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Technical Report Overview

Report: Calcite Relationship with Fish Spawning and Incubation 2017 Report

Overview: This report provides results from further investigations into the relationship between calcite and fish incubation conditions. It presents information collected as part of an ongoing assessment of the relationship between stream calcite and spawning habitat suitability and summarizes the potential use of other field-based assessment methods. This report also provides considerations for the 2018 calcite biological effects monitoring program.

This report was prepared for Teck by Ecofish Research Ltd.

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Teck Coal Ltd

2017 Monitoring Relationship of Calcite with Fish Spawning and Incubation

Prepared for:

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EXECUTIVE SUMMARY

Calcite formation has been observed in streams near Teck mining activities, such as some locations in the Fording River and, to a lesser extent, in the Elk River. Calcite may also occur in reference streams unaffected by mining, but typically to a lesser extent. Teck Coal Limited (Teck) commissioned a phased study approach to assess fish incubation and spawning habitat conditions in relation to calcite levels. A pilot study conducted in 2016 to investigate the linkage between calcite and incubation conditions (as represented by dissolved oxygen and flow) found calcite index (CI) score was an important predictor of dissolved oxygen (DO) in the substrate.

This report provides results from further investigations on the link between calcite and incubation conditions, presents information collected as part of an ongoing assessment of the link between stream calcite and spawning habitat suitability, and summarizes the potential for use of other field-based assessment methods (incubation cassettes and emergence traps). Considerations for the 2018 calcite effects monitoring program are also provided.

Incubation Conditions

Building on the 2016 calcite effects monitoring program, a field study was conducted in late August and early September 2017. The study measured CI, hyporheic conditions (i.e., DO concentration at depth and hyporheic flow), as well as other potential covariates (i.e., key fish habitat variables, hyporheic water quality, substrate composition, and surface hydrology) at Greenhills Creek, Line Creek Operations (LCO) Dry Creek and Henretta Creek. The three streams are tributaries to the upper Fording River with spawning habitat used by Westslope Cutthroat Trout. Results were used to model relationships between hyporheic conditions and CI, taking into consideration site characteristics and covariates. Greenhills Creek was sampled in 2016 and 2017 to allow comparison of data collection methods.

Antecedent Streamflow and Precipitation

Flows were similar during and a month prior to the late summer field sampling program in both years of study (2016 and 2017).

FHAP and Fish Observations

Fish habitat surveys (FHAP) were completed in the lower reaches of Greenhills Creek and Henretta Creek. FHAP was completed in LCO Dry Creek in 2016 (Buchanan *et al.* 2016). During field work, Westslope Cutthroat Trout or redds were observed in Greenhills Creek and LCO Dry Creek, but not at all the study reaches. No fish or redds were observed in Henretta Creek, although moderate quality spawning habitat was noted at HEN-CA01.

Calcite Index Measures

Surface calcite levels were measured using the calcite index (CI). CI varied spatially throughout the study area, as expected from previous studies. The lowest CI was measured in LCO Dry Creek (both sites had a CI of 0.00). The CI at the Greenhills Creek sites ranged from 0.98 to 1.37 (similar to the

CI measured at the same sites in 2016), and CI at the Henretta Creek sites ranged from 0.49 to 0.90. Calcite occurrence was also assessed in relation to depth, but was not measured with the same method as surface calcite measurements. Calcite occurred only at the surface in LCO Dry Creek, whereas calcite occurred to greater depths in the streambed at the Greenhills Creek sites. Calcite occurred at the surface and relatively shallow depths (7 cm) at the Henretta Creek sites.

CI was measured at two scales: a mesohabitat scale typical of the standard CI measurements in the broader Elk Valley calcite monitoring program, and a smaller area near each piezometer location intended to represent the spatial scale of a Westslope Cutthroat Trout redd. There was generally minimal difference in CI between the two spatial scales, suggesting little variation of CI within the mesohabitat. The exception was in Henretta Creek, where HEN-CA02 exhibited greater differences in CI between the two measurement scales. The variability in CI observed within each site was similar to that observed in 2016.

Hyporheic Dissolved Oxygen Concentration and in situ Water Quality

Dissolved oxygen (DO) and specific water quality parameters (temperature, pH, and specific conductivity) were measured in the hyporheic zone (the saturated interstitial area beneath and alongside a streambed, where there is a mixing of shallow groundwater and surface water) at several depths in the streambed (surface, 30 cm and 50 cm) at all the study sites.

At Greenhills Creek, instantaneous DO measurements generally exhibited a moderate saturation condition ranging from 5.2 to 8.6 mg/L concentration. The concentration of DO fell below the instantaneous minimum approved British Columbia Water Quality Guideline for the Protection of Aquatic Life (BC WQG; 6 mg/L; MOE 2018) for buried embryo/alevin life stages at one GRE-CA03 piezometer location, at 30 and 50 cm depths. Overall, measured DO concentrations at the Greenhills Creek sites fluctuated around the 30-day average guideline (8 mg/L) for buried embryo/alevin life stages suggesting that if these concentrations occurred over the long-term, adverse effects to buried life stages may occur. DO generally decreased from the surface to 50 cm below the surface, while water temperature generally increased with depth below the surface. Water temperatures ranged from 14.4 ºC to 18.0 ºC at both Greenhills Creek locations, and were generally above the optimal maximum temperature range for Westslope Cutthroat Trout rearing activities. Incubation and emergence was likely completed at the time of sampling.

At LCO Dry Creek, DO generally exhibited a moderate to well-saturated condition ranging from a concentration of 7.5 mg/L to 10.8 mg/L. DO concentrations changed negligibly with depth. DO concentrations were all above the instantaneous minimum BC WQG (6 mg/L) and only below the 30-day minimum (8 mg/L) on one occasion at LCDRY-CA01. LCO Dry Creek sites exhibited cooler water temperatures (6.3 °C to 9.2 °C) compared to Greenhills Creek sites. In general, water temperature increased with depth in the substrate and was less than the optimal temperature minimum for the incubation period.

At Henretta Creek, DO generally exhibited a moderate to well-saturated condition ranging in concentration from 9.00 to 10.86 mg/L. DO concentration changed negligibly with depth, with the exception of one piezometer location at HEN-CA02 where readings at depth were less than the instantaneous minimum BC WQG (6 mg/L) for buried embryo/alevin life stages. Data were typically well above the long-term 30-day guidelines (8 mg/L). Water temperatures ranged from 6.4 °C to 9.7 °C. In general, temperature did not change appreciably or exhibit discernible trends with depth in the substrate and water temperature was within the optimal temperature range for Westslope Cutthroat Trout incubation.

The Greenhills Creek sites exhibited a pH range from 7.73 to 8.76 and a specific conductivity range of 1,570 to 1,625 µS/cm. Specific conductivity was higher than typically observed in BC surface water (100 to 500 µS/cm), indicting a higher concentration of dissolved ions. In general, the average pH at each site decreased with depth, while the average conductivity remained fairly constant.

At LCO Dry Creek, pH ranged from 7.42 to 8.38 and specific conductivity ranged from 167 to 354 µS/cm, which are typical ranges in BC streams. Similarly, the Henretta Creek sites exhibited a pH range from 7.59 to 8.15 and specific conductivity ranged from 538 to 561 µS/cm.

Hyporheic Water Quality: Laboratory Analysis

Water quality samples were collected at each piezometer location at the surface and at 30 cm and 50 cm depths in the substrate. The analytical results were screened against the applicable approved BC WQG (MOE 2018) and the working BC WQG (MOE 2017) for the protection of aquatic life.

Laboratory data for pH and specific conductivity were compared to the in situ result for these parameters. In all three creeks, laboratory measured pH was greater than 8.0 (basic) and results were similar to those obtained in situ. Specific conductivity lab results were similar to the in situ results.

The water quality parameters collected at the surface were compared to those collected at depth in the substrate. The majority of piezometer locations had total and dissolved metal concentrations that were similar in surface water and hyporheic water; calcium and magnesium concentrations were the exception, with higher concentrations found at depth in Greenhills Creek. Suspended solids and turbidity concentrations were also greater at depth at the Greenhills sites, while concentrations of total dissolved solids were greater in the surface water compared to hyporheic water at 50 cm depth. Water hardness ($CaCO_3$) and bromide concentrations were higher in the surface water than hyporheic water at LCDRY-CA02, compared to the difference in concentrations between the surface and hyporheic water at other sites.

Water quality parameters were compared to the short- and long-term BC Water Quality Guidelines (WQG) and the Elk Valley Water Quality Plan (EVWQP) ecological benchmarks developed for selenium, nitrate, and sulphate specific to fish spawning and incubation (Teck 2014). The following parameters were above the applicable short-term or long-term BC WQG and/or the EVWQP ecological benchmarks. Total selenium (Se) concentrations were above the BC WQG (0.002 mg/L and the EVWQP benchmark for reproductive effects on WCT (0.07 mg/L) at all three creeks, with

Greenhills Creek exhibiting the highest concentrations ranging from 0.164 to 0.173 mg/L. The EVWQP benchmark for juvenile fish growth is not applicable to the upper Fording River, because studies with juvenile WCT have reported no effects at the Level 1 and Level 2 benchmarks (>0.046 mg/L and >0.466 mg/L, respectively). Total uranium concentrations were above the long-term working BC WQG (0.0085 mg/L; MOE 2017) at Greenhills Creek sites only. Sulphate concentrations in Greenhills Creek were above the hardness dependent long-term BC WQG (429 mg/L for hardness > 250 mg/L) and EVWQP benchmarks (429 mg/L for hardness > 250 mg/L) at all sampling locations. Water hardness (as $CaCO_3$) was high in Greenhills Creek ranging from 1,070 to 1,080 mg/L; values did not change appreciably with depth in the substrate. Nitrate concentrations were also above the long-term BC WQG for nitrate (3 mg/L) at Greenhills Creek and Henretta Creek sites, but below the hardness-dependent Level 1 and Level 2 EVWQP benchmarks for fish in the Fording River (16 and 21 mg/L of NO_3-N, respectively).

Hyporheic Flow

Groundwater exchange rates were modelled with Darcy's equation using measured hydraulic head and hydraulic conductivity estimates based on grain size distribution relations (Kalbus *et al.* 2006). Hydraulic head was measured at 30 cm and 50 cm depths within the streambed.

At Greenhills Creek, the average hydraulic head generally increased (became more positive) with depth, indicating downwelling. At GRE-CA03, both downwelling and upwelling flow patterns were recorded at 50 cm streambed depth; hydraulic head ranged from -0.003 to 0.017 m.

At LCO Dry Creek, the average hydraulic head decreased (became more negative) with depth at LCDRY-CA01 and increased with depth at LCDRY-CA02. There was little hydraulic head difference between the 30 cm and 50 cm depths at the three piezometer locations at LCDRY-CA01, suggesting weak downwelling; hydraulic head ranged from -0.006 to 0.004 m. The hydraulic head results indicate strong upwelling at LCDRY-CA02.

At Henretta Creek, both upwelling (HEN-CA01) and downwelling (HEN-CA02) flow patterns were recorded; hydraulic head ranged from -0.013 to 0.445 m.

The average groundwater exchange rates for all piezometer locations ranged from -1.8 to 332.3 m/day at 30 cm depth and 0.5 to 187.0 m/day at 50 cm depth. The maximum groundwater exchange rate was less than 55 m/d at all but two of the sites at 30 cm depth, and all but one site at 50 cm depth. The groundwater exchange rates were unrealistically high at two of the sites (LCDRY-CA02 and HEN-CA01) given typical groundwater exchange rates reported in the literature. The high values are likely the result of poor estimates of hydraulic conductivity (K). It is therefore recommended that the groundwater exchange rates obtained from the hydraulic head method be treated as indicative of direction of flow and relative magnitude.

Comparison of Sampling Methods

The method to collect hyporheic DO, water quality, and flow measurements was modified for the 2017 field program based on Environmental Monitoring Committee (EMC) review comments from the 2016 study results. The modifications to the 2016 methods included the use of piezometers with smaller screen lengths, use of a larger diameter inner drive point during piezometer installation, purging water within the piezometer prior to measuring hydraulic head and DO at each depth, and installing a stilling well over the piezometer when taking hydraulic head measurements. To determine if this modified methodology had an effect on the measurement of hyporheic conditions, both sampling techniques (unmodified and modified) were used to measure DO and hydraulic head at GRE-CA01 and GRE-CA03, and mixed-effects modelling was used to compare data collected at the two Greenhills Creek sites. The piezometer method used did not have a significant affect ($p > 0.05$) on the observed dissolved oxygen concentration or the hyporheic flow from the hydraulic head method from samples taken in 2017 using both methods at GRE-CA01 and GRE-CA03.

Modelling of Calcite versus Physical Parameters

The relationship between calcite index and hyporheic dissolved oxygen and flow was modeled using both years of data collection (2016, 2017) and a model selection procedure that fitted a series of linear mixed-effects models using the "lme4" and "MuMIn" packages (Bates *et al.* 2015) for R statistical software (R Core Team 2013). Models were fit for two key response variables: dissolved oxygen concentration; and hyporheic flow as measured by the hydraulic head method. The predictor variables included in each model were calcite index and habitat and sampling variables hypothesized to affect hyporheic conditions (depth within substrate, water temperature, water quality, water column depth, flow, percent fines, substrate size, sampling year, site). Predictor variables include fixed effects (variables that we are interested in and test directly) and random effects (variables that we are less interested in but need to account for in the analysis). To combine data from both 2016 and 2017 in a consistent manner, only data collected in September at depths of 0, 30, or 50 cm were used.

Westslope Cutthroat Trout may not spawn frequently in substrates with CI scores greater than some threshold. We tested the relationship between CI score and hyporheic conditions using a subset of the data to explore whether trends were similar. We subsetted the data to only include sites with CI scores < 1.25, and then re-ran the modeling procedure as described above. A threshold value of 1.25 was chosen to reflect conditions when Westslope Cutthroat Trout may have easier access to the substrate for spawning, based in part on preliminary observations described in Minnow Environmental (2016). This approach produced two modeling results for each predictor variable using: 1) all data (CI < 3); and 2) subsetted data (CI < 1.25).

In the analysis using all of the data (CI < 3) collected over two years (2016 and 2017), stream sites with higher calcite index scores were found to have lower DO in the substrate, but not lower hyporheic flow measured using the hydraulic head method. Consistent with results from 2016, CI was an important predictor of DO concentrations in the substrate, but this effect increased with depth in the substrate (i.e., there was a significant interaction between CI and depth). Hyporheic DO decreased with depth in the substrate (independent of CI) and was lower at sites with higher percent fines. Results using the subsetted data (CI < 1.25) were similar to the full dataset, although the effect of CI on hyporheic DO was weaker, at least partly due to a smaller sample size of the subsetted data.

The average redd depth for Westslope Cutthroat Trout is between 10 and 30 cm (DeVries 1997, Magee and McMahon 1996). The model for DO using all of the data predicts that at a maximum CI score of 3, the average instantaneous DO is ~7.5 mg/L at a depth of 30 cm and ~6 mg/L at a depth of 50 cm, both of which are at or above the instantaneous minimum BC WQG for buried embryos/alevins. However, these model predictions represent mean conditions, and DO concentrations below the minimum BC WQG may occur at some sites, particularly where fines occur in conjunction with high CI scores.

Overall, these results highlight that DO concentrations below the minimum guidelines for the protection of buried life stages were observed in this study; however, such low DO concentrations were not observed at depths that WCT would typically build redds.

Investigation of Spawning Conditions

There are three objectives to assessing the link between calcite and spawning habitat suitability: 1) develop a calcite vs. habitat response curve; 2) apply the response curve within tributaries to assess availability of spawning habitat in relation to calcite; and 3) assess temporal trends in availability of spawning habitat in relation to calcite. Further investigations into spawning conditions are intended to focus on development of the response curve and habitat mapping (including calcite) within specific tributaries, and will likely need to be carried out over multiple spawning seasons.

Habitat data and mesohabitat-specific calcite data were collected at three tributaries (Greenhills Creek, LCO Dry Creek, and Henretta Creek). Redd surveys were carried out on LCO Dry Creek near the end of the Westslope Cutthroat Trout spawning season in June and early July 2017, as part of ongoing work and permit requirements associated with another Teck biological program (Faulkner *et al.* 2018). Redd surveys on Greenhills Creek and Henretta Creek were deferred to 2018 due to timing of spawning relative to finalization of the study design for the 2017 calcite effects monitoring program.

Investigation of other Assessment Methods

The EMC previously discussed the potential use of field-based methods to directly assess egg-to-fry survival in relation to calcite and other variables. The feasibility of such a study was explored and a summary of possible approaches is provided in this report. Permitting requirements and regulatory restrictions for use of some of the techniques in the Elk Valley were discussed with Provincial fisheries staff from BC Ministry of Forest, Lands and Natural Resource Operations and Rural Development (FLNRORD). Variations of two main approaches were reviewed: 1) outplanting of fertilized eggs in incubators across a gradient of calcite and, 2) sampling of wild redds to estimate the number of surviving fry across a gradient of calcite. These approaches include the use of in situ incubators for outplanting hatchery eggs, use of emergence traps, or hydraulic sampling of natural redds. Considerations for each of these methods are discussed with respect to the assessment of egg-to-fry survival, as well as other challenges of conducting such a study. A review of scientific literature for studies on Westslope Cutthroat Trout spawning habitat selection preferences was conducted, with a specific focus on spawning site hydraulics. Our review confirmed that most of the available literature examining spawning site hydraulics has focused on fall spawning species and that reports of hydraulic properties of redds of spring spawning species are scarce in the literature. Though relatively scarce, the literature on redd hydraulics of spring spawning trout suggests that spawning often occurs in areas of downwelling.

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1. INTRODUCTION

Teck Coal Limited (Teck) operates five steelmaking coal mines in the Elk River watershed in south-eastern British Columbia. Calcite formation has been observed in the tributaries downstream of Teck mining activities, at some locations in the Fording River and, to a lesser extent, in the Elk River and in reference streams unaffected by mining. Calcite is created by the reaction between dissolved calcium (Ca^{2+}) and carbonate (CO_3^{2-}) ions under conditions that can occur naturally, but can be enhanced when water passes through waste rock from mining. A number of seasonal factors can contribute to the precipitation or dissolution of calcite, including physical forces (e.g., scouring of the substrate during high flow turbid periods) and water chemistry (water temperature, pH, composition of dissolved ions and minerals); therefore, timing and location of calcite formation can be challenging to predict (Minnow Environmental 2016).

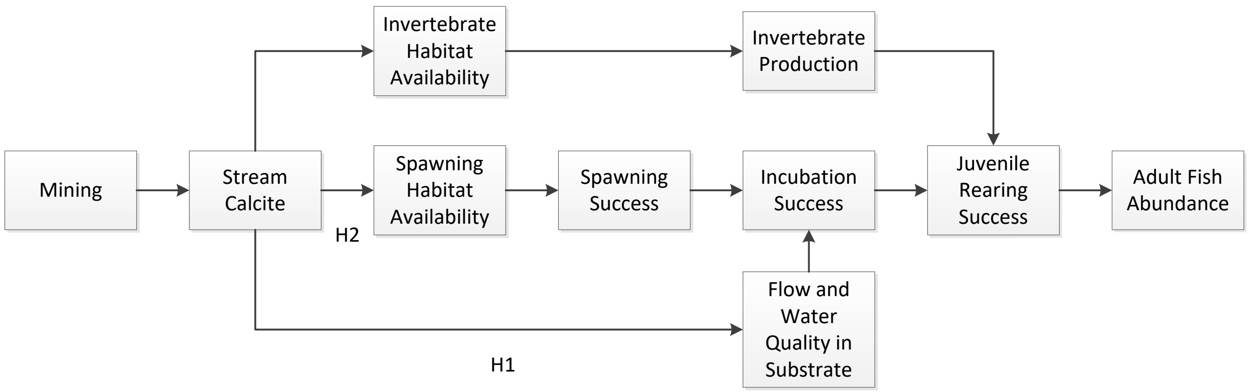
In the Elk River watershed, there are wide ranges in the spatial extent of calcite cover, as well as seasonal fluctuations in calcite cover. Calcite cover ranges from areas with minimal calcite formation to areas in certain streams where calcite precipitation can completely cover portions of the stream bed, making the gravels largely immovable. There are concerns that high levels of calcite may have an effect on fish and other biota.

In the Elk Valley Water Quality Plan (EVWQP), Teck committed to continuing a program of monitoring and management for calcite with the objective of understanding and managing mine-related calcite formation such that streambed substrates in the Elk and Fording rivers and their tributaries can support abundant and diverse communities of aquatic plants, benthic invertebrates, and fish comparable to those in reference areas (Teck 2014). Teck's requirements for monitoring biological effects as part of its Regional Aquatic Effects Monitoring Program (RAEMP) include:

> "Teck shall complete the assessment to determine the potential relationships between calcite and benthic invertebrate community structure, periphyton productivity and fish spawning and incubation success. Teck shall work in collaboration with the Ministry and Ktunaxa Nation representatives ideally in a monitoring committee forum to prepare study designs for work proposed in 2015 and 2016."

This study addresses the "fish spawning and incubation success" aspects of the RAEMP requirements described above by furthering assessment of potential calcite effects on spawning and incubation habitat. The study design builds on the outcomes of previous studies in the Elk Valley, including a pilot study implemented in 2016 that measured hyporheic flow and dissolved oxygen over a range of sites with varying levels of calcite (Wright *et al.* 2017), and takes advantage of ongoing biological programs being undertaken by Teck. The basic premise of the study is that calcite accumulation on a streambed influences the suitability of spawning habitat and incubation conditions, and thereby the carrying capacity of fish habitat. The effects of calcite on spawning and incubation habitat are hypothesized links in effect pathways linking calcite to fish production (Figure 1). The objective of this study is to provide additional information on the link between calcite and incubation conditions (i.e., impact hypothesis H1), and collect information required to assess the link between stream calcite and habitat availability (i.e., impact hypothesis H2).

Figure 1. Effect pathway diagram linking calcite on the streambed to fish production.



1.1. Management Questions and Impact Hypotheses

The calcite biological program aims to address the following three management questions:

1. To what extent does calcite influence incubation conditions within the shallow hyporheic zone?
2. What is the response relationship between calcite and spawning habitat suitability in Elk Valley tributaries affected by Teck operations?
3. What is the status of spawning habitat as affected by calcite in Elk Valley tributaries?

In addressing the questions, the study is designed to test the following two null hypotheses:

$H_0$1: Observed calcite conditions on stream substrates have no effect on hyporheic flow and dissolved oxygen.

$H_0$2: Observed calcite conditions on stream substrates have no effect on suitability of fish spawning habitat.

Habitat use by fish is well known in the upper Fording River and tributaries (Cope *et al.* 2016), so the impact hypotheses were tested by empirically assessing incubation conditions and spawner use in tributaries to the upper Fording River. As discussed at the EMC#12 meeting[1], some aspects of the management questions may have to be addressed over multiple years, as conditions allow for adequate sampling.

[1] EMC#12 meeting, 26 April 2017, Cranbrook, BC.

1.2. Scope of Study

There are three distinct components to this study: investigation of incubation conditions, investigation of spawning conditions, and investigation of other assessment methods. Each of these is discussed separately below.

1.2.1. Incubation Conditions

This component focussed on addressing review questions posed by the EMC in response to results from the 2016 study of hyporheic conditions (Wright *et al.* 2017), and additional aspects discussed at the EMC#12 meeting. This component has four objectives:

1. Validate the study techniques employed in 2016;
2. Compare additional water quality parameters within the hyporheic and water column;
3. Add new study sites to examine the link between calcite presence and hyporheic conditions; and
4. Re-run statistical models from 2016 to include 2017 results.

The approach focused on the link between calcite and hyporheic conditions. The hyporheic zone is the saturated interstitial region beneath and alongside a streambed, where there is mixing of shallow groundwater and surface water (Findlay 1995). Dissolved oxygen (DO) concentration and flow within the substrate have been of particular interest as these are hyporheic factors known to affect fish incubation success and invertebrate production (e.g., Bowernan *et al.* 2014). The experimental design approach used in 2016 was mensurative rather than manipulative in that measurements were taken over a range of existing calcite levels. Hyporheic measurements were made using DO meters, temperature sensors, and piezometers. A number of covariates thought to influence hyporheic DO and flows were also measured, including water depth, water velocity, water flow, temperature, depth within the substrate, and substrate characteristics. At EMC#12 there was interest in expanding the scope of these measurements to assess other water quality constituents to help understand whether shallow hyporheic water quality is notably different than water quality in the water column above the substrate.

The study component focused on tributary habitat in the upper Fording watershed identified in the upper Fording River Westslope Cutthroat Trout Population Assessment and Telemetry Project (Cope *et al.* 2016) as important spawning habitat. In 2016, study sites were selected on the mainstem Fording River, Clode Creek, and Greenhills Creek. Selected sites represent a diversity of habitats and a range of calcite conditions. The 2017 program consisted of testing adjustments to the 2016 methods (e.g., piezometers with smaller screen lengths) on the lower reaches of Greenhills Creek, measuring additional sites on LCO Dry Creek[2] and Henretta Creek, and further sampling hypoheic water quality.

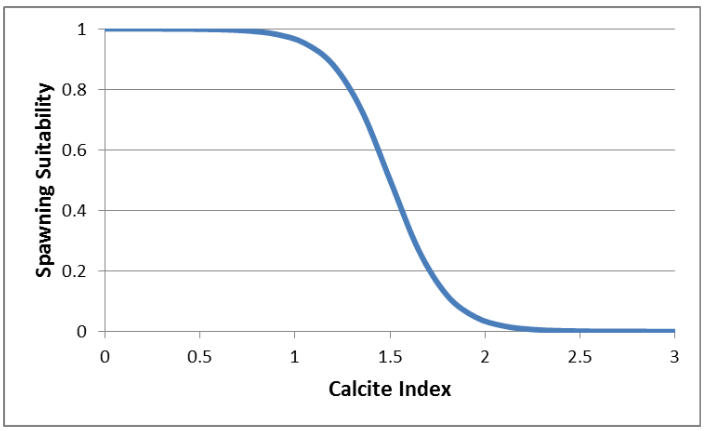
1.2.2. Spawning Conditions

This component focusses on assessing the link between calcite and spawning habitat suitability. There are three objectives:

1. Develop a calcite vs. habitat response curve;
2. Apply the response curve within tributaries to assess availability of spawning habitat in relation to calcite; and
3. Assess temporal trends in availability of spawning habitat in relation to calcite.

The relationship between calcite and spawning habitat will be referred to here as a response curve (Figure 2), which quantitatively describes the influence of calcite (i.e., habitat) on salmonid habitat quality (i.e., biological response). A response curve can be used in combination with habitat surveys to describe the status of spawning habitat within an area. It can thus be used for direct quantitative estimation of habitat availability, including trend monitoring of fish habitat (i.e., habitat availability over time).

Figure 2. Conceptual response curve for calcite as it relates to spawning habitat suitability for salmonids.



There are two fundamental challenges to developing a response curve for calcite. First, calcite is one of many influences on fish and fish habitat, and these other influences (e.g., substrate type, cover, gradient, water quality, etc.) need to be considered as potential covariates when developing the response curve. Likewise, it is necessary to assess where fish are spawning as well as where they are not spawning, or the response curve will be incomplete. Second, detecting and measuring Westslope

[2] Since there are two "Dry Creeks" in the area, we refer to this one as "LCO Dry Creek" because it is within Line Creek Operations footprint.

Cutthroat Trout spawning intensity in the upper Fording is fraught with substantial challenges, such as variable spawn timing, variable longevity of detectability of redds, distinguishing between redds and other disturbances, and field conditions like water clarity. These challenges suggest that a response curve is likely to be developed over multiple spawning seasons, rather than a single season. Furthermore, it suggests that completing the response curve may require inputs from experts with local knowledge.

Investigations into spawning conditions focused on two separate but related aspects of this study component: 1) development of the response curve; and 2) habitat mapping (including calcite) within specific tributaries. The following aspects defined the scope of this study component::

1. The study focused on tributary habitat in the upper Fording watershed identified in the Westslope Cutthroat Trout report (Cope *et al.* 2016) as important spawning habitat. Selected sites represented a diversity of habitats and a range of calcite conditions in the Elk Valley. The 2017 efforts focused on the lower reaches of Greenhills Creek, LCO Dry Creek, and Henretta Creek.
2. Redd surveys were also conducted in the lower reaches of Greenhills Creek, Henretta Creek, and LCO Dry Creek. A higher reach of Greenhills Creek (above the settling pond, where fish are present) was sampled to obtain information from a stream section with high calcite. Habitat characteristics, including calcite, was measured at redd locations and at a range of locations in the same streams where redds are not found.
3. For portions of the lower reaches of Greenhills Creek, LCO Dry Creek, and Henretta Creek that have not already been surveyed, Level 1 Fish Habitat Assessment Procedure (FHAP; Johnston and Slaney 1996) was used to develop habitat maps of these stream reaches. Calcite will be quantified using the calcite index (CI) measured at a subsample of habitat units.

The 2017 program included collection of additional habitat data and mesohabitat-specific calcite data on the three study tributaries (Greenhills Creek, LCO Dry Creek, and Henretta Creek) where data gaps were found to exist. Additionally, redd surveys were completed on LCO Dry Creek near the end of the Westslope Cutthroat Trout spawning season in June and early July as part of ongoing work and permit requirements associated with another program (Faulkner *et al.* 2018). Redd surveys on Greenhills Creek and Henretta Creek were deferred to 2018 due to timing of spawning relative to EMC finalization of the study design for the calcite biological program.

1.2.3. Other Assessment Methods

At EMC#12 there was discussion about the potential use of field-based methods to directly assess egg-to-fry survival in relation to calcite and other variables. To determine the feasibility of such a study, we completed a review of potential in situ incubation methods and permitting requirements and regulatory restrictions for use of these techniques in the Elk Valley. Two approaches were reviewed: 1) outplanting of hatchery-produced Westslope Cutthroat Trout embryos across a gradient of calcite and, 2) sampling of wild redds to estimate the number of emerging fry across a gradient of calcite. These approaches include the use of in situ incubators for outplanting hatchery eggs, emergence traps, and hydraulic sampling of natural redds. Considerations for each of these methods are discussed with respect to the assessment of egg-to-fry survival, and the challenges of conducting such a study.

A review of Westslope Cutthroat Trout spawning habitat selection, with a specific focus on spawning site hydraulics was conducted to provide some insight into whether incubating embryos in natural redds would be subjected to downwelling or upwelling, and potential differences in water quality associated with groundwater versus surface water; a summary is provided.

2. STUDY SITES

The study was conducted in the upper Fording River watershed. The Fording River is a tributary to the Elk River and is located in the East Kootenay region of south-eastern British Columbia. Study sites were selected to represent tributary spawning habitat used by Westslope Cutthroat Trout in the upper Fording River watershed above Josephine Falls (Cope *et al.* 2016, Minnow Environmental 2016, Beswick 2007) and to represent a range of calcite conditions based on previous calcite monitoring (Minnow Environmental 2016, Robinson *et al.* 2016) (Map 1, Table 1). Spawning was visually confirmed (i.e., redds, spawning fish) at the sites selected in the lower Greenhills Creek (Cope *et al.* 2016) and LCO Dry Creek (Buchanan *et al.* 2016, Faulkner *et al.* 2018). Cope *et al.* (2013) identified fish presence within the lower reaches of Henretta Creek; however, spawning was not confirmed. The calcite index (CI) can range between 0.00 and 3.00 and calcite conditions previously reported for the selected sites (or adjacent areas) ranged from 0.00 to 1.60 (Minnow Environmental 2016, Robinson *et al.* 2016).

2.1.1. Greenhills Creek

Greenhills Creek is located entirely within Greenhills Operations (GHO) mine property. Greenhills Creek can be divided into three stream segments: 1) the lowermost reaches with fish connectivity (at most flows) to the mainstem upper Fording River, 2) Greenhills settling pond which is isolated from lower reaches and the Fording River by a fish barrier (hanging culvert), and 3) reaches upstream of the settling pond. The calcite indices generally increase from low to high as one moves up Greenhills Creek to the headwaters (Minnow Environmental 2016, Robinson *et al.* 2016).

Two study sites were selected in the lower reaches of Greenhills Creek located below the Fording River Road culvert, which is a barrier to upstream movements by upper Fording River Westslope Cutthroat Trout (Cope *et al.* 2016, Beswick 2007). Lower Greenhills Creek spawning habitat receives settling pond outflows with water quality concerns related to elevated concentrations of mine-related constituents (Windward *et al.* 2014). Lower Greenhills Creek has low to moderate CI sites (0.10 to 1.60) and generally increases with distance upstream (Minnow Environmental 2016). The lower section is used by Westslope Cutthroat Trout for spawning and, to a lesser extent, fry and juvenile rearing (Cope *et al.* 2016, Beswick 2007). Documentation of spawning and rearing use dates back to 1979 before development of GHO (BC Research 1981).

Conditions at study sites within the lower Greenhills Creek section have been generally described as 2.2 m wetted width, <1% stream gradient, gravel-fines dominant-subdominant bed material and mean water depths of ~15 cm. Fine particulates were identified as a concern for incubation success and fry rearing within the substrate interstitial environment (Cope *et al.* 2016).

2.1.2. LCO Dry Creek

LCO Dry Creek is located within Line Creek Operations (LCO) mine property. LCO Dry Creek is a 9 km-long stream that discharges into the Fording River ~ 7 km east of Elkford, BC (Teck 2011). The watershed is ~28 km² and contains one large unnamed tributary (commonly referred to as "LCO Dry Creek East Tributary") and numerous smaller tributaries. Mining occurs in the watershed upstream of the East Tributary confluence (~1/3 of the watershed), and all flow in LCO Dry Creek upstream of the East Tributary confluence is diverted to the LCO Dry Creek Water Management System (DCWMS), consisting of a headpond and two sediment ponds in parallel, where suspended matter is allowed to settle prior to water release into LCO Dry Creek.

Two study sites were selected in LCO Dry Creek, one located upstream of the railway culvert and the other downstream of the railway and Fording River Road culverts; both locations are in Reach 1 (Teck 2011). Previous surveys found no calcite in LCO Dry Creek (CI score is 0) below the settling ponds or at the confluence with the Fording River (Minnow Environmental 2016). Fish and spawning habitat have been observed in reaches 1 (at the Fording River confluence) through 4 (at the East Tributary confluence) of LCO Dry Creek (Teck 2011, Buchanan *et al.* 2016).

Conditions within Reach 1 of LCO Dry Creek have been generally described as 3.9 m wetted width, 1.7% stream gradient, cobbles and gravels dominant-subdominant bed material, and mean water depths of ~40 cm (Buchanan *et al.* 2016).

2.1.3. Henretta Creek

Henretta Creek is located entirely within Fording River Operations (FRO) mine property. Teck has carried out extensive reclamation of the lower watershed, including construction of a 3.5 ha lake (Henretta Lake) and diversion of Henretta Creek through large diameter steel culverts to allow fish passage beneath a road. Two study sites were selected in the lowermost reach, downstream of the culverts. The surface water quality of Henretta Creek upstream of the confluence with Fording River is comparable to reference locations and is considered to be relatively good with low concentrations of mine-related constituents (Windward *et al.* 2014). Henretta Creek upstream of the confluence with Fording River has a CI of 0.9; as a comparison, the CI of Henretta Creek upstream of all mining operations is 0.1 (Minnow Environmental 2016). Cope *et al.* (2013) identified Westslope Cutthroat Trout presence within the lower reaches of Henretta Creek; however, spawning has not been confirmed.

Conditions at study sites within the lowermost Henretta Creek section have been generally described as 10 m wetted width, <2% stream gradient, boulder-gravel-fines dominant-subdominant bed material and mean water depths of ~30 cm (data collected during this 2017 field study).

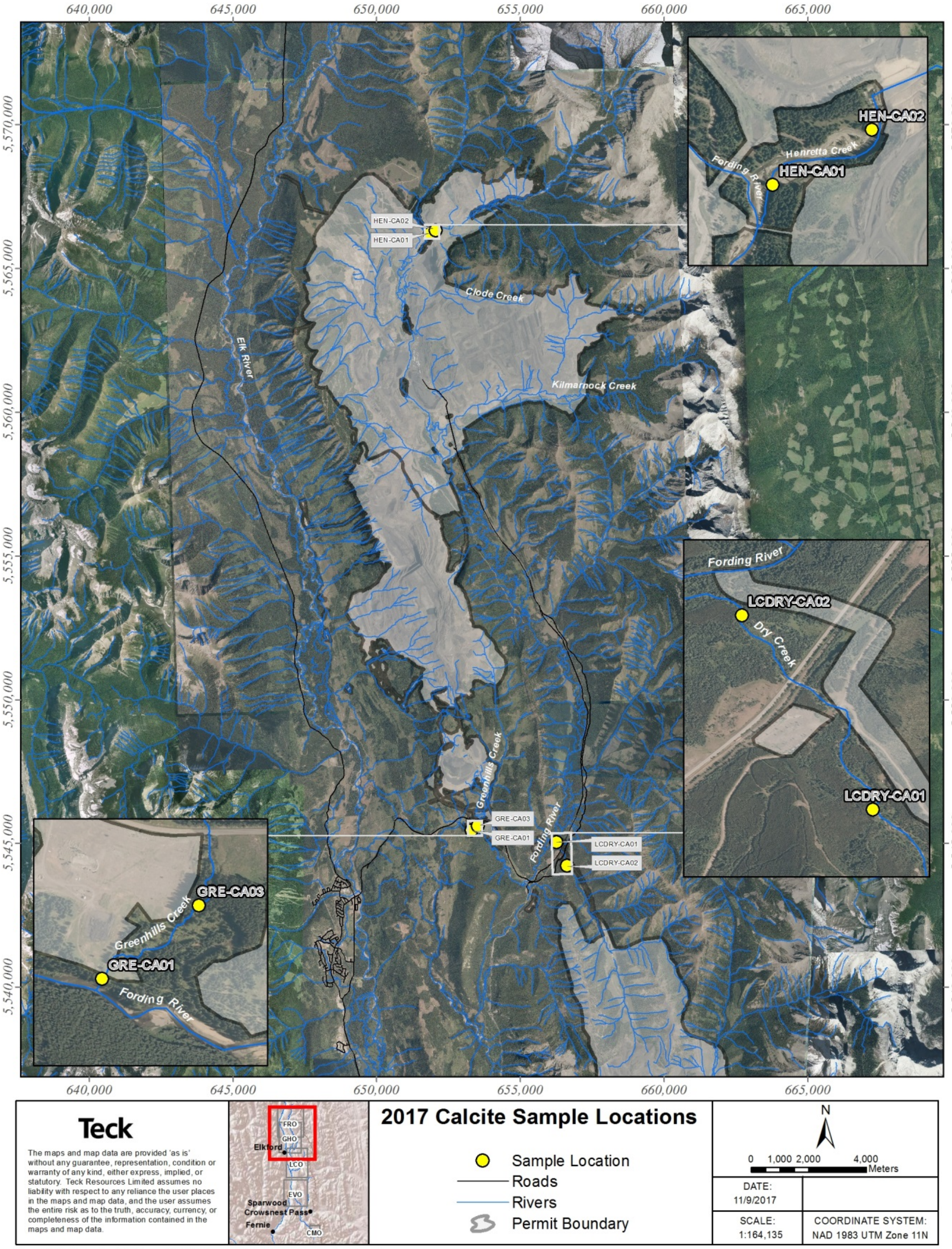
Table 1. Calcite study sites including watercourse, calcite character, and nomenclature used to reference sites within the report.

Watercourse	Character	C.I. Range[1]	Site	UTM Coordinates (Zone 11 U)		Elevation (masl)[2]
				Easting	Northing	
Greenhills Creek (lower)	low to moderate level of calcite presence	0.1 - 1.60	GRE-CA01	653314	5545461	1491
			GRE-CA03	653520	5545616	1495
LCO Dry Creek	no to low level of calcite presence	0.00	LCDRY-CA01	656270	5545022	1522
			LCDRY-CA02	656637	5544218	1553
Henretta Creek	low level of calcite presence	0.90	HEN-CA01	651845	5566195	1707
			HEN-CA02	652070	5566323	1715

[1] Previously reported in Minnow Environmental (2016) and Robinson *et al.* (2016).

[2] Elevation was determined from Google Earth.

Map 1. 2017 Calcite study sites and overview map.

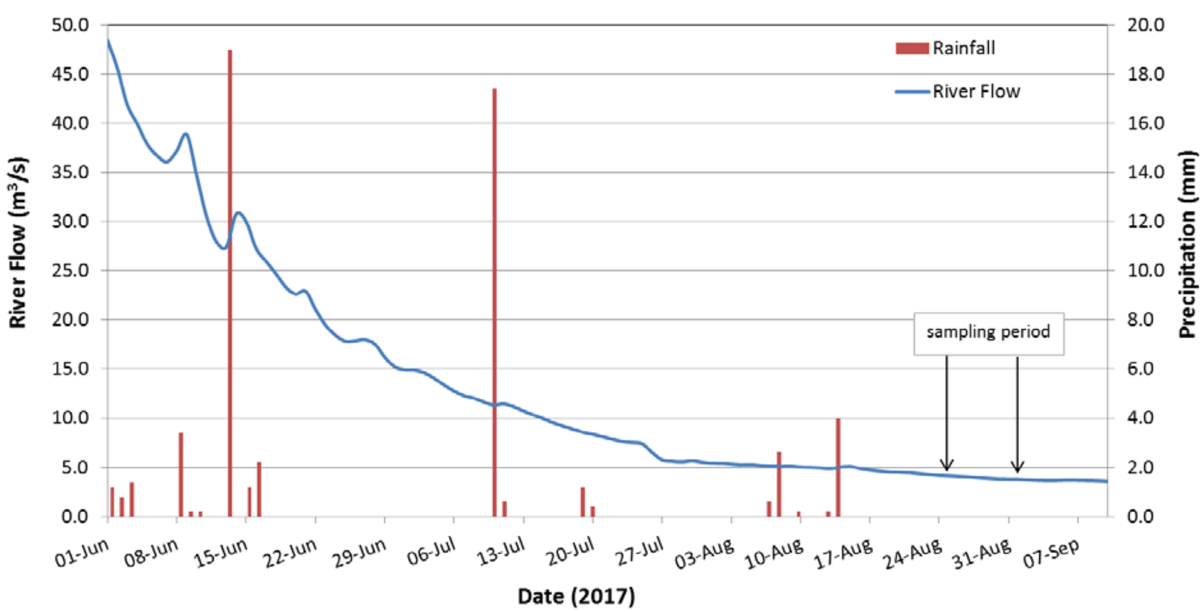


2.2. Antecedent Streamflow and Precipitation

Hyporheic conditions are likely to be influenced by precipitation and streamflow prior to and during periods of observation. Flow data collected at the mouth of the Fording River (Water Survey of Canada Station, WSC, 08NK018) and precipitation data collected at the Environment Canada (EC) Sparwood climate station (1152899) provided a continuous data record with which to characterize conditions prior to the study periods. Discharge measurements were collected at each target stream to determine the flow on the day at which hyporheic conditions were measured (see Section 3.1.1.5 and 4.1.1.5).

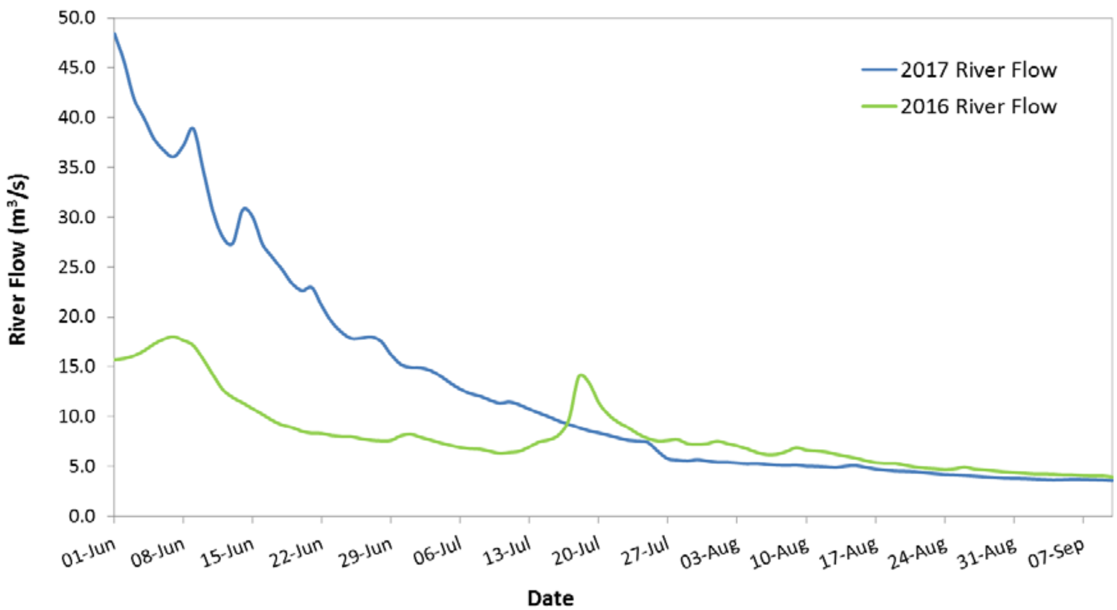
Flows at the mouth of the Fording River showed a steady decline from a peak of 48.47 m^3/s on June 1 to 4.41 m^3/s on August 25, the start of the 2017 field program (Figure 3); flows continued to decline throughout the study period. Precipitation was relatively low (4.0 mm or less) throughout late spring and summer, excluding two significant rainfall events on June 9 (19 mm) and July 10 (17.4 mm). No rain fell during the study.

Figure 3. Daily average flow data collected at the WSC 08NK018 hydrometric station and precipitation at the Environment Canada Sparwood climate station prior to and during the August 25-September 1, 2017 measurement period.



Flows varied during spring and mid-summer of 2016 and 2017 but were similar in both years one month prior to and during the late summer field sampling program (Figure 4). Comparatively, the flow in late spring 2017 was more than three times greater than 2016. On June 1, 2017 the flow was 48.47 m^3/s, while on the same date in 2016 flow was 15.69 m^3/s (Figure 4). While the flows declined more rapidly in 2017, they remained higher throughout late spring and early summer. Flows in mid-summer were greater in 2016 than 2017, due to a relatively large rain event on July 20, 2016 (Figure 4).

Figure 4. Daily average flow data collected at the WSC 08NK018 hydrometric station from June 1 to September 10, 2016 and 2017.



3. METHODS

There are three distinct components to the methods sections: investigation of incubation conditions, investigation of spawning conditions, and investigation of other assessment methods.

3.1. <u>Incubation Conditions</u>

3.1.1. Fish Habitat, Calcite, and Hyporheic Conditions

This section describes the methods used to measure the stream habitat variables at each site, including calcite cover, substrate composition and hyporheic conditions (DO and flow) hypothesized to influence salmonid incubation success. The selected study sites occur across a gradient of pre-existing calcite levels (Table 1) and other naturally varying potential covariates such as substrate size and channel morphology. Measurements were taken in areas representative of spawning habitat during the late summer growing period, on August 25 to September 1, 2017. For consistency in field techniques and methods between years, one of the 2016 field crew members led the 2017 field work. All sites and measurements were photo documented; representative photos are presented in Appendix A.

Hyporheic conditions were measured at each of the study sites including DO (see Section 3.1.1.3) and hyporheic flow measured using hydraulic head (see Section 3.1.1.6). Similar to the 2016 study, hyporheic DO and hydraulic head were measured with piezometers; however, some of the techniques used to measure hyporheic conditions in the 2016 study were modified based on EMC review questions and comments. These modifications included use of new piezometers with a smaller screen size (10 cm), using an internal exclusion sheath with a better fit within the piezometer to limit sediment build-up during installation, purging water within the piezometer prior to measuring hydraulic head and DO at each depth, and installing a shallow stilling well over the piezometer when taking hydraulic head measurements.

Within each mesohabitat, piezometers were installed at three locations across the stream at approximately ¼, ½, and ¾ of the wetted width. Piezometers were custom made to be robust, reusable, and maintain tight contact between the bed material and the piezometer. The body of the piezometer was made of 1" S40 stainless steel with an inner diameter of 26 mm. A stainless steel drive point tip was welded to the bottom of the body and a manual slide hammer was permanently attached to aid installation. The screen length of the piezometer used in 2016 was 14 cm, whereas the modified piezometer screen length was 10 cm. A ¾ inch PVC pipe fitted with a drive point was inserted into the piezometer during installation to prevent suspended sediment and small substrate from entering the screen. A smaller diameter wood doweling was used in 2016.

The piezometers were driven vertically into the streambed substrate to the desired depth and purged with a peristaltic pump at low flow rates. An equivalent of three piezometer volumes was pumped. The piezometers were left to equilibrate for a minimum of 15 minutes until the water level had stabilized[3]. Water samples were collected from the piezometer to test for a suite of dissolved metals and total metals, major ions, and nutrients using the peristaltic pump and autoclavable silicon tubing (collection methods are provided in Section 3.1.1.4). Once the water quality samples were collected, the piezometers were left to equilibrate. The water quality probes and water level tape were then lowered into the standpipe piezometer to take measurements of DO, specific conductivity, pH, water temperature, and hydraulic head. Once the measurements were recorded, the probes/tape were removed and the piezometer was driven deeper or moved to another location within the same study site and allowed to equilibrate prior to completing another set of water quality sampling, and hydraulic head and DO measurements.

To validate the techniques employed in 2016, the DO and hydraulic head measurements were repeated at the two Greenhills Creek sites using the unmodified (2016) and modified (2017) techniques. Measurements using the unmodified and modified approach were made at 30 cm and 50 cm depths, at six locations within each study site (three locations for each approach). The

[3] The equilibration time was determined by undertaking measurements every 5 minutes for 30 minutes (more time was not required) at three sites, taking care to test equilibrium times at sites with different substrate conditions. Trends in water level, DO, and temperature were assessed over this duration and were used to confirm that sufficient equilibration time was allowed before each measurement during the study.

unmodified piezometers were installed at a distance of 0.5 – 1 m from the modified piezometers, and in similar substrate.

3.1.1.1. Fish Habitat Assessment and Fish Observations

A Level 1 Fish Habitat Assessment Procedure (FHAP), as described by Johnston and Slaney (1996), was used to quantify fish habitat in the lower reaches of Greenhills and Henretta creeks in 2017. FHAP was completed within the lower reach of Greenhills Creek from the Fording River confluence, upstream to the Fording Road crossing. On Henretta Creek, FHAP was completed from the Fording River confluence through to the upstream extent of HEN-CA01, and from the downstream extent of HEN-CA02 to the concrete weir structure and pool. FHAP was completed in LCO Dry Creek in 2016 (Buchanan *et al.* 2016).

Habitat unit types were classified according to definitions in Johnston and Slaney (1996). Table 2 lists the physical parameters surveyed along with the units of measurement and the equipment used. Parameters were measured rather than estimated wherever possible. Estimates were made for dominant and subdominant bed materials, and percent cover.

Habitat units were classified as pools, glides, runs, riffles and cascades. Johnston and Slaney (1996) recommend using only pools, glide, riffle, cascade and "other"; however, we added "run" to better define the habitat units. Units were additionally classified by location within the stream as primary, secondary, and tertiary. Primary habitat units occupy more than 50% of the wetted width of the main channel. Secondary units occupy secondary channels, and tertiary units are embedded within primary units but meet the minimum size criteria (Table 3).

For each habitat unit type, the average wetted and bankfull areas, widths, depths, and gradients were determined by averaging data from individual units within a given reach. Photographs of each habitat unit were taken.

Substrate was classified according to a modified Wentworth scale into the following categories: fines (<2 mm), gravel (2 to 64 mm), cobble (64 to 256 mm), boulder (256 to 4,000 mm) and bedrock (>4,000 mm) (Lewis *et al.* 2004). The dominant and subdominant substrate type within each habitat unit was estimated based on coverage area. Dominant and subdominant substrate types within a reach were then determined from the percentage of habitat units in which a particular substrate type was either dominant or subdominant (further described in Section 3.1.1.2).

Observations of fish, redds, and egg presence were recorded during the field work. Additional details that were recorded include approximate age class of the fish (i.e., fry, parr, adult), quality of spawning habitat, and wettedness of redds.

Table 2. Physical parameters, units of measure and equipment used during FHAP.

Parameter	Unit	Measured or Estimated	Equipment Used
Banfull Width	m	Measured	Meter Tape or Rangefinder
Bed Material Tyipe	n/a	Visual Estimate	Visual
Cover Proportions	n/a	Visual Estimate	Visual
Cover Types	n/a	Visual Estimate	Visual
Gradient	%	Measured	Clinometer
Habitat Unit Length	m	Measured	Meter Tape or Rangefinder
Maximum Pool Depth	m	Measured	Meter Stick
Wetted Depth	m	Measured	Meter Stick
Wetted Width	m	Measured	Meter Tape or Rangefinder

Table 3. Minimum size criteria for tertiary habitat unit types.

Bankfull Channel Width (m)	Minimum Area (m^2)	Minimum Residual Depth (m)
0 - 2.5	1.0	0.20
2.5 - 5	2.0	0.40
5 - 10	4.0	0.50
10 - 15	6.0	0.60
15 - 20	8.0	0.70
> 20	10.0	0.80

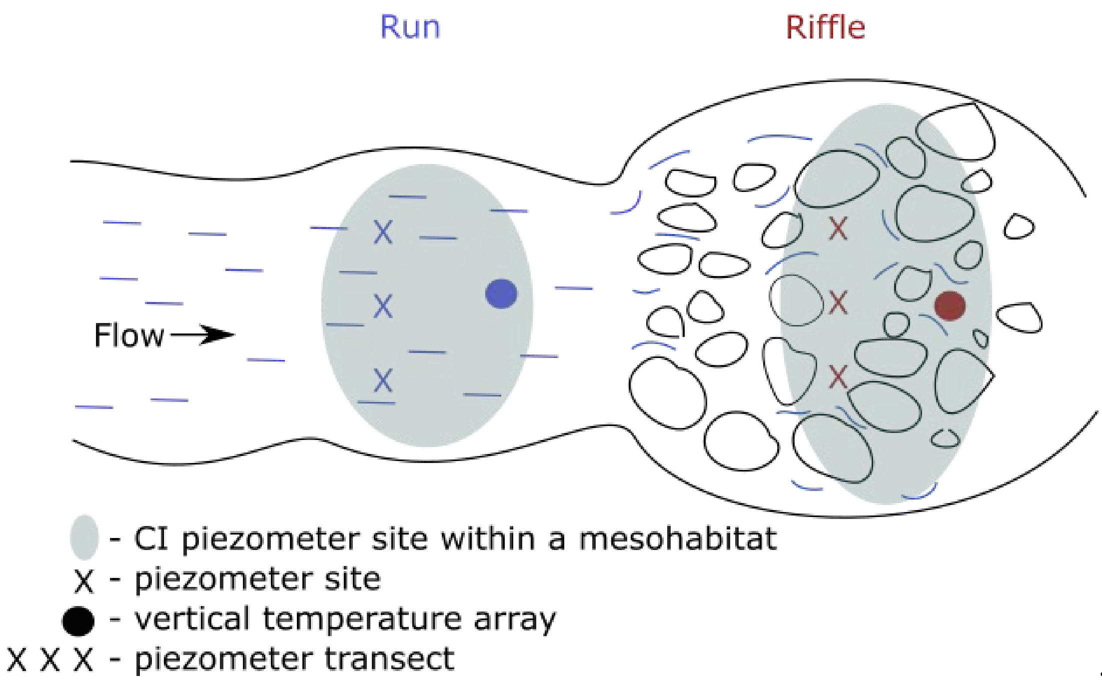
3.1.1.2. Calcite Index Measures and Substrate Composition

CI was measured at the mesohabitat unit scale and again at a smaller spatial scale within the mesohabitat corresponding to the primary location of hyporheic conditions data collected for this study. CI measurement methods followed the practices and procedures used by Teck in their Calcite Monitoring Program (Robinson and MacDonald 2014, Minnow Environmental 2016, Robinson *et al.* 2016). Prior to field work, the crew received training in determining calcite presence/absence and CI procedures from Kevin Atherton, Teck's Superintendent of Calcite Management. The procedures employed in this study are described below.

