Technical Report Overview

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Report: Line Creek Local Aquatic Effects Monitoring Program (LAEMP), 2015

Overview: This report presents the 2015 results of the local aquatic effects monitoring program developed for Teck's Line Creek Operations. The program 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**

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Line Creek Local Aquatic Effects Monitoring Program (LAEMP), 2015

Prepared For:
Teck Coal Limited
Sparwood, British Columbia

Prepared By:
Minnow Environmental Inc.
Georgetown, Ontario

May 2016
(Updated July 2017)

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Prepared for:

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Prepared by:

Minnow Environmental Inc.
Georgetown, Ontario

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EXECUTIVE SUMMARY

A local aquatic effects monitoring program (LAEMP) for Teck's Line Creek Operations (LCO) was developed to monitor potential effects of the West Line Creek Selenium Active Water Treatment Facility (AWTF) on biological productivity and tissue selenium accumulation downstream from the AWTF discharge. This report presents the second year of data collection for the Line Creek LAEMP, which included monitoring of:

- Periphyton productivity based on chlorophyll-a concentrations and ash-free dry mass (AFDM);
- Bryophyte productivity based on estimation of areal coverage and shoot length;
- Benthic invertebrate biomass and tissue selenium concentrations; and
- Concentrations of phosphorus, nitrogen, and selenium forms in water.

In 2015, it was anticipated that the AWTF would recommence operations in August, so periphyton samples were collected at the various study areas along Line Creek in July 2015 for analysis of chlorophyll-a and AFDM to further characterize pre-operational conditions. However, the start-up was delayed until October 24, 2015, with full time operation commencing January 31, 2016 (after a 120-day commissioning period). As a result, the biological sampling associated with the LAEMP in September 2015 represented pre-operational conditions.

Results for primary productivity endpoints (i.e., periphyton AFDM and chlorophyll-a) were highly variable among replicates within areas. Chlorophyll-a concentrations in periphyton also varied considerably at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC) over the growing season. Chlorophyll-a concentrations in one or more samples from LILC3, LIDSL, LI8 and FO23 were greater than the MOE guideline for recreational uses (50 mg/m^2), while LILC3 and FO23 had concentrations that were also greater than the guideline for the protection of aquatic life (100 mg/m^2). However, median concentrations were less than both guidelines in all areas and years except LILC3 in 2015.

Concentrations of nutrients in water varied over the 2015 growing season, and with the exception of nitrate, did not show any obvious patterns over time or among areas. Concentrations of nitrate were generally above the MOE guideline of 3 mg/L at the mine-exposed areas, and were highest at LILC3 and decreased with distance downstream. Nitrate concentrations were lowest (and below the MOE guideline) in the reference areas. In the Fording River upstream of Line Creek, nitrate concentrations were higher than those downstream, indicating that water from Line Creek acted as a source of dilution. Nitrate concentrations in individual samples collected at the Compliance Point were consistently below the daily maximum discharge limit of 20 mg/L, but were greater than the monthly average discharge limit of 14 mg/L in February and December 2015. Concentrations of all other nutrients (i.e., total phosphorus, ortho-phosphate, nitrite, ammonia and TKN) were generally lowest in reference areas, and within the Fording River, were similar to or lower than those at LI8.

Selenium concentrations in water at the Compliance Point were below the daily maximum and monthly average discharge limits throughout 2015. Selenium concentrations in water (primarily present as dissolved selenate) and benthic invertebrates showed a similar spatial pattern among areas, with highest concentrations occurring in Line Creek closest to the mine (LILC3) and progressively lower concentrations downstream at LIDSL followed by LI8. Single-taxon invertebrate samples (i.e., Ephemeroptera or Rhyacophilidae) collected over two years showed variability similar to or greater than composite samples.

The LAEMP will be repeated annually for at least two more years to monitor potential changes in the receiving environment associated with the AWTF discharge. Based on the analysis of data collected during the first two years of the LAEMP (which showed redundancy in the biological components being monitored for assessment of productivity; Appendix B), the 2016 study design has been refined to focus on analysis of water quality and benthic invertebrates community structure, biomass and tissue selenium (see Minnow 2016 for the detailed design). High within-area and temporal variability for periphyton chlorophyll-a results make this an insensitive endpoint for detecting changes in productivity over time. Also, chlorophyll-a concentrations were above previously defined trigger levels for management actions prior to water treatment being initiated (Golder and Minnow 2014; triggers applicable only during AWTF operation). Therefore, periphyton chlorophyll-a monitoring will no longer be part of the LAEMP and new triggers for management responses will need to be developed.

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1.0 INTRODUCTION

1.1 Background

Through issuance of Draft Permit 5353 and associated communications, and later through Permit 107517, the British Columbia Ministry of the Environment (MOE) requested that Teck Coal Limited (Teck) develop a local aquatic effects monitoring program (LAEMP) related to the commissioning of the West Line Creek Selenium Active Water Treatment Facility (AWTF) at Teck's Line Creek Operations (LCO; Figure 1.1). The fluidized bed reactor technology used at the AWTF for selenium removal requires the addition of phosphorus to the treatment process. Although the 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 AWTF discharge (Golder and Minnow 2014). MOE 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 from the AWTF.

Another concern expressed by MOE related to the AWTF is potential change in the form of selenium that will be released into Line Creek from the AWTF. 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 AWTF, selenium will be removed via uptake into microorganisms within the treatment system. Losses of selenium from the AWTF are expected to be minimal, but 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). It is expected that lower concentrations of total selenium (organic and inorganic) will occur in Line Creek as a result of selenium removal at the AWTF; however, chemically reduced forms of selenium (selenite and organoselenium) are more bioavailable and readily accumulated by aquatic biota than selenate (Ogle et al. 1988; Riedel et al. 1996; Stewart et al. 2010).

The Line Creek LAEMP, described in this document, was designed to monitor biological productivity and tissue selenium accumulation downstream from the AWTF discharge. The LAEMP includes monitoring for the following main components:

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

MAP INFORMATION
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Figure 1.1: Teck's Line Creek Operations within the Elk River Valley, Southeast British Columbia

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- Bryophyte productivity based on estimation of areal coverage and shoot length;
- Benthic invertebrate biomass and tissue selenium concentrations; and
- Concentrations of phosphorus, nitrogen, and selenium forms in water.

The LAEMP is repeated annually and the first study was conducted in 2014. Assessment of potential mine-related effects on the aquatic environment on a broader spatial scale is also completed every three years (most recently in 2015) as part of the Regional Aquatic Effects Monitoring Program (RAEMP). Results from each cycle of the RAEMP will be incorporated into the next LAEMP report after the RAEMP report has been submitted (i.e., 2015 RAEMP results will be summarized in the Line Creek LAEMP report for data collected in 2016).

Evaluation of bull trout spawning in Line Creek is also conducted annually and reported under separate cover (e.g., Lotic 2014). This information will also be summarized in future LAEMP reports.

1.2 Summary of 2014 Results

In 2014, biological sampling occurred between September 2nd and 8th, shortly after the AWTF began discharging during commissioning (August 27, 2014). Primary and secondary productivity endpoints revealed a pattern of highest productivity in Line Creek nearest to LCO and progressively lessening farther downstream. The monitoring area located closest to the mouth of Line Creek (LI8) showed slightly greater primary and secondary production than observed at reference areas at the south fork of upper Line Creek (LI24) and at South Line Creek (SLINE). Selenium concentrations in composite and single-taxon (Ephemeroptera and *Rhyacophila* sp.) benthic invertebrate tissue samples showed a similar pattern, with selenium concentrations decreasing with distance from the AWTF. Invertebrates at the most downstream mine-exposed area on Line Creek (LI8) had tissue selenium concentrations similar to those observed at the reference areas. Concentrations of various phosphorus, nitrogen, and selenium forms in water also generally reflected the pattern observed for biological endpoints, with decreasing concentrations progressing downstream from LCO and the AWTF. An exception was total Kjeldahl nitrogen (TKN) which was highest at reference areas during the growing season (i.e., June 15 to September 30).

Shortly after completion of the LAEMP in September, the AWTF was shut down (on October 17, 2014) as a precautionary measure in response to observations of fish mortality downstream of the AWTF. Regulators, including MOE, were immediately notified of the incident. A comprehensive internal investigation was completed and associated corrective actions were taken.

1.3 2015 AWTF Operations and LAEMP Implementation

In 2015, it was anticipated that the AWTF would recommence operations in August, so periphyton samples were collected at the various study areas along Line Creek in July 2015 for analysis of chlorophyll-a and AFDM to further characterize pre-operational conditions and meet Permit 107517 Section 3.4.1.1 requirements. However, the start-up was delayed until October 24^{th} (with a 120 day commissioning period starting October 4^{th}, and recirculation until October 24^{th}). The commissioning period ended on January 31, 2016, after which, the AWTF has been operating full time. As a result, the biological sampling associated with the LAEMP in September 2015 represented pre-operational conditions. Thus the data presented in this report are considered baseline with respect to the evaluation of potential effects of the AWTF on the receiving environment.

2.0 METHODS

2.1 Overview

Water sampling associated with Line Creek and the AWTF Operations was completed annually, as required under Permit 5353 and Permit 107517 (Table 2.1).

Biological samples were collected at three mine-exposed areas on Line Creek (LILC3, LIDSL, LI8), two reference areas (south fork of upper Line Creek, also called Tornado Creek [LI24] and South Line Creek [SLINE]), and two areas of the Fording River upstream (FOUL) and downstream (FO23) of Line Creek (Figure 2.1; Table 2.2). Biological samples associated with the LAEMP (i.e., periphyton and benthic invertebrates) were collected from September 10th to 17th, 2015, to correspond with the 2014 LAEMP sampling program and the 2015 RAEMP. Chlorophyll-a and ash-free dry mass samples were also collected from July 7th to 9th, 2015 at the mine-exposed areas on Line Creek (LILC3, LIDSL, LI8) and associated reference areas (LI24 and SLINE).

In accordance with permit condition 3.4.1.1 of 107517, five periphyton samples for chlorophyll-a analysis were collected at LIDSL (the Compliance Point, also referred to as LC_LCDSSLCC) on three occasions during the growing season (i.e., July 15th to September 30th). The sampling dates included August 10th, August 25th and September 12th (with September 12th samples being part of the LAEMP).

As indicated above, sampling associated with the RAEMP was also conducted in September 2015. Since the reporting deadline for the RAEMP is May 31, 2017, a summary of the findings associated with Line Creek with be included in the 2017 Line Creek LAEMP report to be submitted on the same date.

2.2 Water Chemistry

The following routine water quality monitoring data collected by Teck (January to December, 2015) were downloaded from Teck's EQuIS database for stations corresponding to biological sampling areas (Table 2.1 and Figure 2.1):

- Nutrient concentrations (nitrate, nitrite, ammonia, total Kjeldahl nitrogen, total phosphorus, dissolved phosphorus, and ortho-phosphate);

- Total and dissolved selenium concentrations and selenium speciation data (i.e., concentrations of selenate, selenite, selenocyanate, methylseleninic acid, and selenomethionine).

Table 2.1: Summary of water quality monitoring associated with the LAEMP.

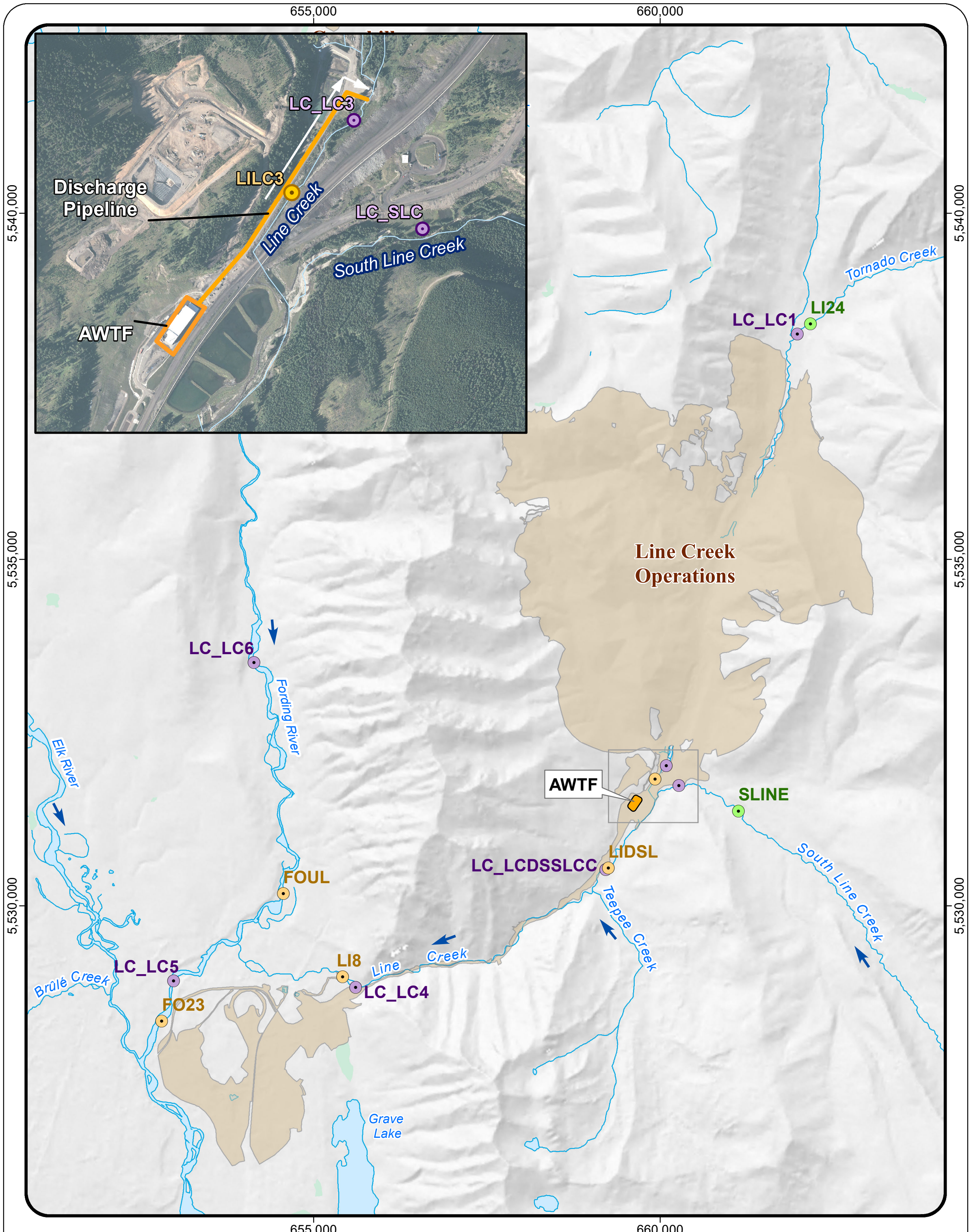
Location Description	Water Station ID (associated biological Station ID in brackets)	EMS Number	UTM (11U)		Water Quality Samples			
			Easting	Northing	Designation	Field Parameters[a]	Selenium Speciation[b]	All other parameters required under mine permits[c]
Line Creek upstream of LCO	LC_LC1 (LI24)	E216142	661979	5538254	Reference	T	T	W/M
South Line Creek	LC_SLC (SLINE)	E282149	660271	5531737	Reference	T	T	M
Line Creek ~200 m downstream of the AWTF	LC_LC3 (LILC3)	200337	660090	5532023	Exposed	T	T	W/M
Line Creek downstream South Line Creek	LC_LCDSSLCC (LIDSL)	E297110	659218	5530522	Exposed	T	T	M
Line Creek upstream of the process plant and ~5,550 m downstream of the AWTF	LC_LC4 (LI8)	200044	655604	5528824	Exposed	T	T	W/M
Fording River upstream Line Creek	LC_LC6 (FOUL)	200338	654140	5533513	Exposed	M	-	M
Fording River downstream Line Creek	LC_LC5 (FO23)	200028	652977	5528919	Exposed	M	-	W/M

T - twice monthly; M - monthly; W - weekly during freshet (March 15 to July 15).

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

[b] Selenate, selenite, organoselenium - June 15 - September 30th only.

[c] 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.



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MAP INFORMATION
Map Projection: UTM Zone 11N NAD 1983
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- Exposed Biological Sampling Area
- Reference Biological Sampling Area
- Teck Water Quality Station
- Active Water Treatment Facility (AWTF)
- Teck Coal Mine Operation
- Waterbody
- Wetland
- Watercourse
- Water Flow Direction

Figure 2.1: Line Creek LAEMP Biological Monitoring Areas and Teck Water Monitoring Stations, 2015

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Table 2.2: Summary of biological monitoring associated with the LAEMP in 2015.

Location Description		Biological Sampling			July 7 - 9, 2015		August 10, 2015	August 25, 2015	September 10 - 17, 2015							
					Periphyton		Periphyton	Periphyton	Periphyton		Bryophytes		Benthic Invertebrates			
		Station ID (Teck water quality Station ID in brackets)	UTM (11U) Easting	UTM (11U) Northing	Chlorophyll-a (# of samples)	Ash-free dry mass (# of samples)	Chlorophyll-a (# of samples)	Chlorophyll-a (# of samples)	Chlorophyll-a (# of samples)	Ash-free dry mass (# of samples)	Areal coverage (# of transects)	Shoot length (# of transects)	Biomass (# of samples)	Ephemeroptera Selenium (# of samples)	Rhyacophilidae Selenium (# of samples)	Composite-taxon Selenium (# of samples)
Reference	Tornado Creek (south fork of upper Line Creek)	LI24 (LC_LC1)	661968	5538259	10	10	-	-	10	10	3	3	10	1	1	1
	South Line Creek	SLINE (LC_SLC)	660980	5531449	10	10	-	-	10	10	3	3	10	1	1	1
Mine-exposed	Line Creek upstream South Line Creek and downstream AWTF discharge	LILC3 (LC_LC3)	659947	5531859	10	10	-	-	10	10	3	3	10	1	1	1
	Line Creek downstream South Line Creek and AWTF discharge	LIDSL (LC_LCDSSLCC)	659320	5530619	10	10	5	5	10	10	3	3	10	1	1	1
	Line Creek near mouth	LI8 (LC_LC4)	655421	5528971	10	10	-	-	10	10	3	3	10	1	1	1
	Fording River upstream Line Creek	FOUL (LC_LC6)	654530	5530162	-	-	-	-	10	10	-	-	-	-	-	1
	Fording River downstream Line Creek	FO23 (LC_LC5)	652995	5528937	-	-	-	-	10	10	-	-	-	-	-	1

Water samples were collected and analyzed by Teck at LC_LC1, LC_SLC, LC_LC3, LC_LC4, and LC_LCDSSLCC according to requirements set forth in Permit 5353 and 107517 (Table 2.1). These water monitoring stations correspond with biological monitoring areas LI24, SLINE, LILC3, LI8, and LIDSL, respectively (Table 2.1 and Figure 2.1). Two stations on the Fording River were also monitored upstream and downstream from the confluence with Line Creek - LC_LC6 (FOUL) and LC_LC5 (FO23), respectively. Detailed information regarding sampling methods and results of water quality monitoring that are not presented in this report can be found in the Annual Water Quality Monitoring Reports for Permit 107517 and PE5353 (Teck 2016a,b).

Routine water quality monitoring samples collected by Teck were analyzed at ALS Environmental in Burnaby, BC. Samples collected for selenium speciation were analyzed by Applied Speciation and Consulting, LCC, located in Bothell, Washington. Quality assurance and quality control (QA/QC) associated with water sampling was reported by Teck (Teck 2016a,b).

2.3 Primary Production

2.3.1 Periphyton

Periphyton samples were collected from 5 or 10 stations located a minimum of 5 m apart in each sampling area, depending on the sampling period (Table 2.2). At each station, a total of five rocks of similar size were sampled (i.e., large enough to collect separate samples for both chlorophyll-a and AFDM analyses) and the periphyton scrapings from the five rocks were combined to form a single composite sample. The five sampling areas associated with Line Creek were LILC3, LIDSL, and LI8 (mine-exposed) and LI24 and SLINE (reference; Table 2.2). Additional samples were collected in the Fording River upstream (FOUL) and downstream (FO23) of Line Creek during the main LAEMP sampling program in September (Table 2.2; Figure 2.1). Periphyton samples were collected from riffle habitats with a water depth of at least 5 cm, near-bottom water velocity of approximately 0.1-0.4 m/s, 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., too small, 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.

After a suitable rock was selected, the technician returned to shore with the rock and placed a thin acetate template with a 4 cm2 opening on the rock, and scraped all periphyton from the surface of the rock within the opening using a scalpel. This process was repeated with four additional 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 (in July and September; Table 2.2). 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 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)

2.3.2 Bryophytes

Bryophyte productivity was assessed at the three mine-exposed areas on Line Creek (LILC3, LIDSL, and LI8) in September. Reference areas were not sampled as bryophytes were not present (as expected based on the results of the 2014 sampling program). Bryophyte growth was measured along three transects across the stream wetted-width, each a minimum of 10 m apart (Table 2.2; Figure 2.1). Transect locations were chosen in the field to have similar habitat characteristics to those targeted for periphyton sampling (e.g., uniform substrate, large flat rocks, etc.). Transects were marked by securing a measuring tape to a stable object on each stream bank to ensure a straight line slightly above the water surface that would not move during sampling. Beginning at the stream edge, the technician moved towards the first totally submerged rock that was located directly under the transect line, and was 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 was covered by bryophytes was recorded (to the nearest 10%). The depth of the bryophyte growth at the center of each bryophyte patch was measured using a ruler (i.e., the plant length extending out from the rock to the nearest millimeter). The percent bryophyte coverage and depth of bryophyte growth on all large, submerged rocks located along the transect was recorded for each of the three transects in the three areas sampled.

2.4 Secondary Productivity

Benthic invertebrates were collected using a Hess sampler with 500 µm mesh, for measurement of biomass relative to the area sampled. Ten stations were sampled at each of the five Line Creek areas (LI24, SLINE, LILC3, LIDSL, and LI8) in September (Table 2.2; Figure 2.1). Stations were located a minimum of 5 m apart to ensure they were representative of the same overall area from which periphyton samples were collected. 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 collected with the sample 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 Tissue Selenium Concentrations (Invertebrates)

Benthic invertebrate tissue samples were collected for selenium analysis in September (Table 2.2; Figure 2.1) using the CABIN kick and sweep sampling method (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 (400 µm mesh) being held immediately downstream from the technician's feet, the detritus and invertebrates disturbed from the substrate were passively collected in the kick-net by the stream current. After sampling, the technician 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 plastic trays. 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 concentrations of consumer organisms (e.g., fish, birds).
- Separate samples of two representative benthic invertebrate taxa (i.e., Ephemeroptera and Rhyacophilidae). Analysis of representative taxa was anticipated to minimize variability relative to samples composed of different proportions of multiple taxa, thereby facilitating detection of potential trends in selenium concentrations over time.

Two single-taxon samples, plus one composite sample, were collected from all five sampling areas on Line Creek (Table 2.2). 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 single-taxon 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 cryovials 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 University of Missouri-Columbia Research Reactor Center (MURR) in Columbia, Missouri, where they were freeze-dried and analyzed for selenium using Neutron Activation Analysis (NAA). Results were reported on a dry weight (dw) basis, along with moisture content (based on the difference between wet and freeze-dried sample weights) to allow conversion to wet weight values if required. Certified reference material samples (NIST SRM 1577 Bovine Liver) analyzed concurrent with tissue samples for quality control purposes, met the established recovery criteria of between 70 and 130% (n = 6; mean ± SD = 1.06 ± 0.22 mg/kg compared to the certified value of 1.1 ± 0.1 mg/kg). Duplicate analysis of each of the samples also revealed an average relative percent difference of 4.5% (range = 0.06% to 12.5%) which is well below the data quality objective of 30%, as defined in the RAEMP study design; Minnow 2015).

2.6 Data Analysis

2.6.1 Primary Production

Periphyton chlorophyll-a and AFDM data were converted to units per m^2 by dividing the total AFDM and chlorophyll-a values reported by the laboratory with the surface area sampled (20 cm^2) at each station. Mean values (n = 10) and ranges (maximum and minimum value) for chlorophyll-a and AFDM were plotted for all seven study areas. Mine-exposed areas were compared to reference areas on Line Creek and FO23 was compared to FOUL. Chlorophyll-a results were also compared to the MOE guidelines for the protection of aquatic life (100 mg/m^2) and recreational uses (50 mg/m^2) (MOE 2001), and triggers for management action (Table 2.3) at the Compliance Point (i.e., LIDSL). The management action triggers were originally developed in 2014 in response to MOE concerns related to release of excess phosphorus from the AWTF (Golder and Minnow 2014). However, since the AWTF was not operating in 2015 when sampling was occurring, triggers and associated management actions were not applicable. One AFDM sample from LI24 having an inordinately high value (i.e., LI24-9 = 128 g/m^2) was excluded from the data analysis as the result was suspected to be related to laboratory sample handling error (e.g., a different sample was inadvertently substituted for LI24-9 in the laboratory report). Field photographs indicated that the rocks sampled at LI24-9 had similar periphyton coverage to all other rocks sampled at LI24 (Appendix Figure A.1), and thus could not have had an AFDM result of 128 g/m^2. Chlorophyll-a results corroborated the photographic evidence, with similar results reported for all stations at LI24 (including LI24-9; Appendix Table A.1).

Boxplots of the transect (n = 3) percent bryophyte coverage and shoot length per rock with ranges (maximum and minimum value) were prepared for each of the three mine-exposed areas on Line Creek. Stream transects were also divided into seven equal segments to

Table 2.3: Triggers for management response based on chlorophyll-a concentrations in periphyton at the compliance location (LIDSL / LC_LCDSSLCC; from Golder and Minnow 2014).

Average 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. standardize visual comparisons (bar charts) of bryophyte coverage and growth among areas having different wetted widths.

Patterns in primary production among areas were evaluated relative to nutrient concentrations in water through visual comparison of productivity plots and nutrient concentration scatterplots. Nutrient concentrations in water were also evaluated relative to MOE guidelines (where applicable), and nitrate concentrations were evaluated relative to discharge limits from Permit 107517 at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC). Primary productivity data from 2013 and 2014 were also shown with 2015 data, where available.

2.6.2 Secondary Production

Benthic invertebrate biomass data (preserved wet weight) were standardized by area sampled (i.e., per m^2). Boxplots showing median and range (minimum and maximum) benthic invertebrate biomass values were prepared for each of the five Line Creek areas (three mine-exposed and two reference areas, n=10 samples per area). The relative percent of biomass associated with taxonomic groups and dominant taxa (i.e., taxa comprising at least 5% of the total biomass at one or more stations) were displayed in stacked bar charts. Biomass data from 2014 were also shown for comparison to 2015 data.

2.6.3 Tissue Selenium Concentrations

Selenium concentrations in different sample types (i.e., composite, Ephemeroptera, and Rhyacophilidae) were compared among the five sampling areas of Line Creek through visual inspection of data plots and relative to the benchmark of 11.0 µg/g dw for potential dietary effects to fish (Windward 2014) and the MOE tissue guideline of 4.0 µg/g dw. Data from 2012 and 2014 were also shown for comparison to 2015.

Through visual inspection, patterns in tissue selenium concentrations among areas were evaluated relative to concentrations of total and dissolved selenium in water (scatterplots) which in turn were evaluated relative to the different species of selenium (i.e., selenate, selenite, selenocyanate, methylseleninic acid, and selenomethionine). Selenium concentrations in water were also evaluated relative to the MOE guideline (2 µg/L), and the discharge limits from Permit 107517 at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC).

3.0 PRODUCTIVITY

3.1 Primary Productivity

3.1.1 Peryphyton

In 2015, median periphyton AFDM values were highest at LILC3 followed by LIDSL, and were lowest farther downstream at LI8 and at the two reference areas (Figure 3.1; Appendix Table A.1). The median AFDM value was also higher at the Fording River downstream from Line Creek (FO23) compared to upstream (FOUL) (Figure 3.1). Median AFDM values at the reference areas, LI8, and the Fording River in September 2015 were similar to those observed in September 2013 and 2014, with the greatest amount of variability among replicates being found at FO23 (Figure 3.1). In contrast, AFDM values at LILC3 and LIDSL were highly variable among replicates within areas and among years, with evidence of an increase in median AFDM from 2013 to 2015 at LILC3, whereas highest values at LIDSL occurred in 2014 (Figure 3.1). Median AFDM values were similar between July and September 2015 at all areas, with highest levels observed at LILC3 (Figure 3.2; Appendix Table A.2).

Median chlorophyll-a concentrations showed the same general pattern as AFDM in September 2015, with the highest values observed at LILC3, and progressively lower concentrations in Line Creek farther downstream (Figure 3.3; Appendix Table A.1). Substantial within-area variability was observed at all areas in September 2015 with the exception of LI24 and FOUL (Figure 3.3). Chlorophyll-a concentrations were highest in all areas except FOUL in September of 2015 compared to 2013 and 2014 (Figure 3.3). Chlorophyll-a concentrations at LILC3, LIDSL, LI8 and FO23 were greater than the MOE guideline for recreational uses (50 mg/m^2) in one or more samples, while periphyton collected at LILC3 and FO23 also had concentrations greater than the guideline for the protection of aquatic life (100 mg/m^2) (Figure 3.3). However, median concentrations were less than both guidelines in all areas and years except LILC3 in 2015. Median chlorophyll-a concentrations were higher in August at LILC3, LIDSL, and SLINE compared to July 2015, but were similar between months at LI24 and LI8 (Figure 3.4; Appendix Table A.2).

