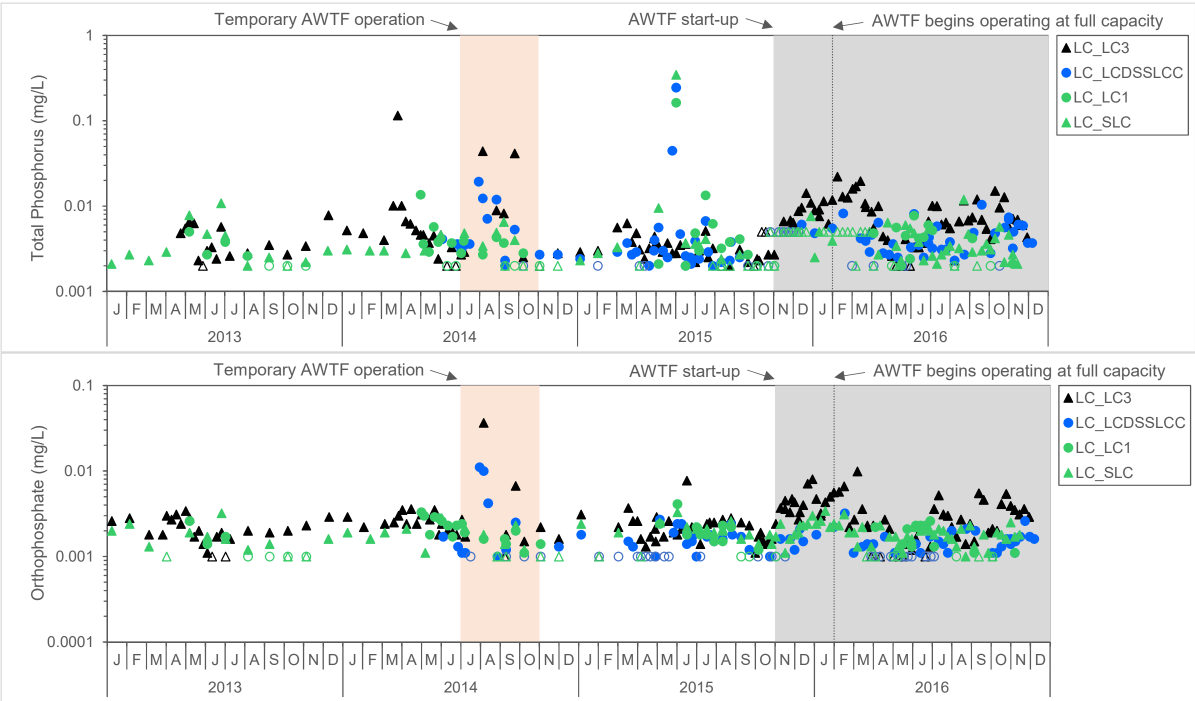


Figure 2.2: Observed Concentrations of Total Phosphorus and Orthophosphate at Line Creek Stations

Note: Data presented for LC_LC3 (~60 m downstream from the AWTF outfall), LC_LCDSSLCC (Compliance Point, ~1.5 km, downstream from AWTF outfall), and reference stations on upper Line Creek (LC_LC1) and South Line Creek (LC_SLC). Concentrations below the detection limit (DL) are plotted as open symbols at the DL. Pink shade indicates initial operation of the AWTF in 2014. Grey shade indicates current operating period.

from the AWTF were evaluated relative to the mean monthly concentrations for the pooled reference area data set. Concentrations of total phosphorus and orthophosphate were significantly greater at LC_LC3 than at reference areas prior to AWTF operation (25% and 7% for TP and ortho-P, respectively[3]), but were more elevated after treatment commenced (84% and 58%, respectively). However, this resulted in average concentrations of total phosphorus at LC_LC3 of only 0.007 mg/L in 2016 compared to 0.004 mg/L prior to AWTF operation (Table 2.1). Farther downstream, at WL_LCUCP_SP23 and WL_DCP_SP24, concentrations of total phosphorus, but not orthophosphate were also greater than those observed at reference areas, and concentrations of both phosphorus forms were progressively less with distance downstream from the AWTF (Table 2.1; Figure 2.3).

[3] Data collected at LC_LC3 between July and October 2014 (when the AWTF was in temporary operation), were excluded for the purposes of characterizing concentrations prior to AWTF operation.

Table 2.1: Statistical Comparisons of of Total Phosphorus and Orthophosphate Concentrations[a]

Nutrient	Area Comparison	Period	Test	P-value	Area	n	Mean[b]	Magnitude of Diffference and Time Period	Explanation of Differences
Total Phosphorus	LC_LC1 vs LC_SLC	May 2013 - Nov 2016	One-sample t-test on (LC_LC1 - LC_SLC)	0.478	LC_LC1	26	0.0033	6.3%	Concentrations were similar between reference areas (relative percent difference = 6.3%).
					LC_SLC	26	0.0035		
	LC_LC3 vs Pooled Ref	No Treatment (May 2009 - June 2014 and Nov 2014 - Oct 2015)	One-sample t-test on (LC_LC3 - Ref)	0.061	LC_LC3	30	0.0039	25% (No Treatment Period)	Concentrations at LC_LC3 were, on average, 25% greater than reference prior to AWTF treatment.
					Pooled Ref	30	0.0031		
	LC_LC3 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (LC_LC3 - Ref)	<0.001	LC_LC3	13	0.0067	84% (Treatment Period)	Concentrations at LC_LC3 were, on average, 84% greater than reference since treatment began.
					Pooled Ref	13	0.0037		
	WL_LCUCP_SP23 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (WL_LCUCP_SP23 - Ref)	0.007	WL_LCUCP_SP23	13	0.0050	37% (Treatment Period)	Concentrations at WL_LCUCP_SP23 were, on average, 37% greater than reference since treatment began.
					Pooled Ref	13	0.0037		
	WL_DCP_SP24 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (WL_DCP_SP24 - Ref)	0.038	WL_DCP_SP24	13	0.0047	27% (Treatment Period)	Concentrations at WL_DCP_SP24 were, on average, 27% greater than reference since treatment began.
					Pooled Ref	13	0.0037		
	LC_LCDSSLCC vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (LC_LCDSSLCC - Ref)	0.225	LC_LCDSSLCC	13	0.0042	14% (Treatment Period)	Concentrations at LC_LCDSSLCC were not significantly different from reference areas since treatment began (14% greater, on average).
					Pooled Ref	13	0.0037		
	LC_LC3 vs Pooled Ref	No Treatment (Jan 2013 - June 2014 and Nov 2014 - Oct 2015) Treatment (Nov 2015 - Nov 2016)	Two-sample t-test on (LC_LC3 - Ref) for Treatment vs. No Treatment	0.026	-	-	-	25% (No Treatment Period) 84% (Treatment Period)	Concentrations at LC_LC3 were, on average, 25% and 84% greater than reference prior to AWTF treatment and during AWTF treatment, respectively.
Ortho-phosphate	LC_LC1 vs LC_SLC	Oct 2010 - Nov 2016	One-sample t-test on (LC_LC1 - LC_SLC)	0.541	LC_LC1	38	0.0017	4.8%	Concentrations were similar between reference areas (relative percent difference = 4.8%).
					LC_SLC	38	0.0016		
	LC_LC3 vs Pooled Ref	No Treatment (May 2009 - June 2014 and Nov 2014 - Oct 2015)	One-sample t-test on (LC_LC3 - Ref)	0.180	LC_LC3	61	0.0021	14% (No Treatment Period)	Concentrations at LC_LC3 were not significantly different from reference areas prior to AWTF treatment (14% greater, on average).
					Pooled Ref	61	0.0018		
	LC_LC3 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (LC_LC3 - Ref)	0.003	LC_LC3	13	0.0027	58% (Treatment Period)	Concentrations at LC_LC3 were, on average, 58% greater than reference since treatment began.
					Pooled Ref	13	0.0017		
	WL_LCUCP_SP23 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (WL_LCUCP_SP23 - Ref)	0.264	WL_LCUCP_SP23	13	0.0019	11% (Treatment Period)	Concentrations at WL_LCUCP_SP23 were not significantly different from reference areas since treatment began (11% greater, on average) .
					Pooled Ref	13	0.0017		
	WL_DCP_SP24 vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (WL_DCP_SP24 - Ref)	0.605	WL_DCP_SP24	13	0.0018	4.1% (Treatment Period)	Concentrations at WL_DCP_SP24 were not significantly different from reference areas since treatment began (4.1% greater, on average).
					Pooled Ref	13	0.0017		
	LC_LCDSSLCC vs Pooled Ref	Treatment (Nov 2015 - Nov 2016)	One-sample t-test on (LC_LCDSSLCC - Ref)	0.146	LC_LCDSSLCC	13	0.0015	-13% (Treatment Period)	Concentrations at LC_LCDSSLCC were not significantly different from reference areas since treatment began (13% lower, on average).
					Pooled Ref	13	0.0017		
	LC_LC3 vs Pooled Ref	No Treatment (May 2009 - June 2014 and Nov 2014 - Oct 2015) Treatment (Nov 2015 - Nov 2016)	Two-sample t-test on (LC_LC3 - Ref) for Treatment vs. No Treatment	0.019	-	-	-	14% (No Treatment Period) 58% (Treatment Period)	Concentrations at LC_LC3 were, on average, 14% and 58% greater than reference prior to AWTF treatment and during AWTF treatment, respectively.

P-value < 0.1

[a] Based on monthly mean concentrations (log_{10}-transformed) observed at stations downstream from the AWTF (LC_LC3, WL_LCUCP_SP23, WL_DCP_SP24, and LC_LCDSSLCCa) and reference stations (LC_LC1 and LC-SLC). Distances downstream from AWTF are: LC_LC3 ~60 m; WL_LCUCP_SP23 ~650 m; WL_LCDCP_SP24 ~950 m; LC_LCDSSLCC ~1.8 km.

[b] Geometric mean (to support statistical analyses conducted on log_{10}-transformed data)

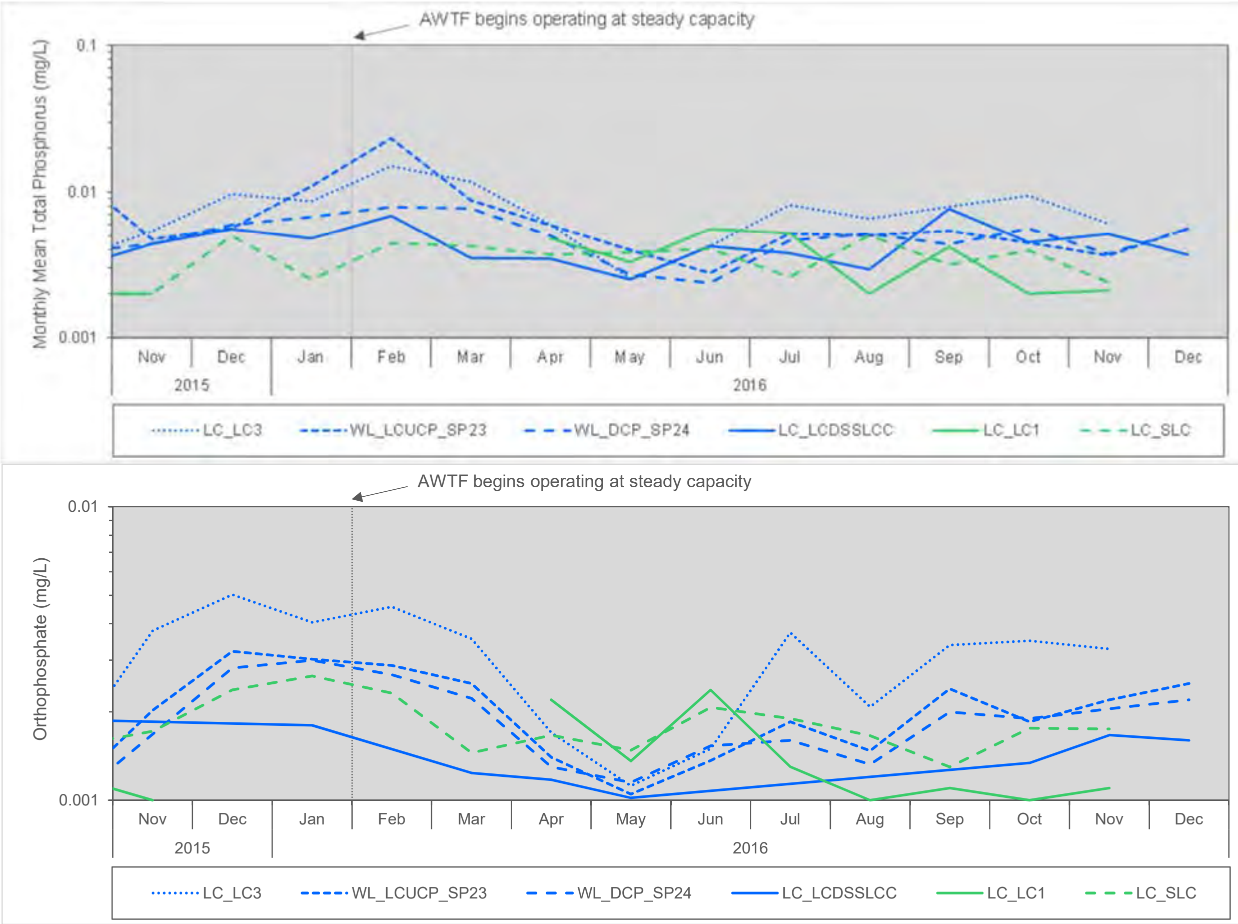


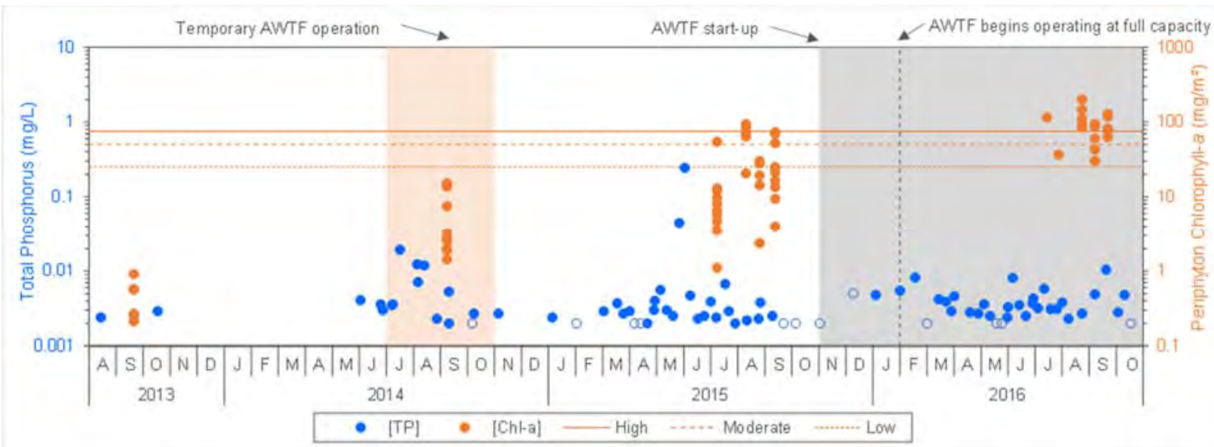
Figure 2.3: Observed Monthly Mean Concentrations of Total Phosphorus and Orthophosphate in Line Creek

Note: Reference areas (LC_LC1 and LC_SLC) in green. Mine-exposed areas in blue. Distances downstream from AWTF: LC_LC3 ~60 m; WL_LCUCP_SP23 ~650 m; WL_LCDCP_SP24 ~950 m; LC_LCDSSLCC ~1.5 km. Data are presented as lines instead of dots to better illustrate relative concentrations among areas over time. Grey shade indicates current AWTF operating period.

AWTF operation has not caused total phosphorus or orthophosphate concentrations at the Compliance Point (LC_LCDSSLCC) to be elevated above background concentrations. However, mass-balance analysis suggested that some of the phosphorus load is unaccounted for at LC_LCDSSLCC (Appendix E). Nevertheless, the average total phosphorus concentration at LC_LCDSSLCC during the 2016 growing season (calculated from samples collected at least every two weeks between June 15 and September 30) was 0.0042 mg/L, which was much less than the 0.02 mg/L "concern" level identified by the MOE prior to AWTF commissioning. The 2016 average (0.0042 mg/L), which reflected steady state-capacity AWTF operation was also comparable to the average of pooled reference area samples (0.0037 mg/L) for the same time period (Table 2.1).

3 PERIPHYTON PRODUCTIVITY COMPARED TO NUTRIENT CONCENTRATIONS

Periphyton chlorophyll-a concentrations measured in 2014 to 2015 sometimes exceeded initial management triggers and the SPO (Table 2.1, Figure 3.1) even though the AWTF was not operating for most of that period[4] and aqueous phosphorus concentrations were in the range of those observed in the upstream reference areas (Figures 2.2 and 2.3; Table 2.1).



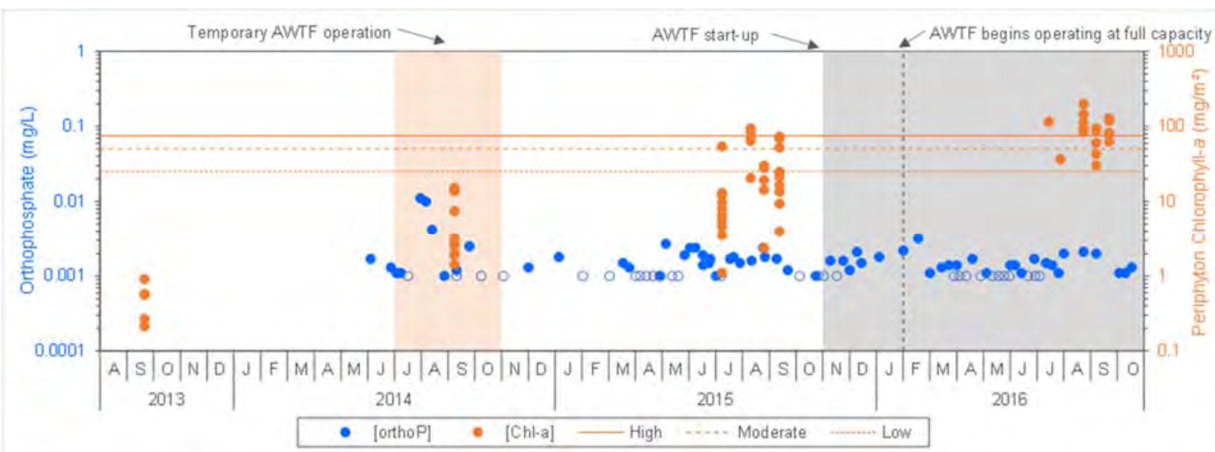


Figure 3.1: Observed Concentrations of Total Phosphorus or Orthophosphate versus Periphyton Chlorophyll-a at LC_LCDSSLCC

Note: LC_LCDSSLCC is Compliance Point in Line Creek downstream from the AWTF and South Line Creek. Previously proposed management triggers (high, which is the current SPO for chlorophyll-a in Section 3.4.1, moderate, and low) for periphyton chlorophyll-a are also presented (orange horizontal lines). Concentrations below the detection limit (DL) are plotted as open symbols at the DL. Pink shade indicates initial operation of the AWTF in 2014. Grey shade indicates current operating period.

[4] In 2014, commissioning-phase discharge from the AWTF began August 27, 2014, and the facility was shut down on October 17, 2014. Biological sampling in 2014 was conducted between September 2nd and 8th. Due to the brief period of exposure to less-than-capacity AWTF effluent, biological data from 2014 are not considered representative of steady-state AWTF operation. Recommissioning of the AWTF occurred in October 2015, after the periphyton growing season; therefore, biological data from 2013 and 2015 are considered baseline.

Despite a lack of AWTF-related change in phosphorus concentrations, periphyton chlorophyll-a concentrations at LC_LCDSSLCC appear to have increased over time (Figures 3.1 and 3.2). The periphyton chlorophyll-a concentrations were compared statistically among LC_LCDSSLCC and the two upstream reference areas (LC_LC1, LC_SLC) for the time periods where data were available for all three areas (Figure 3.3). A two-way analysis of variance was conducted with factors *Area* and *Time period*, excluding data for September 2016 when only a single sample was collected at each of the reference areas. There was a significant ($p < 0.001$) interaction between *Area* and *Time* indicating that there were significant differences among areas but they depended on the time period compared. Tukey pairwise comparisons ($\alpha = 0.05$) conducted for the 12 groups (area and time period combinations) indicated no significant differences in periphyton chlorophyll-a concentrations among areas in the July and September 2015 time periods. Periphyton chlorophyll-a concentrations at LC_LCDSSLCC were significantly greater than at the reference areas in September 2014 (see footnote #5), and concentrations at LC_LCDSSLCC were significantly less than one reference area in September 2013 (Figure 3.3). The results indicate that the temporal increase in periphyton chlorophyll-a concentrations at LC_LCDSSLCC is not mine-related because the same pattern was observed at the upstream reference areas.

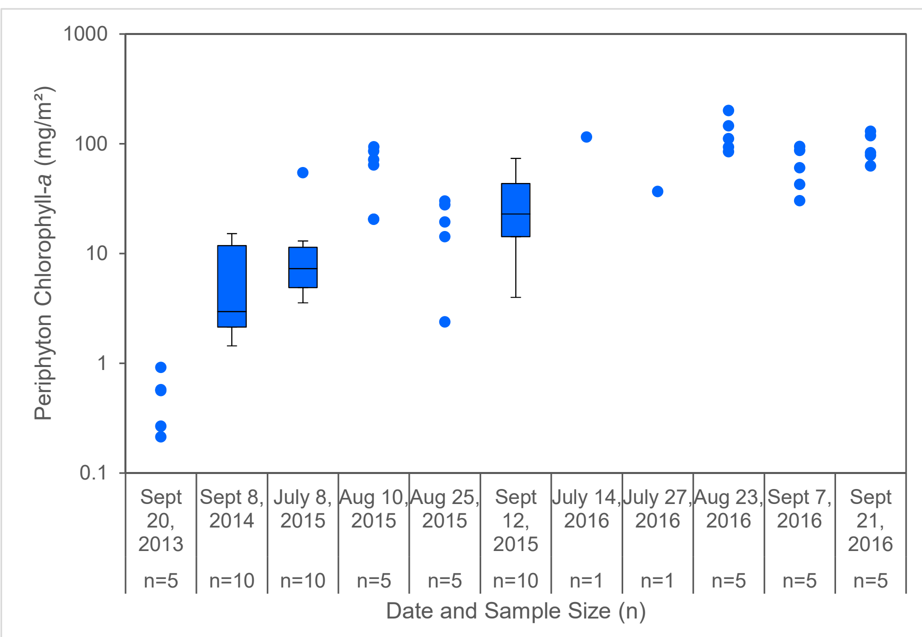


Figure 3.2: Observed Concentrations of Periphyton Chlorophyll-a at LC_LCDSSLCC (LIDSL).

Note: Boxplots for n>5 and individual values are plotted if n ≤ 5 for a given sampling event and location. The box represents the 25th percentile, median, and 75th percentile and the whiskers represent the minimum and maximum values; however, values 1.5 times the height of the box beyond the 25th and 75th percentiles are plotted as individual values in which case the whisker is truncated to the next value in the data set.

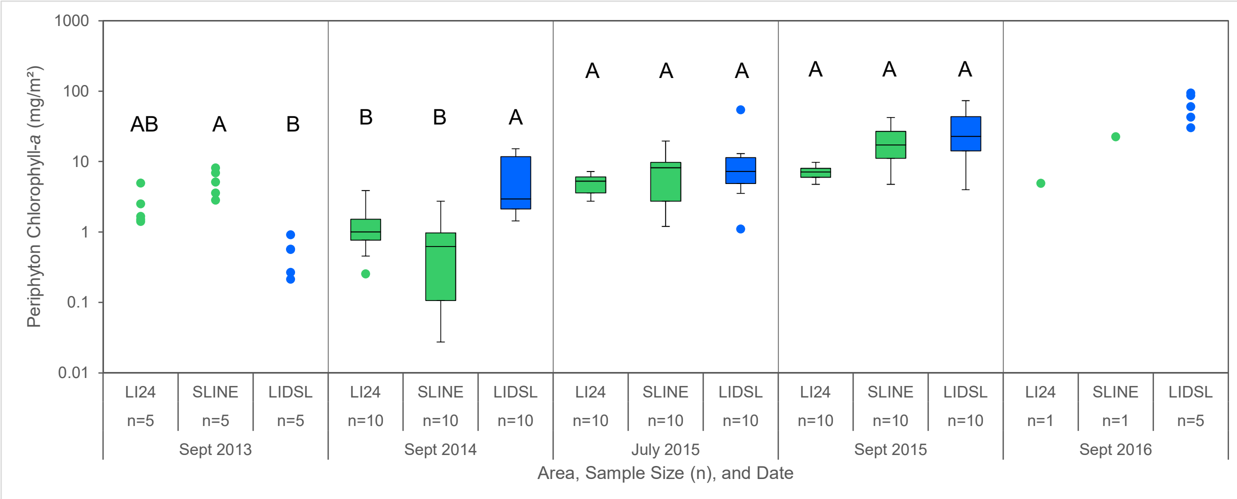


Figure 3.3: Observed Concentrations of Periphyton Chlorophyll-a at LC_LCDSSLCC (LIDSL) and Reference Areas

Note: Green- reference areas (LC_LC1/LI24 and LC_SLC/SLINE) over five sample periods. Blue- LC_LCDSSLC (LIDSL). Boxplots for n>5 and individual values are plotted if n ≤ 5 for a given sampling event and location. The box represents the 25th percentile, median, and 75th percentile and the whiskers represent the minimum and maximum values; however, values 1.5 times the height of the box beyond the 25th and 75th percentiles are plotted as individual values in which case the whisker is truncated to the next value in the data set. Stations within a sampling period that do not share a letter are significantly different. No statistical comparisons conducted for September 2016, due to insufficient sample size.