To maintain consistency with Teck's Calcite Monitoring program, calcite data were collected at a mesohabitat scale. At each mesohabitat unit, the observer systematically moved over the unit, stopping every one, two or three steps to randomly select a pebble ≥ 2 mm in diameter (i.e., gravel or larger) along a stream section of variable length (20 to 100 m). If the substrate selected was < 2 mm in diameter, this was noted and another pebble was chosen for a total count of 100 pebbles.

Within each mesohabitat unit, three piezometers were installed along a transect to collect hyporheic water quality data (dissolved oxygen, water temperature, pH and specific conductivity) and flow data (Figure 5; see Section 3.1.1.3 and 3.1.1.5). The area immediately surrounding the piezometers, referred to hereafter as the CI piezometer site, was sampled for calcite to obtain information at a spatial scale reflecting individual piezometer locations and a scale more representative of individual Westslope Cutthroat Trout redds than the entire mesohabitat unit. This information was also used to describe within-mesohabitat variability in calcite and substrate conditions. The area of a CI piezometer site varied depending on site conditions, but was on average ~8.5 m^2 at Greenhills Creek, 11.5 m^2 at LCO Dry Creek, and 37.8 m^2 at Henretta Creek sites. The average area is based on the channel width measured at the piezometer transects and the ~3 m length of the river that was sampled for CI.

Figure 5. A CI piezometer site consisted of three piezometer sites located in a transect within a mesohabitat (e.g., run or riffle).



A total of 100 pebbles were sampled for each CI measurement and the following information was recorded for each pebble:

- The concretion score: if the pebble was removed with negligible resistance (not concreted, score = 0), notable resistance but removable (partially concreted, score = 1), or immovable (fully concreted, score = 2);
- Absence or presence of calcite (score = 0 or 1 respectively); and

- The b-axis length of the pebble, to the nearest mm. Pebbles less than 5 mm (b-axis) were recorded as fines for the purpose of CI calculations.

Additional substrate classification was recorded for fines and sand (<2 mm) (Table 4) and the FHAP unit type (riffle, run, cascade, pool, glide) was also recorded and mapped.

To sample the CI piezometer sites, an additional 100 pebbles were evaluated. This approach was designed to be consistent with the approach used in Minnow Environmental (2016). The data recorded from pebbles that were located in both the mesohabitat and the piezometer site were used for both CI calculations. For example, if 40 pebbles overlapped the two sites an additional 60 pebbles were evaluated in the piezometer site and an additional 60 in the mesohabitat.

The results for each area were then expressed as a CI score using the following equation:

$$CI = CP + CC$$

where,

$CI = Calcite\ Index$

$$CP = \text{Calcite Presence Score } = \frac{\text{Number of pebbles with calcite}}{\text{Number of pebbles counted}}$$

$$CC = \text{Calcite Concretion Score } = \frac{\text{Sum of pebble concretion scores}}{\text{Number of pebbles counted}}$$

Table 4. Substrate classification scheme.

Substrate Type	Substrate Category	Size Range (mm)
Fines and Sand	Clay	<0.0039
	Silt	0.0039-0.0625
	Sand	0.0625-2
Gravel	Small Gravels	2-16
	Large Gravels	16-64
Cobble	Small Cobble	64-128
	Large Cobble	128-256
Boulders	-	256-4000
Bedrock	-	>4000

Calcite presence at depth and vertical substrate characteristics were measured at each site to a depth of approximately 40 cm. The percent composition of different substrate class sizes and the vertical extent (depth) of calcite presence was recorded at four depth intervals (approximately 0-7 cm, 10-15 cm, 30-35 cm and 38-40 cm). Calcite was recorded as present based on a single occurrence of calcite on a rock at each depth interval. The vertical extent of calcite presence within the substrate is not an indication of calcite concretion with depth.

Substrate measurements were grouped according to the Wentworth Scale (Table 4). The distribution of substrate size or grain size distribution (GSD) was reported as: (a) a cumulative percentage of grain size (mm) and (b) the number of grains in increasing size categories (mm). Particles <2 mm were assigned a value of 1 mm for the sake of plotting and representative grain size calculation.

3.1.1.3. Hyporheic Dissolved Oxygen Concentration and in situ Water Quality

DO, water temperature, pH and electrical conductivity were measured in situ at approximately 0 cm (substrate surface), 30 cm, and 50 cm substrate depths at each piezometer site (Figure 5) in Greenhills Creek (Map 2), LCO Dry Creek (Map 3), and Henretta Creek (Map 4). Site locations and sampling parameters are provided in Table 5 and Table 6. Two methods were used to obtain water quality samples at depth in the substrate (30 cm and 50 cm) in 2017: an unmodified method originally used in 2016 and repeated in 2017 at the Greenhills Creek sites only (Wright *et al*. 2017) and a modified method adapted from the 2016 method (see Section 3.1.1 for description of the methodology) used at all the sampling sites. In situ meters were left in the piezometer until a steady reading was obtained; readings were recorded in triplicate.

Table 5. Study site locations and water quality sampling dates for 2017.

Watercourse	Site	In situ Sampling Date	Lab Sample Collection Date[1]
Greenhills Creek	GRE-CA01	27-Aug	28-Aug
	GRE-CA03	28-Aug	28-Aug
Dry Creek	LCDRY-CA01	29-Aug	29-Aug
	LCDRY-CA02	31-Aug	31-Aug
Henretta Creek	HEN-CA01	30-Aug	30-Aug
	HEN-CA02	01-Sep	30-Aug

[1] Sampling performed by Ecofish and then samples were delivered to Teck immediately following sample collection.

Table 6. In situ water quality sampling parameters and meters.

Parameter	Units	Meter
pH	pH units	YSI Pro Plus
Specific Conductivity	µS/cm	YSI Pro Plus
Water Temperature	°C	YSI ProODO (Optical Dissolved Oxygen), YSI Pro Plus
Air Temperature	°C	Alcohol thermometer
Dissolved Oxygen	mg/L	YSI ProODO (Optical Dissolved Oxygen)
Dissolved Oxygen	% saturation	YSI ProODO (Optical Dissolved Oxygen)

QA/QC and Data Analysis

Water quality meters were maintained and calibrated and water quality sampling procedures followed the guidelines of the British Columbia Field Sampling Manual, Part E Water and Wastewater Sampling (Clark 2013).

All field data were entered into Ecofish's proprietary data management platform, EcoDAT. This data management platform has built-in rigorous QA/QC protocols. Hardcopy data from field forms were transcribed into EcoDAT and entries were visually compared by a second person to check for data entry errors.

Water quality summary statistics (average, minimum, maximum and standard deviation) were calculated for each sampling site and each sampling depth based on the results recorded at the three piezometer sites (n=3). Actual depths were noted for those cases where the measurement depth varied within the three sites.

Summary statistics for dissolved oxygen (% saturation and mg/L), water temperature (°C), pH and specific conductivity (µS/cm) were generated for each site at each measured depth. In most cases, the average was calculated from three single measurements (n=3) taken at three distinct piezometer sites within a mesohabitat unit (i.e., at river right, mid-channel and at river left).

DO is likely to decrease with increasing depth in the streambed assuming reduced gas exchange with the surface water or infiltration of groundwater, which is typically lower in DO in comparison to surface water (MOE 1997b). Where an unusual trend was observed or if the trends between sites were markedly different, the data were depicted graphically to facilitate interpretation.

Data were compared to typical ranges in BC watercourses (Table 7) and the applicable approved BC WQG (MOE 2018) for DO (Table 8). The instantaneous minimum BC WQG for the protection of buried embryo/alevin life stages for DO is 6 mg/L. Water temperature data were also compared to the provincial optimum water temperature ranges for Westslope Cutthroat Trout incubation period of 9.9-12.0 °C (Oliver and Fidler 2001, MOE 2018).

Table 7. Typical range of specific conductivity, pH and dissolved oxygen in BC watercourses.

Parameter	Unit	Typical Range in BC	Reference
Specific Conductivity	µS/cm	The typical value in coastal British Columbia streams is 100 µS/cm, while interior streams range up to 500	RISC (1998)
pH	pH units	Natural fresh waters have a pH range from 4 to 10, and lakes tend to have a pH ≥ 7.0.	RISC (1998)
Dissolved Oxygen	mg/L	In BC surface waters are generally well aerated and have DO concentrations greater than 10 mg/L	MOE (1997a)
Dissolved Oxygen	% saturation	In BC surface waters are generally well aerated and have DO concentrations close to equilibrium with the atmosphere (i.e., close to 100% saturation)	MOE (1997a)

Table 8. BC Water Quality Guidelines for the Protection of Aquatic Life for dissolved oxygen (mg/L).

BC Guidelines for the Protection of Aquatic Life[1]			
	Life Stages Other Than Buried	**Buried Embryo/Alevin[2]**	**Buried Embryo/Alevin[2]**
Dissolved Oxygen Concentration	Water column mg/L O_2	Water column mg/L O_2	Interstitial Water mg/L O_2
Instantaneous minimum[3]	5	9	6
30-day mean[4]	8	11	8

[1] MOE (1997a) and MOE (1997b)

[2] For the buried embryo / alevin life stages these are in-stream concentrations from spawning to the point of yolk sac absorption or 30 days post-hatch for fish; the water column concentrations recommended to achieve interstitial dissolved oxygen values when the latter are unavailable. Interstitial oxygen measurements would supersede water column measurements in comparing to criteria.

[3] The instantaneous minimum level is to be maintained at all times.

[4] The mean is based on at least five approximately evenly spaced samples. If a diurnal cycle exists in the water body, measurements should be taken when oxygen levels are lowest (usually early morning).

3.1.1.4. Hyporheic Water Quality: Laboratory Analysis

In addition to in situ sampling, water quality samples were collected for laboratory analysis at the surface and each sampling depth (Table 5). Methods followed procedures outlined in Clark (2013). Surface and hyporheic water samples were obtained by pumping water from the piezometers using a peristaltic pump (Water Spectra Field Pro) with autoclavable silicon tubing. The tubing was changed for each replicate within a study site.

The parameters measured in the laboratory were established as per Permit 107517. Physical parameters, anions and nutrient parameters, units and ALS Environmental (ALS) minimum detection limits (MDL) are provided in Table 9. Total and dissolved metals (including mercury) were also analysed; the MDLs varied for each parameter and are provided in ALS laboratory reports. Samples were collected in 1 L plastic or amber glass bottles as required; sample containers and preservatives were provided by ALS (Calgary). Samples were packaged in clean coolers filled with ice packs, then brought to a Teck representative, who couriered the samples to ALS in Calgary within 24 hours of collection. Standard Chain of Custody procedure was developed between Ecofish and Teck, and was strictly adhered to.

Table 9. Water quality physical, anion and nutrient parameters with units and ALS minimum detection limits (MDL).

Parameter Name	Parameter Unit	Parameter MDL
Physical Tests		
Sp. Conductivity (lab)	µS/cm	2
Alkalinity, Total (as CaCO3)	mg/L	1
Hardness (as CaCO3)	mg/L	0.5
Total Dissolved Solids	mg/L	10 to 20
Total Suspended Solids	mg/L	1
Turbidity (lab)	NTU	0.1
pH (lab)	pH units	0.1
Dissolved Organic Carbon	mg/L	0.5
Total Organic Carbon	mg/L	0.5
Anions and Nutrients		
Ammonia, Total (as N)	mg/L	0.005
Bicarbonate	mg/L	1
Bromide (Br)	mg/L	0.05 to 0.25
Carbonate	mg/L	1
Chloride (Cl)	mg/L	0.5 to 2.5
Dissolved Orthophosphate (as P)	mg/L	0.001
Fluoride (F)	mg/L	0.02 to 0.1
Hydroxide	mg/L	1
Nitrate (as N)	mg/L	0.005 to 0 0.025
Nitrite (as N)	mg/L	0.001 to 0.005
Sulfate (SO4)	mg/L	0.3 to 1.5
Total Kjeldahl Nitrogen	mg/L	0.05 to 0.25
Total Phosphorus (P)	mg/L	0.001 to 0.002

ALS MDL varied for a number of parameters due to sample matrix effects.

QA/QC and Data Analysis

Quality assurance and quality control (QA/QC) followed the procedures provided in the BC Field Sampling Manual, Part E (Clark 2013) and required by Permit 107517. A duplicate QA/QC sample was collected at HEN-CA01 on August 30, 2017. A field blank and a trip blank were collected at HEN-CA02 on September 1, 2017. QA/QC samples for the full suite of parameters represented 14% of the total sampling effort (3 of 21 samples). In addition, field blanks for total mercury analysis were collected at each site/sampling date.

ALS maintains a Quality Management System that adheres to the requirements of the ISO:IEC 17025:2005 standards. ALS laboratory QC procedures included replicate analysis of a subset of samples, analysis of standard reference materials, and method blanks. Filtering and preservation were completed at ALS labs.

Parameters were screened against the applicable approved BC Water Quality Guidelines (BC WQG) (MOE 2018) or Working BC WQG (MOE 2017) for the protection of aquatic life. ALS hold time exceedances, field blank results (detections and non-detections) and ALS QA/QC were reviewed and summarized.

Parameters were also screened against Level 1 (~10% effect) and Level 2 (~20% effect) selenium, nitrate, and sulphate water quality Elk Valley Water Quality Plan (EVWQP) benchmarks applicable to the upper Fording River (Teck 2014). The selenium benchmark for juvenile fish growth is not applicable to the upper Fording River, because studies with juvenile WCT have reported no effects at the Level 1 benchmark (Teck 2014). The Level 1 selenium water-quality benchmark applicable to the upper Fording River is 0.07 mg/L, which is based on reproductive effects on WCT. The EVWQP benchmark for juvenile fish growth is not applicable to the upper Fording River, because studies with juvenile WCT have reported no effects at the Level 1 benchmark (>0.046 mg/L; Level 2 benchmark >0.466 mg/L). The hardness-dependent Level 1 and Level 2 benchmarks for fish in the Fording River are 16 and 21 mg/L of NO_3-N, respectively, at 360 mg/L as $CaCO_3$. The site-specific results indicate that rainbow trout sensitivity to sulphate does not increase at hardness >250 mg/L as $CaCO^3$ within the Elk and Fording rivers. Consequently, the sulphate benchmark for hardness conditions >250 mg/L as $CaCO_3$ is set to 429 mg/L, which is equal to the B.C. WQG for hardness conditions.

Detailed analyses of the laboratory water quality results were beyond the scope of this study, but a brief review of notable trends or comparisons to the applicable BC WQGs is provided. Laboratory water quality results for pH and specific conductivity among depths and sites were compared to the in situ results to determine differences between surface and hyporheic water quality specifically for these parameters. The remaining water quality parameters were summarized for each site in data tables.

3.1.1.5. Surface Hydrology

A number of physical factors in addition to calcite are likely to influence hyporheic conditions, and measurements were taken to allow assessment of these as covariates during analysis. Water depth and water velocity were measured at each piezometer site on the day at which hyporheic conditions were measured. Water depth was measured as surface level to streambed using a meter stick. Water velocity was measured at the piezometer as the average water column velocity using a Swoffer meter, following RISC (2009) standards.

Discharge measurements were collected to determine the flow on the day at which hyporheic conditions were measured. The flow at each transect was assumed to be representative of all sites within each target stream or reach. A temporary staff gauge was installed at the discharge transect sites to determine the change in stage between measurement days. If stage change was greater than 3 mm, a second discharge measurement was collected.

Discharge measurements were collected once on lower Greenhills Creek, as measurements at the two study sites were made over two consecutive days with little (1 mm) change in stage between the days. These measurements were collected at the same transect location used in 2016. Teck has a hydrometric gauge (LC-DC1) on LCO Dry Creek, located immediately upstream of a railway crossing, just downstream from one of the study sites. These data were used for LCDRY-CA02. Due to the distance between the two LCO Dry Creek study sites, and the potential for inflows between them, discharge measurements were collected downstream of the hydrometric gauge near LCDRY-CA01. Discharge measurements were collected twice during the study period (once at the start of the study and again at the end) at Henretta Creek. The transect locations were recorded so that flow measurements could be made at the same locations in future years.

For the flow measurements, velocities at a transect were measured with a standard USGS magnetic head Pygmy current meter and water depths were taken with a 1.4 m top-set wading rod. The midsection method (a velocity-area method; RISC 2009, Rantz *et al.* 1982) was used to estimate discharge at each transect.

3.1.1.6. Hyporheic Flow

Hyporheic flow was measured using the hydraulic head method at each piezometer site. The vertical head gradient (VHG) was calculated as the water level inside the piezometer minus water level outside the piezometer (recorded in m below the top of the piezometer), divided by the distance between the streambed and the midpoint of the piezometer perforations or screen. The VHG was used to estimate the extent of upwelling from or downwelling to the streambed at a site. Positive vertical hydraulic head indicates downwelling flow, whereas negative vertical hydraulic head indicates upwelling flow. Flow direction was defined in this way to be consistent with the 2016 calcite study.

Water surface elevations were measured using an electronic interface measuring tape (Solinst; 1 mm accuracy). To reduce the water level fluctuations on the outside of the piezometer, a stilling well was placed over the piezometer before measuring water surface elevation. Water level measurements were repeated a minimum of three times at each piezometer depth and location (e.g., river right, mid-channel and river left), until consecutive measurements were the same, to allow sufficient equilibrium time (i.e., water levels inside and outside of the piezometers remained consistent and stable) and to reduce the potential for human error in reading the measuring tape.

The downwelling or upwelling rate from each site and date was calculated using VHG and Darcy's equation (Kalbus *et al.* 2006). Hydraulic conductivity (K) of each site was estimated based on grain size distributions (Koch *et al.* 2015). Hydraulic conductivity represents the ease with which a fluid can move through substrate, and is highly correlated to porosity. The calculated K values were also applied to each VHG measurement to assess the variation of groundwater exchange at different depths, and laterally across each transect.

K estimates were taken as the average of values obtained using the recommended method of Salarashayeri and Siosemarde (2012) and the empirical curves prepared by She *et al.* (2006). The estimates based on Salarashayeri and Siosemarde (2012) used a relationship dependent on GSD D10, D50, and D60 (i.e., the value of the grain diameter at 10%, 50%, and 60% in the cumulative GSD), and the estimates based on She *et al.* (2006) relied on visual estimation of fines content and fines composition. Porosity was also estimated based on grain size distribution for each site using the curves prepared by She *et al.* (2006), which provided estimates based on sand content and fines composition. The calculated K values were applied to each VHG measurement to assess the variation of groundwater exchange at different depths, and laterally across each transect.

3.1.2. Testing Impact Hypothesis H_01

3.1.2.1. Comparison of Sampling Method

As described in Section 3.1.1, the methodology used to sample hyporheic conditions was modified in 2017 based on EMC feedback. To determine if this modified methodology had an effect on the measurement of hyporheic conditions, mixed-effects modelling was used to compare data collected at sites GRE-CA01 and GRE-CA03 in 2017, where both sampling techniques (unmodified and modified) were applied. Separate models were tested for each of the dependent variables: dissolved oxygen concentration, and hyporheic flow from the hydraulic head method. Both models had sampling method as an independent categorical variable, and site as a random effect. The p-value corresponding to the sampling method variable was used to assess if the measurements of hyporheic conditions were significantly different between sampling methods.

3.1.2.2. Modelling of Hyporheic Conditions vs Calcite Index

Relationships between CI and hyporheic DO and flow were investigated using a model selection procedure and fitting a series of linear mixed-effects models using the “lme4” and “MuMIn” packages for R statistical software (Bates *et al.* 2015). Two separate models were fit, one for each key response variable: 1) dissolved oxygen concentration; and 2) hyporheic flow from the hydraulic head method. The predictor variables included in each model were habitat and sampling variables hypothesized to affect hyporheic conditions (CI, depth in substrate, water temperature, water depth, water velocity, substrate composition, sample year, and sample site). Predictor variables include fixed effects (variables that we are interested in and test directly [CI, depth in substrate, water temperature, water depth, water velocity, substrate composition, year]) and random effects (variables that we are less interested in but need to account for in the analysis [site]). To combine data from both 2016 and 2017 in a consistent manner, only data collected in August/September at depths of 0, 30, or 50 cm were used. Moreover, a single data point with a dissolved oxygen concentration of 0.37 mg/L and a CI score of 0 was considered a major outlier and removed to prevent model bias.

Model selection techniques were used to assess the relative importance of each predictor variable, including CI, in explaining hyporheic conditions (e.g., Zuur *et al.* 2009, Grueber *et al.* 2011). In the first step of the model selection procedure, data were explored to screen the variables to include in each model. Predictor variables that were highly correlated with one another were excluded due to multicollinearity. In addition, variables with a low number of observations (e.g., specific conductivity and pH) were also excluded. The following predictor variables were used in the analysis: site, year, CI score, depth in substrate, average substrate size, percent fines, flow, water temperature, water depth, and a CI score*depth in substrate interaction term. The CI score*depth interaction term was included as a predictor because it was hypothesized that the relationship between surface CI and hyporheic conditions would vary by depth of measurement in the substrate. All of the predictor variables were modelled as fixed effects, with the exception of site, which was modelled as a random effect. The predictor variables were all scaled by subtracting their respective means, and dividing by twice their respective standard deviations, to allow for direct comparisons of predictor effects at the same scale (see Grueber *et al.* 2011). When hyporheic flow was analyzed as the response variable, it was also scaled because the data included extremely low values and large outliers.

Once the initial 'global model' was determined, the second step of the model selection procedure involved an all-model-combinations model selection approach where candidate models containing all possible combinations of each predictor variable were competed against one another to find the top models that best predict hyporheic conditions. To prevent overfitting, the candidate models were limited to a maximum of four predictors. For each candidate model, the goodness of fit was quantified using Akaike Information Criterion, corrected for small sample sizes (AICc), which balances model simplicity with variance explained. A subset of the candidate models was then retained based on the difference between each model's AICc value and the AICc of the best model (the ΔAICc). Only models with a ΔAICc of less than 4 were retained, a cut-off threshold used to prevent the inclusion of overly complex models (Grueber *et al.* 2011). The retained models within ΔAICc <4 were then model-averaged to obtain a final, weighted model. Model-averaged products for each response variable include the set of top models that explain hyporheic conditions, and the parameter estimates, confidence and relative variable importance associated with each predictor variable.

Westslope Cutthroat Trout may not spawn frequently in substrates with CI scores greater than some threshold. We tested the relationship between CI scores and hyporheic conditions using a subset of the data to explore whether trends were similar. We subsetted the data to only include sites with CI scores < 1.25, which was chosen to reflect conditions when WCT may have easier access to the substrate for spawning, based in part on preliminary observations described in Minnow Environmental (2016). . Further investigation into CI levels that prevents redd digging is ongoing. Using the subsetted data, models were generated using the same procedure as described above. This approach produced two modeling results for each predictor variable using: 1) all data (CI ≤ 3); and 2) subsetted data (CI < 1.25).

3.2. Spawning Conditions

During the 2017 field program, FHAP data, calcite cover and substrate composition data were collected and used to develop habitat maps of the study streams to support the investigation of spawning conditions.

Redd surveys were conducted in the lower reaches of LCO Dry Creek in June and early July 2017, as part of ongoing work and permit requirements associated with another program (Faulkner *et al.* 2018). During the present late summer field study (between August 29 and September 1, 2017), additional calcite cover and substrate composition data were collected in LCO Dry Creek at nine redd locations and at 11 locations where redds were not found in June and July 2017. Measurement methods followed those outlined in Section 3.1.1.2.

A qualitative assessment of spawning conditions on LCO Dry Creek under low flow conditions was conducted between August 29 and September 1, 2017. An experienced fisheries technician inspected sections of stream where redds had been observed during the June and July spawning surveys in 2017 (Faulkner *et al.* 2018). Data collected included the following:

- Mesohabitat type;
- Spawning habitat quality rating (poor, moderate, good);
- Presence of redds;
- Substrate compaction (low, med, high);
- Substrate embeddedness (low, med, high); and
- Comments on spawning habitat suitability.

The areas surveyed, their location upstream of the Fording River confluence, and respective FHAP unit numbers (Buchanan *et al.* 2016), are provided below:

- 574 to 793 m (FHAP units 44 to 55);
- 1,251 to 1,320 m (FHAP unit 80 to 81);
- 1,729 to 1,792 m (FHAP unit 101);
- 2,081 to 2,129 m (FHAP units 114 to 116);
- 3,341 to 3,387 m (FHAP units 238 to 240);
- 3,817 to 3,993 m (FHAP units 271 to 282); and
- 4,549 to 4,634 m (FHAP units 329 to 335).

Redds were also observed in the lower 200 m of LCO Dry Creek in 2017, although this section was not included in this assessment.

3.3. Other Assessment Methods

This study component investigated permitting requirements, restrictions for use, and methods of in situ incubation techniques to study egg-to-fry survival in the Elk Valley, and addressed the following questions:

1. Permitting. What permits are required, and who (agencies, personnel) are the primary contacts for permitting?
2. Source of eggs. What are the viable options for use of eggs from hatchery stock (e.g., is it permissible to use existing hatchery stock or would broodstock need to be collected)?
3. Location. Would it be permissible to outplant eggs from hatchery stock to the upper Fording River or elsewhere in the Elk Valley?
4. Methods. What are differences among the available methods for in situ incubation assessment of egg to fry survival? Assuming the available methods are permissible, what methods are the best candidates for consideration in the Elk Valley?
5. What are the challenges and considerations of using in situ egg incubation studies to assess potential calcite effects and to inform management decisions?

Permitting requirements were assessed through discussions with regulators primarily from the BC Ministry of Forest, Lands and Natural Resource Operations (FLNRO), as well as the Introductions and Transfers Committee (joint BC-DFO committee). Given incubation cassettes and other outplanting techniques involve hatchery-fertilized eggs, the logistics of acquiring and handling fertilized eggs were discussed with the Bull River Hatchery (Freshwater Fisheries Society of BC).

A brief review of the primary literature was conducted to assess the technique(s) for conducting experimental trials of incubation success, assuming outplanting is permitted. The review also considered other approaches that may be used to assess egg-to-fry survival and additional considerations for such a study. The approaches considered in this report, and provided in Appendix H are as follows:

1. Outplanting of Westslope Cutthroat Trout eyed eggs in test incubators from Bull River Hatchery (using incubation capsules, cassettes or pipe incubators);
2. Emergence traps installed at wild redds (a method that can provide a survival rate based on an estimate of potential egg deposition to fry emergence); and
3. Hydraulic sampling of wild redds (a method that can provide a survival rate based on an estimate of potential egg deposition to the time of sampling, or pre-emergence).

An additional review of the primary literature was conducted to compile information on Westslope Cutthroat Trout spawning habitat selection, with a specific focus on spawning site hydraulics. Literature was identified using searches in Google Scholar. Due to a relative dearth of information on Westslope Cutthroat Trout specifically, the search was expanded to include literature related to the spawning hydraulics of spring spawning salmonids.

4. RESULTS

4.1. Incubation Conditions

4.1.1. Fish Habitat, Calcite Index, and Hyporheic Conditions

4.1.1.1. Fish Habitat Assessment and Fish Observations

Results of the FHAP surveys for 2017 are shown on Map 2 and Map 4 and summarized in Table 10. The raw data and photographs for individual units are provided in Appendix B. A total of 47 mesohabitat units were assessed in Greenhills Creek, and seven mesohabitat units were assessed adjacent to the two calcite index sites within Henretta Creek (HEN-CA01 and HEN-CA02). As discussed in the methods, FHAP in LCO Dry Creek was completed in 2016 (Buchanan *et al.* 2016); the results are shown on Map 3.

The Greenhills Creek 2017 study sites (GRE-CA01 and GRE-CA03) were located in riffle habitat units that were 8.5 and 51.8 m long, with gradients of 2.0 to 4.0 % (Table 10). The wetted widths were 1.6 and 2.4 m, and the average water depths were 0.07 and 0.14 m.

The LCO Dry Creek study sites were also located in riffle habitat units (Table 10). The lengths of the units were 44.0 m and 63.0 m, with gradients of 2.0 to 3.5 %. The wetted widths, as measured under higher flow conditions in June 2016, were 5.0 and 6.5 m, and the average water depths were 0.25 and 0.41 m.

In Henretta Creek, one calcite study site was located in a 19.2 m long glide, and one was located in a 66.0 m long riffle (Table 10). The gradient in the glide was 1.0 %, with a wetted width of 11.0 m and mean depth of 0.22 m. The gradient in the riffle unit was 1.5 %, with a wetted width of 20.1 m and mean depth of 0.18 m.

Streambed composition varied within and among the three study streams, with a higher prevalence of smaller substrates in the low gradient sections. Fines and gravel were the dominant substrate type in the lower gradient sections of Greenhills Creek, downstream of GRE-CA03. In the upper sections from GRE-CA03 to the Fording Road crossing, gravels and cobbles were dominant. Calcite study sites within Greenhills Creek generally contained less fines than nearby habitat units, and were mainly comprised of cobble and gravel. In LCO Dry Creek, substrate in the upper calcite study site (LCDRY-CA02) was predominantly cobble and boulder, compared to gravel and cobble in the lower study site (LCRDRY-CA01). In Henretta Creek, cobble was the dominant substrate type throughout most of the FHAP survey sections. The upstream study site (HEN-CA02) had some large substrate and was classified as cobble dominant, boulder subdominant. Further downstream, near the Fording River confluence (HEN-CA01), the dominant and subdominant substrates types were cobble and gravel, respectively.

Stream cover available for fish was also assessed during the FHAP study (Table 10). Greenhills Creek study sites had stream cover for fish in the form of overhanging vegetation, small woody debris, and boulders. Stream cover in the LCO Dry Creek study sites, based on the 2016 FHAP (Buchanan *et al.* 2016), was comprised of overhanging vegetation and large woody debris. Henretta Creek had a more open channel, with less overhanging vegetation than the other streams. Boulders were the dominant cover type, followed by cobble and small woody debris.

During the field work, fish were observed in Greenhills Creek and LCO Dry Creek (Table 11). We were unable to visually identify the fish to species, without capturing them or observing underwater, but based on the known species distribution it was assumed that all fish and redds observed were Westslope Cutthroat Trout.

Trout were observed throughout the study reach in Greenhills Creek from <10 m upstream of the Fording River confluence, to the culvert outfall pool immediately downstream of the Fording Road bridge crossing. No obvious redds were observed in Greenhills Creek, although the observation of fry indicated that spawning most likely occurred in spring 2017. In LCO Dry Creek, one trout parr was observed during the field work, in the lower section downstream of the Fording Road bridge crossing. Redds were observed in three locations; FHAP unit 45 (580 m upstream of the Fording River), FHAP unit 238 (3,341 m upstream of the Fording River), and FHAP unit 282 (4 km upstream of the Fording River) (Buchanan *et al.* 2016). At the uppermost site (FHAP 282), the redds were partially dewatered, confirming that they had been formed during higher flows, perhaps in late spring or early summer. No fish or redds were observed in Henretta Creek, although moderate quality spawning habitat was noted at HEN-CA01.

Table 10. Summary of FHAP results at each calcite study site.

Site	Date	Type	Unit Length (m)	Width (m)		Area (m^2)		Average Water Depth (m)	Gradient (%)	Weighted Gradient (%)	Substrate[1]		Dominant Cover[2]		Sub-dominant Cover[2]	
				Wetted Width	Bankfull Width	Wetted Area	Bankfull Area				Dominant	Sub-dominant	Type	%	Type	%
GRE-CA01	26-Aug-17	Riffle	8.5	2.4	4.3	20	37	0.07	2.0	17.0	GR	CO	OV	30	SWD	5
GRE-CA03	26-Aug-17	Riffle	51.8	1.6	3.6	83	186	0.14	4.0	207.2	CO	GR	BO	15	SWD	10
LCDRY-CA01[3]	07-Jun-16	Riffle	44.0	5.0	4.0	176	220	0.25	3.5	154	GR	CO	OV	30	LWD	15
LCDRY-CA02[3]	09-Jun-16	Riffle	63.0	6.5	4.0	252	410	0.41	2.0	126	CO	BO	OV	10	LWD	5
HEN-CA01	30-Aug-17	Glide	19.2	11.0	16.5	211	317	0.22	1.0	19.2	CO	GR	BO	20	SWD	3
HEN-CA02	01-Sep-17	Riffle	66.0	20.1	24.7	1327	1630	0.18	1.5	99.0	CO	BO	BO	20	LWD	5

[1] BO = Boulder, CO = Cobble, GR = Gravel, S/FI = Sand/Fines

[2] BO = Boulder, DP = Deep Pool, LWD = Large Woody Debris, LC = Large Cobble, CU = Undercut Bank, OV = Overhead Vegetation
Category - "Primary - occupy more than 50% of the wetted width of the main channel" at all sites.

[3] Data from Buchanan et al. 2016.

Table 11. Westslope Cutthroat Trout, redd, and spawning gravel observations recorded during the August/September 2017 field study.

Location	Date	Details
GRE-FHAP04	26-Aug-17	fry observed
GRE-FHAP05	26-Aug-17	fry observed
GRE-FHAP06	26-Aug-17	4 fry observed
GRE-FHAP12	26-Aug-17	2 small fish observed
GRE-FHAP14	26-Aug-17	small adult trout observed
GRE0FHAP17	26-Aug-17	multiple trout observed
GRE-FHAP30	26-Aug-17	parr and fry observed
GRE-FHAP35	26-Aug-17	trout observed
GRE-FHAP41	26-Aug-17	several small adult trout observed in pool below culvert
GRE-CA01	27-Aug-17	fry observed upstream of potential spawning habitat
LCDRY-FHAP54	29-Aug-17	trout parr observed
LCDRY-FHAP101	21-Aug-17	possible old redd
LCDRY-FHAP114/115	31-Aug-17	no obvious redds, but likely some historic spawning
LCDRY-FHAP238	31-Aug-17	two redds observed
LCDRY-FHAP271	31-Aug-17	redd observed
LCDRY-FHAP282	31-Aug-17	partially dewatered redds observed
HEN-CA01	30-Aug-17	moderate quality spawning gravel in glide

4.1.1.2. Calcite Measures and Substrate Composition

Calcite Index

Calcite levels varied spatially throughout the study area, as expected from previous studies (Minnow Environmental 2016, Robinson *et al.* 2016). The lowest CI was measured in LCO Dry Creek; both sites had a CI of 0.00. CI at Greenhills Creek was 0.98 (GRE-CA01) and 1.37 (GRE-CA03) at the mesohabitat scale (Figure 6), similar to CI measured at the same sites in late August 2016 (0.89 at GRE-CA01 and 1.38 at GRE-CA03) (Wright *et al.* 2017). CI at Henretta Creek was 0.49 (HEN-CA02) and 0.90 (HEN-CA01) at the mesohabitat scale (Figure 7). The maximum possible value for the CI is 3.00, which corresponds to calcite presence and a fully concreted (immovable) condition for all pebbles evaluated. Thus, the sites sampled in 2017 had relatively low CI (Table 12).

Relatively low variability in CI was observed within each site. The absolute difference between the mesohabitat and piezometer sites ranged from 0.00 to 0.35; half the sites had a difference of 0.00 (Table 12). The greatest variation in CI within a piezometer site was measured at HEN-CA02 (absolute difference of 0.35) (Table 12). The variability in CI observed within each site (0.12) is similar to that observed in 2016 (the majority of sites had CI differences of <0.10) (Wright *et al.* 2017).

The presence of calcite was also measured in relation to vertical depth within the substrate; presence ranged from surface only (LCDRY-CA02 and HEN-CA02) to a depth of 40 cm (Table 12). No calcite was found at LCDRY-CA01. Note that these data were meant to provide an indication of calcite depth and did not replicate the procedure used in generating the surface CI score. In general, the sites with higher CI values also exhibited greater depth of calcite presence (Table 12).

Figure 6. Summary of CI at Greenhills Creek sites, 2017. CI ranges from 0 to 3.

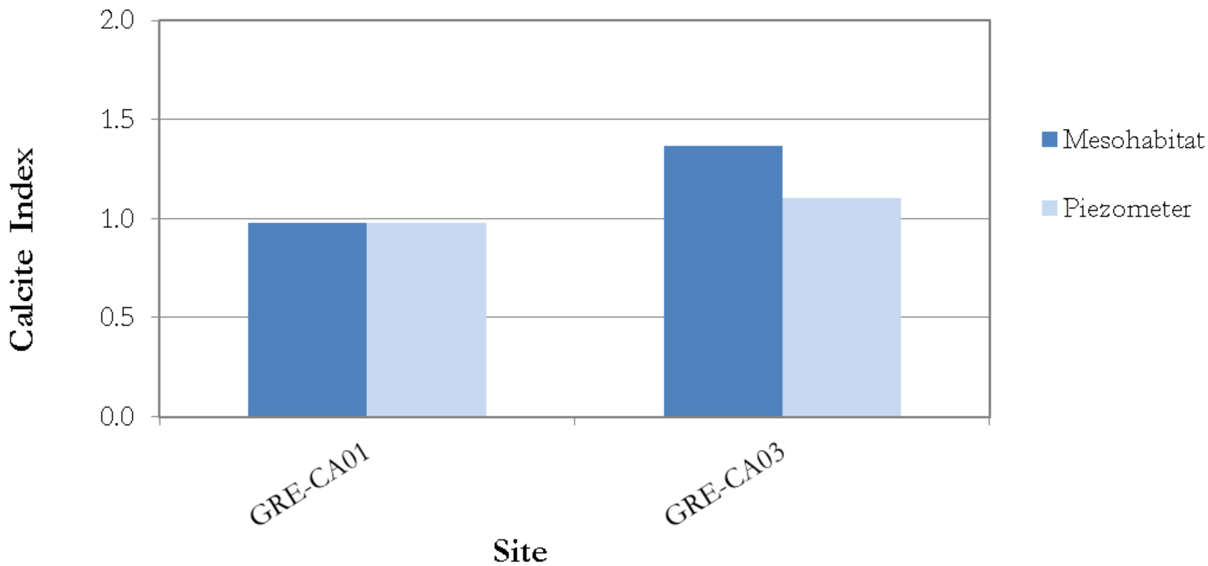


Figure 7. Summary of CI at Henretta Creek sites, 2017. CI ranges from 0 to 3.

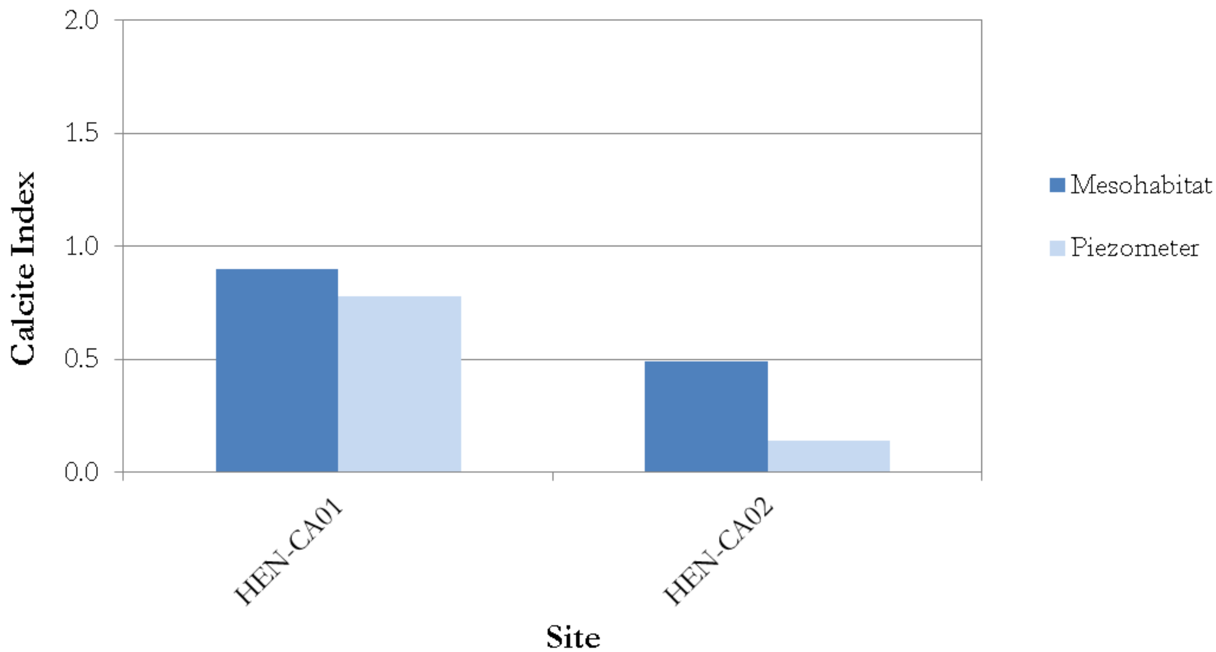


Table 12. Summary of CI and calcite depth at piezometer and mesohabitat sites, 2017.

Water Body	Site	CI Mesohabitat Site	CI Piezometer Site	Depth of Calcite Presence within the Substrate[1] (cm)
Greenhills Creek	GRE-CA01	0.98	0.98	40
	GRE-CA03	1.37	1.11	40
LCO Dry Creek	LCDRY-CA01	0.00	0.00	None
	LCDRY-CA02	0.00	0.00	0 (surface)
Henretta Creek	HEN-CA01	0.90	0.78	7
	HEN-CA02	0.49	0.14	0 (surface)

[1] Calcite present on one or more rocks at depth.

Substrate Composition

GSD was measured to provide an estimate of the porosity of each site (see Section 3.1.1.6). The cumulative particle size distribution (distribution curve) and the number of particles per size class (box plots) are provided in Figure 1 to Figure 12 for each site (mesohabitat and piezometer) in Appendix C.

The Greenhills Creek sites exhibited similar GSD between the piezometer sites and the D50 values estimates in August/September were 42 and 56 mm and 39 and 43 mm at the GRE-CA01 and GRE-CA03 mesohabitat and piezometer sites, respectively (Wright *et al.* 2017).

The LCO Dry Creek and Henretta Creek sites also exhibited similar GSD between the piezometer sites and mesohabitat sites at each of the calcite study locations (Table 13). Generally, the downstream study sites had a greater mean diameter than the more upstream sites. In LCO Dry Creek, the D50 estimates for the mesohabitat were 52 mm (LCDRY-CA01) and 74 mm (LCDRY-CA02), while in Henretta Creek, estimates were 58 mm (HEN-CA01) and 71 mm (HEN-CA02) (Table 13).

Table 13. Substrate size (mm) composition in the Greenhills Creek, Henretta Creek, and LCO Dry Creek measured in the mesohabitat (meso) and piezometer (piez) sites in August/September 2017.

Substrate Diameter (mm)	GRE-CA01		GRE-CA03		LCDRY-CA01		LCDRY-CA02		HEN-CA01		HEN-CA02	
	meso	piez	meso	piez	meso	piez	meso	piez	meso	piez	meso	piez
D10	20	23	15	22	30	26	36	27	29	23	37	30
D16	23	24	20	25	34	29	43	31	35	33	42	34
D40	33	31	33	37	45	40	66	52	51	45	64	50
D50	38	35	37	42	52	44	74	61	58	52	71	59
D60	42	39	41	48	60	49	81	73	64	58	78	68
D84	60	56	64	72	81	61	115	117	89	81	112	90
D90	67	67	76	81	87	64	128	138	114	88	135	111

D values represent the % grain diameter of a given size in the cumulative GSD
D50: median diameter by mass

4.1.1.3. Hyporheic Dissolved Oxygen Concentration and in situ Water Quality

Water quality summary statistics for dissolved oxygen (% saturation and mg/L), water temperature (°C), pH and specific conductivity (µS/cm) were generated for each site at the surface and each measured depth (data tables are found in Appendix E). Data obtained along each piezometer transect (Figure 5) were also summarized in figures with the applicable BC WQG guidelines for DO (Figure 8, Figure 9) and water temperature (Figure 10, Figure 11). The piezometer sampling method was modified in 2017 in comparison to the method used in 2016. In Greenhills Creek both methods were used during the 2017 sampling to assess the validity of the results collected in 2016. DO and water temperature data collected in August/September 2016 at these sites is included alongside the 2017 data to allow comparison of the results from both methods (Figure 8 to Figure 11). A statistical comparison of the results was also conducted, and the results are summarized in Section 4.1.2.1.

Dissolved Oxygen

In Greenhills Creek, the concentration of DO generally decreased from the surface to 50 cm below the surface (Figure 8). At GRE-CA01 and GRE-CA03 dissolved oxygen ranged from 5.2 mg/L (at GRE-CA03 50 cm depth) to 8.6 mg/L (at GRE-CA03 surface water). The concentration of DO fell below the instantaneous minimum BC WQG (6 mg/L) at one piezometer location at GRE-CA03 (Figure 8, Table 8). Overall DO concentrations fluctuated around the 30-day guideline (8 mg/L) suggesting that if these concentrations were experienced over the long-term, adverse effects to buried life stages may occur (Table 8, BC MOE 2017). To apply the long-term guidelines, samples are typically collected weekly over a 30-day period.

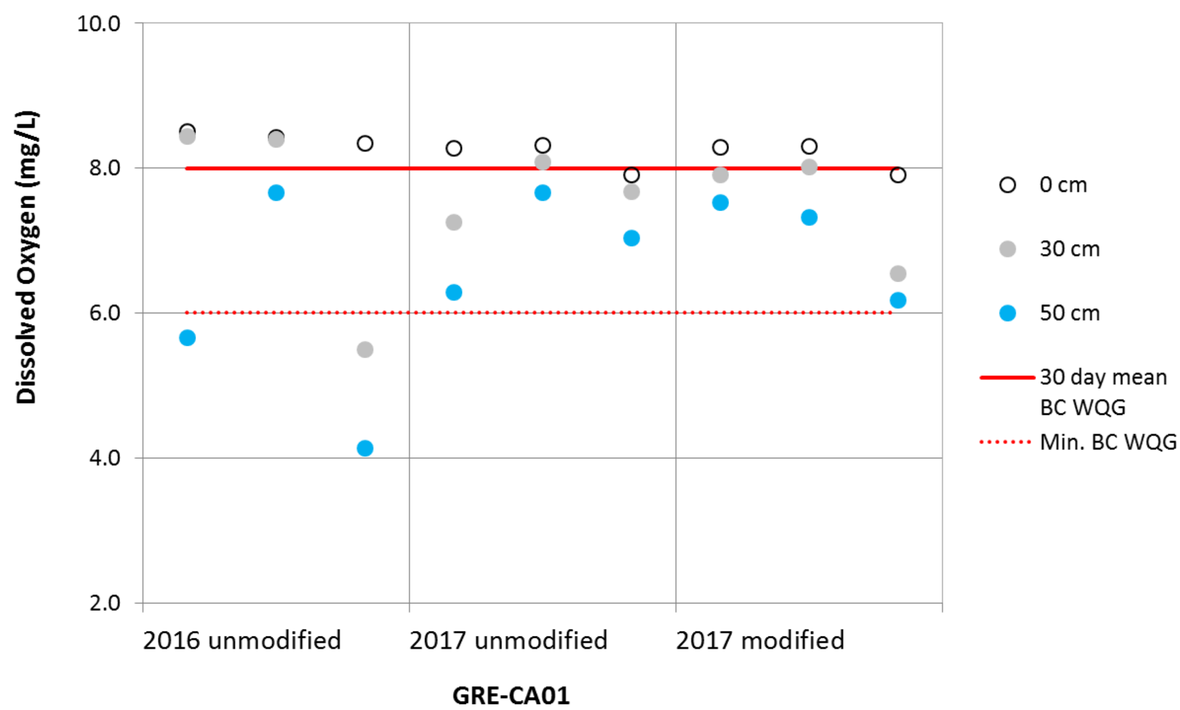
In 2017, the water quality results collected from the unmodified methodology and the new modified methodology in Greenhills Creek were similar (Figure 8). The 2017 water quality results were also similar to the 2016 results at the Greenhills Creek study sites, considering inter-annual variations in water temperature and hydrology, as well as diurnal fluctuations of DO (Figure 8).

LCO Dry Creek sites exhibited higher DO concentration overall (DO ranged from 7.5 to 10.8 mg/L) in comparison to Greenhills Creek sites. DO concentration changed negligibly with depth at LC-DRY CA02 (Figure 9, Appendix E). DO concentrations were all above the instantaneous minimum BC WQG (6 mg/L) and only below the 30-day minimum (8 mg/L) on one occasion at LCDRY-CA01 (Figure 9).

Henretta Creek sites also exhibited higher DO concentrations overall in comparison to Greenhills Creek sites. DO concentration changed negligibly with depth at HEN-CA01 and HEN-CA02, with the exception of one piezometer location at HEN-CA02 where readings at depth were less than the instantaneous minimum BC WQG (6 mg/L) (Figure 9). Data were typically well above the long-term 30-day guidelines (8 mg/L).

Overall variability in DO data between piezometer sites along the transect (Figure 5) were observed at each sampling site, with outer/edge sites generally exhibiting greater decrease in DO at depth.

Figure 8. Dissolved oxygen measured at surface and at depth in Greenhills Creek using the unmodified approach (September 2016 and August 2017) and modified approach (August 2017) at GRE-CA01 and GRE-CA03. Dissolved oxygen 30-day mean and minimum BC WQG are provided (MOE 2017).



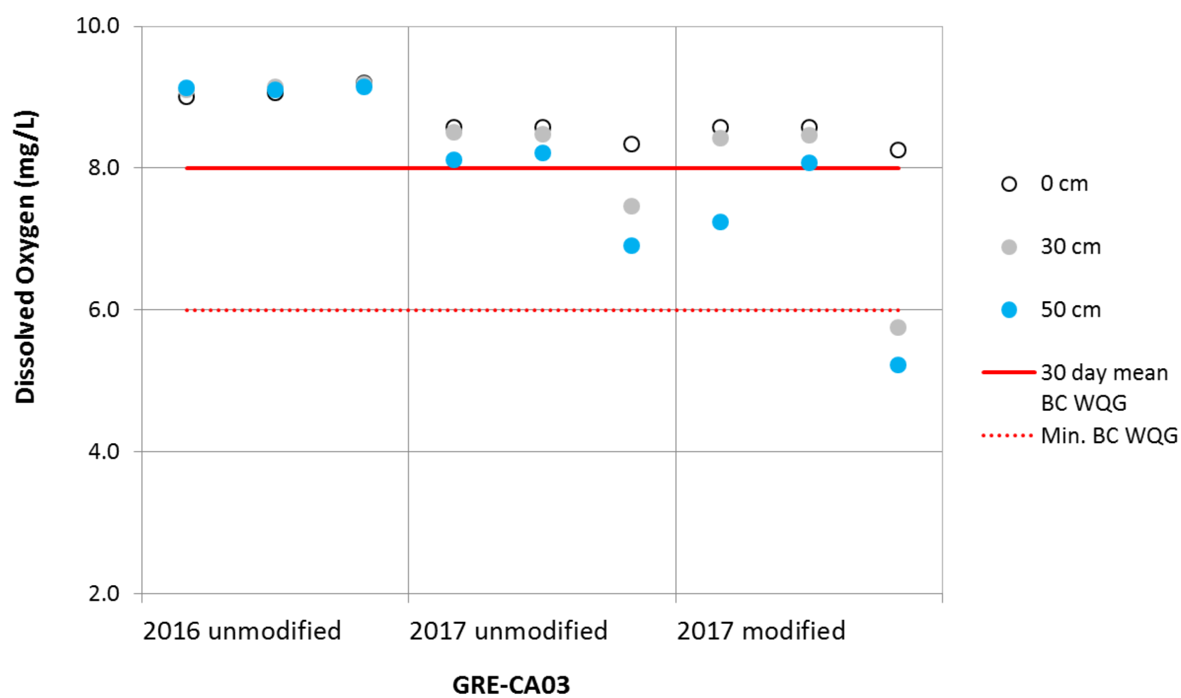
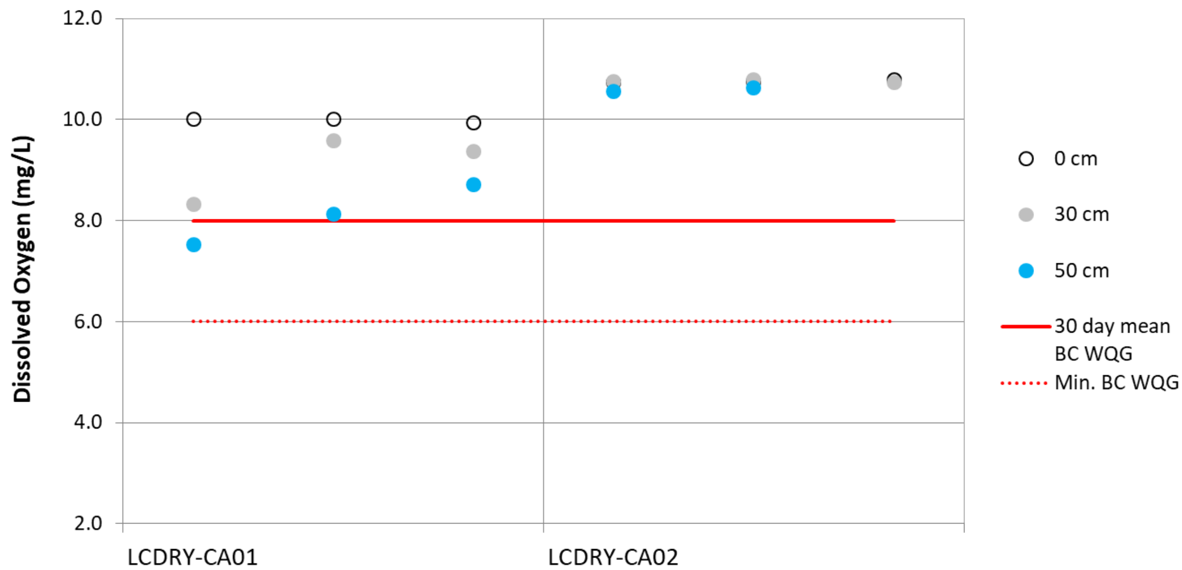


Figure 9. Dissolved oxygen measured at surface and at depth in a) LCO Dry Creek and b) Henretta Creek. Dissolved oxygen 30-day mean and minimum BC WQG are provided (MOE 2017).

a)



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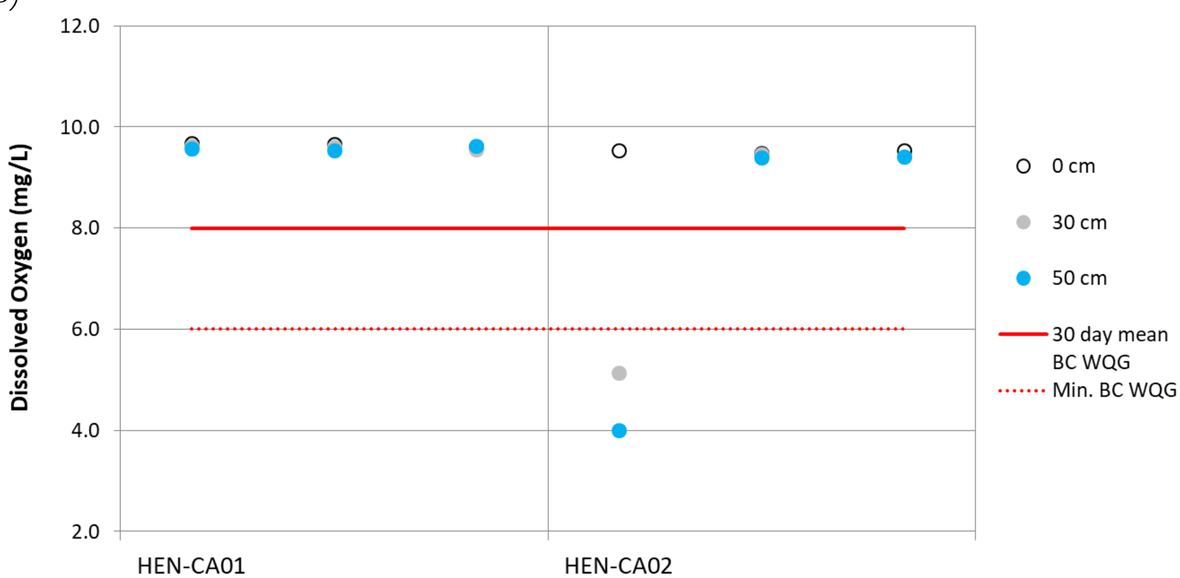


Water Temperature, pH and Specific Conductivity

Water temperature can influence DO saturation and concentration (DO saturation is inversely related to water temperature), and may also influence embryo development and incubation success;

therefore, water temperature data were compared to the provincial optimum water temperature range for Cutthroat Trout incubation of 9.0-12.0 ºC (Oliver and Fidler 2001). This range is applicable to the temperature of the water column during the incubation period.