Triggers related to AWTF management actions were established during the initial design of the LAEMP based on periphyton chlorophyll-a concentrations (Golder and Minnow 2014; Table 2.3). When the AWTF is in operation, management actions are triggered at mean chlorophyll-a concentrations starting at 25 mg/m^2 at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC) (Table 2.3). In September 2013 and 2014, mean periphyton chlorophyll-a concentrations were less than the lowest management trigger, as was expected prior to

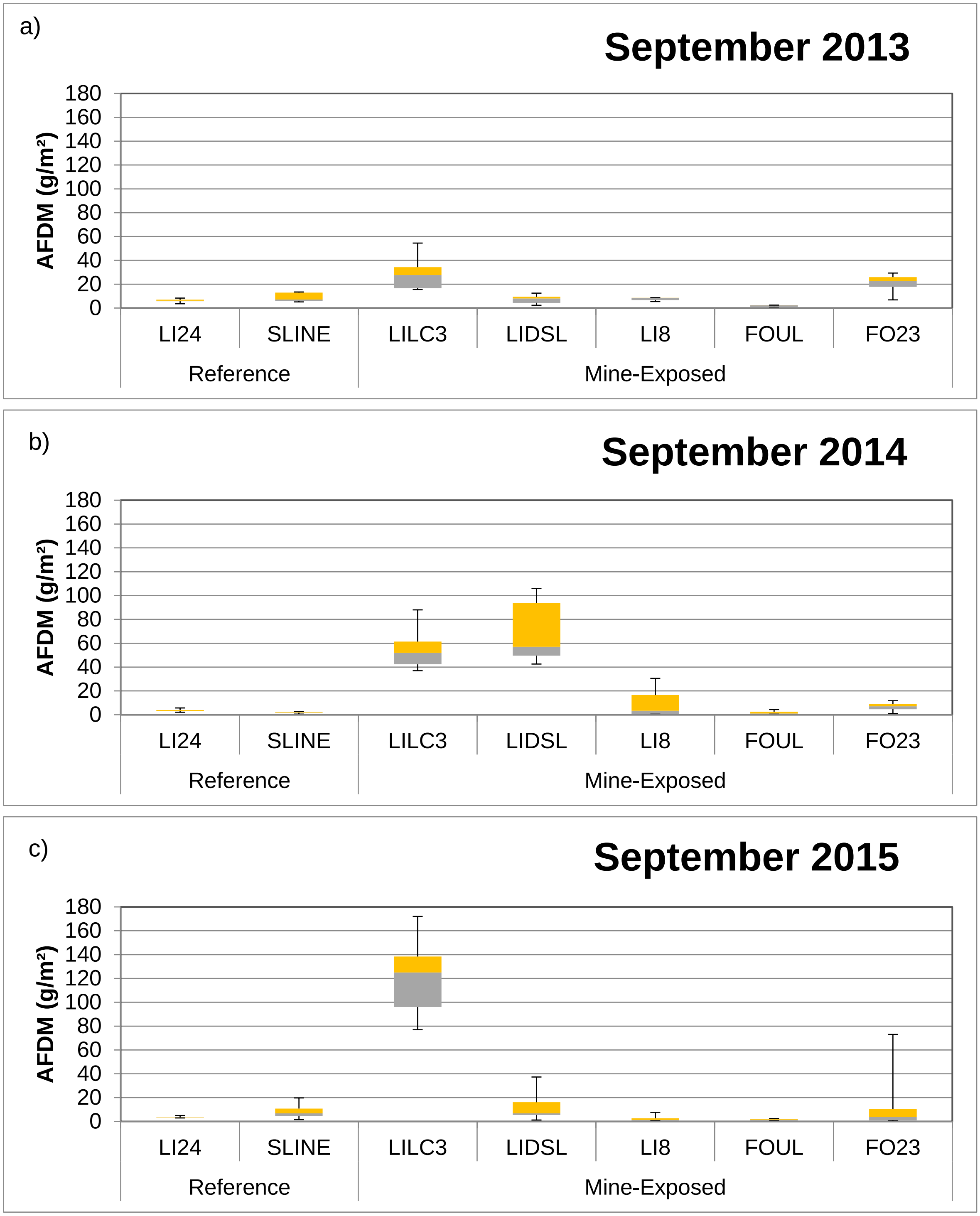
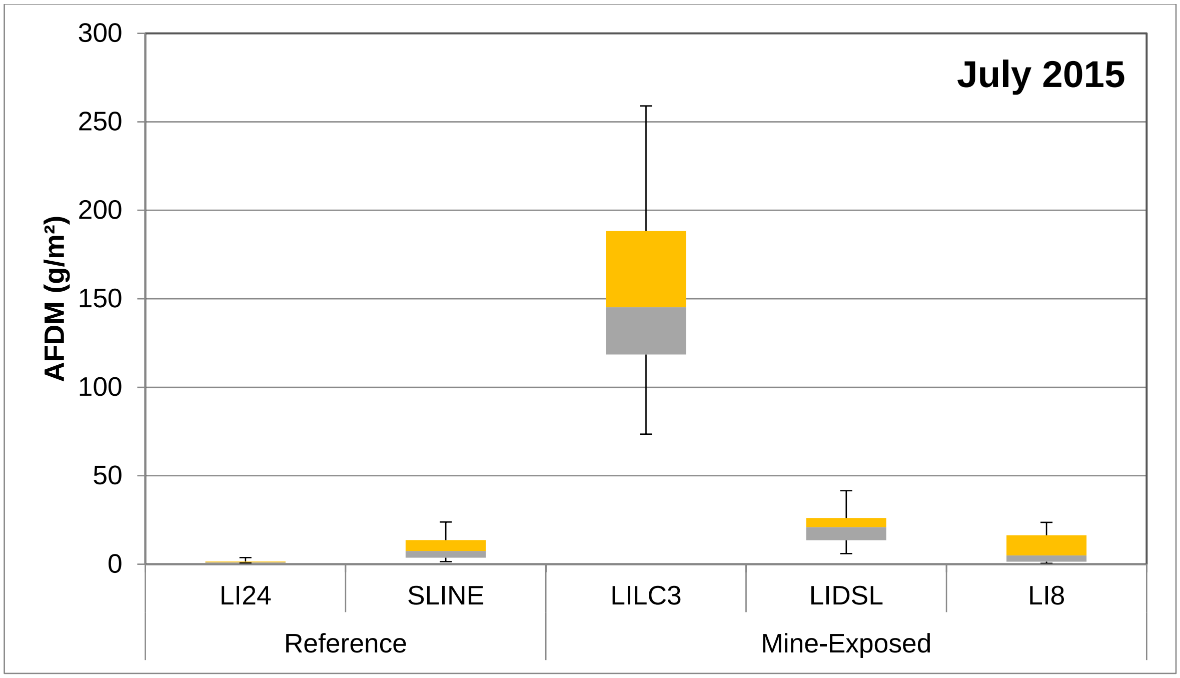


Figure 3.1: Median, 25th and 75th percentiles, and range of ash-free dry mass (AFDM) values for periphyton samples collected from areas in the Line Creek and Fording River in a) September 2013 (n = 5), b) September 2014 (n = 10), and c) September 2015 (n = 10).



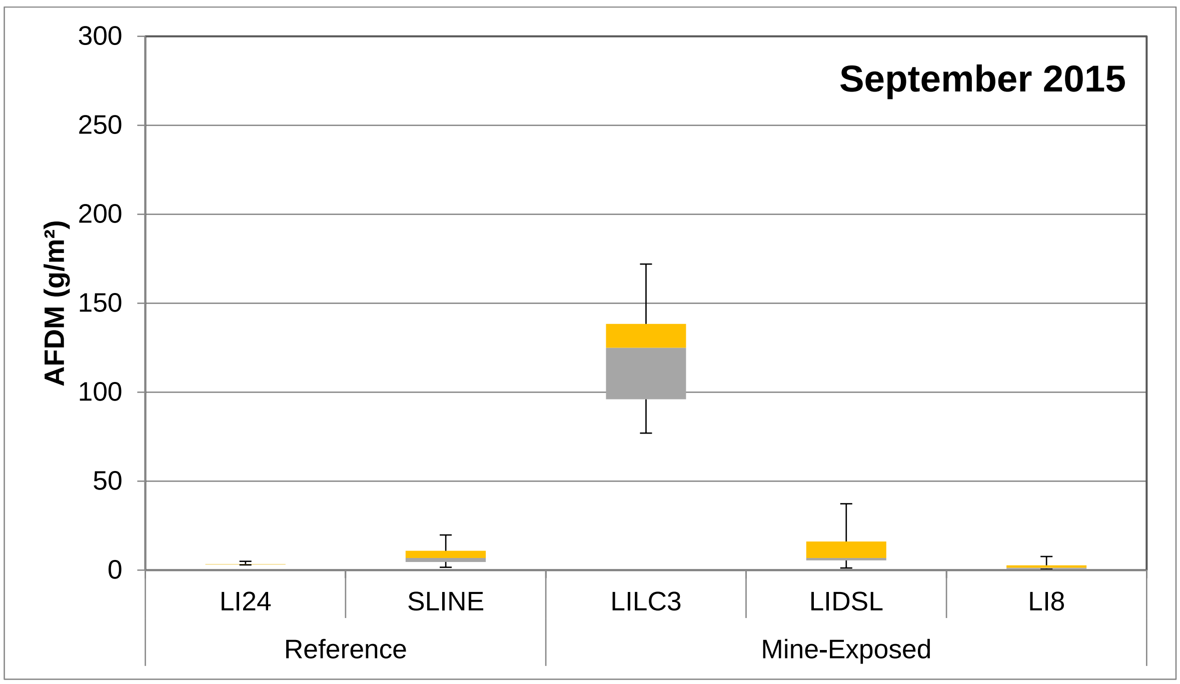


Figure 3.2: **Median, 25th and 75th percentiles, and range of ash-free dry mass (AFDM) values for periphyton samples collected from areas in Line Creek, July and September 2015.**

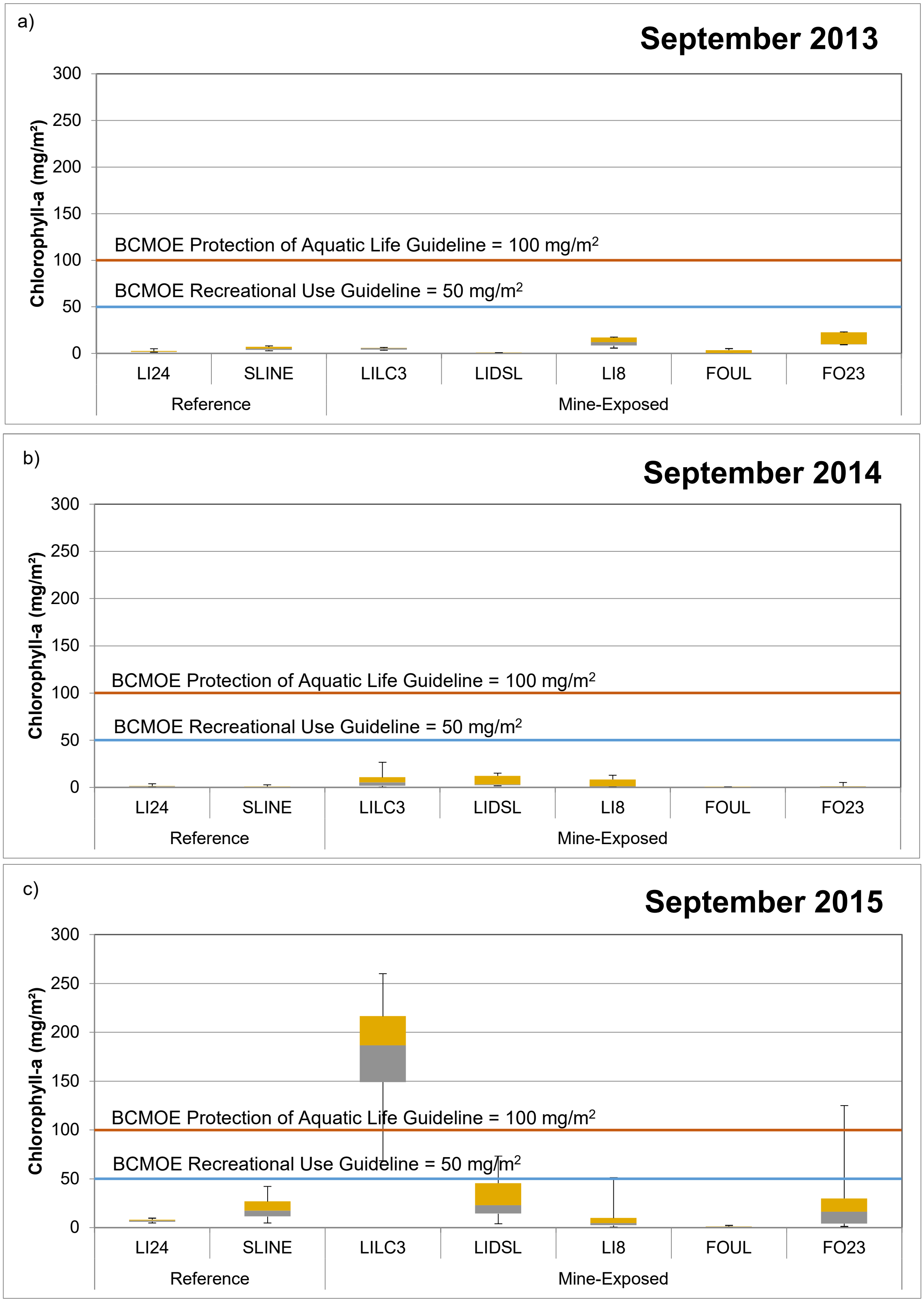


Figure 3.3: Median, 25th and 75th percentiles, and range of chlorophyll-a values for periphyton samples collected from areas in the Line Creek and Fording River in a) September 2013 (n = 5), b) September 2014 (n = 10), and c) September 2015 (n = 10).

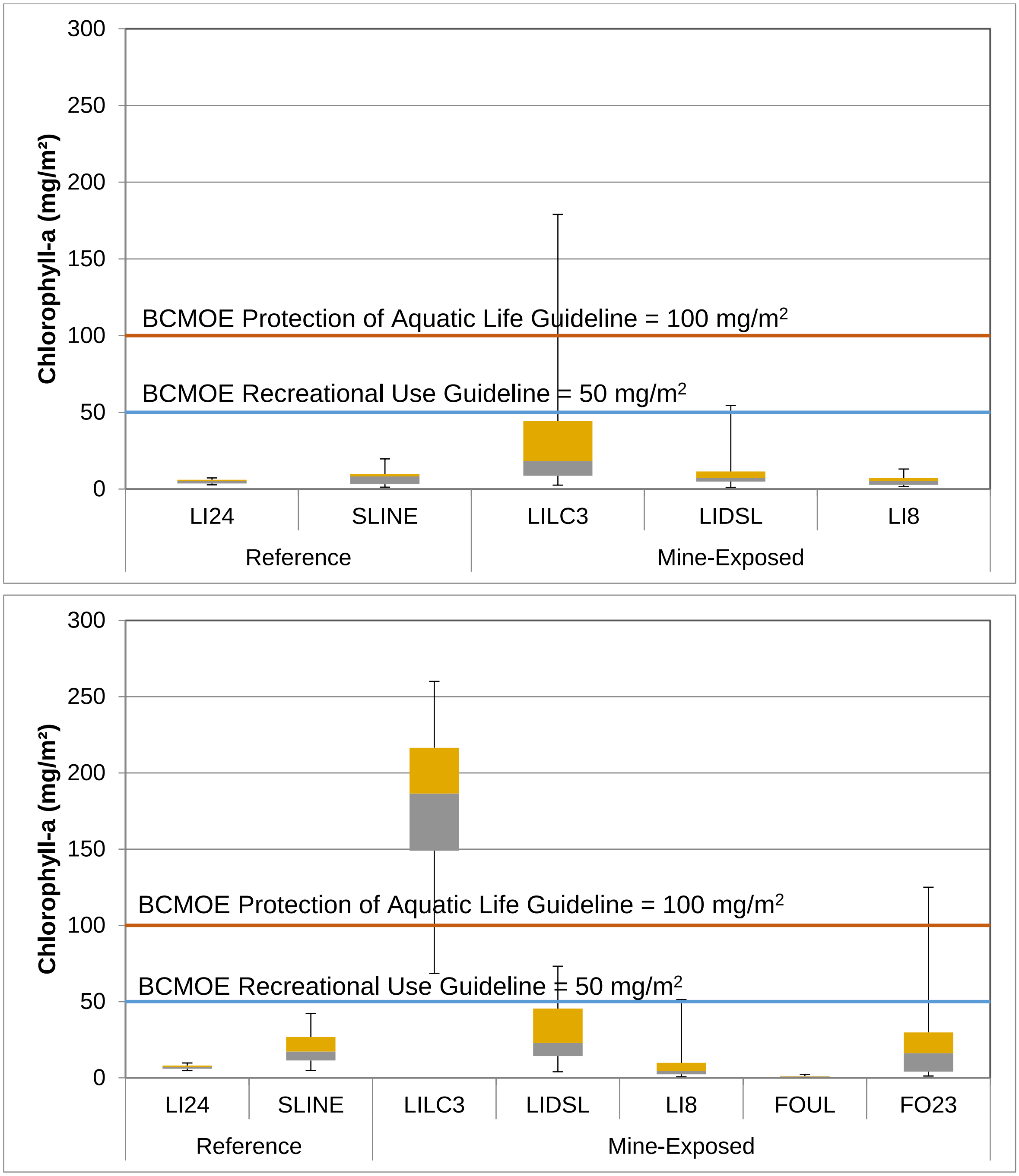


Figure 3.4: Median, 25th and 75th percentiles, and range of chlorophyll-a concentrations for periphyton samples collected from areas in Line Creek in July and September 2015.

AWTF operation (Figure 3.5). However, in 2015, mean chlorophyll-a concentrations were at the low management action level on September 12th, and the moderate action level on August 10th, even though the AWTF was not yet operating (Figure 3.5). This indicates that periphyton chlorophyll-a concentrations can exceed the management action levels in the absence of water treatment, and action levels and/or the monitoring component upon which action levels are based (i.e., periphyton chlorophyll-a) need to be re-evaluated in consultation with the Environmental Monitoring Committee (EMC).

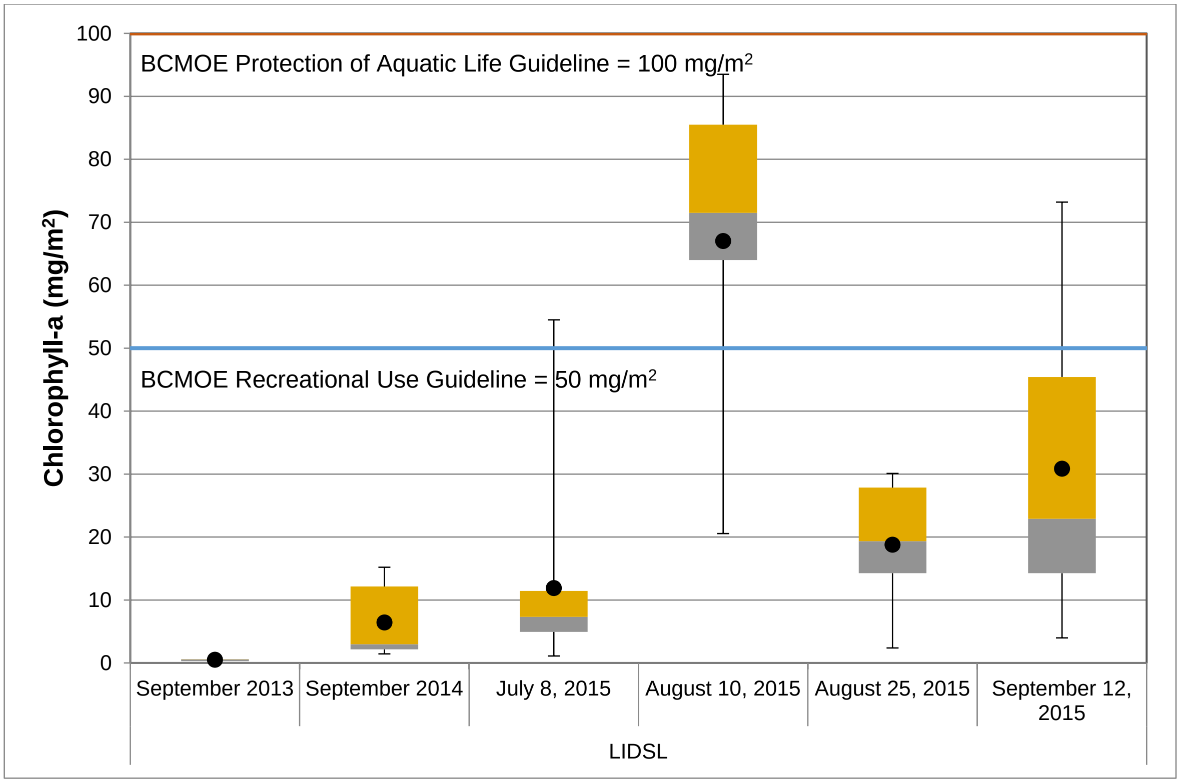


Figure 3.5: Median, 25th and 75th percentiles, and range of chlorophyll-a values for periphyton samples collected from LIDSL in September 2013 (n = 5), September 2014 (n = 10), July 8, 2015 (n = 10), August 10 and 25, 2015 (n = 5), and September 12, 2015 (n = 10). Black dots are mean concentrations. Triggers for management action occur at mean chlorophyll-a concentrations of 25-50 mg/m², 50-75 mg/m², and >75 mg/m² (see Table 2.3).

3.1.2 Bryophytes

Bryophyte areal coverage and shoot length were also measured as indicators of primary productivity. In general, the spatial pattern of bryophyte growth was similar to that observed for periphyton productivity, with the greatest mean coverage and shoot length observed at LILC3, less coverage at LIDSL, and no bryophytes observed at the most downstream station (LI8) in 2015 (Figure 3.6; Appendix Table A.3). Bryophytes were also absent at the reference areas. Areal coverage and shoot length were lower at LILC3 in September 2015 compared to 2014 (Figure 3.6), and were again greatest at mid channel, and lowest toward the stream banks (Figure 3.7). Very sparse bryophyte coverage was noted on a few rocks across the stream channel at LIDSL, with the greatest coverage observed closest to the right bank (when facing upstream; Figure 3.7; Appendix Table A.3). The difference in bryophyte coverage across the stream transects at LILC3 and LIDSL is likely due to stream morphology, with transects at LILC3 reflecting braided and shallow habitat (mean depth of 15.5 cm), whereas transects at LIDSL were associated with a deeper “V”-shaped channel morphology (mean depth of 27 cm).

3.1.3 Water

Concentrations of nutrients in water varied over the 2015 growing season, and with the exception of nitrate, did not show any obvious patterns over time or among areas (Figures 3.8 and 3.9; Appendix Table A.4). Nitrate concentrations were highest at LILC3 and decreased with distance downstream (from LIDSL to LI8; Figure 3.9). Nitrate concentrations were generally higher in the Fording River upstream of Line Creek (FOUL) compared to water entering the Fording River from Line Creek (at LI8). This resulted in lower nitrate concentrations downstream from Line Creek in the Fording River at FO23 compared to upstream at FOUL (Figure 3.9). As expected, nitrate concentrations were lowest in the reference areas, and well below the MOE guideline (Figure 3.9).

Nitrate concentrations in individual samples collected at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC) were consistently below the daily maximum discharge limit of 20 mg/L (for the period up to December 31, 2015, as defined in Permit 107517; Figure 3.10). However, monthly average nitrate concentrations were slightly greater than the monthly average discharge limit of 14 mg/L in February and December 2015 (Figure 3.10). The AWTF did not begin treating water until October 24th, 2015, and was not fully commissioned until January 31st, 2016. Thus, for most of the year, water treatment was not occurring, and in December, while the plant was being commissioned, was not treating maximum design volumes.

Concentrations of all other nutrients (i.e., total phosphorus, ortho-phosphate, nitrite, ammonia and TKN) were generally lowest in reference areas, and within the Fording River, were similar to, or lower than those at LI8 (Figures 3.8 and 3.9). Total phosphorus and TKN concentrations peaked in most areas, particularly the reference areas and LIDSL, on June

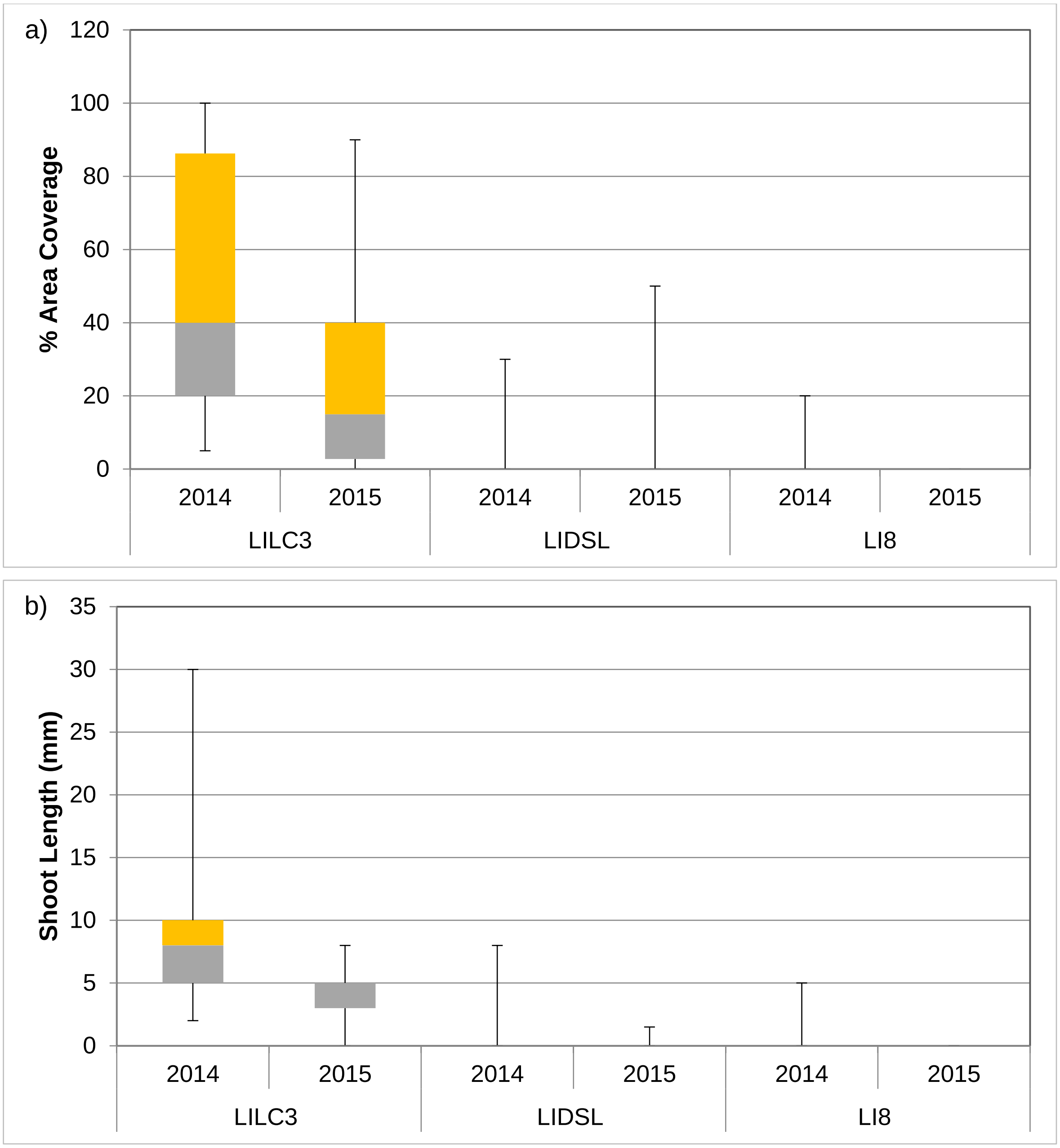
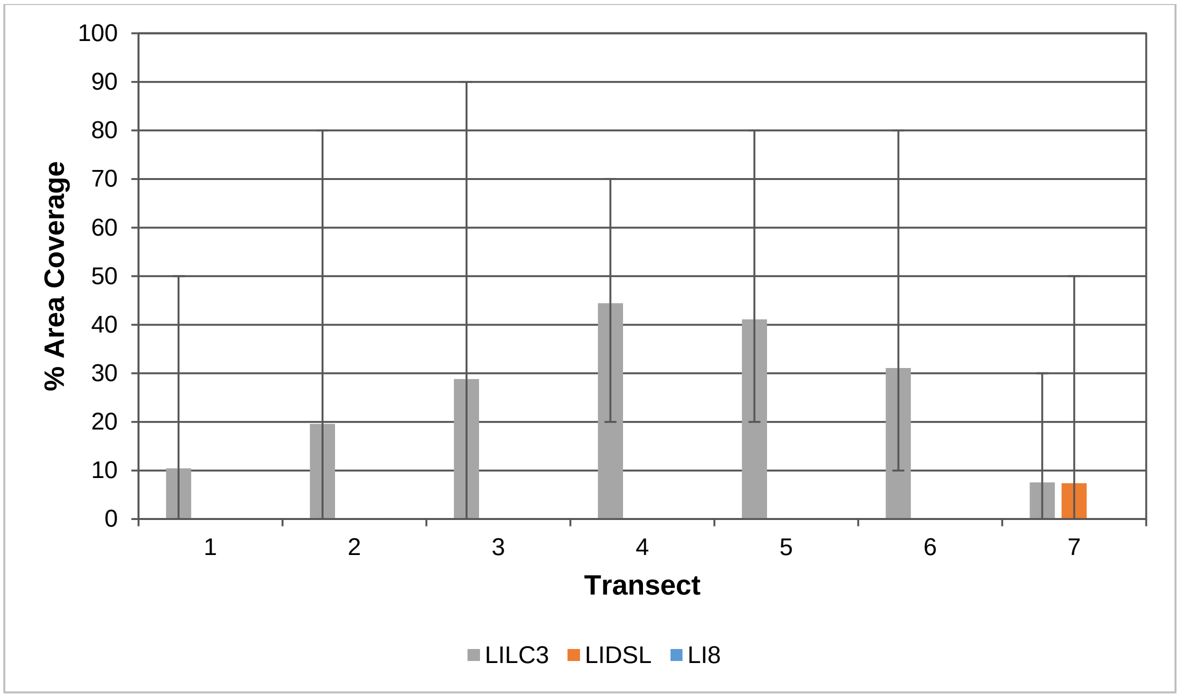


Figure 3.6: Median, 25th and 75th percentiles, and range of a) bryophyte areal coverage and b) shoot length at mine-exposed areas along Line Creek, September 2014 and 2015. Reference areas (LI24 and SLINE) are not shown because bryophytes were not present.



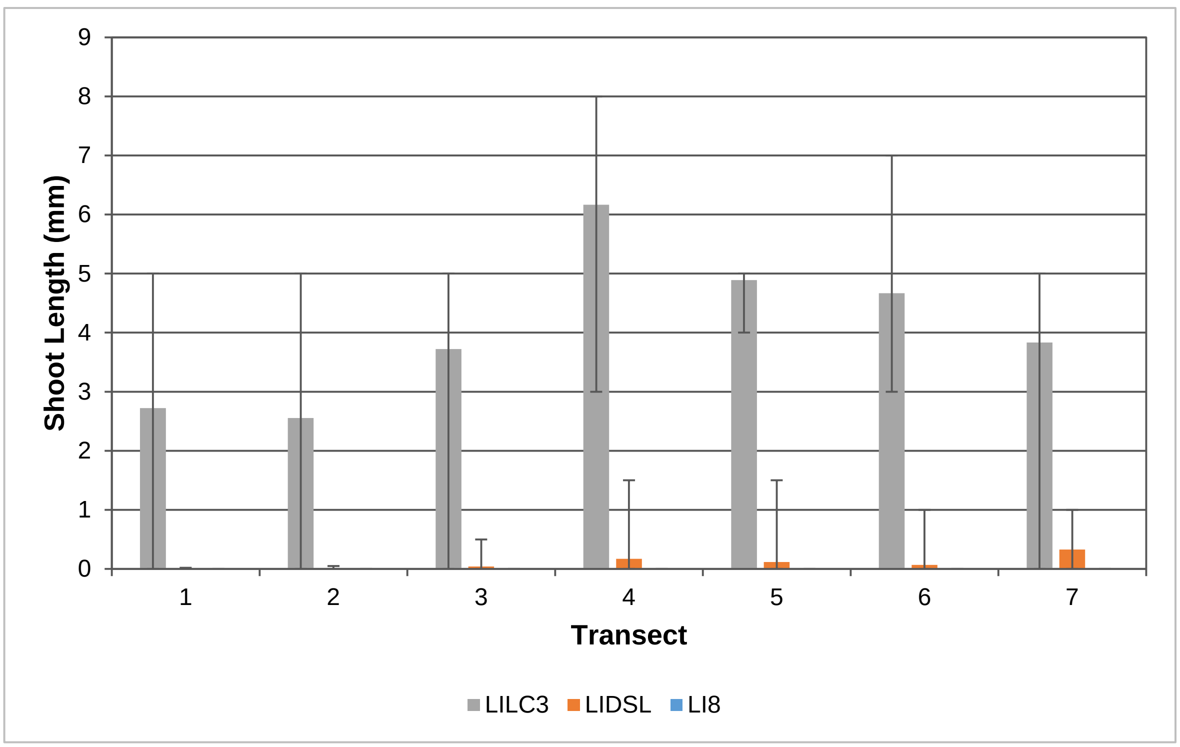


Figure 3.7: Mean and range (n = 3 per area) bryophyte coverage and shoot length across Line Creek transects, with each divided into 7 segments to facilitate comparisons among transects where stream wetted widths differed. Reference areas (LI24 and SLINE) are not shown because bryophytes were not present. Data presented is from September 2015.