There were no temporal trends in concentration of nitrate, total phosphorus, and orthophosphate, or for water temperature[5], at LC_LCDSSLCC from 2013 to 2016 (Appendix Table C.1; Figures C.1-C.3, C.6). There was also no evidence of a temporal increase in periphyton ash-free dry mass (AFDM) or total benthic invertebrate abundance at the Line Creek sampling areas from 2012 to 2016 (Appendix Figures C.4 and C.5).

No obvious relationship was found between phosphorus concentrations in water and chlorophyll-a concentrations in periphyton measured over time at LC_LCDSSLCC[6] (Figure 3.1). To explore this further, correlations were conducted (Table 3.1) between periphyton productivity endpoints and nutrient concentrations in water samples collected at the same time, as well as average nutrient concentrations in water samples collected over the 60-day period preceding each periphyton sampling event for all of the Line Creek LAEMP sampling areas. Both periphyton chlorophyll-a and AFDM were significantly correlated ($p<0.05$) with nitrate concentrations in water at the time of periphyton sampling and, in the case of AFDM, also with the preceding 60-day

[5] Water temperature is measured monthly or weekly (March 15-July 30) in accordance with collection of samples for laboratory chemistry. Trends were evaluated for annual water temperature, as well as water temperature measured over the periphyton growing season (June 15-September 30, as defined in Permit 2017517), and in the month prior to periphyton sampling (August and first week of September). No significant trends were detected.

[6] The biological monitoring area corresponding to LC_LCDSSLCC is identified as LIDSL in some documents.

Table 3.1: **Spearman Correlations between Periphyton Productivity Indicators and Aqueous Nutrient Concentrations**

Variable	Statistic	Periphyton Chlorophyll-*a*	AFDM	Nitrate	Total Phosphorus	Ortho-phosphate	60-d Nitrate	60-d Total Phosphorus	60-d Ortho-phosphate
Periphyton Chlorophyll-*a* (n=29)	r	-	0.559	0.407	-0.201	0.085	0.317	-0.312	0.022
	P-value	-	0.004	0.028	0.337	0.667	0.094	0.130	0.910
AFDM (n=25)	r	0.559	-	0.492	-0.007	-0.016	0.540	-0.106	0.352
	P-value	0.004	-	0.012	0.975	0.940	0.005	0.646	0.091

indicates r < -0.6 or r > 0.6
indicates p-value < 0.05

Note: Data are from samples collected at two reference (LC-LC_LC1/LI24 and LC_SLC/SLINE) and three mine-influenced areas (LC_LC3/LILC3, LC_LCDSSLCC/LIDSL, and LC_LC4/LI8) in Line Creek from 2013 to 2016. Correlation.s included nutrient concentrations at the time of periphyton sampling or the average nutrient concentration over the 60-day period prior to the periphyton sampling. Plots for significant correlations are presented in Appendix Figure B.1.

average nitrate concentration (Table 3.1). However, the scatterplots showing the data for these Spearman rank correlations do not indicate that there is a relationship between the periphyton endpoints and nitrate concentrations (Appendix Figure B.1). The significance of the rank correlation appears to have been driven by the occurrence of two separate clusters of points along the x-axis (i.e., low nitrate concentrations at reference areas versus elevated concentrations at mine-exposed areas) rather than a continuous distribution of nitrate concentrations along the x-axis. A relationship would not be expected between periphyton productivity indicators (chlorophyll-a and AFDM) and nitrate concentrations because phosphorus is the limiting nutrient (see regional data in Figures 5.3 and 5.4, below). The periphyton productivity endpoints were not significantly correlated with orthophosphate or total phosphorus concentrations in water (Table 3.1).

4 REGIONAL CONTEXT

Further analyses were completed that incorporated data collected in the 2015 RAEMP to determine if conclusions based on Line Creek data are supported by other regional data. Also, future decisions about the need and approach for evaluation of potential mine-related effects on biological productivity will influence the scope of other LAEMPs and the RAEMP. Lastly, the inclusion of regional data in this evaluation contributes to addressing the condition for "additional studies to assess nutrient loading in the Fording and Elk Rivers from mine-related sources", which was specified in MOE's approval of the RAEMP design.

The 2015 RAEMP data showed that even reference area periphyton chlorophyll-a concentrations can exceed the SPO defined in Section 3.4.1 of Permit 107517, and there was no direct relationship between periphyton chlorophyll-a concentrations and aqueous total phosphorus or orthophosphate concentrations (Figure 4.1). Sample concentrations of total phosphorus were also above the 0.02 mg/L maximum SPO specified by Permit 107517 at several reference areas sampled in September 2015 (Figure 4.1), and at both Line Creek reference areas during a sampling event in the spring of 2015 (Figure 2.2).

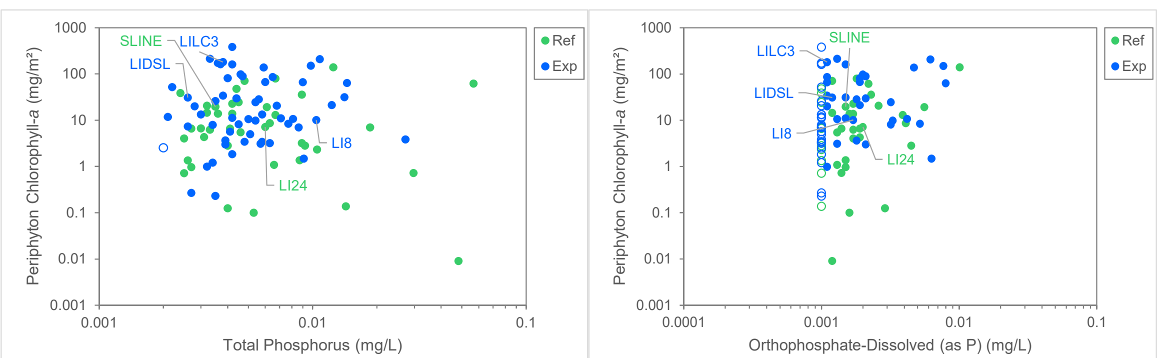


Figure 4.1: Periphyton Chlorophyll-*a* Concentrations versus Aqueous Total Phosphorus and Orthophosphate Concentrations

Note: Water samples were collected at the same time as periphyton among 40 reference and 58 mine-influenced areas sampled in the RAEMP, September 2015. Line Creek sampling areas are specifically identified (LIDSL is the Compliance Point LC_LCDSSLCC, see Figure 1.2). Phosphorus concentrations below the detection limit (DL) are plotted as open symbols at the DL.

High within-area variability for periphyton chlorophyll-a at LC_LCDSSLCC (Figure 3.1) as well as the other sampling areas included in the Line Creek LAEMP (Figure 4.2 – note y-axis $\log_{10}$ scale) also means that only large spatial or temporal differences in periphyton chlorophyll-a concentrations would be detected with reasonable statistical power (Appendix B in Minnow 2016b). A separate study showed that periphyton community endpoints correlated with productivity endpoints, but large variation in community composition among reference areas provided further evidence that periphyton is strongly influenced by natural habitat factors unrelated to mining that cannot be effectively measured or controlled during sampling (Minnow and Larratt 2016; also see further discussion in Section 6.1). These results suggest that alternative biological monitoring endpoints should be considered for monitoring productivity areas where phosphorus concentrations exceed or are projected to exceed background concentrations.

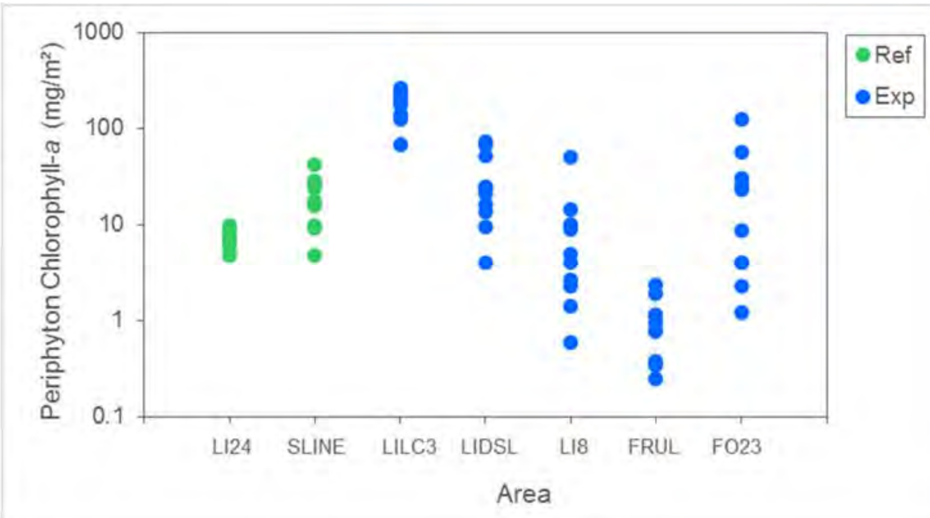


Figure 4.2: Periphyton Chlorophyll-a Concentrations in Line Creek, September 2015

Note: N=10 samples per area. Data for 2016 are not presented because sample sizes were reduced, except at the Compliance Point, based on recommendations in the 2016 study design.

5 ALTERNATIVE INDICATORS OF PRODUCTIVITY

Strong correlations were observed among biological endpoints measured in the LAEMP (as indicated by statistically significant p-values and high correlation coefficient [r] values), indicating there is redundancy for assessing aquatic productivity (Table 5.1). Bryophyte growth was patchy, being most evident in Line Creek upstream from the Compliance Point (at LILC3), and absent in lower Line Creek (LI8) and at the two reference areas (Minnow 2016b). Neither bryophyte endpoints showed a strong linear relationship with benthic invertebrate biomass (Appendix Figure B.2). Therefore, bryophyte growth is considered less useful for monitoring biological productivity and was not evaluated further.

Of the periphyton and benthic invertebrate endpoints, benthic invertebrate density had the lowest within-area variability (Table 5.2), suggesting that smaller spatial and temporal differences would be detected in statistical comparisons in relation to the other endpoints using the same sample size, α, and β. Benthic invertebrate biomass correlated more strongly with periphyton chlorophyll-a than benthic invertebrate density (i.e., lower p-value, higher r), but benthic invertebrate density correlated more strongly with periphyton AFDM than chlorophyll-a (Table 5.1).

Table 5.1: Spearman correlations Based on Mean Productivity Endpoints for Line Creek LAEMP Areas

Variable (and N for means)	Statistic	Chlorophyll-a	AFDM	Bryophyte Area	Bryophyte Shoot Length	Benthic Invertebrate Density	Benthic Invertebrate Biomass
Chlorophyll-*a* N = 14	r	-	**0.723**	0.446	0.304	**0.552**	**0.782**
	P-value	-	0.003	0.196	0.393	0.098	0.008
AFDM N = 14	r	**0.723**	-	0.873	0.886	**0.915**	**0.806**
	P-value	0.003	-	0.001	0.001	<0.001	0.005
Bryophyte Area N = 10	r	0.446	0.873	-	0.959	0.925	0.847
	P-value	0.196	0.001	-	<0.001	<0.001	0.002
Bryophyte Shoot Length N = 10	r	0.304	0.886	0.959	-	0.925	0.782
	P-value	0.393	0.001	<0.001	-	<0.001	0.007
Benthic Invertebrate Density N = 10	r	**0.552**	**0.915**	0.925	0.925	-	**0.891**
	P-value	0.098	<0.001	<0.001	<0.001	-	0.001
Benthic Invertebrate Biomass N = 10	r	**0.782**	**0.806**	0.847	0.782	**0.891**	-
	P-value	0.008	0.005	0.002	0.007	0.001	-

Notes: Samples were collected at two reference (LI24 and SLINE) and five mine-exposed areas (LILC3, LIDSL, LI8, FRUL, and FO23) in Line Creek and the Fording River in 2014, 2015, and 2016. The number of samples (n) included in the mean for productivity endpoints is n = 10 per area per year, except for bryophytes with n = 3 per area per year). Plots for significant correlations are presented in Appendix Figure B.2. **Bold text** indicates Pearson correlation coefficient, regular text indicates Spearman rank correlation coefficient

indicates r < -0.6 or r > 0.6

indicates p-value < 0.05

Table 5.2: Within-Area Variability (expressed as the Coefficient of Variation) of Periphyton and Benthic Invertebrate Endpoints, September, 2015

Area	Coefficient of Variation (%)			
	Chlorophyll-a (mg/m²)	AFDM (g/m²)	Benthic Invertebrate Density (#/m²)	Benthic Invertebrate Biomass (g wet weight/m²)
LI24	24	246	30	31
SLINE	57	64	32	41
LILC3	32	27	25	21
LIDSL	81	90	30	68
LI8	150	102	33	37
FRUL	67	57	-	-
FO23	135	190	-	-

Note: "-" = no data.

The regional monitoring data set also showed strong redundancy of information among endpoints indicative of biological productivity, but the biological endpoints showed only weak or no relationship with concentrations of major nutrients in water (i.e., numerous non-significant p-values and low r values; Table 5.3).

Although the sampling method for benthic invertebrates in the RAEMP was a timed- rather than area-based technique (i.e., 3-minute travelling kick method of Environment Canada 2012), there was a strong relationship between timed- and area-based kick samples collected at a subset of areas (Minnow 2016a) (Figure 5.1), suggesting that even sample abundance from timed kick samples (i.e., abundance data reflected in Table 5.3) provides a reasonable estimate of biological productivity. Simple visual scores of periphyton coverage associated with the Environment Canada (2012) invertebrate sampling method were correlated with periphyton chlorophyll-a and AFDM results, as well as invertebrate abundance (Table 5.3; Appendix Figure B.3).

As observed in the scatterplot of periphyton chlorophyll-a versus total phosphorus in water (Figure 4.1), there was no direct relationship between benthic invertebrate abundance and total phosphorus concentrations in water, or between benthic invertebrate abundance and aqueous nitrate concentrations among reference and mine-exposed areas sampled in the RAEMP (Figure 5.2). Also evident from Figure 5.2 is that nitrate concentrations, but not total phosphorus concentrations, tend to be elevated among mine-exposed areas compared to reference areas.

Table 5.3: Pearson Correlations of Productivity-Related Endpoints

Variable	Statistic	log_{10}(Chlorophyll-*a*)	log_{10}(AFDM)	Periphyton Coverage Score	log_{10}(Total BI Abundance)	log_{10}(Nitrate)	log_{10}(Total Nitrogen)	log_{10}(Orthophosphate)	log_{10}(Phosphorus)
log_{10}(Chlorophyll-*a*)	r	-	0.830	0.430	0.472	0.293	0.329	0.203	-0.097
	P-value	-	<0.001	<0.001	<0.001	0.003	0.001	0.044	0.342
log_{10}(AFDM)	r	0.830	-	0.452	0.377	0.206	0.239	0.101	-0.077
	P-value	<0.001	-	<0.001	<0.001	0.042	0.018	0.323	0.449
Periphyton Coverage Score	r	0.430	0.452	-	0.618	0.114	0.159	0.015	-0.172
	P-value	<0.001	<0.001	-	<0.001	0.268	0.122	0.886	0.095
log_{10}(Total BI Abundance)	r	0.472	0.377	0.618	-	0.115	0.156	0.149	-0.164
	P-value	<0.001	<0.001	<0.001	-	0.256	0.124	0.142	0.106
log_{10}(Nitrate)	r	0.293	0.206	0.114	0.115	-	0.958	-0.210	-0.157
	P-value	0.003	0.042	0.268	0.256	-	<0.001	0.037	0.120
log_{10}(Total Nitrogen)	r	0.329	0.239	0.159	0.156	0.958	-	-0.212	-0.171
	P-value	0.001	0.018	0.122	0.124	<0.001	-	0.035	0.090
log_{10}(Orthophosphate)	r	0.203	0.101	0.015	0.149	-0.210	-0.212	-	0.292
	P-value	0.044	0.323	0.886	0.142	0.037	0.035	-	0.003
log_{10}(Phosphorus)	r	-0.097	-0.077	-0.172	-0.164	-0.157	-0.171	0.292	-
	P-value	0.342	0.449	0.095	0.106	0.120	0.090	0.003	-

Notes: Data were from 40 reference and 59 mine-exposed areas sampled for the RAEMP September, 2015. Plots for significant correlations are presented in Appendix Figure B.3.

indicates $r < -0.6$ or $r > 0.6$ (pink shading)

indicates p-value < 0.05 (grey shading)

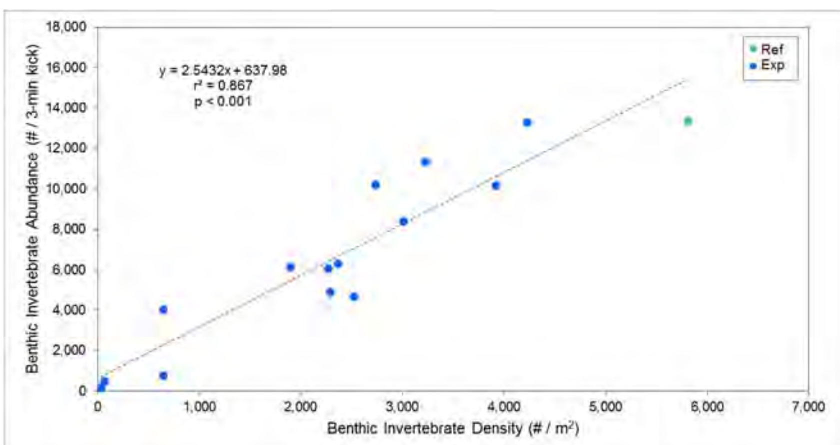


Figure 5.1: Scatterplot and Linear Regression of Benthic Invertebrate Abundance Based On Density versus Timed Samples

Note: Data based on 3-minute travelling kick samples versus benthic invertebrate density (#/m^2) from kick sampling over three 1-m^2 areas

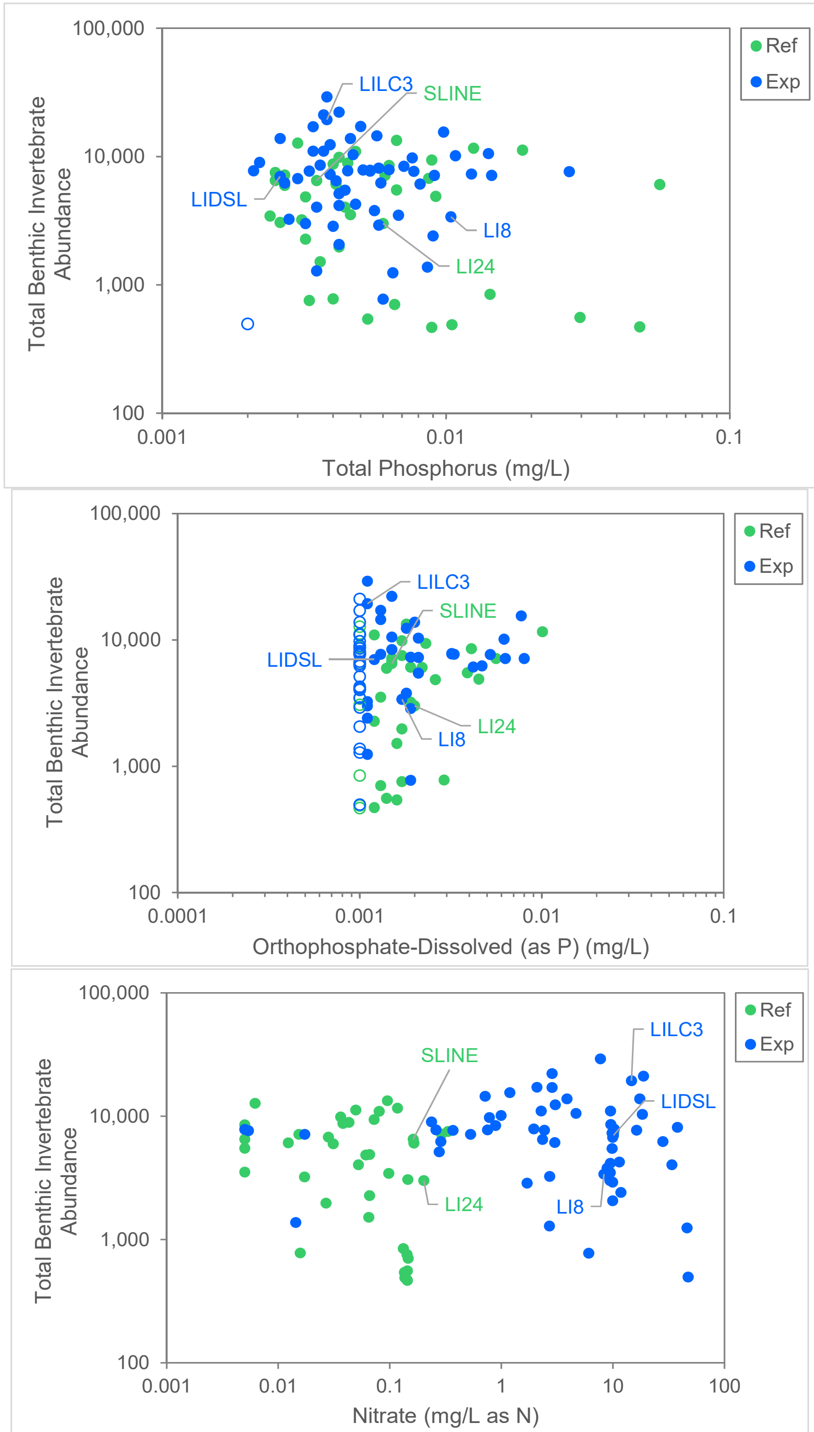


Figure 5.2: Scatterplots of Benthic Invertebrate Abundance versus Total Phosphorus, Orthophosphate and Nitrate Concentrations, September 2015

Note: Data are from 40 reference and 59 mine-exposed areas sampled for the RAEMP September, 2015. Line Creek sampling areas are specifically identified. Concentrations below the detection limit (DL) are plotted as open symbols at the DL

This suggests that phosphorus is likely the limiting nutrient in mine-exposed areas of the Elk River watershed. Indeed, most reference and mine-exposed areas sampled in September 2015 had ratios of total nitrogen to total phosphorus concentrations (N:P) greater than 15 (Figure 5.3), indicating that phosphorus is the limiting nutrient based on categories defined by McDowell et al. (2009) for mass concentrations:

- N:P < 7 Nitrogen-limited
- 7 < N:P < 15 Co-limited (nitrogen and phosphorus)
- N:P > 15 Phosphorus-limited.

Of the 59 mine-exposed areas sampled in 2015, 56 would be considered phosphorus-limited, while three would be considered co-limited (Figure 5.4).

The results confirm that phosphorus inputs from mining have the potential to increase productivity in the Elk River watershed but, as indicated by Figures 2.2, 4.1 and 5.2, phosphorus concentrations and biological productivity in Line Creek and within the broader Elk River watershed are currently within the ranges observed among regional reference areas. Increases in nitrate downstream from mining is not expected to result in increased productivity due to the phosphorus-limited nature of the system in mine-exposed areas.

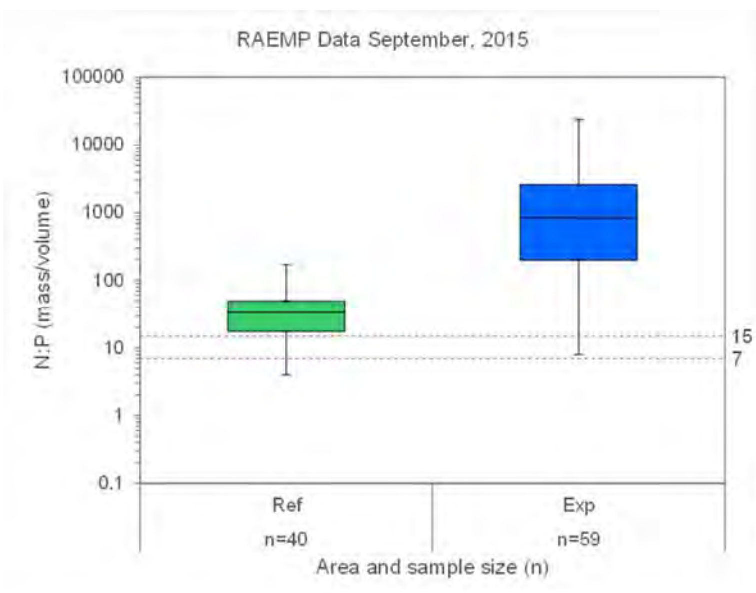


Figure 5.3: Boxplot of ratios of total nitrogen to total phosphorus (N:P) mass concentrations

Note: Data are from 40 reference and 59 mine-exposed areas sampled in the RAEMP, September 2015. The box represents the 25th percentile, median, and 75th percentile and the whiskers represent the minimum and maximum values.