In Greenhills Creek, the temperature generally increased with depth below the surface, although this trend was reversed at one of the outer edge piezometer locations (right bank) at both sites using either method (Figure 10). During late summer when the surface water temperature tends to be seasonally high, groundwater temperature is typically less than surface water temperature (Hayashi and Rosenberry 2002, Webb *et al.* 2008). Overall, the opposite trend was observed in Greenhills Creek; cooler surface temperatures may be the result of a thermal lag in bed temperature as a result of heat storage in the creek bed (Constantz 2008). Temperature differences between locations within the same site are attributed to small-scale differences in bed form and substratum composition, as well as vegetation cover.

At GRE-CA01 and GRE-CA03 water temperatures ranged from 14.4 ºC to 18.0 ºC, and were generally above the optimal maximum temperature range for Cutthroat Trout incubation, as well as the optimal temperature range for rearing activities (7.0 °C to 16.0 °C; Oliver and Fidler 2001). Incubation and emergence was likely mostly completed at the time of sampling.

In 2017, the water temperature results using the unmodified methodology and the new modified methodology in Greenhills Creek were similar (Figure 10). A comparison of the 2017 results to the 2016 data at these sites indicated similarity, considering that inter annual variation in water temperature and hydrology is expected; GRE-CA03 water temperature was cooler in 2016 in comparison to 2017.

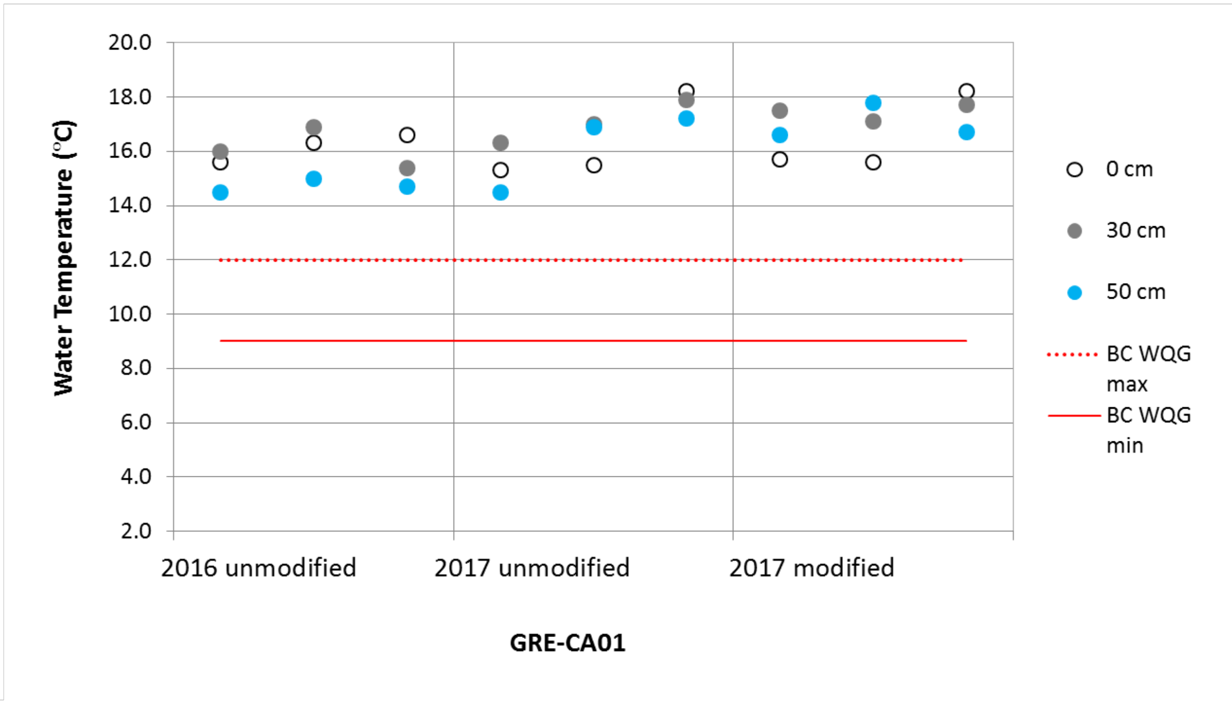
LCO Dry Creek sites exhibited cooler water temperatures (range of 6.3 °C to 9.2 °C) in comparison to Greenhills Creek sites (Figure 11, Appendix E). In general, water temperature increased with depth in the substrate and was less than the optimal temperature minimum for the incubation period (Figure 11).

Henretta Creek sites also exhibited cooler water temperatures (range of 8.9 °C to 10.9 °C) in comparison to the Greenhills Creek sites. In general, temperature did not change appreciably or exhibit any discernible trends with depth in the substrate and water temperature was within the optimal temperature range for Cutthroat Trout incubation (Figure 11).

In situ specific conductivity and pH data are provided in summary tables in Appendix E. The Greenhills Creek sites exhibited a pH range from 7.73 (at 50 cm depth) to 8.76 (at 30 cm depth) and a specific conductivity range of 1,570 to 1,625 μS/cm. Specific conductivity is higher than typically observed in BC surface water (100 to 500 μS/cm), indicting a higher concentration of dissolved ions (Appendix E). In general, the average pH at each site decreased with depth, while the average conductivity remained fairly constant.

In LCO Dry Creek, pH ranged from 7.42 to 8.38 and specific conductivity ranged from 167 to 354 μS/cm, which are within typical ranges of BC streams (100 to 500 μS/cm), though appear to be locally quite variable in this stream (Appendix E). Similarly, in Henretta Creek, pH ranged from 7.59 to 8.15 and specific conductivity ranged from 538 to 561 μS/cm; these values are somewhat higher than typical ranges in BC streams, which may be a consequence of natural variability, anthropogenic effects (e.g., forest harvesting), and/or inputs (e.g., mining, wastewater inputs). These data are compared to the laboratory analysis results in Section 4.1.1.3.

Figure 10. Water temperature at depth in Greenhills Creek using the unmodified approach (September 2016 and August 2017) and modified approach (August 2017) at GRE-CA01 and GRE-CA03. Optimum BC WQG temperature range for Cutthroat Trout incubation life stage is provided (Oliver and Fiddler 2001).



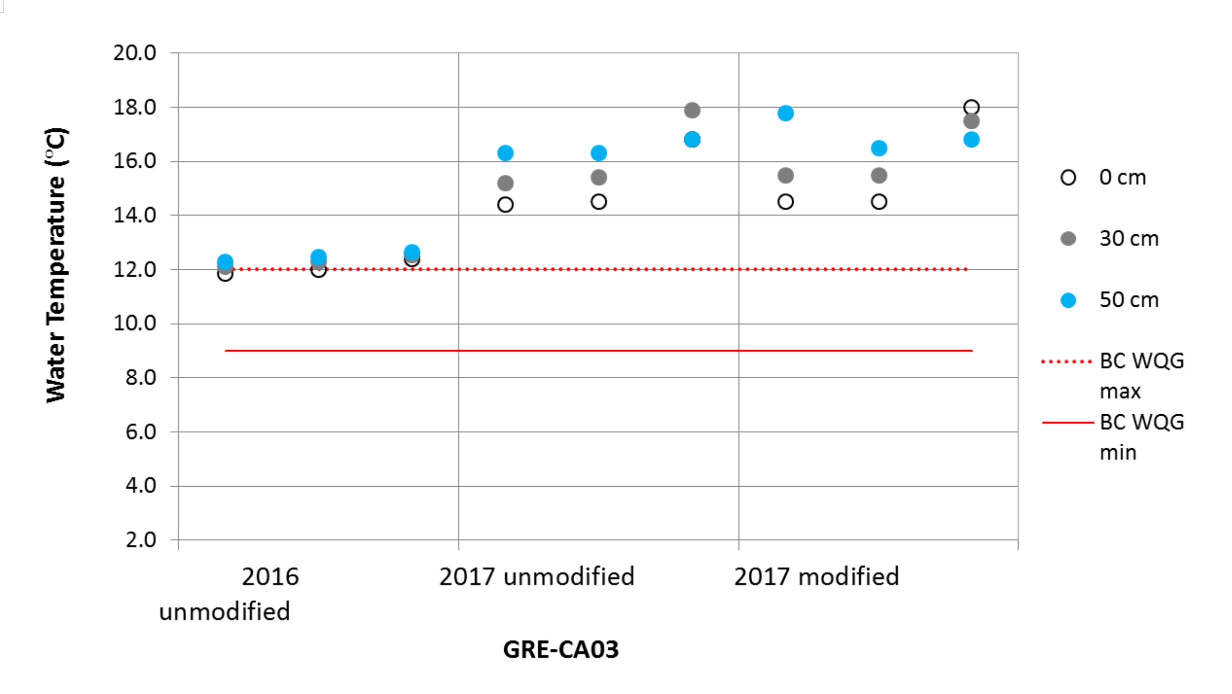
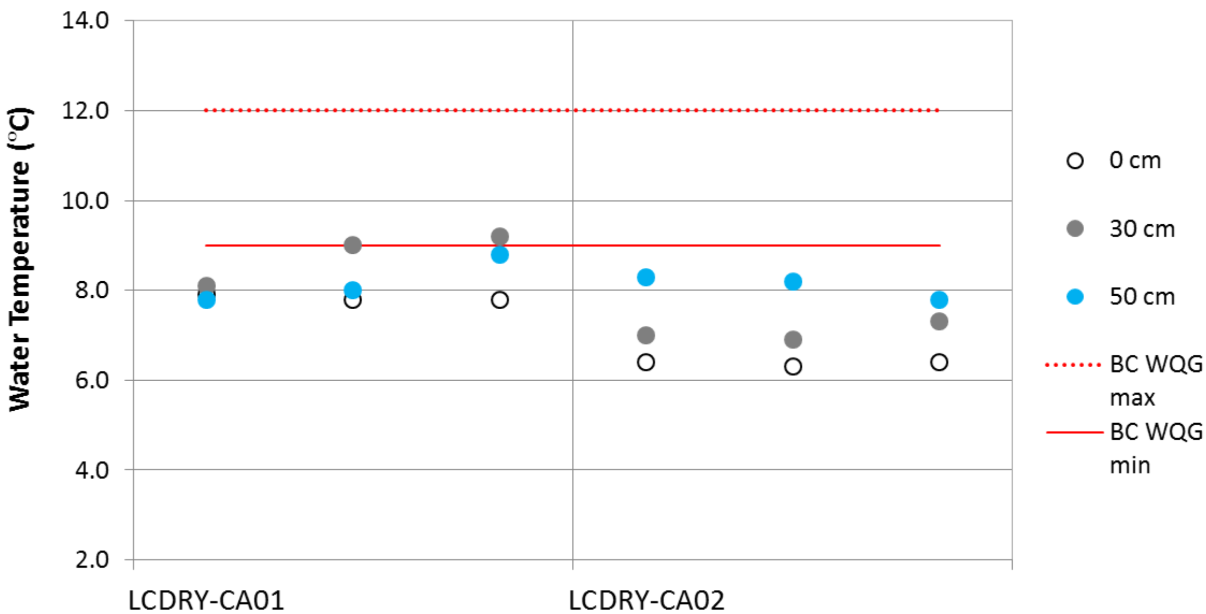
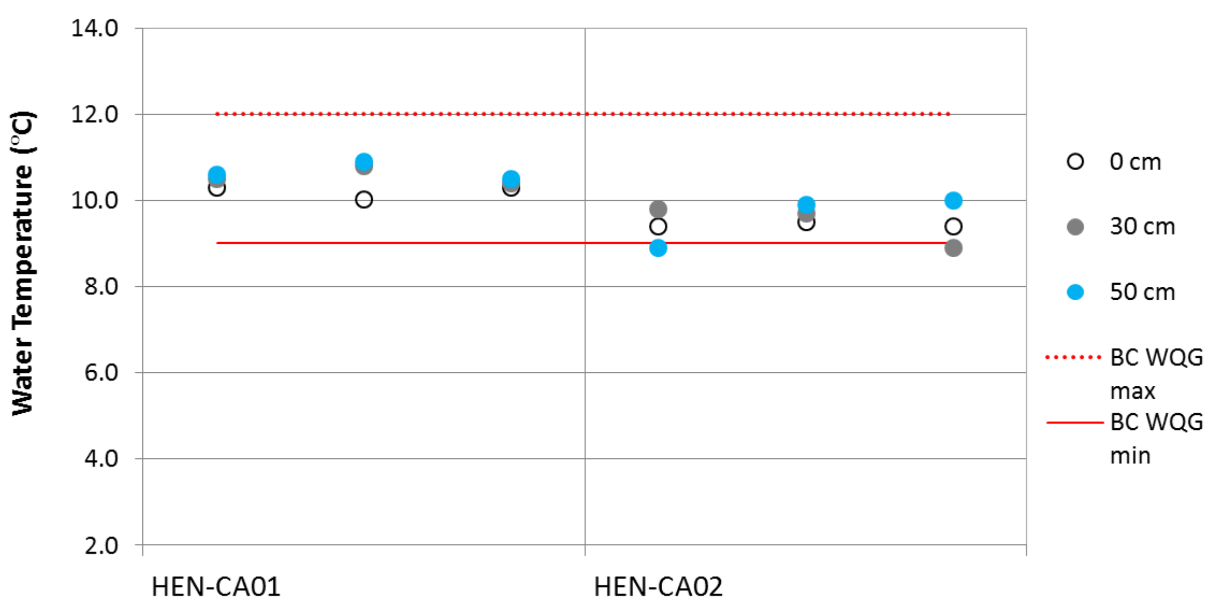


Figure 11. **Water temperature at depth in a) LCO Dry Creek and b) Henretta Creek. Optimum BC WQG temperature range for the Cutthroat Trout incubation life stage is provided (Oliver and Fiddler 2001).**

a)



b)



4.1.1.4. Hyporheic Water Quality: Laboratory Analysis

Water quality samples were collected at each sampling site at the surface and at 30 cm and 50 cm depths in the substrate. The analytical results were screened against the applicable BC WQG for the protection of aquatic life and are summarized in data tables in Appendix E; ALS laboratory reports are provided in Appendix F.

Laboratory data for pH and specific conductivity were compared to the in situ results for these parameters. In all three creeks, laboratory measured pH was greater than 8.0 (basic) and results were similar to those obtained in situ (Section Appendix E). Specific conductivity lab results were also similar to the in situ results. The highest specific conductivity was measured in Greenhills Creek where values ranged from 1,570 to 1,680 μS/cm. Specific conductivity ranged from 306 to 367 μS/cm in LCO Dry Creek and from 546 to 555 μS/cm in Henretta Creek (Appendix E).

The water quality parameters collected at the surface were compared to those collected at depth. The majority of sites had similar total and dissolved metal concentrations in the surface water as in the hyporheic water; calcium and magnesium concentrations were the exception, with higher concentrations found at depth in Greenhills Creek (Appendix F). Suspended solids and turbidity concentrations were also greater at depth (76.3 mg/L and 50.7 mg/L at 50 cm depth, respectively compared to 7.5 mg/L and 2.02 mg/L at the surface, respectively) at the Greenhills Creek sites, while the concentration of total dissolved solids was greater in the surface water (1,510 mg/L) compared to hyporheic water at 50 cm depth (1,450 mg/L). Total alkalinity or water hardness ($CaCO_3$) and bromide concentrations were substantially higher in the surface water (241 mg/L and 58.6 mg/L, respectively) than hyporheic water (194 mg/L and 10.6 mg/L, respectively at 50 cm depth) at LCDRY-CA02, compared to the difference in concentrations between the surface and hyporheic water at other sites (Appendix E and Appendix F).

The following parameters were above the applicable Approved BC WQG (MOE 2018) with the exception of uranium, which was above the Working BC WQG (MOE 2017). Total selenium (Se) concentrations above the long term BC WQG (0.002 mg/L) and the EVWQP benchmark for reproductive effects on WCT (0.07 mg/L) were observed in all three creeks with Greenhills Creek exhibiting the highest concentrations ranging from 0.164 mg/L to 0.173 mg/L. The EVWQP benchmark for juvenile fish growth is not applicable to the upper Fording River, because studies with juvenile WCT have reported no effects at the Level 1 and Level 2 benchmarks (>0.046 mg/L and >0.466 mg/L, respectively). Total uranium concentrations were above the long term Working BC WQG (0.0085 mg/L) at Greenhills Creek sites only. Sulphate in Greenhills Creek was above the hardness dependent BC WQG (429 mg/L for hardness > 250 mg/L) and EVWQP benchmarks (429 mg/L for hardness > 250 mg/L) at all sampling sites (Appendix E). Water hardness (as $CaCO_3$) was high in Greenhills Creek ranging from 1,070 to 1,080 mg/L; values did not change appreciably with depth. Nitrate concentrations were also above the long-term BC WQG (3 mg/L) at Greenhills Creek and Henretta Creek sites, but below the hardness-dependent Level 1 and Level 2

EVWQP benchmarks for fish in the Fording River (16 and 21 mg/L of NO_3-N, respectively) (Appendix E).

QA/QC results indicated that one travel blank detection occurred on September 1, 2017 for Total Kjeldahl Nitrogen. The travel blank was provided by ALS laboratory and remained unopened in the cooler. Contamination of the travel blank may have occurred during preparation, transport, or analysis. The concentration recorded in the travel blank was an order of magnitude higher than the analytical results; therefore, it is unlikely that the samples experienced similar contamination; nevertheless caution should be used when evaluating Total Kjeldahl Nitrogen for further data analysis. All other field blank and travel blank data were less than applicable minimum detection limits.

Hold time exceedances occurred for each sampling date for pH, which is unavoidable as the hold time is 15 minutes, and for dissolved orthophosphate where the recommended hold time is three days; actual hold time ranged from 5 to 9 days (Appendix F). Dissolved orthophosphate results were less than detection limits in most cases at Greenhills Creek and Henretta Creek suggesting that hold time exceedances did not affect the results. In LCO Dry Creek, dissolved orthophosphate results were above detection limits. If the LCO Dry Creek orthophosphate data are to be used for further analysis, hold time exceedances should be noted. Comparison of the LCO Dry Creek orthophosphate data to future sampling of orthophosphate will improve confidence in the analytical results. Typically orthophosphate levels are low in natural waters since orthophosphate is readily utilized by aquatic plant life.

4.1.1.5. Surface Hydrology

Water depth and velocity measurements made at each piezometer location were predictor variables hypothesized to affect hyporheic conditions (see Section 3.1.2). A summary of these measurements is provided in Appendix D. At many sites, water depth and velocity varied across the stream due to differences in the streambed topography and substrate. Water depths were highest at LCDRY-CA02 and lowest at GRE-CA01 and GRE-CA03 (Appendix D). Water velocities ranged from an average of 0.25 m/s (GRE-CA01) to 0.42 m/s (HEN-CA02) (Appendix D).

Discharge measurements collected at each stream are summarized in Section 2.2, and are provided in Appendix D. Discharge was lowest at Greenhills Creek (0.03 m^3/s), and highest at Henretta Creek (0.34 m^3/s at HEN-CA02).

4.1.1.6. Hyporheic Flow

Hyporheic flow estimates generated with Darcy's equation (the hydraulic head method) were variable between sites and found to have unrealistically high downwelling values at some sites due to uncertainty in the hydraulic conductivity estimates. Thus, the groundwater exchange rates provided here should be used for comparison purposes only, although the estimate of direction of flow is considered valid. The results are discussed in the *Groundwater Exchange Rate* section below.

4.1.1.7. Hyporheic Flow

Hydraulic Head

The hydraulic head generally increased (became more positive) with depth at most sites, indicating downwelling; however, the magnitude of the hydraulic gradient with depth varied within and amongst sites and there were some instances of upwelling flow within sites.

In Greenhills Creek, the average hydraulic head generally increased (became more positive) with depth, and was larger at GRE-CA01 (Figure 12). At GRE-CA03, both downwelling and upwelling flow patterns were recorded at 50 cm streambed depth; hydraulic head ranged from -0.003 to 0.017 m.

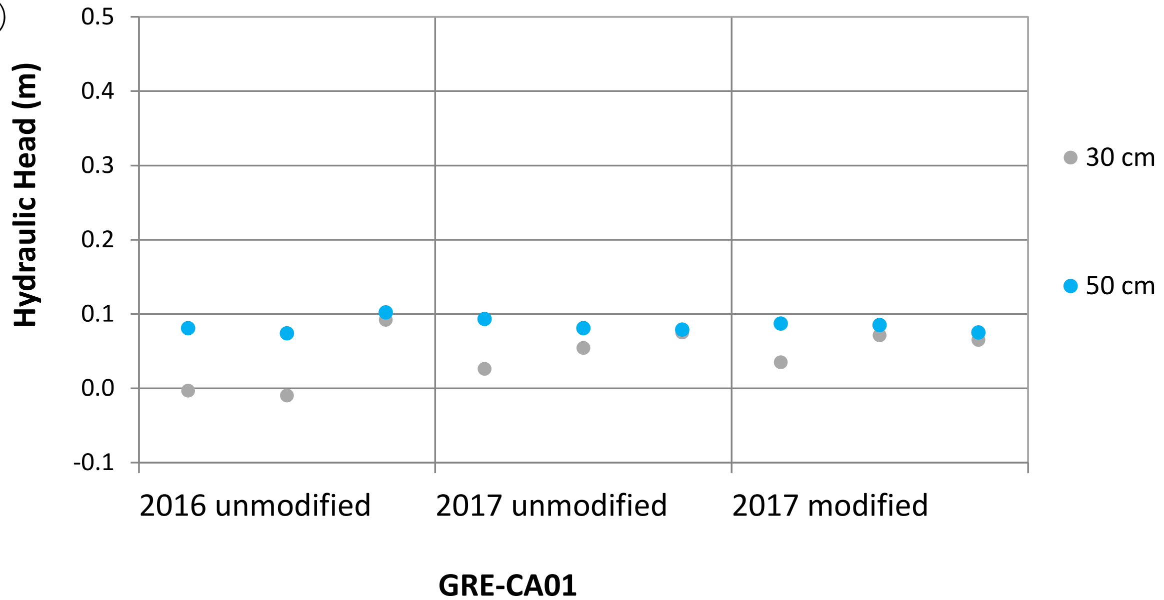
Two approaches were used to collect hydraulic head data at the Greenhills Creek sites. The unmodified method used in 2016 and the modified 2017 approach generally yielded similar results (Figure 12). The average hydraulic head measured using the unmodified and modified methods were similar at 30 cm depth (0.052 m and 0.057 m, respectively) and 50 cm depth (0.084 m and 0.082 m, respectively) at GRE-CA01; similar differences were observed at 30 cm depth (0.017 m and 0.022 m) at GRE-CA03. The modified method yielded higher average hydraulic head (0.029 m) at 50 cm than the unmodified approach (0.008 m) at GRE-CA03.

In LCO Dry Creek, the average hydraulic head decreased with depth at LCDRY-CA01 and increased with depth at LCDRY-CA02 (Table 2 in Appendix D). There was little hydraulic head difference between the 30 cm and 50 cm depths at the three piezometer locations at LCDRY-CA01 (Figure 13), suggesting weak downwelling; hydraulic head ranged from -0.006 to 0.004 m. The hydraulic head variability was greater at LCDDRY-CA02 than LCDRY-CA01 at both 30 cm and 50 cm depths (Figure 13). The hydraulic head results indicate strong upwelling at LCDRY-CA02 (Figure 13).

At Henretta Creek, both upwelling (HEN-CA01) and downwelling (HEN-CA02) flow patterns were recorded; hydraulic head ranged from -0.013 to 0.445 m (Appendix D). The hydraulic head was higher at both 30 cm and 50 cm depths at HEN-CA01 compared to HEN-CA02 (Figure 13). The hydraulic head exhibited high variability across the channel at LCDRY-CA01, with increasing head from river left to river right at both 30 cm and 50 cm depths (Figure 13).

Figure 12. Hydraulic head measured at depth in Greenhills Creek using the unmodified approach (August 2016 and 2017) and modified approach (August 2017) at a) GRE-CA01 and b) GRE-CA02.

a)



b)

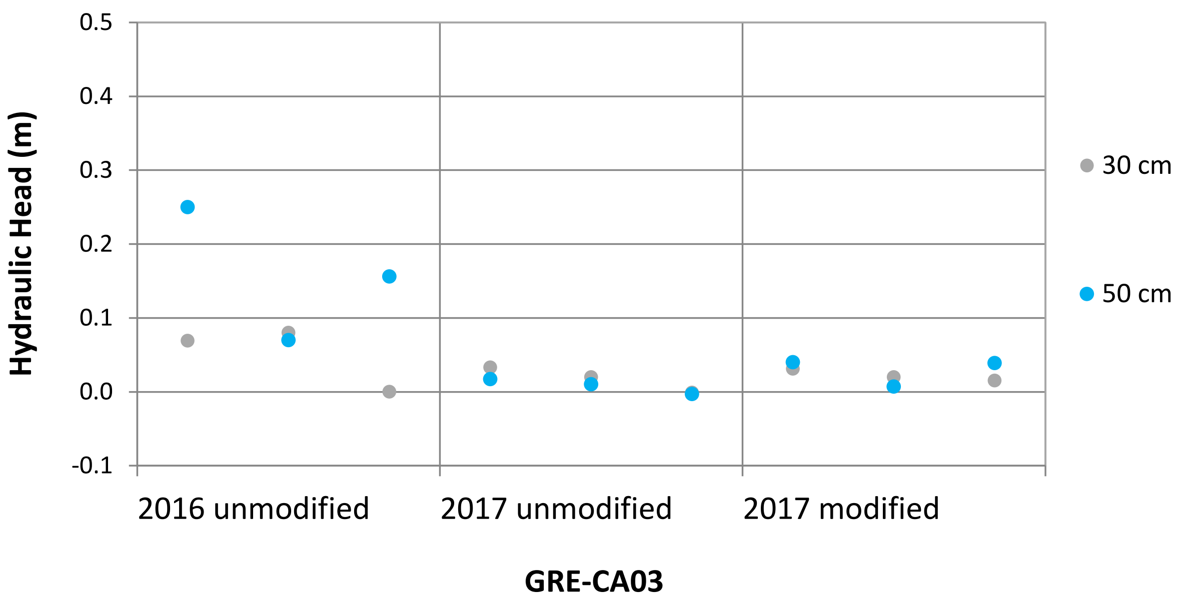
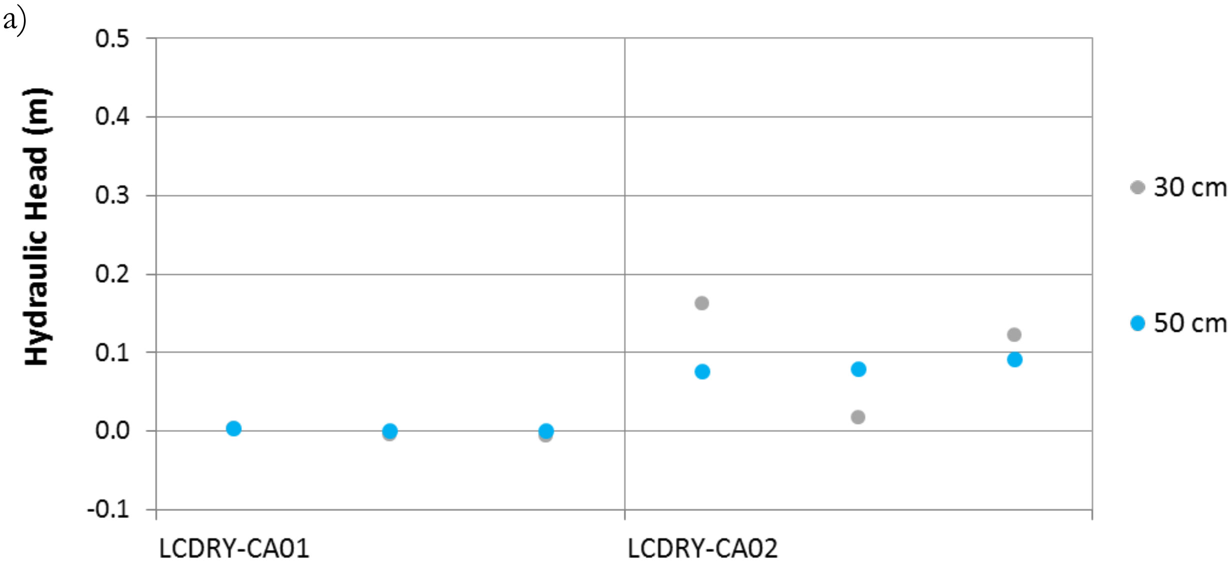
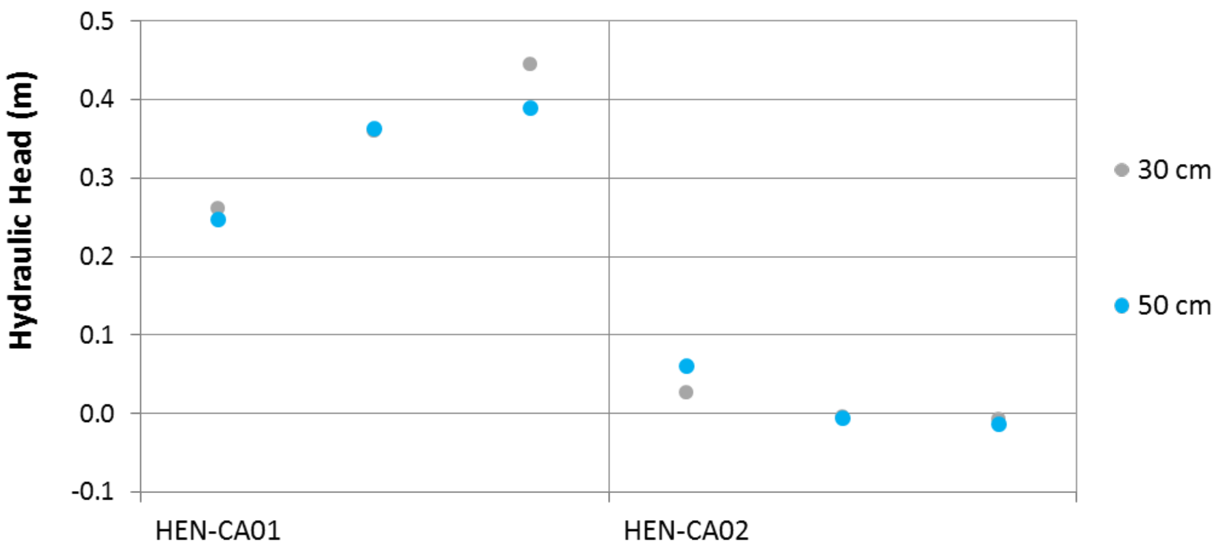


Figure 13. Hydraulic head measured at depth in a) LCO Dry Creek and b) Henretta Creek in August 2017.

a)



b)



Groundwater Exchange Rate

Hydraulic conductivity (K) was estimated using GSD based relations and subsurface exchange rates were calculated from these values and the VHG measurements (Figure 12 and Figure 13) using Darcy's equation (Table 14). The differences in K estimates between sites were of relatively similar magnitude (1762 to 2452 m/day), and are expected to result from differences in substrate characteristics of sampling locations. Porosity estimates based on GSD are also presented in Table 14. Porosities ranged from 0.23 at LCDRY-CA02 and HEN-CA01 to 0.48 at GRE-CA01, with an average of 0.36. The relatively high porosities result from the relatively low fines percentage at many of the sites.

The strongest and weakest downwelling rates were observed at Henretta Creek, followed by LCO Dry Creek, where one of the sites (LCDRY-CA01) also exhibited weak upwelling at 30 cm depth (Figure 14). The average groundwater exchange rates for all sites ranged from -1.8 to 332.3 m/day at 30 cm depth and 0.5 to 187.0 m/day at 50 cm depth (Table 14).

The groundwater exchange rates computed from the VHG obtained from the unmodified 2016 method and modified 2017 approach were similar in magnitude and direction at each of the Greenhills Creek sites, providing confidence in the 2016 results.

The maximum groundwater exchange rate was less than 55 m/d at all but two of the sites at 30 cm depth, and all but one site at 50 cm depth (Table 14). The groundwater exchange rates were unrealistically high at two of the sites (e.g., LCDRY-CA02 and HEN-CA01) given typical groundwater exchange rates observed in the literature (e.g., 1 m/d from Birkel *et al.* (2016), 0.47 m/d from Bianchin *et al.* (2010), and range of -0.12 to -0.35 m/d from Briggs *et al.* (2013), and maximum of 51 m/d from Massman and Butchart (2001)). The high values are likely the result of poor estimates of K. Estimation of K based on pebble counts and visual assessment of fines distribution has greater uncertainty than other methods. It is therefore recommended that the groundwater exchange rates obtained from the hydraulic head method be treated as indicative of direction of flow and relative magnitude, but with unreliable estimates of absolute magnitude.

Table 14. GSD and porosity estimates, calculated K values, and groundwater exchange rates (q) calculated with Darcy's equation using GSD based K estimates for each site.

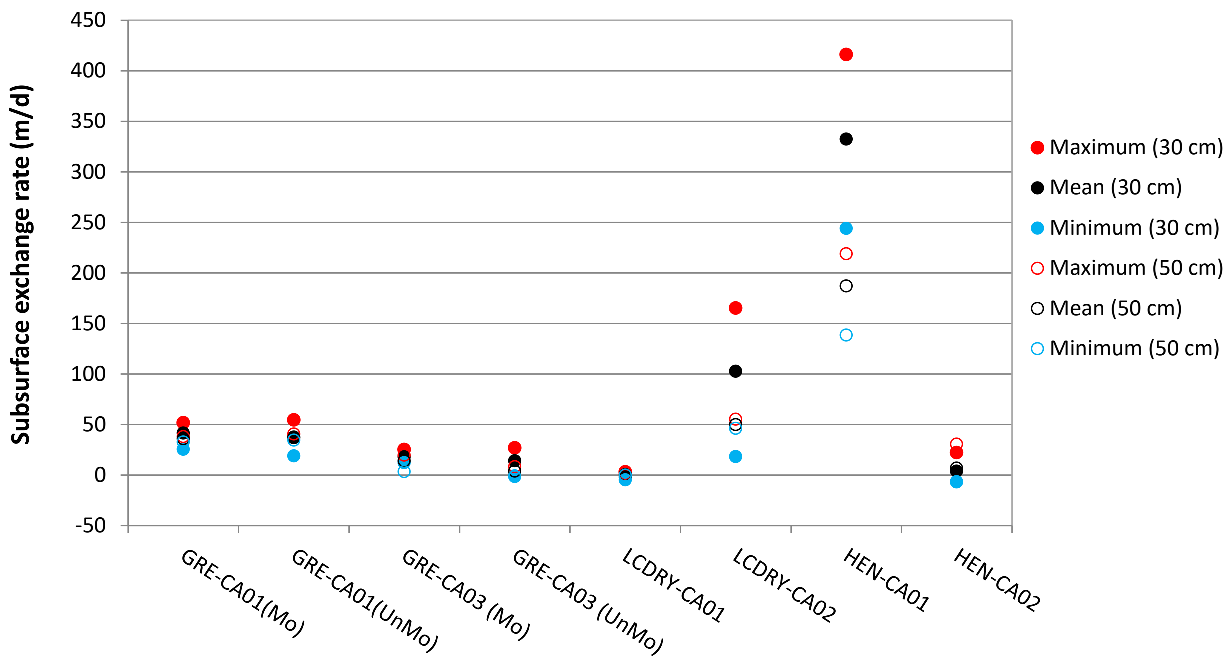
Site	Fines %	Fines class[1]	Mean porosity[2]	K (m/d)	q using Darcy's equation and reduction factor[3] (m/d) (30 cm) Avg	(30 cm) Min	(30 cm) Max	(50 cm) Avg	(50 cm) Min	(50 cm) Max	Comments
GRE-CA01	15.0	100% C	0.48	1762.6	**41.5**	25.5	51.7	**36.0**	32.8	38.0	Modified method
				1762.6	**37.6**	18.9	54.6	**36.9**	34.5	40.7	Unmodified method
GRE-CA03	10.0	50% C, 50% F	0.46	1978.5	**18.0**	12.3	25.4	**14.1**	3.4	19.6	Modified method
				1978.5	**14.2**	-0.8	27.0	**3.9**	-1.5	8.3	Unmodified method
LCDRY-CA01	20.0	50% C, 50% M	0.47	1903.7	**-1.8**	-4.7	3.1	**0.5**	0.0	1.4	-
LCDRY-CA02	10.0	50% C, 50% M	0.23	2452.2	**102.7**	18.2	165.2	**49.9**	46.2	55.3	-
HEN-CA01	10.0	100% C	0.23	2262.5	**332.3**	244.1	416.2	**187.0**	138.6	218.8	-
HEN-CA02	20.0	100% F	0.31	2062.9	**4.0**	-6.8	22.2	**7.0**	-6.7	30.7	-

[1] Fines class estimated visually from field samples; C = coarse sand, M = medium sand, F = fine sand.

[2] Based on analytical model from She *et al.* (2006).

[3] Reduction factor of 12.4% applied, which was the average exchange rate difference between Darcy's and 1DTempPro estimates from 2016.

Figure 14. Groundwater exchange rate (q) calculated with Darcy's equation using GSD based K estimates.



Uncertainty in Hyporheic Flow Estimates

Variation in VHG at different depths within the streambed was also observed by Birkel *et al.* (2016), which suggests that vertical variations in K may be common. The variable head differential measurements at piezometer sites and across the transects is likely due to natural heterogeneity of interstitial flow at different points across the stream. Variance may be a function of several factors, including measurement error and piezometer water level not stabilizing. To obtain accurate water level measurements and ensure that flow within the piezometer had reached equilibrium (i.e., water levels inside and outside of the piezometers remained consistent and stable), water levels measurements were repeated a minimum of three times (and until equilibrium was reached) at each piezometer.

Surface flow across the piezometer transect was variable at some sites (e.g., LCDRY-CA02; Appendix D) with the presence of preferential flow paths due to differences in streambed topography that may also have had an impact on interstitial flow paths resulting in higher amounts of downwelling at some piezometer sites than others. The different directions in flow may also be due to substrate characteristics at depth.

4.1.2. Testing Impact Hypothesis H_01

4.1.2.1. Comparison of Sampling Method

The piezometer method used did not have a significant effect on the observed dissolved oxygen concentration or the hyporheic flow as estimated by the hydraulic head method. Samples in 2017 using both methods at GRE-CA01 and GRE-CA03 produced similar results as evidenced by p-values for method that were substantially greater than a typical alpha level of 0.05 (Table 15).

Table 15. Results for linear modelling testing the effect of the modified vs. unmodified methods on hyporheic DO and flow. P-values associated with the test of 'Method' are >0.05.

Response Variable	Term	Estimate	p-value
Dissolved Oxygen	Intercept	7.6	2.7E-28
	Method	0.29	0.31
Hyporheic Flow (Hydraulic Head Method)	Intercept	3.2E-04	0.046
	Method	-4.9E-05	0.30

4.1.2.2. Statistical Modelling of Hyporheic Conditions vs. Calcite

In an analysis of data collected over two years (2016 and 2017), stream sites with higher calcite index scores had lower DO in the substrate, but not lower hyporheic flow as measured using the hydraulic head method. The effect of CI on hyporheic DO was much stronger when using all of the data (CI < 3) compared to effects observed using a subset of the data (CI < 1.25; chosen to reflect conditions when Westslope Cutthroat Trout may have easier access to the substrate for spawning, based in part on preliminary observations described in Minnow Environmental (2016)). (Figure 15, Figure 16, Figure 17, Figure 18). Figure 15 and Figure 16 show the predicted relationship between hyporheic DO and CI scores of the substrate using all of the data (CI < 3) versus a subset of the data (CI < 1.25). The depth sampled in the substrate influences the relationship between DO and CI score, particularly when CI scores are high. Overall, these results show that there is a negative relationship between CI score and DO in the substrate, although the effects are most pronounced deep in the substrate (i.e., 50 cm depth) and when CI scores are greater than 1.25.

Table 16 shows the top model (i.e., the best combination of variables) for each response variable quantified using the Akaike Information Criterion, corrected for small sample sizes (AICc). The top model weight refers to the likelihood that the specified top model is the best model among all other possible combinations of predictor variables considered. For DO, the top models for both the full data set and the CI < 1.25 data set included the same predictors: CI score, depth in the substrate, the CI score*depth interaction, and percent fines (Table 16). Hyporheic DO was lower at increasing depth in the substrate and with increasing percent fines in the substrate.

There were two main differences in the results for the effect of CI on hyporheic DO when using the full dataset (CI < 3) versus the subsetted data (CI < 1.25): 1) the confidence in the relationship between CI and DO was weaker for CI < 1.25; and 2) the CI score*depth interaction term was more important in the model using the full dataset (CI < 3). Figure 17 and Figure 18 show the model-averaged coefficient plots (with 95% confidence intervals) and relative variable importance (RVI) scores for hyporheic DO using all of the data (CI < 3) versus a subset of the data (CI < 1.25). RVI scores indicate the likelihood that each variable shown occurs in the top set of models and is a measure of variable importance relative to other variables. The CI of the stream site had an RVI = 1 in the full dataset (CI < 3) and an RVI = 0.51 in the subsetted data (CI < 1.25). The CI score*depth interaction had a RVI of 0.64 in the full dataset (CI < 3) and an RVI = 0.13 in the subsetted data (CI < 1.25). The differences in results between the full dataset and the subset are not surprising given that confidence in relationships typically increases with larger sample size and observations made across a broader range of conditions.

Variation in hyporheic flow calculated via the hydraulic head method was not strongly explained by CI score nor any of the measured habitat variables (Figure 19, Figure 20, Table 16). The top model was an intercept-only model using all of the data (CI < 3) or a subset of the data (CI < 1.25) (Table 16). The calcite index and all habitat variables had RVI scores of less than 0.5, indicating weak associations with hyporheic flow as calculated via the hydraulic head method.

Figure 15. **Scatterplot of DO in the substrate versus CI score at all sites sampled in 2016 and 2017 (CI < 3). Lines indicate the predicted relationships between DO and CI at different depths in the substrate based on the model-averaged coefficients that best predict DO.**

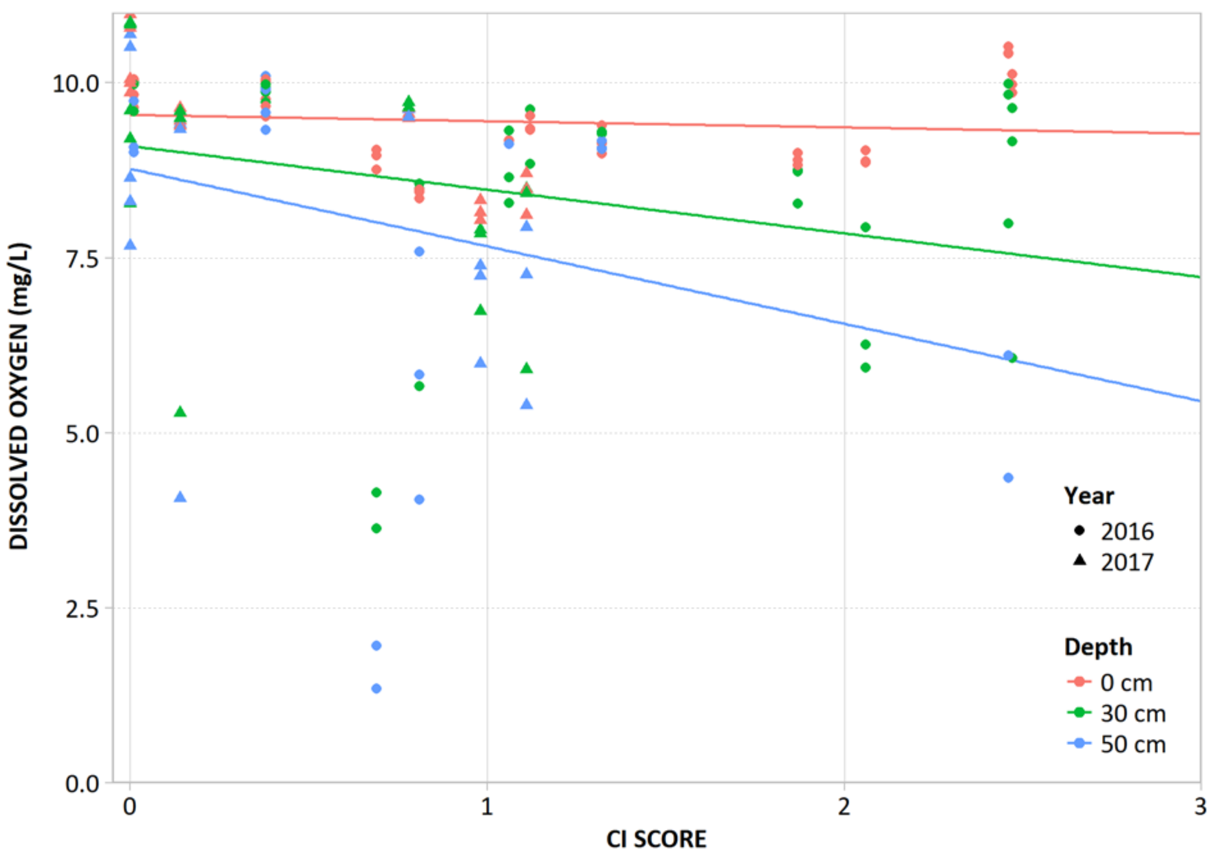


Figure 16. Scatterplot of DO in the substrate versus CI score at sites with CI < 1.25. Lines indicate the predicted relationships between DO and CI at different depths in the substrate based on the model-averaged coefficients that best predict DO.

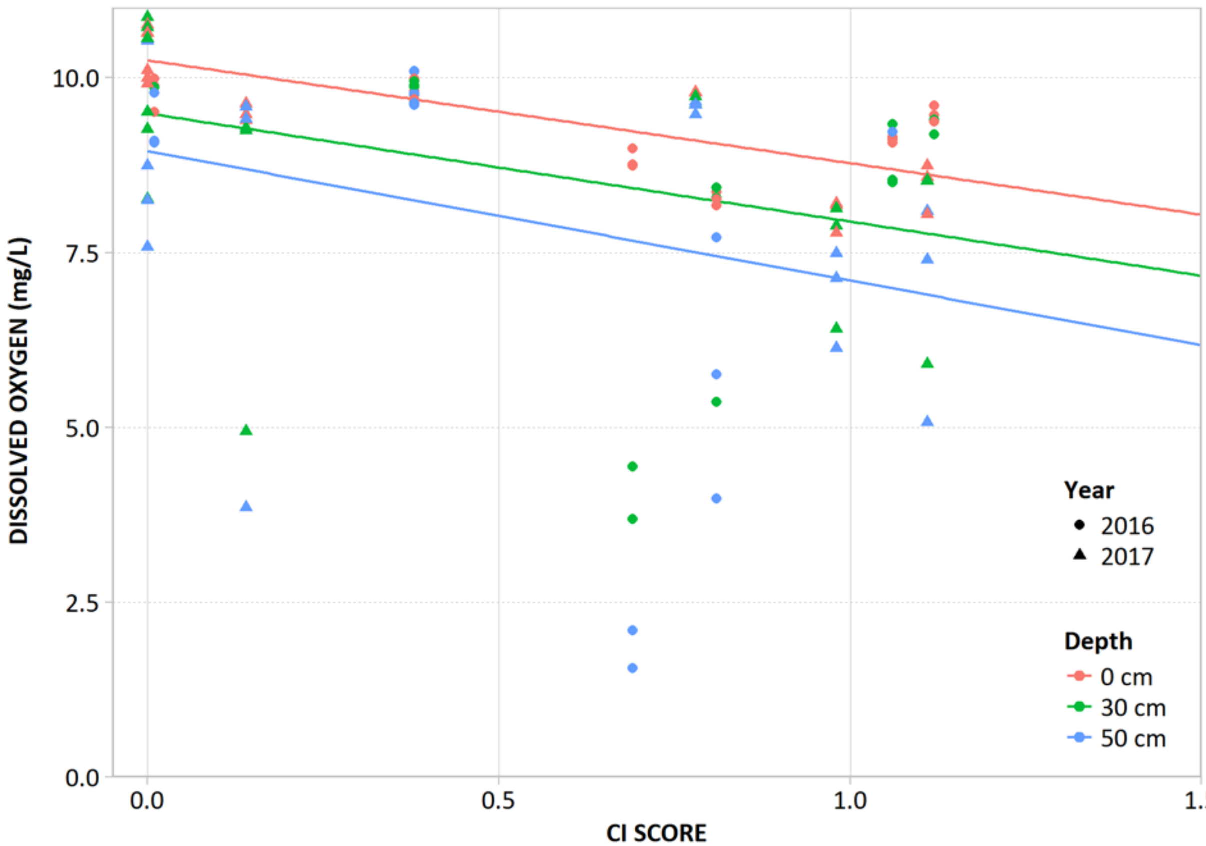


Table 16. Summary of top models for both response variables representing hyporheic conditions.

Response Variable[2]	Fixed Effects[1,2]	df	AICc	ΔAICc[3]	Weight[4]
Dissolved Oxygen (All Data)	CI Score, Depth, CI Score*Depth, Percent Fines	7	483.77	3.16	0.535
Dissolved Oxygen (CI < 1.25)	CI Score, Depth, CI Score*Depth, Percent Fines	7	366.18	0.36	0.096
Hyporheic Flow (Hydraulic Head Method, All Data)	Intercept Only	3	64.16	1.52	0.387
Hyporheic Flow (Hydraulic Head Method, CI < 1.25)	Intercept Only	3	38.30	0.33	0.130

[1]Random effects: Site

[2]All variables except for Dissolved Oxygen were scaled by subtracting the mean and dividing by twice the standard

[3]Change in AICc from top model to next best model

[4]Weight in averaged model

Figure 17. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting hyporheic dissolved oxygen across all sites (CI < 3). RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4. p-values represent probability that the coefficient is equal to 0.

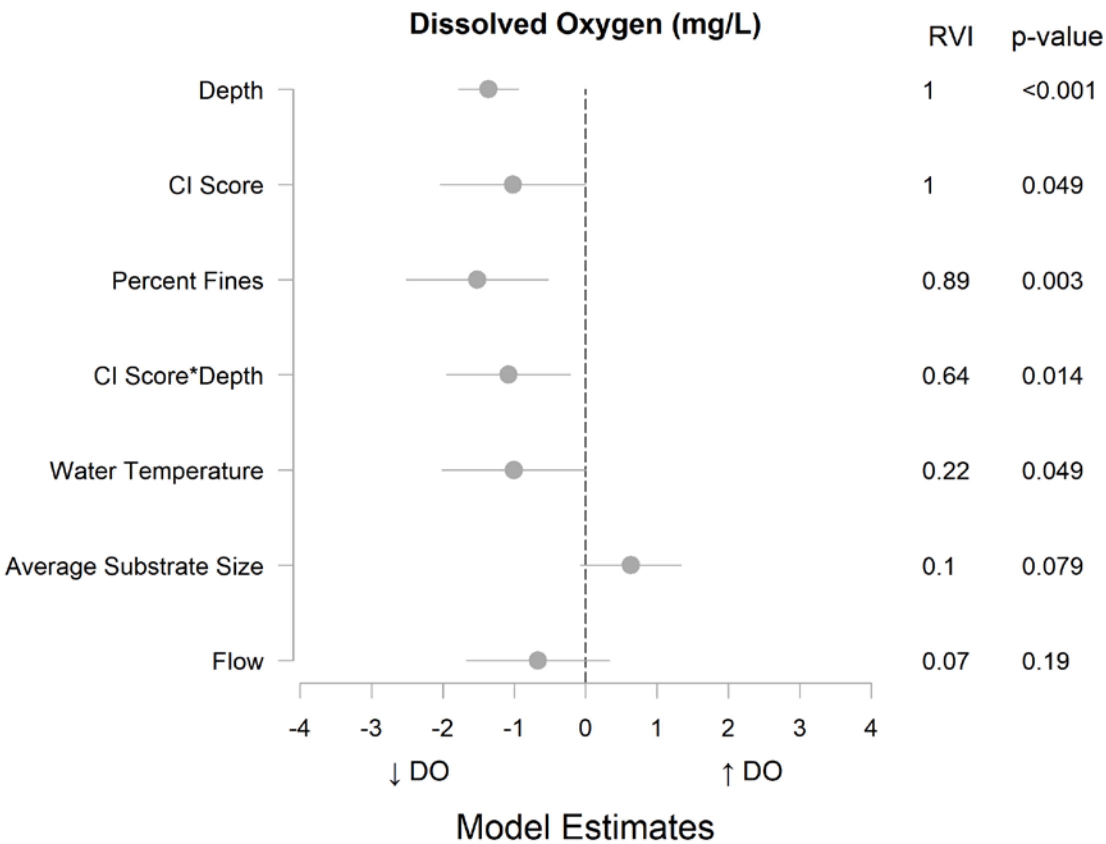


Figure 18. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting hyporheic dissolved oxygen across sites with CI < 1.25. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4. p-values represent probability that the coefficient is equal to 0.