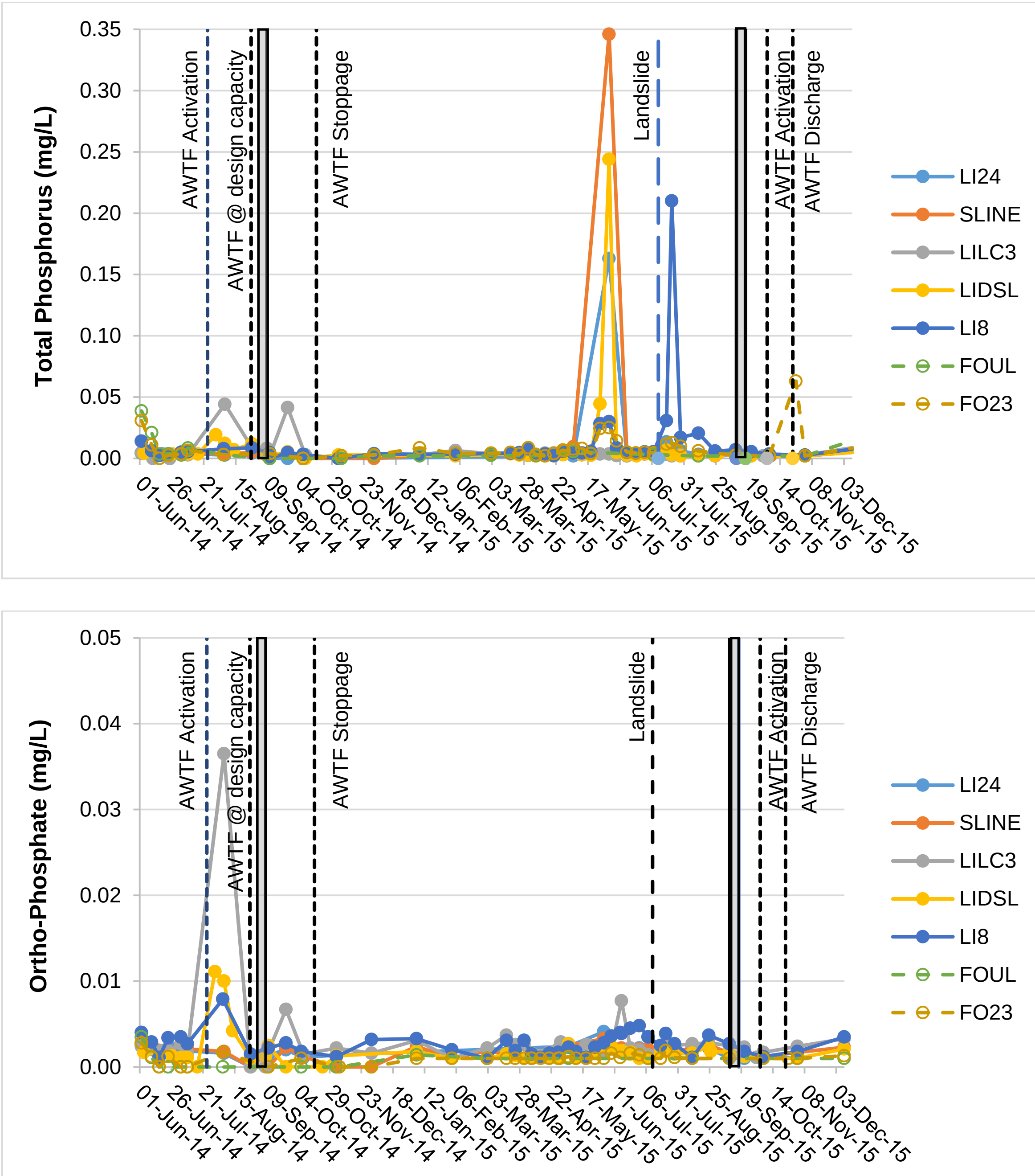


Figure 3.8: Concentrations of total phosphorous and ortho-phosphate at Line Creek and Fording River study areas from June 2, 2014 to December 9, 2015. Shaded bars indicate when biological sampling was completed.

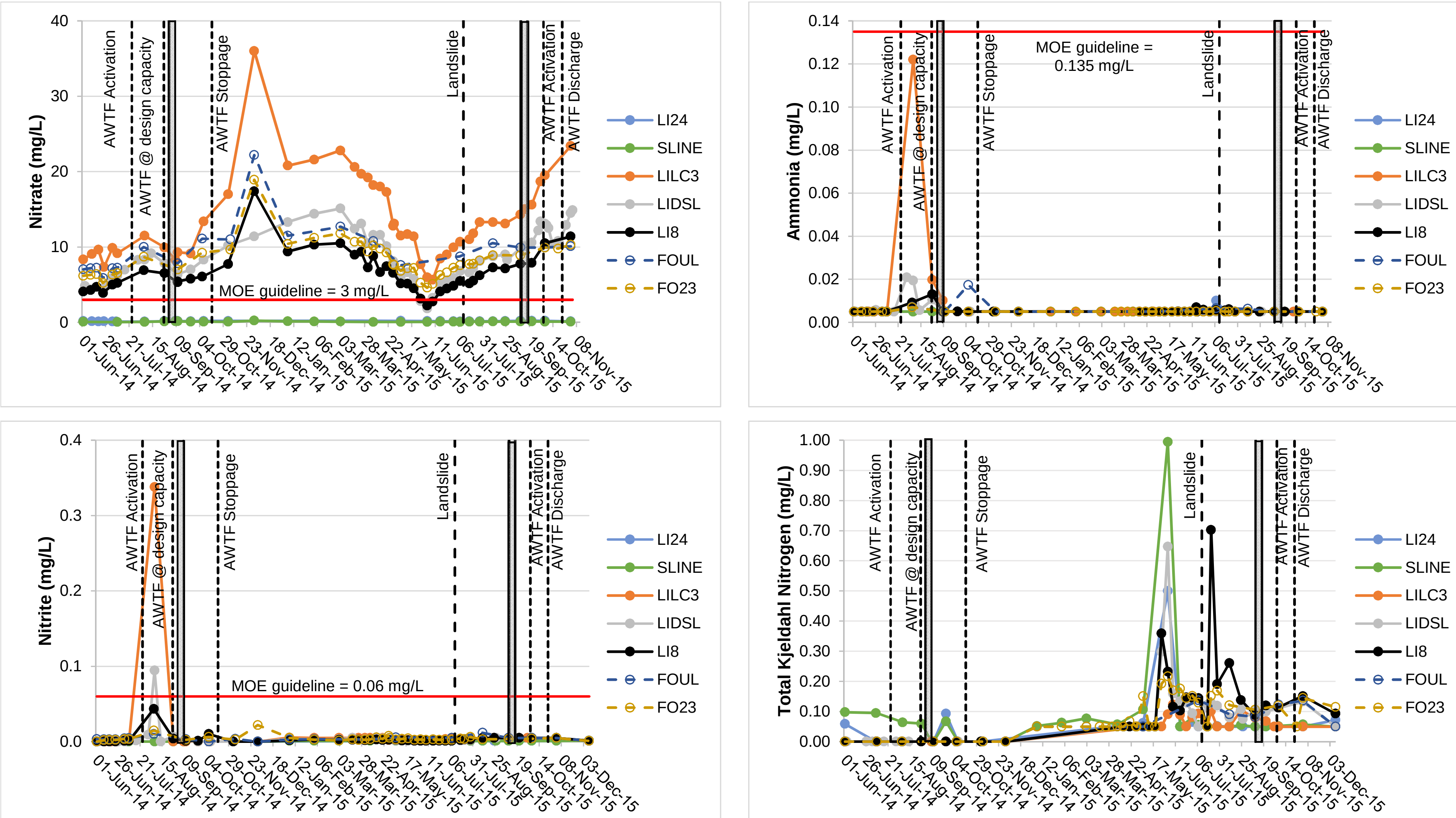


Figure 3.9: Concentrations of nitrogen forms at Line Creek and Fording River study areas from June 2, 2014 to December 9, 2015 (Note different y-axis scales). Shaded bars indicate when biological monitoring was completed.

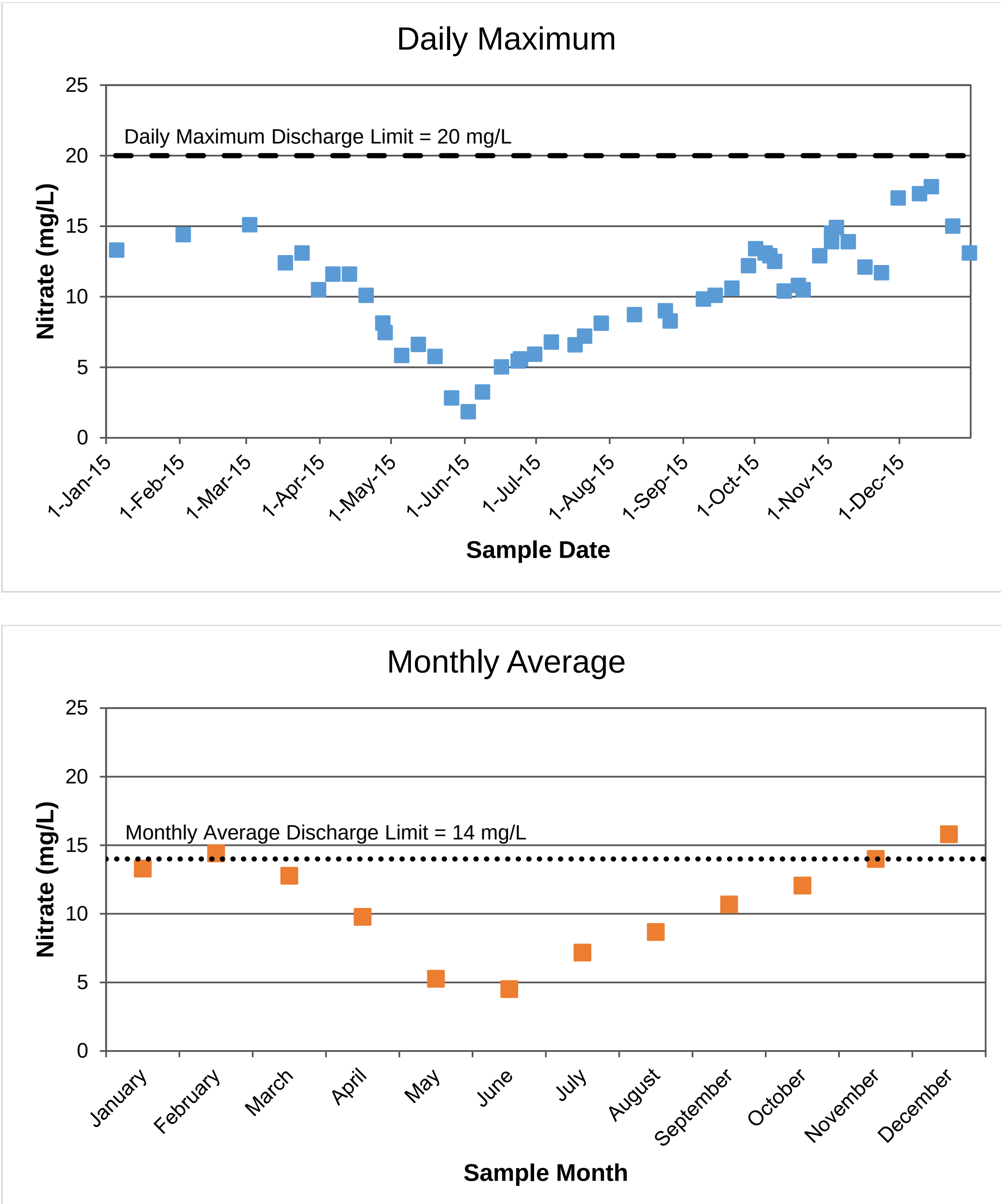


Figure 3.10: Concentrations of nitrate in water at the compliance point (LIDSL) relative to discharge limits from Permit 107517 in 2015.

2nd, 2015. The temporary increase in phosphorus and TKN concentrations was observed at both reference and mine-exposed stations so the results could not be attributed to mining activities. Total phosphorus and TKN concentrations were again elevated at LI8 on July 21st, and may have been related to a landslide that occurred in the canyon just upstream (i.e., between LIDSL and LI8) on July 11th.

Chlorophyll-a was measured in water at LIDSL on eight occasions during the 2015 growing season. Concentrations peaked at 1.17 µg/L on June 30th, 2015, and were otherwise less than 1 µg/L (Figure 3.11). MOE does not currently have a guideline for chlorophyll-a in water.

Based on the intermittent and short duration of AWTF operation over the past two years, additional years of monitoring are required to distinguish any influence of the AWTF discharge on spatial and temporal water quality patterns.

3.2 Secondary Productivity

3.2.1 Benthic Invertebrate Biomass

Benthic invertebrate biomass was highest at LILC3, followed by LIDSL, LI8, and the reference areas in 2015 (Figure 3.12; Appendix Tables A.5 to A.7). The pattern was very similar to that observed in 2014, with the exception that median biomass was slightly higher at most areas in 2015 (Figure 3.12). The spatial pattern observed generally reflected that of nitrate concentrations in water, periphyton productivity, and bryophyte coverage. However, the year-to-year variability was considerably lower for benthic invertebrate biomass compared to periphyton productivity endpoints.

Insects accounted for the vast majority of the benthic invertebrate biomass at each of the sampling areas (Figure 3.13). At the family level, Hydropsychidae, Chironomidae and to a lesser extent, Rhyacophilidae, tended to dominate the biomass at mine-exposed areas, whereas Ephemerellidae, Heptageniidae and Perlodidae contributed to a greater proportion of the biomass at reference areas (Figure 3.14). With the exception of an apparent shift to a greater proportion of Hydropsychidae biomass in 2015 compared to 2014 and a correspondingly lower proportion of Chironomidae, there were few differences between years (Figure 3.14).

3.3 Productivity Summary

The pattern of highest productivity at LILC3, and progressively lower productivity with increasing distance downstream was generally observed with all components of the monitoring program (i.e., periphyton chlorophyll-a and AFDM, bryophyte coverage, and

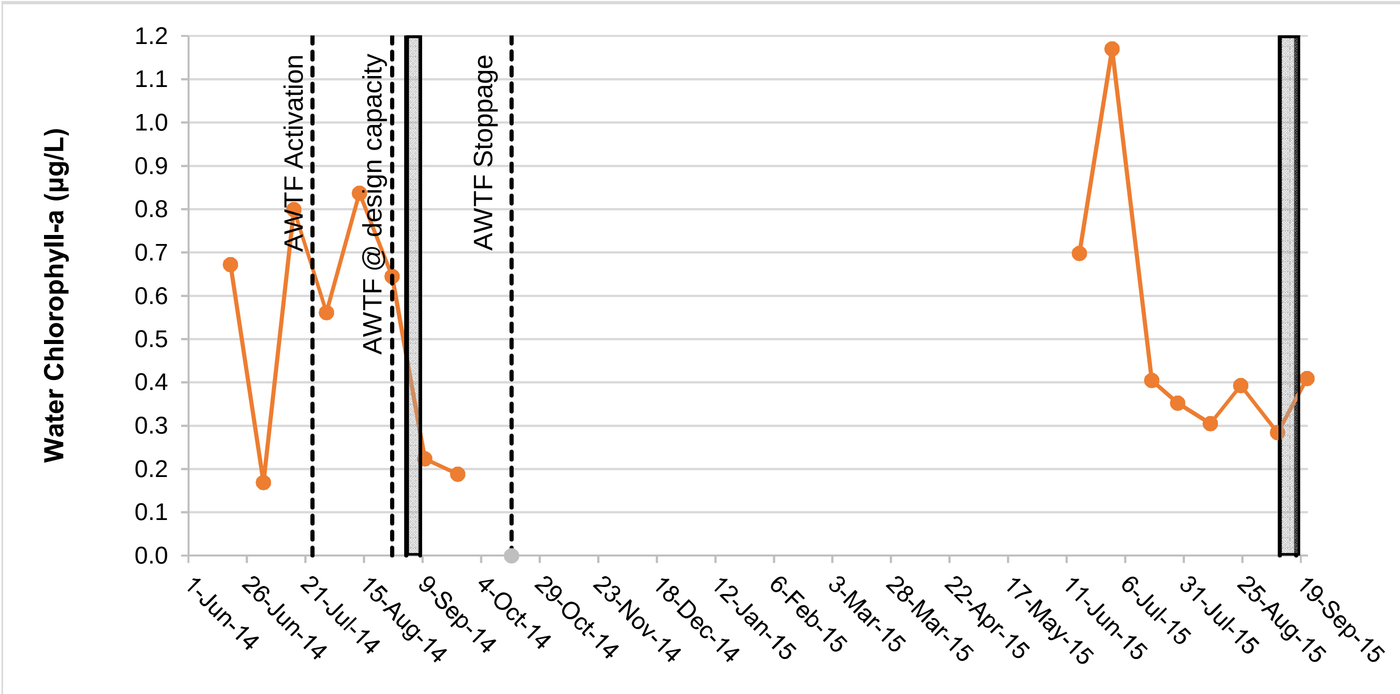
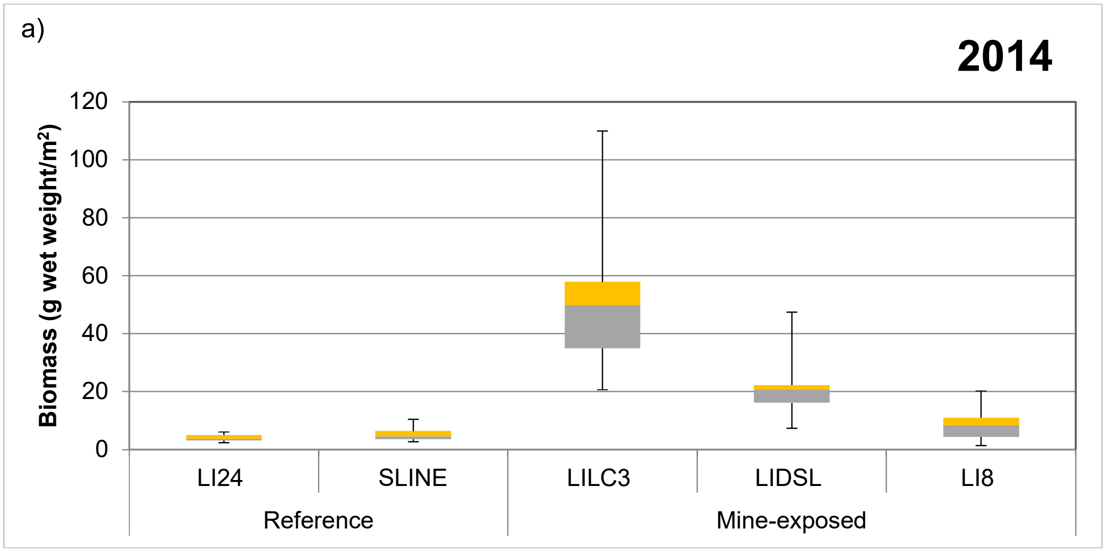


Figure 3.11: Concentrations of chlorophyll-a in water at exposed area LIDSL (LC-LCDSSLCC) Line Creek from June 2, 2014 to September 21, 2015. Shading indicates when biological monitoring was completed.



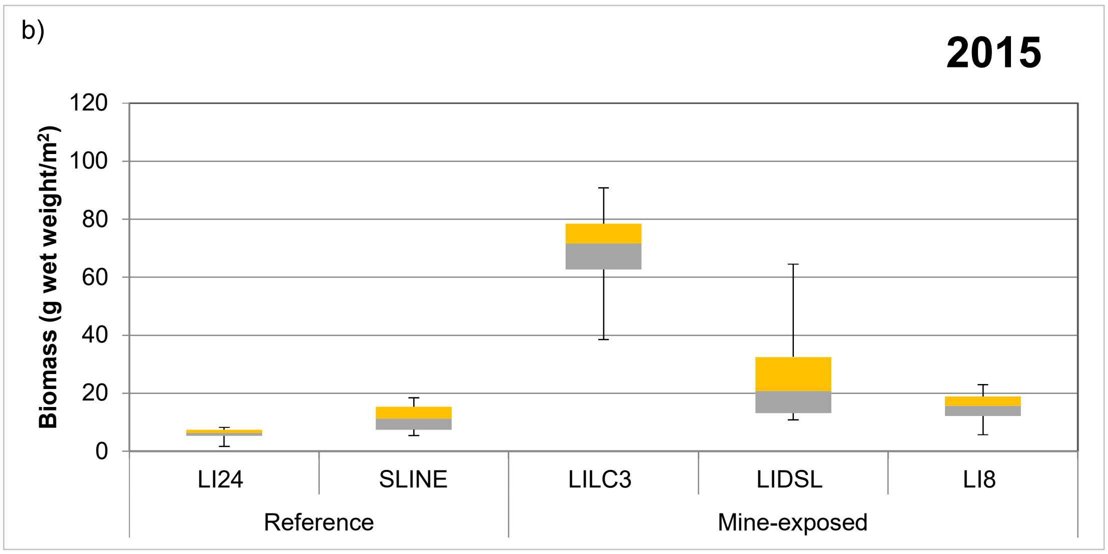


Figure 3.12: Median, 25th and 75th percentiles, and range (n = 10) of total benthic invertebrate biomass at each Line Creek monitoring area in a) September 2014 and b) September 2015.

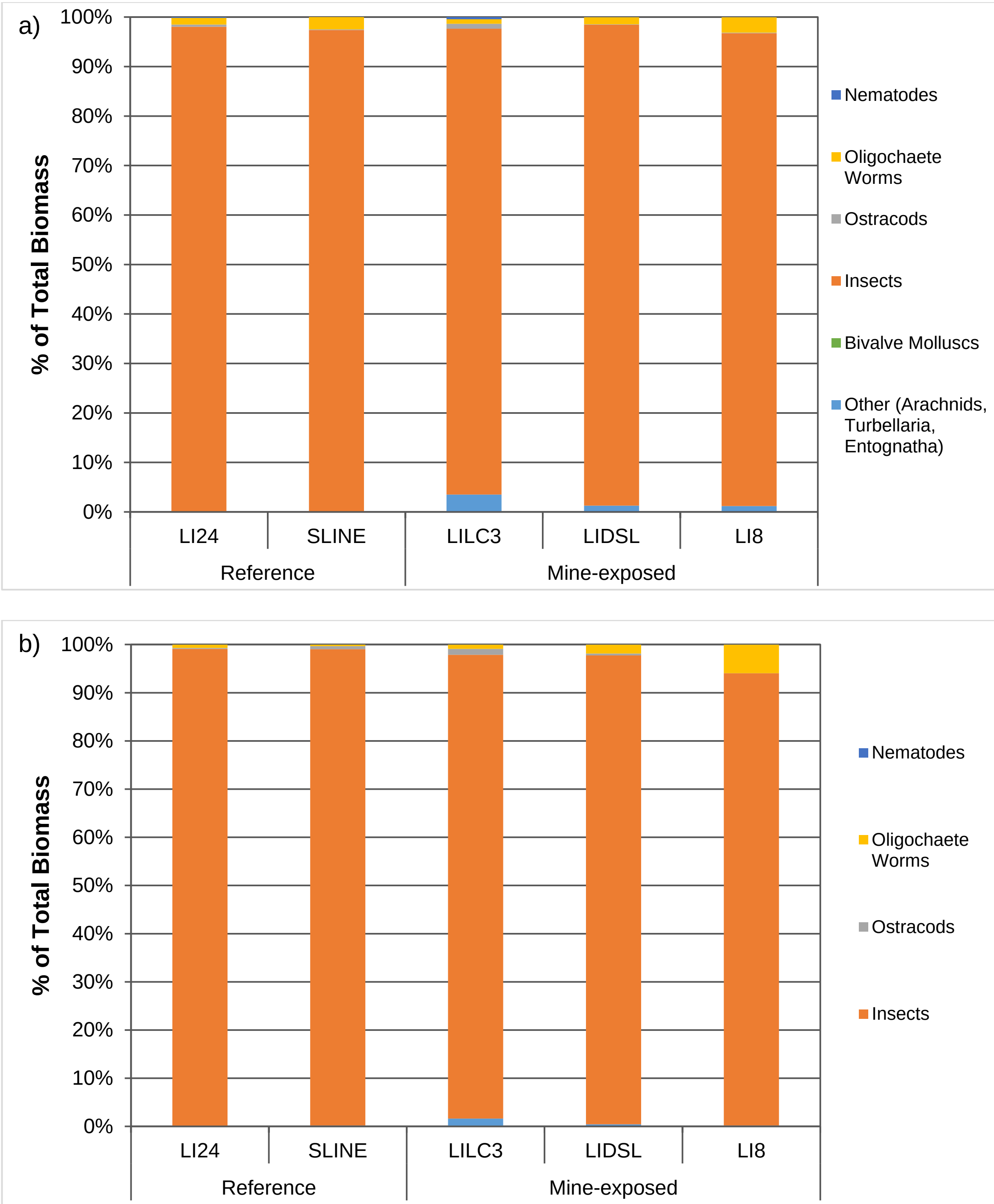
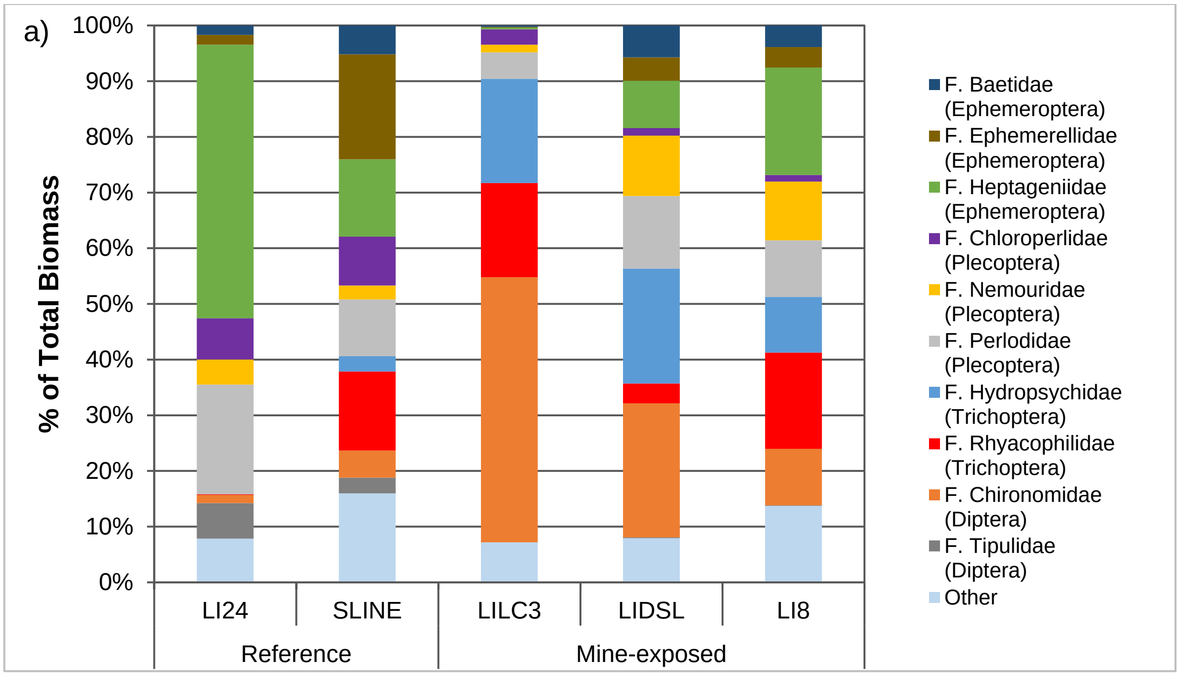


Figure 3.13: Relative biomass of major groups of benthic invertebrates in Line Creek in a) September 2014 and b) September 2015



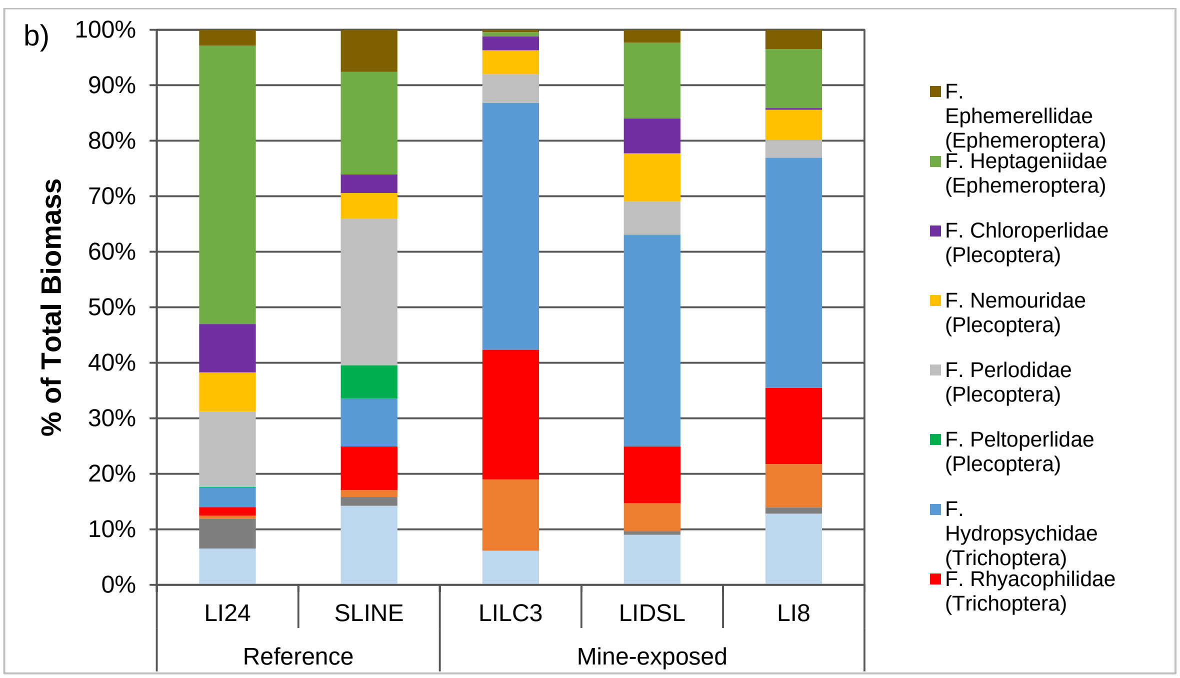


Figure 3.14: Comparison of relative biomass of dominant benthic invertebrate taxa along Line Creek in a) September 2014 and b) September 2015. Only taxa comprising at least 5% of the total biomass of individuals at one or more stations are depicted individually.

benthic invertebrate biomass), and was supported by the same pattern in aqueous nitrate concentrations. Results for primary productivity endpoints were highly variable among replicates within areas. Chlorophyll-a concentrations in periphyton also varied considerably at the Compliance Point over the growing season, with mean concentrations exceeding the triggers for management action (which were not applicable at the time because the AWTF was not in operation) in both early August and mid-September. Based on the LAEMP results for 2014 and 2015, the practicality of using periphyton chlorophyll-a as the biological monitoring trigger should be re-evaluated and/or at the trigger levels for management action should be revised.

4.0 SELENIUM

Invertebrate tissue selenium concentrations were variable among years and sample types (i.e., Composite, Ephemeroptera, Rhyacophilidae; Figure 4.1). The highest selenium concentrations were typically found in samples collected from LILC3 followed by LIDSL, whereas selenium concentrations in samples from LI8 and the two reference areas (SLINE and LI24) were similar (Figure 4.1).

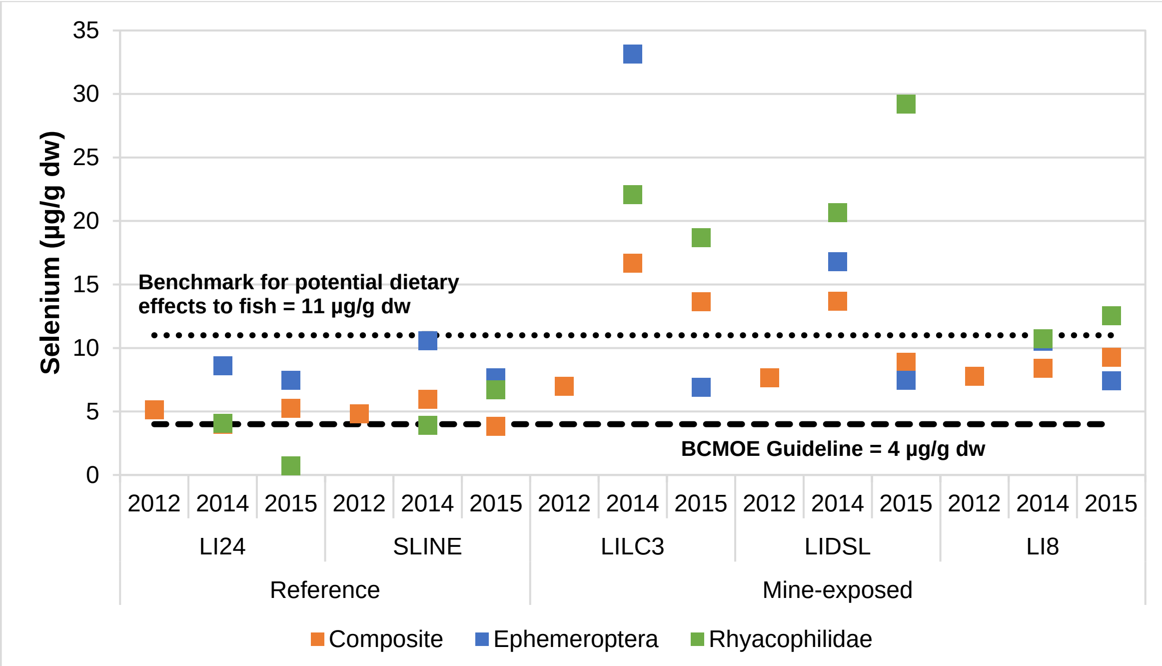


Figure 4.1: Selenium concentrations (µg/g dw) in benthic invertebrates sampled at areas along Line Creek in September 2012, 2014 and 2015. The mean concentration is shown when more than one sample was collected.