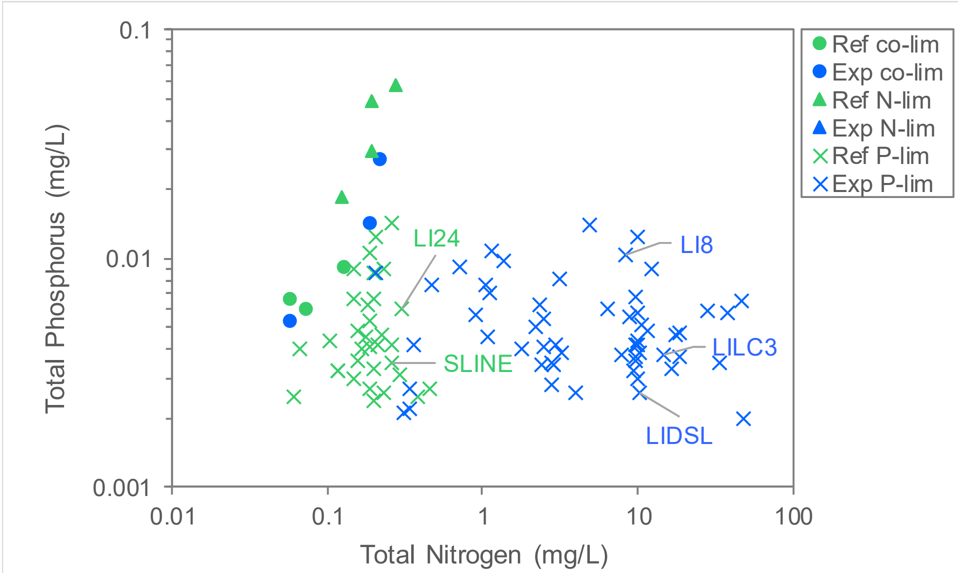


Figure 5.4: Scatterplot of total phosphorus versus total nitrogen concentrations

Note: Data are from 40 reference and 59 mine-exposed areas sampled for the RAEMP, September 2015. Areas are categorized as nitrogen-, phosphorus-, or co-limited based on categories defined by McDowell et al. (2009). Line Creek sampling areas are specifically identified.

6 SUMMARY AND INTERPRETATION

6.1 Nutrients versus Primary Productivity

Phosphorus use at the Line Creek AWTF has been much less than was predicted and, as a result, concentrations of phosphorus in effluent and receiving water have also been well below projections. Although total phosphorus and orthophosphate concentrations have been elevated in Line Creek immediately downstream from the AWTF outfall since treatment began, concentrations are still low (e.g., 0.007 mg/L on average at LC_LC3 in 2016), and diminish with distance downstream such that they are indistinguishable from reference area concentrations at the Compliance Point (LC_LCDSSLCC, ~1.5 km downstream from the AWTF outfall). Average total phosphorus concentrations at LC_LCDSSLCC during the growing season (June 15 - September 30) were 0.003 and 0.004 mg/L in 2015 (pre-operation) and 2016 (steady state-capacity operation), respectively. These concentrations are well below the 0.02 mg/L level of "concern" identified by MOE prior to AWTF commissioning.

Although periphyton chlorophyll-a concentrations increased at the Compliance Point from 2013 to 2016, the same pattern was observed at the upstream reference areas. There were no temporal trends for aqueous nitrate, total phosphorus, or orthophosphate concentrations, nor for water temperature. Periphyton AFDM or benthic invertebrate abundance also have not increased over time. Spatial and temporal variabilities of periphyton chlorophyll-a and AFDM are not explained by variations in nitrate, total phosphorus, or orthophosphate concentrations in water. Total phosphorus and orthophosphate concentrations at the Compliance Point (LC_LCDSSLCC) have remained within the range of concentrations measured at upstream reference areas. Therefore, the temporal change in periphyton chlorophyll-a concentrations at this location is not related to mining or nutrient concentrations in water, and was not corroborated by other biological indicators of productivity (periphyton AFDM or invertebrate abundance).

Data collected in the RAEMP also showed no relationship between periphyton productivity endpoints and total phosphorus or orthophosphate concentrations in water among reference and mine-exposed areas, even though phosphorus is the growth-limiting nutrient. Dodds et al. (2002) concluded that, although nutrient availability can explain as much as 40% of the variability in periphyton biomass among areas, multiple factors affect primary productivity. Much of the scientific literature shows inconsistent to no statistical linkages between nutrient and chlorophyll- a concentrations, especially in aquatic habitats with low nutrient concentrations (see meta-analysis: Francoeur 2001). There appears to be a threshold (P > 0.030 mg/L, N > 0.040 mg/L) above which periphyton growth is more closely associated with nutrient concentrations, and below which primary productivity is related primarily to abiotic factors (Lewis and McCutchan 2010). Of the two, the phosphorus threshold of 0.03 mg/L is more relevant to conditions in the Elk River watershed, because it is the limiting nutrient.

Of abiotic factors, Lewis and McCutchan (2010) identified water temperature and the length of growing season as primary factors contributing to periphyton biomass. The streams in that study were located in the Colorado mountains and foothills, and had total phosphorus concentrations ranging from 0.003 to 0.413 mg/L, with a median of 0.011 mg/L and mean of 0.027 mg/L (Lewis and McCutchan 2010). Periphyton chlorophyll-a concentrations may also be influenced by stream gradient (Dodds et al. 2002). Shade, or more specifically streambed irradiance (Lewis and McCutchan 2010), is also a contributing factor controlling primary productivity (Death and Zimmerman 2005; Dudgeon and Chan 1992). In the Elk Valley, calcite deposition is another factor that may be associated with periphyton growth, with periphyton potentially providing nucleation sites for calcite formation and/or with calcite serving as a suitable substrate for growth of some periphyton species. In addition, substrate disturbance related to highly variable discharge regimes appears to positively correlate with producer richness and net production of biomass (Cardinale et al. 2005). The abundance of grazing benthic macroinvertebrates does not seem to consistently explain low periphyton biomass, as several studies have shown a strong positive correlation between primary productivity and invertebrate abundance and richness (Death and Zimmerman 2005; Dudgeon and Chan 1992; Kiffney and Richardson 2001; Lewis and McCutchan 2010; Quinn et al. 1997). Studies reporting a negative relationship between invertebrate grazers and periphyton biomass were typically laboratory experiments in which grazer abundance was controlled; such relationships were much less evident in short-term experiments conducted in the field (reviewed in Feminella and Hawkins 1995).

6.2 Proposed SPO Update

It is proposed that the SPO for phosphorus management in Permit 107517 be revised to focus on phosphorus concentrations in water. The evaluation presented in Appendix B shows that phosphorus loads from the AWTF represent only 35% of the total load immediately downstream (LC_LC3), on average. As a result, the average annual concentration of total phosphorus at LC_LC3 increased to only 0.007 mg/L in 2016 from 0.004 mg/L prior to AWTF operation. And given the limiting status of this nutrient for primary productivity, some of the additional load may be taken up in the near-field receiving environment where there is abundant periphyton and bryophyte growth, which may account for the “missing” portion of total load calculated farther downstream at the Compliance Point (Appendix B).

Concentrations of total phosphorus at the Line Creek reference areas and Compliance Point (LC_LCDSSLCC) have been less than the current SPO of 0.020 mg/L during all times when the

AWTF was operational (Figure 6.1), which is less than the threshold of 0.030 mg/L reported by Lewis and McCutchan (2010) for effects on periphyton growth.

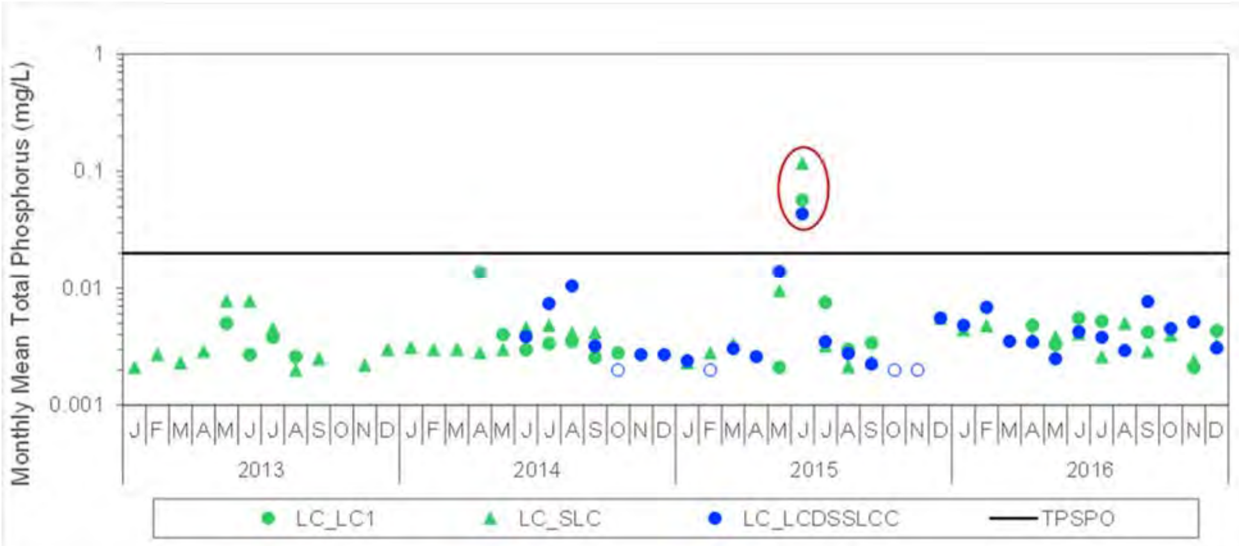


Figure 6.1: Concentrations of total phosphorus compared to the current SPO of 0.020 mg/L.

Note: Data are from the reference areas (LC_LC1 and LC_SLC) and the Compliance Point (LC_LCDSSLCC), 2013 to 2016. Concentrations below the detection limit (DL) are plotted as open symbols at the DL. Red circle highlights a sample date when concentrations were elevated at the Compliance Point and the reference areas when the AWTF was not operating.

Therefore, the available information justifies retaining an SPO of 0.02 mg/L for total phosphorus. However, the SPO based on measurement of chlorophyll-a in periphyton should be removed. The SPO for total phosphorus in water will be supported by other water quality monitoring (Section 6.3) and biological monitoring (Section 6.4).

6.3 Supporting Water Quality Monitoring

Monitoring of total phosphorus and orthophosphate in water will continue at reference areas and in areas downstream from the AWTF. In terms of data evaluation, the SPO for total phosphorus in water will be supported by:

1. Evaluation of data on an on-going basis to detect patterns indicative of an increasing trend.
2. Reporting of annual average concentrations for the reference areas, at LC_LC3 and at the Compliance Point (LC_LCDSSLCC).

The figures presented below illustrate a method that would allow for easy visual detection of changes in phosphorus concentrations downstream from the AWTF compared to reference areas on an on-going (month-to-month) basis. The example approach is based on monitoring data for LC_LC3 because:

- There is a longer historical record of phosphorus concentrations at LC_LC3 than at LC_LCDSSLCC (so historical baseline conditions can be characterized); and
- Increasing trends are more likely to be detected at LC_LC3, closer to the discharge, than at LC_LCDSSLCC.

The example uses data for orthophosphate because there were poor detection limits for total phosphorus during the earliest portion of the time period incorporated in the example.

The method involves two steps. First, the monthly upper limit of phosphorus concentrations (97.5th percentile) is computed for the baseline (pre-AWTF operation) period at LC_LC3 (Figure 6.2).

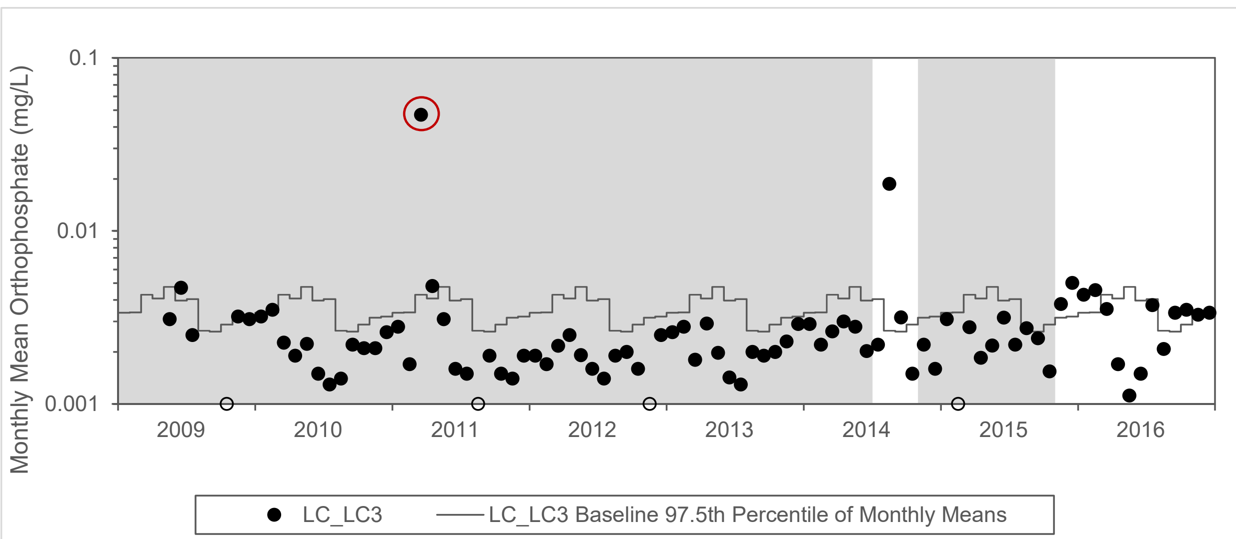


Figure 6.2: Upper Limit of Baseline Orthophosphate Concentrations at LC_LC3

Note: Shading represents the baseline period used to define the upper 97.5th percentile for each month. The data used to define the 97.5th percentiles for each month were concentrations for the specified month, the preceding month, and the following month during the baseline (pre-AWTF operation) period (i.e., years combined). Red circle indicates an outlier value that was excluded from the calculations. Concentrations below the detection limit are plotted as open symbols at the detection limit.

Then the monthly orthophosphate concentrations for LC_LC3 were plotted as a ratio of the monthly 97.5th percentile of orthophosphate concentrations (Figure 6.3). Using this approach, the data can be updated monthly and an increasing trend can be detected by a pattern of data points deviating upwards from the line over a period of several consecutive months. Similar figures could be developed for total phosphorus at LC_LC3 and for both total phosphorus and orthophosphate at LC_LCDSSLCC once sufficient data are available. This approach would provide Teck with early warning of changes in phosphorus concentrations downstream from the AWTF. The results would be presented annually in the LAEMP report, along with a description of any actions taken or planned if trends are observed.

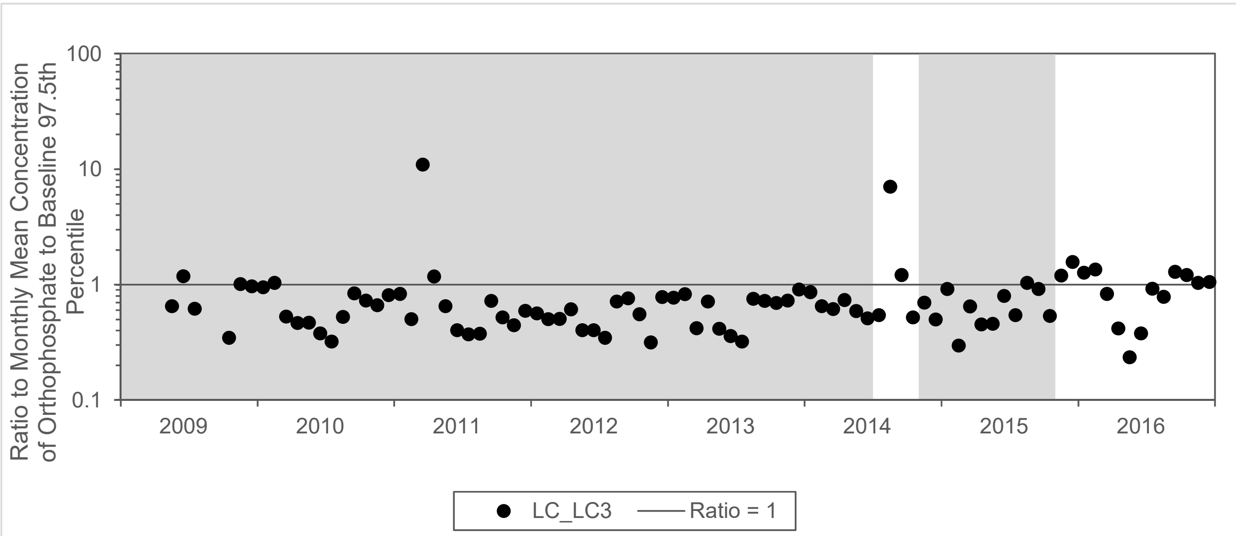


Figure 6.3: Ratio of Monthly Mean Orthophosphate Concentrations to Upper Limit of Baseline Concentrations at LC_LC3

Note: Shading represents the baseline period used to define the upper 97.5th percentile for each month.

In addition, average total phosphorus and orthophosphate concentrations at the Compliance Point should be reported for the year and for the growing season in the LAEMP and discussed relative to the total phosphorus SPO of 0.02 mg/L and the 0.03 mg/L threshold for potential changes in productivity suggested by Lewis and McCutchan (2010) to determine if additional biological monitoring (besides that suggested in Section 6.4) should be triggered. This may include re-introduction of periphyton productivity measurements, if evaluation of the biological endpoints presented in Section 6.4 is ambiguous with respect to potential changes in productivity associated with changes in aqueous phosphorus concentrations.

The method described above will allow for early detection of a potential trend in phosphorus concentrations towards the SPO of 0.02 mg/L, and is proposed as a monitoring tool to support the SPO rather than as part of the SPO itself.

6.4 Monitoring Biological Productivity

Data from the Line Creek LAEMP, supported by data from the RAEMP, showed that benthic invertebrate abundance (kick samples), density, and biomass (Hess samples) correlated with periphyton endpoints indicative of productivity. Positive relationships have also been reported in the literature between measures of stream primary productivity (periphyton biomass, chlorophyll-a, AFDM) and indicators of secondary productivity (benthic invertebrate biomass, density, abundance, community structure) (Death and Zimmerman 2005; Dudgeon and Chan 1992; Lewis and McCutchan 2010). Studies that reported a negative relationship between invertebrate grazers and periphyton biomass did not differentiate between streams with low versus high nutrient concentrations (Feminalla and Hawkins 1995), so such results may not be directly comparable to the Elk Valley where concentrations of the limiting nutrient (phosphorus) are low. In addition, most studies in the literature have been experimental in nature, primarily looking at the effects of nutrient additions to the system, and they do not specifically investigate correlations between ambient nutrient concentrations and primary productivity and how primary relates to secondary productivity (Francoeur 2001; Lewis and McCutchan 2010).

The literature supports the findings of this report that indicators of primary and secondary productivity are correlated at least in nutrient limited systems such as the Elk River watershed. Also, the data presented in Section 5 showed that productivity changes over time are more likely to be statistically detected with invertebrate than periphyton endpoints for a given sample size, α and β. Therefore, it is recommended that Permit 107517 be amended to remove the requirement for monitoring of periphyton chlorophyll-a. Instead, monitoring of potential changes in biological productivity will occur in the LAEMP through measurement of benthic invertebrate biomass based on Hess sampling (and the community endpoints generated from the same samples). The invertebrate endpoints are also proposed for monitoring potential changes over time in other areas of the Elk River watershed where potential changes in productivity are relevant (i.e., other locations where AWTFs are scheduled to be commissioned). It is also recommended that monitoring of benthic invertebrate communities and visual scores of periphyton coverage continue at such locations using the CABIN method of Environment Canada (2012).

The proposed sampling design for monitoring productivity in the Line Creek LAEMP is summarized in Table 6.1. Annual sampling is proposed through 2018 to provide three years of data post-AWTF commissioning, at which time, biological monitoring could move to a cycle of once every three years, provided that:

1. The SPO continues to be met at LC_LCDSSLCC;
2. Total phosphorus and orthophosphorus concentrations in water do not show an increasing trend at LC_LC3; and

3. The relative difference of benthic invertebrate endpoints at LC_LCDSSLCC compared to reference areas does not increase significantly compared to the pre-AWTF period.

Monitoring results will continue to be discussed with the EMC in advance of LAEMP reporting, which will also allow for discussion of potential future changes to the study design if warranted based on evaluation and interpretation of the data.

Table 6.1: Proposed Sampling for the LCO LAEMP Related to Productivity Monitoring

Type	Biological Sampling Area	Water Quality Sampling Station	Periphyton Visual Coverage Score	Benthic Invertebrates		Water Quality
				Kick Sampling	Hess Sampling	
			Annual	Annual	Annual	Weekly/ monthly[a]
Reference	SLINE	LC_SCL	n=5	n=1	n=5	n=1
	LI24	LC_LC1	n=5	n=1	n=5	n=1
Mine-Exposed	LILC3	LC_LC3	n=5	n=1	n=10	n=1
	LIDSL	LC_LCDSSLCC (compliance)	n=5	n=3	n=10	n=1
	LI8	LC_LC4	n=5	n=1	-	n=1

[a] Frequency as specified in Permit 107517.

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APPENDIX A

Original Phosphorus Management Framework for Line Creek

TECHNICAL MEMORANDUM

DATE April 9, 2014 **REFERENCE No.** 1213490016/M06

TO Carla Fraser, Matthew Gay, Sheikh Hossain, Jenny Hutchison, Kevin Podrasky
Teck Coal Limited

CC Megan Hewitt (Golder)

FROM Zsolt Kovats, Ian Halket (Golder), and Patti Orr (Minnow) **EMAIL** zkovats@golder.com; ihalket@golder.com; porr@minnow-environmental.com

PROPOSED RESPONSE FRAMEWORK FOR PHOSPHORUS AND PERIPHYTON DOWNSTREAM OF THE WEST LINE CREEK SELENIUM ACTIVE WATER TREATMENT FACILITY

Teck Coal Limited (Teck), in keeping with its commitments to stabilize and reverse the increasing trend in selenium concentrations in the Elk Valley watershed, is in the process of constructing the West Line Creek Selenium Active Water Treatment Facility (WLC Se AWTF). To support the construction and operation of the WLC Se AWTF, a provincial permitting package was prepared and submitted to the British Columbia (BC) Ministry of Energy and Mines (MEM) and the Ministry of Environment (MOE) in May 2012 to obtain the required permit amendments (i.e., BC *Mines Act* amendment, water licence, and waste discharges). An amended waste (water) discharge permit remains to be secured, due to continuing discussions concerning anticipated changes to phosphorus levels in Line Creek and the potential effect on biota, which are the subject of this technical memorandum.