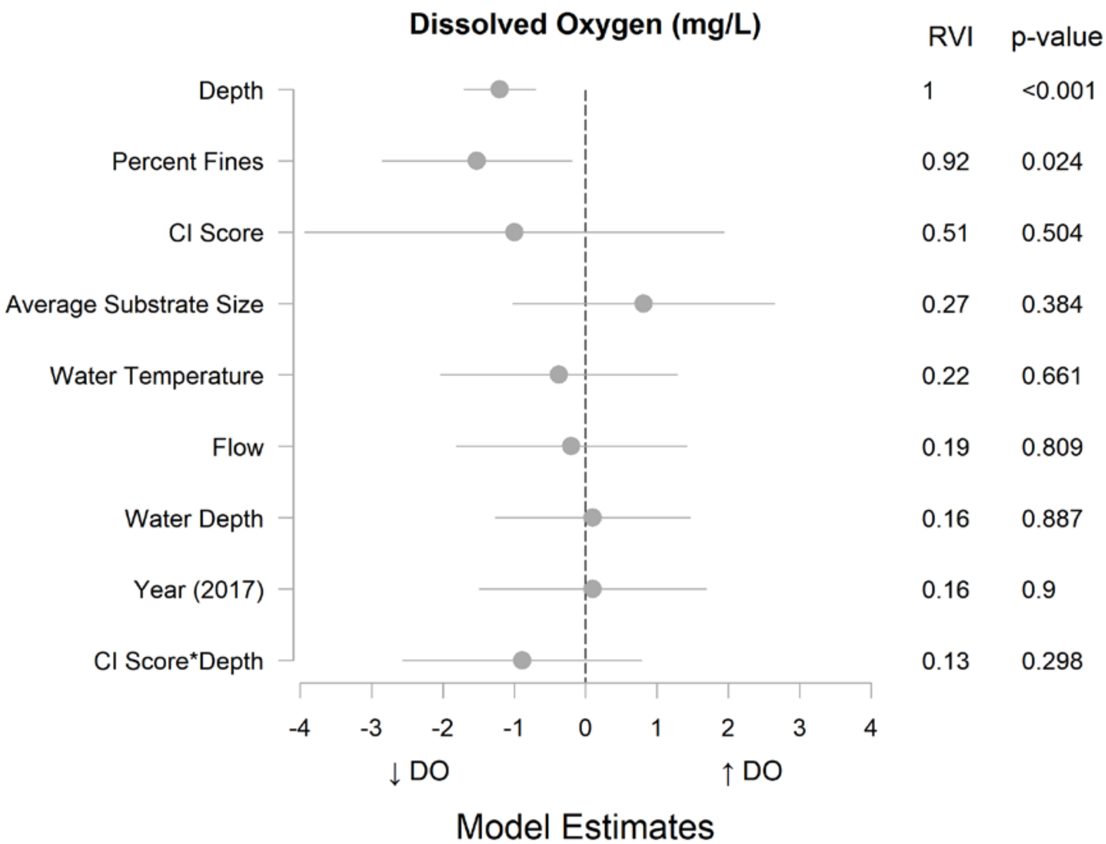


Figure 19. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting hyporheic flow using the hydraulic head method across all sites (CI < 3). RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4. p-values represent probability that the coefficient is equal to 0.

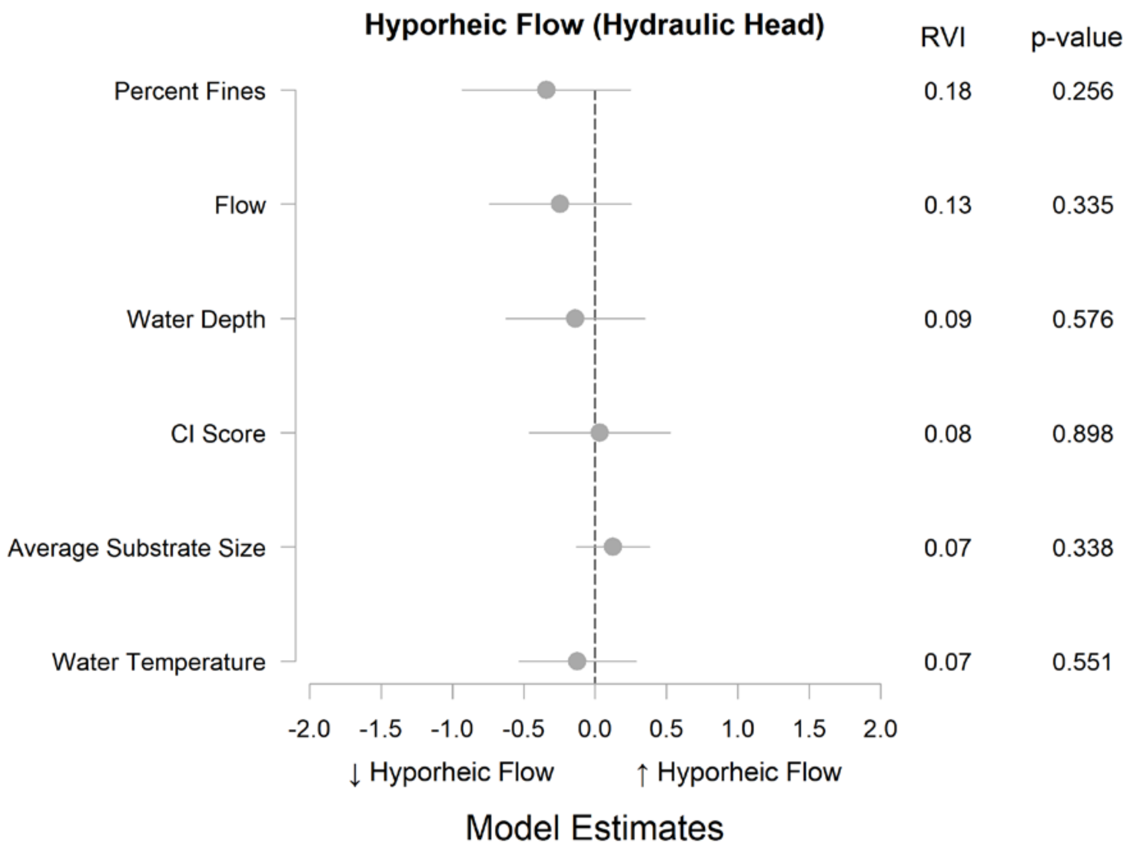
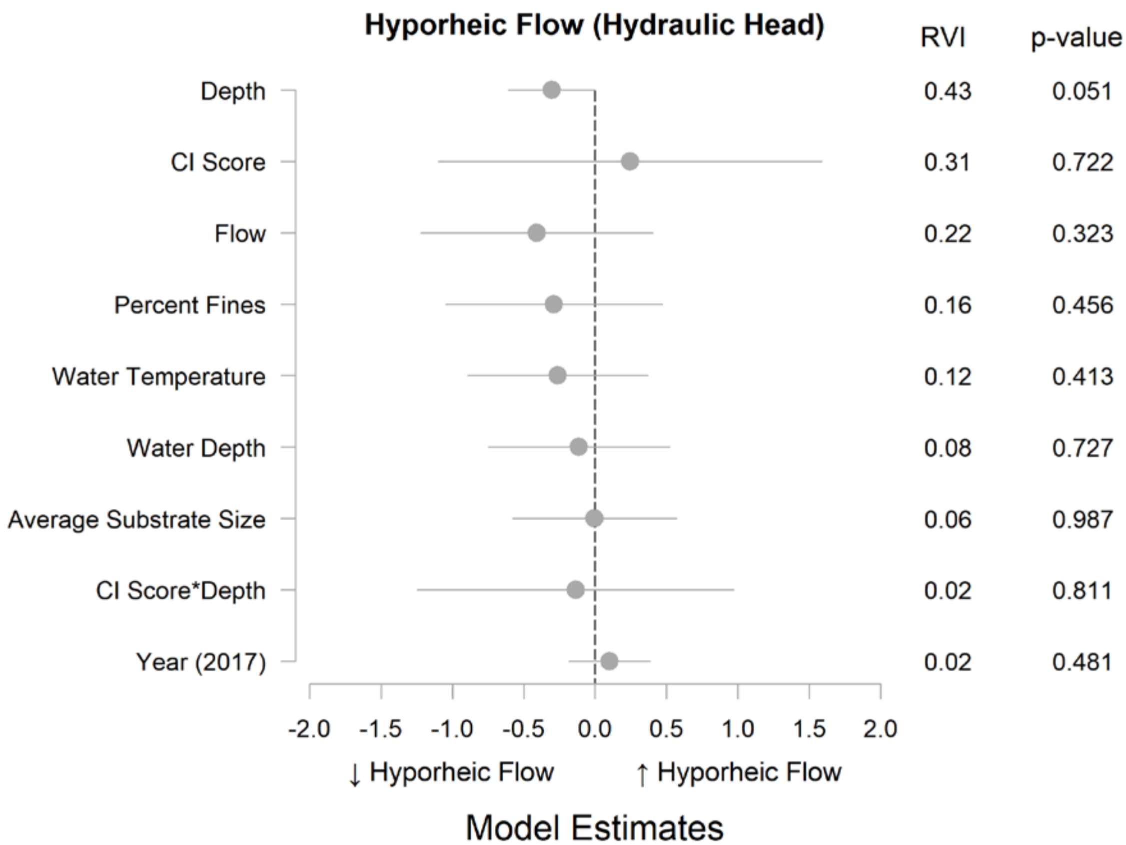


Figure 20. Model averaged coefficients (with 95% confidence intervals) indicating the most important variables predicting hyporheic flow using the hydraulic head method across sites with CI < 1.25. RVI = Relative Variable Importance scores, where a score of 1 indicates that a predictor variable occurs in all top models with ΔAICc < 4. p-values represent probability that the coefficient is equal to 0.



4.2. <u>Spawning Conditions</u>

During the 2017 field program, FHAP, calcite cover, and substrate composition data were collected and will be used to support the ongoing investigation of spawning conditions. A level 1 FHAP was conducted on the lower reaches of Greenhills Creek and Henretta Creek; FHAP results are presented in Section 4.1.1.1 and Appendix B. Calcite cover and substrate composition at two habitat units in Greenhills Creek, LCO Dry Creek, and Henretta Creek are presented in Section 4.1.1.2 and Appendix C. Additional calcite and substrate information were collected at LCO Dry Creek to support the assessment of spawning conditions. These data are provided in Appendix C (Figure 33).

An assessment of spawning conditions was also made in areas where redds were observed during spawning surveys in June and July, 2017 (Faulkner *et al.* 2018). The results of the assessment are summarized in Appendix A. Seven different areas were assessed, including 40 FHAP mesohabitat units (Buchanan *et al.* 2016). Of the 40 units surveyed, potential spawning habitat was observed in 18 units. Obvious redds were observed in three habitat units (FHAP unit 238, 271, and 282); all three of these locations contained redds during the July 2017 spawning assessment (Faulkner *et al.* 2018). No obvious redds were detected in six other habitat units where redds were observed in June or July 2017 (i.e., FHAP unit 48, 55, 101, 115, 116, and 333), and no confirmed redds were observed in areas where redds were observed during the June and July 2016 surveys. Redds that were observed did not have the appearance of being freshly dug, and were located near the stream margin, out of the main flow. There was some evidence of potential digging and redd formation at three sites (FHAP 80, 101 and 115), possibly from spawning activity in previous years.

Spawning habitat typically consisted of small patches of moderate quality spawning gravel that could be utilized by small stream resident trout (< 40 cm). Substrate compaction and embeddedness was rated as moderate/low in the three sites where redds were clearly observed. The majority of other sites contained moderate/highly compacted gravel, with moderate/high embeddedness. Calcite was not detected at the assessment sites, and was not considered to be a contributing factor to substrate compaction or embeddedness.

A database of the observations collected in 2017 (redds and predictor variable values) was developed, but analysis of these data has been deferred until additional data, sampled across a wide range of conditions, has been collected.

4.3. Other Assessment Methods

Permitting requirements, restrictions for use, sources of eggs, outplanting locations, and methods of in situ incubation techniques to study egg-to-fry survival in the Elk Valley were investigated. Appendix H provides a detailed description of our review on these topics. Below is a summary of the permitting requirements and egg sources, and a review of the challenges and considerations of using egg-to-fry survival incubation studies to assess potential calcite effects and to inform management decisions. A substantial challenge for these studies would be the difficulty in teasing out effects of calcite versus effects from water quality on incubation conditions.

4.3.1. Permitting Requirements and Egg Source Availability

Permitting requirements for use of in situ incubation techniques to assess the impact of calcite effects on incubation success in the Elk Valley were discussed with two Provincial biologists in Cranbrook (Heather Lamson, Fisheries Biologist and Herb Tepper, Habitat Biologist). Fish collection permits from FLNRO are required for both experimentation with in situ incubation cassettes loaded with outplanted eggs and the collection of wild emergent fry in emergence traps. An application for a Scientific Fish Collection Permit must be submitted to FrontCounter BC[4] Cranbrook for FLNRO review.

[4] http://www.frontcounterbc.gov.bc.ca/guides/fish-wildlife/scientific-fish-collection/overview/

The Provincial biologists do not support the use of wild Westslope Cutthroat Trout eggs for the incubation study, but would support the use of Westslope Cutthroat Trout triploid eggs from Connor Lake if no live eggs or fry are released back to the wild. These eggs are collected by Bull River Hatchery (Kootenay Trout Hatchery, near Cranbrook) every "even-year" as part of their hatchery program (see Appendix H for a description on the triploid process for trout at Bull River Hatchery). The use of triploid eggs and no release minimizes potential adverse effects on wild Fording River Westslope Cutthroat Trout. Triploid progeny are sterile and unable to reproduce. The practicalities (e.g., timing, cost, approvals, and methods) of obtaining triploid eggs for outlplanting into incubators to assess incubation survival in the Fording River watershed are discussed in Appendix H.

4.3.2. Considerations and Challenges

A study on the potential effects of calcite on the egg-to-fry survival of Westslope Cutthroat Trout can be conducted by evaluating egg incubation success at different sites with varying levels of calcite (low to high). There are two main types of study approach. The first approach involves outplanting hatchery-sourced fertilized eggs in enclosed containers and measuring egg-to-fry survival. This approach can control for the origin of the eggs and compare a metric of incubation success across different locations. Alternatively, naturally-produced redds can be sampled to estimate the number of fry that successfully emerge. (These approaches were reviewed and the specific methods and techniques used for these approaches are described in the Appendix H.) However, there are a number of challenges that need to be considered to determine if an egg incubation study would be beneficial to assessing calcite effects on egg-to-survival and to inform management decisions. These challenges are outlined below, along with a summary of Westslope Cutthroat Trout spawning habitat selection to inform feasibility of an egg-to-fry survival study.

4.3.2.1. Challenges of outplanting fertilized eggs in incubators across a gradient of calcite

In situ incubator design and installation considerations

Several in situ devices have been used in studies for determining the survival of eggs of fluvial spawners and have been used to incubate eggs within existing redds and other locations within a stream (summarized in Appendix H). However, these methods of assessing incubation success can lead to an over-estimate of fry survival because emergence from the gravel is not assessed. After hatching, fry must find their way into the water column through sediment interstices; fine sediments (or calcite) may create a physical barrier that prevents fry from emerging (Chapman 1988, Crisp 1996, Guerrin and Dumas 2001).

The dimensions, design, and techniques for installation of the egg incubators used will require careful consideration. Those with larger dimensions (e.g., Whitlock-Vibert box and the Jordan-Scotty incubator) will be difficult to place directly into an existing redd without disturbing the redd architecture that can be important for maintaining water flow through the redd (Chapman 1988). Given the variability in calcite conditions in the streams, and to maintain consistency in sampling, the egg incubators chosen for study would need to be robust enough to be installed in calcite but also require the least amount of disturbance. The need to disturb the substrate to outplant eggs will likely break the calcite cover, which may provide difficulty in assessing calcite effects to egg-fry-survival.

When eggs are outplanted in incubation devices there is a possibility that some eggs will die and be lost to decomposition (Paulwels and Haines 1994); though some dead eggs may persist, depending on the environmental conditions (e.g., Rubin 1995). Some in-stream incubators (such as the Whitlock-Vibert boxes) are prone to the spread of fungus among eggs that can lead to high mortality. Fungus usually establishes itself on dead eggs but can spread to live and healthy eggs. There is also a risk of disease transfer from hatchery eggs to the wild populations.

Various versions of egg capsules have also been used to monitor egg-to-fry survival. Egg capsules are compact and generally easy to install; a small hand trowel is used to excavate a depression and bury the unit in the substrate. However, they do require gravel disturbance when placed in natural redds and may be difficult to install in areas with higher calcite. A smaller screen liner is required to prevent loss of smaller alevins or fry. Though, there may be an offset, as it is presumed that the larger screen size provided better flow conditions and oxygen levels.

Egg incubator assessment methods that use an enclosed capsule will not provide insight on the influence of fines or substrate embeddedness on fry emergence.

Egg Development Considerations

One of the key considerations in outplanting studies is the developmental stage of the eggs. The use of triploid fertilized eggs that have only been incubating for 1-2 days would provide the longest period for egg-to-fry incubation survival assessment. Bull River Hatchery staff have successfully transported triploid eggs up to 2 days after fertilization; however, considerable coordination would be required to achieve outplanting within such a short time frame. It may be more feasible to outplant eggs when they are at the eyed stage, as newly-fertilized eggs are shock sensitive and care must be taken when transporting and loading the eggs into the gravel. Sealed buried capsules can be recovered at any stage to estimate survival, but ideally they would be recovered after hatch or around emergence.

Peak oxygen demand for incubating embryos occurs at hatch so the most sensitive period of development to dissolved oxygen conditions is likely to be at this stage. It should be noted that fluvial spawning salmonids select redd sites with physical characteristics that lead to higher embryonic survival and growth (Magee *et al.* 1996, Bernier-Bourgault and Magnan 2002) than other sites. Also, females modify the substrate composition during redd construction, such as removal of fine sediments (Chapman 1988).

The sediment composition and water quality of randomly selected incubation sites may differ considerably from that of a redd built by a spawning female. For many fluvial spawning salmonids, a number of habitat factors, such as water velocity, water temperature, ground water seepage, sedimentation, and bottom substrate composition influence survival and growth of embryos in a redd (Chapman 1988, Curry *et al.* 1994, 1995, Bernier-Bourgault and Magnan 2002). Therefore, the incubation methods are best considered for assessing relative success among sites, rather than absolute measures.

It will be a challenge to use the egg-to-fry survival results for management decisions with such a difference in spawning and embryonic growth conditions. Other concerns include the risk of escape and possibility of introgression, as the triploid process is not 100% effective.

4.3.2.2. Challenges of sampling wild redds to estimate the number of surviving fry across a gradient of calcite

The biggest challenge to this approach is that the Provincial biologists do not support the use of wild Westslope Cutthroat Trout eggs for the incubation study, and therefore this approach is unlikely to be permitted. Human-made redds could conceivably be constructed and challenges and considerations for measuring incubation success using redd caps, fry emergence traps, and hydraulic sampling techniques are summarized here.

Estimates of survival from egg deposition (fertilization) to emergence has been measured using redd caps or emergence traps. Emergence traps can be used to assess egg-to-fry survival when placed on human-made redds with a known number of deposited eggs. This approach is a more direct observation of realized fry survival but requires identifying a sufficient number of redds across different habitats and estimating the initial number of eggs in a redd. This can be done by measuring or estimating the length of the spawning female to determine fecundity. It is generally assumed that the female deposited all of the eggs at this location and no other female spawned in the immediate area. These may or may not be valid assumptions.

There are a number of challenges associated with the use of redd caps and fry emergence traps. These techniques are labour intensive, can have inherent inaccuracies associated with assumptions of female spawner fecundity, redd superimposition, egg loss during redd construction, trap efficiency (loss of fry that escape from the trap net), surface sedimentation caused by the trapping device, and high flows and debris damaging the trap (Bradford 1994, Radtke 2008, Fitzsimmons 2014). In addition, emerging fry may escape capture by moving laterally through the gravel. Lateral movements within gravel can be extensive in large uniform substrate, but would be negligible in substrates with high proportion of fines (Phillips and Koski 1969).

River flow conditions are an important consideration when choosing study sites for emergence traps; reaches with high river discharge should be avoided. Stable river flow conditions prior to and during the predicted fry emergence period allows for redd caps to be properly installed and remain sealed and functional until emergence is complete. After fry emergence, it is important to ensure that the redd cap is adequately sealed and maintains flow conditions inside the cap that are safe for the fry.

Hydraulic sampling is a field procedure that can be used to estimate total survival of wild salmonid eggs from egg deposition to the time of sampling; this method requires sampling prior to the onset of fry emergence. Survival estimates are based on estimates of female fecundity and the abundance of live eggs, alevins, or pre-emergent fry. Loss of eggs due to egg retention in the body cavity, water velocity during egg deposition, gravel scouring during flood events, and/or predation and decomposition, would be unaccounted-for sources of mortalities. Care must also be taken to only sample one redd at a time during the field assessment.

An experienced hydraulic sampler can effectively recover 93% of the contents of a redd in approximately 5-15 minutes with little egg/alevin/fry damage. McNeil (1964) estimated 0.24% mortality and found good agreement between hydraulic sampling survival and fry downstream trapping. However, in situations where the percent fines content and compaction in the gravel substrate (or calcite cover) is high, hydraulic sampling may be more difficult and corresponding survival less reliable (Bowerman *et al.* 2014, Franssen *et al.* 2012).

Varying levels of fine sediment in the spawning substrate can have a dramatic effect on emergence success (Weaver and Fraley 1993, Jensen *et al.* 2009, Koski 1966). The fry can be fully developed in the gravel but are entombed by fine sediment and cannot emerge (Bowerman *et al.* 2014, Franssen *et al.* 2012, Burt and Ellis 2006). In an incubation study conducted by DFO biological support staff in the 1980s, Coho Salmon eggs incubated in artificial upwelling incubators with only sand substrate all survived and were fully developed, but none were able to emerge (Lofthouse, pers. comm. 2017).

Kondolf (2000) reviewed and critiqued literature that assessed spawning gravel quality and incubation success. Kondolf found that the gravel requirements of salmonids differ with life stage as the role of the gravel changes. The interstitial sediments finer than about 1 mm (or <0.83 mm) reduce the permeability of the gravel and can prevent intragravel flow from providing sufficient oxygen to embryos and removing metabolic wastes, while sediments in the 1 –10 mm size range are known to block fry emergence through intragravel spaces.

4.3.2.3. Westslope Cutthroat Trout Spawning Site Selection

We reviewed the scientific literature to compile information on Westslope Cutthroat Trout spawning habitats selection, with a specific focus on spawning site hydraulics. Literature was identified using searches in Google Scholar. Due to a relative dearth of information on Westslope Cutthroat Trout specifically, the search was expanded to include literature related to the spawning hydraulics of spring spawning salmonids. The primary purpose of this review was to provide some insight into whether incubating embryos in natural redds would be subjected to downwelling or upwelling, and potential differences in water quality associated with groundwater versus surface water.

Our review confirmed that most studies examining spawning site hydraulics have focused on fall spawning species and that hydraulic properties of redds of spring spawning species are relatively understudied. We found no studies that directly assessed spawning site hydraulics of Westslope Cutthroat Trout. The literature review identified one study that assessed spawning site hydraulics of a spring spawning trout (Kuzishchin *et al.* 2008) and one study that inferred hydraulic conditions based on Arctic Grayling (*Thymallus arcticus*) spawning locations.

Though relatively limited, the literature on redd hydraulics of spring spawning trout suggests that spawning often occurs in areas of downwelling. Kuzishchin *et al.* (2008) report that Kamchatka Rainbow Trout (*Parasalmo mykiss*) spawn exclusively in areas of downwelling. Spawning site selection by Rainbow Trout (*Oncorhynchus mykiss*) in North America has been studied (Workman *et al.* 2004, Holecek and Walters 2007); however, groundwater hydraulics have not been reported. Additionally, Arctic Grayling have been observed spawning on gravel bars, which Zeh and Dohi (1999) suggest may be areas of downwelling.

Studies examining the spawning site hydraulics of fall spawning salmonids have focused on Bull Trout (*Salvelinus confluentus*; Baxter and Hauer 2000), Brook Trout (*S. fontinalis*; Curry and Noakes 1995), Chinook Salmon (*O. tshawytscha*; Geist and Dauble 1998), Coho Salmon (*O. kisutch*; Mull and Wilzbach 200), Chum Salmon (*O. keta*; Geist *et al.* 2002), Sockeye Salmon (*O. nerka*; Hall & Wissmar 2004) and Atlantic Salmon (*S. salar*; Alexander and Caissie 2003, Beechie *et al.* 2008). Studies of Pacific Salmon species have predominantly observed increased spawning activity in areas where upwelling groundwater maintains stable temperature and oxygen levels throughout the winter (Groot and Margolis 1991, Beechie *et al.* 2008). Atlantic Salmon studies consistently report increased spawning activity in areas of upwelling and downwelling (e.g. Alexander and Caissie 2003, Beechie *et al.* 2008), and findings by Coulombe-Pontbriande and Lapointe (2004) suggest that hyporheic exchange may have a greater influence than substrate quality on site selection by this species. Baxter and Hauer (2000) report that Bull Trout selected downwelling spawning sites, despite an abundance of upwelling within spawning reaches. Spawning reaches used by Brook Trout are often influenced by upwelling; however, selection of spawning sites based on groundwater hydraulics has not been verified (Curry *et al.* 1995).

5. DISCUSSION

5.1. Incubation Conditions

5.1.1. Fish Habitat, Calcite Index, and Hyporheic Conditions

The objectives of this study component were to:

- Test the modifications made to the 2016 methods;
- Sample additional water quality parameters; and
- Expand on the results from the 2016 Calcite Effects program to assess the extent to which hyporheic DO and flow are influenced by calcite by sampling two additional creeks (LCO Dry Creek and Henretta Creek) within the Upper Fording watershed.

Hyporheic DO and flow are of interest due to their influence on incubation success of salmonid eggs buried in stream substrates.

The method to collect hyporheic DO, water quality, and flow measurements was modified for the 2017 field program based on EMC review comments from the 2016 study results. The modifications to the 2016 methods included the use of piezometers with smaller screen lengths, a larger diameter inner drive point during piezometer installation, purging water within the piezometer prior to measuring hydraulic head and DO at each depth, and installing a shallow stilling well over the piezometer when taking hydraulic head measurements. Both sampling techniques (unmodified and modified) were used to measure DO and hydraulic head at GRE-CA01 and GRE-CA03, and mixed-effects modelling was used to compare the data collected. The modifications to the 2016 methods had no significant effect on the observed dissolved oxygen or the hyporheic flow at the two Greenhills Creek sites, and validate the results obtained during the 2016 field program. For this reason, all data from 2016 and 2017 were combined and used to test the impact hypothesis (see Section 5.1.2.)

The additional sites measured in 2017 had relatively low CI scores (0.00 to 0.90). Similar to the results found during the 2016 program, CI measured at the mesohabitat scale generally showed good agreement and low variance with CI measured within the mesohabitat, suggesting that the CI score at the mesohabitat scale is representative of calcite presence and concretion at smaller scales within the mesohabitat. Data presented here show relative consistency in CI within each mesohabitat unit, but there was high spatial variance in the response and predictor variables within the sites.

At the EMC#12 Meeting there was interest in expanding the scope of measurements to assess other water quality constituents to help understand whether shallow hyporheic water quality is notably different than water quality in the water column above the substrate. Similar to the 2016 study results, DO generally declined with increased depth in the substrate, while water temperature increased with depth with the exception of the Henretta Creek sites where there were no discernible trends in water temperature with depth in the substrate. The majority of sites had similar total and dissolved metal concentrations in the surface water as in the hyporheic water; calcium and magnesium concentrations were the exception, with higher concentrations found at depth in Greenhills Creek. Suspended solids and turbidity concentrations were also greater at depth at the Greenhills sites, while total dissolved solids was greater in the surface water compared to hyporheic water at 50 cm depth. Water hardness (as $CaCO_3$) and bromide concentrations were higher in the surface water than hyporheic water at LCDRY-CA02, compared to the difference in concentrations between the surface and hyporheic water at other sites.

An in-depth analysis of the water quality results was beyond the scope of this study, but samples were screened against the applicable BC WQG for the protection of aquatic life. DO concentrations were typically above the instantaneous minimum BC WQG (6 mg/L) and the 30-day minimum (8 mg/L), though concentrations at the Greenhills Creek sites fluctuated about the 30-day guideline suggesting that if these concentrations were experienced over the long-term, adverse effects to buried life stages may occur. At all sites, specific conductivity was higher than typically observed in BC surface water (100 to 500 µS/cm), indicting natural variability of dissolved ions in this region, anthropogenic effects (e.g., logging), and/or inputs (e.g., mining, wastewater) may be occurring. The following water quality parameters were observed to be above the applicable short-term or long-term BC WQG (MOE 2018):

- Total selenium in all three creeks;
- Nitrate at Greenhills Creek and Henretta Creek sites; and
- Uranium and sulphate at Greenhills Creek sites only.

The above water quality parameters were also above the applicable EVWQP Level 1 and Level 2 benchmarks, with the exception of nitrate concentrations which were below the hardness-dependent EVWQP benchmarks for fish in the Fording River at all sites. Water hardness (as $CaCO_3$) was high in Greenhills Creek ranging from 1,070 to 1,080 mg/L; values did not change appreciably with depth.

Estimates of hyporheic flow were derived from the hydraulic head method (Darcy's equation) using piezometers. There was general consistency in the direction of flow measured by the hydraulic head method within piezometer sites, but not among piezometer locations across the channel. Both upwelling and downwelling flow was observed at all three creeks. The strongest and weakest downwelling rates were observed at Henretta Creek, followed by LCO Dry Creek, where one of the sites (LCDRY-CA01) also exhibited weak upwelling at 30 cm depth. The average groundwater exchange rates for all sites ranged from -1.8 to 332.3 m/day at 30 cm depth and 0.5 to 187.0 m/day at 50 cm depth; the maximum groundwater exchange rate was less than 55 m/d at all but two of the sites at 30 cm depth, and all but one site at 50 cm depth. The groundwater exchange rates were unrealistically high at two of the sites (LCDRY-CA02 and HEN-CA01) given typical groundwater exchange rates observed in the literature. The high values are likely due to the difficulty in accurately estimating hydraulic conductivity based on GSD relations. It is therefore recommended that the groundwater exchange rates obtained from the hydraulic head method be treated as indicative of direction of flow and relative magnitude, but not absolute magnitude.

5.1.2. Testing the Impact Hypothesis

Data collected over two years (2016 and 2017) show that stream sites with higher calcite index scores had lower DO in the substrate, but not lower hyporheic flow as measured using the hydraulic head method. Results from 2016 and 2017 show that CI is an important predictor of DO concentrations in the substrate, but this effect increases with depth in the substrate. This result is intuitive, in that shallow depths within the substrate likely experience greater DO and water exchange with the surface water column than do points deeper in the substrate, even in the presence of high CI. Depending on the extent of exchange, there may be generally sufficient DO to offset biological and chemical DO consumption in shallow substrates. Since exchange is less at greater depths within the substrate, the DO levels may be influenced more by biological and chemical DO consumption. The model for DO predicts that average instantaneous DO is ~7.5 mg/L at a depth of 30 cm at a CI score of 3 (green line in Figure 15). At a depth of 50 cm, average instantaneous DO is predicted to be ~6 mg/L at a CI Score of 3 (blue line in Figure 15). DO in the substrate also decreased with higher % fines. For example, the lower Greenhills sites (GRE-CA01 and GRE-CA02) had relatively high % fines and low DO, particularly deeper in the substrate.

The average redd depth for Westslope Cutthroat Trout is between 10 and 30 cm (DeVries 1997, Magee and McMahon 1996). Using a maximum egg deposition depth of 30 cm, our model predicts that average DO concentrations during incubation will be above 6 mg/L (the instantaneous minimum threshold for buried embryos/alevins from the BC WQG) at all levels of calcite in the stream. However, these model predictions represent mean conditions, and occasional or periodic exceedances of the BC WQG may occur at some sites, particularly where fines occur in conjunction with high CI scores; however, there is insufficient data to determine how often DO was above BC WQGs. We caution that the effect of calcite on DO is most apparent at depths that are deeper than typical redd depths of Westslope Cutthroat Trout.

Westslope Cutthroat Trout may not spawn frequently in substrates with CI scores greater than some threshold. We tested the relationship between CI scores and hyporehic conditions using a subset of the data (CI < 1.25) chosen to reflect possible conditions when Westslope Cutthroat Trout may have easier access to the substrate for spawning. An effect of CI on DO was observed with the subsetted dataset, although the results were weaker when compared to those using all of the data (CI < 3), at least partly due to a smaller sample size of the subsetted data. DO concentrations below the minimum guidelines for the protection of buried life stages were observed in this study, but the most significant effects on incubation conditions are predicted at sites with CI scores higher than ~1.25, sites with relatively high % fines, and at depths deeper than typical redd depths. This suggests that at depths less than 30 cm, DO concentrations and interstitial flow may not be an important factor in determining spawning success. Additional investigation effort may therefore be better placed on understanding the relation between CI and fish spawning, the current availability of useable spawning habitats, and trends in availability.

CI was not a predictor of hyporheic flow as measured with the hydraulic head method. The top model using both the full dataset and the subsetted data (CI < 1.25) was the null model. Calcite and the other measured habitat variables were generally poor predictors of hyporheic flow measured using the hydraulic head method. After two years of sampling it appears that calcite presence and concretion does not markedly and consistently alter flow within the substrate, at least over the range of conditions assessed.

Overall, we conclude that stream sites with high levels of calcite may experience some reduction in hyporheic DO, although these effects are predicted to be greatest at depths greater than typical Westslope Cutthroat Trout spawning and at CI scores that may prevent access to the substrate for spawning. The methods were employed at 16 sites in five different streams with large variations in environmental conditions (e.g., CI, stream width, substrate type and size, flow velocity, and water depth), and repeated across two years of data collection (2016 and 2017). Hyporheic and environmental conditions were highly heterogeneous both among and within sites, and with depth. Despite the range in conditions, the DO and hydraulic head measurements were fairly consistent across sites, lending confidence that these results are applicable to a wider range of settings in the Elk Valley.

5.2. Spawning Conditions

Habitat data (FHAP and substrate composition) and mesohabitat-specific calcite (CI) data were collected on three tributaries (Greenhills Creek, LCO Dry Creek, and Henretta Creek) during the 2017 field program to support the development of a calcite vs. habitat response curve as part of the ongoing investigation of spawning conditions. Redd surveys were carried out on LCO Dry Creek in June and early July 2017, as part of ongoing work and permit requirements associated with another Teck biological program (Faulkner *et al.* 2018). Redd surveys on Greenhills Creek and Henretta Creek are planned for 2018. A database of the observations collected in 2017 (redds and predictor variable values) was developed, but analysis of these data has been deferred until additional data, sampled across a wide range of conditions, has been collected.

5.3. Other Assessment Methods

At the EMC#12 Meeting there was discussion about the potential use of two field-based methods, incubation cassettes and emergence traps to assess egg-to-fry survival. There are various techniques that could assess the potential effects of calcite on the survival of Westslope Cutthroat Trout eggs (these are described in Appendix H). A study could be performed that compares egg incubation survival in areas with low and high levels of calcite (or across a gradient of calcite). Two general groups of approaches are possible. First, hatchery-origin fertilized eggs could be outplanted in incubators in areas with low and high levels of calcite. The review of current methodology indicates that there are various types of containers with different strengths and weaknesses (see Appendix H). The logistics of this approach seem feasible and permissible, based on conversations with hatchery and provincial staff and scientists. however, there are a number of challenges and considerations that need to be taken into account. Embryos are sensitive to mechanical shock from about one hour after fertilization until the eyed egg stage. To achieve exposure durations equivalent to wild embryos would require stream-side fertilization and use of diploids rather than triploids. This approach would likely meet permitting challenges. The need to disturb the substrate to outplant eggs would break the calcite cover, making it difficult to assess calcite effects on egg survival across a gradient of calcite conditions. There is some risk of disease transfer and escape of embryos, either of which present risks for the wild population.

The second category of approaches — sampling of wild redds — could provide information on the number of surviving fry across different locations with spawning trout. However, use of hydraulic sampling or emergence traps requires good estimates of the number of deposited eggs, which can be challenging, and there may be more difficulty obtaining permits for investigation of wild redds with intrusive techniques.

6. CONSIDERATIONS FOR 2018 CALCITE EFFECTS PROGRAM

We suggest the following tasks be considered as part of the 2018 Calcite Biological Program:

1. Consider which aspects of the effect pathways (Figure 1) are the highest priority for investigation. We suggest that data from 2016 and 2017 indicate that impact hypothesis H1 is less important than other pathways. Other pathways, such as H2, should be the focus of work in 2018.

2. Continue data collection and analysis related to impact hypothesis H2. Development of a response curve for calcite as it relates to spawning habitat suitability for salmonids requires additional data from redd surveys on tributaries in combination with the collection of habitat data. At this time, it seems reasonable to continue to focus on tributary habitats in the upper Fording. Additional work could include redd surveys on Greenhills Creek and Henretta Creek, and habitat measurements at these sites such as CI, substrate type, cover, gradient, water quality (e.g., DO, pH, water temperature), and other covariates of interest. We should select additional sites for sampling that are representative of spawning habitat across a wide range of calcite conditions (while understanding that high calcite may preclude use of potential spawning habitats). At the same time, detecting and measuring Westslope Cutthroat Trout spawning intensity in the upper Fording is fraught with real challenges, such as variable spawn timing, variable longevity of detectability of redds, distinguishing between redds and other disturbances, and field conditions like variable flows and water clarity.

3. The EMC previously indicated interest in direct assessment of incubation success in streams affected by calcite. The review of potential methods, as provided in this report, indicates potential approaches for use in the Elk Valley. Our discussions with agencies also indicated that it is possible to obtain the necessary permits for implementing some of these techniques, such as use of triploid hatchery stock. Based on a review of possible techniques, experimental design, permitting challenges, and discussions with the EMC, we recommend not proceeding with the in situ incubation experiments at this time. In the meantime, the program should focus on building the calcite vs. spawning response curve and understanding the outcome of calcite mitigations.

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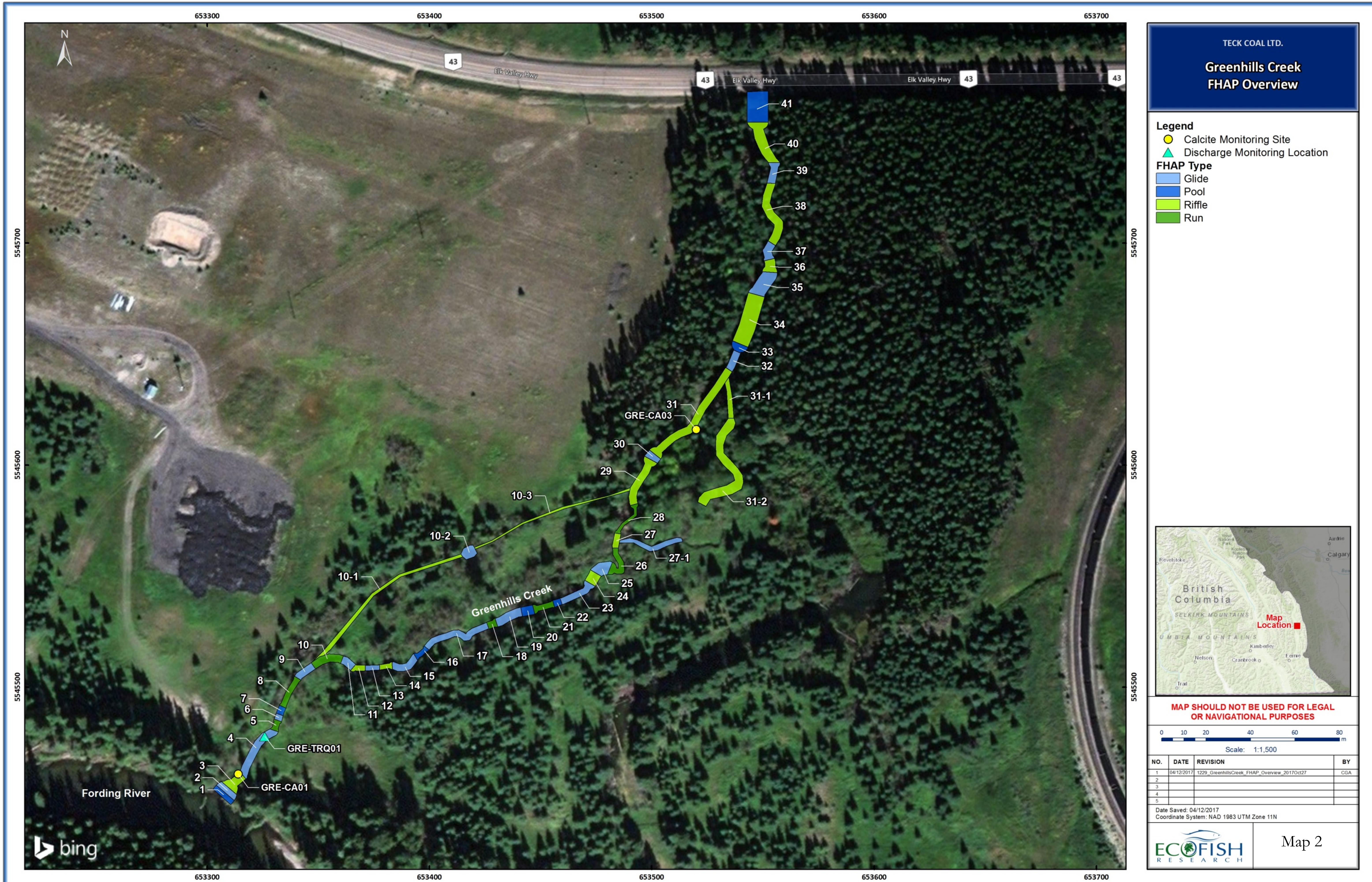
PROJECT MAPS



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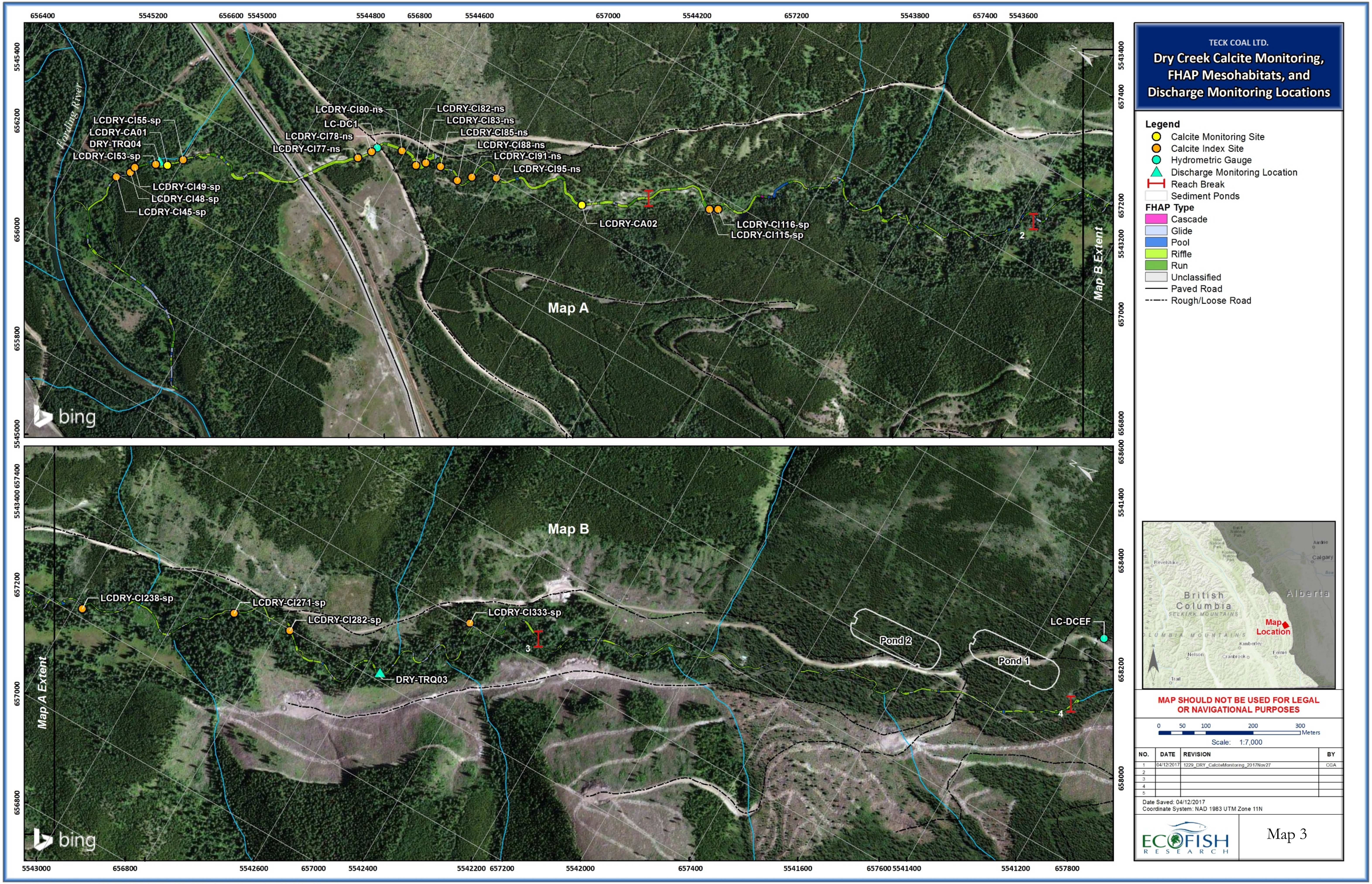

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APPENDICES

Appendix A. Calcite Study Site Photographs

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Figure 1. Looking upstream at GRE-CA01 on August 26, 2017.

Figure 2. Looking downstream at GRE-CA01 on August 26, 2017.

Figure 3. Looking RR to RL at GRE-CA01 on August 26, 2017.

Figure 4. Looking upstream at GRE-CA03 on August 28, 2017.

Figure 5. Looking downstream at GRE-CA03 on August 28, 2017.

Figure 6. Looking RR to RL at at GRE-CA03 on August 28, 2017.

Figure 7. Looking upstream at LCDRY-CA01 on August 29, 2017.

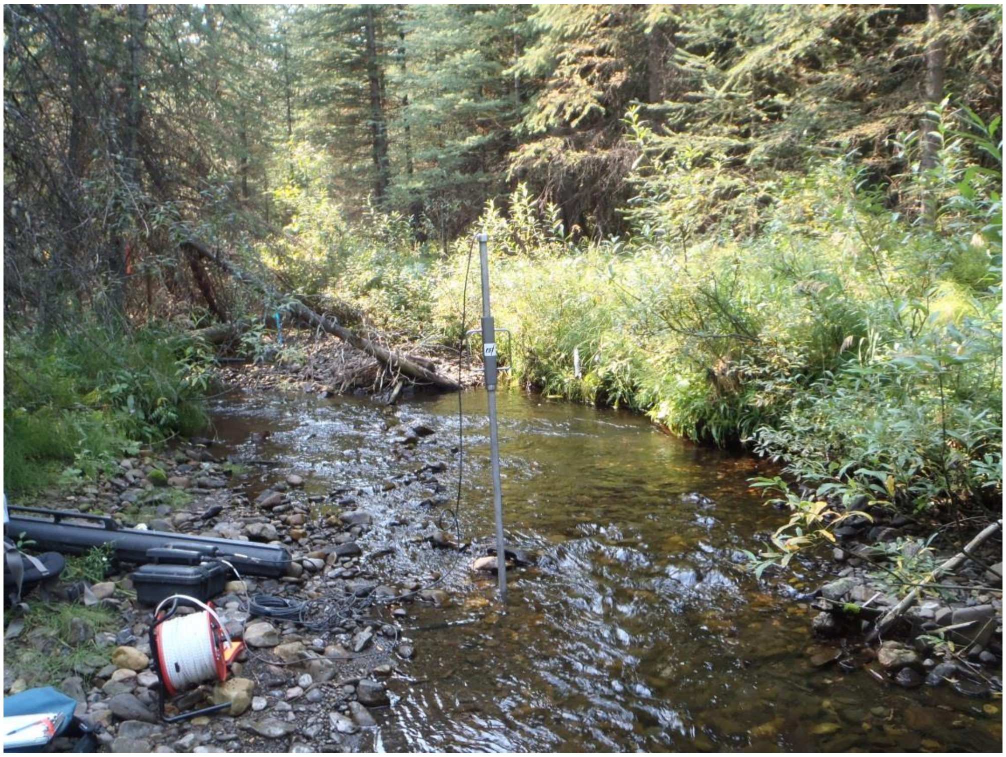

Figure 8. Looking downstream at LCDRY-CA01 on August 29, 2017.

Figure 9. Looking RR to RL at LCDRY-CA01 on August 29, 2017.

Figure 10. Looking upstream at LCDRY-CA02 on August 31, 2017.

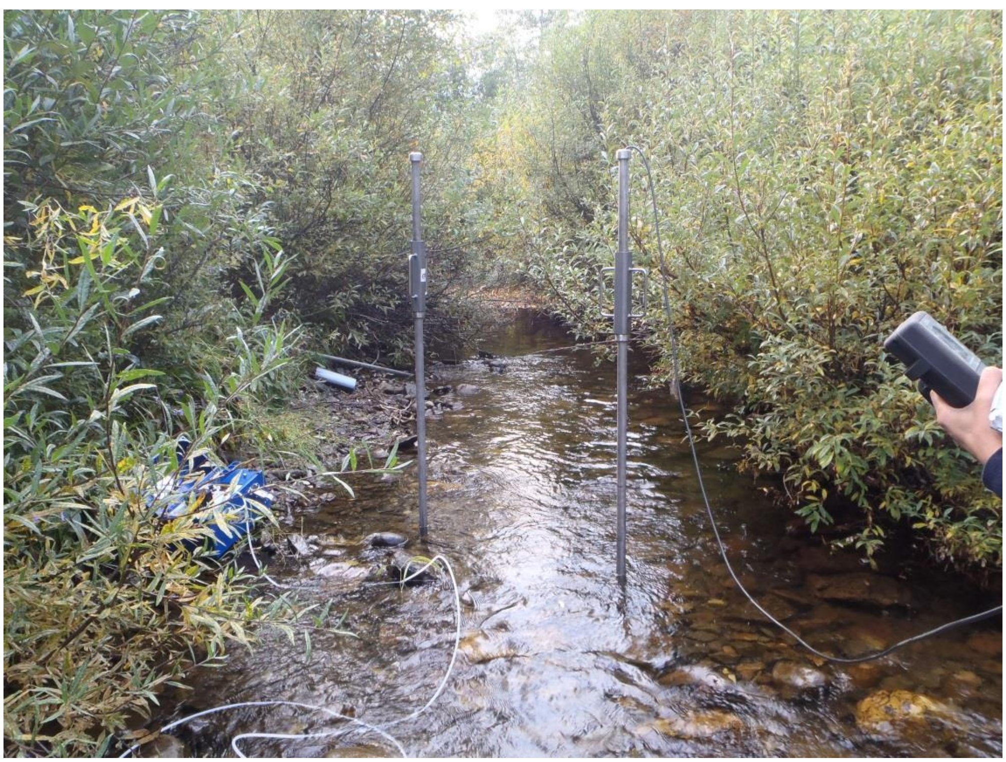

Figure 11. Looking downstream at LCDRY-CA02 on August 31, 2017.

Figure 12. Looking RL to RR at LCDRY-CA02 on August 31, 2017.

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Figure 13. Looking upstream at HEN-CA01 on August 30, 2017.

Figure 14. Looking downstream at HEN-CA01 on August 30, 2017.

Figure 15. Looking RL to RR at HEN-CA01 on August 30, 2017.

Figure 16. Looking upstream at HEN-CA02 on September 1, 2017.

Figure 17. Looking downstream at HEN-CA02 on September 1, 2017.

Figure 18. Looking RR to RL at HEN-CA02 on September 1, 2017.

Appendix B. Fish Habitat Assessment Procedure (FHAP) Data and Photographs

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Table 1. FHAP information for Greenhills Creek collected August 26, 2017.