In 2015, one or more invertebrate samples collected at LILC3, LIDSL and LI8 had selenium concentrations above the benchmark for potential dietary effects to fish (11 µg/g dw), whereas selenium concentrations in all samples collected from the reference areas were below the benchmark (Figure 4.1 and Appendix Table C.1). With the exception of the Rhyacophilidae sample from LI24 (0.74 µg/g dw) and the composite sample from SLINE (3.9 µg/g dw), all samples had selenium concentrations above the MOE guideline of 4 µg/g dw (Figure 4.1 and Appendix Table C.1).

Single-taxon samples collected over two years showed variability similar to or more than composite samples and therefore do not appear to improve sensitivity to detect trends in selenium concentrations over time. Ephemeroptera had selenium concentrations greater than those of composite samples at all areas in 2014; however, in 2015, selenium concentrations in Ephemeroptera from the mine-exposed areas were the lowest (Figure 4.1). Rhyacophilidae generally had the highest selenium concentrations among samples in mine-exposed areas, but were often lowest in reference areas (Figure 4.1). Composite benthic invertebrate samples tended to show the least amount of variability among years, and typically had selenium concentrations that were within the range of the two same-year single-taxon samples (Figure 4.1).

Selenium concentrations in water (total and dissolved) generally reflected the pattern observed for benthic invertebrate tissue selenium samples, with highest concentrations at LILC3 followed by LIDSL, LI8, and the reference areas (LI24, and SLINE; Figure 4.2). Most of the selenium measured in water samples was in the dissolved form (~95%: Figure 4.2 and Appendix Table A.1). Selenium concentrations were generally lowest during the spring freshet period (Figure 4.2).

While selenium concentrations in water at all mine-exposed areas were above the MOE guideline of 2 µg/L, concentrations at the Compliance Point (LIDSL / LC_LCDSSLCC) were consistently below the daily maximum and monthly average discharge limits of 95 µg/L and 80 µg/L, respectively (up to December 31, 2015, as indicated in Permit 107517; Figure 4.3).

The chemical forms of selenium were analyzed twice monthly during the growing season (i.e., June through September) in samples collected in all areas except for SLINE, which was not sampled on July 28th, 2015 (the sample was collected but inadvertently sent to the wrong laboratory, and by the time the error was noted, the sample hold time had passed). Aqueous selenium was predominantly in the form of selenate at all areas (Figure 4.4 and Appendix Table A.1). Consistent with patterns observed for all other data (i.e., primary and secondary productivity, nitrate, total and dissolved selenium), concentrations of selenate were generally highest at LILC3 and progressively lower downstream (LIDSL and LI8). Concentrations of selenite, selenomethionine, selenocyanate, methylseleninic acid, and other unknown species of selenium were low or below analytical method detection limits in all samples (Figure 4.4). Additional monitoring will be required to assess changes in aqueous selenium species relative to sustained operation of the AWTF.

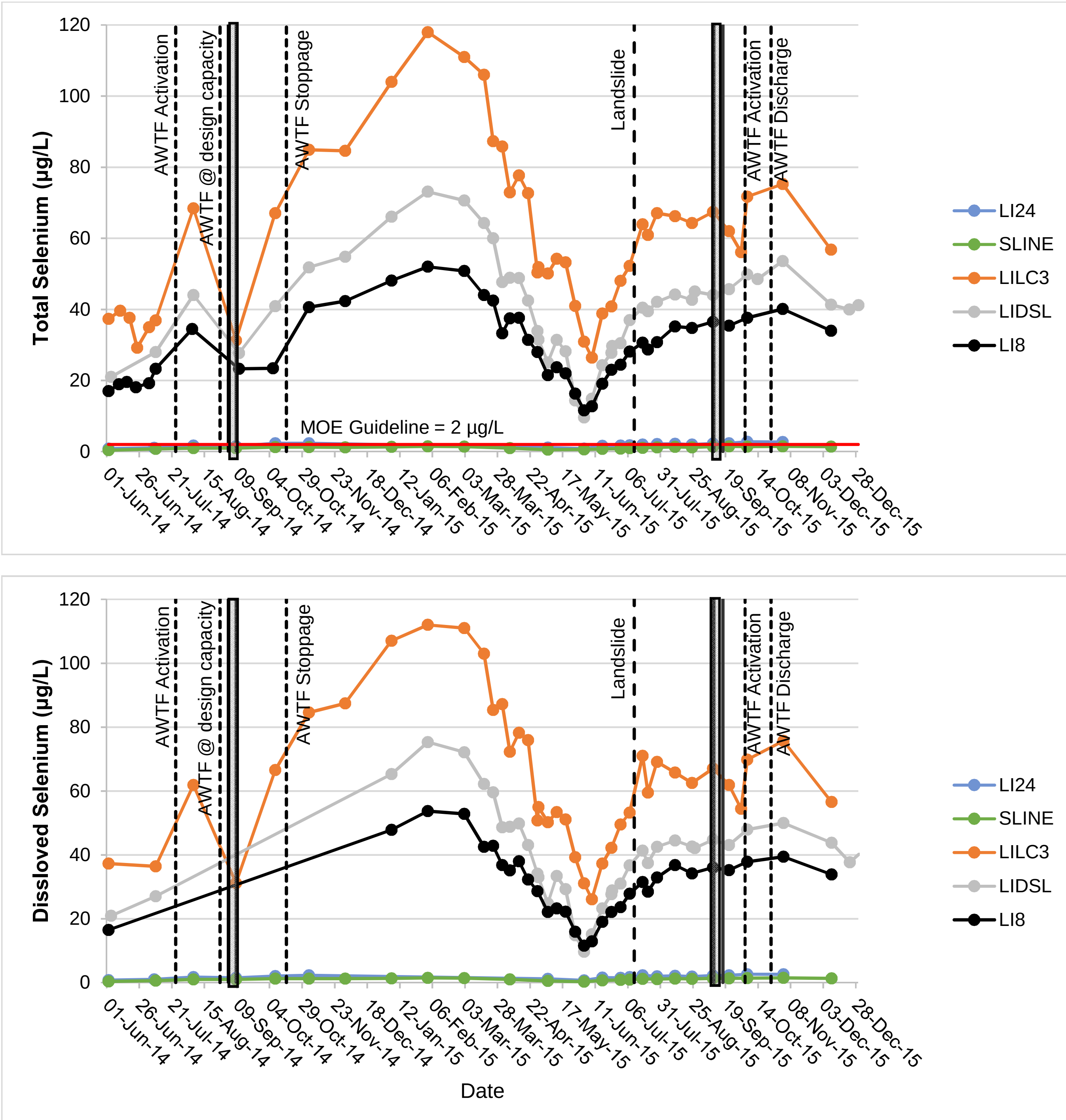
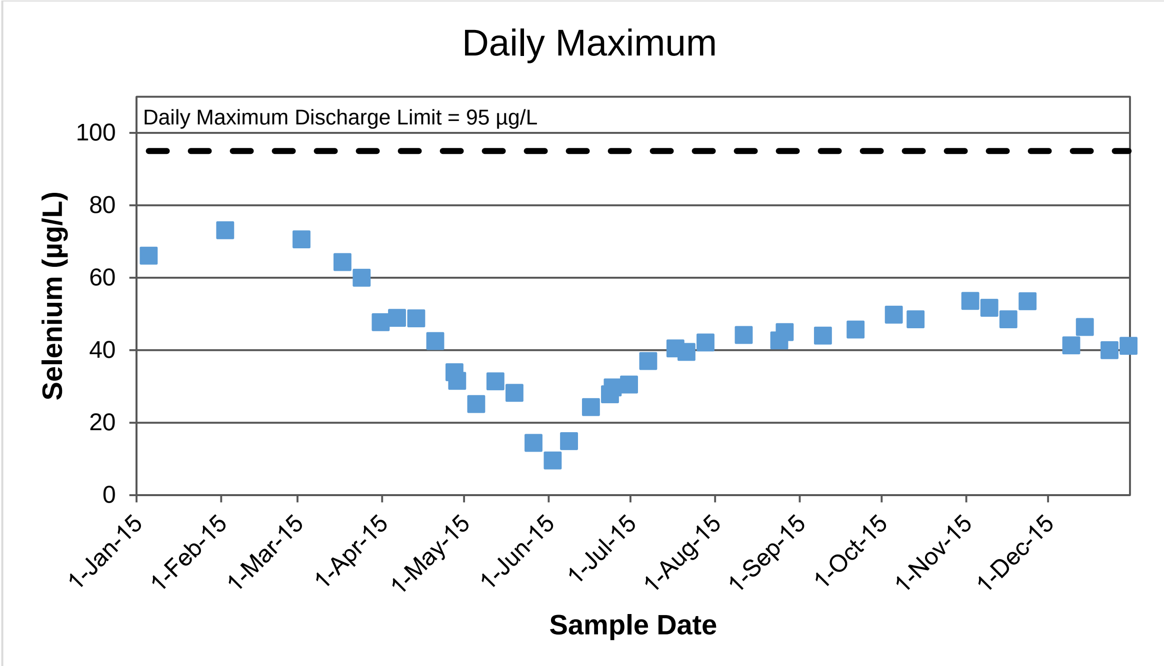


Figure 4.2: Concentrations of total and dissolved selenium at Line Creek study areas from June 2, 2014 to December 30, 2015. Shaded bars indicate when biological monitoring was completed.



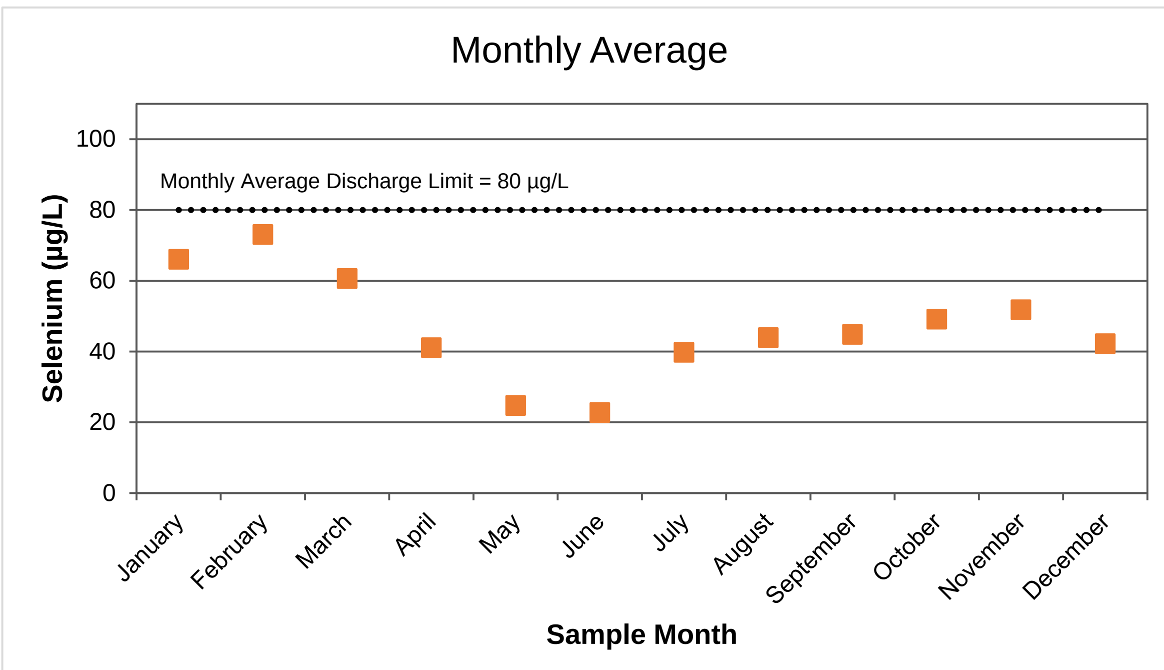


Figure 4.3: Concentrations of selenium in water at the compliance point (LIDSL) relative to discharge limits from Permit 107517 in 2015.

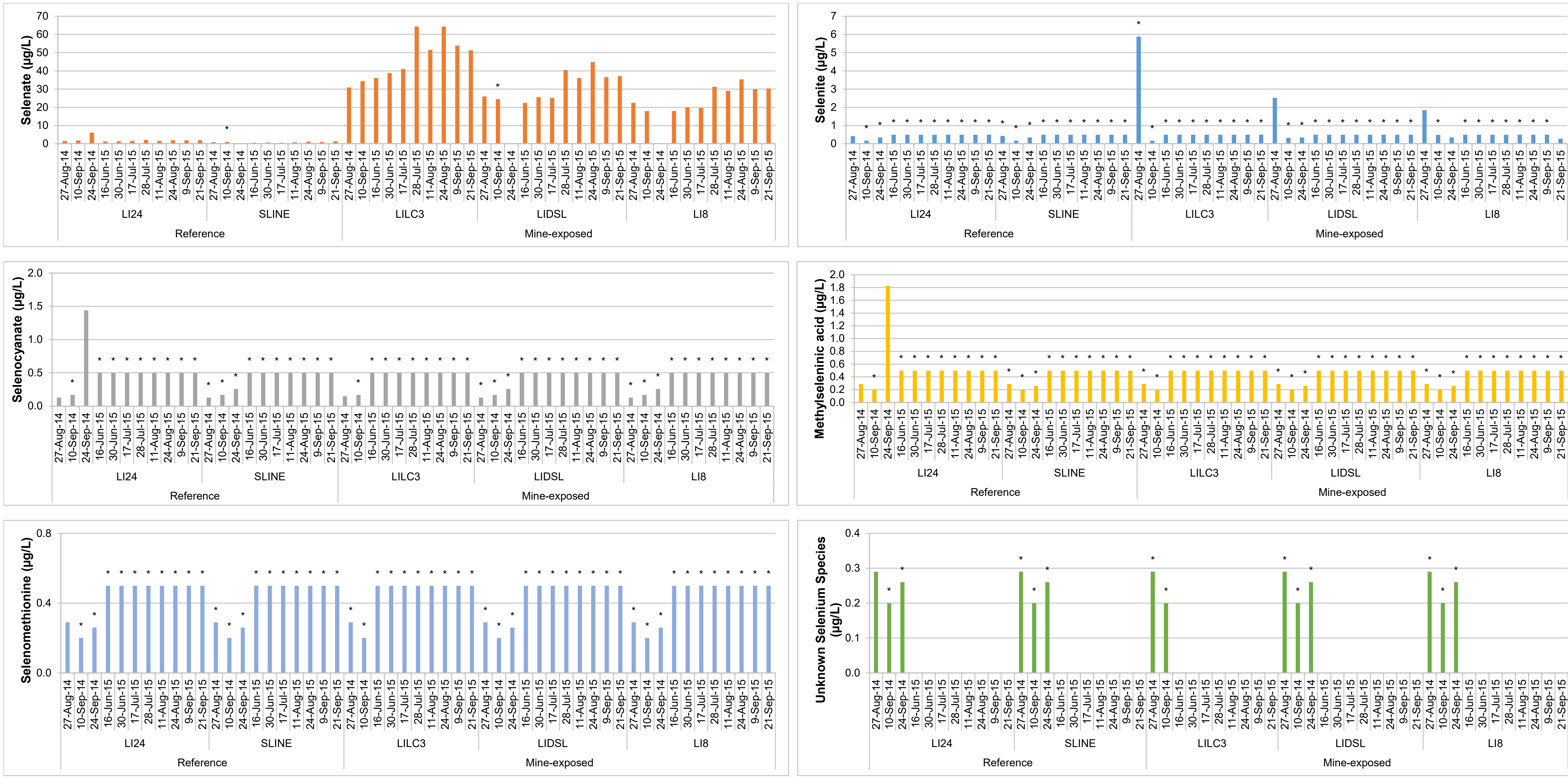


Figure 4.4: Concentrations of selenium species at study areas from August 27, 2014 to December 30, 2015. An asterisk (*) indicates values reported below the Method Detection Limit (MDL).

5.0 TOXICITY

In 2015, the West Line Creek AWTF did not begin operating until October 24th (with a 120 day commissioning period starting October 4th, and recirculation until October 24th). Following commencement of discharge, acute toxicity tests using *Daphnia magna* and rainbow trout (*Oncorhynchus mykiss*) were performed on AWTF effluent samples collected on a weekly basis (more frequent prior to, and during the first week of discharge). All tests completed during the 2015 commissioning phase (a total of 30 tests) passed (i.e., not acutely lethal; Table 5.1). Detailed reports associated with each test are provided in the annual report for Permit 107517 (Teck 2016a).

Table 5.1: Results for acute toxicity tests conducted on the AWTF effluent (LC_WTF_OUT) during commissioning in 2015.

Date	Percent Survival	
	Daphnia magna	*Oncorhynchus mykiss*
20-Oct-15	100	100
21-Oct-15	100	100
24-Oct-15	100	100
26-Oct-15	100	90
31-Oct-15	100	100
02-Nov-15	100	100
09-Nov-15	100	100
16-Nov-15	100	100
23-Nov-15	90	100
01-Dec-15	100	100
07-Dec-15	100	100
11-Dec-15	100	100
14-Dec-15	100	100
21-Dec-15	100	100
28-Dec-15	100	100

In addition to acute toxicity testing of AWTF effluent samples, quarterly (*Ceriodaphnia dubia* and *Pseudokirchneriella subcapitata*) and semi-annual (*O. mykiss*) chronic toxicity tests were also completed on water collected from the Compliance Point (LC_LCDSSLCC / LIDSL). Most chronic toxicity tests showed no evidence of adverse effects. For the tests in which significant differences were reported (some of which occurred at LC_LCDSSLCC), most were consistent with normal variability in the performance of test organisms, and water quality results did not suggest the potential for adverse effects (Golder 2016). Only one second quarter test of water from LC_LCDSSLCC using *P. subcapitata* yielded results that were lower than both reference and the range of normal variability, which was attributed to an adverse response to the test water (Golder 2016).

6.0 CONCLUSIONS AND RECOMMENDATIONS

Periphyton AFDM and chlorophyll-a, benthic invertebrate biomass and nitrate concentrations were generally highest in Line Creek closest to the mine (LILC3) and decreased progressively with distance downstream (from LIDSL to LI8) in the absence of water treatment. The patterns observed during LAEMP sampling in September 2015 were similar to September 2014. The AWTF was not operating prior to the LAEMP in September 2015, and only operated for a little over a month (at a reduced capacity during commissioning) prior to the LAEMP in September 2014. Thus, the biological sampling associated with both LAEMPs largely represented untreated/baseline conditions.

Results for primary productivity endpoints (i.e., periphyton AFDM and chlorophyll-a) were highly variable among replicates within areas. Chlorophyll-a concentrations in periphyton also varied considerably at the Compliance Point (i.e., LIDSL / LC_LCDSSLCC) over the growing season, with mean concentrations exceeding the triggers for management action (which were not applicable at the time because the AWTF was not in operation) in both early August and mid-September. Chlorophyll-a concentrations in one or more samples from LILC3, LIDSL, LI8 and FO23 were greater than the MOE guideline for recreational uses (50 mg/m^2), while LILC3 and FO23 had concentrations that were also greater than the guideline for the protection of aquatic life (100 mg/m^2). However, median concentrations were less than both guidelines in all areas and years except LILC3 in 2015.

Concentrations of nutrients in water varied over the 2015 growing season, and with the exception of nitrate, did not show any obvious patterns over time or among areas. Concentrations of nitrate were generally above the MOE guideline of 3 mg/L at the mine-exposed areas, and were highest at LILC3 and decreased with distance downstream. Nitrate concentrations were lowest (and below the MOE guideline) in the reference areas. In the Fording River upstream of Line Creek, nitrate concentrations were higher than those downstream, indicating that water from Line Creek acted as a source of dilution. Nitrate concentrations in individual samples collected at the Compliance Point were consistently below the daily maximum discharge limit of 20 mg/L, but were greater than the monthly average discharge limit of 14 mg/L in February and December. Concentrations of all other nutrients (i.e., total phosphorus, ortho-phosphate, nitrite, ammonia and TKN) were generally lowest in reference areas, and within the Fording River, were similar to, or lower than those at LI8.

Selenium concentrations in water at the Compliance Point were below the daily maximum and monthly average discharge throughout 2015. Selenium concentrations in water (primarily present as dissolved selenate) and benthic invertebrates showed a similar spatial pattern among areas, with highest concentrations occurring in Line Creek closest to the mine (LILC3) and progressively lower concentrations downstream at LIDSL followed by LI8. Single-taxon invertebrate samples (i.e., Ephemeroptera or Rhyacophilidae) collected over two years showed variability similar to or more than composite samples and therefore will not improve sensitivity to detect trends in selenium concentrations over time.

Statistical analysis of data collected during the 2014 and 2015 LAEMPs, as well as preliminary data collected in the 2015 RAEMP, showed redundancy among many of the study components used in the assessment of biological productivity (i.e., periphyton AFDM, chlorophyll-a, bryophyte coverage and benthic invertebrate biomass; see Appendix B). Of these components, benthic invertebrate biomass was shown to be the most sensitive for detecting changes over time (Appendix B). Based on the findings presented in Appendix B, the 2016 study design has been refined to focus on analysis of water quality, and benthic invertebrate community structure, biomass and tissue selenium (see Minnow 2016 for the detailed design). High within-area and temporal variability for periphyton chlorophyll-a results make this an insensitive endpoint for detecting changes in productivity over time. Also, chlorophyll-a concentrations were above previously defined trigger levels for management actions prior to water treatment being initiated (Golder and Minnow 2014; triggers applicable only during AWTF operation). Therefore, periphyton chlorophyll-a monitoring will no longer be part of the LAEMP and new triggers for management responses will need to be developed.

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Appendix A

Detailed Data

Table A.1: Periphyton ash-free dry mass (AFDM) and chlorophyll-a for samples collected in Line Creek and Fording River, September 2015.

Site Description	Sample ID	Date	AFDM (g/m^2)	Chlorophyll-a (mg/m^2)
Line Creek Reference - Tornado Creek (LI24)	LI24-1	10-Sep-15	3.4	7.2
	LI24-2	10-Sep-15	3.5	9.7
	LI24-3	10-Sep-15	3.3	7.1
	LI24-4	10-Sep-15	5.0	7.9
	LI24-5	10-Sep-15	4.8	9.6
	LI24-6	10-Sep-15	3.0	4.9
	LI24-7	10-Sep-15	3.2	6.5
	LI24-8	10-Sep-15	3.0	8.1
	LI24-9*	10-Sep-15	-*	5.8
	LI24-10	10-Sep-15	3.2	4.8
		Mean[a] =	**4**	**7.2**
South Line Creek Reference (SLINE)	SLINE-1	15-Sep-15	20	42
	SLINE-2	15-Sep-15	6.3	16
	SLINE-3	15-Sep-15	11	24
	SLINE-4	15-Sep-15	13	29
	SLINE-5	15-Sep-15	7.4	18
	SLINE-6	15-Sep-15	9.6	28
	SLINE-7	15-Sep-15	4.2	9.9
	SLINE-8	15-Sep-15	3.8	9.2
	SLINE-9	15-Sep-15	1.6	4.8
	SLINE-10	15-Sep-15	6.1	17
		Mean[a] =	**8.3**	**20**
Line Creek Upstream of Active Water Treatment Facility (LILC3)	LILC3-1	14-Sep-15	81	69
	LILC3-2	14-Sep-15	77	123
	LILC3-3	14-Sep-15	89	179
	LILC3-4	14-Sep-15	168	260
	LILC3-5	14-Sep-15	118	242
	LILC3-6	14-Sep-15	172	223
	LILC3-7	14-Sep-15	117	197
	LILC3-8	14-Sep-15	132	185
	LILC3-9	14-Sep-15	140	188
	LILC3-10	14-Sep-15	135	139
		Mean[a] =	**123**	**180**
Line Creek Downstream of South Line Creek and Contingency Ponds (LIDSL)	LIDSL-1	12-Sep-15	37	73
	LIDSL-2	12-Sep-15	17	69
	LIDSL-3	12-Sep-15	5.3	9.4
	LIDSL-4	12-Sep-15	14	25
	LIDSL-5	12-Sep-15	26	52
	LIDSL-6	12-Sep-15	6.1	25
	LIDSL-7	12-Sep-15	7.6	17
	LIDSL-8	12-Sep-15	5.2	14
	LIDSL-9	12-Sep-15	1.2	4.0
	LIDSL-10	12-Sep-15	5.9	21
		Mean[a] =	**13**	**31**
Line Creek Downstream of Canyon (LI8)	LI8-1	13-Sep-15	0.50	1.4
	LI8-2	13-Sep-15	<0.50	0.59
	LI8-3	13-Sep-15	5.2	15
	LI8-4	13-Sep-15	2.7	9.0
	LI8-5	13-Sep-15	0.75	2.6
	LI8-6	13-Sep-15	1.5	4.0
	LI8-7	13-Sep-15	0.75	2.3
	LI8-8	13-Sep-15	1.1	4.9
	LI8-9	13-Sep-15	2.7	10
	LI8-10	13-Sep-15	7.7	51
		Mean[a] =	**2.3**	**10**
Fording River Upstream of Line Creek (FOUL)	FOUL-1	17-Sep-15	2.5	0.95
	FOUL-2	17-Sep-15	2.0	1.1
	FOUL-3	17-Sep-15	1.3	1.1
	FOUL-4	17-Sep-15	<0.50	0.77
	FOUL-5	17-Sep-15	<0.50	0.37
	FOUL-6	17-Sep-15	<0.50	1.9
	FOUL-7	17-Sep-15	1.9	0.35
	FOUL-8	17-Sep-15	1.9	0.25
	FOUL-9	17-Sep-15	0.50	0.80
	FOUL-10	17-Sep-15	1.7	2.3
		Mean[a] =	**1.3**	**0.99**
Fording River Downstream of Line Creek (FO23)	FO23-1	16-Sep-15	0.65	4.1
	FO23-2	16-Sep-15	5.4	26
	FO23-3	16-Sep-15	15	31
	FO23-4	16-Sep-15	73	125
	FO23-5	16-Sep-15	3.9	24
	FO23-6	16-Sep-15	3.9	8.7
	FO23-7	16-Sep-15	12	57
	FO23-8	16-Sep-15	0.90	2.3
	FO23-9	16-Sep-15	<0.50	1.2
	FO23-10	16-Sep-15	1.3	4.1
		Mean[a] =	**12**	**28**

* AFDM result of 128 g/m^2 for LI24-9 believe to be incorrect due to laboratory sample handling error.

[a] The Method Detection Limit (MDL) was used to calculate the mean where measured concentrations were below the MDL.

Table A.2: Periphyton ash-free dry mass (AFDM) and chlorophyll-a for samples collected in Line Creek in July 2015.

Site Description	Sample ID	Date	AFDM (g/m^2)	Chlorophyll-a (mg/m^2)
Line Creek Reference - Tornado Creek (LI24)	LI24-1	08-Jul-15	3.8	7.0
	LI24-2	08-Jul-15	1.0	2.7
	LI24-3	08-Jul-15	2.1	5.6
	LI24-4	08-Jul-15	1.1	5.0
	LI24-5	08-Jul-15	0.80	6.2
	LI24-6	08-Jul-15	1.2	5.8
	LI24-7	08-Jul-15	0.85	2.9
	LI24-8	08-Jul-15	1.7	3.5
	LI24-9	08-Jul-15	0.65	4.1
	LI24-10	08-Jul-15	0.75	7.3
		Mean[a] =	**1.4**	**5.0**
South Line Creek Reference (SLINE)	SLINE-1	09-Jul-15	14	2.1
	SLINE-2	09-Jul-15	5.1	1.7
	SLINE-3	09-Jul-15	3.3	1.2
	SLINE-4	09-Jul-15	23	10
	SLINE-5	09-Jul-15	13	20
	SLINE-6	09-Jul-15	24	7.7
	SLINE-7	09-Jul-15	9.9	13
	SLINE-8	09-Jul-15	1.5	8.7
	SLINE-9	09-Jul-15	1.7	6.5
	SLINE-10	09-Jul-15	4.9	9.1
		Mean[a] =	**10**	**7.9**
Line Creek Upstream of Active Water Treatment Facility (LILC3)	LILC3-1	07-Jul-15	74	9.2
	LILC3-2	07-Jul-15	118	16
	LILC3-3	07-Jul-15	120	57
	LILC3-4	07-Jul-15	177	24
	LILC3-5	07-Jul-15	101	2.5
	LILC3-6	07-Jul-15	128	6.5
	LILC3-7	07-Jul-15	163	8.5
	LILC3-8	07-Jul-15	259	20
	LILC3-9	07-Jul-15	259	51
	LILC3-10	07-Jul-15	192	179
		Mean[a] =	**159**	**37**
Line Creek Downstream of South Line Creek and Contingency Ponds (LIDSL)	LIDSL-1	08-Jul-15	12	4.7
	LIDSL-2	08-Jul-15	20	12
	LIDSL-3	08-Jul-15	9.4	55
	LIDSL-4	08-Jul-15	23	8.1
	LIDSL-5	08-Jul-15	24	5.7
	LIDSL-6	08-Jul-15	42	13
	LIDSL-7	08-Jul-15	18	9.6
	LIDSL-8	08-Jul-15	27	3.6
	LIDSL-9	08-Jul-15	35	1.1
	LIDSL-10	08-Jul-15	6.0	6.6
		Mean[a] =	**21**	**12**
Line Creek Downstream of Canyon (LI8)	LI8-1	09-Jul-15	24	4.9
	LI8-2	09-Jul-15	<0.50	<2.0
	LI8-3	09-Jul-15	2.8	7.6
	LI8-4	09-Jul-15	12	7.4
	LI8-5	09-Jul-15	0.80	5.3
	LI8-6	09-Jul-15	1.6	13
	LI8-7	09-Jul-15	7.2	5.1
	LI8-8	09-Jul-15	20	6.9
	LI8-9	09-Jul-15	18	2.1
	LI8-10	09-Jul-15	1.4	1.6
		Mean[a] =	**8.8**	**5.6**

[a] The Method Detection Limit (MDL) was used to calculate the mean where measured concentrations were below the MDL.

Table A.3: Bryophyte quantification for Line Creek, September 2015.