The Fluidized Bed Reactor technology planned for removing selenium at the WLC Se AWTF requires the addition of phosphorus to the treatment train. Although the treatment train is designed to minimize the amount of residual phosphorus, the amount of total phosphorus introduced to Line Creek will be greater than naturally occurring levels. MOE has expressed concern that this may increase aquatic productivity in the receiving environment and has, therefore, suggested that the following Site Performance Objectives (SPOs) be applied as "triggers for action" in Line Creek downstream of South Line Creek (MOE 2013):

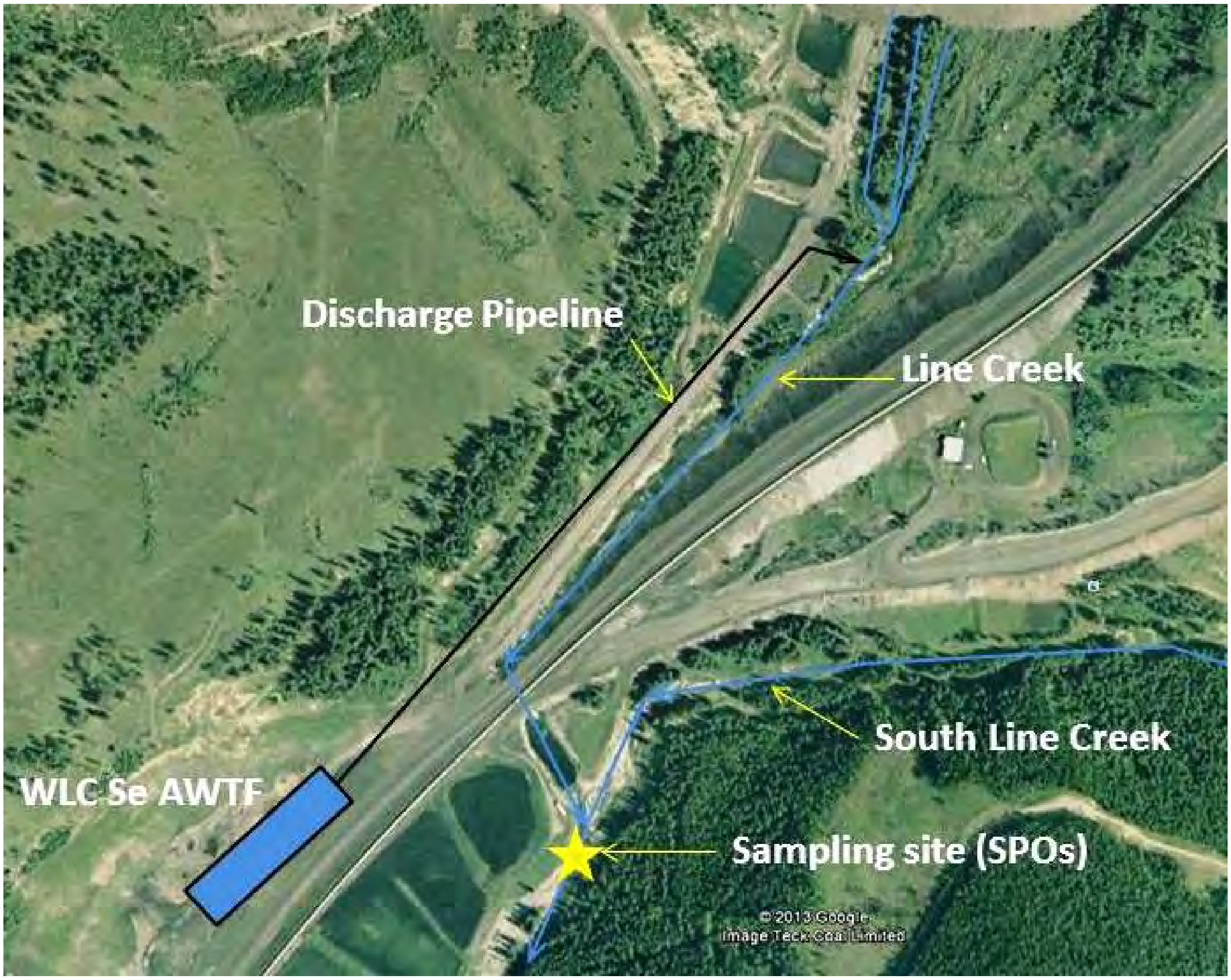
- Periphyton chlorophyll-*a* ≤100 mg/m^2 (the BC water quality guideline [BCWQG] for rivers[1])
- Dissolved oxygen (DO) ≥5.0 mg/L
- Average total phosphorus (TP) concentration of ≤20 µg/L (CCME 2004[2]) during the growing season (i.e., twice monthly measurements from June 15 to September 30)

[1] BCWQG for nutrients and algae recognize fundamental differences between streams and lakes; total phosphorus concentrations in a stream is a relatively poor indicator of algal biomass. As a result, algal biomass itself (measured as chlorophyll-*a*) is the criterion, and is designed to protect fish habitat and changes in communities of organisms such as benthic invertebrates. The criterion applies to naturally growing periphytic algae as opposed to algae growing on artificial substrates. Sub-samples are to be taken randomly from the stream section and the mean biomass of the sample is to be compared to the criterion.

[2] Consistent with the 2004 Canadian Council of Ministers of the Environment (CCME) guidelines, a trigger range is a desired concentration range; exceedance of the upper limit of the range indicates the potential for adverse effects, and therefore, "triggers" further investigations.

Consistent with MOE’s December 2013 suggestion, the above-listed SPOs would apply at a sampling site (“assessment point”) located downstream of the mixing zone South Line Creek and Line Creek (Figure 1). In addition to routine water quality monitoring, biological responses at the location will be assessed through a comprehensive local aquatic effects monitoring program (LAEMP), as described in more detail below and in Attachment A.

Figure 1: Sampling Site to Evaluate Site Performance Objectives (SPOs) Associated with the West Line Creek Selenium Active Water Treatment Facility.



Note: the assessment point in Line Creek is identified as “Sampling site (SPOs)”.

This memorandum identifies how Teck will monitor and assess conditions relative to the SPOs and also proposes a response framework to ensure that appropriate action is taken to minimize nutrient effects in the receiving environment downstream of the AWTF discharge.

Predicted Total Phosphorus Concentrations in Line Creek

To evaluate the potential of exceeding the SPO of 20 µg TP/L at the assessment point in Line Creek, a mass balance equation was used to estimate concentrations in Line Creek downstream of the treatment plant following implementation of the WLC Se AWTF. The equation used to complete the calculation was as follows:

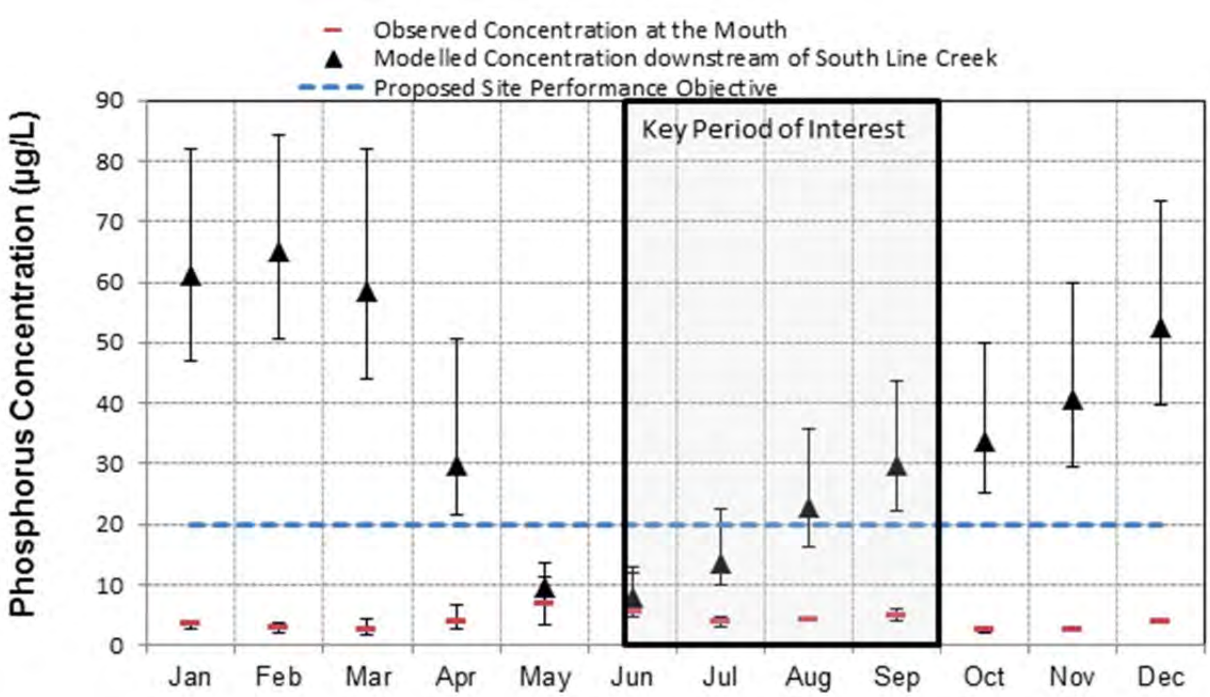
$$C_{DS} = \frac{Q_{Eff} * C_{Eff} + (Q_{DS} - Q_{Eff}) * C_{BG}}{Q_{DS}}$$

Where:

C_{DS}	=	TP concentration in Line Creek downstream of the WLC Se AWTF
C_{Eff}	=	TP concentration in treated water discharge from the WLC Se AWTF
Q_{Eff}	=	flow from the WLC Se AWTF
C_{BG}	=	average background TP concentration in Line Creek
Q_{DS}	=	flow in Line Creek downstream of the WLC Se AWTF

For the purposes of this evaluation, average background TP concentrations (C_{BG}) were calculated using data from 2010 to 2013 as recorded at the mouth of Line Creek (4.0 µg/L). In-stream TP concentrations were modelled using monthly flows as calculated for an average flow year, as well as 1 in 10-year high and low flows. Modelled monthly TP concentrations are shown in Figure 2 under average flows (triangle) with error bars spanning the range under low and high flows. Average monthly TP concentrations previously observed at the mouth of Line Creek are also shown in Figure 2.

Figure 2: Modelled Concentrations Downstream of South Line Creek Compared to Observed Total Phosphorus Data at the Mouth of Line Creek



As illustrated in Figure 2 and detailed in Table 1, it is anticipated that the SPO for TP can be met over the June 15 to September 30 growing season in average and high flow scenarios; however, it is likely that average TP concentrations will exceed the SPO in low-flow scenarios. The environmental consequences of such occurrences, if any, cannot be predicted based on existing information in the literature regarding phosphorus effects on stream biota and productivity. Therefore, Teck's plans for monitoring and for responding to monitoring results are outlined below.

Table 1: Average Modelled Total Phosphorus Concentrations in Line Creek from June 15 to September 30

Flow Scenario	Line Creek Downstream of South Line Creek (Assessment Point) [µg/L]	Line Creek At the Mouth [µg/L]
Low	**31**	**26**
Average	20	17
High	15	13

Note: Concentrations in bold exceed the proposed Site Performance Objective of 20 µg/L TP.

Environmental Monitoring

Relevant water quality monitoring by Teck will include collection of monthly surface water grab samples at five monitoring locations: 1) the SPO assessment point in Line Creek downstream of South Line Creek, 2) Line Creek upstream of the SPO assessment point, 3) Line Creek near the mouth, 4) a reference area located upstream of LCO on Line Creek, and 5) a reference area on South Line Creek (see Attachment A for map). The samples will be analyzed for a full suite of chemical parameters and field measurements, consistent with mine permit requirements. Also, during the June through September growing season, water sampling frequency at the SPO assessment point and the South Line Creek reference station will be increased to twice monthly, with one of the monthly sampling events to coincide with the regular monthly surface water sampling required by the Environment Management Act Permit 5353 and the other to occur in the middle of the month.

Field measurements at each monitoring station will include temperature, DO, pH, and specific conductivity. Water samples collected at each station will undergo laboratory analyses of routine parameters (e.g., total organic carbon, major cations/anions), total and dissolved metals, and nutrients (e.g., nitrate, TP). For the first two years of AWTF operation, duplicate samples will be collected and analyzed for TP at both the SPO sampling station on Line Creek and the South Line Creek reference station during all sampling events. As field-measured DO concentrations and laboratory phosphorus data are received during the June-September period, Teck will compare the results to the SPOs to determine if action is warranted (see proposed Response Framework, below).

Based on the pattern of predicted TP concentrations (Figure 2), it is unlikely that a change in periphyton chlorophyll-*a* levels would be detectable until late summer when water phosphorus concentrations have higher probability of exceeding the TP SPO of 20 µg/L. Therefore, the LAEMP (Attachment A), proposed for implementation in 2014, will involve a late-summer annual biological monitoring survey at relevant locations. In addition to the five monitoring areas in the Line Creek watershed, listed above, the LAEMP will include sampling of periphyton chlorophyll-*a* concentrations in the Fording River upstream and downstream of Line Creek to evaluate potential cumulative effects of nutrients from Line Creek on the Fording River. In brief, the LAEMP will complement Teck's routine water quality monitoring by measuring and evaluating the following (Attachment A):

- periphyton productivity based on chlorophyll-*a* concentrations and ash-free dry mass (AFDM);

- bryophyte productivity based on estimation of areal coverage and shoot length; and
- benthic invertebrate biomass and tissue concentrations.

LAEMP data interpretation will integrate the biological data with water quality data collected over the preceding summer months. Thus, the monitoring program will measure conditions relative to the SPOs, and also enable a detailed evaluation of the influence of the WLC Se AWTF on receiving water quality and associated biological responses. The results will enable MOE and Teck to mutually evaluate the performance of the WLC Se AWTF on an annual basis, to ensure that potential increases in phosphorus are not adversely affecting Line Creek or the Fording River, and, if required, serve to identify the need for additional investigations or implementation of mitigation measures.

Proposed Response Framework

The Response Framework is intended to clearly define the link between observed monitoring results and potential management or mitigation responses by Teck. The various proposed management approaches and action triggers proposed are discussed below.

During operation of the treatment facility, phosphorus will be tightly monitored and controlled through the following:

- at a minimum, daily onsite phosphorus measurements at multiple sampling points within the treatment process to control and optimize phosphorus dosage;
- full time operator (24/7) staffing of the treatment facility to decrease the likelihood of potential upsets and to monitor and control phosphorus dosage within a narrow range of tolerance;
- regular calibration of phosphorus feed pumps; and
- in the unlikely event of a higher than required phosphorus dosage, the ability to recycle water back to the front of the treatment process for re-treatment before it is discharged to Line Creek.

Despite the above, Figure 2 shows that the SPO may be exceeded at the assessment point in Line Creek downstream of South Line Creek during the growing season of low-flow years. Although performance will be evaluated relative to all three SPOs, it is proposed that the potential need for phosphorus mitigation be assessed mainly on periphyton chlorophyll-*a* levels, because:

- a TP concentration in a stream is a relatively poor indicator of algal biomass, so a direct measure of mean algal biomass is more relevant and appropriate for assessing potential environmental effects of the AWTF (BCWQG 2001);
- there is a provincial guideline for periphyton chlorophyll-*a* to aid in defining acceptable versus unacceptable levels of primary productivity; and
- the SPO for DO is expected to be of limited benefit as an indicator of increased primary productivity, because water flows and turbulence within Line Creek would likely maintain oxygen levels above the SPO.

Therefore, the SPO for periphyton chlorophyll-*a* should be considered to have greater importance than the water quality SPOs (TP and DO). In other words, receiving water TP concentrations above 20 µg/L may not result in periphyton proliferation, but significant increases in periphyton chlorophyll-*a* concentrations relative to both baseline and reference levels will be direct evidence of an increase in periphyton productivity.

It is proposed that the potential need for phosphorus mitigation be re-evaluated on an annual basis in response to the LAEMP results. At that time, data will show if the phosphorus levels in the receiving environment (based on that year's receiving water flow characteristics) have affected periphyton chlorophyll-*a* concentrations. In each annual LAEMP report, periphyton chlorophyll-*a* levels will be compared to the provincial guideline, baseline levels, and reference area concentrations. Data interpretation will also consider the other LAEMP indicators of productivity (periphyton AFDM and bryophyte growth), water quality performance relative to the TP and DO SPOs, and other water nutrient data, to determine if productivity has increased as a result of phosphorus loads from the AWTF.

Monitoring data collected at the assessment point in Line Creek will be evaluated relative to four proposed action levels (no action, low, moderate, and high) as shown in Table 2. The proposed action levels take into account that chlorophyll-*a* concentrations measured in Line Creek downstream of South Line Creek (LIDSL and LI8) in 2013, and also at most other reference and mine-exposed locations sampled in 2012-13, were less than 25 mg/m^2, and were thus well below the BC guideline of 100 mg/m^2 (Figure 3). Therefore, chlorophyll-*a* concentrations below 25 mg/m^2 will not trigger mitigation; however, higher categories of periphyton chlorophyll-*a* concentration are associated with a corresponding management response, which will be implemented before the next growing season, where possible.

Table 2: Proposed Response Framework Showing Relationship between Annual Periphyton Monitoring Results, Action Levels, and Management Response.

Average Periphyton Chlorophyll-*a* Concentration[(a)]	Action Level	Management Response[(b)]
<25 mg/m^2	No Action	None, other than routine LAEMP reporting
25 to 50 mg/m^2	Low	Determine if the increase in primary productivity is mainly attributable to AWTF nutrient loads (i.e., corroborated by other monitoring results). Provide update to MOE on mitigation options being considered (with rationale), as well as steps and schedule for implementation, should future annual monitoring cycle identify a moderate or high action level.
50 to 75 mg/m^2	Moderate	Provided LAEMP results verify that increased productivity is occurring and is mainly attributable to the AWTF[(a)], confirm mitigation plans with MOE, and initiate management and regulatory steps for implementation.
>75 mg/m^2	High	Provided LAEMP results verify that increased productivity is occurring and is mainly attributable to the AWTF[(a)], implement mitigation.

(a) Average chlorophyll-*a* concentrations must be evaluated relative to reference conditions. If reference conditions are similar to conditions at the assessment point in Line Creek, then no action is required.

(b) Management responses are initiated before the next annual monitoring cycle.

Average periphyton chlorophyll-*a* concentrations above 75 mg/m^2 can be considered well above both reference concentrations within the Elk River watershed and baseline conditions in Line Creek downstream of South Line Creek. Therefore, it is appropriate that the framework proposed in Table 2 triggers mitigation before the chlorophyll-*a* guideline is actually exceeded.

Although periphyton chlorophyll-*a* concentrations should be the primary driver of potential mitigation, twice-monthly measurements of TP and DO concentrations in Line Creek over the growing season will be closely monitored. Interim management actions will be taken, as appropriate, if observed concentrations do not meet the SPOs, particularly with respect to TP concentrations. These actions will include the following steps, which will be undertaken if, and in whatever order, is appropriate based on circumstances:

- Verify with the laboratory that TP measurements were analyzed and reported accurately and there were no issues with respect to sample integrity or hold-time prior to analysis. This step is important for confirming if the observations are valid.
- In the event that any field measurement of DO that does not meet the SPO, additional measurements will be made within 3 days, and repeated every 2-3 days thereafter while such conditions persist.
- Compare observed TP concentrations between the assessment station and upstream and downstream stations to determine if the receiving water concentrations were due to elevated TP concentration in the discharge from the WLC Se AWTF or other factors unrelated to the discharge (e.g., upstream water quality). If the elevation of downstream TP concentrations or decreased DO is confirmed to be related to WLC Se AWTF discharge loads, verify if discharge is meeting the 30 µg/L TP target. If not, review AWTF operations to determine if there has been a system upset or a change to operations that may have affected TP concentrations or if there is any opportunity to reduce phosphorus additions to the AWTF while still maintaining effective treatment system function.
- Depending on the results of actions listed above, potentially collect additional samples.
- Should any of above actions be taken, they will be clearly documented by Teck so that they can be reported and interpreted as part of the annual LAEMP report.

The proposed Response Framework will result in concentrations in Line Creek being closely monitored and evaluated relative to the SPOs throughout the periphyton growing season, until such time as the environmental consequences of the observed conditions can be more thoroughly evaluated by direct measurement of periphyton (and bryophyte) productivity in the annual LAEMP. The full interpretation of data associated with the LAEMP report will be important for determining if the WLC Se AWTF discharge phosphorus target, as well as the SPOs and associated management action triggers, are adequately protecting the environment and/or for early detection and mitigation of adverse environmental effects. Data collected during the initial years of monitoring may indicate that the Response Framework or LAEMP needs to be modified; however, changes will be initiated only after discussion with, and approval by, MOE.

Should mitigation measures be warranted, these may include, in order of estimated increasing effectiveness, the following:

1) The addition of iron or organic based coagulants.

2) The addition of iron coated media to the sand filters.

3) The replacement of the sand filters with Ultra Filtration (UF) membranes.

Mitigation measures will be investigated in more detail through piloting efforts in 2014. Should mitigation be warranted, the required level of mitigation will be compared to pilot performance of individual measures to select the mitigation measure for implementation.

Closure

We trust that this memo provides information that will facilitate the management of phosphorus in Line Creek, using an approach that is mutually agreeable to Teck and regulators. If you have questions or comments, please contact the undersigned.

GOLDER ASSOCIATES LTD.

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Senior Water Quality Modeller

Zsolt Kovats, M.Sc.
Associate, Senior Aquatic Ecologist

Patti Orr, M.Sc.
Principal, Senior Aquatic Scientist

IH/ZK/PO/mh

References

EC (Environment Canada). 2004. *Canadian Guidance Framework for the Management of Phosphorus in Freshwater Systems*. Report No 1-8. February 2004.

MOE (British Columbia Ministry of Environment, Kootenay and Okanagan Regions). 2013. *Memorandum, Review of Proposed Phosphorus Limits and Contingencies for EMA Application*. Dated 13 December, 2013.

Attachments

Attachment A - Study Design for Local Aquatic Effects Monitoring in Line Creek

ATTACHMENT A

Study Design for Local Aquatic Effects Monitoring in Line Creek

Kevin Podrasky
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February 28, 2014

A.J. Downie,
Environmental Quality Section Head,
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401-333 Victoria Street
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Attention: AJ Downie, Environmental Quality Section Head,

Re: Line Creek Operations LAEMP Study Design and Phosphorus Management Framework

As agreed in discussions earlier this month, please find enclosed the Final LAEMP Study Design for Line Creek and the updated Phosphorus Management Framework Document in association with Permit PE5353.

We look forward to meeting with you in March to answer any questions you may have on the enclosed documents. Should you have any questions or comments prior to this meeting, please feel free to contact Kevin Podrasky at +1-250-425-3169 or via email at Kevin.Podrasky@teck.com.

Regards,

FOR
Kevin Podrasky
Superintendent Environment

Enclosure

C.c. Robyn Roome, Regional Director, BC Ministry of Environment
Ian Anderson, General Manager, Line Creek Operations

Technical Memorandum

Date:	February 27, 2014
To:	Kevin Podrasky, Jenny Hutchison, Teck Coal Limited
Cc:	Carla Fraser, Teck Coal Limited
From:	Patti Orr, Shari Weech, Minnow Environmental Inc.
RE:	**Study Design for Local Aquatic Effects Monitoring in Line Creek**

Background

Through issuance of Draft Permit 5353, and associated communications with Teck Coal Limited (Teck), the British Columbia Ministry of Environment (BCMOE) has requested that Teck develop a local aquatic effects monitoring program (LAEMP) related to the commissioning of the West Line Creek Selenium Active Water Treatment Facility (AWTF). The fluidized bed reactor technology that will be used at the AWTF for selenium removal requires the addition of phosphorus to the treatment train. Although the AWTF will be managed to minimize the amount of residual phosphorus in treated effluent, it is expected that phosphorus concentrations will increase in Line Creek. BCMOE has expressed concern that the predicted concentrations may increase algal growth and cause a shift in trophic status and biotic community structure in Line Creek downstream of the AWTF.

Another concern expressed by BCMOE related to the AWTF is potential change in the form of selenium that will be released from West Line Creek into Line Creek. Selenate has been the dominant form of selenium in surface waters downstream of Teck's coal mines, as would be expected in the well-oxygenated, flowing stream habitats that dominate the Elk River watershed. At the AWTF, selenium will be removed via uptake into microorganisms within the AWTF. In biological tissues, selenium is transformed to organoselenium. Organoselenium losses from the AWTF are expected to be minimal due to high retention of live and dead organisms ("solids") within the treatment system, but there is potential for some of the residual selenium in treated water to be in the form of selenite or organoselenium species. These reduced forms of selenium are more bioavailable and readily accumulated by aquatic biota than selenate (Ogle et al. 1988; Riedel et al. 1996; Stewart et al. 2010).

Consequently, BCMOE has requested that the Line Creek Operation (LCO) LAEMP be designed to monitor potential changes in aquatic productivity and selenium accumulation in aquatic biota in Line Creek downstream of the AWTF discharge.

Phosphorus and Aquatic Productivity

Aquatic plants require inorganic phosphate for nutrition, typically in the form of orthophosphate ions (PO_4^{3-}) (CCME 2004). This is the most significant form of inorganic phosphorus, and is the only form of soluble inorganic phosphorus directly utilized by aquatic biota (CCME 2004). However, in-stream orthophosphate concentrations are difficult to quantify (CCME 2004) and many factors besides phosphorus concentrations can affect primary productivity in streams, including the concentrations of other nutrients (e.g., nitrogen), water flow, substrate characteristics, grazing, and light intensity (Reddy et al. 1996; Dodds and Welch 2000; Withers and Jarvie 2008). Therefore, it is very challenging to predict the extent to which aquatic biological communities may respond to changes in nutrient loads, especially in stream (compared to lake) environments. For example, in a study of 10 North American streams representing diverse physical habitat characteristics, more than a third did not show any response to nitrogen (N) or phosphorus (P) additions over a 21-day period (based on the amount of algal colonization on nutrient-diffusing substrates), while the others showed varying degrees of response to nitrogen or phosphorus alone or in combination (Tank and Dodds 2003).