Unit Number	Type	Category	Unit Length (m)	Width		Area		Average Water Depth (m)	Gradient (%)	Weighted Gradient (%)	Substrate[1]		Dominant Cover[2]		Sub-dominant Cover[2]	
				Wetted Width (m)	Bankfull Width (m)	Wetted Area (m^2)	Bankfull Area (m^2)				Dominant	Sub-dominant	Type	%	Type	%
1	Pool	Primary	2.4	1.7	10.7	4.1	25.7	0.29	0.0	0.0	S/FI	GR	DP	50	LWD	30
2	Glide	Primary	2.7	1.55	7.8	4.2	21.1	0.18	1.0	2.7	S/FI	GR	LWD	60	SWD	10
3	Riffle[3]	Primary	8.5	2.4	4.3	20.4	36.6	0.07	2.0	17.0	GR	CO	OV	30	SWD	5
4	Glide	Primary	25.6	3	3.7	76.8	94.7	0.26	0.5	12.8	S/FI	CO	OV	20	SWD	15
5	Run	Primary	4.75	2.14	2.7	10.2	12.8	0.18	0.5	2.4	S/FI	GR	LWD	40	OV	20
6	Glide	Primary	2.8	2.2	3.5	6.2	9.8	0.24	0.5	1.4	GR	S/FI	SWD	15	OV	10
7	Pool	Primary	3.75	2	3.3	7.5	12.4	0.41	0.0	0.0	S/FI	GR	LWD	25	DP	20
8	Run	Primary	14.5	2	2.7	29.0	39.2	0.33	2.5	36.3	S/FI	-	LWD	60	OV	10
9	Glide	Primary	9.1	1.5	3.4	13.7	30.9	0.34	0.5	4.6	S/FI	GR	SWD	30	LWD	20
10	Run	Primary	13.9	1.95	3.6	27.1	50.0	0.26	1.5	20.9	S/FI	GR	SWD	60	CU	10
10-1	Riffle	Secondary	82.4	0.9	1.2	74.2	98.9	0.05	1.5	123.6	S/FI	-	SWD	50	OV	40
10-2	Glide	Secondary	6.1	1.1	4.8	6.7	29.3	0.11	0.5	3.1	S/FI	-	SWD	30	LWD	20
10-3	Riffle	Secondary	64.3	0.75	0.8	48.2	51.4	0.08	1.0	64.3	S/FI	-	SWD	35	LWD	20
11	Glide	Primary	6.2	3.05	3.7	18.9	22.9	0.29	1.0	6.2	S/FI	-	OV	30	DP	20
12	Riffle	Primary	5.5	2.1	2.7	11.6	14.9	0.18	2.0	11.0	GR	CO	BO	30	LWD	20
13	Glide	Primary	6.5	2	2.5	13.0	16.3	0.29	0.0	0.0	S/FI	GR	BO	30	OV	15
14	Riffle	Primary	5.7	2.1	2.3	12.0	13.1	0.09	2.5	14.3	GR	CO	BO	15	OV	10
15	Glide	Primary	12.8	3.1	3.4	39.7	43.5	0.37	0.0	0.0	S/FI	CO	OV	15	LWD	10
16	Pool	Primary	6.5	1.9	2.2	12.4	14.3	0.56	0.0	0.0	S/FI	-	DP	60	OV	20
17	Glide	Primary	31.9	2.5	3	79.8	95.7	0.29	0.3	8.0	S/FI	GR	OV	15	LWD	10
18	Run	Primary	4.1	2.7	3.3	11.1	13.5	0.18	1.0	4.1	GR	S/FI	OV	20	LWD	15
19	Glide	Primary	12.4	3.6	4.1	44.6	50.8	0.20	0.3	3.1	S/FI	GR	LWD	50	OV	30
20	Pool	Primary	5.6	2.9	4.3	16.2	24.1	0.42	0.0	0.0	S/FI	CO	LWD	40	OV	30
21	Run	Primary	9.22	1.5	2.6	13.8	24.0	0.15	1.5	13.8	S/FI	GR	LWD	70	OV	10
22	Pool	Primary	3.6	2.9	3.2	10.4	11.5	0.46	0.0	0.0	S/FI	GR	LWD	40	DP	30
23	Glide	Primary	15.9	2.9	3.1	46.1	49.3	0.41	0.0	0.0	S/FI	GR	SWD	10	OV	10
24	Riffle	Primary	5.3	2.8	5.4	14.8	28.6	0.20	1.5	8.0	S/FI	GR	SWD	40	OV	15
25	Glide	Primary	7.1	5.4	5.8	38.3	41.2	0.22	0.3	1.8	S/FI	GR	SWD	25	LWD	15
26	Run	Primary	16.6	1.8	2.5	29.9	41.5	0.27	2.0	33.2	S/FI	GR	BO	30	SWD	20

[1] BO = Boulder, CO = Cobble, GR = Gravel, S/FI = Sand/Fines

[2] BO = Boulder, DP = Deep Pool, LWD = Large Woody Debris, LC = Large Cobble, CU = Undercut Bank, OV = Overhead Vegetation

[3] Location of monitoring site.

Table 1. Continued.

Unit Number	Type	Category	Unit Length (m)	Width		Area		Average Water Depth (m)	Gradient (%)	Weighted Gradient (%)	Substrate[1]		Dominant Cover[2]		Sub-dominant Cover[2]	
				Wetted Width (m)	Bankfull Width (m)	Wetted Area (m^2)	Bankfull Area (m^2)				Dominant	Sub-dominant	Type	%	Type	%
27	Riffle	Primary	6.7	2.62	2.9	17.6	19.4	0.10	4.0	26.8	GR	GR	OV	20	SWD	10
27-1	Glide	Secondary	31.8	0.42	1.9	13.4	60.4	0.08	2.0	63.6	S/FI	GR	SWD	30	OV	15
28	Run	Primary	16.5	1.2	1.5	19.8	24.8	0.18	2.0	33.0	GR	S/FI	OV	30	BO	25
29	Riffle	Primary	22.4	2.3	3.6	51.5	80.6	0.15	2.0	44.8	GR	CO	SWD	20	OV	8
30	Glide	Primary	3	2.2	6.6	6.6	19.8	0.24	0.5	1.5	S/FI	GR	SWD	40	BO	5
31	Riffle[3]	Primary	51.8	1.6	3.6	82.9	186.5	0.14	4.0	207.2	CO	GR	BO	15	SWD	10
31-1	Riffle	Secondary	15.3	0.85	2.5	13.0	38.3	0.07	4.0	61.2	S/FI	GR	SWD	25	OV	5
31-2	Riffle	Secondary	44	1.15	3.7	50.6	162.8	0.09	3.0	132.0	GR	CO	LWD	10	OV	10
32	Glide	Primary	8.9	2.3	3.4	20.5	30.3	0.21	2.0	17.8	CO	CO	BO	30	LWD	10
33	Pool	Primary	3.65	1.4	2.8	5.1	10.2	0.38	0.0	0.0	S/FI	CO	LWD	40	DP	20
34	Riffle	Primary	23.4	2.7	7.6	63.2	177.8	0.12	4.0	93.6	CO	CO	BO	25	LWD	20
35	Glide	Primary	12	2.2	6.7	26.4	80.4	0.17	0.5	6.0	CO	CO	BO	25	CU	15
36	Riffle	Primary	5.7	2	4.9	11.4	27.9	0.13	4.0	22.8	CO	CO	BO	20	SWD	8
37	Glide	Primary	8.1	2.4	3.9	19.4	31.6	0.22	1.5	12.2	S/FI	CO	SWD	20	BO	15
38	Riffle	Primary	37.2	3.6	4.1	133.9	152.5	0.16	4.0	148.8	CO	CO	BO	30	OV	5
39	Glide	Primary	8.8	2.6	3.6	22.9	31.7	0.19	1.0	8.8	GR	CO	BO	20	OV	15
40	Riffle	Primary	27.1	3.6	5.3	97.6	143.6	0.13	4.0	108.4	CO	GR	LWD	30	BO	15
41	Pool	Primary	14	9.1	9.5	127.4	133.0	0.78	0.0	0.0	S/FI	CO	DP	80	LWD	10

[1] BO = Boulder, CO = Cobble, GR = Gravel, S/FI = Sand/Fines

[2] BO = Boulder, DP = Deep Pool, LWD = Large Woody Debris, LC = Large Cobble, CU = Undercut Bank, OV = Overhead Vegetation

[3] Location of monitoring site.

Table 2. FHAP information for HEN-CA01 collected on September 1, 2017.

Unit Number	Type	Category	Unit Length (m)	Width		Area		Average Water Depth (m)	Gradient (%)	Weighted Gradient (%)	Substrate[1]		Dominant Cover[2]		Sub-dominant Cover[2]	
				Wetted Width (m)	Bankfull Width (m)	Wetted Area (m^2)	Bankfull Area (m^2)				Dominant	Sub-dominant	Type	%	Type	%
1	Riffle	Primary	86.0	11.0	18.30	946	1574	0.12	3.0	258.0	CO	BO	BO	30	SWD	5
2	Glide[3]	Primary	19.2	11.0	16.50	211	317	0.22	1.0	19.2	CO	GR	BO	20	SWD	3
3	Riffle	Primary	25.6	6.0	14.60	154	374	0.25	4.0	102.4	CO	GR	BO	30	SWD	5

[1] BO = Boulder, CO = Cobble, GR = Gravel, S/FI = Sand/Fines

[2] BO = Boulder, DP = Deep Pool, LWD = Large Woody Debris, LC = Large Cobble, CU = Undercut Bank, OV = Overhead Vegetation

[3] Location of monitoring site.

Table 3. FHAP information for HEN-CA02 collected on August 30, 2017.

Unit Number	Type	Category	Unit Length (m)	Width		Area		Average Water Depth (m)	Gradient (%)	Weighted Gradient (%)	Substrate[1]		Dominant Cover[2]		Sub-dominant Cover[2]	
				Wetted Width (m)	Bankfull Width (m)	Wetted Area (m^2)	Bankfull Area (m^2)				Dominant	Sub-dominant	Type	%	Type	%
1	Run	Primary	35.0	10.10	12.80	353.5	448.0	0.41	1.5	52.5	CO	BO	BO	20	LC	10
2	Riffle	Primary	39.3	9.10	19.20	357.6	754.6	0.42	2.5	98.3	BO	GR	BO	35	LC	5
3	Riffle[3]	Primary	66.0	20.10	24.70	1326.6	1630.2	0.18	1.5	99.0	CO	BO	BO	20	LWD	5
4	Glide	Primary	22.0	13.70	22.00	301.4	484.0	0.44	0.5	11.0	CO	BO	BO	20	LC	5

[1] BO = Boulder, CO = Cobble, GR = Gravel, S/FI = Sand/Fines

[2] BO = Boulder, DP = Deep Pool, LWD = Large Woody Debris, LC = Large Cobble, CU = Undercut Bank, OV = Overhead Vegetation

[3] Location of monitoring site.

Figure 1. Looking downstream at GRE FHAP Unit 1 on August 26, 2017.

Figure 2. Looking downstream at GRE FHAP Unit 2 on August 26, 2017.

Figure 3. Looking downstream at GRE FHAP Unit 3 on August 26, 2017.

Figure 4. Looking upstream at GRE FHAP Unit 4 on August 26, 2017.

Figure 5. Looking upstream at GRE FHAP Unit 5 on August 26, 2017.

Figure 6. Looking downstream at GRE FHAP Unit 6 on August 26, 2017.

Figure 7. Looking downstream at GRE FHAP Unit 7on August 26, 2017.

Figure 8. Looking downstream at GRE FHAP Unit 8 on August 26, 2017.

Figure 9. Looking downstream at GRE FHAP Unit 9 on August 26, 2017.

Figure 10. Looking downstream at GRE FHAP Unit 10 on August 26, 2017.

Figure 11. Looking upstream at GRE FHAP Secondary Unit 10-1 on August 26, 2017.

Figure 12. Looking downstream at GRE FHAP Secondary Unit 10-2 on August 26, 2017.

Figure 13. Looking downstream at GRE FHAP Secondary Unit 10-3 on August 26, 2017.

Figure 14. Looking downstream at GRE FHAP Unit 11 on August 26, 2017.

Figure 15. Looking upstream at GRE FHAP Unit 12 on August 26, 2017.

Figure 16. Looking upstream at GRE FHAP Unit 13 on August 26, 2017.

Figure 17. Looking upstream at GRE FHAP Unit 14 on August 26, 2017.

Figure 18. Looking upstream at GRE FHAP Unit 15 on August 26, 2017.

Figure 19. Looking downstream at GRE FHAP Unit 16 on August 26, 2017.

Figure 20. Looking downstream at GRE FHAP Unit 17 on August 26, 2017.

Figure 21. Looking downstream at GRE FHAP Unit 18 on August 26, 2017.

Figure 22. Looking upstream at GRE FHAP Unit 19 on August 26, 2017.

Figure 23. Looking upstream at GRE FHAP Unit 20 on August 26, 2017.

Figure 24. Looking upstream at GRE FHAP Unit 21 on August 26, 2017.

Figure 25. Looking river left to river right at GRE FHAP Unit 22 on August 26, 2017.

Figure 26. Looking downstream at GRE FHAP Unit 23 on August 26, 2017.

Figure 27. Looking downstream at GRE FHAP Unit 24 on August 26, 2017.

Figure 28. Looking river left to river right at GRE FHAP Unit 25 on August 26, 2017.

Figure 29. Looking downstream at GRE FHAP Unit 26 on August 26, 2017.

Figure 30. Looking downstream at GRE FHAP Unit 27 on August 26, 2017.

Figure 31. Looking downstream at GRE FHAP Secondary Unit 27-1 on August 26, 2017.

Figure 32. Looking upstream at GRE FHAP Unit 28 on August 26, 2017.

Figure 33. Looking upstream at GRE FHAP Unit 29 on August 26, 2017.

Figure 34. Looking downstream at GRE FHAP Unit 30 on August 26, 2017.

Figure 35. Looking downstream at GRE FHAP Unit 31 on August 26, 2017.

Figure 36. Looking downstream at GRE FHAP Secondary Unit 31-1 on August 26, 2017.

Figure 37. Looking downstream at GRE FHAP Unit 31-2 on August 26, 2017.

Figure 38. Looking downstream at GRE FHAP Unit 32 on August 26, 2017.

Figure 39. Looking upstream at GRE FHAP Unit 33 on August 26, 2017.

Figure 40. Looking downstream at GRE FHAP Unit 34 on August 26, 2017.

Figure 41. Looking downstream at GRE FHAP Unit 35 and Unit 36 on August 26, 2017.

Figure 42. Looking upstream at GRE FHAP Unit 37 on August 26, 2017.

Figure 43. Looking upstream at GRE FHAP Unit 38 on August 26, 2017.

Figure 44. Looking upstream at GRE FHAP Unit 39 on August 26, 2017.

Figure 45. Looking downstream at GRE FHAP Unit 40 on August 26, 2017.

Figure 46. Looking river right to river left at GRE FHAP Unit 41 on August 26, 2017.

Figure 47. Looking downstream at HEN-CA01 Unit 1 on August 30, 2017.

Figure 48. Looking upstream at HEN-CA01 Unit 2 on August 30, 2017.

Figure 49. Looking upstream at HEN-CA01 Unit 3 on August 30, 2017.

Figure 50. Looking upstream at HEN-CA02 Unit 1 on September 1, 2017.

Figure 51. Looking upstream at HEN-CA02 Unit 2 on September 1, 2017.

Figure 52. Looking downstream at HEN-CA02 Unit 3 on September 1, 2017.

Figure 53. Looking upstream at HEN-CA02 Unit 4 on September 1, 2017.

Appendix C Substrate Grain Distribution Plots

LIST OF FIGURES

Figure 1. Substrate Grain Distribution at GRE-CA01 (mesohabitat site) in Greenhills Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

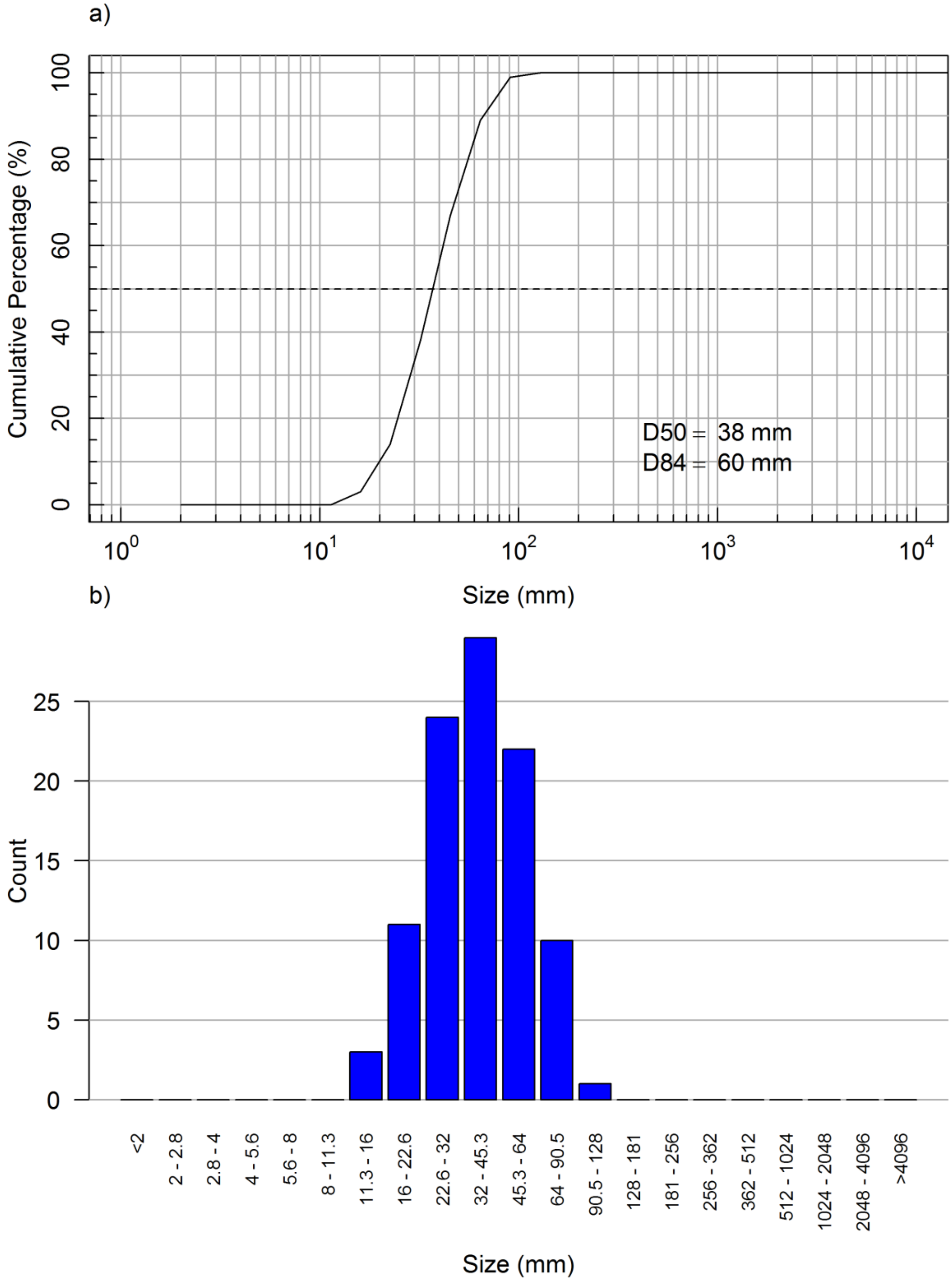


Figure 2. Substrate Grain Distribution at GRE-CA01 (piezometer site) in Greenhills Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

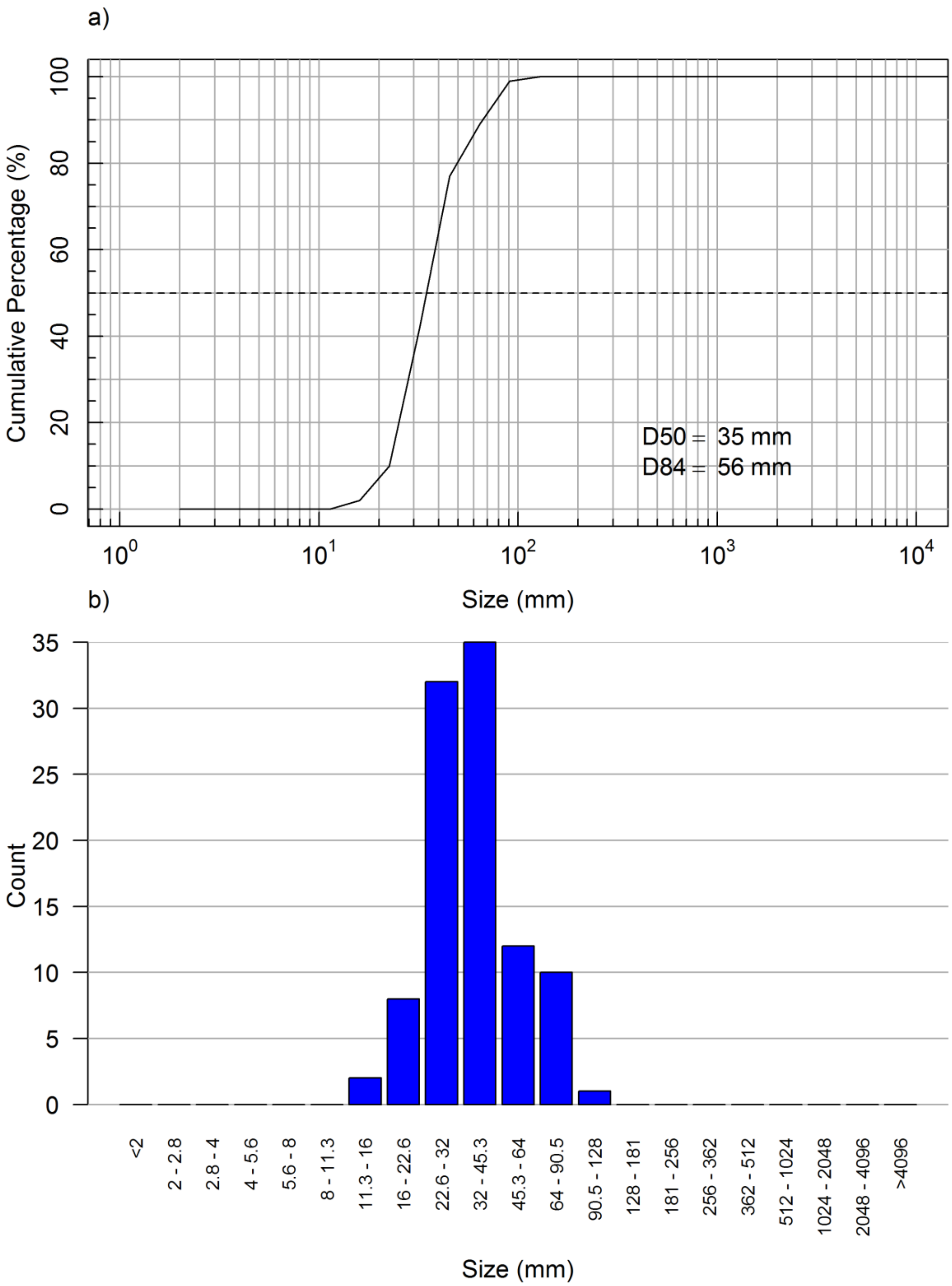


Figure 3. Substrate Grain Distribution at GRE-CA03 (mesohabitat site) in Greenhills Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

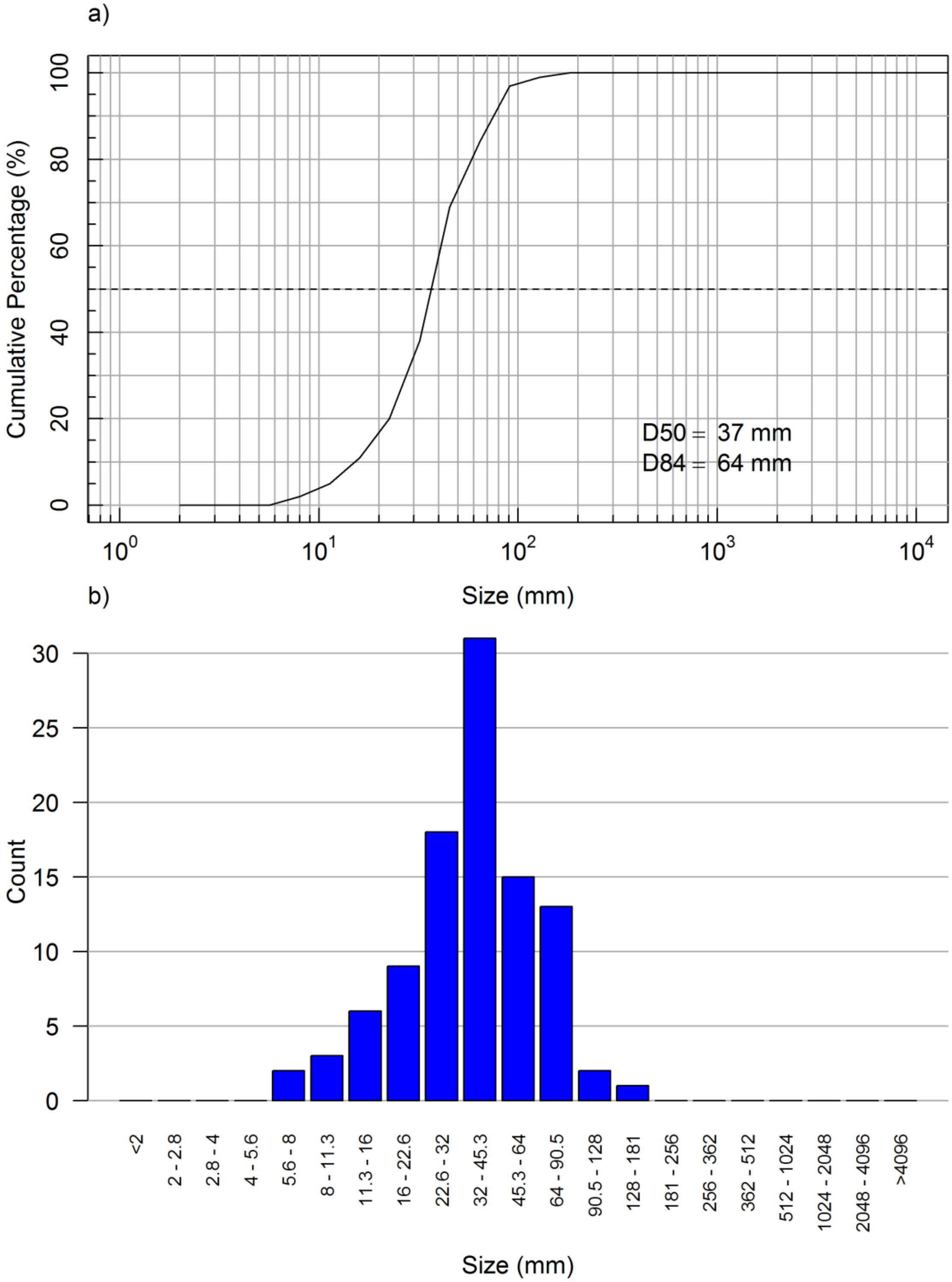


Figure 4. **Substrate Grain Distribution at GRE-CA03 (piezometer site) in Greenhills Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**

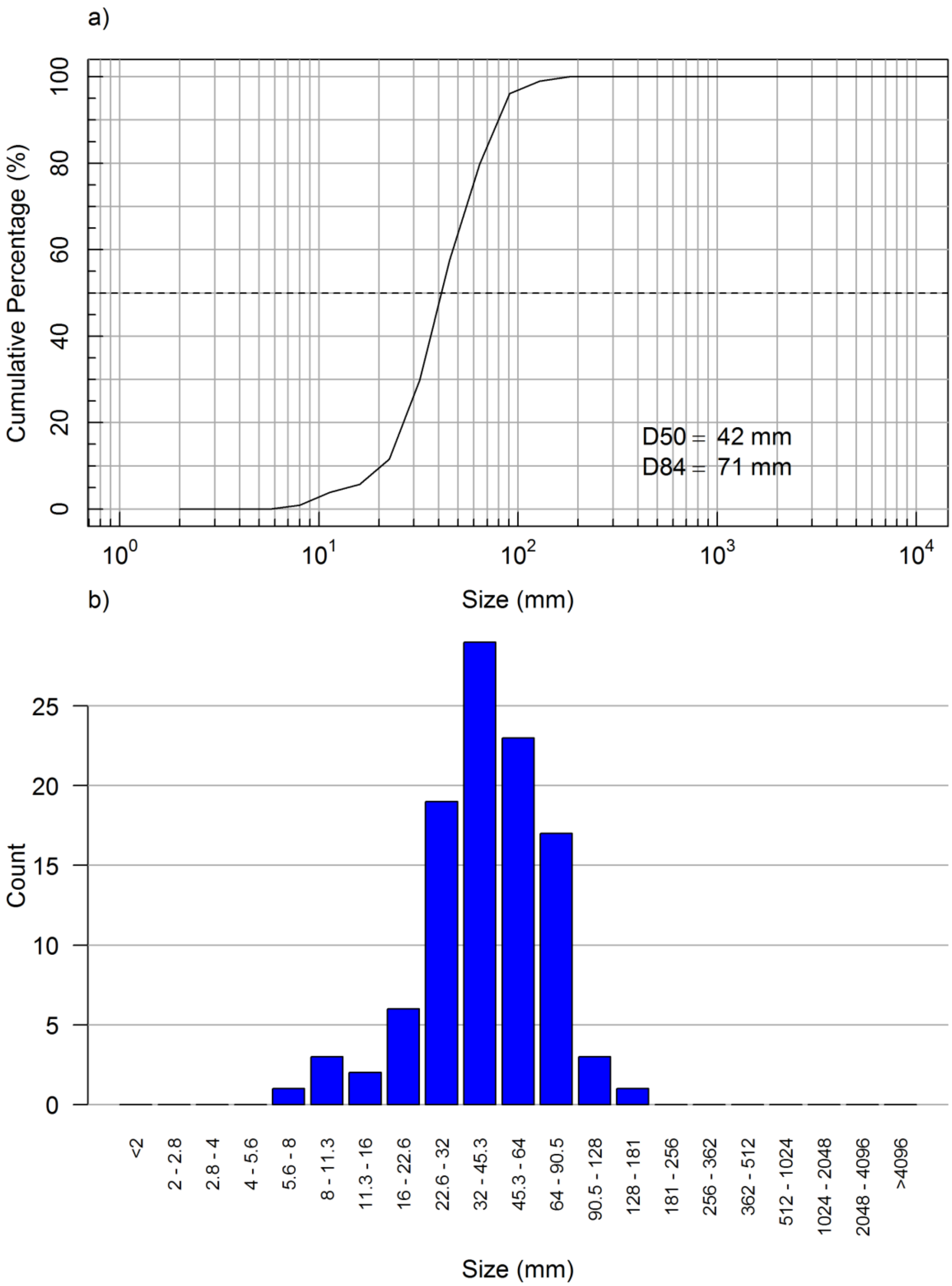


Figure 5. **Substrate Grain Distribution at HEN-CA01 (mesohabitat site) in Henretta Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**

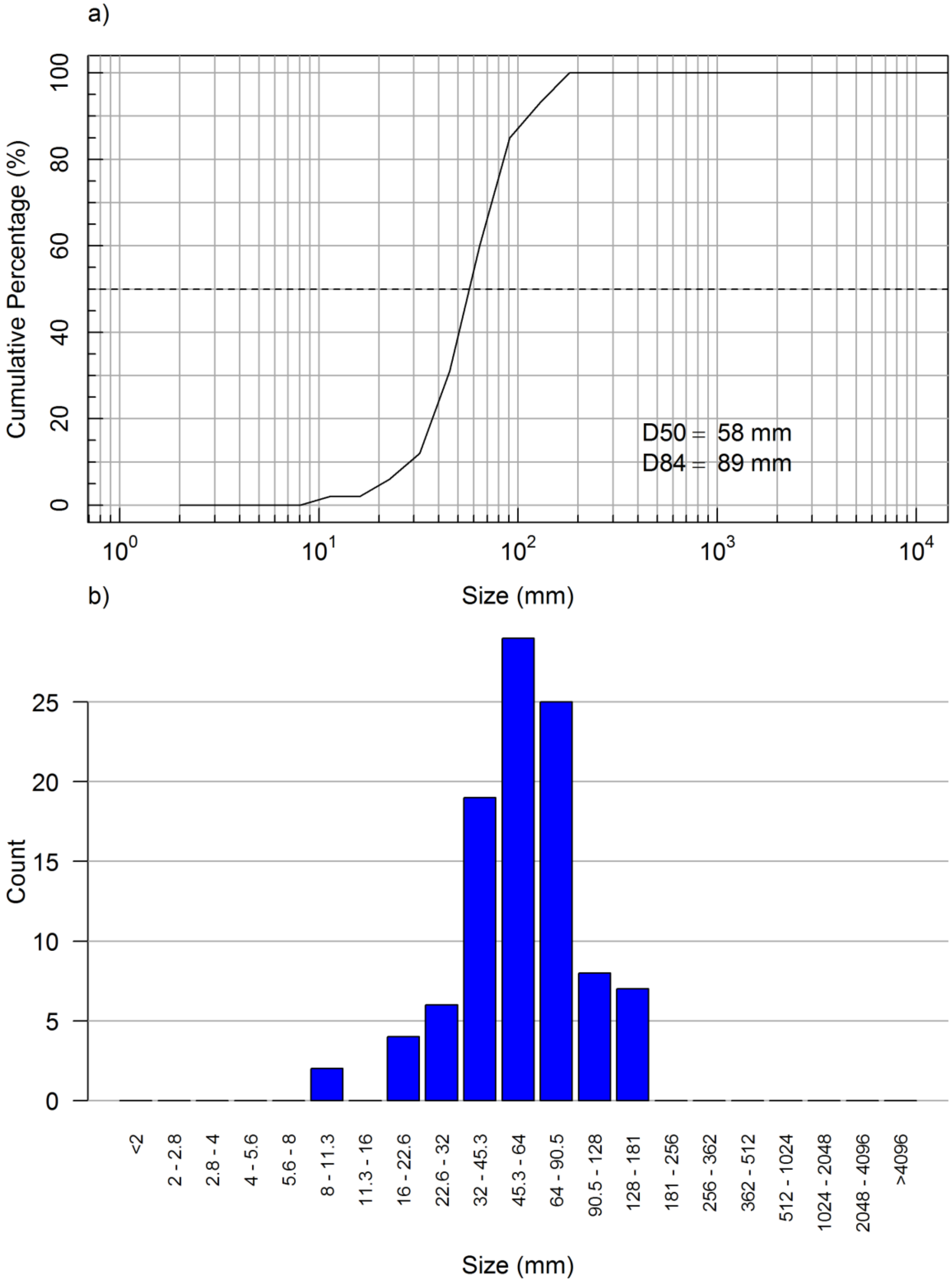


Figure 6. **Substrate Grain Distribution at HEN-CA01 (piezometer site) in Henretta Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**

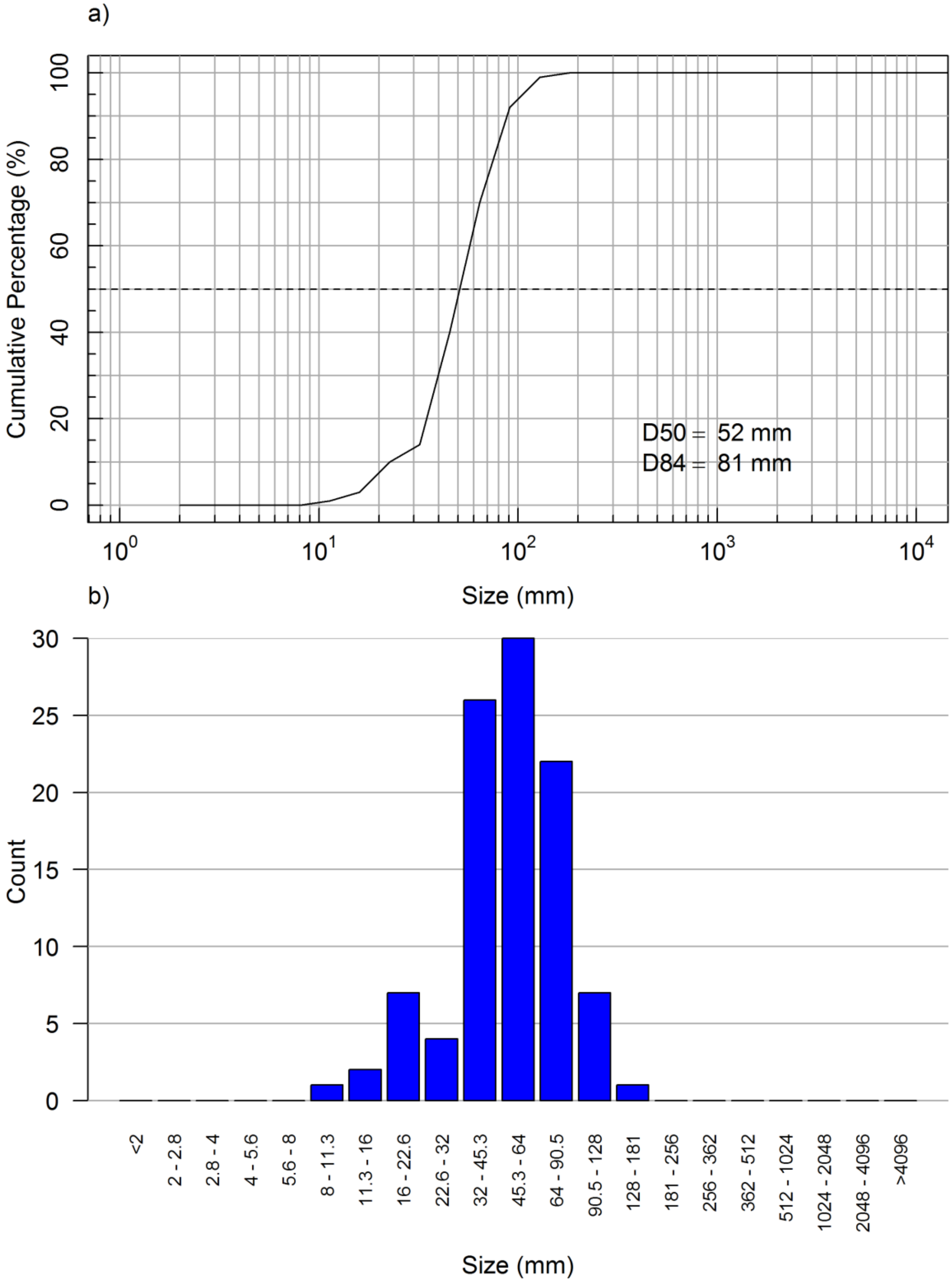


Figure 7. Substrate Grain Distribution at HEN-CA02 (mesohabitat site) in Henretta Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

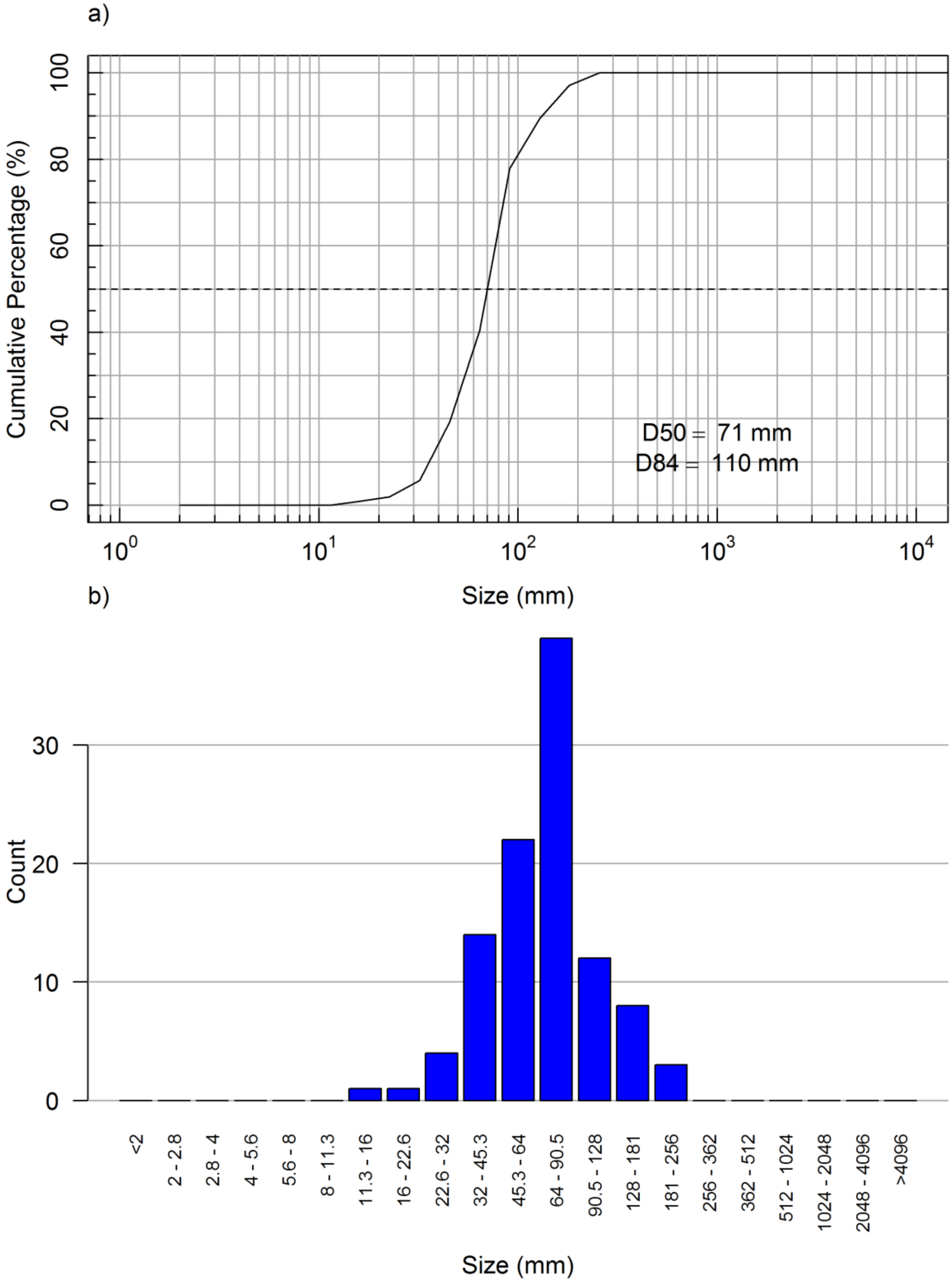


Figure 8. Substrate Grain Distribution at HEN-CA02 (piezometer site) in Henretta Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

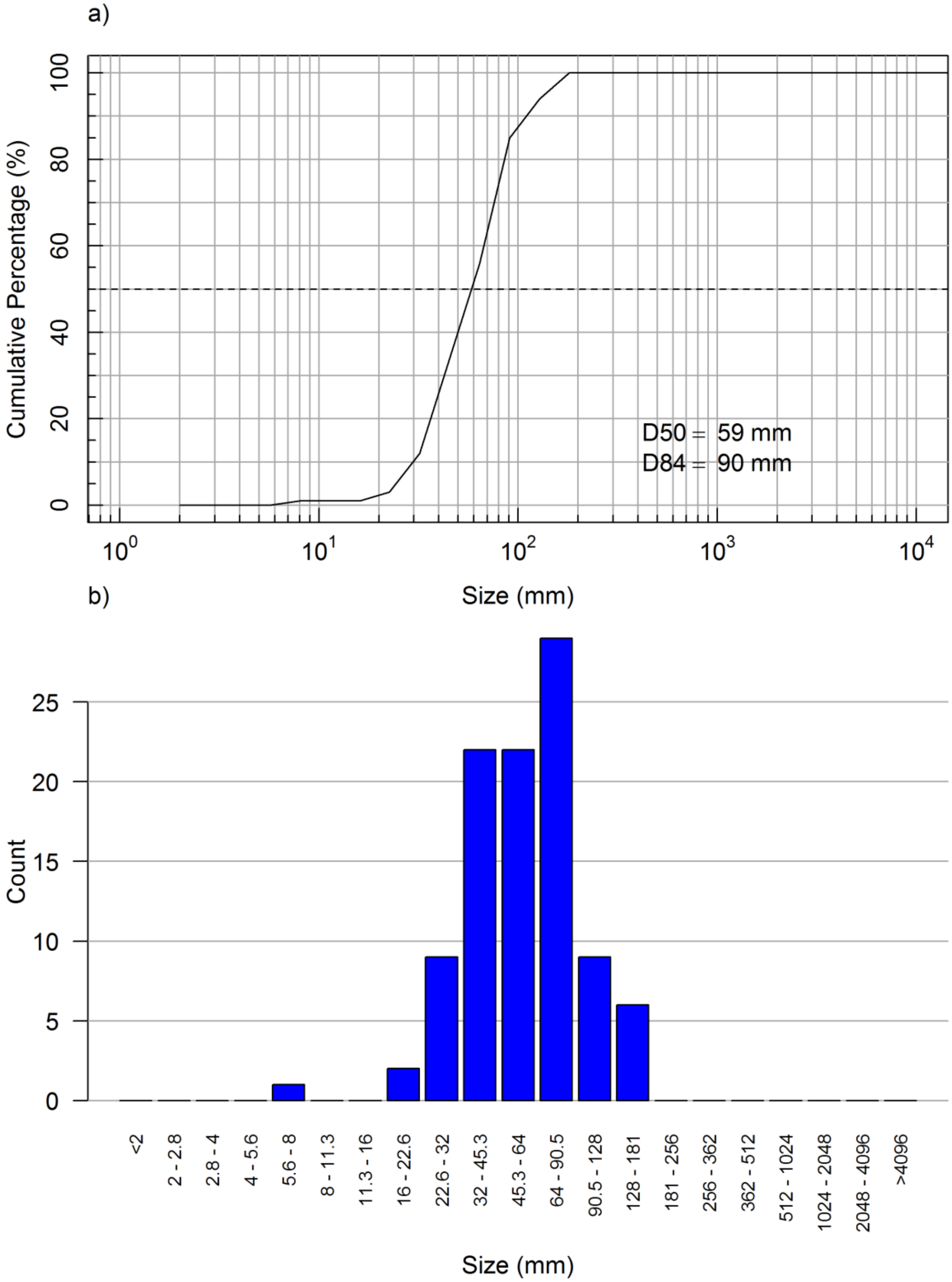


Figure 9. Substrate Grain Distribution at LCDRY-CA01 (mesohabitat site) in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

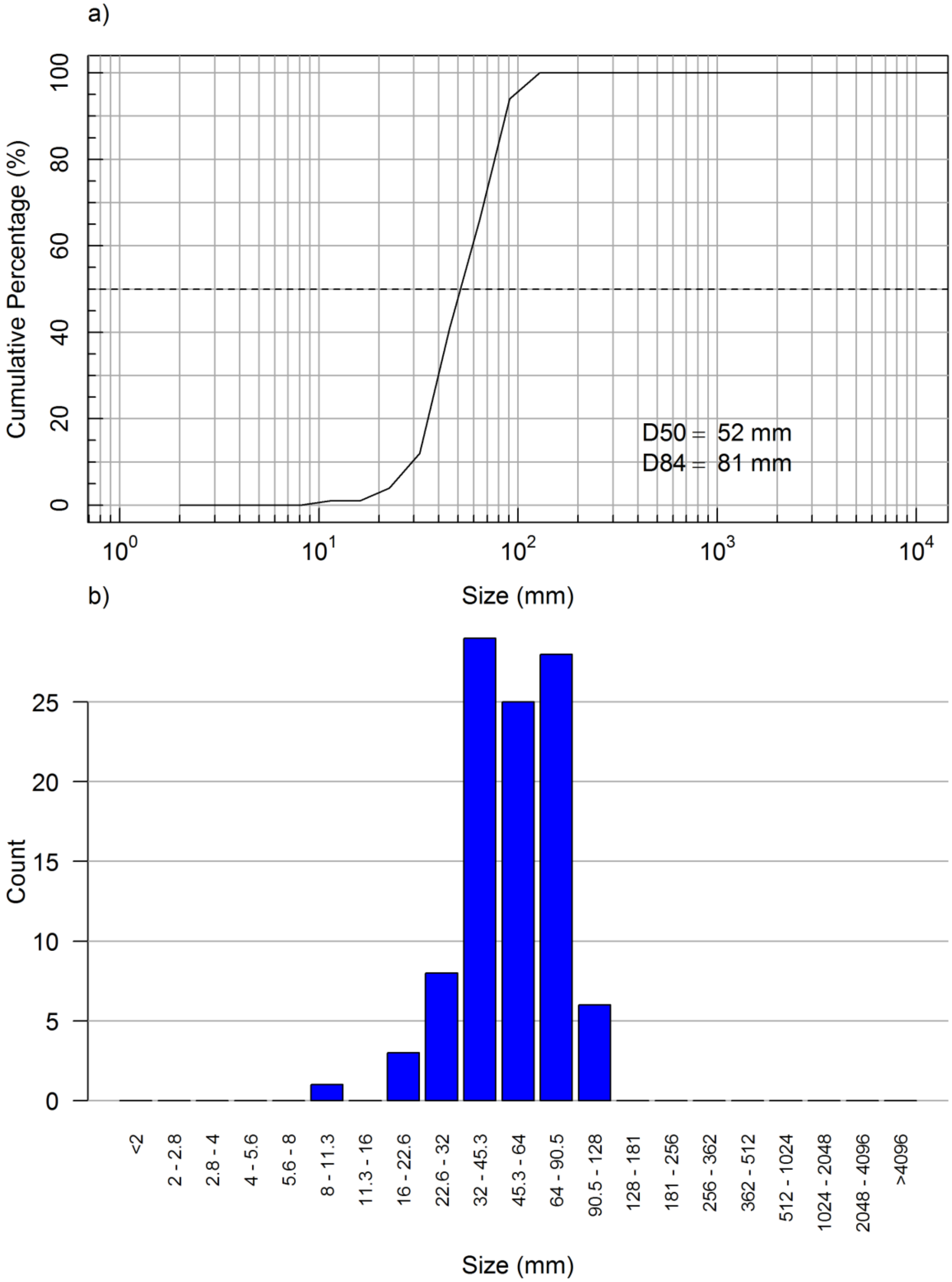


Figure 10. Substrate Grain Distribution at LCDRY-CA01 (piezometer site) in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

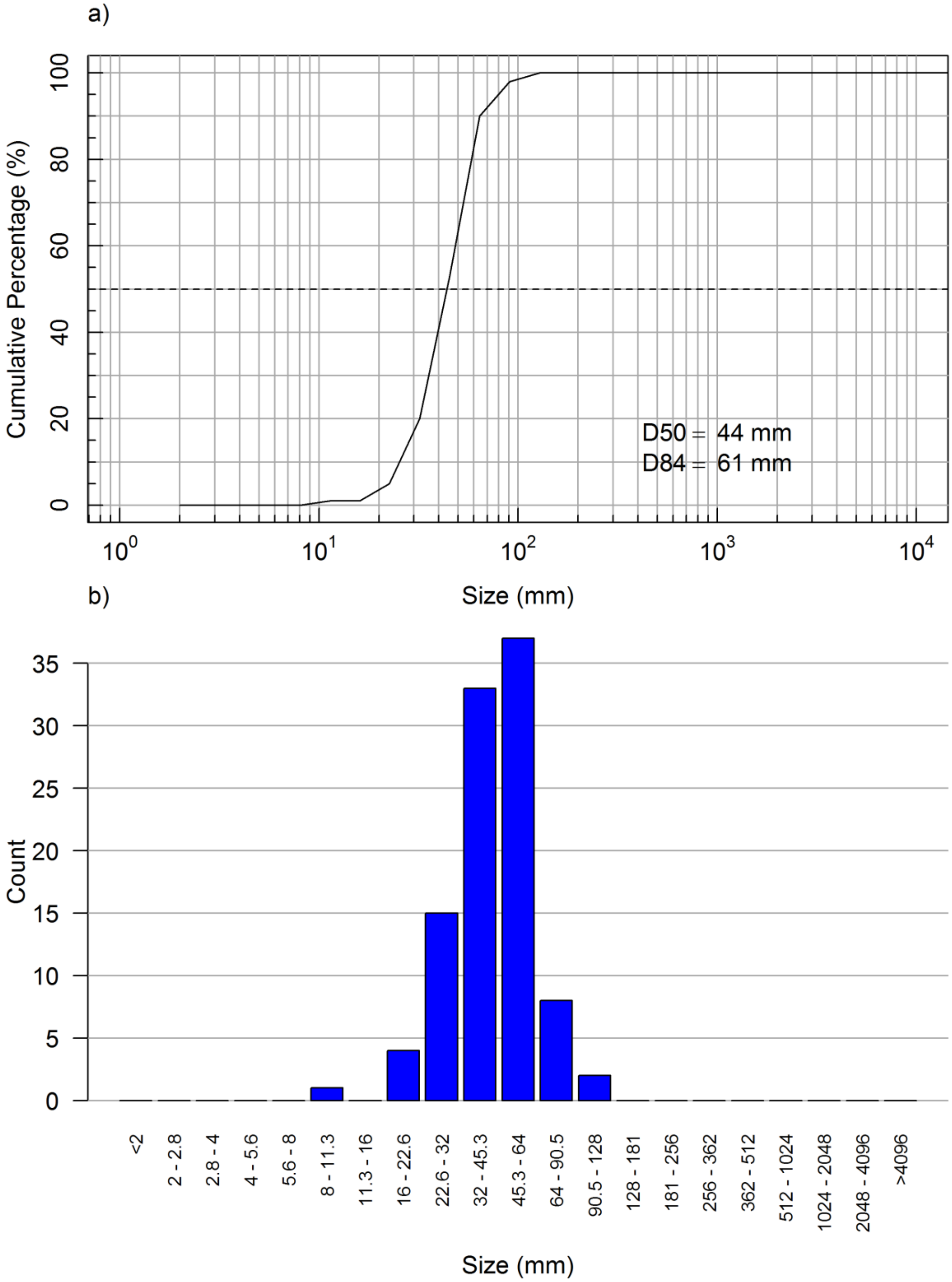
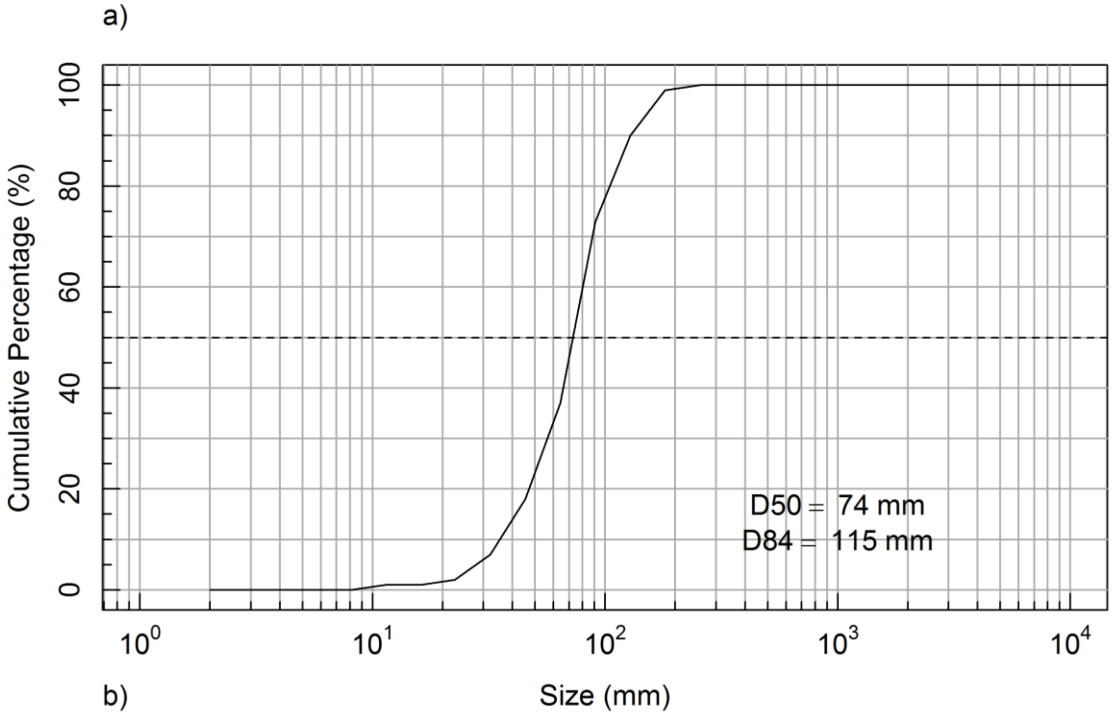


Figure 11. Substrate Grain Distribution at LCDRY-CA02 (mesohabitat site) in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.