Transect #		Rock #	Distance from Shore (m)	Depth (cm)	Max Axis (cm)	Inter Axis (cm)	% Area Coverage	Shoot Length (mm)
LILC3	1	1	0.5	9	29	16.5	2	4
		2	1	11	14	6	20	3
		3	1.5	15	12.5	10.5	50	5
		4	2	10	19	17	80	4
		5	2.5	8	13	11.5	2	3
		6	3	18	24	16.5	80	5
		7	3.5	18	12.5	9	5	5
		8	4	28	13	7	30	5
		9	4.5	18	12.5	6	40	5
		10	5	10	17.5	15	20	3
		11	5.5	12	15.5	12	80	5
		12	6	10	18.5	16.5	30	5
		13	6.5	6	18	10	20	5
		14	7	8	14	13	10	5
		15	7.5	12	12	10	10	3
		16	8	10	16	16	20	7
		17	8.5	14	13	7	10	5
		18	9	16	19	18	10	5
		19	9.5	13	26	22	5	5
		Total Width = 9 m						
	2	1	0.5	22	19.5	13	0	0
		2	1	30	19	17.5	10	3
		3	1.5	32	26	10.5	30	3
		4	2	28	23.5	15	5	2
		5	2.5	20	12	8	90	5
		6	3	20	12	9.5	5	2
		7	3.5	22	14	6.5	70	7
		8	4	17	18.5	11	70	8
		9	4.5	13	12.5	9.5	40	5
		10	5	10	12.5	11	20	5
		11	5.5	10	15	11.5	10	5
		12	6	9	13	9	10	3
		13	6.5	15	12	8.5	2	3
		14	7	13	18	12	0	0
		Total Width = 6.5 m						
	3	1	0.5	11	15	13	0	0
		2	1	15	19	18	5	3
		3	1.5	18	33	21	2	5
		4	2	13	19	7.5	0	0
		5	2.5	9	17	8	0	0
		6	3	5	14.5	8	1	5
		7	3.5	10	13	9	0	0
		8	4	4	14	9	1	5
		9	4.5	4	13.5	11.5	1	3
		10	5	12	19	10	20	8
		11	5.5	22	20	14	40	5
		12	6	22	23.5	12	40	8
		13	6.5	26	19	12	20	5
		14	7	24	29	12.5	50	4
		15	7.5	18	15	8	80	5
		16	8	28	30	16	80	5
		17	8.5	30	24	15	80	5
		18	9	28	18	13.5	50	5
		19	9.5	14	15	8.5	30	5
		20	10	14	17.5	8	10	5
		21	10.5	3	18	15.5	0	5
		Total Width = 10 m						
LIDSL	1	1	0	2	13	10	0	0
		2	0.25	8	28	14	0	0
		3	0.5	17	21	11	0	0
		4	0.75	16	16	15	0	0
		5	1	21	18	10	0	0
		6	1.25	22	17	10	0	0
		7	1.5	25	14	7.5	0	0
		8	1.75	24	25	11.5	0	0
		9	2	24	14	13	0	0
		10	2.25	30	36	30	0	0
		11	2.5	30	20	14	0	0
		12	2.75	39	20	15	0	0
		13	3	39	23	13	0	0
		14	3.25	39	21	15	0	0
		15	3.5	42	14	9	0	0
		16	3.75	39	28	21	0	0
		17	4	45	16	10	0	0
		18	4.25	45	25	18	0	0
		19	4.5	48	24	16	0.01	1.5
		20	4.75	30	13.5	7	0	0
		21	5	35	13	10	0	0
		22	5.25	47	24	15	0.01	1.5
		23	5.5	51	16	8.5	0	0
		24	5.75	24	18	11	0	0
		25	6	31	34	30	0	0
		26	6.25	26	19	10	0.01	1
		27	6.5	24	30	25	0	0
		28	6.75	16	35	21	0	0
		29	7	27	16	13	0	0

Table A.3: Bryophyte quantification for Line Creek, September 2015.

Transect #		Rock #	Distance from Shore (m)	Depth (cm)	Max Axis (cm)	Inter Axis (cm)	% Area Coverage	Shoot Length (mm)
LIDSL	1	30	7.25	27	16	6	0	0
		31	7.5	25	21	14	0	0
		32	7.75	18	14	10	0	0
		33	8	18	30	16	0	0
		34	8.25	9	20	14	40	1
		35	8.5	5	30	15	50	1
		Total Width = 8.5 m						
	2	1	0	11	22	15	0	0
		2	0.25	8	24	9	0	0
		3	0.5	17	16	11	0	0
		4	0.75	13	21	13	0	0
		5	1	15	12	11	0	0
		6	1.25	26	24	15	0	0
		7	1.5	24	15	12	0	0
		8	1.75	27	21	12	0	0
		9	2	25	21	12	0.01	0.5
		10	2.25	29	34	28	0	0
		11	2.5	29	13	10	0	0
		12	2.75	38	14	12	0.01	0.2
		13	3	40	19	13	0.01	0.2
		14	3.25	45	34	17	0.01	0.2
		15	3.5	35	26	24	0.01	0.2
		16	3.75	44	16	12	0	0
		17	4	32	33	25	0	0
		18	4.25	40	22	20	0	0
		19	4.5	30	22	9	0	0
		20	4.75	32	17	13	0	0
		21	5	30	14	10	0	0
		22	5.25	25	16	13	0	0
		23	5.5	14	19	14	0	0
		24	5.75	18	26	17	0	0
		25	6	13	26	15	10	1
		Total Width = 6 m						
	3	1	0	7	22	15	0	0
		2	0.25	8	16	13	0	0
		3	0.5	10	19	12	0	0
		4	0.75	2	19	14	0.01	0.02
		5	1	10	19	15	0	0
		6	1.25	11	14	8.5	0	0
		7	1.5	19	12	10	0.01	0.05
		8	1.75	19	25	17	0	0
		9	2	32	20	11	0	0
		10	2.25	25	21	20	0	0
		11	2.5	39	23	15	0	0
		12	2.75	40	14	7	0.01	0.05
		13	3	38	28	24	0	0
		14	3.25	39	12	7.5	0	0
		15	3.5	41	20	16	0	0
		16	3.75	42	17	10	0	0
		17	4	31	15	10	0	0
		18	4.25	38	16	9	0	0
		19	4.5	pebble	-	-	-	-
		20	4.75	46	16	12	0	0
		21	5	56	14	8	0	0
		22	5.25	30	21	9	0	0
		23	5.5	7	24	14	5	1
		Total Width = 5.5 m						
LI8	1	1	0.5	7	21	10	0	0
		2	1	2	25	22	0	0
		3	1.5	10	24	16.5	0	0
		4	2	15	21	19	0	0
		5	2.5	19	17	14	0	0
		6	3	22	18	15.5	0	0
		7	3.5	30	16	12	0	0
		8	4	27	13.5	9.5	0	0
		9	4.5	23	13	6.5	0	0
		10	5	24	16.5	13	0	0
		11	5.5	22	16.5	7	0	0
		12	6	30	32	17	0	0
		13	6.5	33	21	15.5	0	0
		14	7	29	19.5	15	0	0
		15	7.5	34	17	10.5	0	0
		16	8	35	18	13	0	0
		17	8.5	33	15	11.5	0	0
		18	9	31	29	15	0	0
		19	9.5	31	22	9.8	0	0
		20	10	pebble	-	-	-	-
		21	10.5	48	14	11	0	0
		Total Width = 10 m						
	2	1	0.5	6	19	14.5	0	0
		2	1	17	21	16	0	0
		3	1.5	25	13	9	0	0
		4	2	30	21	12	0	0
		5	2.5	34	28	14.5	0	0
		6	3	35	25	16.5	0	0
		7	3.5	36	14.5	10.5	0	0

Table A.3: Bryophyte quantification for Line Creek, September 2015.

Transect #		Rock #	Distance from Shore (m)	Depth (cm)	Max Axis (cm)	Inter Axis (cm)	% Area Coverage	Shoot Length (mm)
LI8	2	8	4	35	19	10.5	0	0
		9	4.5	34	17.5	11	0	0
		10	5	31	24	19.5	0	0
		11	5.5	29	16.5	15	0	0
		12	6	29	17	11	0	0
		13	6.5	30	14.5	12	0	0
		14	7	32	21.5	13	0	0
		15	7.5	32	42	18	0	0
		16	8	33	13.5	8.5	0	0
		17	8.5	25	12	7.5	0	0
		18	9	27	17	10	0	0
		19	9.5	21	14	9.5	0	0
		20	10	18	17.5	13	0	0
		21	10.5	16	14	10.5	0	0
		22	11	15	16.5	12	0	0
		Total Width = 10.5 m						
	3	1	0.5	17	16	11	0	0
		2	1	27	14.5	9.5	0	0
		3	1.5	34	25	22	0	0
		4	2	35	22.5	18	0	0
		5	2.5	42	27.5	18	0	0
		6	3	47	21	13.5	0	0
		7	3.5	45	30	21	0	0
		8	4	36	15	10	0	0
		9	4.5	38	24	20	0	0
		10	5	42	15.5	11.5	0	0
		11	5.5	37	15	14.5	0	0
		12	6	31	19	16	0	0
		13	6.5	34	21.5	14	0	0
		14	7	30	13.5	11	0	0
		15	7.5	24	32	15	0	0
		16	8	26	16	12	0	0
		17	8.5	20	22	4.5	0	0
		Total Width = 8 m						

Table A.4: Selected water quality data from Teck's monitoring program, 2015.

Area	Sample Date	Physical	Anions and Nutrients							Selenium Speciation				Selenium Speciation	Selenium	
		Temperature	Ammonia (as N)	Nitrate (as N)	Nitrite (as N)	Total Kjeldahl Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho-Phosphate	Selenite [Se(IV)]	Selenate [Se(VI)]	Selenocyanate (SeCN)	Methylseleninic Acid [MeSe(IV)]	Selenomethionine (SeMe)	Total Selenium (Se)	Dissolved Selenium (Se)
		(°C)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
LC_LC1 (LI24) Reference	31-Mar-15	1.5														
	20-Apr-15	2.7														
	27-Apr-15	3.6														
	5-May-15	2.6	<0.005	0.206	<0.001	0.06	0.002		0.002						1.12	1.15
	11-May-15	3.2														
	19-May-15	4.4														
	26-May-15	2.9														
	2-Jun-15	3.0	<0.005	0.178	<0.001	0.50	0.163		0.004						0.83	0.68
	8-Jun-15	3.0														
	16-Jun-15	3.3	<0.005	0.170	<0.001	<0.05	0.002	0.003	0.002	<0.50	1.33	<0.50	<0.50	<0.50	1.61	1.53
	16-Jun-15	3.3														
	23-Jun-15	4.6														
	30-Jun-15	6.7	<0.005	0.146	<0.001	0.07	0.005	0.004	0.002	<0.50	1.43	<0.50	<0.50	<0.50	1.70	1.48
	7-Jul-15	6.7	0.0101	0.125	<0.001	<0.05	0.003		0.002						1.72	1.74
	17-Jul-15	4.5	<0.005	0.150	0.002	<0.05	0.013	0.003	0.002	<0.50	1.57	<0.50	<0.50	<0.50	1.98	2.29
	21-Jul-15	4.5														
	28-Jul-15	4.1	<0.005	0.157	<0.001	0.05	0.006	0.003	0.002	<0.50	2.15	<0.50	<0.50	<0.50	2.08	1.96
	11-Aug-15	6.2	<0.005	0.134	<0.001	<0.05	0.003	<0.002	0.002	<0.50	1.71	<0.50	<0.50	<0.50	2.16	2.04
	11-Aug-15		<0.005	0.134	<0.001	<0.05	<0.002		0.002						2.21	2.14
	24-Aug-15	4.3	<0.005	0.185	<0.001	<0.05	0.004	0.002	0.002	<0.50	1.93	<0.50	<0.50	<0.50	1.94	1.85
	9-Sep-15	3.8	<0.005	0.204	<0.001	<0.05	0.004	<0.002	<0.001	<0.50	1.98	<0.50	<0.50	<0.50	2.24	2.17
	21-Sep-15	3.7	<0.005	0.215	<0.001	<0.05	0.003	<0.002	<0.001	<0.50	2.06	<0.50	<0.50	<0.50	2.34	2.27
	6-Oct-15	2.5	<0.005	0.211	<0.001	0.05	<0.002		0.001						2.78	2.62
	2-Nov-15	2.9	<0.005	0.130	<0.001	0.07	<0.002		<0.001							
LC_SLC (SLINE) Reference	5-Jan-15	0.3	<0.005	0.135	<0.0010	0.052	0.0023		0.002						1.34	1.35
	2-Feb-15	0.2	<0.005	0.122	<0.0010	0.063	0.0028		<0.001						1.43	1.48
	2-Mar-15	0.1	<0.005	0.100	<0.0010	0.077	0.0033		0.002						1.40	1.41
	6-Apr-15	1.5	<0.005	0.035	<0.0010	0.057	<0.002		<0.001						0.98	0.98
	5-May-15	4.5	<0.005	0.062	<0.0010	0.107	0.0095		0.003						0.56	0.54
	2-Jun-15	3.8	<0.005	0.063	<0.0010	0.994	0.346		0.003						0.62	0.31
	16-Jun-15	5.8	<0.005	0.071	<0.0010	<0.050	0.0037	0.0034	0.002	<0.50	0.63	<0.50	<0.50	<0.50	0.78	0.72
	30-Jun-15	6.6	<0.005	0.067	<0.0010	0.079	0.0036	0.0033	0.002	<0.50	0.74	<0.50	<0.50	<0.50	0.83	0.87
	7-Jul-15	7.1	<0.005	0.058	<0.0010	0.056	0.0035		0.002						0.95	0.94
	17-Jul-15	5.5	<0.005	0.095	0.0018	<0.050	0.0041	0.0035	0.002	<0.50	0.68	<0.50	<0.50	<0.50	1.02	1.14
	28-Jul-15	6.4	<0.005	0.069	<0.0010	<0.050	<0.002	0.0029	0.002						1.19	1.09
	11-Aug-15	6.5	<0.005	0.095	<0.0010	<0.050	0.0024	0.0021	0.002						1.29	1.22
	11-Aug-15		<0.005	0.096	<0.0010	<0.050	<0.002		0.002	<0.50	0.87	<0.50	<0.50	<0.50	1.23	1.15
	24-Aug-15	5.3	<0.005	0.109	<0.0010	0.055	<0.002	0.0031	0.003	<0.50	1.26	<0.50	<0.50	<0.50	1.19	1.17
	9-Sep-15	5.1	<0.005	0.098	<0.0010	<0.050	0.0027	0.002	0.002	<0.50	1.01	<0.50	<0.50	<0.50	1.38	1.29
	21-Sep-15	5.3	<0.005	0.118	<0.0010	<0.050	<0.002	0.002	0.002	<0.50	1.4	<0.50	<0.50	<0.50	1.43	1.36
	6-Oct-15	3.8	<0.005	0.085	<0.0010	<0.050	<0.002		0.001						1.42	1.41
	6-Oct-15		<0.005	0.085	<0.0010	0.052	<0.002		0.001						1.39	1.41
	2-Nov-15	3.0	<0.005	0.090	<0.001	0.06	<0.002		0.002							
	9-Dec-15		<0.005	0.128	0.001	<0.05	<0.005		0.002							
LC_LC3 (LILC3) Mine-exposed	5-Jan-15	2.9	<0.005	20.8	0.006		0.003	0.003	0.003						104	107
	6-Jan-15	2.9					0.003			0.16	76.3		0.09	0.09		
	6-Jan-15						0.006			0.16	76.3		0.09	0.09		
	2-Feb-15	3.4	<0.005	21.6	<0.005		0.006		0.001						118	112
	2-Mar-15	3.0	<0.005	22.8	<0.005		0.004		0.002						111	111
	17-Mar-15	4.2	<0.005	20.6	<0.005		0.005		0.004						106	103
	24-Mar-15	4.1	<0.005	19.7	<0.005		0.003		0.003						87	85
	31-Mar-15	4.2	<0.005	19.2	<0.005		0.002		0.003						86	87
	6-Apr-15	3.8	<0.005	18.2	<0.005		0.003		0.002						73	72
	13-Apr-15	4.6	<0.005	18.0	<0.005		0.004		0.001						78	78
	20-Apr-15	4.8	<0.005	17.3	<0.005		0.004		0.002						73	76
	27-Apr-15	4.6	<0.005	12.8	0.002		0.004		0.002						50	51
	28-Apr-15	4.9	<0.005	13.1	0.003		0.003		0.002						52	52
	29-Apr-15	4.4	<0.005	13.1	0.002		0.003		0.003						56	55
	5-May-15	4.7	<0.005	11.5	<0.002	<0.05	0.004		0.003						50	50
	11-May-15	4.1	<0.005	11.7	<0.002	<0.05	0.003		0.002						54	53
	19-May-15	5.0	<0.005	11.4	<0.002	<0.05	0.003		0.003						53	51

Table A.4: Selected water quality data from Teck's monitoring program, 2015.

Area	Sample Date	Physical	Anions and Nutrients							Selenium Speciation				Selenium Speciation	Selenium	
		Temperature	Ammonia (as N)	Nitrate (as N)	Nitrite (as N)	Total Kjeldahl Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho-Phosphate	Selenite [Se(IV)]	Selenate [Se(VI)]	Selenocyanate (SeCN)	Methylseleninic Acid [MeSe(IV)]	Selenomethionine (SeMe)	Total Selenium (Se)	Dissolved Selenium (Se)
		(°C)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
LC_LC3 (LILC3) Mine-exposed	26-May-15	4.4	<0.005	7.7	<0.001	<0.05	0.004		0.002						41	39
	2-Jun-15	4.3	<0.005	6.0	<0.001	0.09	0.004		0.002						31	31
	8-Jun-15	4.7	<0.005	5.7	<0.001	0.12	0.002		0.002						26	26
	16-Jun-15	5.7	<0.005	8.4	<0.001	0.09	0.002		0.008	<0.50	36.2		<0.50	<0.50	39	37
	23-Jun-15	5.4	<0.005	9.0	<0.002	<0.05	0.003		0.002						41	42
	30-Jun-15	6.2	<0.005	9.9	0.003	0.08	0.005		0.002	<0.50	38.9		<0.50	<0.50	48	50
	7-Jul-15	6.2	<0.005	10.7	<0.005	0.09	0.003		0.001						52	53
	17-Jul-15	6.1	<0.005	11.0	0.002	<0.05	0.003		0.002	<0.50	41.1		<0.50	<0.50	64	71
	21-Jul-15	6.9	<0.005	11.8	<0.002	0.10	0.002		0.003						61	60
	28-Jul-15	6.4	<0.005	13.3	<0.002	<0.05	0.003		0.003	<0.50	64.4		<0.50	<0.50	67	69
	11-Aug-15	6.6	<0.005	13.3	<0.005	<0.05	<0.002		0.003	<0.50	51.6		<0.50	<0.50	66	66
	24-Aug-15	6.7	<0.005	13.1	<0.005	0.10	0.002	0.003	0.003	<0.50	64.3		<0.50	<0.50	64	63
	9-Sep-15	7.1	<0.005	14.3	<0.005	0.08	0.003	0.002	0.003	<0.50	53.9		<0.50	<0.50	67	67
	17-Sep-15			15.0			0.003									
	21-Sep-15	6.2	<0.005	15.6	<0.005	0.07	0.002	0.003	0.002	<0.50	51.4		<0.50	<0.50	62	62
	1-Oct-15		<0.005	18.7	<0.005	<0.05	<0.002		0.001						56	54
	6-Oct-15	5.6	<0.005	0.01	<0.001	<0.05	<0.002		0.001						<0.050	<0.050
	6-Oct-15	5.3	<0.005	19.5	<0.005	<0.05	0.002		0.002						72	70
	26-Oct-15															
	2-Nov-15	5.3	<0.005	23.4	<0.005	0.18	0.003		0.002							
	9-Dec-15		0.006	25.0	<0.001	<0.05	0.009		0.003							
	16-Dec-15			25.6												
	16-Dec-15			20.5												
	18-Dec-15			23.3												
	18-Dec-15			35.7												
LC_LCDSSL CC (LIDSL) Mine-exposed	5-Jan-15	1.0		13.3	0.004		0.002		0.002						66.1	65.3
	2-Feb-15	1.7		14.4	0.003		<0.002		<0.001						73.1	75.3
	2-Mar-15	1.2		15.1	0.003		0.003		<0.001						70.6	72.1
	17-Mar-15	3.0		12.4	<0.005		0.004		0.002						64.3	62.2
	24-Mar-15	3.4		13.1	0.002		0.003		0.001						60.0	59.6
	31-Mar-15	3.7		10.5	0.003		0.003		<0.001						47.7	48.6
	6-Apr-15	3.0		11.6	0.002		<0.002		<0.001						48.9	48.8
	13-Apr-15	4.3		11.6	0.004		<0.002		<0.001						48.8	49.8
	20-Apr-15	4.5		10.1	0.004	<0.05	0.002		<0.001						42.5	43.1
	27-Apr-15	5.6	<0.005	8.1	0.003	<0.05	0.003		0.001						33.9	34.1
	28-Apr-15	6.4	<0.005	7.5	0.003	<0.05	0.004		<0.001						31.5	33.0
	5-May-15	5.6	<0.005	5.8	0.001	<0.05	0.006		0.003						25.1	24.8
	12-May-15	3.9	<0.005	6.6	0.001	<0.05	0.003		<0.001						31.4	33.4
	19-May-15	3.3	<0.005	5.8	<0.001	<0.05	0.003		<0.001						28.2	29.3
	26-May-15	4.2	<0.005	2.8	<0.001	0.30	0.045		0.002						14.4	14.8
	2-Jun-15	4.3	<0.005	1.9	<0.001	0.65	0.244		0.002						9.6	9.7
	8-Jun-15	5.6	<0.005	3.2	<0.001	0.16	0.005		0.002						14.9	15.1
	16-Jun-15	6.2	<0.005	5.0	<0.001	0.13	0.003	0.003	0.002	<0.50	22.5		<0.50	<0.50	24.3	23.2
	23-Jun-15	5.8	<0.005	5.4	<0.001	0.13	0.003		0.002						27.8	27.7
	24-Jun-15	7.9	<0.005	5.6	0.002	0.13	0.002		0.002						29.7	28.9
	30-Jun-15	6.8	<0.005	5.9	0.001	0.09	0.004		0.001	<0.50	25.7		<0.50	<0.50	30.5	31.0
	7-Jul-15	6.9	<0.005	6.8	<0.001	<0.05	0.002		<0.001						37.0	36.7
	17-Jul-15	6.5	<0.005	6.6	0.002	0.12	0.007		0.002	<0.50	25.2		<0.50	<0.50	40.5	41.3
	21-Jul-15	8.7	<0.005	7.2	<0.002	0.13	0.003		0.002						39.5	37.4
	28-Jul-15	7.2	<0.005	8.1	<0.002	0.12	0.002		0.002	<0.50	40.5		<0.50	<0.50	42.1	42.5
	11-Aug-15	7.2	<0.005	8.7	<0.005	0.08	0.002		0.002	<0.50	36.2		<0.50	<0.50	44.2	44.5
	24-Aug-15	6.7	<0.005	9.0	<0.005	0.11	0.002	0.003	0.002	<0.50	44.9		<0.50	<0.50	42.7	42.6
	26-Aug-15	7.8	<0.005	8.3	<0.005	0.08	0.004		0.002						45.0	42.1
	9-Sep-15	7.1	<0.005	9.8	<0.005	0.10	0.003		0.002	<0.50	36.6		<0.50	<0.50	44.0	44.7
	14-Sep-15			10.1												
	21-Sep-15	7.8	<0.005	10.6	<0.005	0.10	<0.002	<0.002	0.001	<0.50	37.2		<0.50	<0.50	45.7	43.1
	28-Sep-15			12.2												
	1-Oct-15			13.4												
	5-Oct-15	7.4	<0.005	13.1	<0.005		<0.002		<0.001						49.8	47.9
	7-Oct-15			12.9												
	9-Oct-15			12.5												
	13-Oct-15			10.4											48.5	
	19-Oct-15			10.8												

Table A.4: Selected water quality data from Teck's monitoring program, 2015.

Area	Sample Date	Physical	Anions and Nutrients							Selenium Speciation				Selenium Speciation	Selenium	
		Temperature	Ammonia (as N)	Nitrate (as N)	Nitrite (as N)	Total Kjeldahl Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho-Phosphate	Selenite [Se(IV)]	Selenate [Se(VI)]	Selenocyanate (SeCN)	Methylseleninic Acid [MeSe(IV)]	Selenomethionine (SeMe)	Total Selenium (Se)	Dissolved Selenium (Se)
		(°C)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
LC_LCDSSL CC (LIDSL) Mine-exposed	21-Oct-15			10.5												
	26-Oct-15	5.3														
	28-Oct-15			12.9												
	2-Nov-15			13.9												
	2-Nov-15	4.5	<0.005	14.5	<0.005	0.133	<0.002		<0.001	<0.50	51.2	<0.50	<0.50	<0.50	53.6	50.0
	4-Nov-15			14.9												
	9-Nov-15	4	<0.005	13.9	<0.001	<0.050	<0.005		0.0016	<0.50	41.5	<0.50	<0.50	<0.50	51.7	49.4
	16-Nov-15															
	16-Nov-15	3.1	<0.005	12.1	<0.001	<0.050	<0.005		<0.001	<0.50	40.1	<0.50	<0.50	<0.50	48.5	49.5
	23-Nov-15									<0.50	48.6	<0.50	<0.50	<0.50		
	23-Nov-15	2.5	<0.005	11.7	<0.001	<0.050	<0.005		0.0016						53.5	51.5
	30-Nov-15	1.5	<0.005	17	0.0014		<0.005		0.0012	<0.50	51.1	<0.50	<0.50	<0.50		
	7-Dec-15	3.1														
	9-Dec-15	2.4	<0.005	17.3	0.0014	<0.050	<0.005		0.0021						41.3	43.8
	14-Dec-15	2.6	<0.005	17.8	<0.001	<0.050	0.0061		0.0015	0.57	40.4	<0.50	<0.50	<0.50	46.4	48.0
	23-Dec-15			15											40.0	37.7
	30-Dec-15			13.1											41.2	40.2
LC_LC4 (LI8) Mine-exposed	5-Jan-15	-0.1		9.4	0.002		0.003		0.003						48.1	47.8
	2-Feb-15	1.3		10.3	0.003		0.003		0.002						52.0	53.7
	2-Mar-15	0.1		10.5	0.002		0.004		<0.001						50.8	52.8
	17-Mar-15	2.1		9.0	0.003		0.004		0.003						44.0	42.5
	24-Mar-15	3.2		9.4	0.003		0.005		0.002						42.5	42.8
	31-Mar-15	3.8		7.3	0.002		0.008		0.003						33.3	36.8
	6-Apr-15	2.4		8.8	<0.002		0.003		0.002						37.5	35.1
	13-Apr-15	4.0	<0.005	6.7	0.003	<0.05	0.004		0.001						37.6	38.0
	20-Apr-15	3.7	<0.005	7.4	0.002	<0.05	0.002		0.002						31.4	32.3
	27-Apr-15	5.6	<0.005	6.6	0.003	<0.05	0.006		0.002						28.0	28.6
	4-May-15	6.7	<0.005	5.2	0.002	<0.05	0.004		0.002						21.5	22.1
	11-May-15	4.9	<0.005	5.1	0.002	<0.05	0.004		0.002						23.7	23.2
	19-May-15	6.4	<0.005	4.5	0.002	<0.05	0.006		0.001						22.0	22.2
	26-May-15	4.5	0.005	3.2	<0.001	0.36	0.028		0.002						16.3	15.9
	2-Jun-15	4.7	<0.005	2.2	<0.001	0.23	0.030		0.003						11.6	11.6
	8-Jun-15	6.1	<0.005	2.7	<0.001	0.12	0.009		0.004						12.7	12.9
	15-Jun-15		0.007	4.0	0.001		<0.02		0.004						19.3	
	16-Jun-15	5.9	<0.005	4.1	<0.001	0.10	0.005		0.004	<0.50	18.0	<0.50	<0.50	<0.50	19.1	19.0
	23-Jun-15	5.8	0.006	4.5	<0.001	0.15	0.004		0.005						23.0	22.1
	30-Jun-15	6.9	<0.005	4.8	0.001	0.15	0.005		0.005	<0.50	20.0	<0.50	<0.50	<0.50	24.4	23.6
	7-Jul-15	6.9	0.006	5.5	<0.001	0.14	0.005		0.004						28.1	27.8
	17-Jul-15	7.1	0.006	5.2	0.002	<0.05	0.031		0.003	<0.50	19.7	<0.50	<0.50	<0.50	30.6	31.5
	21-Jul-15	9.2	0.006	5.5	0.003	0.70	0.210		0.004						28.7	28.5
	28-Jul-15	7.1	<0.005	6.2	0.003	0.19	0.017		0.003	<0.50	31.3	<0.50	<0.50	<0.50	30.8	32.9
	11-Aug-15	7.5	<0.005	7.3	<0.005	0.26	0.021		0.001	<0.50	29.1	<0.50	<0.50	<0.50	35.2	36.8
	24-Aug-15	6.3	<0.005	7.2	<0.005	0.14	0.006	0.003	0.004	<0.50	35.4	<0.50	<0.50	<0.50	34.8	34.2
	9-Sep-15	6.1	<0.005	7.8	<0.005	0.09	0.007	0.003	0.003	<0.50	30.0	<0.50	<0.50	<0.50	36.5	36.0
	21-Sep-15	6.7	<0.005	7.9	<0.005	0.12	0.005	0.002	0.002	0.29	30.4	<0.50	<0.50	<0.50	35.4	35.2
	6-Oct-15	4.5	<0.005	10.5	<0.005	0.11	0.004		0.001						37.6	37.8
	2-Nov-15	4.0	<0.005	11.4	<0.005	0.15	0.003		0.002							
	9-Dec-15		<0.005	13.0	0.001	0.09	0.008		0.004							
LC_LC6 (FOUL) Mine-exposed	5-Jan-15	0.1	<0.005	11.5	0.003	<0.05	<0.002		0.001						41.7	42.2
	2-Mar-15	-0.1	<0.005	12.7	0.003	<0.05	0.003		<0.001						46.7	47.1
	6-Apr-15	1.1	<0.005	10.8	0.003	<0.05	0.002		<0.001						41.4	40.9
	4-May-15	7.0	<0.005	7.6	0.006	<0.05	0.006		<0.001						30.5	30.7
	7-Jul-15	10.5	0.007	8.8	0.005	0.14	0.003		<0.001						29.9	29.0
	11-Aug-15	15.6	0.006	10.5	0.012	0.09	<0.002		<0.001						36.7	35.1
	9-Sep-15	5.5	<0.005	9.9	<0.005	0.08	<0.002		<0.001						37.2	36.5
	5-Oct-15	4.5	<0.005	9.9	<0.005	0.12	<0.002		<0.001						36.9	35.4
	2-Nov-15	2.8	<0.005	10.1	<0.005	0.14	<0.002		<0.001							
	9-Dec-15		<0.005	9.8	<0.001	<0.05	0.014		<0.001							
LC_LC5 (FO23) Mine-exposed	5-Jan-15	0.0	<0.005	10.4	<0.005	<0.05	0.009		0.001						40.6	41.5
	2-Feb-15	0.6	<0.005	11.2	0.003	<0.05	0.004		<0.001						45.0	45.8
	2-Mar-15	-0.1	<0.005	11.8	0.002	<0.05	0.004		<0.001						45.8	46.9
	17-Mar-15	1.4	<0.005	10.7	0.003	<0.05	0.005		<0.001						43.0	42.0
	24-Mar-15	2.6	<0.005	10.7	0.002	<0.05	0.003		<0.001						41.8	41.0
	31-Mar-15	3.5	<0.005	9.4	0.003	<0.05	0.009		<0.001						39.3	40.3
	6-Apr-15	1.7	<0.005	10.2	0.003	<0.05	0.003		<0.001						39.0	38.6

Table A.4: Selected water quality data from Teck's monitoring program, 2015.