In addition, timing of sampling relative to the change in nutrient concentrations, and the type of sample collected, can affect the conclusions that may be drawn regarding the aquatic effects of nutrient additions. For example, experimental fertilization of an oligotrophic river in the Arctic tundra of Alaska, resulted in increased epilithic algal biomass and production in each of the first two summers of the experiment, but in the third summer, algal production and biomass returned to pre-fertilization levels, apparently due to increased production of grazing insects (Bowden et al. 1994). In other words, primary productivity continued to be increased in the third year, but the trophic level at which the nutrient addition effects were measurable, shifted from periphyton to benthic invertebrates after two years. Also, in addition to potential effects on the algal (primary producer) component of periphyton, other components of the periphyton community may be affected, such as bacteria and fungi, which play important roles in carbon, nutrient, and energy cycling in aquatic systems (Buesing and Gessner 2006).

Although bryophytes have not been widely observed in submerged areas of the Elk River watershed, they are present in Line Creek downstream of West Line Creek (LILC3) and downstream of South Line Creek (LIDSL) (Figure 1). They are of relevance to the Line Creek LAEMP because primary production by aquatic bryophytes can equal or exceed that of periphytic algae (Stream Bryophyte Group 1999). In the study by Bowden et al. (1994) described above, an unexpected and extensive increase in cover by aquatic bryophytes was noticed in the Arctic tundra river seven years after phosphorus fertilization began, giving further evidence of the temporal variability associated with stream responses to nutrient levels. The authors of the study concluded that the bryophyte community became the dominant sink for P in the fertilized reach.

In consideration of the information provided above, it will be necessary to measure a number of components of the aquatic system, such as periphyton chlorophyll-*a*, ash free dry mass (AFDM), bryophyte productivity, and total benthic invertebrate biomass, over a series of growing seasons[1], in order to characterize and understand the potential effects of nutrient additions to a stream environment.

Line Creek LAEMP

Based on the above, the LCO LAEMP will address the nutrient and selenium concerns in Line Creek by monitoring four main components:

- Periphyton productivity based on chlorophyll-*a* concentrations and AFDM;
- Bryophyte productivity based on estimation of areal coverage and shoot length;
- Benthic invertebrate biomass and tissue selenium concentrations; and
- Water concentrations of nutrients and selenium species (based on LCO's routine water monitoring program).

Monitoring will focus on the area in Line Creek downstream of both the AWTF discharge and South Line Creek (i.e., the "SPO sampling site", LIDSL; Figure 1). Additional monitoring areas will be located in Line Creek slightly farther upstream (LILC3) and downstream near the mouth (LI8). Reference stations on Line Creek (LI24) and South Line Creek (SLINE) will also be monitored for comparison (Table 1). These same locations were sampled as part of the 2013 periphyton and benthic Invertebrate study (Minnow, in preparation), so baseline data are available. Care will be taken to ensure that all samples and in-stream measurements are taken by moving from a downstream to upstream direction within each sampling area so that results are not affected by previous disturbance of upstream substrates.

Samples will be collected annually in late summer (e.g., early September) to correspond with maximum growth of primary producers and to facilitate evaluation of primary and secondary productivity relative to observed nutrient concentrations throughout the growing season (Table 1).

Methods for sampling and analysis of each component are described in more detail in the following sections:

1. Periphyton Productivity

Two periphyton samples, one each for chlorophyll-*a* and AFDM, will be collected at ten sampling stations, a minimum of 5 m apart, in each sampling area (Table 1). At each station, a

[1] A growing season is defined as June 15th to September 30th (Golder 2014)

total of five rocks of similar size will be sampled (i.e., large enough to collect separate samples for both chlorophyll-*a* and AFDM analyses) and the periphyton scrapings from the five rocks will be composited to form a single sample. The five sampling areas on Line Creek will be:

- Reference area LI24 (Line Creek);
- Reference area SLINE (South Line Creek);
- Line Creek immediately downstream of West Line Creek (LILC3);
- Line Creek downstream of South Line Creek (LIDSL), and
- Line Creek near the mouth (LI8).

In addition, periphyton samples will be collected in the Fording River upstream (FOUL) and downstream (FO23) of Line Creek.

Periphyton sampling areas will target riffle habitat with water depth of at least 5 cm, near-bottom water velocity of approximately 0.1-0.2 m/s, and uniform substrate characteristics including relatively flat rocks with a diameter of at least 12 cm. When a sampling area with such characteristics has been identified, the sampler will step into the area and reach down without looking to select the rock closest to the foot that last stepped. This technique is similar to the random pebble size assessment associated with the Canadian Aquatic Biomonitoring Network (CABIN; Environment Canada 2010). If a rock chosen by this method is judged unsuitable for sampling (e.g., too small, highly angular, or uncharacteristic surface texture), an alternative rock in close proximity, having visibly similar periphyton coverage, will be sampled. This approach will minimize some of the natural habitat variability that might otherwise confound sampling results, while still encouraging randomized selection of individual rocks within targeted habitats.

After selection of each suitable rock, the technician will return to shore and a thin rubber or acetate template, with a 4-cm^2 opening in the middle, will be placed firmly on the rock so that the periphyton can be scraped from the opening using a scalpel. Collection of each sample will take place over a clean plastic tub to ensure no sample is lost. This process will be repeated with four additional rocks, and all five scrapings will be placed on a wetted Whatman GF/F glass fibre filter (e.g., 90 mm diameter, 0.7 µm pore size) to provide a single, composite sample per station. The filter paper containing the composite sample will be folded in half twice and then tightly wrapped with aluminum foil. The foil-wrapped sample will be placed in a labelled Whirl-pak bag and stored in a cooler with freezer packs (in the field) until transfer later in the day to a freezer for storage until shipped to the laboratory. Samples can be stored frozen for up to 30 days as long as they are not exposed to light (APHA et al. 1998).

The same rocks sampled for chlorophyll-*a* analysis will be used to collect separate scrapings for analysis of AFDM. Each composite sample for AFDM analysis will be placed in a small sealed container and kept cool until transfer to a freezer later in the day.

The steps above will be repeated at the other stations within each area until 10 stations, each a minimum of 5 m apart, have been sampled. Samples will be shipped frozen to the laboratory for analysis of chlorophyll-*a* content and AFDM.

Periphyton coverage will also be visually scored at each station based on the categories stipulated by the CABIN protocol (Environment Canada 2010):

1. Rocks not slippery, no obvious colour (<0.5 mm thick)
2. Rocks slightly slippery, yellow-brown to light green colour (0.5-1 mm thick)
3. Rocks have noticeable slippery feel, patches of thicker green to brown algae (1-5 mm thick)
4. Rocks are very slippery, numerous clumps (5-20 mm thick)
5. Rocks mostly obscured by algae mat, may have long strands (>20 mm thick)

2. Bryophyte Productivity

Bryophyte productivity will be assessed by measuring bryophyte growth along five transects across the stream width, each a minimum of 10 m apart, at the same five Line Creek areas being sampled for periphyton: LI24, SLINE, LILC3, LIDSL and LI8 (Table 1). Transect locations will be selected in the field to have similar habitat characteristics to those recommended for periphyton sampling (e.g., uniform substrate, large flat rocks, etc.). Transects will be marked by securing a measuring tape to a stable object on each stream bank to ensure the transect follows a straight line slightly above the water surface and will not move while the transect is being sampled. Beginning at the stream edge, the technician will move towards the first totally submerged rock that is located directly under the transect line and is at least 12 cm in diameter (e.g., large cobble, boulders, or bedrock). The distance along the transect from the stream margin and the percentage of the rock surface that is covered by bryophytes will be recorded (to the nearest 10%). The technician will also measure and record the depth of the bryophyte growth at the centre of the bryophyte patch using a ruler (i.e., plant length extending out from the rock). The technician will continue across the stream to record the percent bryophyte coverage and depth of bryophyte growth on all large, submerged rocks located along the transect. The technician may work with the aid of a diving mask to facilitate underwater measurements if the rocks are too large to extract from the streambed. The same process will be repeated at all five transects per area.

3. Benthic Invertebrate Biomass and Selenium

Benthic invertebrate biomass will be monitored to assess secondary productivity. Invertebrate samples will be collected using a Hess sampler with 500 µm mesh, which will allow for expression of biomass relative to the area sampled. Ten stations will be sampled in each of the same five areas being assessed for primary productivity, with the stations located a minimum of 5 m apart so as to be representative of the same overall area from which periphyton samples are collected (Table 1). A single sample will be collected at each station by carefully inserting the base of the Hess sampler into the substrate to a depth of approximately 5-10 cm, after which gravel and cobble contained within the sampler will be carefully washed while allowing the current to carry dislodged organisms into the mesh collection net. All organisms collected into the net will be carefully rinsed to the container at the end of the net, and then into a labelled wide-mouth plastic jar. Samples will be preserved to a level of 10% buffered formalin in ambient water within approximately six hours of collection to ensure that biomass is not lost through predation or decomposition of tissues before the samples can be sorted at the laboratory. At a qualified laboratory, all preserved organisms in each sample will be sorted from the sample debris into groups separated at the family-level of taxonomy for weighing. Each family group of organisms will be gently placed onto a fine cloth or paper towel to drain excess surface moisture (preservative) before being weighed to the nearest 0.1 g. Total and family-level biomass will be reported for each sample.

Benthic invertebrate samples also will be collected for selenium analysis using the CABIN kick and sweep sampling method (Environment Canada 2010). Two types of samples will be collected for analysis of tissue selenium:

- One or two representative benthic invertebrate taxa such as *Rhyacophila* sp. and/or *Baetis* sp. Both groups are found in all tributaries and main stem streams associated with LCO and individuals are sufficiently large to enable collection of adequate biomass for chemical analysis. *Rhyacophila* sp. are particularly easy to identify in the field and are distinctly different from all other benthic invertebrate groups. *Baetis* sp. are more difficult to distinguish from other mayflies in the field, but all belong to the same functional feeding group. Analysis of a single genus will minimize variability relative to samples composed of different proportions multiple taxa, thereby facilitating detection of potential trends in tissue chemistry over time.
- A composite sample of benthic invertebrates for chemical analysis. These samples will be useful for comparison to baseline data, and as an estimate of dietary concentrations of consumer organisms (e.g., fish, birds).

One single-taxon sample (or two samples if two taxa can be found in sufficient abundance in each area) plus one composite sample will be collected from each mine-exposed area: LILC3, LIDSL, and LI8. Single (Table 1). Triplicate single-taxon samples and one composite sample will also be collected at both reference areas LI24 and SLINE; however, field crews will attempt to collect two to three samples of this type in each reference area for the first three years of the program, because reference (data are presently lacking for single-taxon samples in reference areas) (Table 1). Invertebrates will be picked free of debris in the field, and then frozen. For composite samples, to minimize sample bias toward large mobile organisms, a random sub-sample will be transferred to a white enamel tray and as many organisms in the sub-sample as possible will be carefully removed using tweezers until about 2 g of wet tissue is obtained.

Invertebrate tissue samples will be placed into labelled 30-mL (1-oz) Whirl-Pak® bags and stored in a cooler with ice packs until transferred to a freezer later in the day. Frozen samples will be shipped to the laboratory for analysis of dry weight selenium concentration and percent moisture.

Supporting Information and Measurements

All sampling areas and transects will be identified using a hand-held GPS and recorded on field sheets as UTMs (Universal Transverse Mercator) using the North American Datum of 1983. Measurements of water temperature, dissolved oxygen (DO), pH, and specific conductance will be taken in each area using a field meter that has been appropriately calibrated. Near-bottom water velocity (i.e., near the sampled rock surfaces) will also be recorded at all stations where periphyton samples are collected and at a minimum of three locations along each bryophyte transect.

All field observations and measurements will be recorded on standardized field data collection forms copied on waterproof paper.

Routine water quality monitoring by Teck will also provide important supporting information. This will include measurements of (Table 1):

- Nutrient concentrations (nitrate, nitrite, ammonia, total phosphorus, dissolved phosphorus);
- Dissolved oxygen concentrations, pH, conductivity, and water temperature;
- Major cations/anions (including organic carbon)
- Total and dissolved metals (including selenium speciation; selenate, selenite, organoselenium).

As indicated within Table 1 analyses will be done twice monthly during the periphyton growing season (mid-June to end September) at LC-LC1, LC-SLC, LC-LC3, LC-LC4, and at a new station downstream of South Line Creek (i.e., the "SPO sampling site"). These water monitoring locations correspond with the biological monitoring stations LI24, SLINE, LILC3, LI8, and LIDSL, respectively (Figure 1).

Data Analysis and Interpretation

Potential effects of phosphorus discharged from the AWTF will be evaluated by comparing:

- periphyton chlorophyll-*a* concentrations at LIDSL with the action values outlined in the Response Framework (Golder 2014);
- within-year periphyton chlorophyll-*a* and AFDM among reference and receiving environment areas, and also with results from previous years;

- bryophyte productivity over time;
- benthic invertebrate biomass over time; and
- primary and secondary productivity data (described above) with water nutrient data collected by Teck as part of routine water monitoring.

Interpretation will focus on determining if productivity has increased in Line Creek since the AWTF was commissioned. Emphasis will be placed on the results of periphyton chlorophyll-*a* monitoring because they link directly to potential management decisions by Teck (Golder 2014); however, the other data will be important for providing supporting lines of evidence and broader context for interpretation of chlorophyll-*a* results relative to changes in nutrient concentrations in Line Creek.

Benthic invertebrate selenium concentrations will be compared with data collected in the same areas during previous years to assess potential changes in food web accumulation associated with the AWTF discharge. Water selenium speciation data collected by Teck during routine water monitoring will also be summarized and considered as part of data interpretation.

Results of each annual cycle of monitoring will be reported to BCMOE the following January, with recommendations for adjustments to future monitoring cycles, if justified by the available information.

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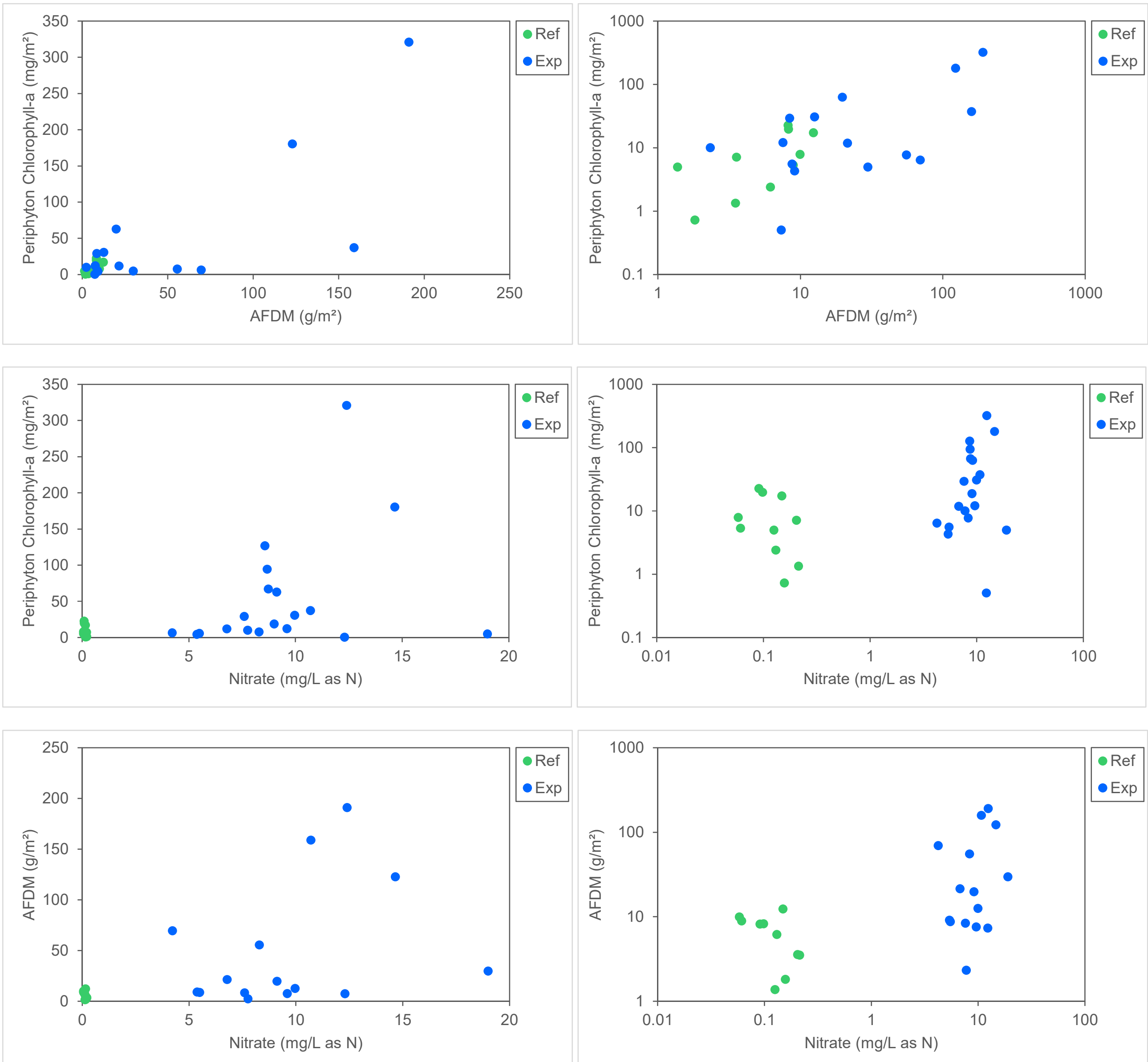
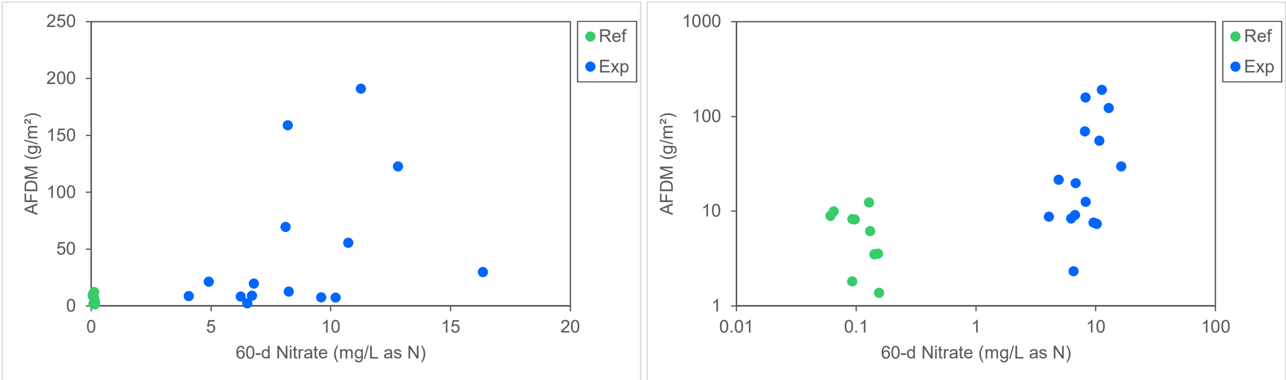
APPENDIX B

Plots of Significant Correlations



Notes: Paired variables are plotted two on the untransformed axes and $\log_{10}$ scaled axes to show patterns in the data.

Figure B.1: Scatterplots for significant correlations shown in Table 3 between periphyton productivity indicators and nutrient concentrations in water (at the time of periphyton sampling or the average nutrient concentration over the 60 day period prior to the periphyton sampling). Data are plotted based on both untransformed axes (panels on left) and $\log_{10}$ scaled axes (panels on right) to show patterns in the data. Data are from samples collected at two reference (LI24 and SLINE) and three mine-exposed areas (LILC3, LIDSL, and LI8) in Line Creek from 2013 to 2016.



Notes: Paired variables are plotted two on the untransformed axes and log_{10} scaled axes to show patterns in the data.

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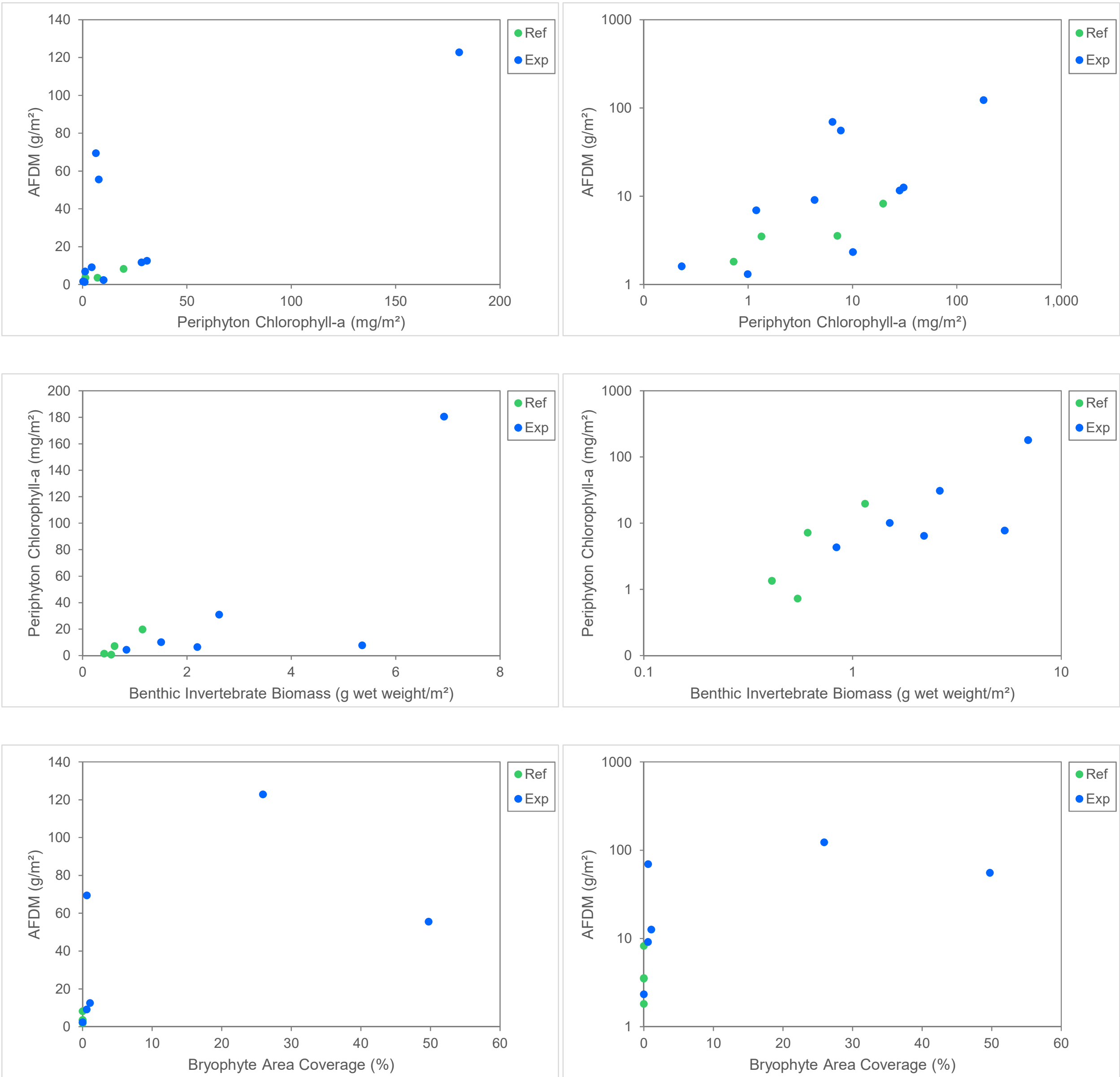
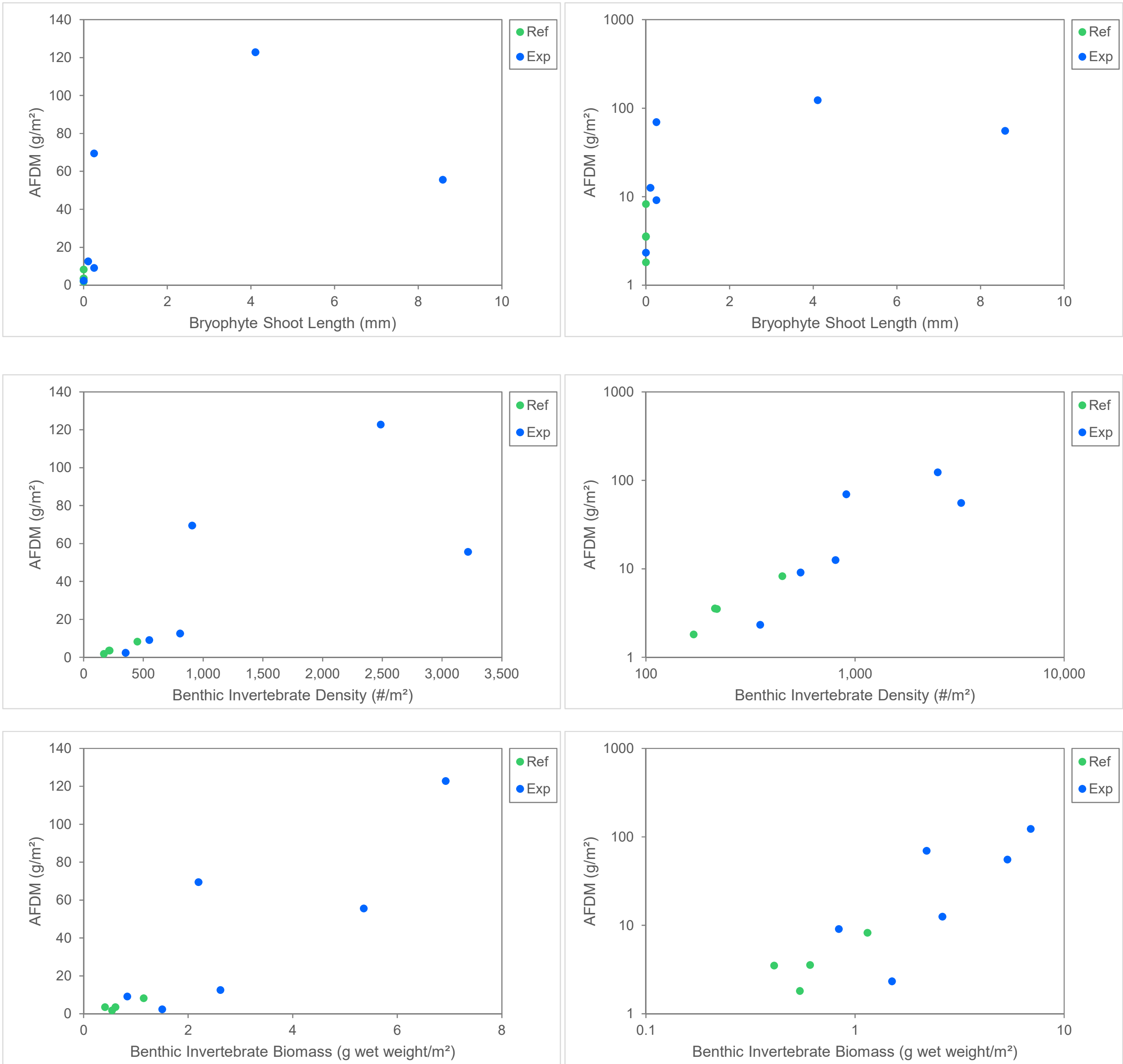


Notes: Paired variables are plotted two on the untransformed axes and $\log_{10}$ scaled axes to show patterns in the data. Bryophyte endpoints were not transformed because the data set contained values of zero.