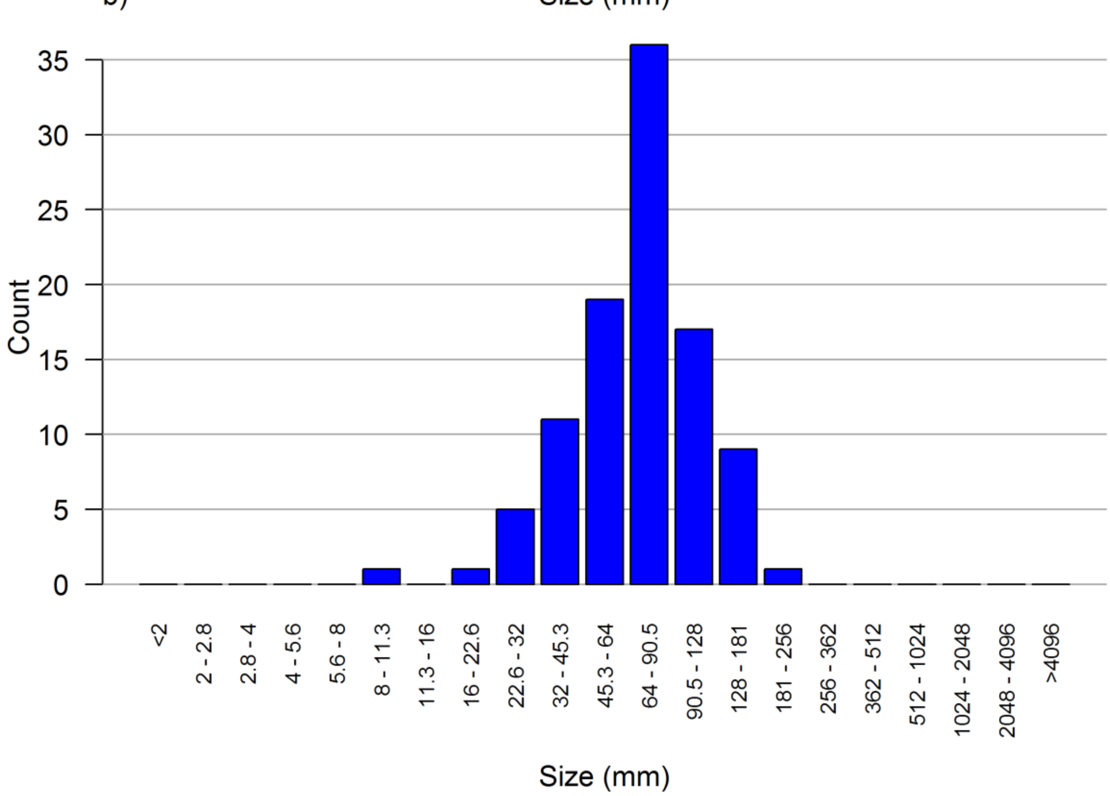


Figure 12. Substrate Grain Distribution at LCDRY-CA02 (piezometer site) in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

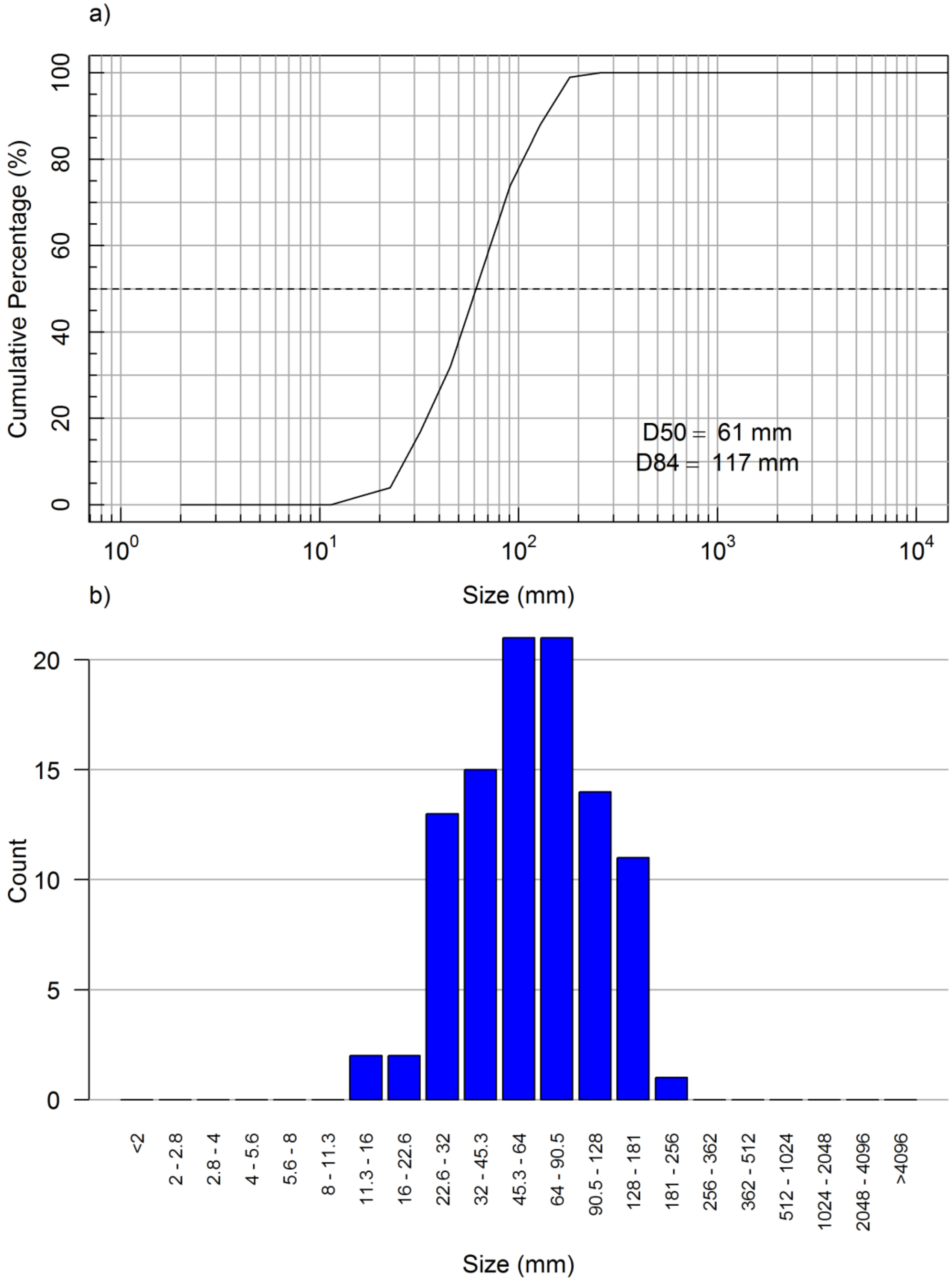
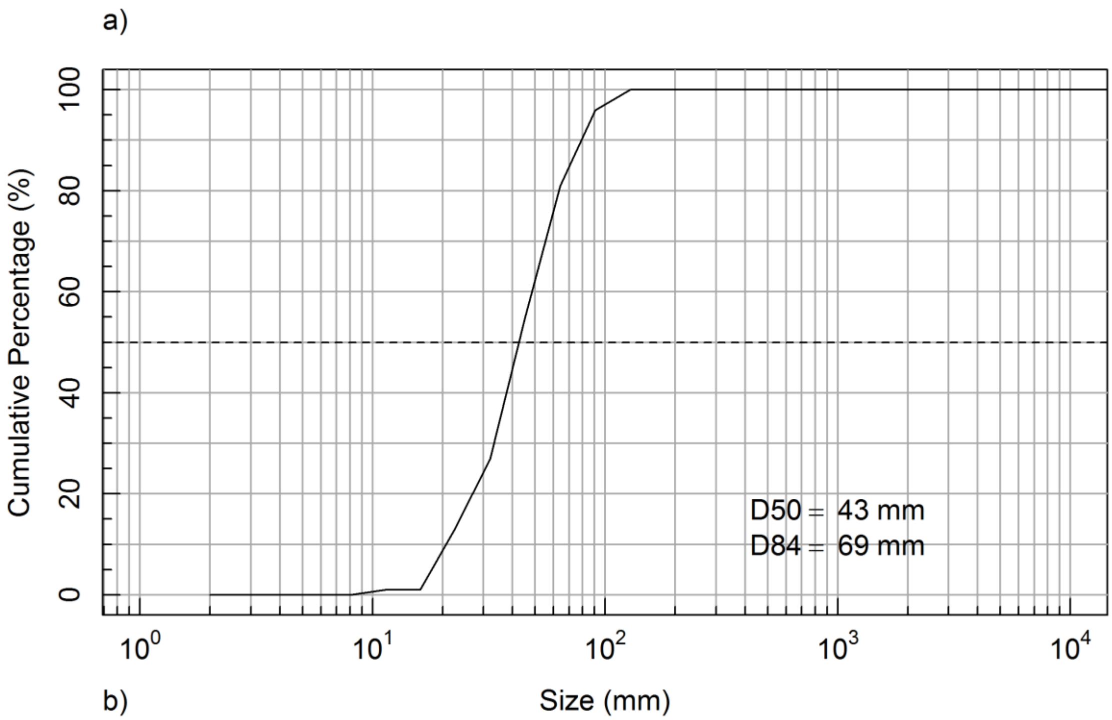


Figure 13. **Substrate Grain Distribution at LCDRY-CI45 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**



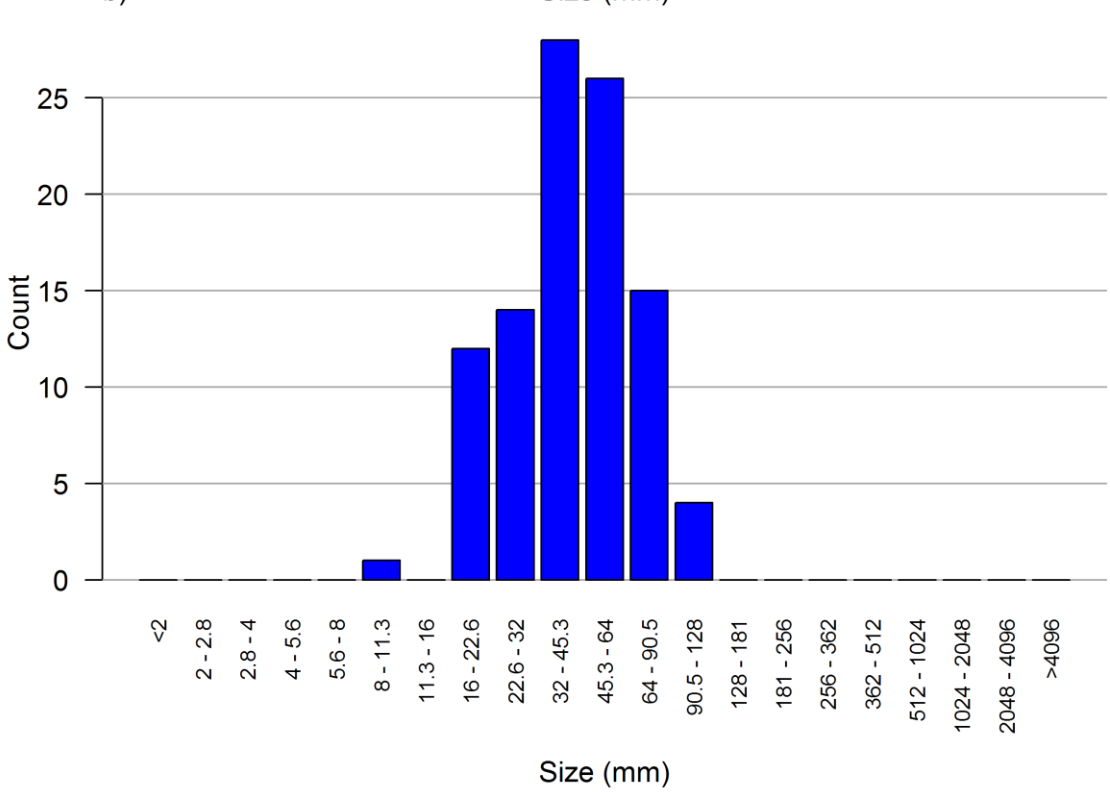


Figure 14. Substrate Grain Distribution at LCDRY-CI48 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

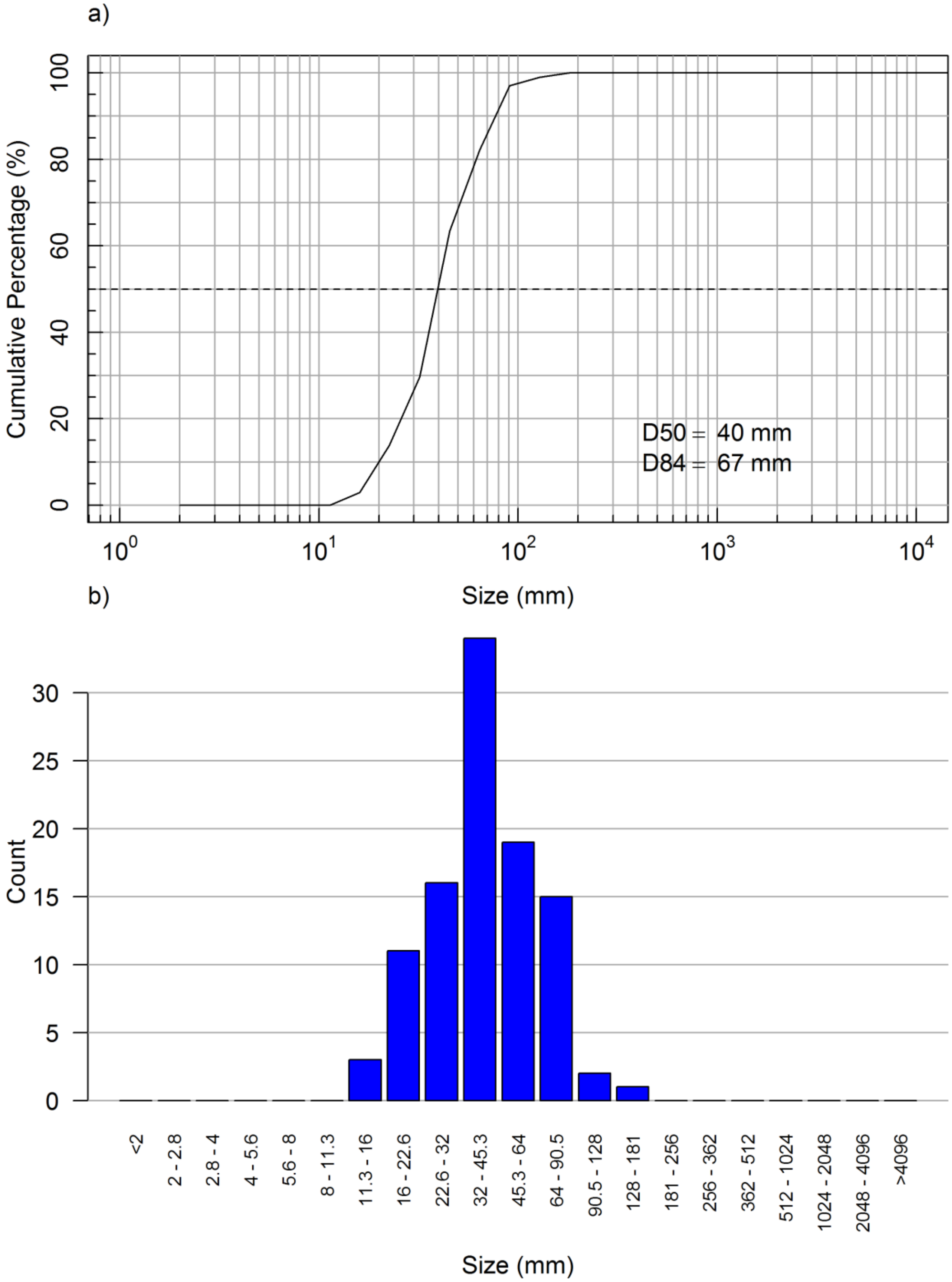


Figure 15. Substrate Grain Distribution at LCDRY-CI49 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

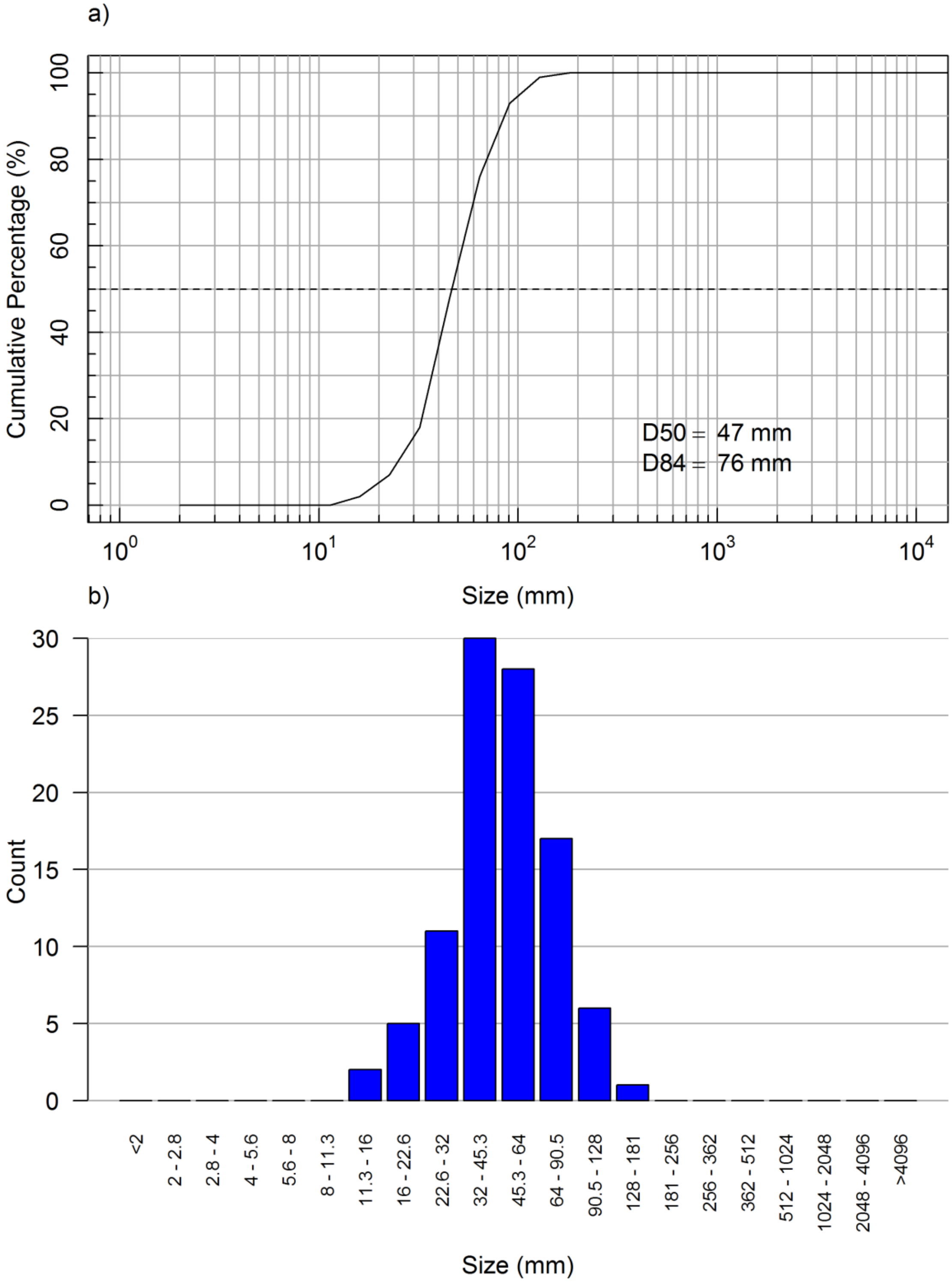


Figure 16. Substrate Grain Distribution at LCDRY-CI53 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

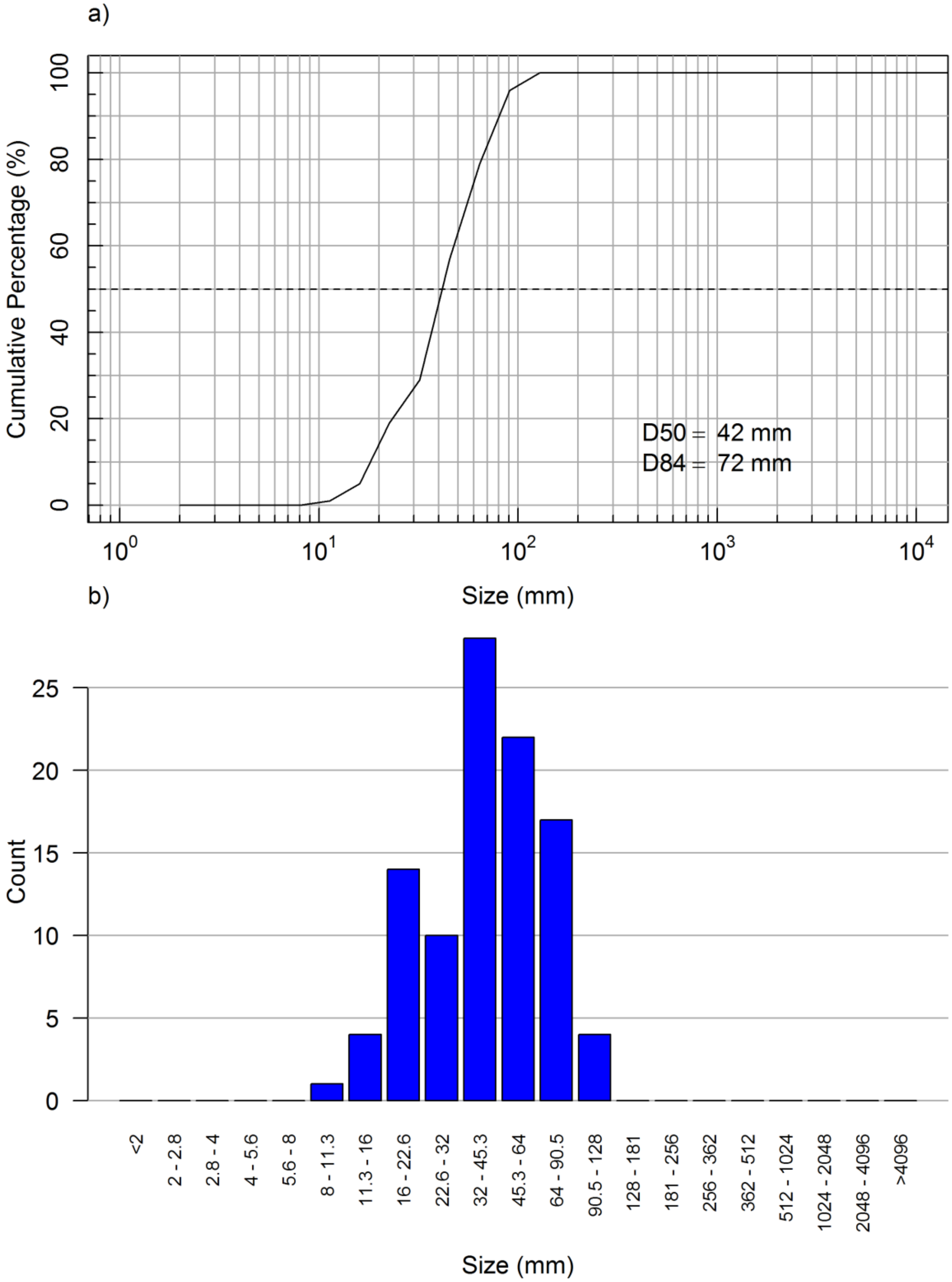


Figure 17. Substrate Grain Distribution at LCDRY-CI55 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

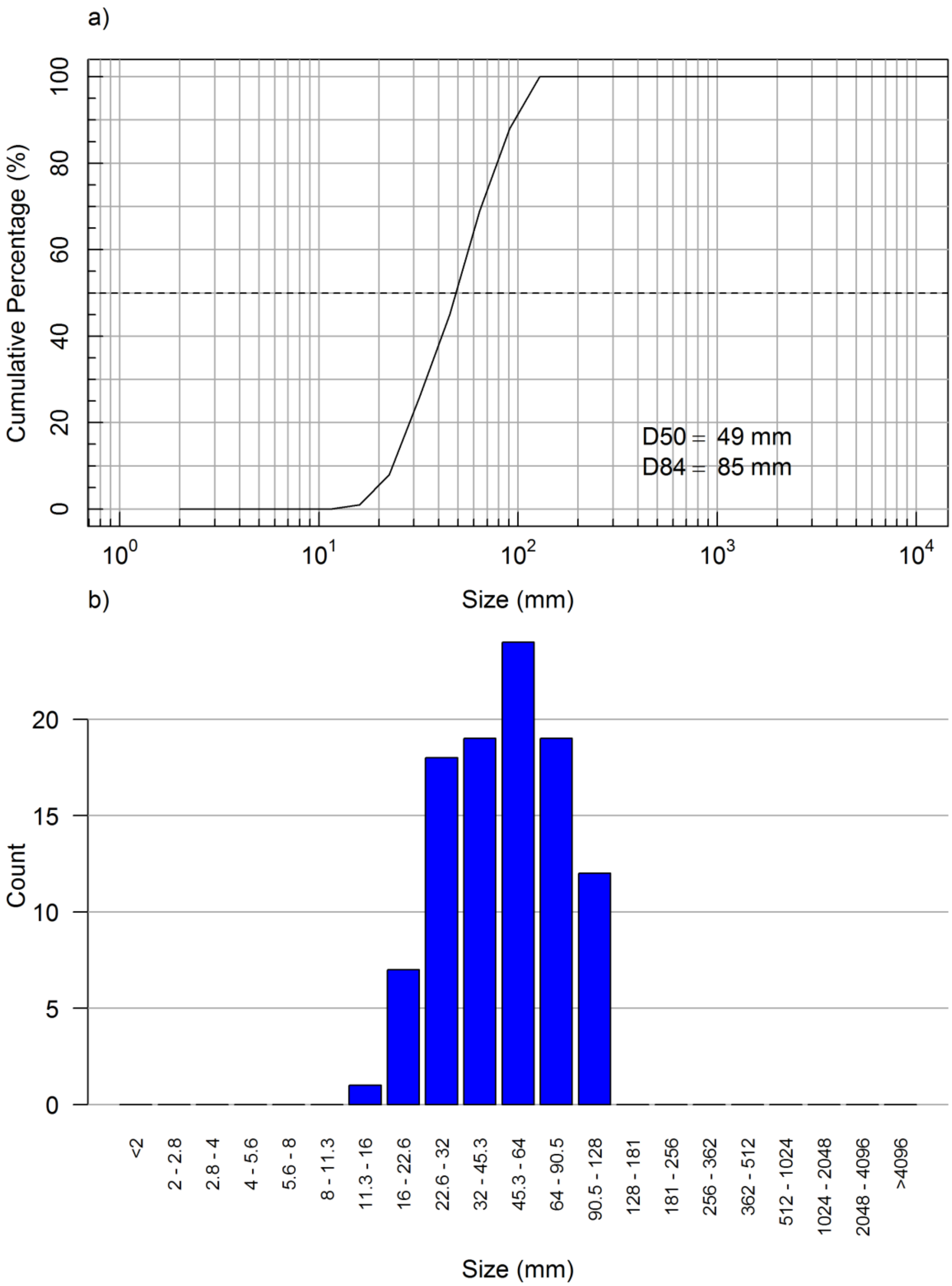


Figure 18. Substrate Grain Distribution at LCDRY-CI77 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

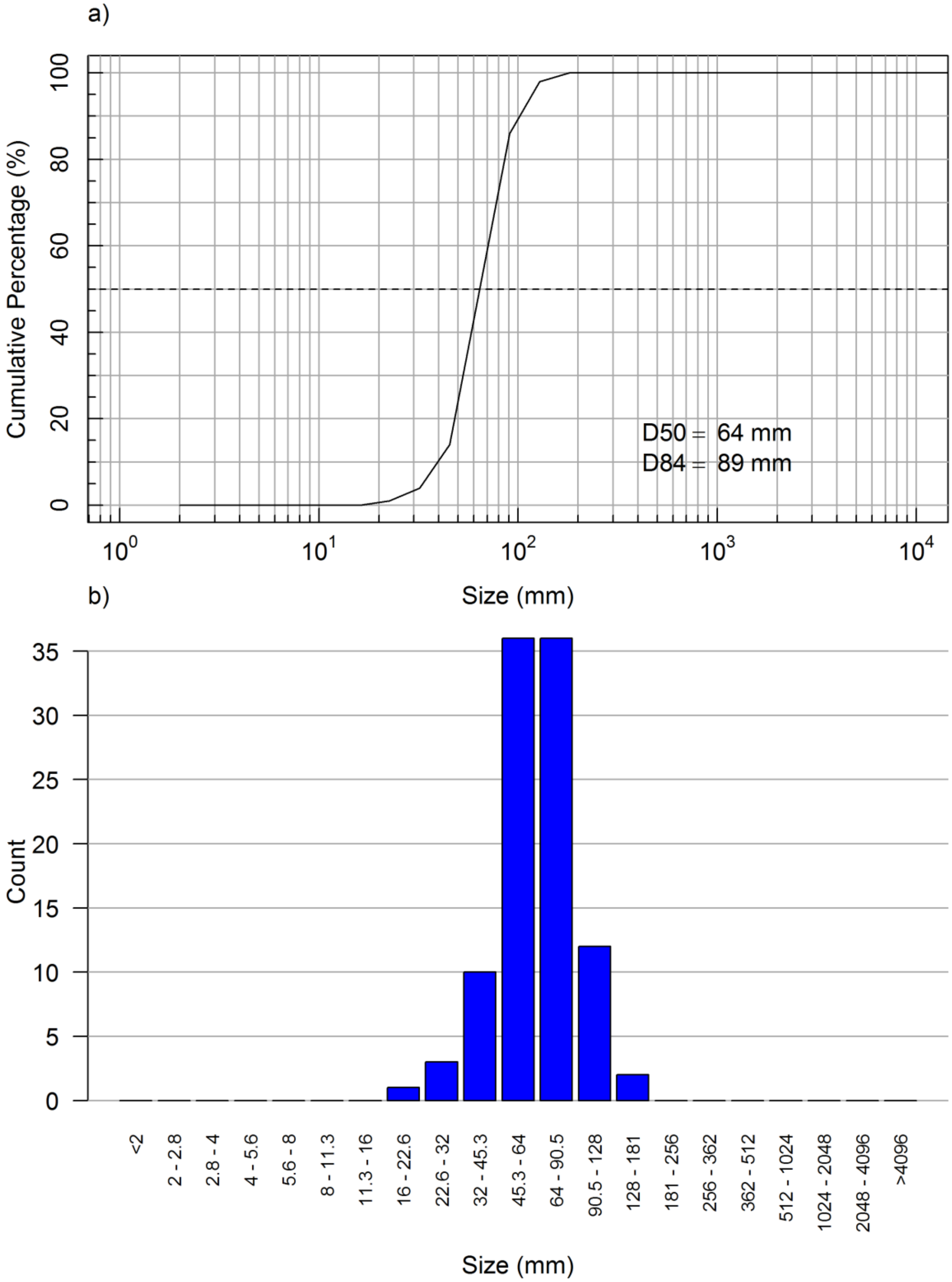


Figure 19. Substrate Grain Distribution at LCDRY-CI78 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

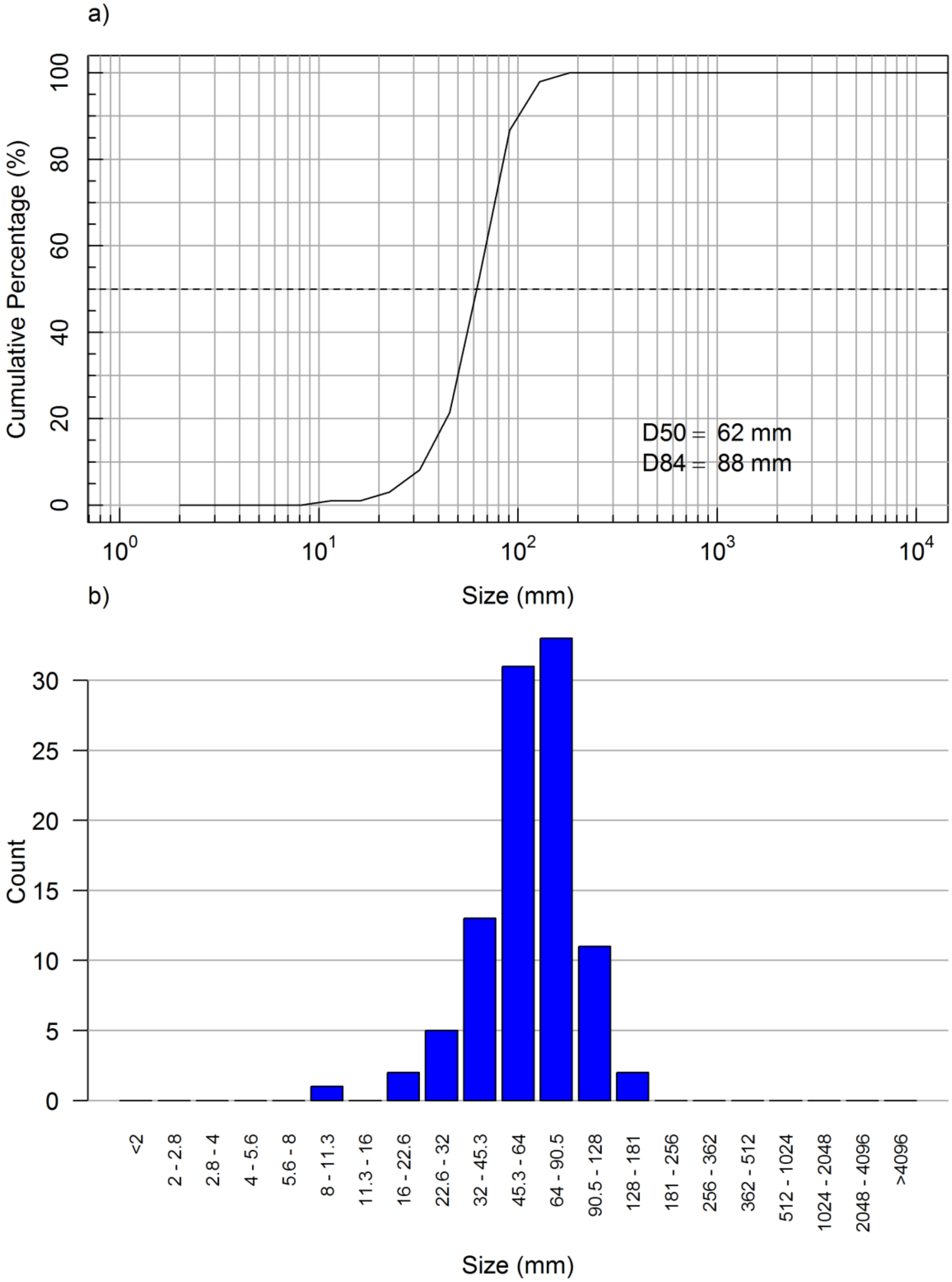


Figure 20. Substrate Grain Distribution at LCDRY-CI80 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

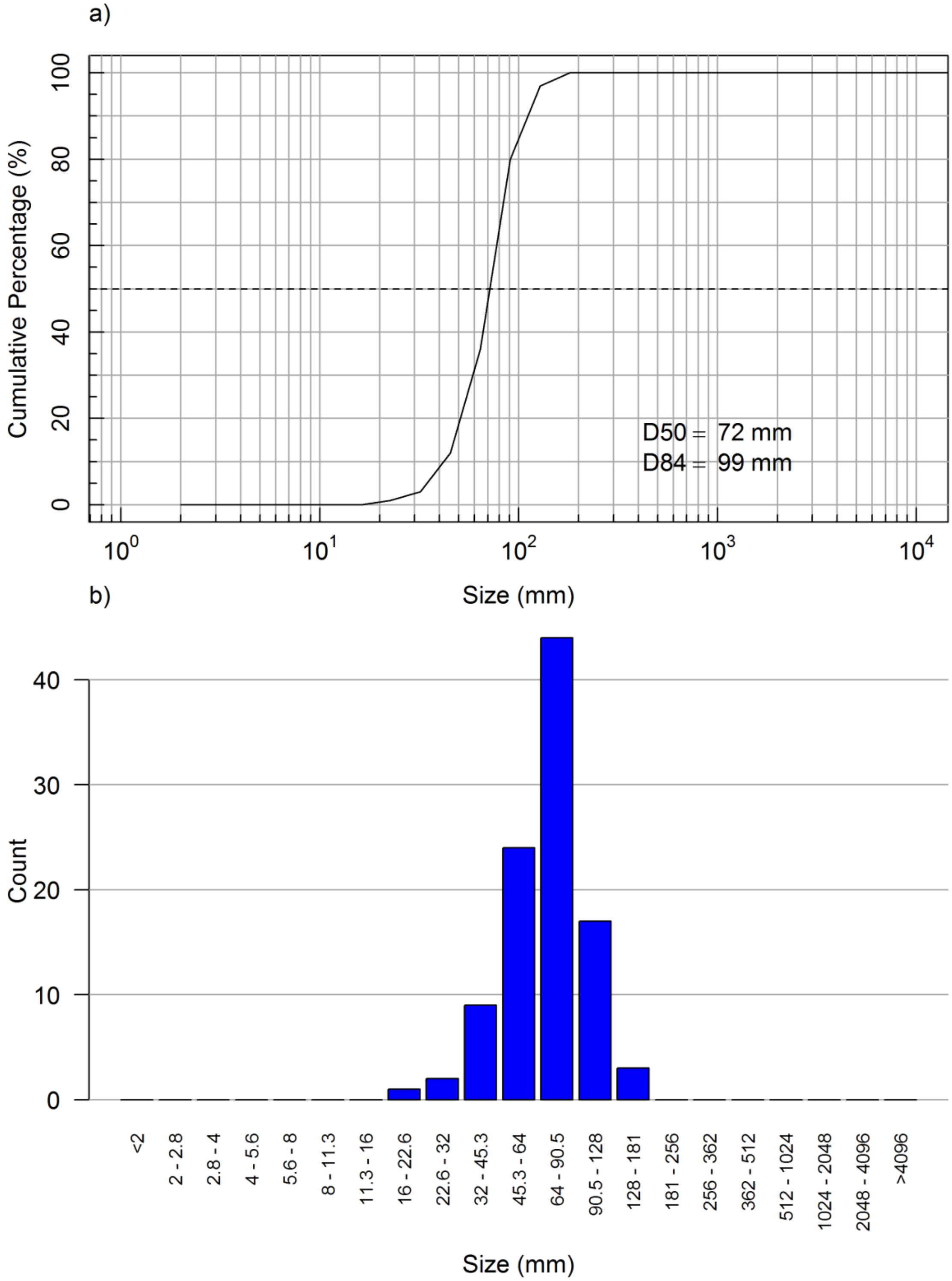
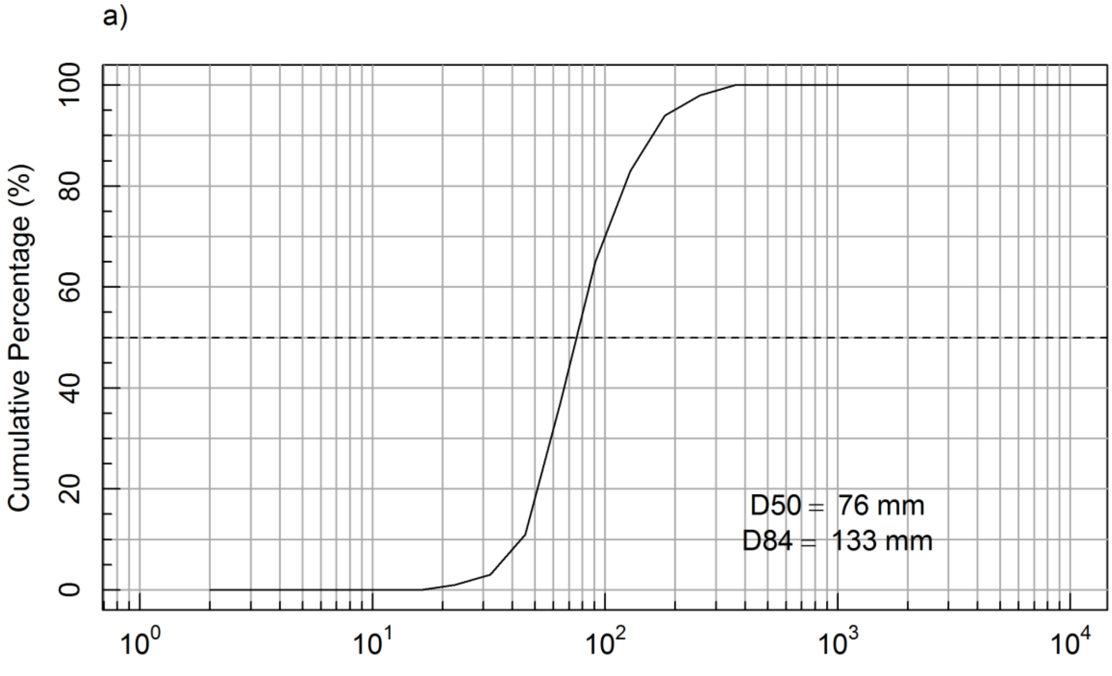


Figure 21. **Substrate Grain Distribution at LCDRY-CI82 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**



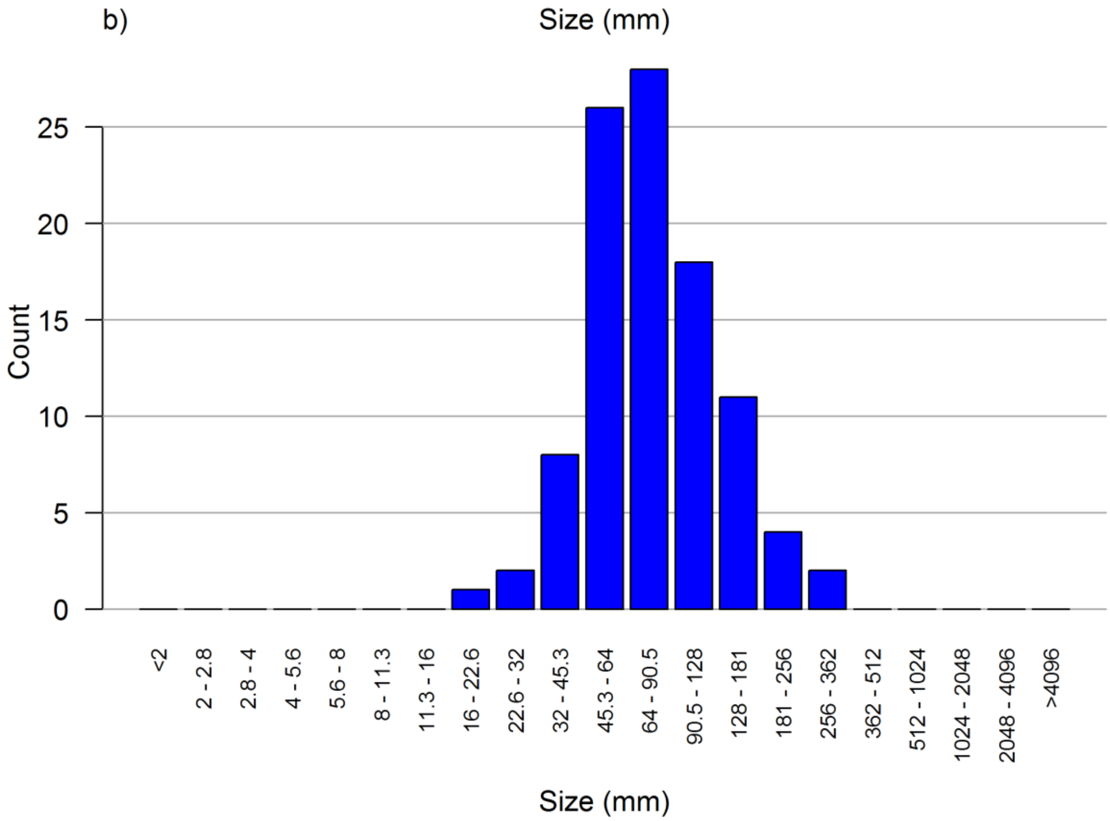


Figure 22. **Substrate Grain Distribution at LCDRY-CI83 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.**

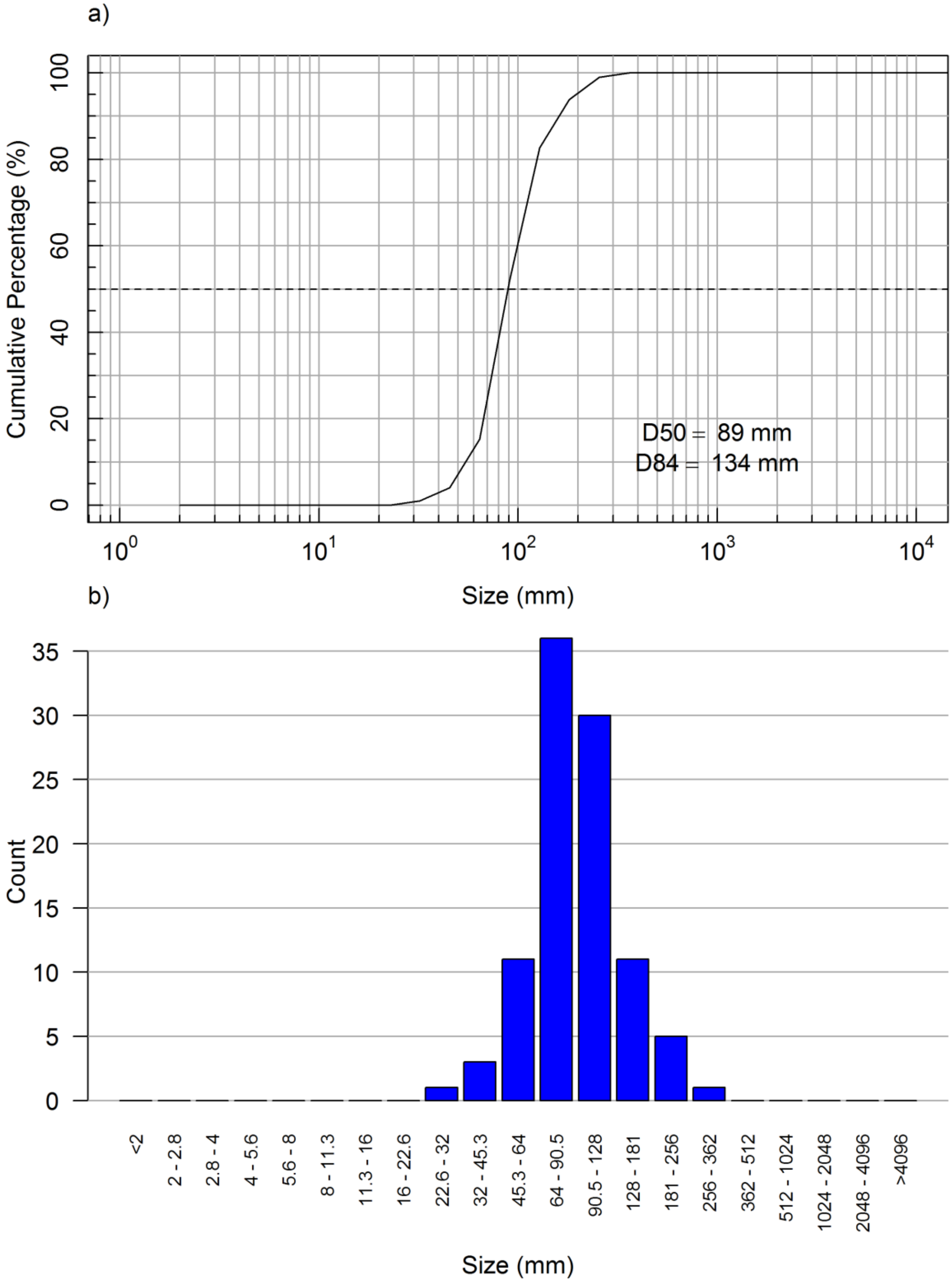


Figure 23. Substrate Grain Distribution at LCDRY-CI85 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

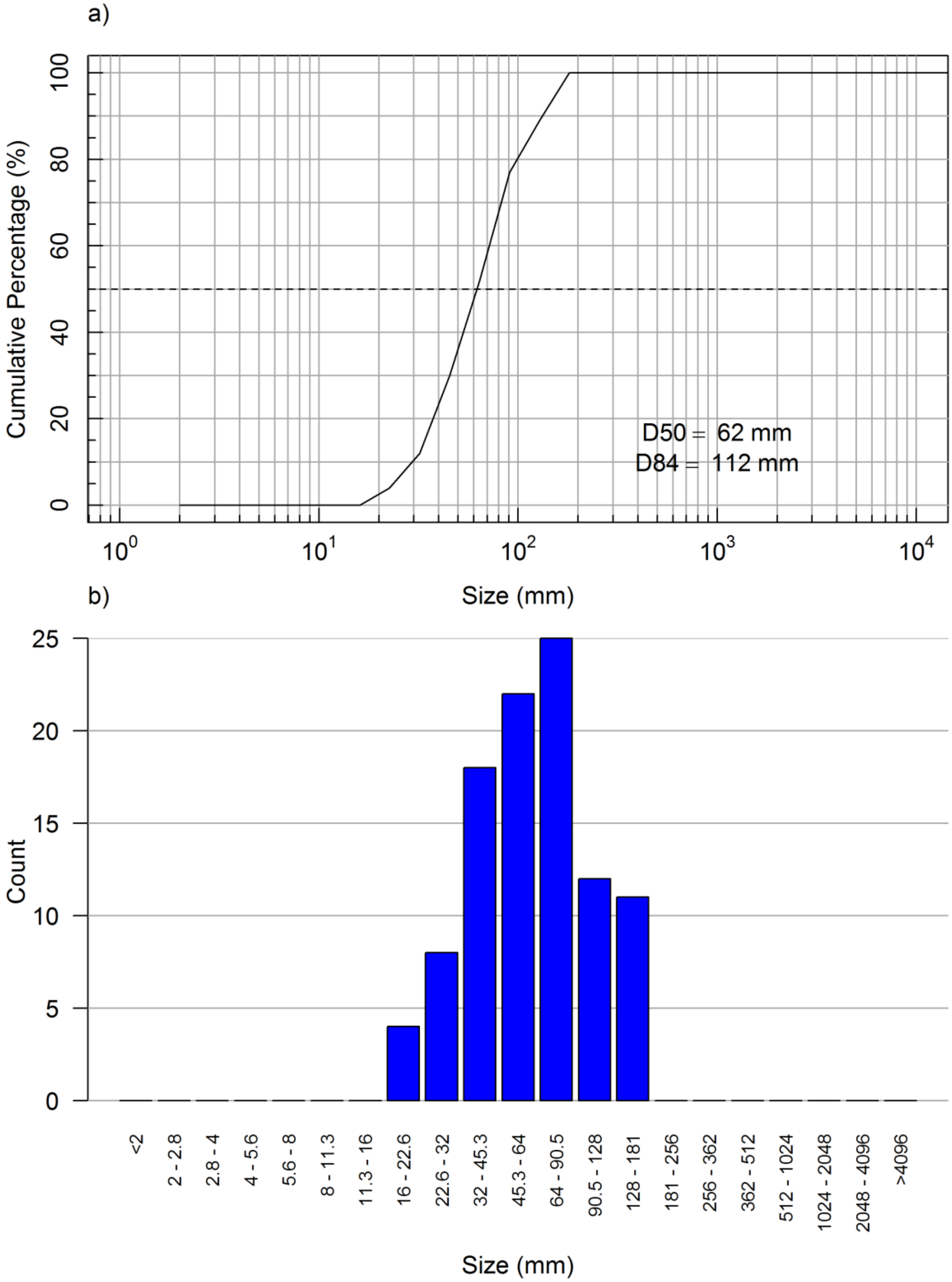


Figure 24. Substrate Grain Distribution at LCDRY-CI88 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

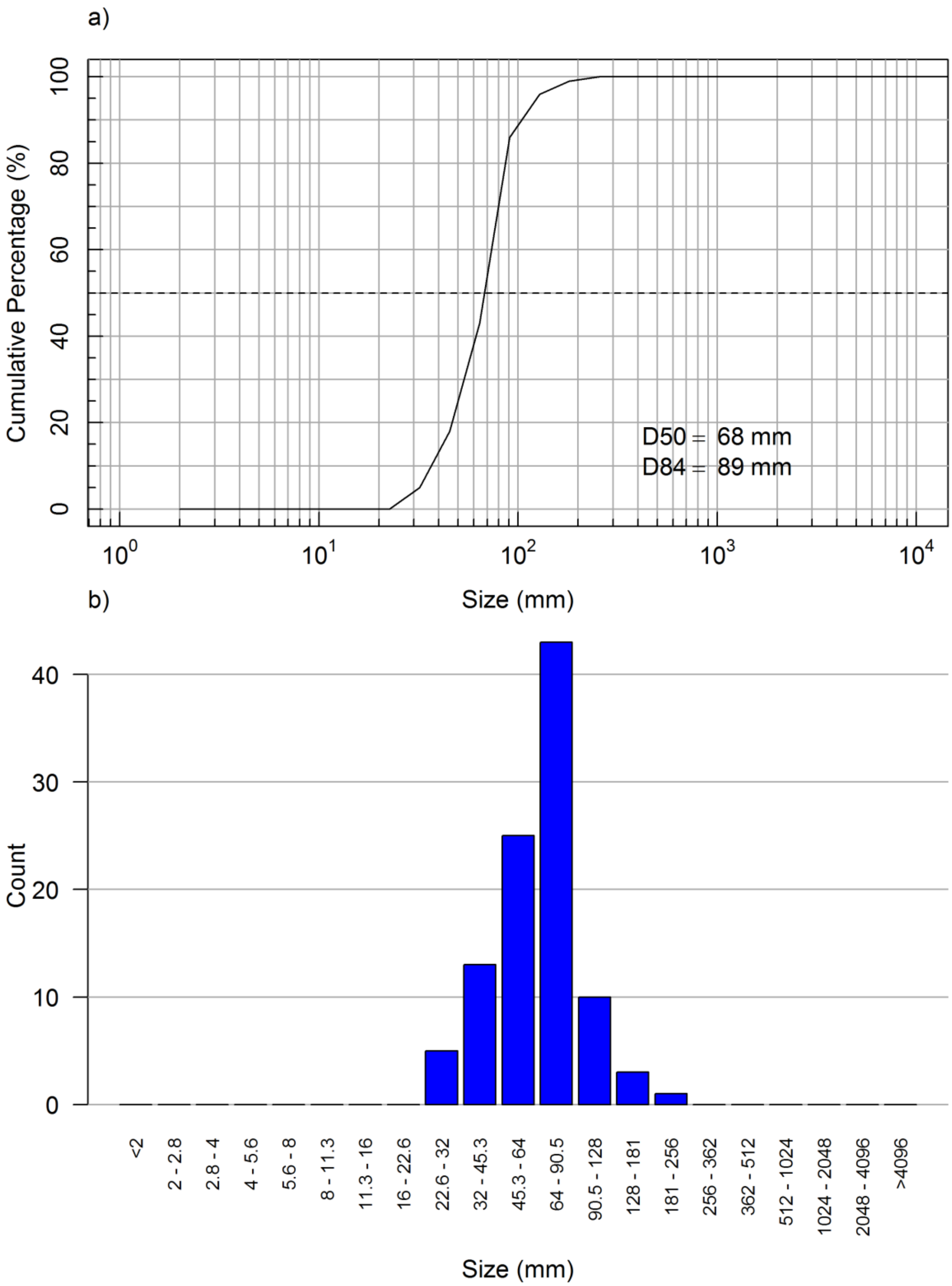


Figure 25. Substrate Grain Distribution at LCDRY-CI91 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