Area	Sample Date	Physical	Anions and Nutrients							Selenium Speciation				Selenium Speciation	Selenium	
		Temperature	Ammonia (as N)	Nitrate (as N)	Nitrite (as N)	Total Kjeldahl Nitrogen	Total Phosphorus	Dissolved Phosphorus	Ortho-Phosphate	Selenite [Se(IV)]	Selenate [Se(VI)]	Selenocyanate (SeCN)	Methylseleninic Acid [MeSe(IV)]	Selenomethionine (SeMe)	Total Selenium (Se)	Dissolved Selenium (Se)
		(°C)	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
LC_LC5 (FO23) Mine-exposed	13-Apr-15	3.1	<0.005	9.8	0.006	<0.05	<0.002		<0.001						39.6	41.3
	20-Apr-15	3.6	<0.005	9.2	0.004	0.07	0.004		<0.001						38.2	38.9
	27-Apr-15	4.8	<0.005	7.7	0.008	<0.05	0.007		<0.001						32.2	33.8
	28-Apr-15	7.4	<0.005	7.6	<0.005	<0.05	0.006		<0.001						32.8	35.1
	4-May-15	6.6	<0.005	6.8	0.003	0.15	0.006		<0.001						27.7	27.7
	5-May-15	6.9	<0.005	6.7	0.002	<0.05	0.008		0.001						27.3	26.4
	11-May-15	5.4	<0.005	7.2	0.004	<0.05	0.008		<0.001						28.1	27.8
	19-May-15	4.4	<0.005	7.2	0.005	<0.05	0.004		<0.001						28.3	27.0
	26-May-15	6.0	<0.005	5.3	0.003	0.19	0.024		<0.001						21.2	19.6
	2-Jun-15	6.7	<0.005	4.6	0.003	0.22	0.025		<0.001						17.5	17.4
	8-Jun-15	8.2	<0.005	5.1	0.002	0.17	0.014		0.002						17.6	17.8
	15-Jun-15	8.6	<0.005	6.3	0.003	0.18	0.005		0.001						23.0	22.4
	23-Jun-15	7.7	<0.005	6.6	0.003	0.14	0.004		0.002						25.6	25.5
	30-Jun-15	9.8	<0.005	7.2	0.003	0.15	0.005		0.001						27.9	26.7
	7-Jul-15	9.8	0.005	7.6	0.002	0.13	0.005		<0.001						28.4	28.2
	17-Jul-15	9.3	<0.005	7.7	0.004	<0.05	0.012		<0.001						31.8	33.0
	21-Jul-15	13.0	<0.005	7.8	0.003	0.15	0.013		0.002						29.9	29.0
	28-Jul-15	8.9	<0.005	8.2	0.006	0.17	0.010		0.001	<0.50	30.7	<0.50	<0.50	<0.50	30.9	32.3
	11-Aug-15	14.7	<0.005	8.9	0.003	0.12	0.006		<0.001						33.6	34.3
	9-Sep-15	5.9	<0.005	8.9	0.004	0.11	0.003		<0.001						36.8	35.3
	5-Oct-15	4.4	<0.005	9.9	0.004	0.12	<0.002		<0.001						36.4	35.0
	26-Oct-15	3.3	<0.005	9.8	<0.001	<0.05	0.063		0.001							
	2-Nov-15	3.4	<0.005	10.3	<0.005	0.15	<0.002		<0.001							
	9-Dec-15		<0.005	10.2	<0.001	0.12	0.008		0.001							

Table A.5: Preserved benthic invertebrate biomass (g wet weight/m^2) measured at Line Creek areas, September 2015.

Species		LI8											LI24							
		1	2	3	4	5	6	7	8	9	10	Mean	1	2	3	4	5	6	7	8
Nematodes	P. Nemata	0	0	0.00100	0.00200	0.00100	0	0.018	0	0	0	0.0022	0.00100	0.00100	0.00100	0.00100	0	0.00100	0.00100	0
Oligochaetes	Cl. Oligochaeta	0.652	1.87	0	0.286	0.035	0.035	0.024	1.36	2.32	0.022	0.660	0.112	0.00100	0.00300	0	0	0.00100	0.00200	0
	F. Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Lumbriculidae	0	0	0.061	0	0.346	0.700	0.096	0	0	0.819	0.202	0	0.052	0.219	0.013	0	0	0	0
Ostracods	Cl. Ostracoda	0	0	0	0.00200	0	0.00100	0	0	0	0.00100	0.000400	0.018	0.027	0.025	0.00700	0.011	0.018	0.00100	0.00100
Insects	O. Coleoptera																			
	F. Elmidae	0	0	0	0	0.058	0	0.00600	0	0	0	0.0064	0	0	0	0	0	0	0	0
	O. Ephemeroptera																			
	F. Ameletidae	0.00800	0	0	0.022	0	0	0.00400	0	0	0.00700	0.00410	0.075	0.526	0.107	0.138	0.076	0.169	0.00500	0.402
	F. Baetidae	0.014	0.312	0.295	0.11	0.164	0.196	0.244	0.378	0.594	0.605	0.291	0.168	0	0.0800	0.028	0.064	0	0.107	0.053
	F. Ephemerellidae	0.314	0.496	0.800	0.514	0.236	0.226	0.066	0.55	0.58	1.07	0.485	0.041	0.586	0.069	0.00400	0.108	0.162	0.704	0.089
	F. Heptageniidae	1.26	2.62	1.30	0.564	0.894	0.642	1.90	2.80	0.596	1.89	1.45	2.79	1.83	3.00	2.52	2.36	3.02	4.60	4.47
	O. Plecoptera																			
	F. Capniidae	0	0	0	0	0	0	0	0	0	0	0	0.017	0.015	0.00800	0.00400	0	0	0.014	0
	F. Chloroperlidae	0	0.00400	0.00500	0.00200	0.032	0.224	0	0	0.146	0.0800	0.0493	0.664	0.578	0.401	0.306	0.449	0.78	0.45	0.215
	F. Leuctridae	0.016	0	0	0.012	0	0.024	0	0	0.112	0.0700	0.0234	0.049	0	0.015	0.00700	0	0	0.16	0
	F. Nemouridae	0.362	0.34	1.19	0.852	0.591	0.469	0.508	0.904	0.992	1.24	0.745	0.862	0.057	0.200	0.804	0.257	0.255	1.38	0.21
	F. Perlodidae	0.812	0.00600	1.26	0.356	0.207	0.221	0	0.842	0	0.141	0.385	2.35	0.111	0.365	0.474	0.981	2.58	0.0720	0.582
	F. Peltoperlidae	0	0	0	0	0	0	0	0	0	0	0	0.075	0	0	0.0100	0	0	0	0
	F. Taeniopterygidae	0.0100	0.012	0.032	0.016	0	0.038	0.028	0.054	0.066	0.041	0.0297	0.024	0	0.035	0.029	0.054	0.00700	0.012	0.013
	O. Trichoptera																			
	F. Apataniidae	0.00200	0	0.00100	0	0.00200	0.00500	0	0	0	0.014	0.0024	0	0	0	0	0	0	0	0
	F. Glossosomatidae	0.024	1.04	0.857	0.29	0.200	0.896	0.33	0.562	0.886	0.173	0.525	0	0	0	0	0	0	0	0
	F. Hydropsychidae	3.17	7.17	10.7	1.72	1.06	10.5	7.73	7.19	11.9	5.65	6.68	0	1.30	0.567	0	0.00200	0	0.00900	0
	F. Limnephilidae	0	0	0	0	0	0	0	0	0	0.003	0.0003	0.00900	0.021	0	0.0100	0	0.059	0.0100	0.032
	F. Rhyacophilidae	0.268	0.95	2.23	4.03	0.321	1.29	3.57	2.73	3.06	2.95	2.14	0.00100	0.011	0.234	0.165	0.00700	0	0.33	0.121
	F. Uenoidae	0	0.00200	0.00200	0.038	0.015	0.00500	0.014	0.00800	0.00800	0.00700	0.00990	0	0	0	0	0.00200	0	0	0
	O. Diptera																			
	Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00100	0	0	0	0	0
	F. Ceratopogonidae	0.014	0	0.085	0	0.00100	0	0.016	0.0700	0	0	0.0186	0	0	0	0	0	0	0	0
	F. Chironomidae	0.242	0.358	0.292	2.09	0.954	0.371	4.97	0.234	0.59	0.588	1.07	0.015	0.016	0.088	0.111	0.00100	0.00100	0.075	0.013
	F. Empididae	0	0	0.115	0.146	0.013	0.027	0.054	0.14	0.038	0	0.0533	0	0	0.012	0	0	0	0.027	0
	F. Muscidae	0	0	0	0	0	0	0	0	0	0	0	0.024	0	0	0	0	0	0	0.024
	F. Pelecorhyncidae	0.0100	0	0	0	0	0	0.124	0	0.712	0.019	0.0865	0	0	0	0	0	0	0	0
	F. Psychodidae	0	0	0	0.00200	0.00100	0.00100	0.00600	0.00200	0.00200	0.00100	0.00150	0.00800	0	0	0	0	0	0.023	0.00100
	F. Simuliidae	0	0	0	0	0.046	0	0	0	0	0	0.0046	0	0.055	0	0.176	0	0	0.069	0.129
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Tipulidae	0	0	0.00800	0.042	0.505	0	0	0	0.316	0.127	0.100	0.251	0.024	0.115	0.43	2.01	0.014	0.205	0
Other	Cl. Turbellaria	0	0	0	0.012	0.036	0.00100	0.026	0.016	0.0400	0.00100	0.0132	0	0	0	0	0	0	0	0
	Cl. Arachnida	0	0	0.056	0.026	0.00100	0.00100	0.012	0.00200	0.00200	0.00100	0.0101	0.014	0.0200	0	0.011	0.018	0.00100	0.00100	0.00100
	Cl. Entognatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL BIOMASS		**7.18**	**15.2**	**19.3**	**11.1**	**5.72**	**15.9**	**19.7**	**17.8**	**23.0**	**15.5**	**15.0**	**7.57**	**5.23**	**5.55**	**5.25**	**6.41**	**7.07**	**8.26**	**6.36**

Table A.5: Preserved benthic invertebrate biomass (g wet weight/m^2) measured at Line Creek areas, September 2015.

Species		LI24			LILC3											LIDSL				
		9	10	Mean	1	2	3	4	5	6	7	8	9	10	Mean	1	2	3	4	5
Nematodes	P. Nemata	0.00100	0.00100	0.000800	0.00400	0.00800	0.00200	0.00800	0.0800	0.00400	0.00400	0.00400	0.044	0.024	0.0182	0	0	0.0200	0	0.00100
Oligochaetes	Cl. Oligochaeta	0.00100	0	0.012	0	0	0	0	0	0	0	0	0.100	0	0.0100	0	0	0	0	0
	F. Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.55	0
	F. Lumbriculidae	0	0	0.0284	0.66	2.82	0.056	0.536	0.156	0.604	0.112	0.976	0	0.600	0.652	0	0.284	0	0.897	0
Ostracods	Cl. Ostracoda	0.00100	0.00100	0.011	2.41	0.936	0.538	0.24	0.904	0.380	0.208	0.652	1.49	0.808	0.857	0.00400	0.00400	0.0400	0.00100	0.00800
Insects	O. Coleoptera																			
	F. Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.084	0.023	0
	O. Ephemeroptera																			
	F. Ameletidae	0.00100	0.275	0.177	0	0	0	0.00800	0.00400	0	0.476	0	0	0.00800	0.0496	0	0.22	0.164	0.034	0.00200
	F. Baetidae	0	0	0.05	0.392	0.504	0	0.096	0.0400	0.0800	0.144	0.504	0.308	0.888	0.296	0	1.15	0.168	0.136	0.349
	F. Ephemerellidae	0	0.123	0.189	0.12	0.392	0.132	0	0.22	0.0600	1.03	0.44	0.108	0.368	0.287	0.00400	0.564	0.176	0.176	0.624
	F. Heptageniidae	1.09	4.39	3.01	0.748	0.24	0.482	0.488	0.156	0.508	0.464	0.78	0.488	0.48	0.483	2.36	4.92	4.34	4.35	2.37
	O. Plecoptera																			
	F. Capniidae	0	0.031	0.0089	0	0	0	0	0	0	0	0.096	0	0	0.0096	0	0.992	0.072	0	0.011
	F. Chloroperlidae	0.238	1.00	0.508	2.51	1.34	1.32	1.10	0.456	1.5	1.99	2.27	1.90	2.70	1.71	1.46	2.27	0.836	1.13	0.188
	F. Leuctridae	0.00200	0.037	0.027	0	0	0	0	0	0	0	0	0	0	0	0.556	0	0.024	0.057	0.00100
	F. Nemouridae	0.12	0.381	0.452	2.82	4.50	0.464	4.29	0.608	4.27	5.43	2.47	1.56	3.92	3.03	1.86	1.71	2.85	1.35	1.48
	F. Perlodidae	0.242	0.788	0.854	3.13	4.50	3.05	1.33	6.91	5.52	1.26	0.644	3.86	4.53	3.47	2.25	2.22	2.42	1.34	0.53
	F. Peltoperlidae	0	0	0.0085	0	0.088	0	0	0	0	0	0	0	0	0.0088	0	0	0	0	0
	F. Taeniopterygidae	0	0.00100	0.0175	0	0	0	0	0	0	0.00400	0.00400	0	0	0.000800	0.056	0.00800	0.096	0.137	0.058
	O. Trichoptera																			
	F. Apataniidae	0	0	0	0	0	0	0	0	0	0	0	0	0.048	0.0048	0	0	0	0.00500	0.00900
	F. Glossosomatidae	0	0	0	0.00400	0	0	0	0	0	0	0	0	0	0.000400	0.328	1.33	1.25	0.805	0.224
	F. Hydropsychidae	0	0.00500	0.188	19.1	24.0	17.3	44.1	33.2	51.0	22.0	27.2	30.3	38.1	30.6	3.44	41.0	15.5	5.9	3.73
	F. Limnephilidae	0	0	0.0141	0	0	0	0	0	0	0	0	0	0	0	0.0200	0	0	0	0.00400
	F. Rhyacophilidae	0	0.121	0.099	37.8	37.9	7.49	4.12	5.14	17.2	13.1	24.1	13.8	7.70	16.8	0.728	3.88	4.5	1.81	1.81
	F. Uenoidae	0	0	0.000200	0.00400	0	0.00200	0.00800	0	0	0	0	0	0	0.0014	0.0160	0.00800	0.00800	0	0.00100
	O. Diptera																			
	Unknown	0	0	0.000100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Ceratopogonidae	0	0	0	0	0	0.084	0	0.076	0	0	0	0.00400	9.70	0.99	0	0	0	0.00100	0
	F. Chironomidae	0.00100	0.011	0.0332	8.75	0.856	6.76	14.0	11.2	7.93	8.26	11.9	14.7	0	8.43	1.91	3.30	2.76	0.362	0.094
	F. Empididae	0	0	0.0039	0.084	0.12	0.254	0	0	0.16	0.052	0.32	0.00400	0	0.0994	0	0	0	0.216	0.052
	F. Muscidae	0	0	0.0048	0.608	0	0	0.192	0.724	0	0	0	0	0	0.152	0	0	0	0	0
	F. Pelecorhyncidae	0	0	0	0	0	0	0	0.292	0	0.12	0	0	0	0.0412	0	0	0	0.011	0
	F. Psychodidae	0.00100	0	0.0033	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00100	0.00300
	F. Simuliidae	0	0	0.0429	0	0	0	0	0	0.152	0	0	0	0	0.0152	0.192	0.364	0	0.036	0
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Tipulidae	0.00700	0.405	0.346	0	0	0	0	0	0.212	0	0	0	0	0.0212	0	0	0.264	0.141	0.029
Other	Cl. Turbellaria	0	0	0	0.192	1.71	0.370	1.54	0.252	0.608	1.09	0.764	0.00400	0.52	0.705	0.092	0.32	0.168	0.12	0.00800
	Cl. Arachnida	0	0.00100	0.0067	0.928	0.792	0.232	0.232	0.192	0.520	0.344	0.00400	0.556	0.552	0.435	0.00400	0.00400	0.024	0.00100	0.00400
	Cl. Entognatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00100	0
TOTAL BIOMASS		**1.71**	**7.57**	**6.10**	**80.2**	**80.8**	**38.6**	**72.3**	**60.6**	**90.8**	**56.1**	**73.2**	**69.2**	**71.0**	**69.3**	**15.3**	**64.5**	**35.7**	**20.6**	**11.6**

Table A.5: Preserved benthic invertebrate biomass (g wet weight/m^2) measured at Line Creek areas, September 2015.

Species		LIDSL						SLINE										
		6	7	8	9	10	Mean	1	2	3	4	5	6	7	8	9	10	Mean
Nematodes	P. Nemata	0	0	0	0	0.00200	0.00230	0	0	0.00100	0.00100	0.00100	0	0.00100	0	0	0.00200	0.000600
Oligochaetes	Cl. Oligochaeta	0	0	0.0380	0	0	0.0038	0.00100	0.00100	0	0	0.029	0.00100	0	0	0	0	0.0032
	F. Lumbricidae	0	0	0	0	0	0.155	0	0	0	0	0	0	0	0	0	0	0
	F. Lumbriculidae	0.143	0.0500	0.383	0.356	0.036	0.215	0.00100	0	0.128	0	0	0	0.013	0	0.087	0.16	0.0389
Ostracods	Cl. Ostracoda	0.0500	0.100	0.025	0.0200	0.35	0.0602	0.0300	0.0200	0.00900	0.00300	0.00900	0.0200	0.00100	0.222	0.165	0.218	0.0697
Insects	O. Coleoptera																	
	F. Elmidae	0	0	0	0	0	0.0107	0	0	0	0	0	0	0	0	0	0	0
	O. Ephemeroptera																	
	F. Ameletidae	0.0690	0.308	0.109	0	0.542	0.145	0.226	0.079	0.141	0.00100	0	0.392	0.056	0.663	1.78	2.55	0.588
	F. Baetidae	0.323	0.162	0.411	0.44	0.112	0.325	0.051	0	0	0	0.049	0	0.00100	0	0	0.108	0.0209
	F. Ephemerellidae	0.52	0.806	1.15	0.224	0.518	0.476	0.347	0.029	0.882	0.84	0.107	1.15	0.363	0.82	3.30	0.778	0.862
	F. Heptageniidae	2.83	5.63	2.99	1.68	0.64	3.21	2.07	2.62	1.97	0.621	1.54	2.49	2.33	1.44	2.64	1.96	1.97
	O. Plecoptera																	
	F. Capniidae	0.022	0.014	0	0.00400	0	0.112	0	0	0	0	0	0.00100	0	0	0.00700	0	0.000800
	F. Chloroperlidae	1.60	1.58	1.15	1.58	1.28	1.31	0.095	0.263	0.29	0.167	0.054	0.315	0.095	0.702	0.814	0.908	0.370
	F. Leuctridae	0.032	0.022	0.00900	0.036	0.00600	0.0743	0	0.031	0.011	0	0.00700	0.00600	0.017	0	0	0	0.0072
	F. Nemouridae	2.67	1.71	1.20	1.45	1.22	1.75	0.746	0.443	0.354	0.265	0.400	0.863	0.668	0.397	0.457	0.284	0.488
	F. Perlodidae	0.584	1.03	1.13	0.992	0.594	1.31	7.59	2.29	2.18	2.73	1.51	2.27	2.90	1.83	2.72	1.82	2.78
	F. Peltoperlidae	0.022	0	0	0	0	0.0022	0.475	0.724	1.10	0.267	0.864	1.58	0.475	0	0.187	0.218	0.589
	F. Taeniopterygidae	0.078	0.064	0.035	0.046	0.014	0.0592	0.011	0.017	0.015	0.00600	0.058	0.014	0.011	0.00100	0.011	0.00200	0.0146
	O. Trichoptera																	
	F. Apataniidae	0.00600	0.012	0.00600	0.00500	0	0.0043	0	0	0	0	0	0	0	0	0	0	0
	F. Glossosomatidae	0.134	0.372	0.244	0.118	0.066	0.487	0.066	0	0.00100	0	0	0	0.0200	0.168	0.101	0	0.0356
	F. Hydropsychidae	8.61	31.5	9.38	1.63	3.27	12.4	1.78	0.0160	0.016	0.033	0.00700	1.55	5.53	0.00800	0.114	4.41	1.35
	F. Limnephilidae	0.535	0.0200	0.013	0.013	0.208	0.0813	0.825	0	0	0	0.158	0.034	0	0.332	0.179	3.05	0.458
	F. Rhyacophilidae	2.77	2.47	1.93	1.84	1.4	2.31	0.387	0.308	1.75	0.103	0.792	2.00	1.29	0.375	0.605	1.13	0.874
	F. Uenoidae	0.00700	0.00600	0.00500	0.00600	0.00600	0.00630	0.046	0.052	0.025	0.038	0.0100	0.049	0.108	0.023	0.025	0.024	0.0400
	O. Diptera																	
	Unknown	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Ceratopogonidae	0.00100	0.00600	0	0	0.012	0.00200	0	0	0	0	0	0	0	0	0	0	0
	F. Chironomidae	0.751	0.44	0.265	0.177	1.87	1.19	0.0460	0.106	0.143	0.056	0.188	0.125	0.075	0.149	0.12	0.224	0.123
	F. Empididae	0.11	0.106	0.212	0.031	0.186	0.0913	0.745	0.642	0.311	0.207	0.422	0.407	0.733	0.249	0.472	0.572	0.476
	F. Muscidae	0	0	0	0	0	0	0	0.134	0	0	0	0	0	0	0	0	0.0134
	F. Pelecorhyncidae	0.026	0.014	0	0.11	0	0.0161	0	0	0	0	0	0	0	0	0	0	0
	F. Psychodidae	0.046	0.018	0.00900	0.00100	0.0400	0.0118	0.017	0	0	0	0	0	0	0	0.00500	0.032	0.0054
	F. Simuliidae	0.107	0	0.00100	0	0	0.0700	0	0	0	0.066	0	0.00100	0.042	0	0.061	0	0.017
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.019	0	0.0019
	F. Tipulidae	0.73	0.22	0.278	0.00100	0	0.166	0	0	0	0	0.029	0	0	0	2.5	0	0.253
Other	Cl. Turbellaria	0.092	0.046	0.046	0.055	0.044	0.0991	0	0	0	0.0200	0	0	0.033	0	0	0	0.0053
	Cl. Arachnida	0.013	0	0.021	0.00100	0.026	0.0098	0.00500	0.00900	0	0	0.00100	0.069	0.037	0.013	0.00100	0.034	0.0169
	Cl. Entognatha	0	0	0.00100	0.00100	0	0.000300	0	0	0	0	0	0	0	0.00100	0	0	0.000100
TOTAL BIOMASS		**22.9**	**46.7**	**21.0**	**10.8**	**12.5**	**26.2**	**15.6**	**7.78**	**9.33**	**5.43**	**6.23**	**13.3**	**14.8**	**7.39**	**16.4**	**18.5**	**11.5**

Table A.6: Preserved benthic invertebrate density (#/m^2) measured at Line Creek monitoring areas, September 2015.

Species		LI8										LI24								
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9
Nematodes	P. Nemata	0	0	10	20	10	0	20	0	0	0	20	30	10	40	0	10	40	0	10
Oligochaetes	Cl. Oligochaeta	820	1,860	0	520	50	20	60	900	1,580	30	20	20	20	0	0	10	10	0	10
	F. Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Lumbriculidae	0	0	90	0	570	320	180	0	0	780	0	20	50	10	0	0	0	0	0
Ostracods	Cl. Ostracoda	0	0	0	20	0	10	0	0	0	20	50	110	30	20	30	50	10	10	20
Insects	O. Coleoptera																			
	F. Elmidae	0	0	0	0	20	0	20	0	0	0	0	0	0	0	0	0	0	0	0
	O. Ephemeroptera																			
	F. Ameletidae	20	0	0	20	0	0	20	0	0	30	10	190	50	50	10	40	20	90	10
	F. Baetidae	20	100	80	20	60	70	100	120	200	170	30	0	10	10	20	0	30	10	0
	F. Ephemerellidae	260	400	460	440	200	150	340	340	440	280	40	10	20	20	40	50	60	30	0
	F. Heptageniidae	380	460	790	400	290	320	500	600	660	520	800	870	840	790	1,450	1,290	1,000	1,240	500
	O. Plecoptera																			
	F. Capniidae	0	0	0	0	0	0	0	0	0	0	10	20	10	50	0	0	20	0	0
	F. Chloroperlidae	0	20	20	20	10	20	0	0	80	50	350	280	190	200	210	350	180	140	140
	F. Leuctridae	20	0	0	60	0	20	0	0	120	20	20	0	10	10	0	0	50	0	20
	F. Nemouridae	120	140	290	320	180	190	260	280	500	400	750	60	160	700	230	260	1,330	210	70
	F. Perlodidae	60	20	70	20	30	10	0	60	0	20	100	10	40	60	60	170	70	40	10
	F. Peltoperlidae	0	0	0	0	0	0	0	0	0	0	10	0	0	10	0	0	0	0	0
	F. Taeniopterygidae	120	140	150	120	0	110	260	200	220	180	30	0	50	100	80	30	20	10	0
	O. Trichoptera																			
	F. Apataniidae	20	0	20	0	10	20	0	0	0	30	0	0	0	0	0	0	0	0	0
	F. Glossosomatidae	180	280	290	320	190	160	560	100	400	110	0	0	0	0	0	0	0	0	0
	F. Hydropsychidae	20	180	110	160	20	120	100	140	280	140	0	20	10	0	10	0	10	0	0
	F. Limnephilidae	0	0	0	0	0	0	0	0	0	10	10	20	0	20	0	10	10	20	0
	F. Rhyacophilidae	40	100	160	240	40	130	280	200	380	120	10	20	10	20	30	0	40	20	0
	F. Uenoidae	0	20	10	360	190	80	280	100	120	130	0	0	0	0	10	0	0	0	0
	O. Diptera																			
	indeterminate	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0
	F. Ceratopogonidae	20	0	20	0	10	0	40	40	0	0	0	0	0	0	0	0	0	0	0
	F. Chironomidae	200	280	290	820	450	160	1,380	260	480	280	80	40	30	40	20	10	50	30	10
	F. Empididae	0	0	80	100	50	30	60	40	20	0	0	0	10	0	0	0	10	0	0
	F. Muscidae	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	10	0
	F. Pelecorhyncidae	20	0	0	0	0	0	20	0	40	10	0	0	0	0	0	0	0	0	0
	F. Psychodidae	0	0	0	20	10	10	20	20	60	10	20	0	0	0	0	0	10	10	10
	F. Simuliidae	0	0	0	0	10	0	0	0	0	0	0	10	0	20	0	0	10	20	0
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Tipulidae	0	0	20	20	30	0	0	0	40	10	70	20	30	60	20	40	30	0	40
Other	Cl. Turbellaria	0	0	0	40	30	20	20	20	100	10	0	0	0	0	0	0	0	0	0
	Cl. Arachnida	0	0	70	60	30	50	20	80	80	50	40	20	0	30	50	10	10	20	0
	Cl. Entognatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Number of Organisms		**2,320**	**4,000**	**3,030**	**4,120**	**2,490**	**2,020**	**4,540**	**3,500**	**5,800**	**3,410**	**2,480**	**1,770**	**1,590**	**2,260**	**2,270**	**2,330**	**3,020**	**1,910**	**850**
Total Number of Taxa		**16**	**13**	**19**	**22**	**23**	**21**	**21**	**17**	**19**	**24**	**21**	**18**	**20**	**20**	**15**	**14**	**22**	**16**	**12**

Table A.6: Preserved benthic invertebrate density (#/m^2) measured at Line Creek monitoring areas, September 2015.

Species		LI24	LILC3										LIDSL							
		10	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8
Nematodes	P. Nemata	10	160	240	60	240	1,080	160	240	240	600	640	0	0	80	0	10	0	0	0
Oligochaetes	Cl. Oligochaeta	0	0	0	0	0	0	0	0	0	240	0	0	0	0	0	0	0	0	10
	F. Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
	F. Lumbriculidae	0	160	400	20	160	120	120	80	160	0	80	0	120	0	150	0	70	40	90
Ostracods	Cl. Ostracoda	10	3,480	3,920	1,640	960	3,160	1,320	680	1,720	4,680	3,520	80	120	200	40	30	210	420	100
Insects	O. Coleoptera																			
	F. Elmidae	0	0	0	0	0	0	0	0	0	0	0	0	0	40	10	0	0	0	0
	O. Ephemeroptera																			
	F. Ameletidae	50	0	0	0	80	40	0	120	0	0	80	0	280	240	60	10	70	300	80
	F. Baetidae	0	160	240	0	80	40	40	80	160	120	400	0	200	120	80	120	120	60	150
	F. Ephemerellidae	10	120	80	80	0	200	40	440	200	80	320	80	200	80	100	270	350	220	140
	F. Heptageniidae	1,650	1,000	1,120	1,120	1,680	920	1,720	1,840	1,360	720	1,840	1,640	3,000	4,320	3,670	1,490	3,100	4,060	3,210
	O. Plecoptera																			
	F. Capniidae	30	0	0	0	0	0	0	0	40	0	0	0	80	120	0	20	40	20	0
	F. Chloroperlidae	510	880	560	360	560	440	640	720	760	840	1,040	560	720	520	660	170	650	780	590
	F. Leuctridae	10	0	0	0	0	0	0	0	0	0	0	200	0	120	40	10	70	40	30
	F. Nemouridae	390	360	640	160	800	160	480	760	240	280	560	640	680	960	400	540	1,140	840	470
	F. Perlodidae	60	200	320	340	400	400	320	240	120	440	240	120	240	200	80	50	140	20	80
	F. Peltoperlidae	0	0	160	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0
	F. Taeniopterygidae	20	0	0	0	0	0	0	40	40	0	0	200	120	600	710	320	350	360	300
	O. Trichoptera																			
	F. Apataniidae	0	0	0	0	0	0	0	0	0	0	80	0	0	0	10	10	10	40	10
	F. Glossosomatidae	0	80	0	0	0	0	0	0	0	0	0	40	120	160	80	50	60	200	30
	F. Hydropsychidae	20	240	560	280	3,760	1,120	1,400	800	600	600	1,440	200	760	400	200	90	170	340	120
	F. Limnephilidae	0	0	0	0	0	0	0	0	0	0	0	80	0	0	0	10	40	80	50
	F. Rhyacophilidae	10	560	480	200	160	200	600	640	360	240	160	200	160	200	170	190	280	240	120
	F. Uenoidae	0	40	0	20	80	0	0	0	0	0	0	160	360	40	0	20	120	100	100
	O. Diptera																			
	indeterminate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Ceratopogonidae	0	0	0	40	0	40	0	0	0	40	22,240	0	0	0	20	0	10	20	0
	F. Chironomidae	30	16,040	11,760	10,160	22,160	16,240	11,720	11,560	14,720	23,560	0	3,320	3,120	3,200	300	70	570	720	300
	F. Empididae	0	80	80	80	0	0	80	40	40	40	0	0	0	0	70	40	40	100	100
	F. Muscidae	0	40	0	0	80	40	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Pelecorhyncidae	0	0	0	0	0	40	0	40	0	0	0	0	0	0	10	0	20	20	0
	F. Psychodidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	140	160	90
	F. Simuliidae	0	0	0	0	0	0	40	0	0	0	0	40	80	0	10	0	10	0	10
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	F. Tipulidae	50	0	0	0	0	0	40	0	0	0	0	0	0	160	80	20	60	20	30
Other	Cl. Turbellaria	0	80	480	140	720	240	400	1,040	200	40	320	120	120	120	110	20	70	60	60
	Cl. Arachnida	10	1,040	1,600	560	640	320	920	920	400	600	880	200	200	80	30	20	60	0	80
	Cl. Entognatha	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	30
Total Number of Organisms		**2,870**	**24,720**	**22,640**	**15,260**	**32,560**	**24,800**	**20,040**	**20,280**	**21,360**	**33,120**	**33,840**	**7,880**	**10,680**	**11,960**	**7,120**	**3,600**	**7,990**	**9,260**	**6,380**
Total Number of Taxa		**16**	**18**	**16**	**16**	**16**	**18**	**17**	**18**	**17**	**16**	**16**	**17**	**19**	**21**	**27**	**24**	**28**	**25**	**26**

Table A.6: Preserved benthic invertebrate density (#/m^2) measured at Line Creek monitoring areas, September 2015.