Figure B.2: Scatterplots of significant correlations between biological productivity endpoints. Data are from two reference (LI24 and SLINE) and five mine-exposed areas (LILC3, LIDSL, LI8, FRUL, and FO23) in Line Creek and the Fording River in 2014 and 2015



Notes: Paired variables are plotted two on the untransformed axes and $\log_{10}$ scaled axes to show patterns in the data. Bryophyte endpoints were not transformed because the data set contained values of zero.

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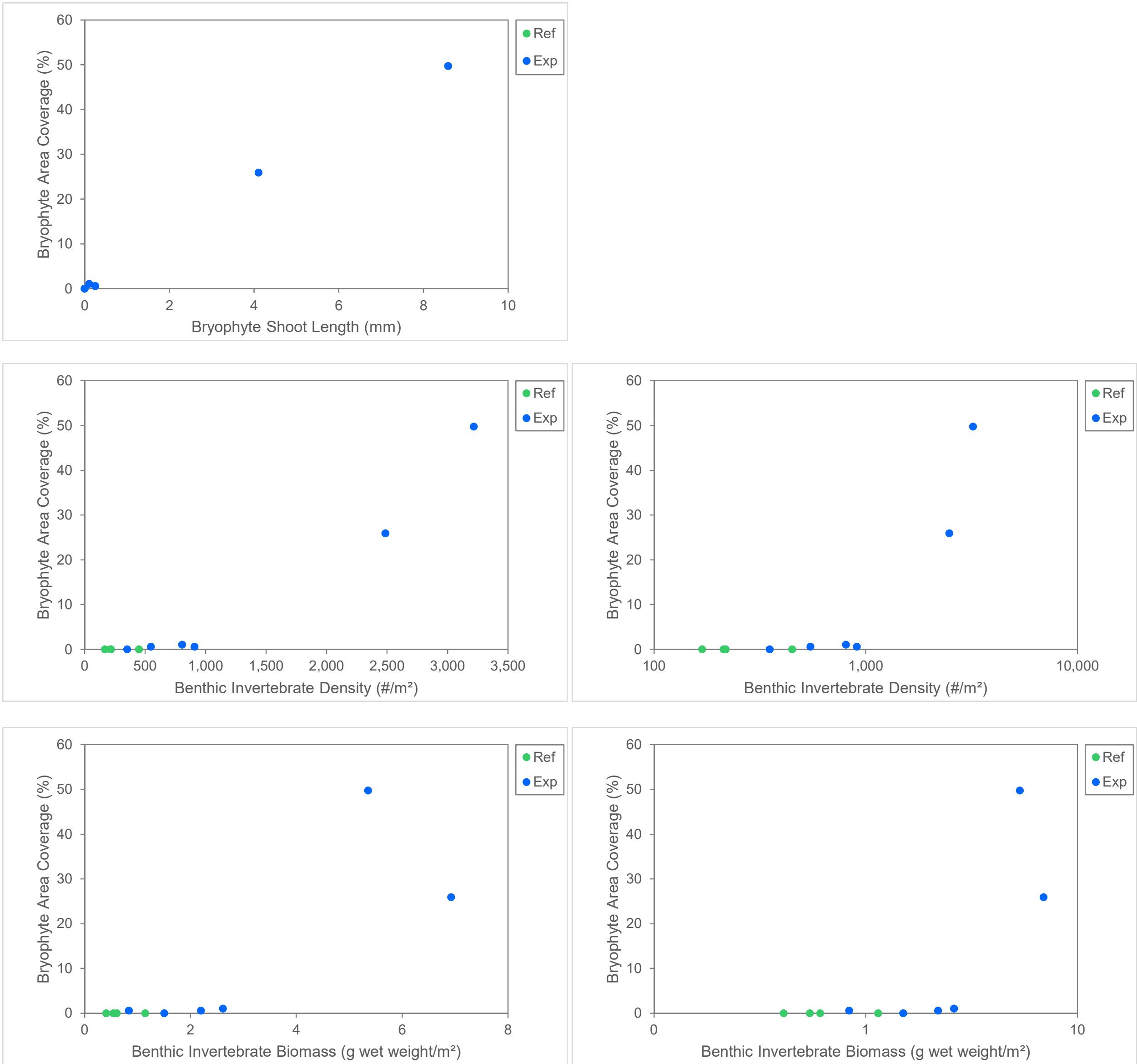

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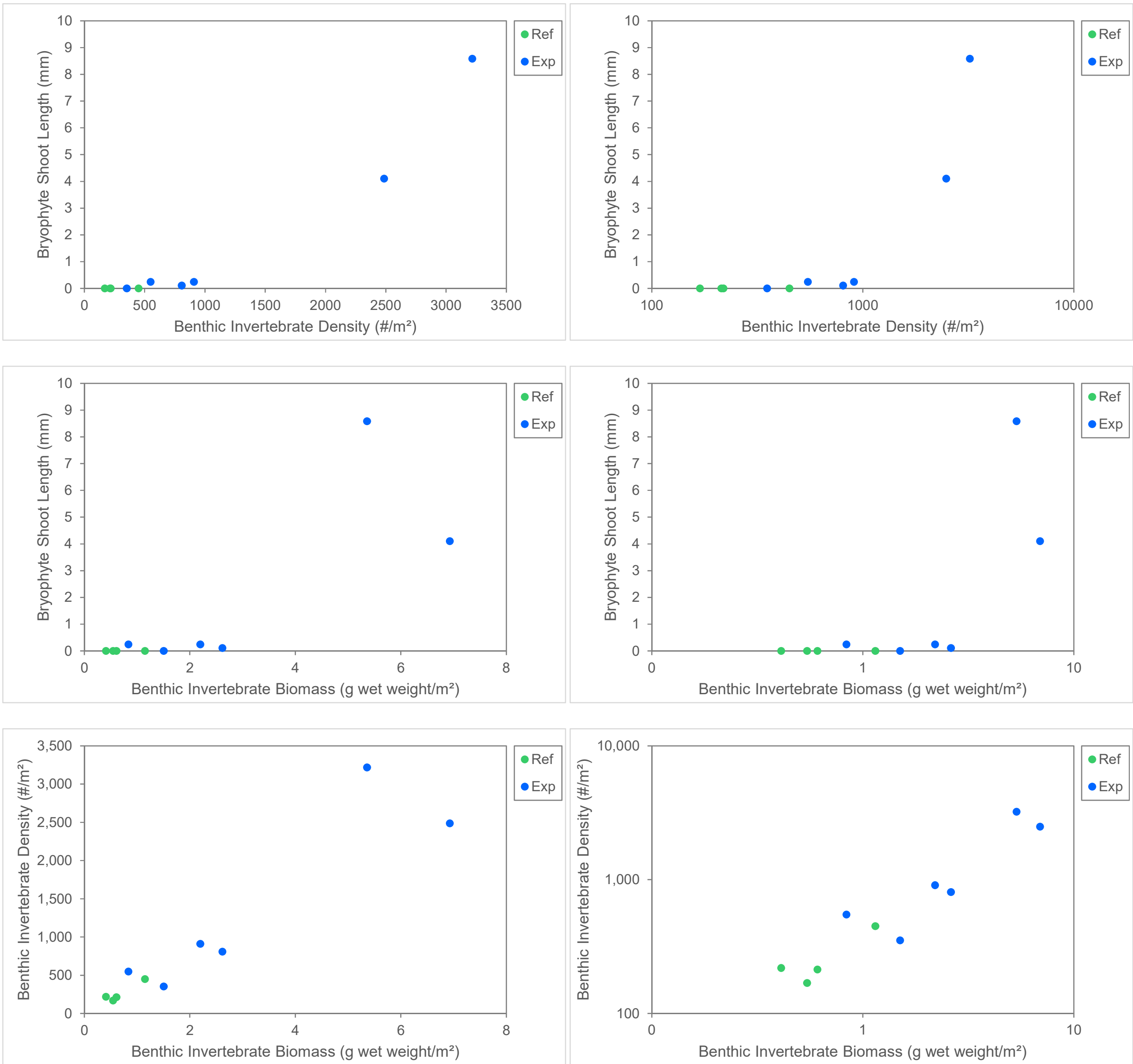

Notes: Paired variables are plotted two on the untransformed axes and log_{10} scaled axes to show patterns in the data. Bryophyte endpoints were not transformed because the data set contained values of zero.

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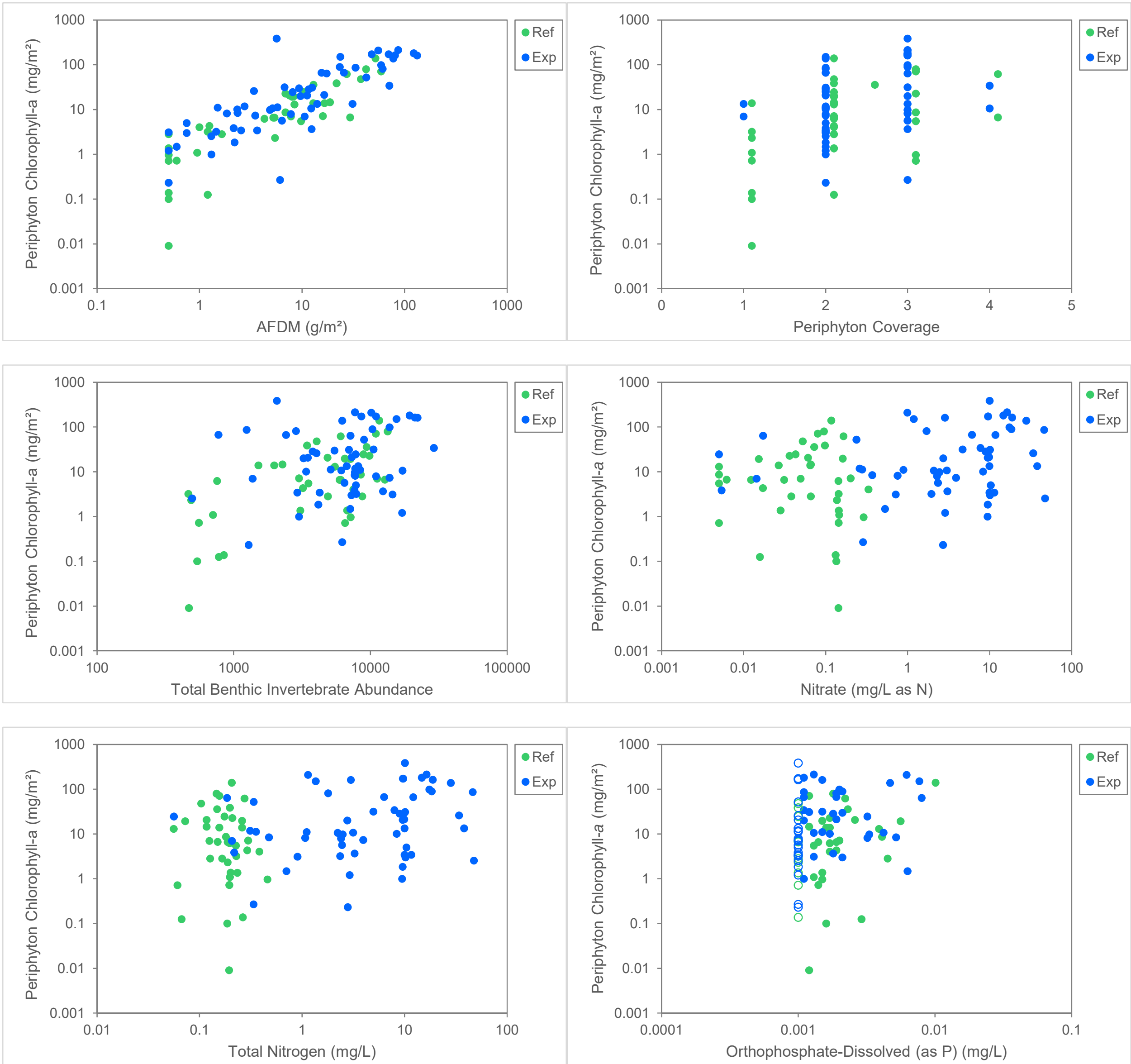
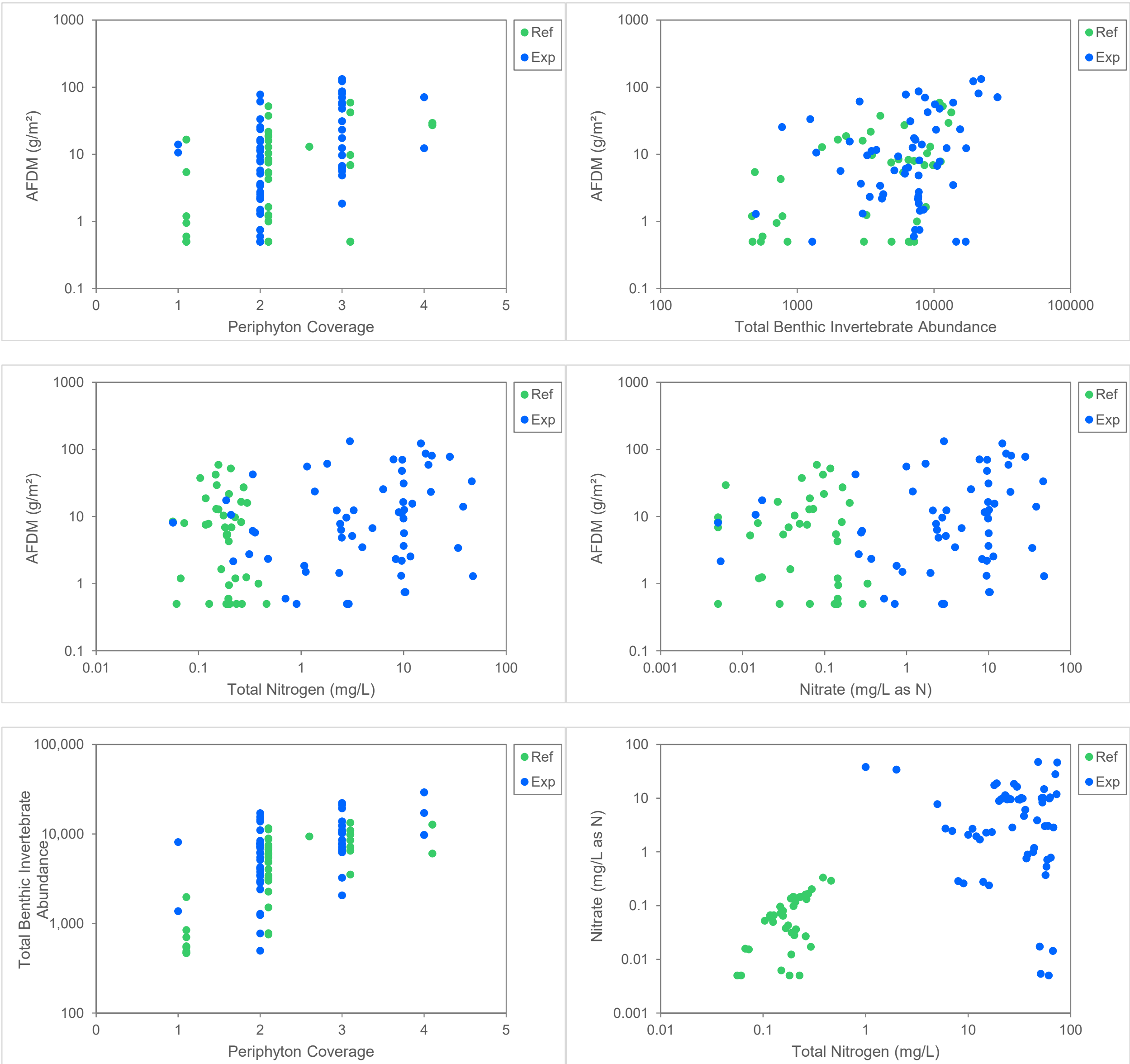


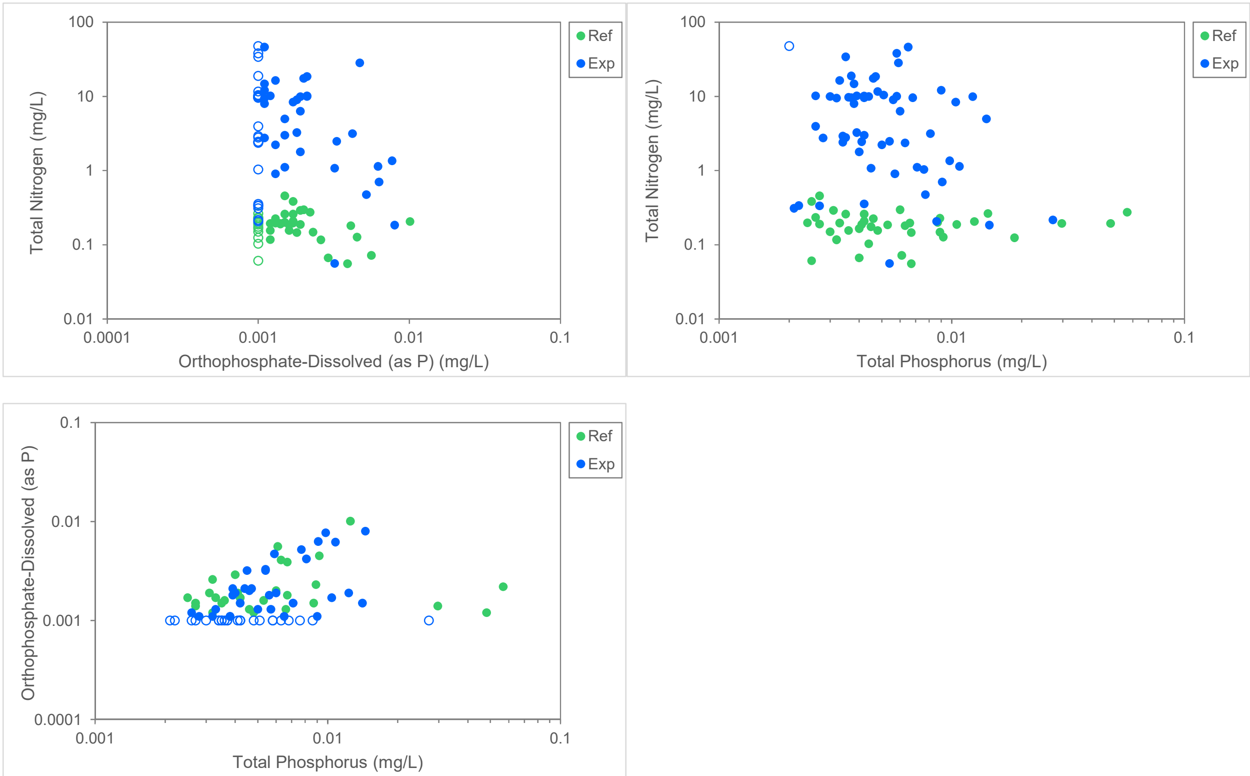
Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL; Periphyton coverage scores for the reference area were adjusted by 0.1 for graphing purposes

Figure B.3: Scatterplots for productivity endpoints and concentrations of major nutrients in water for paired variables with significant correlations (based on Table 6). Data are from 40 reference and 59 mine-influenced areas sampled for the RAEMP September, 2015.



Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL; Periphyton coverage scores for the reference area were adjusted by 0.1 for graphing purposes

Figure B.3: Scatterplots for productivity endpoints and concentrations of major nutrients in water for paired variables with significant correlations (based on Table 6). Data are from 40 reference and 59 mine-influenced areas sampled for the RAEMP September, 2015.



Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL; Periphyton coverage scores for the reference area were adjusted by 0.1 for graphing purposes

Figure B.3: Scatterplots for productivity endpoints and concentrations of major nutrients in water for paired variables with significant correlations (based on Table 6). Data are from 40 reference and 59 mine-influenced areas sampled for the RAEMP September, 2015.

Table B.1: Spearman correlations based on mean productivity endpoints and nutrient concentrations in water at the time of sampling and the average nutrient concentrations in water over the 60 day period prior to biological sampling for samples collected at two reference (LI24 and SLINE) and five mine-influenced areas (LILC3, LIDSL, LI8, FRUL, and FO23) in Line Creek and the Fording River in 2014 and 2015. The number of samples (n) included in the mean for productivity endpoints is n = 10 per area per year, except for bryophytes with n = 3 per area per year).