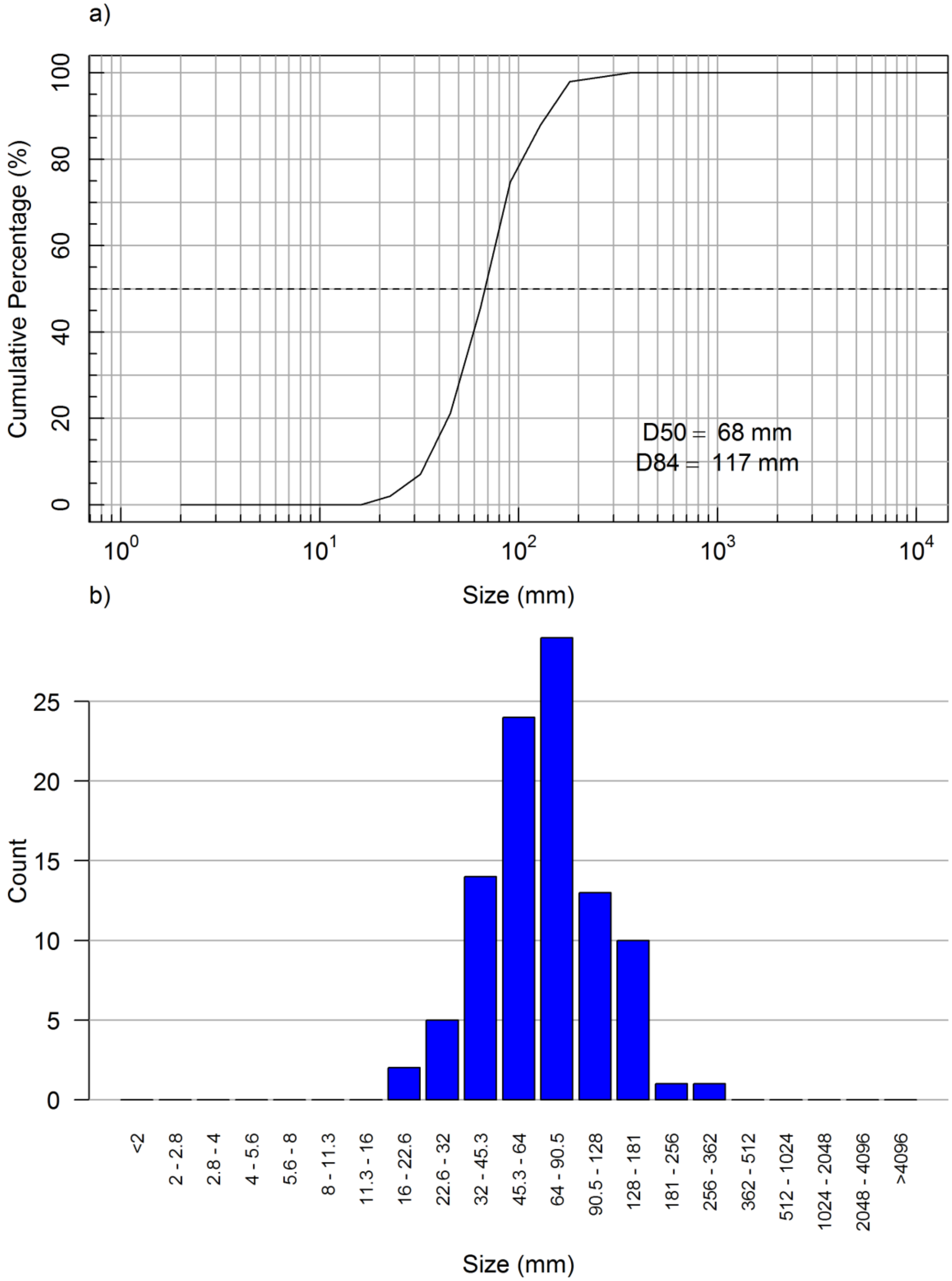


Figure 26. Substrate Grain Distribution at LCDRY-CI95 in LCO Dry Creek on September, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

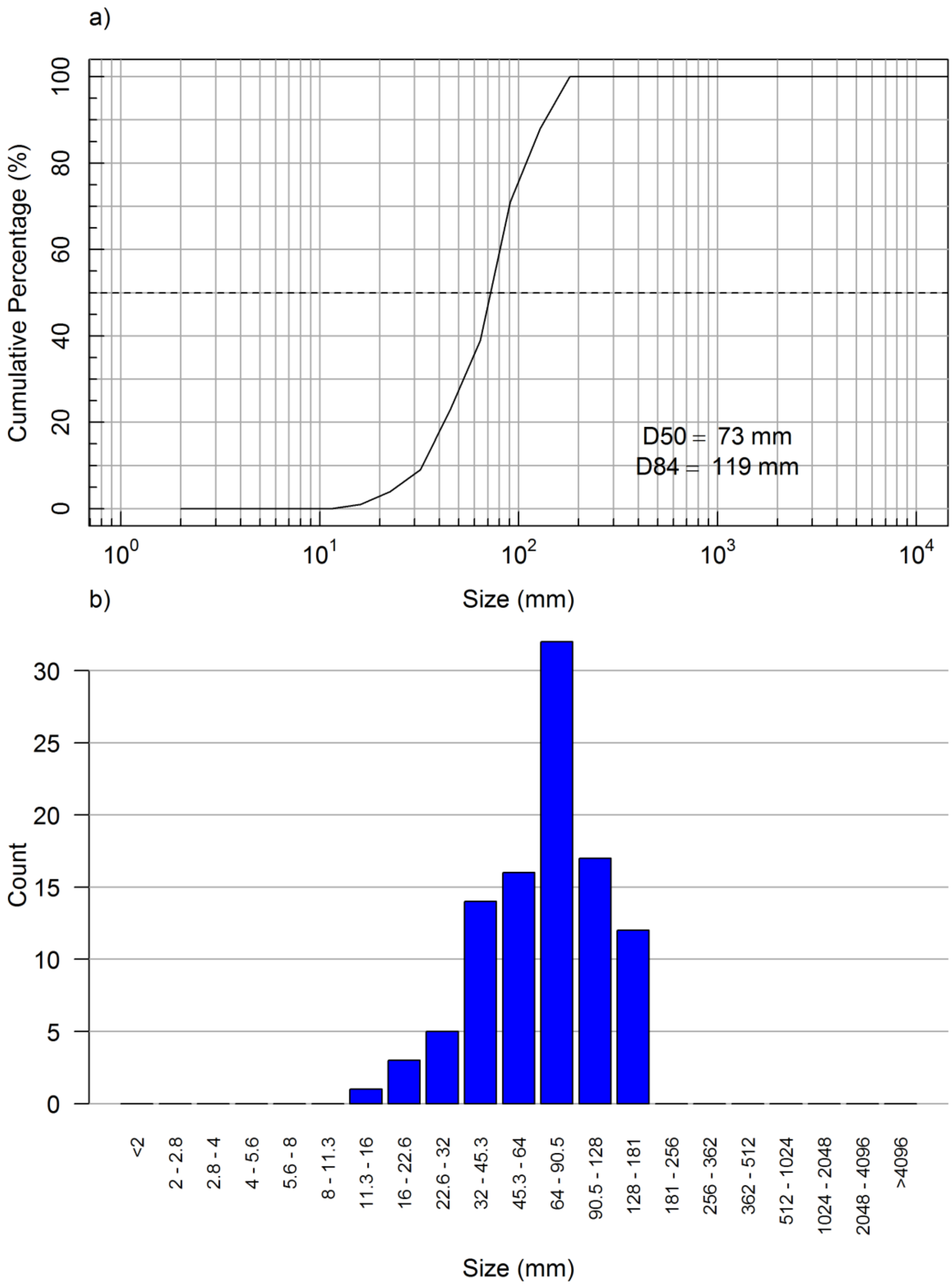


Figure 27. Substrate Grain Distribution at LCDRY-CI115 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

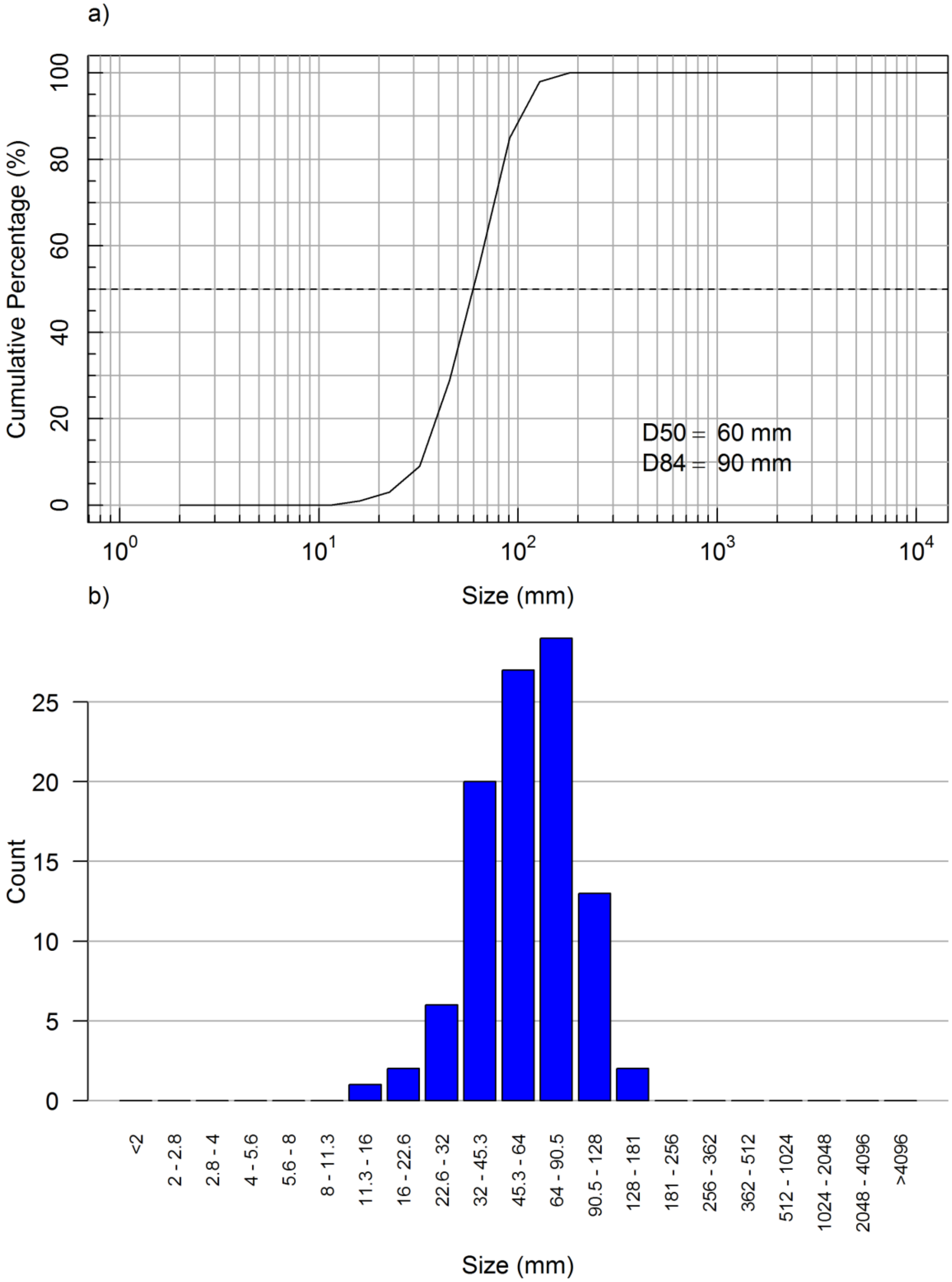


Figure 28. Substrate Grain Distribution at LCDRY-CI116 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

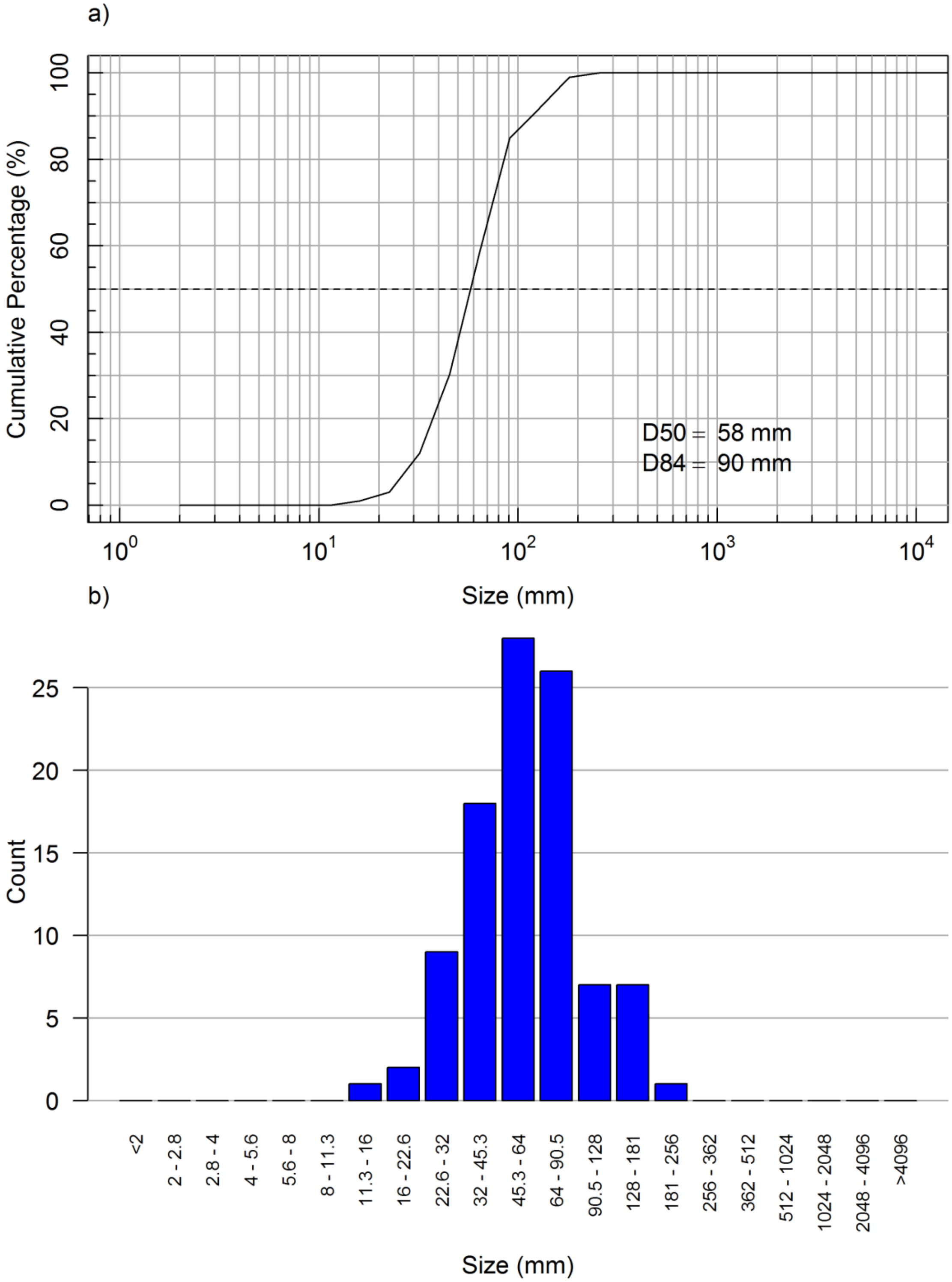
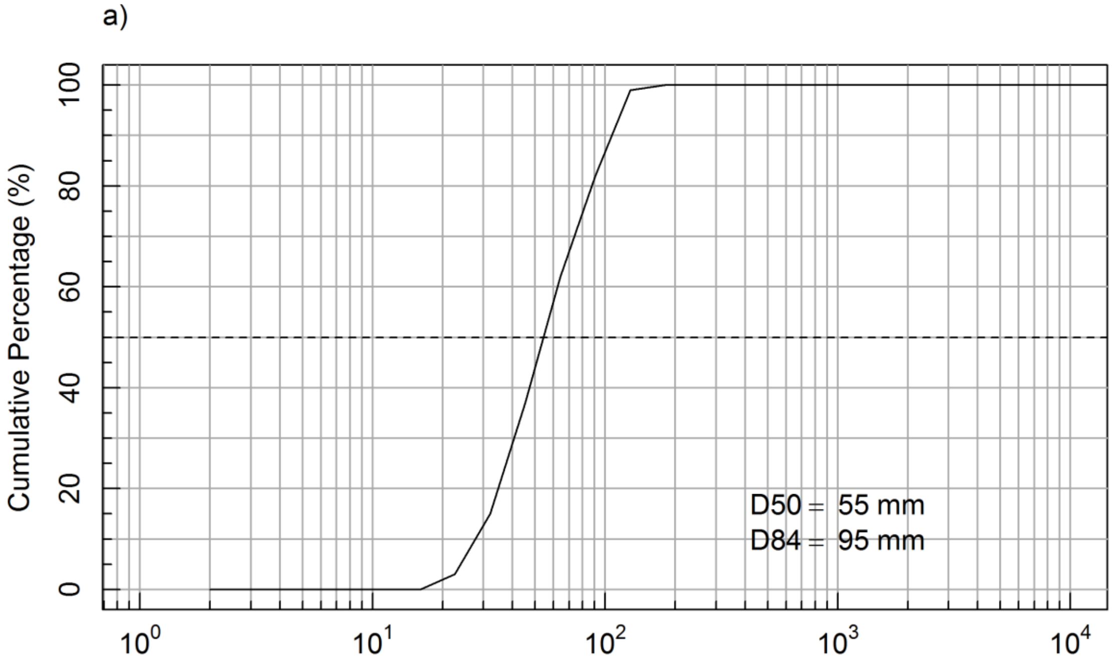


Figure 29. Substrate Grain Distribution at LCDRY-CI238 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.



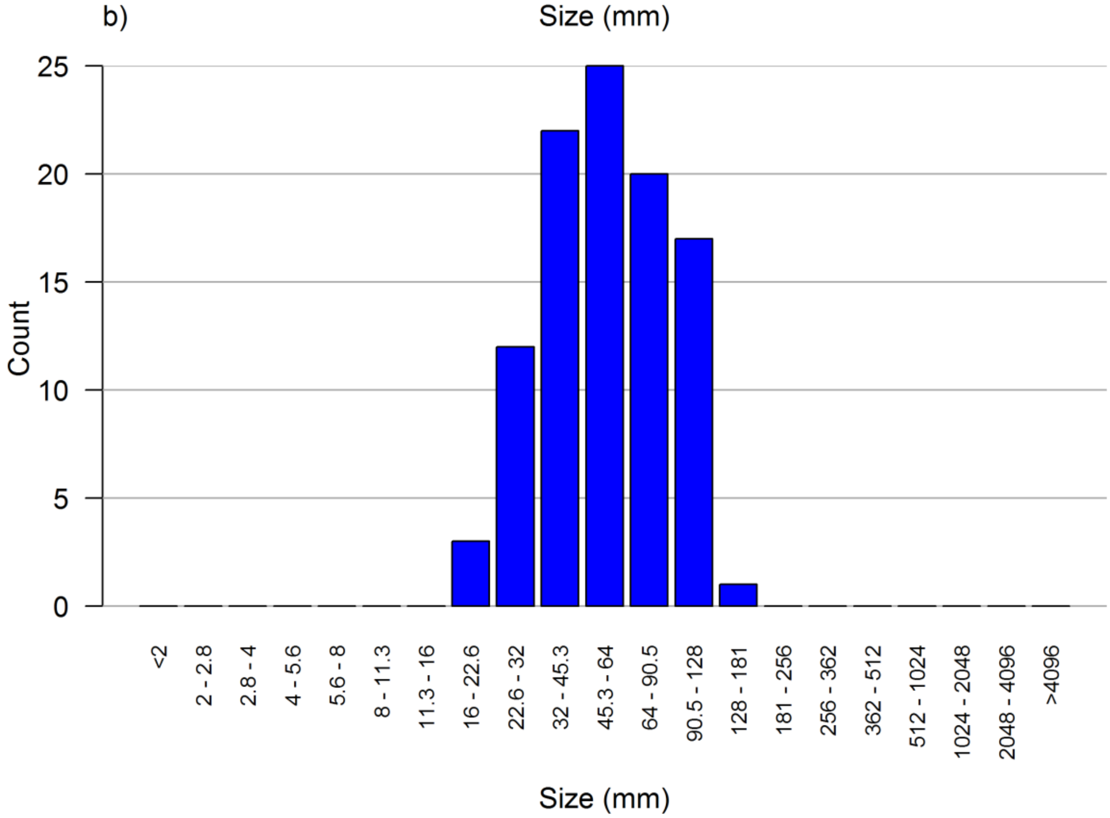


Figure 30. Substrate Grain Distribution at LCDRY-CI271 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

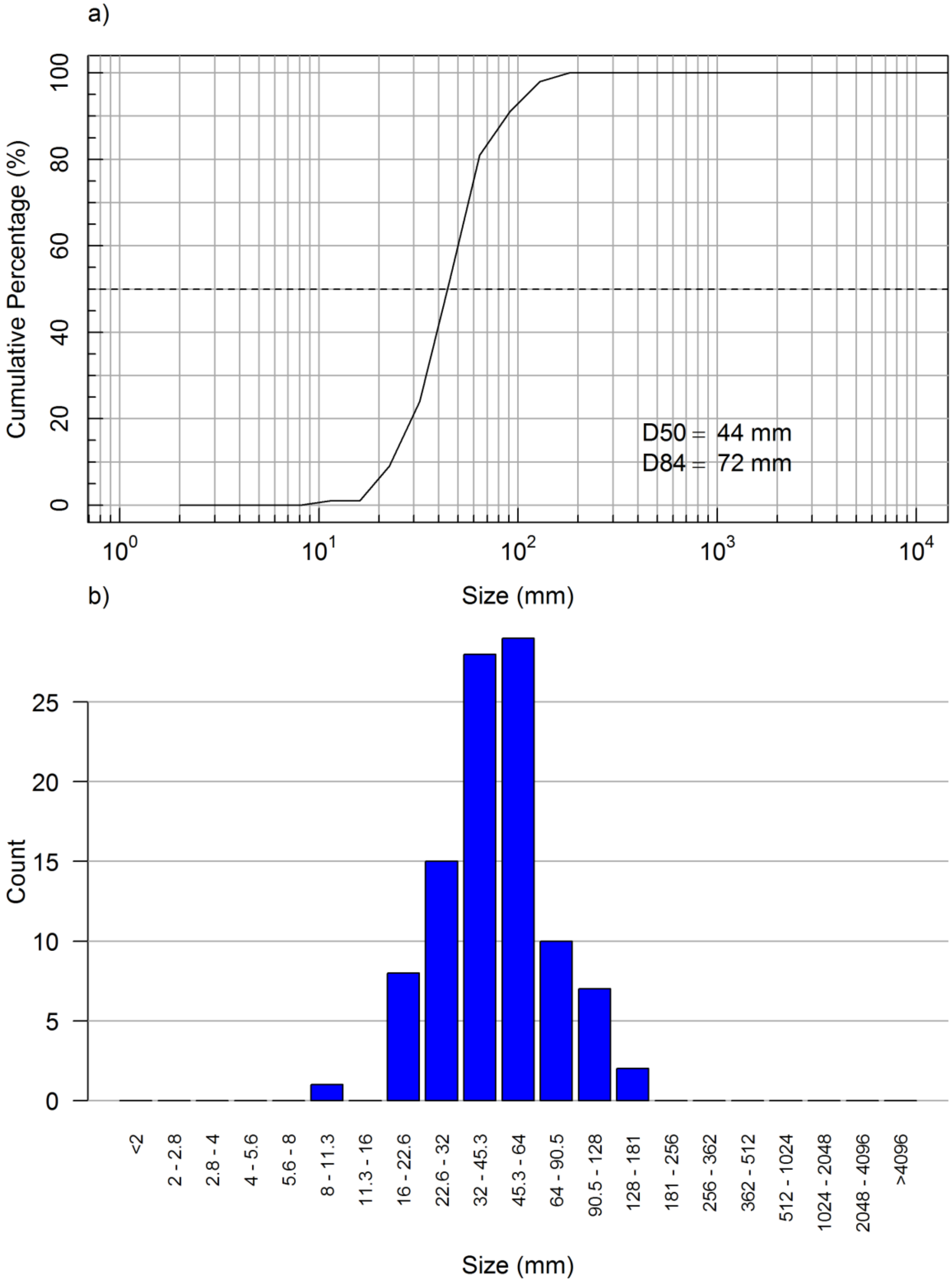


Figure 31. Substrate Grain Distribution at LCDRY-CI282 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.

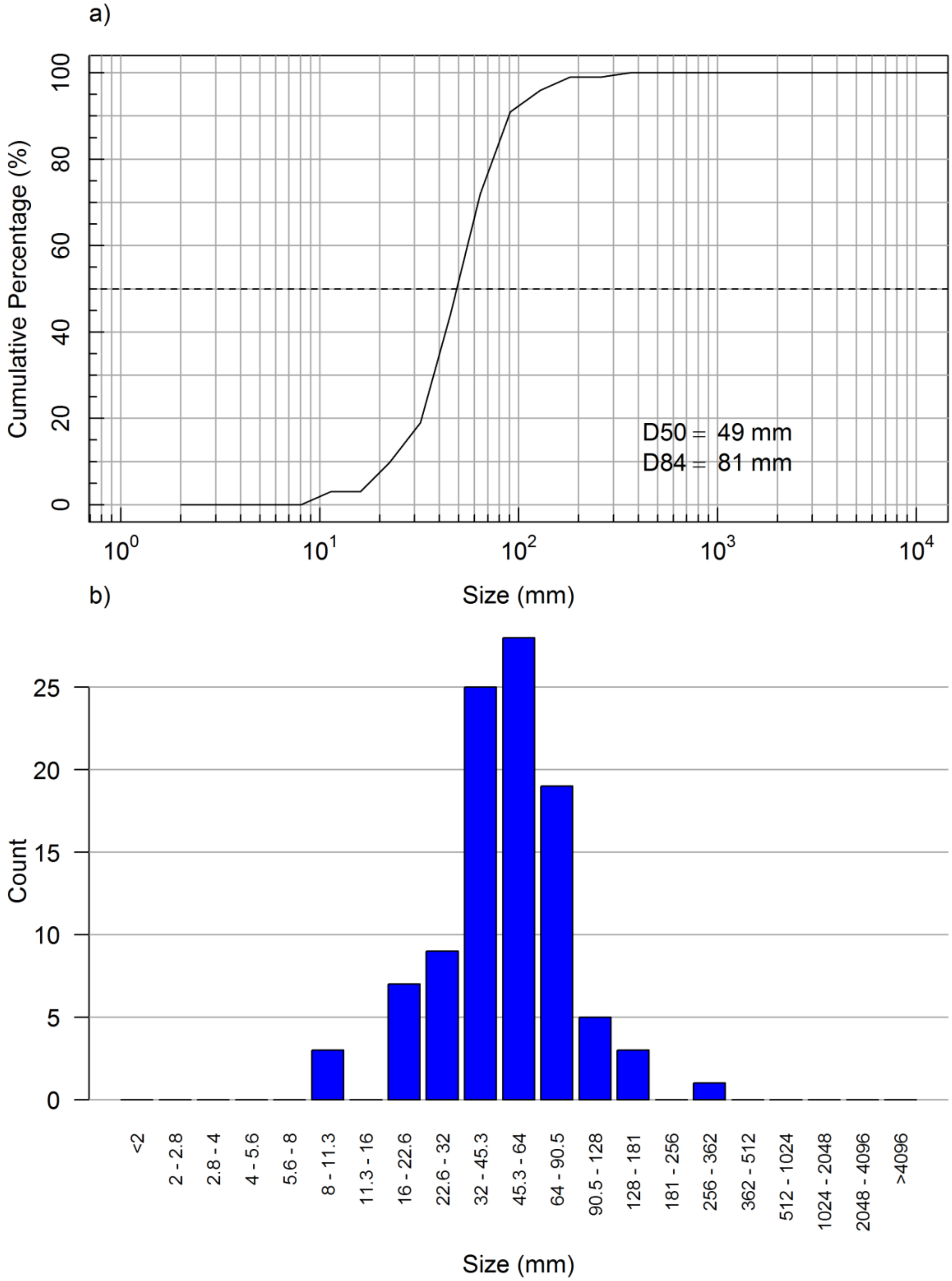
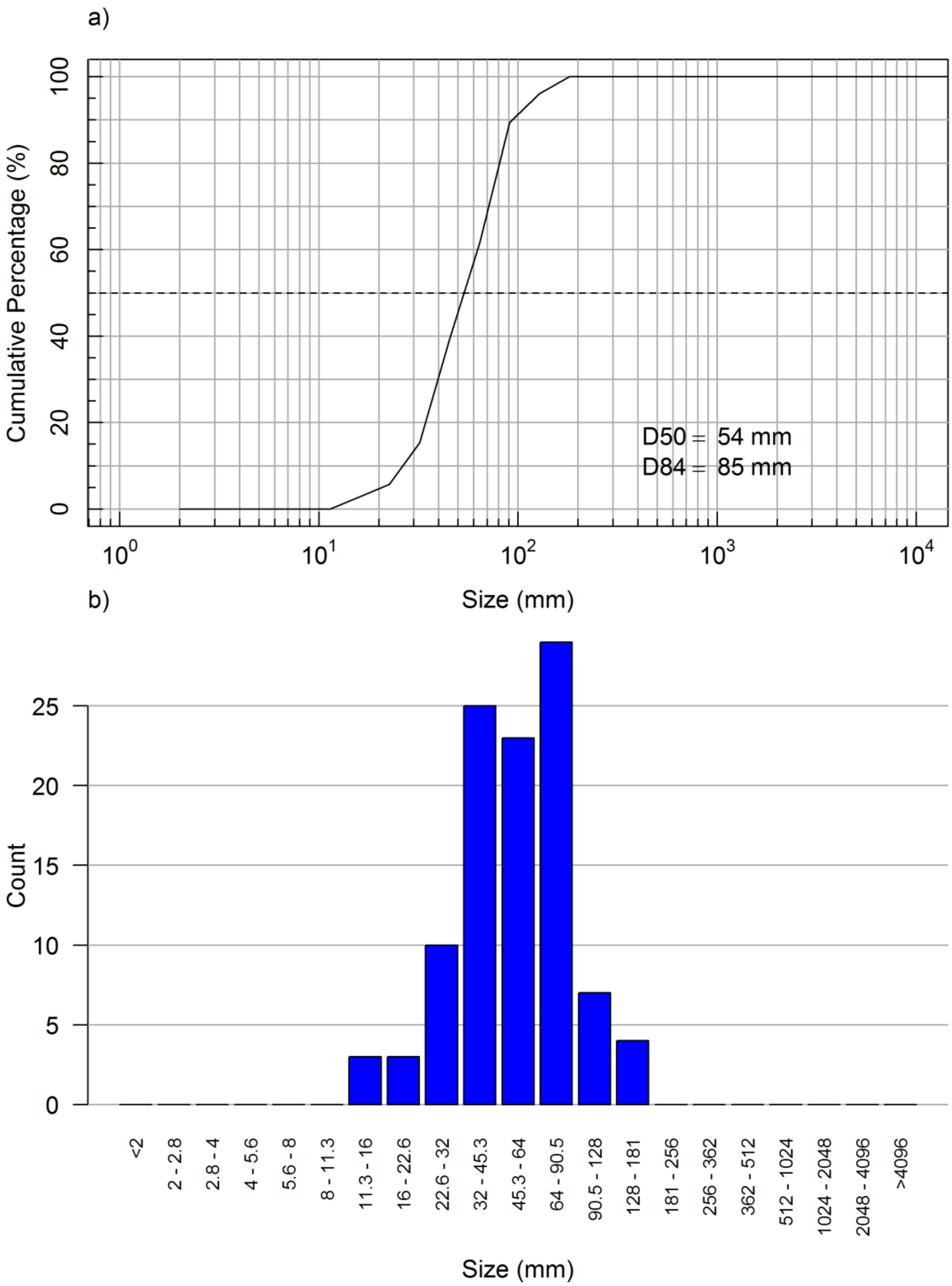


Figure 32. Substrate Grain Distribution at LCDRY-CI333 in LCO Dry Creek on August, 2017. (a) cumulative particle size distribution and (b) number of particles per size class.



Appendix D. Summary of Surface Hydrology and Hydraulic Head Results

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Table 1. Summary of surface hydrology measurements collected in 2017.

Site Name	Measured Flow (m^3/s)[1]	Location	Water Depth (Ruler) (m)	Water Depth (Swoffer) (m)	Flow Velocity[2] (m/s)
GRE-CA01[3]	0.03	River Right	0.06	0.06	0.24
		Mid-Channel	0.09	0.09	0.28
		River Left	0.08	0.08	0.24
GRE-CA01[4]	0.03	River Right	0.08	0.08	0.19
		Mid-Channel	0.07	0.07	0.25
		River Left	0.12	0.12	0.30
GRE-CA03[3]	0.03	River Right	0.08	0.06	0.30
		Mid-Channel	0.12	0.11	0.34
		River Left	0.11	0.10	0.42
GRE-CA03[4]	0.03	River Right	0.08	0.08	0.27
		Mid-Channel	0.08	0.09	0.35
		River Left	0.07	0.07	0.42
HEN-CA01	0.23	River Right	0.11	0.11	0.33
		Mid-Channel	0.15	0.14	0.30
		River Left	0.15	0.15	0.25
HEN-CA02	0.34	River Right	0.15	0.15	0.27
		Mid-Channel	0.12	0.12	0.77
		River Left	0.12	0.12	0.23
LCDRY-CA01	0.04	River Right	0.08	0.08	0.24
		Mid-Channel	0.15	0.15	0.45
		River Left	0.06	0.60	0.25
LCDRY-CA02	0.05	River Right	0.10	0.10	0.26
		Mid-Channel	0.20	0.20	0.17
		River Left	0.18	0.18	0.13

[1]Average flow using Price AA or Pygmy meter, assumed to be representative of the reach flow.

[2] Water velocity measured as average water column velocity using a Swoffer meter.

[3]At location where 2016 study methods were used.

[4]At location where modified methods were used.

Table 2. Summary of hydraulic head measurements collected at Greenhills Creek, LCO Dry Creek, and Henretta Creek in 2017.

Site	Date	Measured Depth (cm)	Hydraulic Head (m)[2]					Note
			n[1]	Avg.	Min.	Max.	SD	
GRE-CA01	27-Aug-17	30	3	0.0570	0.0350	0.0710	0.0193	Modified method
		50	3	0.0823	0.0750	0.0870	0.0064	Modified method
	27-Aug-17	30	3	0.0517	0.0260	0.0750	0.0246	Unmodified method
		50	3	0.0843	0.0790	0.0930	0.0076	Unmodified method
GRE-CA03	28-Aug-17	30	3	0.0220	0.0150	0.0310	0.0082	
		50	3	0.0287	0.0070	0.0400	0.0188	
	28-Aug-17	30	4	0.0173	-0.0010	0.0330	0.0172	
		50	3	0.0080	-0.0030	0.0170	0.0101	
LCDRY-CA01	29-Aug-17	30	3	-0.0023	-0.0060	0.0040	0.0055	
		50	3	0.0010	0.0000	0.0030	0.0017	
LCDRY-CA02	31-Aug-17	30	3	0.1013	0.0180	0.1630	0.0749	
		50	3	0.0820	0.0760	0.0910	0.0079	
HEN-CA01	30-Aug-17	30	3	0.3553	0.2610	0.4450	0.0921	
		50	3	0.3333	0.2470	0.3900	0.0760	
HEN-CA02	01-Sep-17	30	3	0.0047	-0.0080	0.0260	0.0186	
		50	3	0.0137	-0.0130	0.0600	0.0403	

[1] Number of head measurements at a site.

2 Average (Avg), minimum (Min), maximum (Max), and standard deviation (SD) of hydraulic head measurements.

Appendix E. Water quality data tables and QA/QC

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Table 1. Typical range of specific conductivity, pH, and dissolved oxygen in BC surface watercourses.

Parameter	Unit	Typical Range in BC	Reference
Specific Conductivity	µS/cm	The typical value in coastal British Columbia streams is 100 µS/cm, while interior streams range up to 500 µS/cm	RISC (1998)
pH	pH units	Natural fresh waters have a pH range from 4 to 10, and lakes tend to have a pH ≥ 7.0.	RISC (1998)
Dissolved Oxygen	mg/L	In BC surface waters are generally well aerated and have DO concentrations greater than 10 mg/L	MOE (1997a)
Dissolved Oxygen	% saturation	In BC surface waters are generally well aerated and have DO concentrations close to equilibrium with the atmosphere (i.e., close to 100% saturation)	MOE (1997a)

Table 2. BC MOE Guidelines for the Protection of Aquatic Life for dissolved oxygen (mg/L) in the water column and interstitial waters.

	BC Guidelines for the Protection of Aquatic Life[1]		
	Life Stages Other Than Buried Embryo/Alevin	**Buried Embryo/Alevin[2]**	**Buried Embryo/Alevin[2]**
Dissolved Oxygen Concentration	Water column mg/L O_2	Water column mg/L O_2	Interstitial Water mg/L O_2
Instantaneous minimum[3]	5	9	6
30-day mean[4]	8	11	8

[1] MOE (1997a) and MOE (1997b)

[2] For the buried embryo / alevin life stages these are in-stream concentrations from spawning to the point of yolk sac absorption or 30 days post-hatch for fish; the water column concentrations recommended to achieve interstitial dissolved oxygen values when the latter are unavailable. Interstitial oxygen measurements would supersede water column measurements in comparing to criteria.

[3] The instantaneous minimum level is to be maintained at all times.

[4] The mean is based on at least five approximately evenly spaced samples. If a diurnal cycle exists in the water body, measurements should be taken when oxygen levels are lowest (usually early morning).

Table 3. Summary of *in situ* dissolved oxygen (mg/L and % saturation) and water temperature (°C) at Greenhills Creek, LCO Dry Creek, and Henretta Creek calcite study sites in 2017.

Site	Date (2017)	Piezometer Methodology	Depth Zone (cm)	n	Dissolved Oxygen (mg/L)				Dissolved Oxygen (% sat.)				Water Temperature (°C)			
					Avg.	Min.	Max.	SD	Avg.	Min.	Max.	SD	Avg.	Min.	Max.	SD
GRE-CA01	27-Aug	unmodified	0	3	8.2	7.9	8.3	0.2	83.23	82.50	83.90	0.7	16.3	15.3	18.1	1.6
			30	3	7.7	7.3	8.1	0.4	79.50	74.00	83.70	5.0	17.1	16.3	17.9	0.8
			50	3	7.0	6.3	7.7	0.7	68.07	51.90	79.10	14.3	16.2	14.5	17.1	1.5
		modified	0	3	8.2	7.9	8.3	0.2	83.53	83.40	83.80	0.2	16.5	15.6	18.2	1.5
			30	3	7.5	6.6	8.0	0.8	78.27	68.80	83.20	8.2	17.4	17.1	17.6	0.3
			50	3	7.0	6.2	7.5	0.7	72.23	63.50	76.90	7.6	17.0	16.6	17.7	0.7
GRE-CA03	28-Aug	unmodified	0	3	8.5	8.3	8.6	0.1	84.50	83.60	85.90	1.2	15.2	14.4	16.8	1.4
			30	4	8.0	7.3	8.5	0.6	81.75	77.20	84.80	3.7	16.6	15.2	18.2	1.5
			50	3	7.8	6.9	8.2	0.7	79.27	71.20	83.80	7.0	16.5	16.3	16.8	0.3
		modified	0	3	8.5	8.3	8.6	0.2	85.20	84.20	87.10	1.6	15.7	14.5	18.0	2.0
			30	3	7.5	5.8	8.5	1.6	76.43	60.10	84.80	14.1	16.2	15.5	17.3	1.2
			50	3	6.8	5.2	8.1	1.5	70.83	53.70	82.60	15.2	17.0	16.5	17.6	0.7
LCDRY-CA01	29-Aug	modified	0	3	10.0	9.9	10.0	0.0	84.00	83.50	84.50	0.5	7.8	7.8	8.2	0.1
			30	3	9.1	8.3	9.6	0.7	78.23	70.50	82.90	6.7	8.8	8.1	9.5	0.6
			50	3	8.1	7.5	8.7	0.6	68.97	63.20	75.10	6.0	8.2	7.8	8.7	0.5
LCDRY-CA02	31-Aug	modified	0	3	10.8	10.7	10.8	0.0	87.23	87.10	87.40	0.2	6.4	6.3	6.3	0.1
			30	3	10.8	10.7	10.8	0.0	88.77	88.60	89.10	0.3	7.1	6.9	7.2	0.2
			50	2,3	10.6	0.4	10.6	0.0	89.95	3.10	90.10	0.2	8.1	7.8	8.4	0.3
HEN-CA01	30-Aug	modified	0	3	9.6	9.6	9.7	0.0	85.93	85.70	86.20	0.3	10.2	10.0	10.3	0.2
			30	3	9.6	9.5	9.6	0.0	85.90	85.30	86.30	0.5	10.6	10.4	10.7	0.2
			50	3	9.6	9.5	9.6	0.0	86.03	85.90	86.10	0.1	10.7	10.5	10.8	0.2
HEN-CA02	1-Sep	modified	0	3	9.5	9.5	9.5	0.0	83.03	82.90	83.10	0.1	9.4	9.4	9.4	0.1
			30	3	8.0	5.1	9.5	2.5	70.13	44.30	83.10	22.4	9.5	8.9	9.7	0.5
			50	3	7.6	4.0	9.4	3.1	66.93	34.50	83.40	28.1	9.6	8.9	9.9	0.6

Yellow shading indicates the data point was not included in any further data analysis including the avg. and SD. n=2 for DO at 50 cm depth at LCDRYCA02 where fines were encountered and the dissolved oxygen readings did not stabilize in a reasonable timeframe.

Grey shading indicates that the dissolved oxygen concentration (mg/L) is below the instantaneous minimum BC WQG (6 mg/L) for interstitial water for the protection of aquatic life (BC MOE 2017).

Blue shading indicates that the dissolved oxygen concentration (mg/L) is below the BC WQG guidelines for the 30 day mean minimum concentration (8 mg/L) for interstitial water for the protection of aquatic life (BC MOE 2017).

Table 4. Summary of *in situ* pH and specific conductivity at Greenhills Creek, LCO Dry Creek, and Henretta Creek study sites in 2017.

Site	Date (2017)	Piezometer Methodology	Depth Zone (cm)	n	pH				Specific Conductivity (µS/cm)			
					Avg.	Min.	Max.	SD	Avg.	Min.	Max.	SD
GRE-CA01	27-Aug	unmodified	0	3	8.27	8.19	8.40	0.1	1603	1598	1606	5
			30	3	8.51	8.14	8.76	0.3	1606	1600	1614	7
			50	3	8.06	7.73	8.22	0.3	1618	1616	1622	3
		modified	0	3	8.34	8.19	8.63	0.3	1593	1587	1601	7
			30	3	8.33	8.08	8.71	0.3	1597	1591	1602	6
			50	3	8.24	8.01	8.44	0.2	1596	1579	1623	23
GRE-CA03*	28-Aug	unmodified	0	3	8.24	8.15	8.37	0.1	1599	1584	1606	13
			30	4	8.24	8.16	8.33	0.1	1606	1595	1625	14
			50	3	8.34	8.24	8.48	0.1	1594	1570	1611	22
		modified	0	3	8.24	8.20	8.31	0.1	1597	1589	1605	8
			30	3	8.36	7.95	8.63	0.4	1597	1596	1598	1
			50	3	8.15	8.09	8.18	0.0	1606	1603	1613	6
LCDRY-CA01	29-Aug	modified	0	3	8.21	8.20	8.22	0.0	234	167	324	81
			30	3	8.09	7.87	8.23	0.2	335	331	340	4
			50	3	7.78	7.67	8.00	0.2	333	328	337	4
LCDRY-CA02	31-Aug	modified	0	3	8.03	7.99	8.05	0.0	351	349	353	2
			30	3	8.27	8.24	8.30	0.0	352	351	354	2
			50	3	8.03	7.42	8.38	0.5	347	340	350	5
HEN-CA01	30-Aug	modified	0	3	8.08	8.05	8.11	0.0	554	551	555	2
			30	2,3	8.08	8.03	8.14	0.1	554	8.8	561	10
			50	3	8.10	8.06	8.15	0.0	548	544	554	6
HEN-CA02	1-Sep	modified	0	3	7.89	7.87	7.91	0.0	556	555	558	2
			30	3	7.93	7.59	8.14	0.3	553	544	557	8
			50	3	7.90	7.66	8.03	0.2	549	538	556	9

Yellow shading indicates the data point was not included in any further data analysis including the avg. and SD. n=2 at 30 cm depth at HEN-CA01 for specific conductivity, readings did not stabilize in a reasonable time frame.

* An an extra reading was taken at GRE-CA03, n=4 (unmodified method) at 30 cm; one during pumping and one when there was no pumping.

Table 5. Greenhills Creek, field and trip blank physical parameters, anions, and nutrients measured at ALS labs.

Parameter	GRE-CA01			GRE-CA03			FIELD BLANK	TRIP BLANK	BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm				
Date (2017)	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	1-Sep	1-Sep		
Physical Tests (mg/L)										
Sp. Conductivity (lab, µS/cm)	1,600	1,600	1,590	1,580	1,580	1,570	<2.0	<2.0		
Alkalinity, Total (as CaCO3)	214	219	214	224	224	224	<1.0	<1.0		
Hardness (as CaCO3)[1]	1,070	1,070	1,080	1,070	1,070	1,070	<0.50	<0.50		
Total Dissolved Solids	1,510	1,530	1,450	1,510	1,490	1,480	<10	<10		
Total Suspended Solids	7.5	119	76.3	33.5	4.5	10.9	<1.0	<1.0		
Turbidity (lab, NTU)	2.02	38.9	50.7	4.32	2.38	7.78	<0.10	<0.10		
pH (lab, pH units)	8.29	8.06	8.09	8.30	8.32	8.34	5.46	5.76		6.5-9
Dissolved Organic Carbon	2.79	2.92	2.14	2.99	3.48	1.94	<0.50	<0.50		
Total Organic Carbon	2.85	3.14	2.87	3.13	3.20	3.19	<0.50	<0.50		
Anions and Nutrients (mg/L)										
Ammonia, Total (as N)	0.0158	<0.0050	0.0053	0.0171	0.0145	0.0144	<0.0050	<0.0050	0.102	0.68
Bicarbonate	214	219	214	217	213	214	<1.0	<1.0		
Bromide (Br)	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.050	<0.050		
Carbonate	<1.0	<1.0	<1.0	6.8	10.4	9.8	<1.0	<1.0		
Chloride (Cl)	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<0.50	<0.50	150	600
Orthophosphate (as P)	<0.0010	0.0063	0.0050	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		
Fluoride (F)	0.11	<0.10	<0.10	0.10	0.10	<0.10	<0.020	<0.020		EQ
Hydroxide	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		
Nitrate (as N)	7.94	7.95	7.99	8.03	8.04	8.03	<0.0050	<0.0050	3	32.8
Nitrite (as N)	0.0224	<0.0050	<0.0050	0.0296	0.0293	0.0301	<0.0010	<0.0010	EQ	EQ
Sulfate (SO4)[2]	881	876	878	879	881	880	<0.30	<0.30	EQ/429	
Total Phosphorus (P)	0.0074	0.0492	0.0285	0.212	0.0085	0.0077	<0.0020	<0.0020	EQ	
Total Kjeldahl Nitrogen	0.551	0.520	0.610	0.697	0.570	0.602	<0.050	2.59		

[1,2] Grey shading indicates that hardness exceeds the BC WQG "very hard" category (i.e., > 250 mg/L $CaCO_3$), MOE 2017a). In this case application of the total sulphate guidelines may require site specific assessment. For the purpose of data screening, the BC WQG (long term average) of 429 mg/L total sulphate for very hard (181-250 mg/L $CaCO_3$) water was applied.

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

Pink shading indicates a field or trip blank detection. Total Kjeldahl Nitrogen (TKN) was detected in the trip blank prepared by ALS on September 1, 2017. Trip blanks evaluate shipping and laboratory sources of contamination typically due to volatile parameters. The TKN concentration recorded in the trip blank was an order of magnitude higher than the analytical results; therefore, it is unlikely that the samples experienced similar contamination, nevertheless caution should be used when evaluating TKN for further data analysis.

Table 6. Greenhills Creek, field and trip blank total metals measured at ALS labs.

Parameter	GRE-CA01			GRE-CA03			FIELD BLANK	TRIP BLANK	BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm				
Date (2017)	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	1-Sep	1-Sep		
Total Metals (mg/L)										
Aluminum (Al)	0.102	0.207	0.219	0.0190	0.0542	0.0379	<0.0030	<0.0030		
Antimony (Sb)	0.00097	0.00094	0.00092	0.00100	0.00105	0.00098	<0.00010	<0.00010		
Arsenic (As)	0.00034	0.00044	0.00042	0.00026	0.00029	0.00027	<0.00010	<0.00010		0.005
Barium (Ba)	0.0593	0.0703	0.0712	0.0511	0.0531	0.0514	<0.000050	<0.000050	1	
Beryllium (Be)	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.00013	
Bismuth (Bi)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Boron (B)	0.011	0.011	0.011	0.010	0.011	0.010	<0.010	<0.010		1.2
Cadmium (Cd)	0.0000326	0.0000525	0.0000449	0.0000144	0.0000200	0.0000187	<0.0000050	<0.0000050		
Calcium (Ca)	184	182	174	180	180	176	<0.050	<0.050		
Chromium (Cr)	0.00037	0.00078	0.00061	0.00015	0.00022	0.00033	<0.00010	<0.00010		
Cobalt (Co)	0.00019	0.00028	0.00023	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.004	0.11
Copper (Cu)	0.00059	0.00072	0.00067	<0.00050	0.00051	<0.00050	<0.00050	<0.00050	EQ	EQ
Iron (Fe)	0.231	0.447	0.377	0.029	0.067	0.052	<0.010	<0.010		1
Lead (Pb)	0.000206	0.000314	0.000236	<0.000050	0.000115	<0.000050	<0.000050	<0.000050	EQ	EQ
Lithium (Li)	0.0170	0.0171	0.0166	0.0173	0.0178	0.0167	<0.0010	<0.0010		
Magnesium (Mg)	153	151	151	151	153	152	<0.10	<0.10		
Manganese (Mn)	0.0128	0.0307	0.0313	0.00293	0.00414	0.00330	<0.00010	<0.00010	EQ	EQ
Mercury (Hg) (µg/L)	0.00058	0.00147	0.00196	0.00103	0.00127	0.00098	<0.00050	<0.00050	0.00125	
Molybdenum (Mo)	0.00291	0.00309	0.00300	0.00300	0.00311	0.00305	<0.000050	<0.000050	1	2
Nickel (Ni)	0.0265	0.00745	0.00552	0.0282	0.0274	0.0285	<0.00050	<0.00050	EQ	
Potassium (K)	2.74	2.73	2.78	2.66	2.73	2.67	<0.050	<0.050		
Selenium (Se)	0.174	0.173	0.177	0.176	0.179	0.177	<0.000050	<0.000050	0.002	
Silicon (Si)	2.81	2.88	2.96	2.49	2.61	2.54	<0.10	<0.10		
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	EQ	EQ
Sodium (Na)	2.53	2.51	2.55	2.45	2.50	2.45	<0.050	<0.050		
Strontium (Sr)	0.195	0.199	0.191	0.190	0.193	0.185	<0.00020	<0.00020		
Thallium (Tl)	0.000017	0.000016	0.000013	0.000015	0.000014	0.000014	<0.000010	<0.000010		
Tin (Sn)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Titanium (Ti)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Uranium (U)	0.00889	0.00888	0.00878	0.00929	0.00932	0.00895	<0.000010	<0.000010	0.0085	
Vanadium (V)	0.00079	0.00123	0.00116	<0.00050	0.00059	<0.00050	<0.00050	<0.00050		
Zinc (Zn)	0.0035	0.0033	0.0043	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	EQ	EQ

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

Table 7. Greenhills Creek, field and trip blank dissolved metals measured at ALS labs.