Species		LIDSL		SLINE									
		9	10	1	2	3	4	5	6	7	8	9	10
Nematodes	P. Nemata	0	40	0	0	10	20	10	0	10	0	0	40
Oligochaetes	Cl. Oligochaeta	0	0	10	0	0	0	20	10	0	0	0	0
	F. Lumbricidae	0	0	0	0	0	0	0	0	0	0	0	0
	F. Lumbriculidae	100	40	10	0	30	0	0	0	10	0	30	40
Ostracods	Cl. Ostracoda	80	1,220	100	70	30	10	30	70	10	530	640	860
Insects	O. Coleoptera												
	F. Elmidae	0	0	0	0	0	0	0	0	0	0	0	0
	O. Ephemeroptera												
	F. Ameletidae	0	820	50	20	40	10	0	80	20	170	500	800
	F. Baetidae	220	60	10	0	0	0	10	0	10	0	0	20
	F. Ephemerellidae	160	100	220	150	760	240	460	410	390	90	420	160
	F. Heptageniidae	2,770	780	2,130	2,090	2,540	1,130	1,800	1,820	1,300	1,210	3,090	2,020
	O. Plecoptera												
	F. Capniidae	10	0	0	0	0	0	0	20	0	0	10	0
	F. Chloroperlidae	740	540	70	140	250	60	60	160	70	340	440	540
	F. Leuctridae	60	40	0	10	80	0	30	60	20	0	0	0
	F. Nemouridae	510	380	470	240	150	100	220	440	350	320	360	240
	F. Perlodidae	50	80	250	140	160	130	110	150	160	90	150	80
	F. Peltoperlidae	0	0	80	110	220	60	130	200	90	0	40	60
	F. Taeniopterygidae	290	80	50	110	110	60	280	60	80	20	80	20
	O. Trichoptera												
	F. Apataniidae	10	0	0	0	0	0	0	0	0	0	0	0
	F. Glossosomatidae	30	20	10	0	10	0	0	0	10	20	10	0
	F. Hydropsychidae	50	40	70	70	70	110	20	160	300	20	40	100
	F. Limnephilidae	40	460	10	0	0	0	10	20	0	70	110	300
	F. Rhyacophilidae	230	60	140	130	200	100	170	230	210	110	120	180
	F. Uenoidae	30	120	110	100	100	70	40	140	270	120	150	260
	O. Diptera												
	indeterminate	0	0	0	0	0	0	0	0	0	0	0	0
	F. Ceratopogonidae	0	20	0	0	0	0	0	0	0	0	0	0
	F. Chironomidae	490	4,120	110	60	90	100	230	70	140	170	230	660
	F. Empididae	30	140	450	260	170	110	290	170	390	140	310	300
	F. Muscidae	0	0	0	10	0	0	0	0	0	0	0	0
	F. Pelecorhyncidae	10	0	0	0	0	0	0	0	0	0	0	0
	F. Psychodidae	20	480	40	0	0	0	0	0	0	0	20	100
	F. Simuliidae	0	0	0	0	0	10	0	10	10	0	10	0
	F. Stratiomyiidae	0	0	0	0	0	0	0	0	0	0	10	0
	F. Tipulidae	10	0	0	0	0	0	50	0	0	0	10	0
Other	Cl. Turbellaria	70	40	0	0	0	10	0	0	10	0	0	0
	Cl. Arachnida	30	100	40	30	0	0	10	90	60	60	10	120
	Cl. Entognatha	30	0	0	0	0	0	0	0	0	10	0	0
Total Number of Organisms		**6,070**	**9,780**	**4,430**	**3,740**	**5,020**	**2,330**	**3,980**	**4,370**	**3,920**	**3,490**	**6,790**	**6,900**
Total Number of Taxa		**25**	**23**	**21**	**17**	**18**	**17**	**20**	**20**	**22**	**17**	**23**	**20**

Table A.7: Mean benthic invertebrate relative biomass (%) measured at Line Creek monitoring areas, September 2015.

Species		LI8	LI24	LILC3	LIDSL	SLINE
Nematodes	P. Nemata	0.00013	0.00017	0.00028	0.000081	0.000063
Oligochaetes	Cl. Oligochaeta	0.043	0.0017	0.00014	0.00018	0.00049
	F. Lumbricidae	0	0	0	0.0075	0
	F. Lumbriculidae	0.017	0.0052	0.0085	0.011	0.0029
Ostracods	Cl. Ostracoda	0.000031	0.0019	0.012	0.0038	0.0061
Insects	O. Coleoptera					
	F. Elmidae	0.0010	0	0	0.00035	0
	O. Ephemeroptera					
	F. Ameletidae	0.00037	0.029	0.00088	0.0068	0.041
	F. Baetidae	0.019	0.0073	0.0040	0.015	0.0017
	F. Ephemerellidae	0.035	0.029	0.0045	0.023	0.076
	F. Heptageniidae	0.11	0.50	0.0072	0.14	0.18
	O. Plecoptera					
	F. Capniidae	0	0.0013	0.00013	0.0020	0.000050
	F. Chloroperlidae	0.0032	0.087	0.025	0.063	0.033
	F. Leuctridae	0.0014	0.0036	0	0.0046	0.00079
	F. Nemouridae	0.054	0.071	0.043	0.086	0.046
	F. Perlodidae	0.032	0.14	0.052	0.060	0.26
	F. Peltoperlidae	0	0.0012	0.00011	0.000096	0.060
	F. Taeniopterygidae	0.0018	0.0028	0.000013	0.0030	0.0018
	O. Trichoptera					
	F. Apataniidae	0.00019	0	0.000068	0.00023	0
	F. Glossosomatidae	0.033	0	0.0000050	0.018	0.0035
	F. Hydropsychidae	0.41	0.035	0.44	0.38	0.086
	F. Limnephilidae	0.000019	0.0022	0	0.0044	0.030
	F. Rhyacophilidae	0.14	0.015	0.23	0.10	0.078
	F. Uenoidae	0.00085	0.000031	0.000021	0.00032	0.0038
	O. Diptera					
	Unknown	0	0.000018	0	0	0
	F. Ceratopogonidae	0.0011	0	0.014	0.00012	0
	F. Chironomidae	0.078	0.0056	0.13	0.050	0.013
	F. Empididae	0.0035	0.00054	0.0016	0.0050	0.044
	F. Muscidae	0	0.00069	0.0022	0	0.0017
	F. Pelecorhyncidae	0.0040	0	0.00070	0.0012	0
	F. Psychodidae	0.000098	0.00046	0	0.00064	0.00031
	F. Simuliidae	0.00080	0.0073	0.00017	0.0025	0.0019
	F. Stratiomyiidae	0	0	0	0	0.00012
	F. Tipulidae	0.011	0.054	0.00023	0.0067	0.016
Other	Cl. Turbellaria	0.0011	0	0.010	0.0038	0.00059
	Cl. Arachnida	0.00063	0.0011	0.0061	0.00051	0.0013
	Cl. Entognatha	0	0	0	0.000019	0.000014
TOTAL RELATIVE BIOMASS		**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

Table A.8: Selenium concentrations in composite and single taxon benthic invertebrate samples, September 2015.

Area	Sample ID	% Moisture	Selenium Concentration (µg/g)	
			dry wt.	wet wt.
LI24	LI24-BIT-1	83	5.3	0.74
	LI24-MF-1	91	7.5	1.6
	LI24-RYAC-1	77	0.74	0.17
LI8	LI8-BIT-1	85	9.3	1.4
	LI8-MF-1	84	7.4	1.1
	LI8-RYAC-1	81	12.5	1.6
LIDSL	LIDSL-BIT-1	93	8.9	1.4
	LIDSL-MF-1	85	7.5	1.2
	LIDSL-RYAC-1	91	29.2	5.8
LILC3	LILC3-BIT-1	87	13.7	1.7
	LILC3-MF-1	90	6.9	0.45
	LILC3-RYAC-1	83	18.7	5.2
SLINE	SLINE-BIT-1	83	3.9	0.57
	SLINE-MF-1	88	7.7	0.65
	SLINE-RYAC-1	79	6.7	0.90

Table A.9: Selenium concentrations in composite and single taxon benthic invertebrate samples, September 2014.

Area	Sample ID	% Moisture	Selenium Concentration (µg/g)	
			dry wt.	wet wt.
LI24 Reference	LI24-BI	90	4.0	0.39
	LI24-MF1	91	8.6	0.81
	LI24-MF2	91	8.5	0.78
	LI24-MF3	91	8.8	0.78
	LI24-RYAC	78	4.1	0.92
SLINE Reference	SLINE-BI	87	6.0	0.76
	SLINE-MF1	84	11.3	1.8
	SLINE-MF2	85	10.3	1.5
	SLINE-MF3	83	10.2	1.8
	SLINE-RYAC	82	3.9	0.69
LILC3 Mine-exposed	LILC3-BI	87	16.7	2.3
	LILC3-MF	88	33.2	3.8
	LILC3-RYAC	82	22.1	4.0
LIDSL Mine-exposed	LIDSL-BI	88	13.7	1.7
	LIDSL-MF	90	16.8	1.7
	LIDSL-RYAC	79	20.7	4.4
LI8 Mine-exposed	LI8-BI	88	8.4	1.0
	LI8-MF	81	10.5	2.0
	LI8-RYAC	85	10.8	1.6

Table A.10: Selenium concentrations in composite benthic invertebrate samples, September 2012.

Area	Sample ID	% Moisture	Selenium Concentration (µg/g)	
			dry wt.	wet wt.
LI24	LI24-B	79	5.1	1.1
SLINE	SLINE	78	4.8	1.1
LILC3	LILC3-B	74	7.0	1.8
LIDSL	LIDSL-B	76	7.7	1.9
LI8	LI8	81	7.8	1.5

LI24-1

LI24-2

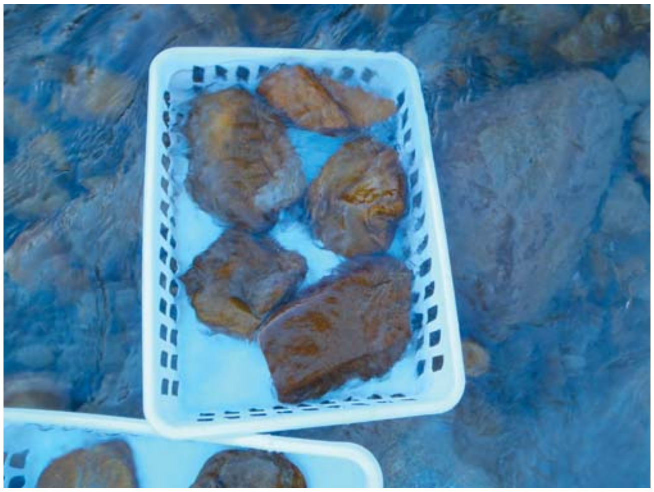
LI24-3

LI24-4

LI24-5

LI24-6

Figure A.1: Rocks Sampled for Periphyton at LI24, September 2015.



LI24-7

LI24-8

LI24-9

LI24-10

Figure A.1: Rocks Sampled for Periphyton at LI24, September 2015.

APPENDIX B

Statistical Approach for Assessing Changes in Productivity Over Time

B.1 INTRODUCTION

Data collected as part of the 2014 and 2015 cycles of the Line Creek LAEMP (Minnow 2015a and 2016), as well as preliminary data collected in the 2015 RAEMP cycle (Minnow, in preparation) were evaluated to support recommendations for future monitoring. The data described in this appendix were presented to the EMC on April 27, 2016.

B.2 PRODUCTIVITY ENDPOINTS

As described in Section 3.0 of this report, the Line Creek LAEMP sampling in 2014 and 2015 involved evaluation of five endpoints related to aquatic ecosystem productivity:

1. Periphyton ash-free dry mass (AFDM)
2. Periphyton chlorophyll-a
3. Bryophyte areal coverage
4. Bryophyte shoot length
5. Benthic invertebrate biomass.

Strong correlations were observed among all five endpoints (Table B.1; Figure B.1), indicating these endpoints are highly redundant in assessing aquatic productivity. The relationships between benthic invertebrate biomass and the periphyton endpoints showed good distribution of values along both axes, providing further support that such measures are redundant. As shown in Figures 3.6 and 3.7 and Figure B.1, bryophyte growth is patchy, and neither bryophyte endpoints showed a strong linear relationship with benthic invertebrate biomass. Of the five productivity endpoints, benthic invertebrate biomass and periphyton AFDM and chlorophyll-a showed the largest magnitudes of difference among areas and strongest correlations amongst each other, and were thus evaluated further to determine the most suitable endpoint for future monitoring of mine-related effects on aquatic productivity.

Periphyton productivity endpoints showed more temporal variability during baseline (pre-AWTF operation) than did benthic invertebrate biomass (Figures 3.1 – 3.5, 3.12, and Figure B.2). Statistical comparisons were completed to assess differences between years and among sampling areas for the periphyton productivity and benthic invertebrate biomass endpoints in 2014 and 2015. A two-way analysis of variance (ANOVA), with area and year as factors, showed that there were significant interactions ($p < 0.001$) for both AFDM and chlorophyll-a, indicating that the relative differences among areas were significantly different from 2014 to 2015 (Figure B.2). The interaction between year and area was not significant ($p = 0.185$) for benthic invertebrate biomass, indicating that the relative differences among areas were not significantly different from 2014 to 2015; however the year and area factors were both significant ($p < 0.001$) indicating that the differences among areas and between 2014 and 2015 were statistically significant (Figure B.2). The smaller temporal variability in benthic invertebrate biomass and the lack of a significant area by year interaction in the ANOVA suggests that the invertebrate biomass endpoint may be more likely to detect a change in productivity after commencement of AWTF operation, than would either of the periphyton endpoints. To determine the best approach for future monitoring of changes in productivity, further analyses were performed that considered different statistical approaches, potential effect sizes, and sample size requirements.

B.3 TEMPORAL CHANGES IN PRODUCTIVITY

One way to detect change over time is to test if there is a linear trend using a simple linear regression. The ability of the three different productivity endpoints to detect linear trends was evaluated using data collected since 2012 in various local and regional monitoring programs and associated supporting studies in the Elk Valley. Mean process (temporal) and sampling (within-area variability) errors were estimated (Tables B.2a-c) using the same approach described by Minnow (2015b). These values were used to estimate the power to detect specific magnitudes of change over time (expressed as percent change per year) based on different scenarios of sampling interval, effect size (percent change per year), and trend duration (Table B.3). The analysis showed that, of the three endpoints evaluated, changes in productivity would be most sensitively detected (i.e., smallest detectable effect size) and detectable soonest through monitoring benthic invertebrate biomass compared to the two periphyton productivity endpoints. Evaluating change using this approach is relatively insensitive to sample size, with as few as two samples per area resulting in reasonably high statistical power (Table B.4). However, linear trend analyses require many years (e.g., nine years as illustrated in Table B.3) to detect a statistically significant trend and are not sensitive enough to detect early warning changes that might be ecologically relevant. Linear trend analyses also have an assumption of linearity in the trend which is frequently not met when monitoring environmental processes. For these reasons, an alternative approach for detecting changes over time was chosen.

The proposed approach is to compare results among areas and years using a before-after/control-impact (BACI) ANOVA model (Underwood 1992). Power analyses were conducted to assess the ability of the BACI model to detect a significant change at LIDSL relative to reference area SLINE over time using data from both areas collected in the Line

Creek LAEMPs in 2014 and 2015. The power to detect a statistically significant change in the relative difference between areas was estimated by conducting simulations of different magnitudes of effect using R (R Core Team 2016; methods described in Section B.4). The power calculations were conducted using only two areas (LIDSL and SLINE) for simplicity as LIDSL is the mine-exposed area that is the compliance point and SLINE is the upstream reference area most comparable to LIDSL in terms of habitat characteristics.

What is not currently known is the magnitude of difference between mine-exposed and reference areas, or for the same area over time, that can be considered ecologically meaningful. The BACI analysis detects changes in the relative difference between areas, but the magnitude of a statistically significant relative difference among areas may be smaller or larger than what could be considered ecologically significant. Significant differences already exist between LIDSL and SLINE, and between LIDSL and the upstream mine-exposed area LILC3, which complicates the determination of the magnitude of effect that is ecologically meaningful to detect in the BACI analysis. For context, the magnitudes of difference observed in 2014 and 2015 between LIDSL and LILC3, and between LIDSL and SLINE for benthic invertebrate biomass and the periphyton productivity endpoints were computed (Table B.5). Again, greater temporal variability between 2014 and 2015 was evident for the periphyton productivity endpoints than for invertebrate biomass. The magnitudes of difference for benthic invertebrate biomass between LIDSL and LILC3 in 2014 and 2015 (144% and 209%) would be considered differences of a relevant magnitude as an upper limit of the magnitude of change to be detected (if possible). Effect sizes for the power analyses to detect changes over time at LIDSL after treatment relative to LIDSL in the before period were therefore selected to be 50%, 100%, and 200%.

A sample size of seven replicates per area is sufficient to detect an approximate 200% increase at LIDSL after initiation of active water treatment relative to LIDSL prior to treatment (the “before” period; Table B.6) with the probability of Type I error (α) equal to the probability of Type II error (β) of 0.1. The 200% increase can be detected as a press effect (observed as a step-change in 2016 that is maintained in 2017), a linear increase to 200% from 2015 to 2017, or a pulse effect that is detected in 2016 alone (these effect types are illustrated and described in more detail in Section B.4). A 200% increase in the mean at LIDSL is equivalent to a 2.16 pooled within-area standard deviation (SD) change. Given that the existing magnitude of difference between LIDSL and SLINE is 2.72 within-area SDs, the 200% increase in the mean at LIDSL after initiation of active water treatment would be equivalent to a 4.88 within-area SD change relative to SLINE prior to treatment.

The statistical power is low (< 0.5) to detect a 200% increase at LIDSL relative to LIDSL in the before period with α = 0.1 for AFDM and chlorophyll-a at n = 10 for each effect scenario (Tables B.7 and B.8).

Family-level densities of benthic invertebrates will also be reported by the laboratory with biomass data. This will allow for evaluation of changes in family-level community metrics over time, using the BACI methods described above for biomass.

B.4 STATISTICAL METHODS AND POWER ANALYSES

Testing for changes in productivity over time and among areas will be conducted using a BACI design which tests for changes in the relative differences among areas over time. The following linear model will be used:

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

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 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

ϵ = the error term.

The BACI model will be used to test for BACI effects (i.e., changes in the relative differences among areas over time). The BACI effects are assessed by testing the significance of the interaction terms containing the BA and CI terms. Interpretation of the ANOVA table will begin by assessing the significance of the interaction between $Area(CI)$ and $Year(BA)$. If the interaction is significant then the relative differences among areas are significantly different over time but depend on which years and areas are compared (i.e., there is a BACI effect that depends on which areas and years are compared; see Figure B.3A). Multiple comparisons (or specific contrasts) can be conducted to determine the areas and years that are causing the significant difference. If the interaction term is not significant, then the interpretation of the ANOVA table can continue 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 are dependent on which year and group (control or impact) are compared (i.e., there is a BACI effect that depends on which years are compared; see Figure B.3B) and whether the relative differences among areas are dependent on which area and period (before or after) are compared (i.e., there is a BACI effect that depends on which areas are compared; see Figure B.3C). If these interaction terms are significant, then multiple comparisons (or specific contrasts) can be conducted to determine where the interaction is occurring. If these interaction terms are not significant, then the interaction between BA and CI can be assessed for significance. If it is significant, then the relative differences between the control and impact areas are dependent 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 B.3D). 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 can be 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.

The power of the BACI model to detect a significant interaction for benthic invertebrate biomass was estimated by simulating effects of different magnitudes and calculating the probability that the model would detect the effect as a significant interaction in the two years following initiation of treatment with two years of baseline data (2014 and 2015). For simplicity, the power was estimated for a BACI model with a single impact area (LIDSL) and a single control area (SLINE). The BACI model was

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

with Y = $\log_{10}$(total biomass) and the factors as described above. The two-way ANOVA comparing benthic invertebrate biomass among the five areas (Figure B.2) showed that the interaction between area and year was not significant. For the power analyses, it was therefore assumed that any process variability over time was consistent among areas and does not influence the coefficients of the interaction terms of the model. The simulations were conducted using normal distributions of $\log_{10}$(total biomass) that reflected the pooled 2014 and 2015 mean values for each area and the pooled within-area standard deviation. Effects were simulated as a pulse effect (increase in one year), a press effect (same increase in both after years), and a linear increase (linear increase from 2015 to the simulated effect size in 2017). These effects are illustrated in Figure B.4. The simulated effect sizes were 50%, 100%, and 200% increases in the mean at LIDSL relative to LIDSL in the before period, as described in Section B.3. The simulations were conducted by randomly selecting "n" samples (n ranging from 5 to 10) from the modelled distributions (Figure B.4). One thousand simulations were conducted for each estimate of power, and power was estimated as the proportion of BACI models that had a significant (α = 0.1) interaction term ($BA \times CI$ or $CI \times Year(BA)$). A power estimate was provided for a specified sample size, significance level (α = 0.1), and effect size.

Power was also estimated for AFDM and chlorophyll-a (Tables B.7 and B.8). The two-way ANOVA comparing AFDM and chlorophyll-a among the five areas (Figure B.2) showed that the interaction between area and year was significant suggesting that any process variability over time is not consistent among area. This variability influences the coefficients of the interaction terms in the BACI model and was included in the modelled distributions for the simulations conducted for the power analyses as shown in Figure B.5 for chlorophyll-a. The distribution for the process variability was assumed to be normal, with mean and standard deviation calculated from the five differences in the mean area values from 2014 and 2015 and used to estimate the mean values in the after period for each area (under the assumption of no effect; Figure B.5). Note that the means for the distributions of the LIDSL and SLINE in Figure B.5 vary over time (a reflection of the process variability) and that the magnitude of the process variability exceeds the simulated effect sizes of 50%, 100%, and 200% increases in the mean at LIDSL relative to LIDSL under no effect. The high variability over time that is not consistent among areas reduces the statistical power of the BACI model to detect an effect (i.e., a significant interaction).

B.5 COMPARISON TO NORMAL RANGE

Temporal and spatial changes in benthic invertebrate biomass (and corresponding community metrics for the same samples) will be assessed as described in Sections B.3

and B.4 using the BACI statistical comparison. To provide perspective for evaluating the magnitude of change in biomass and community structure observed over time at the compliance location, and to consider potential changes in communities over a broader spatial scale, benthic invertebrate communities will also be sampled annually at the two reference (LI24; SLINE) and three mine-exposed (LILC3, LIDSL, LI8) areas in Line Creek, as well as in the Fording River upstream (FOUL) and downstream (FO23) from Line Creek. For this type of evaluation, benthic invertebrate community endpoints will each be compared to the normal (reference area) range derived in the RAEMP (Minnow, in prep.) defined as the 2.5th and 97.5th percentiles of all reference area data. Temporal changes will be assessed by identifying if benthic invertebrate community structure at mine-exposed areas is: a) similar to previous years; b) moving from being within reference condition toward becoming outside of reference condition; or c) moving from outside of the reference condition either closer to or farther from the reference condition. This evaluation will consider if temporal changes are consistent among areas over time, or indicative of localized change. Further details will be developed in consultation with the EMC.

B.6 REFERENCES

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Table B.1: Correlations based on mean productivity endpoints for samples collected at two reference (LI24 and SLINE) and three mine-exposed areas (LILC3, LIDSL, and LI8) of Line Creek in 2014 and 2015 (n = 10 per area per year, except for bryophytes with n = 3 per area per year).

Variable	Pearson Correlation Coefficient (r_p) or Spearman Rank Correlation Coefficient (r_s) and P-value			
	Log_{10} AFDM (g/m^2)	Log_{10} Chlorophyll-a (mg/m^2)	Bryophyte Area (%)	Bryophyte Shoot Length (mm)
Log_{10} Chlorophyll-a (mg/m^2)	$r_p = 0.631$	-	-	-
	$p = 0.050$	-	-	-
Bryophyte Area (%)	$r_s = 0.873$	$r_s = 0.446$	-	-
	$p < 0.001$	$p = 0.196$	-	-
Bryophyte Shoot Length (mm)	$r_s = 0.886$	$r_s = 0.304$	$r_s = 0.959$	-
	$p < 0.001$	$p = 0.393$	$p < 0.001$	-
Log_{10} Benthic Invertebrate Biomass (g/m^2)	$r_p = 0.850$	$r_p = 0.770$	$r_s = 0.847$	$r_s = 0.782$
	$p = 0.002$	$p = 0.009$	$p = 0.002$	$p = 0.007$

p-value less than 0.05.

r_P - Pearson correlation.

r_S - Spearman correlation.

Table B.2a: Estimation of process and sampling errors for periphyton chlorophyll-a concentrations (mg/m²).

Area	Ecosystem	Area ID	Years of Data	Years Sampled	N in Each Year	Process Error[a]	Sampling Error[b]
Mine-exposed	Lotic	EL1	3	2012, 2013, 2015	1, 3, 1	0.000	0.658
	Lotic	EL19	3	2012, 2013, 2015	1, 3, 1	0.928	0.708
	Lotic	FO23	4	2012, 2013, 2014, 2015	1, 5, 10, 10	1.536	1.532
	Lotic	FO29	3	2012, 2014, 2015	1, 1, 1	NC	NC
	Lotic	FOUL	3	2013, 2014, 2015	5, 10, 10	0.754	1.187
	Lotic	LI8	3	2013, 2014, 2015	5, 10, 10	0.798	1.303
	Lotic	LIDSL	3	2013, 2014, 2015	5, 10, 10	1.932	0.867
	Lotic	LILC3	4	2012, 2013, 2014, 2015	1, 5, 10, 10	2.001	1.121
Reference	Lotic	CHCK	4	2012, 2013, 2014, 2015	3, 5, 2, 1	2.373	0.911
	Lotic	LI24	4	2012, 2013, 2014, 2015	1, 5, 10, 10	0.973	0.570
	Lotic	SLINE	3	2013, 2014, 2015	5, 10, 10	1.958	1.050
All Data					**Mean**	**1.325**	**0.991**
					Minimum	**0.000**	**0.570**
					Maximum	**2.373**	**1.532**
Excluding EL1 and EL19.					**Mean**	**1.541**	**1.068**
					Minimum	**0.754**	**0.570**
					Maximum	**2.373**	**1.532**

[a] Process error is the standard deviation of 'year' from linear mixed model.

[b] Sampling error is the standard deviation of 'residual' from linear mixed model.

NC - not calculable.

Table B.2b: Estimation of process and sampling errors for periphyton ash-free dry mass (g/m²).

Area	Ecosystem	Area ID	Years of Data	Years Sampled	N in Each Year	Process Error	Sampling Error
Mine-exposed	Lotic	EL1	3	2012, 2013, 2015	1, 3, 1	0.269	0.179
	Lotic	EL19	3	2012, 2013, 2015	1, 3, 1	0.893	0.217
	Lotic	FO23	4	2012, 2013, 2014, 2015	1, 5, 10, 10	0.592	1.125
	Lotic	FO29	3	2012, 2014, 2015	1, 1, 1	NC	NC
	Lotic	FOUL	3	2013, 2014, 2015	5, 10, 10	0.000	0.714
	Lotic	LI8	3	2013, 2014, 2015	5, 10, 10	0.562	1.343
	Lotic	LIDSL	3	2013, 2014, 2015	5, 10, 10	1.253	0.729
	Lotic	LILC3	4	2012, 2013, 2014, 2015	1, 5, 10, 10	0.656	0.345
Reference	Lotic	CHCK	4	2012, 2013, 2014, 2015	3, 5, 2, 1	0.000	1.361
	Lotic	LI24	4	2012, 2013, 2014, 2015	1, 5, 10, 10	0.566	0.259
	Lotic	SLINE	3	2013, 2014, 2015	5, 10, 10	0.854	0.595
ALL Data					**Mean**	**0.564**	**0.687**
					Minimum	**0.000**	**0.179**
					Maximum	**1.253**	**1.361**
Excluding EL1 and EL19.					**Mean**	**0.560**	**0.809**
					Minimum	**0.000**	**0.259**
					Maximum	**1.253**	**1.361**

[a] Process error is the standard deviation of 'year' from linear mixed model.

[b] Sampling error is the standard deviation of 'residual' from linear mixed model.

NC - not calculable.

Table B.2c: Estimation of process and sampling errors for benthic invertebrate biomass (g/m²).

Area	Ecosystem	Area ID	Years of Data	Years Sampled	N in Each Year	Process Error[a]	Sampling Error[b]
Mine-exposed	Lotic	LILC3	2	2014, 2015	10, 10	0.209	0.388
	Lotic	LIDSL	2	2014, 2015	10, 10	0.000	0.547
	Lotic	LI8	2	2014, 2015	10, 10	0.481	0.634
Reference	Lotic	LI24	2	2014, 2015	10, 10	0.232	0.389
	Lotic	SLINE	2	2014, 2015	10, 10	0.515	0.450
All Data					**Mean**	**0.409**	**0.491**
					Minimum	**0.232**	**0.389**
					Maximum	**0.515**	**0.634**

[a] Process error is the standard deviation of 'year' from linear mixed model.

[b] Sampling error is the standard deviation of 'residual' from linear mixed model.

Table B.3: Power to detect changes in chlorophyll-a (mg/m²), ash-free dry mass (g/m²) and benthic invertebrate biomass (g/m^2) over time for different scenarios of total years and sampling interval based on typical estimates of process and sampling error[a] and 5 samples per area per year. Shade indicates power ≥ 0.8.

Trend Parameters				Chlorophyll-a	Ash-free Dry Mass	Benthic Invertebrate Biomass
Sampling Interval (years)	Percent Change per year(±)	Trend Length (Years)	Total Percent Change	Power (two tail) (α = 0.10)	Power (two tail) (α = 0.10)	Power (two tail) (α = 0.10)
1	10	6	77	0.108	0.147	0.195
3	10	6	77	NC	NC	NC
1	10	9	136	0.132	0.280	0.446
3	10	9	136	0.103	0.119	0.138
1	10	12	214	0.180	0.511	0.774
3	10	12	214	0.115	0.183	0.262
1	20	6	199	0.132	0.279	0.441
3	20	6	199	NC	NC	NC
1	20	9	416	0.225	0.673	0.911
3	20	9	416	0.113	0.170	0.228
1	20	12	792	0.397	0.954	0.999
3	20	12	792	0.157	0.387	0.593
1	50	6	1,039	0.290	0.821	0.976
3	50	6	1,039	NC	NC	NC
1	50	9	3,744	0.697	1.000	1.000
3	50	9	3,744	0.174	0.381	0.525
1	50	12	12,875	0.964	1.000	1.000
3	50	12	12,875	0.403	0.919	0.994
1	100	6	6,300	0.687	1.000	1.000
3	100	6	6,300	NC	NC	NC
1	100	9	51,100	0.996	1.000	1.000
3	100	9	51,100	0.320	0.680	0.847
1	100	12	409,500	1.000	1.000	1.000
3	100	12	409,500	0.826	1.000	1.000
1	200	6	72,800	0.994	1.000	1.000
3	200	6	72,800	NC	NC	NC
1	200	9	1,968,200	1.000	1.000	1.000
3	200	9	1,968,200	0.589	0.954	0.996
1	200	12	53,144,000	1.000	1.000	1.000
3	200	12	53,144,000	0.999	1.000	1.000

[a]Process and sampling errors of 1.541/1.068, and 0.560/0.809, and 0.409/0.491for chlorophyll-a, ash-free dry mass, and benthic invertebrate biomass, respectively (from Tables 1a,b,c).

NC - indicates insufficent years of data to calculate power (i.e. only 2 sampling events).

Table B.4: Effect of sample size per area on power (2-tail test) to detect a 20% increase per year (alpha = 0.10) in chlorophyll-a (mg/m²), ash-free dry mass (g/m²), and benthic invertebrate biomass (g/m²) over 9 years.[a] Shade indicates power ≥ 0.8.

Number of samples per year	Chlorophyll-*a*		Ash-free Dry Mass		Benthic Invertebrate Biomass	
	Sample every Year	Sample every 3 years	Sample every Year	Sample every 3 years	Sample every Year	Sample every 3 years
1	0.19	0.11	0.41	0.13	0.70	0.18
2	0.21	0.11	0.54	0.15	0.83	0.20
3	0.22	0.11	0.61	0.16	0.87	0.21
4	0.22	0.11	0.65	0.17	0.90	0.22
5	0.22	0.11	0.67	0.17	0.91	0.23
6	0.23	0.11	0.69	0.17	0.92	0.23
7	0.23	0.11	0.71	0.18	0.93	0.24
8	0.23	0.11	0.72	0.18	0.93	0.24
9	0.23	0.11	0.72	0.18	0.93	0.24
10	0.23	0.11	0.73	0.18	0.94	0.24
15	0.23	0.11	0.75	0.18	0.94	0.25
20	0.23	0.11	0.76	0.19	0.95	0.25
30	0.23	0.11	0.78	0.19	0.95	0.25
40	0.23	0.11	0.78	0.19	0.95	0.25
50	0.24	0.11	0.79	0.19	0.96	0.25
100	0.24	0.11	0.79	0.19	0.96	0.25

[a] Process and sampling errors of 1.541/1.068, and 0.560/0.809, and 0.409/0.491for chlorophyll-a, ash-free dry mass, and benthic invertebrate biomass, respectively (from Tables 1a,b,c).