Variable	Statistic	AFDM	Chlorophyll-*a*	Bryophyte Area	Bryophyte Shoot Length	Benthic Invertebrate Density	Benthic Invertebrate Biomass	Nitrate @ Time of Biological Sampling	Total Phosphorus @ Time of Biological Sampling	Orthophosphate @ Time of Biological Sampling	Nitrate (Mean Over 2 Months Prior to Biological Sampling)	Total Phosphorus (Mean Over 2 Months Prior to Biological	Orthophosphate (Mean Over 2 Months Prior to Biological
AFDM N = 14	r	-	0.723	0.873	0.886	0.915	0.806	0.328	0.348	0.181	0.367	0.200	0.660
	P-value	-	0.003	0.001	0.001	<0.001	0.005	0.253	0.223	0.536	0.197	0.493	0.010
Chlorophyll-*a* N = 14	r	0.723	-	0.446	0.304	0.552	0.782	0.400	-0.051	0.406	0.314	0.042	0.464
	P-value	0.003	-	0.196	0.393	0.098	0.008	0.156	0.864	0.150	0.274	0.887	0.094
Bryophyte Area N = 10	r	0.873	0.446	-	0.959	0.925	0.847	0.808	0.200	-0.046	0.886	0.071	0.627
	P-value	0.001	0.196	-	<0.001	<0.001	0.002	0.005	0.579	0.900	0.001	0.845	0.052
Bryophyte Shoot Length N = 10	r	0.886	0.304	0.959	-	0.925	0.782	0.718	0.394	-0.033	0.834	0.187	0.743
	P-value	0.001	0.393	<0.001	-	<0.001	0.007	0.019	0.259	0.928	0.003	0.604	0.014
Benthic Invertebrate Density N = 10	r	0.915	0.552	0.925	0.925	-	0.891	0.745	0.188	0.067	0.867	0.079	0.806
	P-value	<0.001	0.098	<0.001	<0.001	-	0.001	0.013	0.603	0.853	0.001	0.829	0.005
Benthic Invertebrate Biomass N = 10	r	0.806	0.782	0.847	0.782	0.891	-	0.818	-0.030	0.104	0.903	0.042	0.636
	P-value	0.005	0.008	0.002	0.007	0.001	-	0.004	0.934	0.774	<0.001	0.907	0.048
Nitrate @ Time of Biological Sampling N = 14	r	0.328	0.400	0.808	0.718	0.745	0.818	-	-0.307	-0.049	0.942	-0.029	-0.028
	P-value	0.253	0.156	0.005	0.019	0.013	0.004	-	0.285	0.867	<0.001	0.923	0.926
Total Phosphorus @ Time of Biological Sampling N = 14	r	0.348	-0.051	0.200	0.394	0.188	-0.030	-0.307	-	0.073	-0.262	0.656	0.705
	P-value	0.223	0.864	0.579	0.259	0.603	0.934	0.285	-	0.805	0.366	0.011	0.005
Orthophosphate @ Time of Biological Sampling N = 14	r	0.181	0.406	-0.046	-0.033	0.067	0.104	-0.049	0.073	-	-0.228	-0.223	0.439
	P-value	0.536	0.150	0.900	0.928	0.853	0.774	0.867	0.805	-	0.434	0.444	0.116
Nitrate (Mean Over 2 Months Prior to Biological Sampling) N = 14	r	0.367	0.314	0.886	0.834	0.867	0.903	0.942	-0.262	-0.228	-	-0.015	-0.033
	P-value	0.197	0.274	0.001	0.003	0.001	<0.001	<0.001	0.366	0.434	-	0.958	0.911
Total Phosphorus (Mean Over 2 Months Prior to Biological Sampling) N = 14	r	0.200	0.042	0.071	0.187	0.079	0.042	-0.029	0.656	-0.223	-0.015	-	0.431
	P-value	0.493	0.887	0.845	0.604	0.829	0.907	0.923	0.011	0.444	0.958	-	0.124
Orthophosphate (Mean Over 2 Months Prior to Biological Sampling) N = 14	r	0.660	0.464	0.627	0.743	0.806	0.636	-0.028	0.705	0.439	-0.033	0.431	-
	P-value	0.010	0.094	0.052	0.014	0.005	0.048	0.926	0.005	0.116	0.911	0.124	-

indicates r < -0.6 or r > 0.6

indicates p-value < 0.05

APPENDIX C

Temporal Patterns

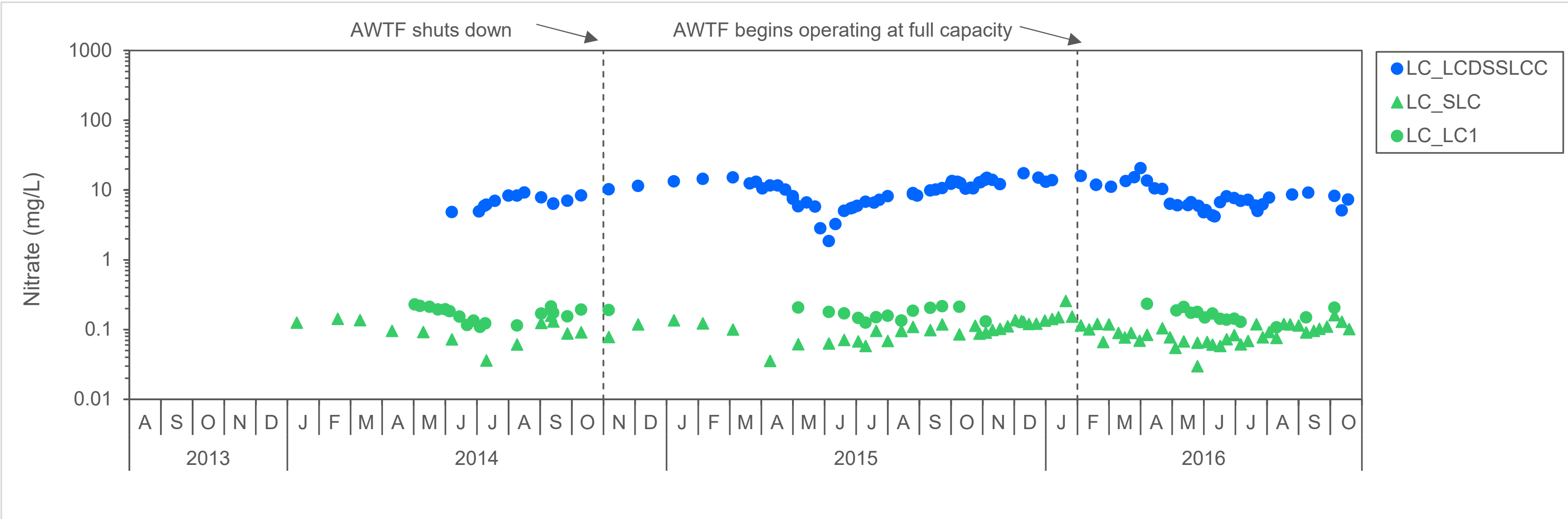


Figure C.1: Scatterplot of observed concentrations of nitrate at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016

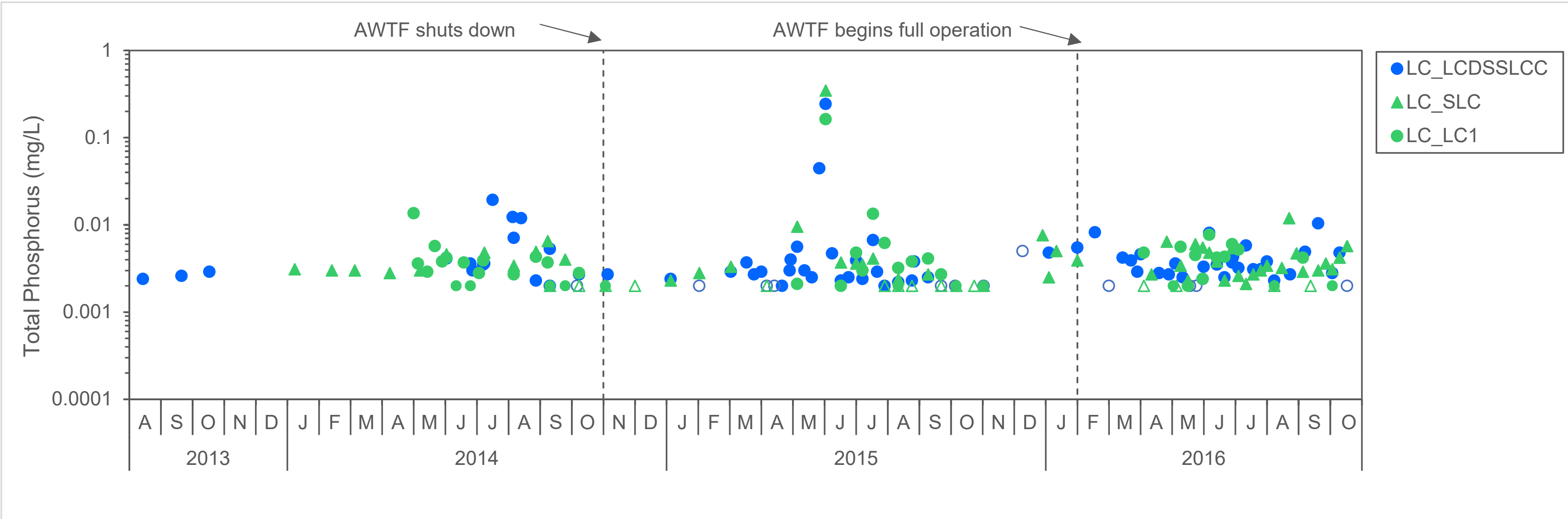


Figure C.2: Scatterplot of observed concentrations of total phosphorus at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016

Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL.

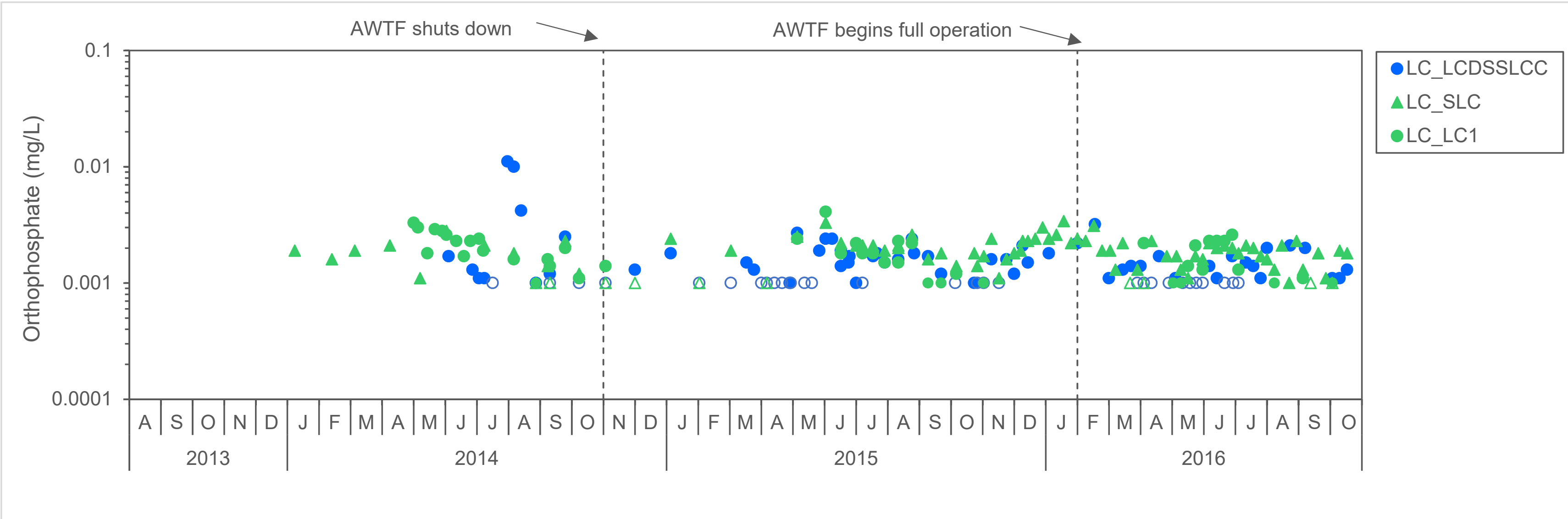


Figure C.3: Scatterplot of observed concentrations of orthophosphate at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016

Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL.

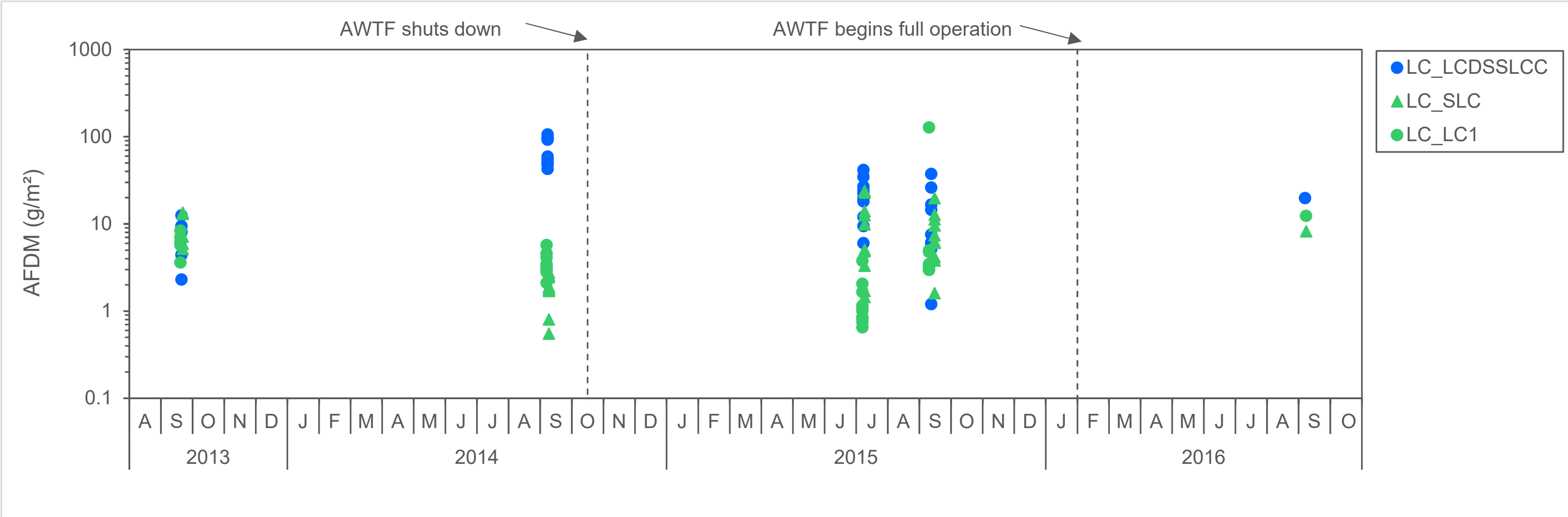


Figure C.4: Scatterplot of observed concentrations of periphyton ash-free dry mass (AFDM) at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016

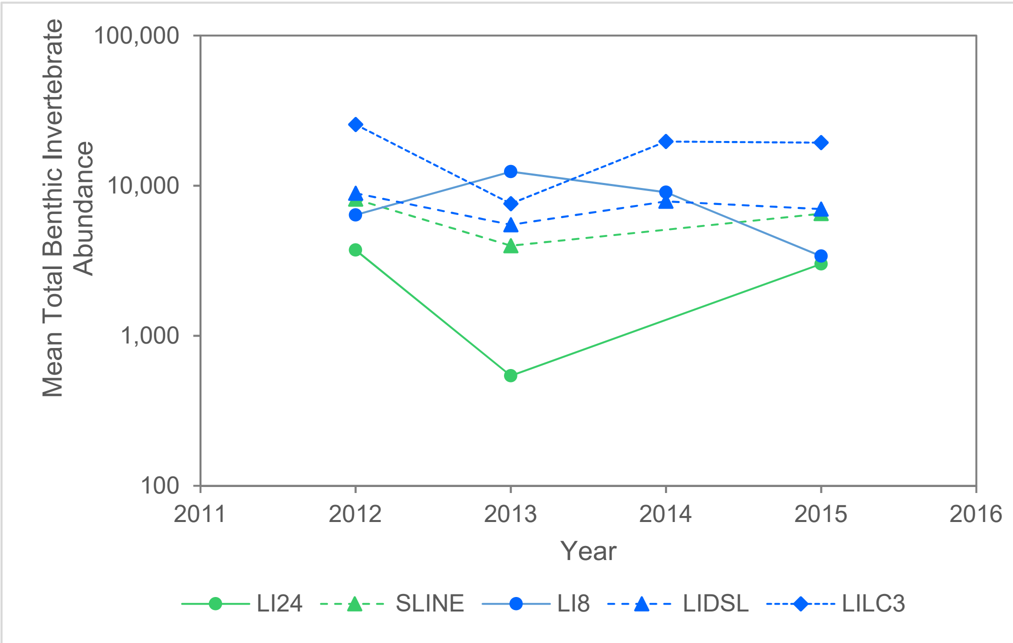


Figure C.5: Scatterplot of mean total benthic invertebrate abundance at LI8, LIDSL (LC_LCDSSLCC), LILC3, and two reference areas (LI24 and SLINE) from 2012 to 2016.

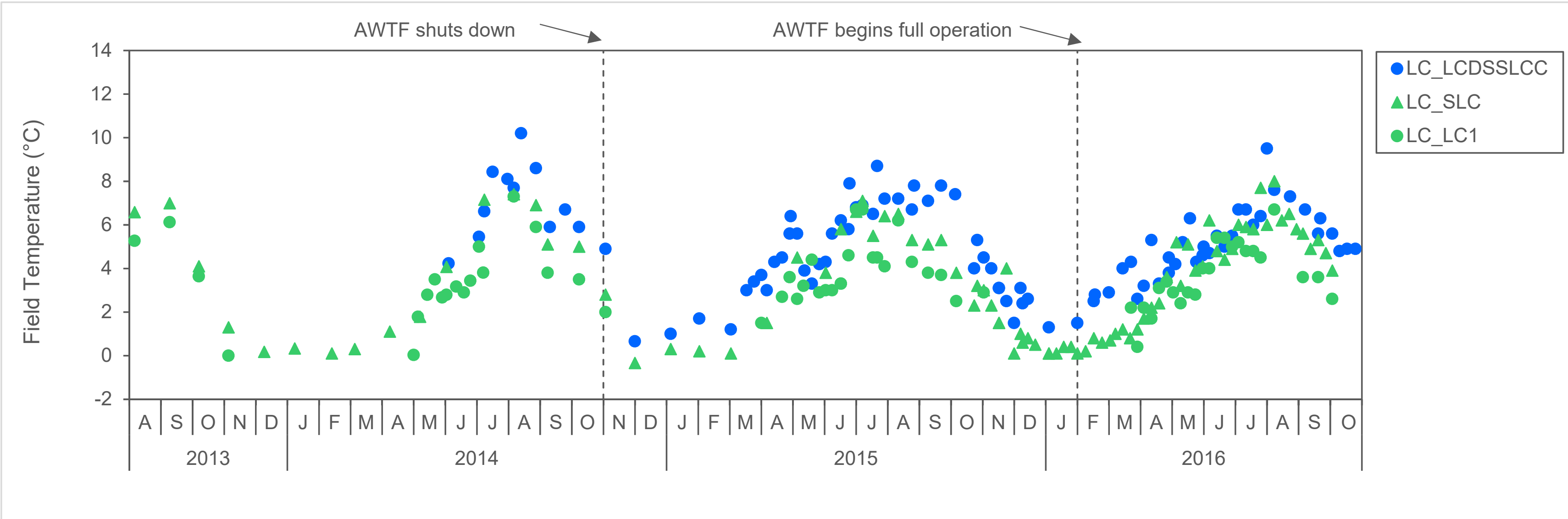


Figure C.6: Scatterplot of field temperature at LIDSL (LC_LCDSSLCC), SLINE (LC_SLC), and LI24 (LC_LC1) August 2013 - October 2016

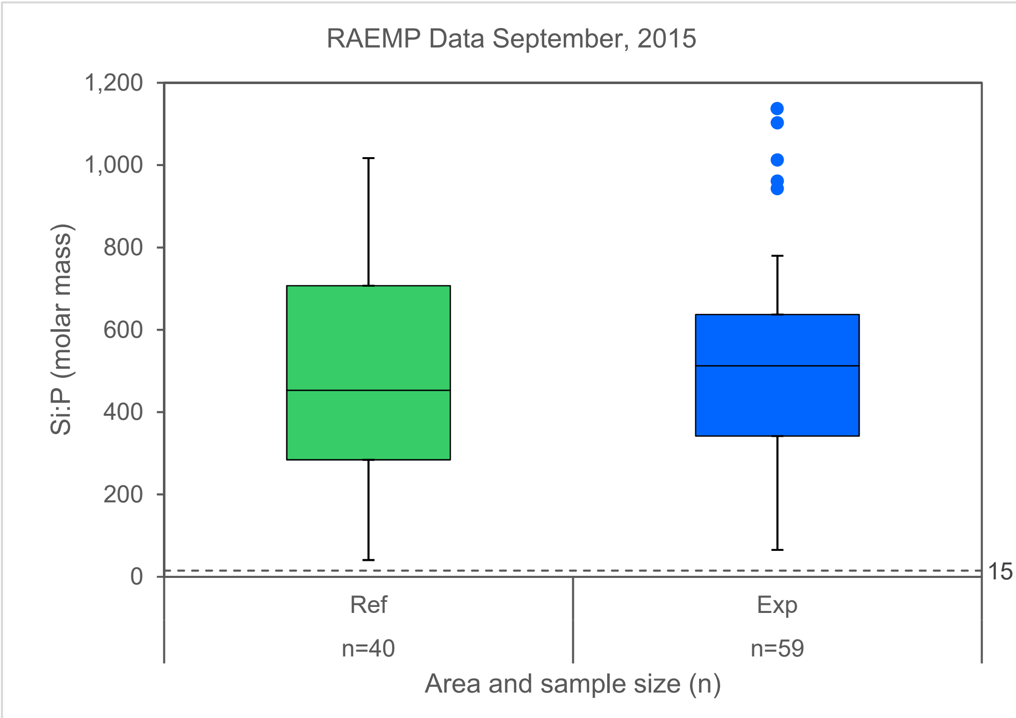
Table C.1: Results for Seasonal Kendall tests for temporal trends in mean monthly nutrient concentrations and field temperature at LIDSL (LC_LCDSSLCC) 2013 - 2016.

Variable	n	Time Period	Start and End of Time Series	τ coefficient	P-value (two-sided)
Nitrate	32	all months	Aug 2013 - Oct 2016	-0.010	0.529
Total Phosphorus	32	all months	Aug 2013 - Oct 2016	-0.010	0.529
Orthophosphate	29	all months	Jun 2014 - Oct 2016	0.020	0.164
Field Temperature	29	all months	Jun 2014 - Oct 2016	-0.005	0.843
Nitrate	14	June 15 to Sept 30	Aug 2013 - Sept 2016	-0.044	0.546
Total Phosphorus	14	June 15 to Sept 30	Aug 2013 - Sept 2016	-0.088	0.159
Orthophosphate	12	June 15 to Sept 30	Jun 2014 - Sept 2016	-0.030	0.794
Field Temperature	12	June 15 to Sept 30	Jul 2014 - Sept 2016	-0.073	0.386

Notes: The Seasonal Kendall test assesses whether the variable consistently increases or decreases over time. The test statistic is calculated by comparing months separately, then combining the comparisons into an overall test for trend. A comparison of field temperature over time (2014 to 2016) was also conducted using analysis of covariance (factor = month, covariate = year) with data collected from Aug. 1 to Sept. 10 (n = 4 samples per year). No significant differences were observed among slopes (p = 0.589) or among months (p = 0.631).

APPENDIX D

Other Supporting Information



Notes: Redfield-Brzezinski nutrient ratio for diatoms is C:Si:N:P = 106:15:16:1 (Brzezinski 1985)

Figure D.1 Boxplot of ratios of silicon to total phosphorus (Si:P) concentrations (by molar mass) for 40 reference and 59 mine-influenced areas sampled for the RAEMP September, 2015.

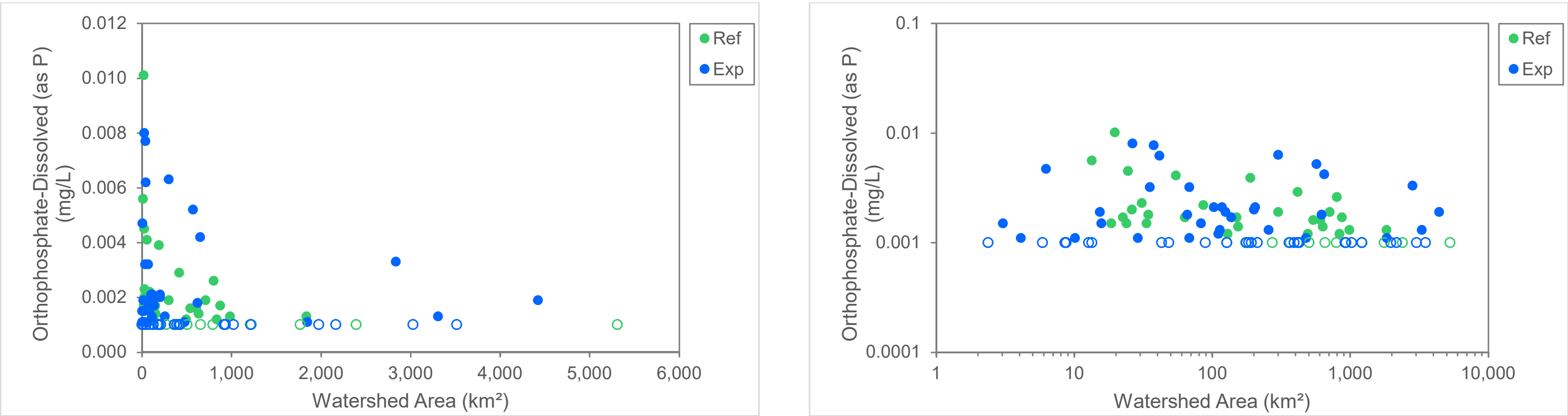


Figure D.2: Scatterplot of dissolved orthophosphate concentrations versus watershed area for locations sampled in the RAEMP, September 2015. Second panel presents same data using log scale for x and y axes.

Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL.

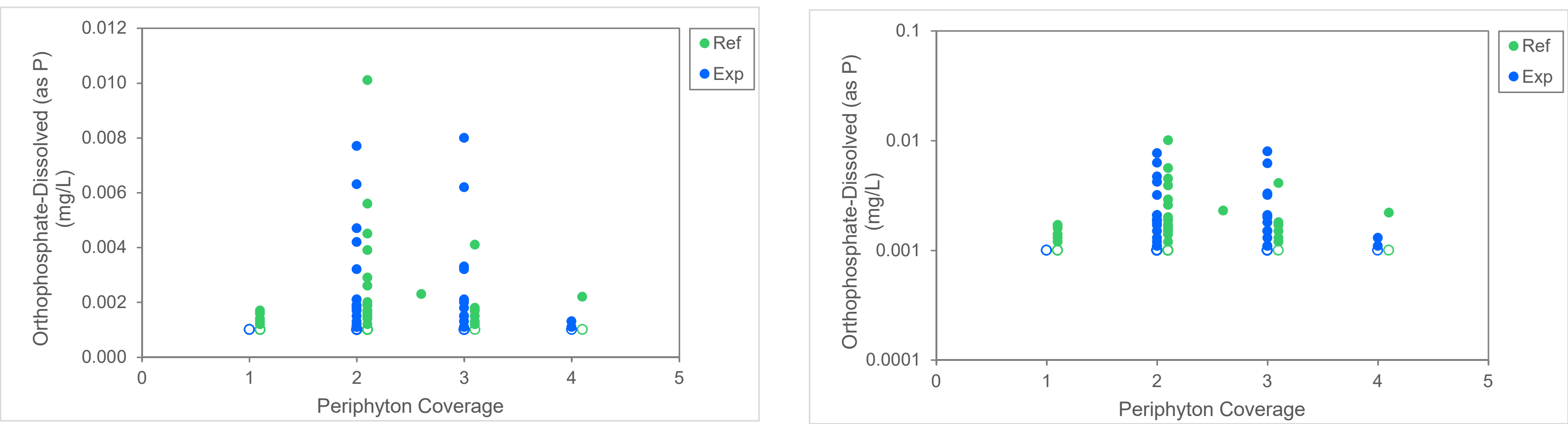


Figure D.3: Scatterplot of dissolved orthophosphate concentrations versus visual scores of periphtyon coverage for areas sampled in the RAEMP, September 2015. Second panel presents same data using log scale for y axis.

Notes: Concentrations below the detection limit (DL) are plotted as open symbols at the DL.

APPENDIX E

Phosphorus Load Balance Analysis

Memorandum

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Teck

To:	Carla Fraser; Lee Wilm; Patti Orr	Date:	April 19, 2017
From:	Ally Wade	Cc:	Kirsten Gillespie
Subject:	LCO Phosphorous Load Balance		

Introduction

The West Line Creek Active Water Treatment Facility (WLC AWTF) is located at Teck's Line Creek Operation (LCO). It is a biological treatment plant which removes selenium and nitrate from West Line Creek (primary) and Line Creek (secondary). The treatment plant began commissioning in November of 2015 and full operations on February 1st, 2016. The treatment process is understood to add phosphorous to the downstream receiving environment. Teck would like to understand the relative phosphorous contributions of the AWTF compared to background levels during and prior to the operation of the AWTF to determine potential environmental impact. This will support the development of an appropriate long term phosphorous monitoring plan.

A phosphorous load balance was completed using Teck's flow and water quality monitoring data at Line Creek Operation (LCO) to determine the relative contribution of the West Line Creek Active Water Treatment Facility (WLC AWTF) to phosphorous loads immediately downstream (LC_LC3), and at the LCO Compliance Point (LC_LCDSSLCC). Figure 1 below shows the locations of monitoring points used in the load balance.

Figure1. Monitoring locations used in assessment.

A chloride load balance was completed in parallel using the same locations on the same days. Chloride is also added by the AWTF and understood to behave conservatively. It is used in this analysis as an indicator of how well mass should be expected to balance within this particular system. A poor chloride mass balance could indicate that mass is being added or lost and not captured at a monitoring point and can also be used to identify expected data variability in the phosphorous load balance.

Methods

Data for the locations in Figure 1 were pulled from Teck's EQuIS database on March 14, 2017. Final continuous flow monitoring data was also pulled from FlowWorks and WLC AWTF flow data was obtained by email from plant personnel.

Chloride and phosphorous grab samples are collected at least monthly at all locations although not necessarily on the same day. Flow data are collected continuously using water level measurements and a stage discharge relationship at LC_LC3. Flow measurements at LC_WLC and at the AWTF intake are collected continuously at a v- notch weir and a pipe respectively. Spot flow measurements are collected at LC_SLC and LC_LCDSSLCC. Flows at LC_LCUSWLC are calculated as the flow at LC_LC3 minus the flow from LC_WLC. Flow data quality is variable and flows measured using engineered structures (ie. LC_WLC and AWTF intake) are expected to be more accurate then those measured across natural channels.

AWTF flows are measured at the intake and outfall of the plant. The flow meter that measures AWTF outflow was configured to account for some internal plant recycle rates in 2016 which confound the flow volume. A more accurate measurement of plant throughput is obtained from intake flow measurements. This load balance is calculated under the assumption that when the AWTF is operating in steady state, flow in is equal to flow out. When the plant is not operating in steady state, this may introduce some uncertainty into the calculations.

All available data from January 1, 2015 to February 14, 2017 was included initially. To minimize sources of error, calculations were completed only on days for which a chloride, phosphorous and flow measurement were available at all locations. If multiple loads were available in one month, loads calculated were averaged to represent that month. This was done to aid data interpretation of seasonal trends and ensure some months were not over represented which may visually bias the presentation of the data.

Figure 2 shows a block flow diagram of the flow areas used in the assessment. Days were identified when a flow and concentration measurement were available for all points on the same day. Influent loads (shown as WLC to AWTF and LC to AWTF in Figure 2) were calculated and subtracted from the calculated AWTF effluent load to isolate the contribution from the WLC AWTF and avoid double counting load downstream. Loads from contributing sources (blue boxes) and the AWTF (orange box) were summed and compared to load calculated from measured flow and concentrations at LC_LC3 and LC_LCDSSLCC.

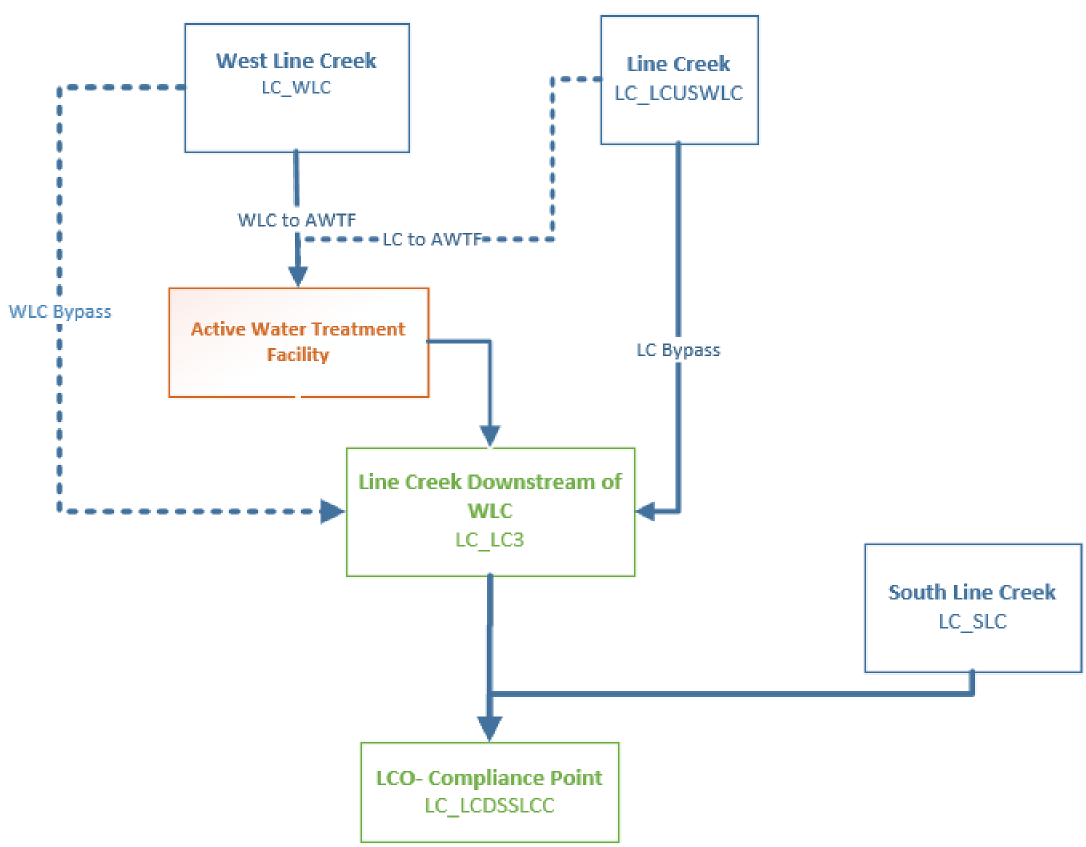

Figure 2. Flow diagram of monitoring locations used in the assessment

Results

Results of the chloride load balance are used to give context to the phosphorous load balance results and are presented first. In Figures 3 and 4 below, load calculated based on monitoring data at the downstream locations are shown as black horizontal bars. Summed loads from upstream are shown as columns and coloured to show the relative contribution of each source. Measurements for most months were available in 2015 prior to the operation of the AWTF and are shown in figures 3 and 4 for comparison.

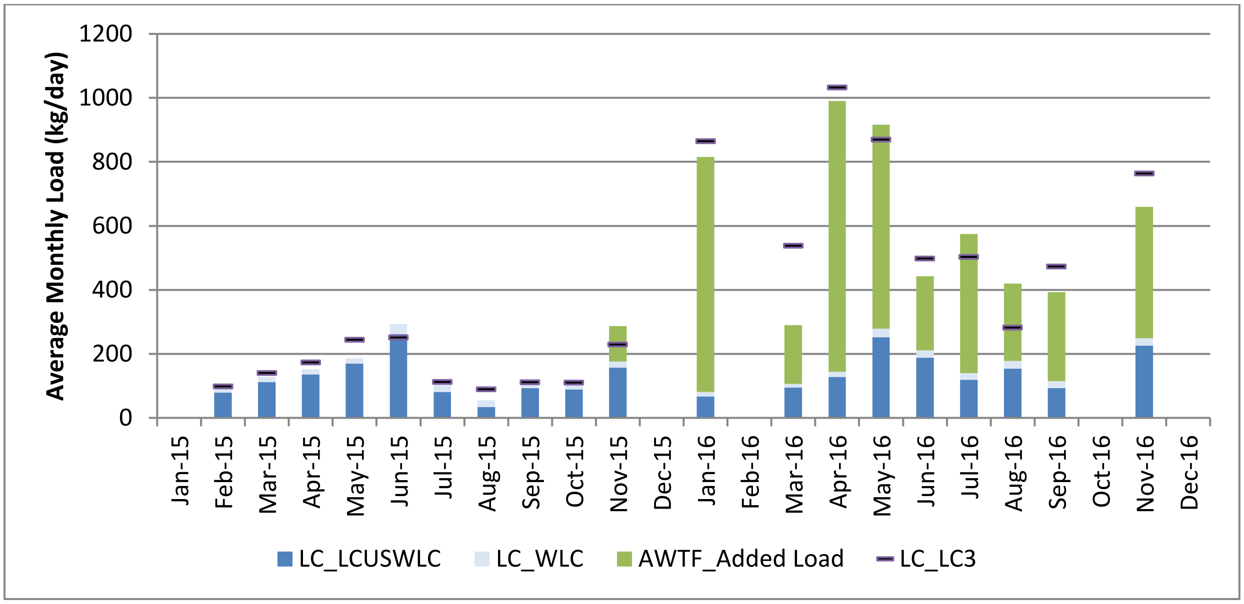

Figure 3. Chloride load balance at LC_LC3

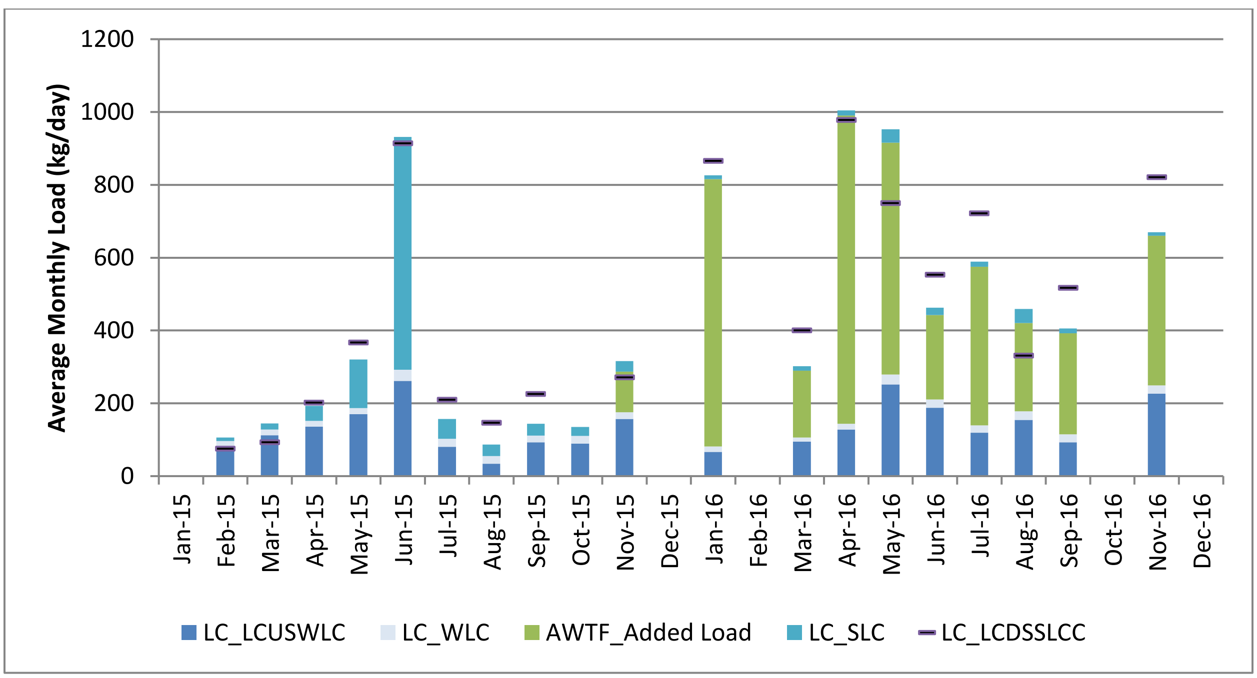

Figure 4. Chloride Load balance at the LCO Compliance Point (LC_LCDSSLCC)

The chloride balance shown in Figures 2 and 3 indicate that there is variability in how well the load balances. In general, loads seems to balance better prior to the operation of the treatment plant. This may be an indication that the AWTF was not operating in steady state for the periods of interest or that loads fluctuate within the course of a day and a finer timescale calculation is needed. Loads calculated from measured flows and concentrations at LC_LC3 and LC_LCDSSLCC are less than the sums of upstream loads during high flow periods in May and August and more than or close during the rest of the year.

The general agreement between summed and calculated downstream loads prior in 2015 indicates that the monitoring points upstream of the AWTF (LC_WLC, LC_LCUSWLC) are capturing most or all of the load contributing to the downstream receiving environment (LC_LC3 and LC_LCDSSLCC). The variability in the balance in 2016 indicates that load is not consistently being missed, which means the discrepancies are likely related to time of monitoring and the combination of using inflow data with outflow concentrations rather than missing and load sources. If phosphorous is conserved in the system, the phosphorous load balance results should look similar to those the chloride balance results.

Results of the phosphorous load balance are presented in Figure 4 and 5 in the same way as chloride results. Phosphorous load calculated based on monitoring data at the downstream locations are shown as black horizontal bars. Summed loads from upstream are shown as columns and coloured to show the relative contribution of each source.

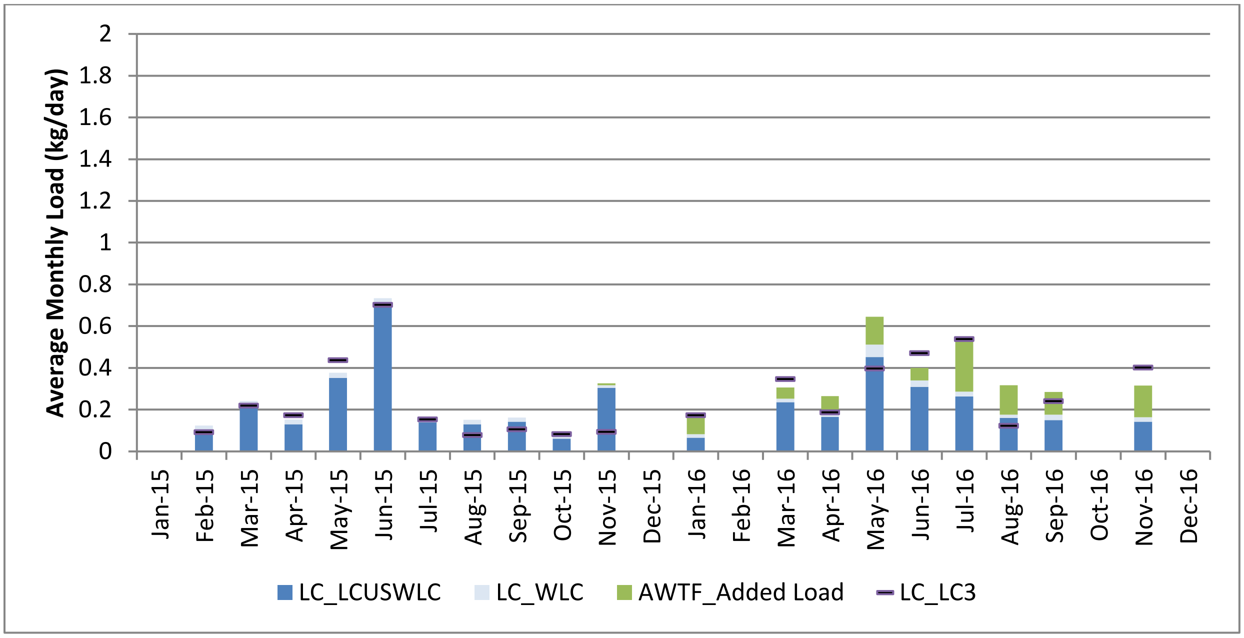

Figure 5. Phosphorous Load balance at LC_LC3

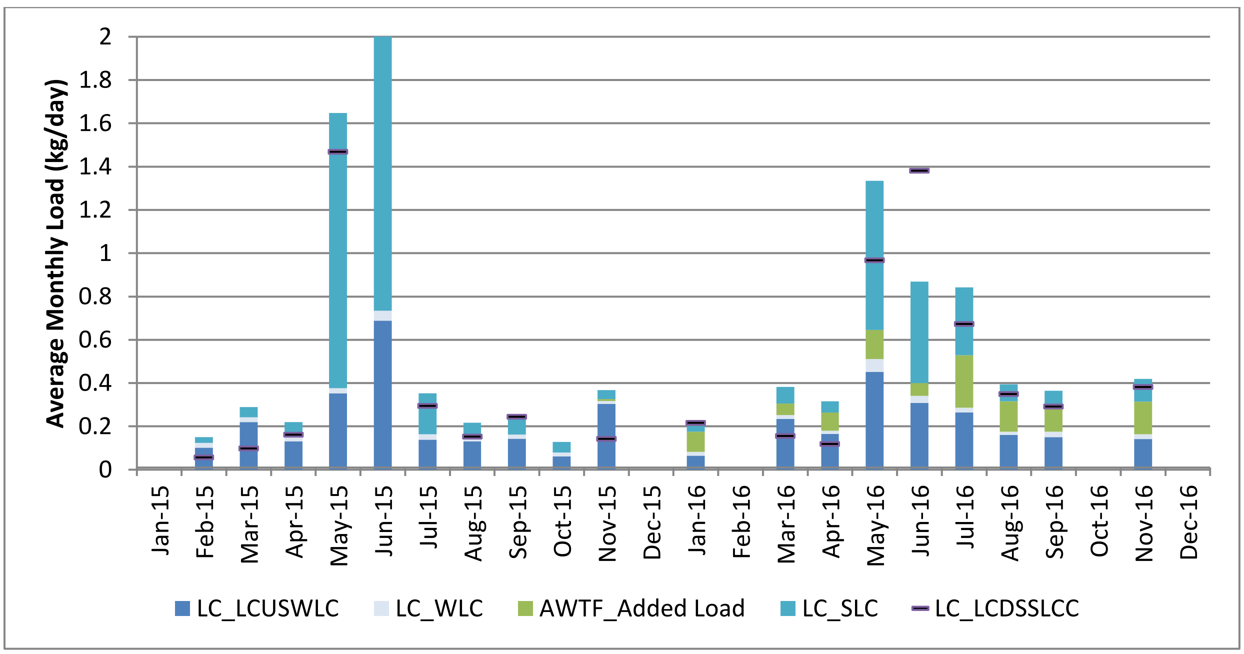

Figure 6. Phosphorous Load balance at LC_LCDSSLCC

Note that the scale has been adjusted to show the majority of the data. Phosphorous load on June 2, 2015 is calculated as 185 kg/day.

The phosphorous load balance shows similar variability to the chloride load balance although summed loads tend to overestimate loads calculated from measured data more often in the phosphorous load balance then in the chloride load balance. The percent difference between summed and calculated load for each constituent was calculated as the summed loads minus the load calculated from monitoring data, divided by the load calculated from monitoring data. A positive percent difference indicates that the sum of upstream loads is greater than the load calculated from monitoring data while a negative percent difference indicates that it is less. Table 1 and 2 show the expected difference from the chloride load balance compared to the actual difference in the phosphorous load balance at LC_LC3 and

LC_LCDSSLCC. Numbers shaded in blue indicate months where measured phosphorous loads are less than expected. This may mean that some phosphorous is consumed in the system. Grey cells indicate that no coincident data was available for use in the months.

Table 1 difference between chloride and phosphorous load balances at LC_LC3

	Percent Difference Between Summed and Measured Chloride Loads	Percent Difference Between Summed and Measured Phosphorous Loads	Relative Difference
Feb-15	-1%	35%	36%
Mar-15	-9%	11%	20%
Apr-15	-12%	-11%	0%
May-15	-24%	-14%	10%
Jun-15	17%	5%	-12%
Jul-15	-8%	7%	15%
Aug-15	-38%	95%	133%
Sep-15	0%	54%	54%
Oct-15			
Nov-15	26%	250%	224%
Dec-15			
Jan-16	-6%	2%	8%
Feb-16			
Mar-16	-46%	-12%	34%
Apr-16	-4%	42%	46%
May-16	5%	63%	57%
Jun-16	-11%	-15%	-4%
Jul-16	14%	-2%	-16%
Aug-16	49%	159%	109%
Sep-16	-17%	19%	36%
Oct-16			
Nov-16	-14%	-22%	-8%

Table 2 difference between chloride and phosphorous load balances at LC_LCDSSLCC

	Percent Difference Between Summed and Measured Chloride Loads	Percent Difference Between Summed and Measured Phosphorous Loads	Relative Difference
Feb-15	41%	160%	119%
Mar-15	57%	191%	134%
Apr-15	-5%	36%	41%
May-15	-13%	12%	25%
Jun-15	2%	-52%	-54%
Jul-15	-25%	19%	44%
Aug-15	-41%	42%	82%
Sep-15	-36%	5%	41%
Oct-15			
Nov-15	17%	158%	142%
Dec-15			
Jan-16	-5%	-7%	-2%
Feb-16			
Mar-16	-25%	145%	169%
Apr-16	3%	165%	163%
May-16	27%	38%	11%
Jun-16	-16%	-37%	-21%
Jul-16	-18%	25%	44%
Aug-16	39%	13%	-26%
Sep-16	-22%	25%	46%
Oct-16			
Nov-16	-18%	10%	28%

Loads in 2016 during operation of the AWTF were within the range of phosphorous loads in 2015, prior to operation. Flows in 2016 were lower than average with an unusually early freshet which may impact the comparison of phosphorous loads prior to and during the operation of the AWTF. Regardless, figures 5 and 6 show that the AWTF is not the primary source of phosphorous load in the receiving environment on an average annual basis, however it may be on certain months (ie. January at LC_LC3). The added load from the active water treatment facility is shown as a percentage of the total load at each of the downstream locations in Table 3 below. Grey cells indicate that no coincident data was available for use in the months.

Table 3. AWTF phosphorous contributions to receiving environment in 2016

	AWTF % load contribution at LC_LC3	AWTF % load contribution at LC_LCDSSLCC
Jan	53%	43%
Feb		
Mar	17%	14%
Apr	32%	27%
May	21%	10%
Jun	15%	7%
Jul	46%	29%
Aug	44%	36%
Sep	38%	30%
Oct		
Nov	48%	36%
Dec		
Average	35%	26%

Conclusions and recommendations

- Chloride load does not balance as well as expected during operations of the treatment plant. Flows, collected at the buffer pond outflow and paired more closely with the time a sample was collected may help improve this balance.
- Compared to the chloride balance, summed upstream phosphorous load tends to over predict loads calculated from measured data indicating that there may be some consumption and/ or other sink of phosphorous load in the system.
- Loads during the AWTF operations in 2016 were within the range of loads in 2015 prior to the operations of the AWTF. 2016 was a low flow year and upstream loads were less than those observed in 2015.
- Phosphorous Loads from the AWTF in 2016 were not the primary source of phosphorous load to the receiving environment except in January at LC_LC3 (see Table 3).