Table B.5: Observed magnitudes of difference between LILC3 and LIDSL, and LIDSL and reference areas (LI24, SLINE) in 2014, and 2015.

Year	Magnitude of Difference (% Change)					
	LILC3 relative to LIDSL			LIDSL relative to Reference Areas		
	Benthic Invertebrate Biomass	AFDM	Chlorophyll-a	Benthic Invertebrate Biomass	AFDM	Chlorophyll-a
2014	144	-19	-24	346	2,683	635
2015	209	1,287	668	183	76	106

Table B.6: Estimated statistical power to detect a 50%, 100%, and 200% change in benthic invertebrate biomass at LIDSL relative to LIDSL using a BACI model with 2 before years (2014 and 2015) for the after years 2016 and 2017 for various effect scenarios and various sample sizes.

Year	Effect Type	Effect Size (Percent Change Relative to LIDSL Before)	Effect Size (# of Pooled Within-Area SDs Relative to LIDSL Before)	Effect Size (Percent Change Relative to SLINE)	Effect Size (# of Pooled Within-Area SDs Relative to SLINE)	Power for Specified n at α = 0.1					
						n = 10	n = 9	n = 8	n = 7	n = 6	n = 5
2016	No Effect	0	0	187	2.08	-	-	-	-	-	-
	Pulse in 2016	50	0.80	331	2.88	0.403	0.384	0.344	0.336	0.323	0.292
		100	1.37	475	3.44	0.704	0.667	0.637	0.606	0.530	0.481
		200	2.16	762	4.24	0.972	0.961	0.937	0.902	0.864	0.771
2017	Pulse in 2016	50	0.80	331	2.88	0.340	0.313	0.292	0.273	0.268	0.230
		100	1.37	475	3.44	0.618	0.607	0.515	0.519	0.459	0.404
		200	2.16	762	4.24	0.939	0.918	0.864	0.803	0.771	0.713
	Press	50	0.80	331	2.88	0.417	0.406	0.352	0.317	0.295	0.289
		100	1.37	475	3.44	0.737	0.692	0.653	0.584	0.536	0.486
		200	2.16	762	4.24	0.972	0.963	0.908	0.899	0.857	0.800
	Linear	50	0.80	331	2.88	0.397	0.362	0.338	0.318	0.317	0.284
		100	1.37	475	3.44	0.729	0.685	0.666	0.604	0.565	0.520
		200	2.16	762	4.24	0.969	0.957	0.932	0.910	0.859	0.769

power greater than 0.9.

Table B.7: Estimated statistical power to detect a 50%, 100%, and 200% change in chlorophyll-a at LIDSL relative to LIDSL using a BACI model with 2 before years (2014 and 2015) for the after years 2016 and 2017 for various effect scenarios and various sample sizes.

Year	Effect Type	Effect Size (Percent Change Relative to LIDSL Before)	Effect Size (# of Pooled Within-Area SDs Relative to LIDSL Before)	Effect Size (Percent Change Relative to SLINE)	Effect Size (# of Pooled Within-Area SDs Relative to SLINE)	Power for Specified n at α = 0.1					
						n = 10	n = 9	n = 8	n = 7	n = 6	n = 5
2016	No Effect	0	0	310	1.36	-	-	-	-	-	-
	Pulse in 2016	50	0.39	515	1.75	0.213	0.212	0.202	0.190	0.178	0.161
		100	0.67	720	2.03	0.265	0.256	0.239	0.216	0.213	0.199
		200	1.06	1,130	2.42	0.376	0.323	0.303	0.278	0.250	0.238
2017	Pulse in 2016	50	0.39	515	1.75	0.207	0.194	0.171	0.166	0.166	0.162
		100	0.67	720	2.03	0.231	0.208	0.204	0.192	0.188	0.168
		200	1.06	1,130	2.42	0.283	0.257	0.255	0.254	0.233	0.227
	Press	50	0.39	515	1.75	0.195	0.193	0.191	0.188	0.187	0.173
		100	0.67	720	2.03	0.275	0.235	0.234	0.212	0.202	0.202
		200	1.06	1,130	2.42	0.358	0.332	0.330	0.299	0.288	0.256
	Linear	50	0.39	515	1.75	0.224	0.212	0.189	0.189	0.186	0.178
		100	0.67	720	2.03	0.245	0.227	0.219	0.215	0.203	0.180
		200	1.06	1,130	2.42	0.345	0.325	0.320	0.281	0.269	0.259

power greater than 0.9.

Table B.8: Estimated statistical power to detect a 50%, 100%, and 200% change in AFDM at LIDSL relative to LIDSL using a BACI model with 2 before years (2014 and 2015) for the after years 2016 and 2017 for various effect scenarios and various sample sizes.

Year	Effect Type	Effect Size (Percent Change Relative to LIDSL Before)	Effect Size (# of Pooled Within-Area SDs Relative to LIDSL Before)	Effect Size (Percent Change Relative to SLINE)	Effect Size (# of Pooled Within-Area SDs Relative to SLINE)	Power for Specified n at α = 0.1					
						n = 10	n = 9	n = 8	n = 7	n = 6	n = 5
2016	No Effect	0	0	612	3.87	-	-	-	-	-	-
	Pulse in 2016	50	0.80	968	4.66	0.227	0.221	0.206	0.189	0.184	0.181
		100	1.37	1,324	5.23	0.268	0.263	0.249	0.237	0.231	0.217
		200	2.16	2,036	6.03	0.411	0.370	0.356	0.331	0.301	0.279
2017	Pulse in 2016	50	0.80	968	4.66	0.202	0.201	0.191	0.185	0.175	0.168
		100	1.37	1,324	5.23	0.256	0.220	0.219	0.216	0.208	0.190
		200	2.16	2,036	6.03	0.339	0.325	0.276	0.272	0.264	0.227
	Press	50	0.80	968	4.66	0.213	0.208	0.202	0.197	0.192	0.191
		100	1.37	1,324	5.23	0.269	0.261	0.244	0.225	0.212	0.205
		200	2.16	2,036	6.03	0.420	0.400	0.357	0.349	0.304	0.280
	Linear	50	0.80	968	4.66	0.209	0.197	0.195	0.195	0.179	0.176
		100	1.37	1,324	5.23	0.284	0.250	0.244	0.222	0.213	0.206
		200	2.16	2,036	6.03	0.399	0.395	0.338	0.326	0.320	0.269

power greater than 0.9.

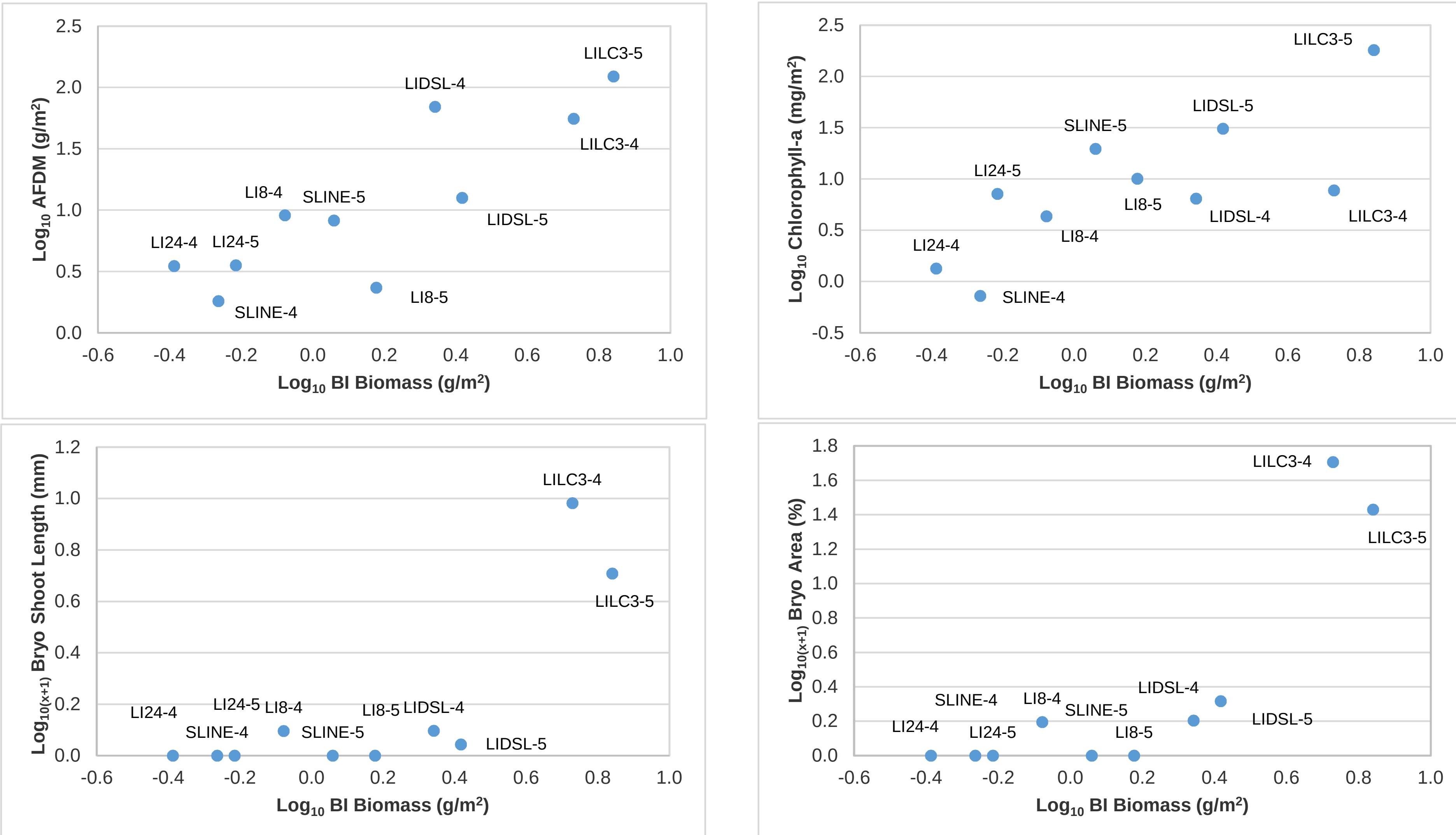


Figure B.1: Relationships between productivity endpoints measured at Line Creek study areas during the LAEMP in 2014 and 2015. Where more than one sample/measurement was taken in an area, the mean value was used in the relationship. Sample IDs ending in -4 or -5 indicate data collected in 2014 and 2015, respectively.

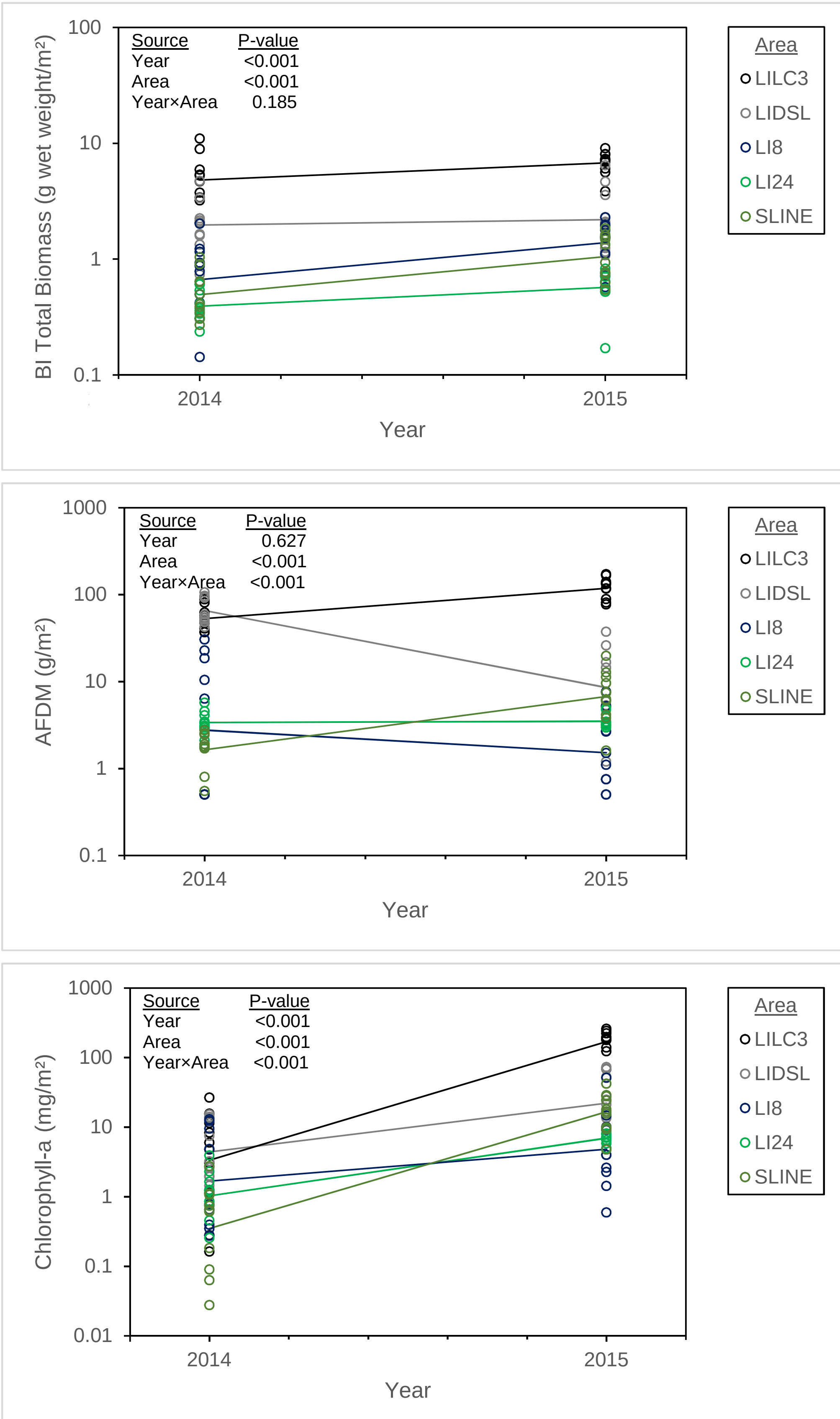
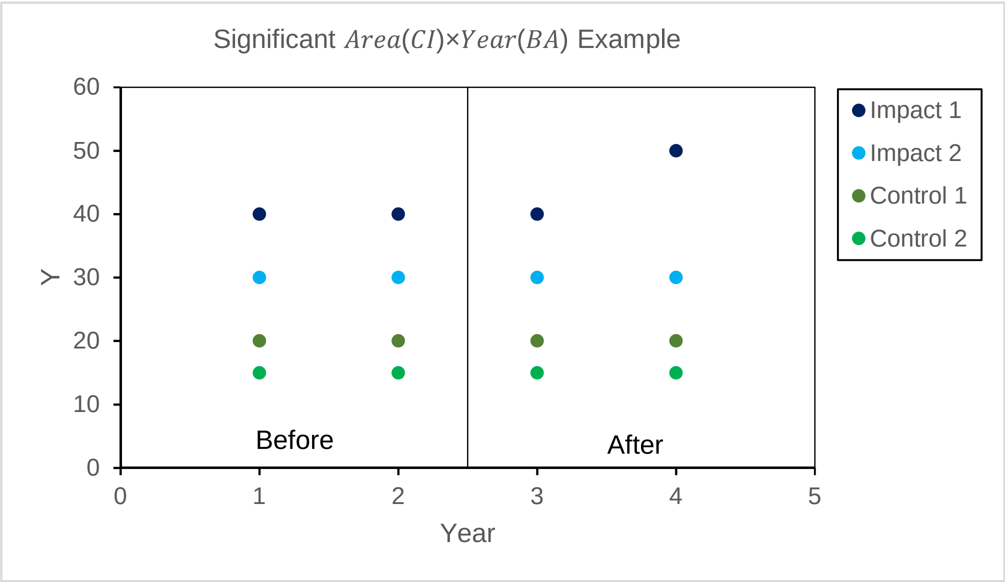


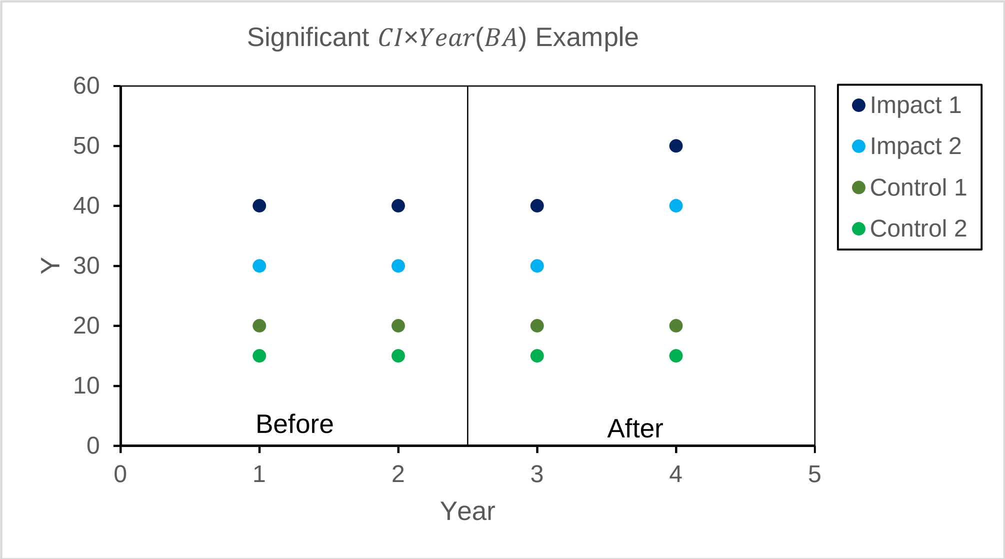
Figure B.2: Scatterplots of benthic invertebrate total biomass, AFDM, and chlorophyll-a versus year for five sampling areas in 2014 and 2015

A



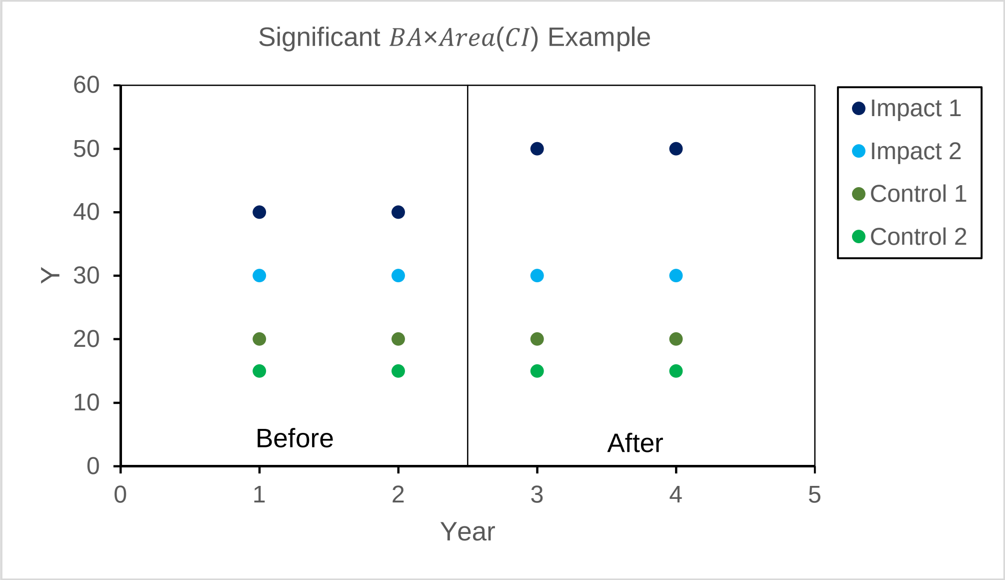
Note: The relative differences among areas over time are significant but depend on the year and area compared (Effect at Impact 1 in Year 4).

B



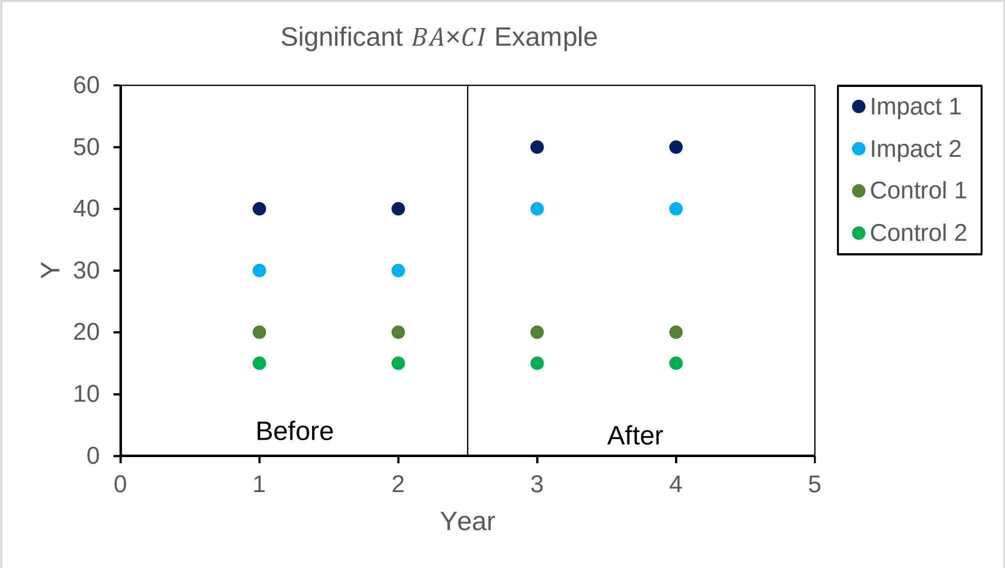
Note: The relative differences among areas over time are significant but depend on the level of CI and area compared (Effect at Impact areas in Year 4).

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 B.3 Examples of significant interactions in the BACI model with two impact areas and two control areas

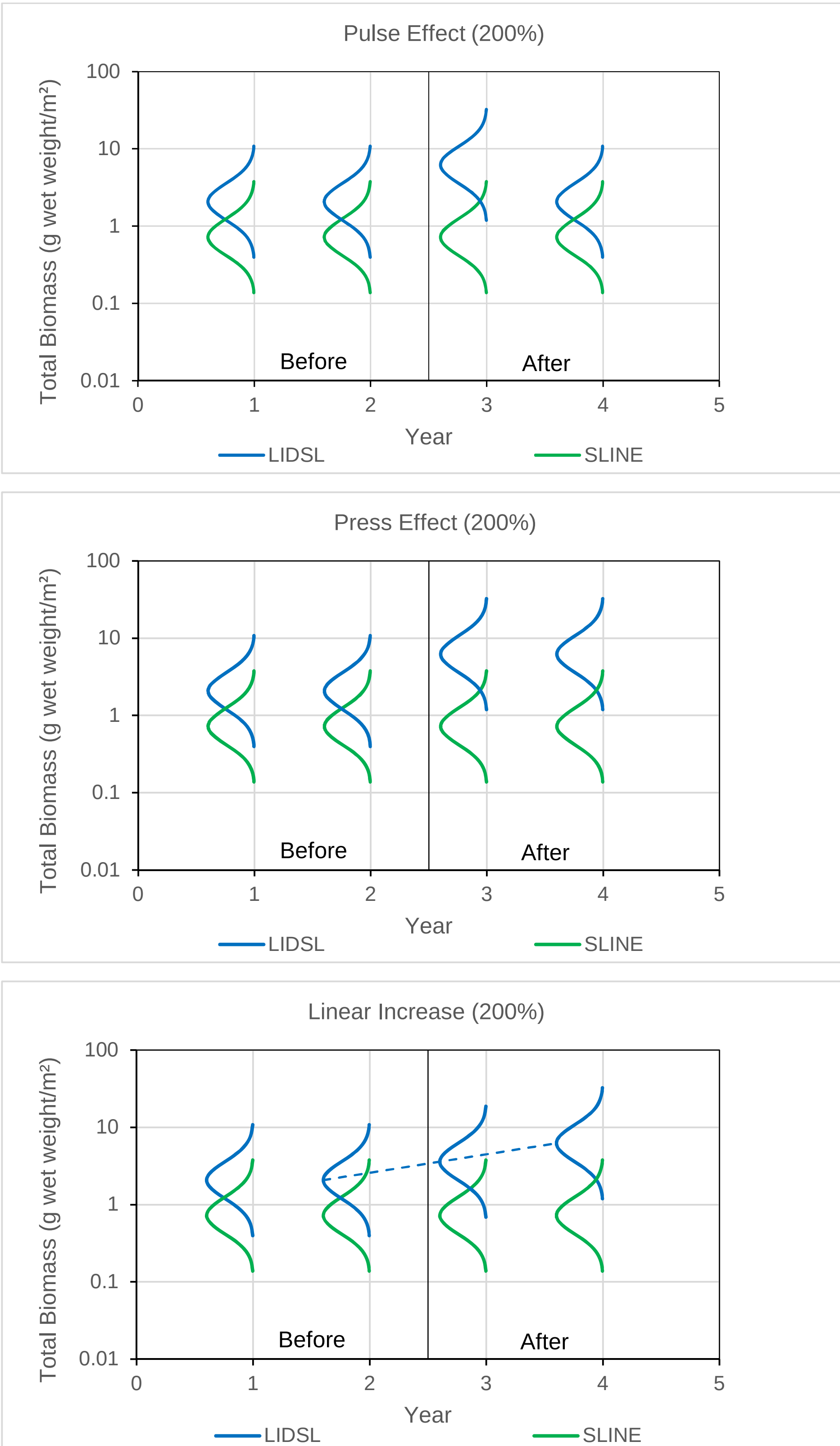


Figure B.4 Modelled distributions of benthic invertebrate biomass for LIDSL and SLINE for 2014 and 2015 (Before) and 2016 and 2017 (After) showing a pulse effect, press effect, and a linear increase of magnitude 200% increase relative to the LIDSL mean in the before period assuming no process variability.

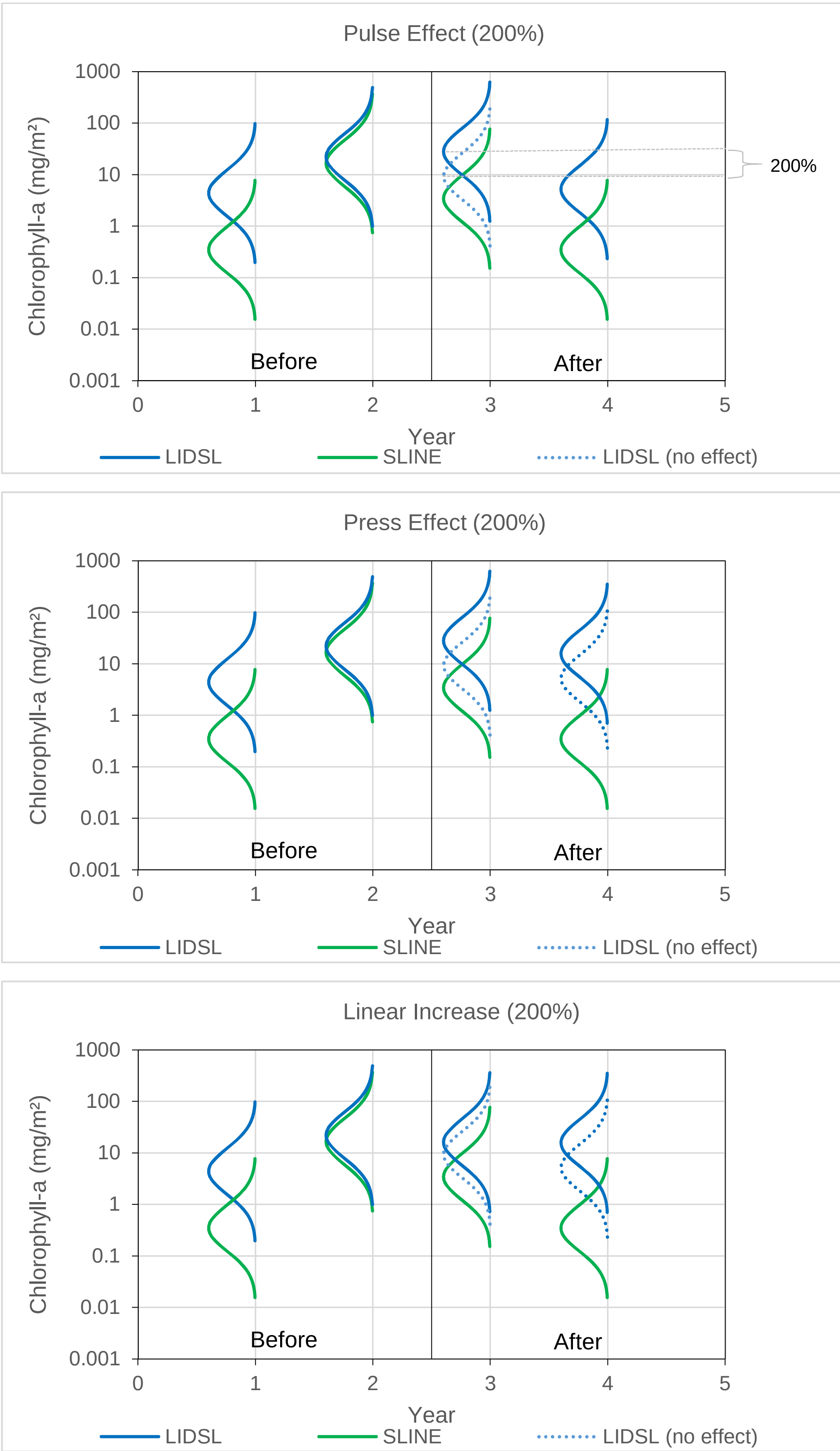


Figure B.5: Modelled distributions of chlorophyll-a for LIDSL and SLINE for 2014 and 2015 (Before) and 2016 and 2017 (After) showing a pulse effect, press effect, and a linear increase of magnitude 200% increase relative to theLIDSL mean in the before period with process variability.

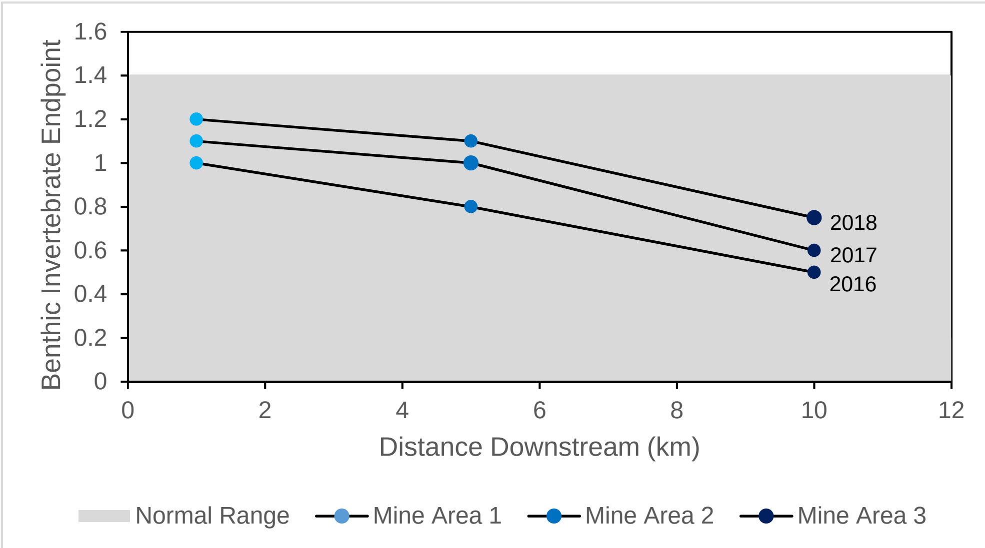


Figure B.6 Scatterplot of an example benthic invertebrate endpoint versus distance downstream for three mine-exposed areas in three years plotted with the normal range