Parameter	GRE-CA01			GRE-CA03			FIELD BLANK	TRIP BLANK	BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm				
Date (2017)	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	28-Aug	1-Sep	1-Sep		
Dissolved Metals (mg/L)										
Aluminum (Al)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	EQ	EQ
Antimony (Sb)	0.00092	0.00092	0.00091	0.00099	0.00094	0.00099	<0.00010	<0.00010		
Arsenic (As)	0.00020	0.00022	0.00022	0.00019	0.00022	0.00019	<0.00010	<0.00010		
Barium (Ba)	0.0564	0.0659	0.0672	0.0498	0.0529	0.0512	<0.000050	<0.000050		
Beryllium (Be)	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020		
Bismuth (Bi)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Boron (B)	0.011	0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Cadmium (Cd)	0.0000166	0.0000227	0.0000233	0.0000108	0.0000135	0.0000116	<0.0000050	<0.0000050	EQ	EQ
Calcium (Ca)	172	169	168	171	166	166	<0.050	<0.050		
Chromium (Cr)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Cobalt (Co)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Copper (Cu)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Iron (Fe)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.35
Lead (Pb)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Lithium (Li)	0.0174	0.0158	0.0150	0.0153	0.0145	0.0151	<0.0010	<0.0010		
Magnesium (Mg)	155	155	155	153	154	153	<0.10	<0.10		
Manganese (Mn)	0.00240	0.00131	0.00091	0.00082	0.00082	0.00073	<0.00010	<0.00010		
Mercury (Hg)	<0.0000050	<0.0000050	0.0000096	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050		
Molybdenum (Mo)	0.00290	0.00301	0.00296	0.00295	0.00286	0.00294	<0.000050	<0.000050		
Nickel (Ni)	0.0247	0.00579	0.00441	0.0277	0.0261	0.0277	<0.00050	<0.00050		
Potassium (K)	2.67	2.70	2.67	2.61	2.68	2.60	<0.050	<0.050		
Selenium (Se)	0.164	0.165	0.165	0.167	0.169	0.173	<0.000050	<0.000050		
Silicon (Si)	2.52	2.42	2.45	2.39	2.36	2.40	<0.050	<0.050		
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010		
Sodium (Na)	2.65	2.62	2.68	2.55	2.58	2.53	<0.050	<0.050		
Strontium (Sr)	0.192	0.188	0.186	0.180	0.177	0.179	<0.00020	<0.00020		
Thallium (Tl)	0.000014	<0.000010	<0.000010	0.000015	0.000013	0.000014	<0.000010	<0.000010		
Tin (Sn)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Titanium (Ti)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Uranium (U)	0.00877	0.00887	0.00878	0.00894	0.00882	0.00891	<0.000010	<0.000010		
Vanadium (V)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Zinc (Zn)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030		

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

Table 8. LCO Dry Creek and Henretta Creek physical parameters, anions, and nutrients measured at ALS labs.

Parameter	LCDRY-CA01			LCDRY-CA02			HEN-CA01				HEN-CA02			BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm	surface	surface - B	30 cm	50 cm	surface	30 cm	50 cm		
Date (2017)	29-Aug	29-Aug	29-Aug	31-Aug	31-Aug	31-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug		
Physical Tests (mg/L)															
Sp. Conductivity (lab, µS/cm)	322	307	306	367	360	359	552	555	555	549	549	546	548		
Alkalinity, Total (as CaCO3)	177	177	176	241	189	194	142	144	145	145	143	144	142		
Hardness (as CaCO3)[1]	189	185	188	192	193	194	299	299	299	295	301	288	289		
Total Dissolved Solids	203	205	200	223	223	218	366	361	364	356	365	361	355		
Total Suspended Solids	1.5	4.3	33.9	1.0	47.8	4.2	1.4	1.0	2.2	7.6	55.6	33.8	102		
Turbidity (lab, NTU)	1.14	4.82	25.7	0.47	24.0	1.13	0.67	0.58	0.68	3.61	15.7	9.78	54.4		
pH (lab, pH units)	8.38	8.37	8.34	8.37	8.39	8.38	8.32	8.31	8.32	8.31	8.27	8.28	8.29		6.5-9
Dissolved Organic Carbon	1.24	1.42	2.39	1.58	1.60	1.36	0.83	0.62	0.79	0.86	1.26	0.90	0.98		
Total Organic Carbon	1.64	1.52	2.28	1.72	1.54	1.49	0.84	0.79	0.79	0.86	1.26	0.90	1.06		
Anions and Nutrients (mg/L)															
Ammonia, Total (as N)	0.0144	0.0126	0.0103	0.0226	0.0227	0.0577	0.0137	0.0102	0.0098	0.0126	0.0131	0.0118	0.0164	0.102	0.68
Bicarbonate	165	166	167	182	178	183	135	138	138	138	143	141	139		
Bromide (Br)	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050		
Carbonate	11.8	10.8	9.0	58.6	11.4	10.6	6.6	6.2	7.2	7.0	<1.0	2.8	2.8		
Chloride (Cl)	0.81	0.84	0.80	0.80	0.85	0.83	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	150	600
Orthophosphate (as P)	0.0070	0.0108	0.0166	0.0050	0.0043	0.0088	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010		
Fluoride (F)	0.094	0.093	0.094	0.095	0.099	0.096	0.214	0.212	0.215	0.208	0.215	0.214	0.214		EQ
Hydroxide	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		
Nitrate (as N)	0.847	0.875	0.913	0.924	0.914	0.920	4.81	4.91	4.89	4.75	4.57	4.58	4.59	3	32.8
Nitrite (as N)	0.0014	0.0011	<0.0010	0.0020	0.0014	0.0012	0.0064	0.0070	0.0065	0.0061	0.0062	0.0062	0.0066	EQ	EQ
Sulfate (SO4)[2]	14.0	13.9	13.9	14.2	14.2	14.4	142	144	143	142	139	139	140	EQ/429	
Total Phosphorus (P)	0.0158	0.0174	0.0454	0.0069	0.0142	0.0086	0.0020	<0.0020	0.0038	0.0029	0.0054	0.0091	0.0131	EQ	
Total Kjeldahl Nitrogen	0.108	0.058	0.109	0.148	0.113	0.117	0.482	0.442	0.435	0.546	0.445	0.466	0.466		

[1,2] Grey shading indicates that hardness exceeds the BC WQG "very hard" category (i.e., > 250 mg/L $CaCO_3$), MOE 2017a). In this case application of the total sulphate guidelines may require site specific assessment. For the purpose of data screening, the BC WQG (long term average) of 429 mg/L total sulphate for very hard (181-250 mg/L $CaCO_3$) water was applied.

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

Table 9. LCO Dry Creek and Henretta Creek total metals measured at ALS labs.

Parameter	LCDRY-CA01			LCDRY-CA02			HEN-CA01				HEN-CA02			BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm	surface	surface - B	30 cm	50 cm	surface	30 cm	50 cm		
Date (2017)	29-Aug	29-Aug	29-Aug	31-Aug	31-Aug	31-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug		
Total Metals (mg/L)															
Aluminum (Al)	0.0074	0.138	0.138	0.0040	0.0659	0.0120	0.0053	0.0055	0.0066	0.0281	0.0738	0.0610	0.221		
Antimony (Sb)	0.00017	0.00023	0.00022	0.00015	0.00019	0.00017	0.00012	0.00014	0.00012	0.00014	0.00012	0.00012	0.00018		
Arsenic (As)	0.00019	0.00031	0.00036	0.00015	0.00021	0.00016	0.00012	0.00011	0.00013	0.00013	0.00014	0.00015	0.00024		0.005
Barium (Ba)	0.205	0.214	0.222	0.217	0.201	0.210	0.0371	0.0368	0.0378	0.0374	0.0385	0.0373	0.0404	1	
Beryllium (Be)	<0.000020	<0.000020	0.000025	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	0.00013	
Bismuth (Bi)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Boron (B)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		1.2
Cadmium (Cd)	0.0000396	0.000104	0.000116	0.0000483	0.0000694	0.0000444	0.0000273	0.0000298	0.0000248	0.0000292	0.0000348	0.0000381	0.0000869		
Calcium (Ca)	48.0	48.9	49.4	47.6	48.0	46.4	74.4	74.7	74.7	74.9	78.4	75.5	78.6		
Chromium (Cr)	<0.00010	0.00081	0.00065	<0.00010	0.00032	0.00018	<0.00010	0.00010	0.00011	0.00024	0.00028	0.00033	0.00116		
Cobalt (Co)	<0.00010	0.00017	0.00019	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011	0.00011	0.00011	0.00033	0.004	0.11
Copper (Cu)	<0.00050	0.00064	0.00071	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00061	EQ	EQ
Iron (Fe)	0.023	0.280	0.353	0.019	0.128	0.028	0.012	0.012	0.014	0.040	0.128	0.091	0.314		1
Lead (Pb)	<0.000050	0.000234	0.000245	<0.000050	0.000114	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	0.000096	0.000078	0.000301	EQ	EQ
Lithium (Li)	0.0102	0.0106	0.0104	0.0118	0.0115	0.0115	0.0087	0.0089	0.0089	0.0087	0.0083	0.0085	0.0086		
Magnesium (Mg)	18.3	18.6	18.4	19.3	18.7	19.0	28.1	28.6	28.6	27.7	28.3	27.8	28.9		
Manganese (Mn)	0.00268	0.00942	0.00985	0.00308	0.00763	0.00309	0.00579	0.00574	0.00551	0.00747	0.0130	0.0119	0.0389	EQ	EQ
Mercury (Hg) (µg/L)	<0.00050	0.00077	0.00138	<0.00050	0.00065	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	0.00059	0.00125	
Molybdenum (Mo)	0.00113	0.00106	0.00119	0.00121	0.00110	0.00116	0.00111	0.00111	0.00107	0.00113	0.00101	0.00105	0.00107	1	2
Nickel (Ni)	<0.00050	0.00128	0.00127	<0.00050	0.00076	<0.00050	0.00108	0.00116	0.00118	0.00147	0.00143	0.00140	0.00242	EQ	
Potassium (K)	1.27	1.39	1.43	1.36	1.32	1.34	0.868	0.874	0.874	0.870	0.872	0.882	0.939		
Selenium (Se)	0.00333	0.00327	0.00324	0.00302	0.00306	0.00302	0.0240	0.0241	0.0243	0.0242	0.0243	0.0245	0.0239	0.002	
Silicon (Si)	3.04	3.32	3.24	3.15	3.02	3.00	1.55	1.58	1.61	1.62	1.69	1.67	1.93		
Silver (Ag)	<0.000010	<0.000010	0.000013	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	EQ	EQ
Sodium (Na)	1.20	1.22	1.19	1.22	1.16	1.19	0.677	0.688	0.676	0.677	0.666	0.674	0.683		
Strontium (Sr)	0.0595	0.0600	0.0613	0.0617	0.0599	0.0594	0.125	0.127	0.125	0.126	0.124	0.126	0.129		
Thallium (Tl)	<0.000010	0.000011	0.000016	<0.000010	0.000011	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	0.000014		
Tin (Sn)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Titanium (Ti)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Uranium (U)	0.000395	0.000428	0.000446	0.000422	0.000432	0.000420	0.00131	0.00137	0.00133	0.00130	0.00128	0.00129	0.00129	0.0085	
Vanadium (V)	0.00068	0.00185	0.00184	0.00052	0.00101	0.00058	<0.00050	<0.00050	<0.00050	<0.00050	0.00050	<0.00050	0.00101		
Zinc (Zn)	<0.0030	0.0040	0.0043	<0.0030	0.0064	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	0.0060	EQ	EQ

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

Table 10. LCO Dry Creek and Henretta Creek dissolved metals measured at ALS labs.

Parameter	LCDRY-CA01			LCDRY-CA02			HEN-CA01				HEN-CA02			BC 30-Day Mean WQG	BC Max WQG
	surface	30 cm	50 cm	surface	30 cm	50 cm	surface	surface - B	30 cm	50 cm	surface	30 cm	50 cm		
Date (2017)	29-Aug	29-Aug	29-Aug	31-Aug	31-Aug	31-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug	30-Aug		
Dissolved Metals (mg/L)															
Aluminum (Al)	<0.0030	0.0033	0.0044	<0.0030	0.0041	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	EQ	EQ
Antimony (Sb)	0.00015	0.00016	0.00017	0.00015	0.00017	0.00014	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00011		
Arsenic (As)	0.00015	0.00017	0.00020	0.00015	0.00015	0.00015	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Barium (Ba)	0.195	0.196	0.195	0.204	0.198	0.206	0.0377	0.0369	0.0376	0.0373	0.0370	0.0369	0.0373		
Beryllium (Be)	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020	<0.000020		
Bismuth (Bi)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Boron (B)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Cadmium (Cd)	0.0000280	0.0000295	0.0000333	0.0000294	0.0000320	0.0000314	0.0000204	0.0000221	0.0000241	0.0000185	0.0000216	0.0000215	0.0000195	EQ	EQ
Calcium (Ca)	44.8	44.9	44.0	47.1	48.2	47.6	75.4	75.3	75.8	74.2	76.5	72.7	72.9		
Chromium (Cr)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Cobalt (Co)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Copper (Cu)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Iron (Fe)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		0.35
Lead (Pb)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050		
Lithium (Li)	0.0107	0.0107	0.0107	0.0104	0.0108	0.0109	0.0093	0.0095	0.0090	0.0089	0.0090	0.0087	0.0087		
Magnesium (Mg)	17.7	17.8	17.6	18.0	17.6	18.3	27.0	27.0	26.7	26.7	26.6	25.9	26.1		
Manganese (Mn)	0.00140	0.00082	0.00074	0.00191	0.00097	0.00144	0.00036	0.00042	0.00034	0.00029	0.00033	0.00027	0.00019		
Mercury (Hg)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050		
Molybdenum (Mo)	0.00108	0.00109	0.00117	0.00117	0.00122	0.00124	0.000964	0.000971	0.000967	0.000971	0.000986	0.000958	0.000926		
Nickel (Ni)	<0.00050	0.00051	<0.00050	<0.00050	<0.00050	<0.00050	0.00092	0.00097	0.00095	0.00108	0.00097	0.00099	0.00100		
Potassium (K)	1.22	1.28	1.30	1.25	1.26	1.27	0.857	0.870	0.866	0.839	0.867	0.832	0.855		
Selenium (Se)	0.00298	0.00310	0.00281	0.00336	0.00330	0.00328	0.0258	0.0263	0.0259	0.0258	0.0256	0.0271	0.0256		
Silicon (Si)	2.87	2.99	2.95	2.91	2.92	2.84	1.39	1.39	1.42	1.43	1.47	1.42	1.39		
Silver (Ag)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010		
Sodium (Na)	1.28	1.26	1.25	1.11	1.10	1.19	0.654	0.657	0.654	0.652	0.656	0.639	0.637		
Strontium (Sr)	0.0578	0.0586	0.0579	0.0566	0.0588	0.0582	0.124	0.126	0.123	0.122	0.127	0.124	0.123		
Thallium (Tl)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010		
Tin (Sn)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010		
Titanium (Ti)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010		
Uranium (U)	0.000384	0.000403	0.000420	0.000387	0.000396	0.000443	0.00115	0.00117	0.00119	0.00116	0.00116	0.00112	0.00113		
Vanadium (V)	0.00052	0.00057	0.00066	<0.00050	0.00050	0.00051	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050		
Zinc (Zn)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030		

Yellow shading indicates exceedance of the applicable BC WQG for the protection of aquatic life (MOE 2017a,b).

REFERENCES

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RISC (Resource Inventory Standards Committee). 1998. Guidelines for Interpreting Water Quality Data. Prepared by the BC Ministry of Environment, Lands and Parks for the Resource Inventory Commission. Available online at: https://www.for.gov.bc.ca/hts/risc/pubs/aquatic/interp/intrptoc.htm. Accessed on May 3, 2017.

Appendix F. ALS laboratory reports and QA/QC

Teck Coal Ltd.
ATTN: Lee Wilm
124-B Aspen Dr
Sparwood BC V0B 2G0

Date Received: 29-AUG-17
Report Date: 12-SEP-17 15:17 (MT)
Version: FINAL

Client Phone: 250-425-8209

Certificate of Analysis

Lab Work Order #: L1982741

Project P.O. #: VPO00517564
Job Reference: REGIONAL EFFECTS PROGRAM
C of C Numbers: REP-ECOFISH
Legal Site Desc:

Lyudmyla Shvets, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-1	L1982741-2	L1982741-3	L1982741-4	L1982741-5
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	13:26	13:55	14:17	09:24	10:12
	Client ID	GH_CAWS01_0_20170828_1326	GH_CAWS01_30_20170828_1355	GH_CAWS01_50_20170828_1417	GH_CAWS02_0_20170828_0924	GH_CAWS02_30_20170828_1012
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	1600	1600	1590	1580	1580
	Hardness (as CaCO3) (mg/L)	1070	1070	1080	1070	1070
	pH (pH)	8.29	8.06	8.09	8.30	8.32
	ORP (mV)	241	253	253	251	260
	Total Suspended Solids (mg/L)	7.5	119	76.3	33.5	4.5
	Total Dissolved Solids (mg/L)	1510	1530	1450	1510	1490
	Turbidity (NTU)	2.02	38.9	50.7	4.32	2.38
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0	3.4	3.4	<1.0	<1.0
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	214	219	214	217	213
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	6.8	10.4
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Total (as CaCO3) (mg/L)	214	219	214	224	224
	Ammonia as N (mg/L)	0.0158	<0.0050	0.0053	0.0171	0.0145
	Bromide (Br) (mg/L)	<0.25 DLHC	<0.25 DLHC	<0.25 DLHC	<0.25 DLHC	<0.25 DLHC
	Chloride (Cl) (mg/L)	<2.5 DLHC	<2.5 DLHC	<2.5 DLHC	<2.5 DLHC	<2.5 DLHC
	Fluoride (F) (mg/L)	0.11 DLHC	<0.10 DLHC	<0.10 DLHC	0.10 DLHC	0.10 DLHC
	Nitrate (as N) (mg/L)	7.94 DLHC	7.95 DLHC	7.99 DLHC	8.03 DLHC	8.04 DLHC
	Nitrite (as N) (mg/L)	0.0224 DLHC	<0.0050 DLHC	<0.0050 DLHC	0.0296 DLHC	0.0293 DLHC
	Total Kjeldahl Nitrogen (mg/L)	0.551 TKNI	0.520 TKNI	0.610 TKNI	0.697 TKNI	0.570 TKNI
	Orthophosphate-Dissolved (as P) (mg/L)	<0.0010 PEHT	0.0063 PEHT	0.0050 RRV	<0.0010 PEHT	<0.0010 PEHT
	Phosphorus (P)-Total (mg/L)	0.0074	0.0492	0.0285	0.212	0.0085
	Sulfate (SO4) (mg/L)	881 DLHC	876 DLHC	878 DLHC	879 DLHC	881 DLHC
	Anion Sum (meq/L)	23.2	23.2	23.1	23.4	23.4
	Cation Sum (meq/L)	21.5	21.4	21.3	21.3	21.0
	Cation - Anion Balance (%)	-3.7	-4.0	-4.1	-4.7	-5.4
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	2.79	2.92	2.14	2.99	3.48
	Total Organic Carbon (mg/L)	2.85	3.14	2.87	3.13	3.20
Total Metals	Aluminum (Al)-Total (mg/L)	0.102	0.207	0.219	0.0190	0.0379
	Antimony (Sb)-Total (mg/L)	0.00097	0.00094	0.00092	0.00100	0.00098
	Arsenic (As)-Total (mg/L)	0.00034	0.00044	0.00042	0.00026	0.00027
	Barium (Ba)-Total (mg/L)	0.0593	0.0703	0.0712	0.0511	0.0514
	Beryllium (Be)-Total (ug/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Total (mg/L)	0.011	0.011	0.011	0.010	0.010
	Cadmium (Cd)-Total (ug/L)	0.0326	0.0525	0.0449	0.0144	0.0187
	Calcium (Ca)-Total (mg/L)	184	182	174	180	176

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

		L1982741-6	L1982741-7	L1982741-8	L1982741-9	L1982741-10
	Sample ID	L1982741-6	L1982741-7	L1982741-8	L1982741-9	L1982741-10
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	12:16	13:26	13:55	14:17	09:24
	Client ID	GH_CAWS02_50_20170828_1216	GH_CAWS01_0_20170828_1326_FB	GH_CAWS01_30_20170828_1355_FB	GH_CAWS01_50_20170828_1417_FB	GH_CAWS02_0_20170828_0924_FB
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	1570				
	Hardness (as CaCO3) (mg/L)	1070				
	pH (pH)	8.34				
	ORP (mV)	254				
	Total Suspended Solids (mg/L)	10.9				
	Total Dissolved Solids (mg/L)	1480				
	Turbidity (NTU)	7.78				
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0				
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	214				
	Alkalinity, Carbonate (as CaCO3) (mg/L)	9.8				
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0				
	Alkalinity, Total (as CaCO3) (mg/L)	224				
	Ammonia as N (mg/L)	0.0144				
	Bromide (Br) (mg/L)	DLHC <0.25				
	Chloride (Cl) (mg/L)	DLHC <2.5				
	Fluoride (F) (mg/L)	DLHC <0.10				
	Nitrate (as N) (mg/L)	DLHC 8.03				
	Nitrite (as N) (mg/L)	DLHC 0.0301				
	Total Kjeldahl Nitrogen (mg/L)	TKNI 0.602				
	Orthophosphate-Dissolved (as P) (mg/L)	PEHT <0.0010				
	Phosphorus (P)-Total (mg/L)	0.0077				
	Sulfate (SO4) (mg/L)	DLHC 880				
	Anion Sum (meq/L)	23.4				
	Cation Sum (meq/L)	21.1				
	Cation - Anion Balance (%)	-5.1				
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	1.94				
	Total Organic Carbon (mg/L)	3.19				
Total Metals	Aluminum (Al)-Total (mg/L)	0.0542				
	Antimony (Sb)-Total (mg/L)	0.00105				
	Arsenic (As)-Total (mg/L)	0.00029				
	Barium (Ba)-Total (mg/L)	0.0531				
	Beryllium (Be)-Total (ug/L)	<0.020				
	Bismuth (Bi)-Total (mg/L)	<0.000050				
	Boron (B)-Total (mg/L)	0.011				
	Cadmium (Cd)-Total (ug/L)	0.0200				
	Calcium (Ca)-Total (mg/L)	180				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-11	L1982741-12			
	Description	WS	WS			
	Sampled Date	28-AUG-17	28-AUG-17			
	Sampled Time	10:12	12:16			
	Client ID	GH_CAWS02_30_20170828_1012_FB	GH_CAWS02_50_20170828_1216_FB			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	ORP (mV)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Acidity (as CaCO3) (mg/L)					
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia as N (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)					
	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (ug/L)					
	Bismuth (Bi)-Total (mg/L)					
	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (ug/L)					
	Calcium (Ca)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-1	L1982741-2	L1982741-3	L1982741-4	L1982741-5
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	13:26	13:55	14:17	09:24	10:12
	Client ID	GH_CAWS01_0_20170828_1326	GH_CAWS01_30_20170828_1355	GH_CAWS01_50_20170828_1417	GH_CAWS02_0_20170828_0924	GH_CAWS02_30_20170828_1012
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	0.00037	0.00078	0.00061	0.00015	0.00033
	Cobalt (Co)-Total (ug/L)	0.19	0.28	0.23	<0.10	<0.10
	Copper (Cu)-Total (mg/L)	0.00059	0.00072	0.00067	<0.00050	<0.00050
	Iron (Fe)-Total (mg/L)	0.231	0.447	0.377	0.029	0.052
	Lead (Pb)-Total (mg/L)	0.000206	0.000314	0.000236	<0.000050	<0.000050
	Lithium (Li)-Total (mg/L)	0.0170	0.0171	0.0166	0.0173	0.0167
	Magnesium (Mg)-Total (mg/L)	153	151	151	151	152
	Manganese (Mn)-Total (mg/L)	0.0128	0.0307	0.0313	0.00293	0.00330
	Mercury (Hg)-Total (ug/L)	0.00058	0.00147	0.00196	0.00103	0.00098
	Molybdenum (Mo)-Total (mg/L)	0.00291	0.00309	0.00300	0.00300	0.00305
	Nickel (Ni)-Total (mg/L)	0.0265	0.00745	0.00552	0.0282	0.0285
	Potassium (K)-Total (mg/L)	2.74	2.73	2.78	2.66	2.67
	Selenium (Se)-Total (ug/L)	174	173	177	176	177
	Silicon (Si)-Total (mg/L)	2.81	2.88	2.96	2.49	2.54
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	2.53	2.51	2.55	2.45	2.45
	Strontium (Sr)-Total (mg/L)	0.195	0.199	0.191	0.190	0.185
	Thallium (Tl)-Total (mg/L)	0.000017	0.000016	0.000013	0.000015	0.000014
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Uranium (U)-Total (mg/L)	0.00889	0.00888	0.00878	0.00929	0.00895
	Vanadium (V)-Total (mg/L)	0.00079	0.00123	0.00116	<0.00050	<0.00050
	Zinc (Zn)-Total (mg/L)	0.0035	0.0033	0.0043	<0.0030	<0.0030
Dissolved Metals	Dissolved Mercury Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD	FIELD	FIELD
	Aluminum (Al)-Dissolved (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Antimony (Sb)-Dissolved (mg/L)	0.00092	0.00092	0.00091	0.00099	0.00099
	Arsenic (As)-Dissolved (mg/L)	0.00020	0.00022	0.00022	0.00019	0.00019
	Barium (Ba)-Dissolved (mg/L)	0.0564	0.0659	0.0672	0.0498	0.0512
	Beryllium (Be)-Dissolved (ug/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Dissolved (mg/L)	0.011	0.010	<0.010	<0.010	<0.010
	Cadmium (Cd)-Dissolved (ug/L)	0.0166	0.0227	0.0233	0.0108	0.0116
	Calcium (Ca)-Dissolved (mg/L)	172	169	168	171	166
	Chromium (Cr)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Dissolved (ug/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Copper (Cu)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-6	L1982741-7	L1982741-8	L1982741-9	L1982741-10
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	12:16	13:26	13:55	14:17	09:24
	Client ID	GH_CAWS02_50_20170828_1216	GH_CAWS01_0_20170828_1326_FB	GH_CAWS01_30_20170828_1355_FB	GH_CAWS01_50_20170828_1417_FB	GH_CAWS02_0_20170828_0924_FB
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	0.00022				
	Cobalt (Co)-Total (ug/L)	<0.10				
	Copper (Cu)-Total (mg/L)	0.00051				
	Iron (Fe)-Total (mg/L)	0.067				
	Lead (Pb)-Total (mg/L)	0.000115				
	Lithium (Li)-Total (mg/L)	0.0178				
	Magnesium (Mg)-Total (mg/L)	153				
	Manganese (Mn)-Total (mg/L)	0.00414				
	Mercury (Hg)-Total (ug/L)	0.00127	<0.00050	<0.00050	<0.00050	<0.00050
	Molybdenum (Mo)-Total (mg/L)	0.00311				
	Nickel (Ni)-Total (mg/L)	0.0274				
	Potassium (K)-Total (mg/L)	2.73				
	Selenium (Se)-Total (ug/L)	179				
	Silicon (Si)-Total (mg/L)	2.61				
	Silver (Ag)-Total (mg/L)	<0.000010				
	Sodium (Na)-Total (mg/L)	2.50				
	Strontium (Sr)-Total (mg/L)	0.193				
	Thallium (Tl)-Total (mg/L)	0.000014				
	Tin (Sn)-Total (mg/L)	<0.00010				
	Titanium (Ti)-Total (mg/L)	<0.010				
	Uranium (U)-Total (mg/L)	0.00932				
	Vanadium (V)-Total (mg/L)	0.00059				
	Zinc (Zn)-Total (mg/L)	<0.0030				
Dissolved Metals	Dissolved Mercury Filtration Location	FIELD				
	Dissolved Metals Filtration Location	FIELD				
	Aluminum (Al)-Dissolved (mg/L)	<0.0030				
	Antimony (Sb)-Dissolved (mg/L)	0.00094				
	Arsenic (As)-Dissolved (mg/L)	0.00022				
	Barium (Ba)-Dissolved (mg/L)	0.0529				
	Beryllium (Be)-Dissolved (ug/L)	<0.020				
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050				
	Boron (B)-Dissolved (mg/L)	<0.010				
	Cadmium (Cd)-Dissolved (ug/L)	0.0135				
	Calcium (Ca)-Dissolved (mg/L)	166				
	Chromium (Cr)-Dissolved (mg/L)	<0.00010				
	Cobalt (Co)-Dissolved (ug/L)	<0.10				
	Copper (Cu)-Dissolved (mg/L)	<0.00050				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-11	L1982741-12			
	Description	WS	WS			
	Sampled Date	28-AUG-17	28-AUG-17			
	Sampled Time	10:12	12:16			
	Client ID	GH_CAWS02_30_20170828_1012_FB	GH_CAWS02_50_20170828_1216_FB			
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (ug/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (ug/L)	<0.00050	<0.00050			
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Selenium (Se)-Total (ug/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
Dissolved Metals	Dissolved Mercury Filtration Location					
	Dissolved Metals Filtration Location					
	Aluminum (Al)-Dissolved (mg/L)					
	Antimony (Sb)-Dissolved (mg/L)					
	Arsenic (As)-Dissolved (mg/L)					
	Barium (Ba)-Dissolved (mg/L)					
	Beryllium (Be)-Dissolved (ug/L)					
	Bismuth (Bi)-Dissolved (mg/L)					
	Boron (B)-Dissolved (mg/L)					
	Cadmium (Cd)-Dissolved (ug/L)					
	Calcium (Ca)-Dissolved (mg/L)					
	Chromium (Cr)-Dissolved (mg/L)					
	Cobalt (Co)-Dissolved (ug/L)					
	Copper (Cu)-Dissolved (mg/L)					

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-1	L1982741-2	L1982741-3	L1982741-4	L1982741-5
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	13:26	13:55	14:17	09:24	10:12
	Client ID	GH_CAWS01_0_20170828_1326	GH_CAWS01_30_20170828_1355	GH_CAWS01_50_20170828_1417	GH_CAWS02_0_20170828_0924	GH_CAWS02_30_20170828_1012
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (Pb)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Dissolved (mg/L)	0.0174	0.0158	0.0150	0.0153	0.0151
	Magnesium (Mg)-Dissolved (mg/L)	155	155	155	153	153
	Manganese (Mn)-Dissolved (mg/L)	0.00240	0.00131	0.00091	0.00082	0.00073
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050	<0.0000050	0.0000096	<0.0000050	<0.0000050
	Molybdenum (Mo)-Dissolved (mg/L)	0.00290	0.00301	0.00296	0.00295	0.00294
	Nickel (Ni)-Dissolved (mg/L)	0.0247	0.00579	0.00441	0.0277	0.0277
	Potassium (K)-Dissolved (mg/L)	2.67	2.70	2.67	2.61	2.60
	Selenium (Se)-Dissolved (ug/L)	164	165	165	167	173
	Silicon (Si)-Dissolved (mg/L)	2.52	2.42	2.45	2.39	2.40
	Silver (Ag)-Dissolved (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Dissolved (mg/L)	2.65	2.62	2.68	2.55	2.53
	Strontium (Sr)-Dissolved (mg/L)	0.192	0.188	0.186	0.180	0.179
	Thallium (Tl)-Dissolved (mg/L)	0.000014	<0.000010	<0.000010	0.000015	0.000014
	Tin (Sn)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Uranium (U)-Dissolved (mg/L)	0.00877	0.00887	0.00878	0.00894	0.00891
	Vanadium (V)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Dissolved (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-6	L1982741-7	L1982741-8	L1982741-9	L1982741-10
	Description	WS	WS	WS	WS	WS
	Sampled Date	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17	28-AUG-17
	Sampled Time	12:16	13:26	13:55	14:17	09:24
	Client ID	GH_CAWS02_50_20170828_1216	GH_CAWS01_0_20170828_1326_FB	GH_CAWS01_30_20170828_1355_FB	GH_CAWS01_50_20170828_1417_FB	GH_CAWS02_0_20170828_0924_FB
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010				
	Lead (Pb)-Dissolved (mg/L)	<0.000050				
	Lithium (Li)-Dissolved (mg/L)	0.0145				
	Magnesium (Mg)-Dissolved (mg/L)	154				
	Manganese (Mn)-Dissolved (mg/L)	0.00082				
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050				
	Molybdenum (Mo)-Dissolved (mg/L)	0.00286				
	Nickel (Ni)-Dissolved (mg/L)	0.0261				
	Potassium (K)-Dissolved (mg/L)	2.68				
	Selenium (Se)-Dissolved (ug/L)	169				
	Silicon (Si)-Dissolved (mg/L)	2.36				
	Silver (Ag)-Dissolved (mg/L)	<0.000010				
	Sodium (Na)-Dissolved (mg/L)	2.58				
	Strontium (Sr)-Dissolved (mg/L)	0.177				
	Thallium (Tl)-Dissolved (mg/L)	0.000013				
	Tin (Sn)-Dissolved (mg/L)	<0.00010				
	Titanium (Ti)-Dissolved (mg/L)	<0.010				
	Uranium (U)-Dissolved (mg/L)	0.00882				
	Vanadium (V)-Dissolved (mg/L)	<0.00050				
	Zinc (Zn)-Dissolved (mg/L)	<0.0030				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1982741-11	L1982741-12			
	Description	WS	WS			
	Sampled Date	28-AUG-17	28-AUG-17			
	Sampled Time	10:12	12:16			
	Client ID	GH_CAWS02_30_20170828_1012_FB	GH_CAWS02_50_20170828_1216_FB			
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)					
	Lead (Pb)-Dissolved (mg/L)					
	Lithium (Li)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					
	Manganese (Mn)-Dissolved (mg/L)					
	Mercury (Hg)-Dissolved (mg/L)					
	Molybdenum (Mo)-Dissolved (mg/L)					
	Nickel (Ni)-Dissolved (mg/L)					
	Potassium (K)-Dissolved (mg/L)					
	Selenium (Se)-Dissolved (ug/L)					
	Silicon (Si)-Dissolved (mg/L)					
	Silver (Ag)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
	Strontium (Sr)-Dissolved (mg/L)					
	Thallium (Tl)-Dissolved (mg/L)					
	Tin (Sn)-Dissolved (mg/L)					
	Titanium (Ti)-Dissolved (mg/L)					
	Uranium (U)-Dissolved (mg/L)					
	Vanadium (V)-Dissolved (mg/L)					
	Zinc (Zn)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	Sample was Filtered and Preserved at the laboratory - dissolved metals (incl. Hg), DOC

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLHC	Detection Limit Raised: Dilution required due to high concentration of test analyte(s).
PEHT	Parameter Exceeded Recommended Holding Time Prior to Analysis
RRV	Reported Result Verified By Repeat Analysis
TKNI	TKN result may be biased low due to Nitrate interference. Nitrate-N is > 10x TKN.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ACIDITY-PCT-CL	Water	Acidity by Automatic Titration	APHA 2310 Acidity

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

ALK-MAN-CL	Water	Alkalinity (Species) by Manual Titration	APHA 2320 ALKALINITY

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

BE-D-L-CCMS-VA	Water	Diss. Be (low) in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

BE-T-L-CCMS-VA	Water	Total Be (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

BR-L-IC-N-CL	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

C-DIS-ORG-LOW-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

C-TOT-ORG-LOW-CL	Water	Total Organic Carbon	APHA 5310 TOTAL ORGANIC CARBON (TOC)

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

CL-IC-N-CL	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-L-PCT-CL	Water	Electrical Conductivity (EC)	APHA 2510B

Conductivity, also known as Electrical Conductivity (EC) or Specific Conductance, is measured by immersion of a conductivity cell with platinum electrodes into a water sample. Conductivity measurements are temperature-compensated to 25C.

Reference Information

F-IC-N-CL Water Fluoride in Water by IC EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA Water Hardness APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-D-CVAA-VA Water Diss. Mercury in Water by CVAAS or CVAFS APHA 3030B/EPA 1631E (mod)

Water samples are filtered (0.45 um), preserved with hydrochloric acid, then undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

HG-T-U-CVAF-VA Water Total Mercury in Water by CVAFS (Ultra) EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

IONBALANCE-BC-CL Water Ion Balance Calculation APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-D-CCMS-VA Water Dissolved Metals in Water by CRC ICPMS APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-T-CCMS-VA Water Total Metals in Water by CRC ICPMS EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NH3-L-F-CL Water Ammonia, Total (as N) J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-BC-L-IC-CL Water Nitrite-N EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

NO3-BC-L-IC-CL Water Nitrate (as N) EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ORP-CL Water Oxidation redution potential by elect. ASTM D1498

This analysis is carried out in accordance with the procedure described in the "ASTM" method D1498 "Oxidation-Reduction Potential of Water" published by the American Society for Testing and Materials (ASTM). Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.

It is recommended that this analysis be conducted in the field.

P-T-L-COL-WP Water Phosphorus, Total APHA 4500 P PHOSPHORUS-L

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorous is determined colourimetrically after persulphate digestion of the sample.

PH-CL Water pH APHA 4500 H-Electrode

pH is determined in the laboratory using a pH electrode. All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PO4-DO-COL-VA Water Diss. Orthophosphate in Water by Colour APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Reference Information

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SO4-IC-N-CL	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-CL	Water	Total Dissolved Solids	APHA 2540 C

A well-mixed sample is filtered through a glass fibre filter paper. The filtrate is then evaporated to dryness in a pre-weighed vial and dried at 180 – 2 °C. The increase in vial weight represents the total dissolved solids (TDS).

TKN-L-F-CL	Water	Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-L-CL	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, and by drying the filter at 104 deg. C.

TURBIDITY-BC-CL	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

REP-ECOFISH

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Teck Coal Ltd.
124-B Aspen Dr
Sparwood BC V0B 2G0
Contact: Lee Wilm

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ALK-MAN-CL	**Water**							
Batch R3815071								
WG2605134-2 LCS								
Alkalinity, Total (as CaCO3)			102.4		%		85-115	29-AUG-17
WG2605134-1 MB								
Alkalinity, Total (as CaCO3)			<1.0		mg/L		1	29-AUG-17
BE-D-L-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-14 LCS								
Beryllium (Be)-Dissolved			101.9		%		80-120	06-SEP-17
WG2609464-13 MB		**NP**						
Beryllium (Be)-Dissolved			<0.000020		mg/L		0.00002	06-SEP-17
BE-T-L-CCMS-VA	**Water**							
Batch R3821772								
WG2609309-3 DUP		**L1982741-1**						
Beryllium (Be)-Total		<0.000020	<0.000020	RPD-NA	mg/L	N/A	20	06-SEP-17
Batch R3821842								
WG2609309-2 LCS								
Beryllium (Be)-Total			109.9		%		80-120	06-SEP-17
WG2609309-1 MB								
Beryllium (Be)-Total			<0.000020		mg/L		0.00002	06-SEP-17
BR-L-IC-N-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Bromide (Br)			98.3		%		85-115	29-AUG-17
WG2609423-1 MB								
Bromide (Br)			<0.050		mg/L		0.05	29-AUG-17
C-DIS-ORG-LOW-CL	**Water**							
Batch R3817000								
WG2607263-2 LCS								
Dissolved Organic Carbon			98.2		%		80-120	01-SEP-17
WG2607263-1 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	31-AUG-17
C-TOT-ORG-LOW-CL	**Water**							
Batch R3817000								
WG2607263-2 LCS								
Total Organic Carbon			85.5		%		80-120	01-SEP-17
WG2607263-1 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TOT-ORG-LOW-CL	**Water**							
Batch R3817000								
WG2607263-1 MB								
Total Organic Carbon			<0.50		mg/L		0.5	31-AUG-17
CL-IC-N-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Chloride (Cl)			100.8		%		90-110	29-AUG-17
WG2609423-1 MB								
Chloride (Cl)			<0.50		mg/L		0.5	29-AUG-17
EC-L-PCT-CL	**Water**							
Batch R3815071								
WG2605134-6 DUP		**L1982741-6**						
Conductivity (@ 25C)		1570	1570		uS/cm	0.2	10	29-AUG-17
WG2605134-2 LCS								
Conductivity (@ 25C)			101.2		%		90-110	29-AUG-17
WG2605134-5 LCS								
Conductivity (@ 25C)			100.2		%		90-110	29-AUG-17
WG2605134-1 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	29-AUG-17
WG2605134-4 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	29-AUG-17
F-IC-N-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Fluoride (F)			97.1		%		90-110	29-AUG-17
WG2609423-1 MB								
Fluoride (F)			<0.020		mg/L		0.02	29-AUG-17
HG-D-CVAA-VA	**Water**							
Batch R3820540								
WG2609337-2 LCS								
Mercury (Hg)-Dissolved			107.1		%		80-120	06-SEP-17
WG2609337-1 MB		**NP**						
Mercury (Hg)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
HG-T-U-CVAF-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-T-U-CVAF-VA	**Water**							
Batch R3820188								
WG2609074-3 DUP		**L1982741-4**						
Mercury (Hg)-Total		0.00103	0.00094	RPD-NA	ug/L	N/A	20	05-SEP-17
WG2609074-2 LCS								
Mercury (Hg)-Total			105.0		%		80-120	05-SEP-17
WG2609074-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	05-SEP-17
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-14 LCS								
Aluminum (Al)-Dissolved			107.0		%		80-120	06-SEP-17
Antimony (Sb)-Dissolved			96.0		%		80-120	06-SEP-17
Arsenic (As)-Dissolved			108.2		%		80-120	06-SEP-17
Barium (Ba)-Dissolved			106.3		%		80-120	06-SEP-17
Bismuth (Bi)-Dissolved			95.3		%		80-120	06-SEP-17
Boron (B)-Dissolved			92.9		%		80-120	06-SEP-17
Cadmium (Cd)-Dissolved			105.8		%		80-120	06-SEP-17
Calcium (Ca)-Dissolved			99.0		%		80-120	06-SEP-17
Chromium (Cr)-Dissolved			101.3		%		80-120	06-SEP-17
Cobalt (Co)-Dissolved			102.2		%		80-120	06-SEP-17
Copper (Cu)-Dissolved			103.5		%		80-120	06-SEP-17
Iron (Fe)-Dissolved			95.4		%		80-120	06-SEP-17
Lead (Pb)-Dissolved			98.8		%		80-120	06-SEP-17
Lithium (Li)-Dissolved			98.8		%		80-120	06-SEP-17
Magnesium (Mg)-Dissolved			107.2		%		80-120	06-SEP-17
Manganese (Mn)-Dissolved			104.8		%		80-120	06-SEP-17
Molybdenum (Mo)-Dissolved			97.3		%		80-120	06-SEP-17
Nickel (Ni)-Dissolved			108.6		%		80-120	06-SEP-17
Potassium (K)-Dissolved			106.1		%		80-120	06-SEP-17
Selenium (Se)-Dissolved			96.6		%		80-120	06-SEP-17
Silicon (Si)-Dissolved			99.8		%		80-120	06-SEP-17
Silver (Ag)-Dissolved			93.9		%		80-120	06-SEP-17
Sodium (Na)-Dissolved			106.2		%		80-120	06-SEP-17
Strontium (Sr)-Dissolved			102.2		%		80-120	06-SEP-17
Thallium (Tl)-Dissolved			98.7		%		80-120	06-SEP-17
Tin (Sn)-Dissolved			95.5		%		80-120	06-SEP-17
Titanium (Ti)-Dissolved			100.5		%		80-120	06-SEP-17

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-14 LCS								
Uranium (U)-Dissolved			98.6		%		80-120	06-SEP-17
Vanadium (V)-Dissolved			103.5		%		80-120	06-SEP-17
Zinc (Zn)-Dissolved			102.7		%		80-120	06-SEP-17
WG2609464-13 MB		**NP**						
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Barium (Ba)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Boron (B)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821772								
WG2609309-3 DUP		**L1982741-1**						
Aluminum (Al)-Total		0.102	0.110		mg/L	7.6	20	06-SEP-17
Antimony (Sb)-Total		0.00097	0.00095		mg/L	2.3	20	06-SEP-17
Arsenic (As)-Total		0.00034	0.00031		mg/L	7.9	20	06-SEP-17
Barium (Ba)-Total		0.0593	0.0596		mg/L	0.4	20	06-SEP-17
Bismuth (Bi)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Boron (B)-Total		0.011	0.011		mg/L	2.5	20	06-SEP-17
Cadmium (Cd)-Total		0.0000326	0.0000381		mg/L	16	20	06-SEP-17
Calcium (Ca)-Total		184	178		mg/L	3.2	20	06-SEP-17
Chromium (Cr)-Total		0.00037	0.00037		mg/L	0.1	20	06-SEP-17
Cobalt (Co)-Total		0.00019	0.00019		mg/L	2.8	20	06-SEP-17
Copper (Cu)-Total		0.00059	0.00061		mg/L	2.9	20	06-SEP-17
Iron (Fe)-Total		0.231	0.235		mg/L	1.8	20	06-SEP-17
Lead (Pb)-Total		0.000206	0.000204		mg/L	1.2	20	06-SEP-17
Lithium (Li)-Total		0.0170	0.0167		mg/L	1.7	20	06-SEP-17
Magnesium (Mg)-Total		153	150		mg/L	2.1	20	06-SEP-17
Manganese (Mn)-Total		0.0128	0.0126		mg/L	1.1	20	06-SEP-17
Molybdenum (Mo)-Total		0.00291	0.00291		mg/L	0.2	20	06-SEP-17
Nickel (Ni)-Total		0.0265	0.0265		mg/L	0.1	20	06-SEP-17
Potassium (K)-Total		2.74	2.70		mg/L	1.3	20	06-SEP-17
Selenium (Se)-Total		0.174	0.173		mg/L	0.4	20	06-SEP-17
Silicon (Si)-Total		2.81	2.79		mg/L	0.8	20	06-SEP-17
Silver (Ag)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Sodium (Na)-Total		2.53	2.49		mg/L	1.5	20	06-SEP-17
Strontium (Sr)-Total		0.195	0.191		mg/L	2.3	20	06-SEP-17
Thallium (Tl)-Total		0.000017	0.000018		mg/L	9.5	20	06-SEP-17
Tin (Sn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Titanium (Ti)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Uranium (U)-Total		0.00889	0.00878		mg/L	1.2	20	06-SEP-17
Vanadium (V)-Total		0.00079	0.00081		mg/L	1.5	20	06-SEP-17
Zinc (Zn)-Total		0.0035	<0.0030	RPD-NA	mg/L	N/A	20	06-SEP-17
Batch R3821842								
WG2609309-2 LCS								
Aluminum (Al)-Total			104.6		%		80-120	06-SEP-17
Antimony (Sb)-Total			110.5		%		80-120	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821842								
WG2609309-2 LCS								
Arsenic (As)-Total			105.1		%		80-120	06-SEP-17
Barium (Ba)-Total			106.7		%		80-120	06-SEP-17
Bismuth (Bi)-Total			105.5		%		80-120	06-SEP-17
Boron (B)-Total			98.7		%		80-120	06-SEP-17
Cadmium (Cd)-Total			102.7		%		80-120	06-SEP-17
Calcium (Ca)-Total			108.4		%		80-120	06-SEP-17
Chromium (Cr)-Total			100.1		%		80-120	06-SEP-17
Cobalt (Co)-Total			104.9		%		80-120	06-SEP-17
Copper (Cu)-Total			103.2		%		80-120	06-SEP-17
Iron (Fe)-Total			107.0		%		80-120	06-SEP-17
Lead (Pb)-Total			107.2		%		80-120	06-SEP-17
Lithium (Li)-Total			113.7		%		80-120	06-SEP-17
Magnesium (Mg)-Total			107.4		%		80-120	06-SEP-17
Manganese (Mn)-Total			107.7		%		80-120	06-SEP-17
Molybdenum (Mo)-Total			106.8		%		80-120	06-SEP-17
Nickel (Ni)-Total			106.0		%		80-120	06-SEP-17
Potassium (K)-Total			106.9		%		80-120	06-SEP-17
Selenium (Se)-Total			104.0		%		80-120	06-SEP-17
Silicon (Si)-Total			108.8		%		80-120	06-SEP-17
Silver (Ag)-Total			106.3		%		80-120	06-SEP-17
Sodium (Na)-Total			107.9		%		80-120	06-SEP-17
Strontium (Sr)-Total			110.4		%		80-120	06-SEP-17
Thallium (Tl)-Total			106.3		%		80-120	06-SEP-17
Tin (Sn)-Total			103.5		%		80-120	06-SEP-17
Titanium (Ti)-Total			95.5		%		80-120	06-SEP-17
Uranium (U)-Total			110.7		%		80-120	06-SEP-17
Vanadium (V)-Total			106.5		%		80-120	06-SEP-17
Zinc (Zn)-Total			102.9		%		80-120	06-SEP-17
WG2609309-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	06-SEP-17
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Barium (Ba)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821842								
WG2609309-1 MB								
Boron (B)-Total			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Total			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Iron (Fe)-Total			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Total			<0.0010		mg/L		0.001	06-SEP-17
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Total			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Total			<0.10		mg/L		0.1	06-SEP-17
Silver (Ag)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Total			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Total			<0.0030		mg/L		0.003	06-SEP-17
NH3-L-F-CL	**Water**							
Batch R3819623								
WG2608866-2 LCS								
Ammonia as N			105.6		%		85-115	05-SEP-17
WG2608866-1 MB								
Ammonia as N			<0.0050		mg/L		0.005	05-SEP-17
NO2-BC-L-IC-CL	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-BC-L-IC-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Nitrite (as N)			103.4		%		90-110	29-AUG-17
WG2609423-1 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	29-AUG-17
NO3-BC-L-IC-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Nitrate (as N)			101.7		%		90-110	29-AUG-17
WG2609423-1 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	29-AUG-17
ORP-CL	**Water**							
Batch R3817550								
WG2607933-2 CRM		**CL-ORP**						
ORP			215		mV		210-230	31-AUG-17
P-T-L-COL-WP	**Water**							
Batch R3820333								
WG2608563-14 LCS								
Phosphorus (P)-Total			107.5		%		80-120	03-SEP-17
WG2608563-13 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	03-SEP-17
Batch R3824184								
WG2613089-6 LCS								
Phosphorus (P)-Total			105.3		%		80-120	11-SEP-17
WG2613089-5 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	11-SEP-17
PH-CL	**Water**							
Batch R3815071								
WG2605134-6 DUP		**L1982741-6**						
pH		8.34	8.32	J	pH	0.02	0.2	29-AUG-17
WG2605134-2 LCS								
pH			7.01		pH		6.9-7.1	29-AUG-17
WG2605134-5 LCS								
pH			7.05		pH		6.9-7.1	29-AUG-17
PO4-DO-COL-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
PO4-DO-COL-VA	**Water**							
Batch R3820320								
WG2609176-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.8		%		80-120	06-SEP-17
WG2609176-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			87.5		%		80-120	06-SEP-17
WG2609176-3 DUP		**L1982741-1**						
Orthophosphate-Dissolved (as P)		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	06-SEP-17
WG2609176-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
WG2609176-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
WG2609176-4 MS		**L1982741-2**						
Orthophosphate-Dissolved (as P)			99.2		%		70-130	06-SEP-17
SO4-IC-N-CL	**Water**							
Batch R3820473								
WG2609423-2 LCS								
Sulfate (SO4)			101.7		%		90-110	29-AUG-17
WG2609423-1 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	29-AUG-17
SOLIDS-TDS-CL	**Water**							
Batch R3819492								
WG2608068-8 LCS								
Total Dissolved Solids			98.0		%		85-115	03-SEP-17
WG2608068-7 MB								
Total Dissolved Solids			<10		mg/L		10	03-SEP-17
TKN-L-F-CL	**Water**							
Batch R3821188								
WG2610037-7 DUP		**L1982741-6**						
Total Kjeldahl Nitrogen		0.602	0.554		mg/L	8.3	20	06-SEP-17
WG2610037-10 LCS								
Total Kjeldahl Nitrogen			103.8		%		75-125	06-SEP-17
WG2610037-9 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	06-SEP-17
WG2610037-8 MS		**L1982741-6**						
Total Kjeldahl Nitrogen			104.0		%		70-130	06-SEP-17
Batch R3822085								
WG2611329-2 LCS								
Total Kjeldahl Nitrogen			98.6		%		75-125	07-SEP-17
WG2611329-1 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
TKN-L-F-CL	**Water**							
Batch R3822085								
WG2611329-1 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	07-SEP-17
TSS-L-CL	**Water**							
Batch R3819525								
WG2608218-2 LCS								
Total Suspended Solids			99.8		%		85-115	03-SEP-17
WG2608218-1 MB								
Total Suspended Solids			<1.0		mg/L		1	03-SEP-17

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH							
	1	28-AUG-17 13:26	29-AUG-17 15:00	0.25	26	hours	EHTR-FM
	2	28-AUG-17 13:55	29-AUG-17 15:00	0.25	25	hours	EHTR-FM
	3	28-AUG-17 14:17	29-AUG-17 15:00	0.25	25	hours	EHTR-FM
	4	28-AUG-17 09:24	29-AUG-17 15:00	0.25	30	hours	EHTR-FM
	5	28-AUG-17 10:12	29-AUG-17 15:00	0.25	29	hours	EHTR-FM
	6	28-AUG-17 12:16	29-AUG-17 15:00	0.25	27	hours	EHTR-FM
Anions and Nutrients							
Diss. Orthophosphate in Water by Colour							
	1	28-AUG-17 13:26	06-SEP-17 03:16	3	9	days	EHT
	2	28-AUG-17 13:55	06-SEP-17 03:20	3	9	days	EHT
	3	28-AUG-17 14:17	06-SEP-17 03:20	3	9	days	EHT
	4	28-AUG-17 09:24	06-SEP-17 03:20	3	9	days	EHT
	5	28-AUG-17 10:12	06-SEP-17 03:20	3	9	days	EHT
	6	28-AUG-17 12:16	06-SEP-17 03:20	3	9	days	EHT

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1982741 were received on 29-AUG-17 09:47.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Teck

COC ID:	REP-2017-08-28	TURNAROUND TIME:	

PROJECT/CLIENT INFO				LABORATORY			
Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	ALS Burnaby		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Loughheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

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teckcoal@equisonline.com			x
carla.fraser@teck.com	x	x	x
andrew.wight@teck.com	x	x	x

SAMPLE DETAILS / ANALYSIS REQUESTED

Filtered ; F: Field, L: Lab, FL: Field & Lab, N: None

Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
FILTERED														
PRESERVED										x			x	
GH_CAWS01_0_20170828_1326	RG_GRE-CA01	WS	NO	8/28/2017	13:26	G	7	x	x	x	x	x	x	x
GH_CAWS01_30_20170828_1355	RG_GRE-CA01	WS	NO	8/28/2017	13:55	G	7	x	x	x	x	x	x	x
GH_CAWS01_50_20170828_1417	RG_GRE-CA01	WS	NO	8/28/2017	14:17	G	7	x	x	x	x	x	x	x
GH_CAWS02_0_20170828_0924	RG_GRE-CA02	WS	NO	8/28/2017	9:24	G	7	x	x	x	x	x	x	x
GH_CAWS02_30_20170828_1012	RG_GRE-CA02	WS	NO	8/28/2017	10:12	G	7	x	x	x	x	x	x	x
GH_CAWS02_50_20170828_1216	RG_GRE-CA02	WS	NO	8/28/2017	12:16	G	7	x	x	x	x	x	x	x
GH_CAWS01_0_20170828_1326_FB	RG_GRE-CA01	WS	NO	8/28/2017	13:26	G	1				x			
GH_CAWS01_30_20170828_1355_FB	RG_GRE-CA01	WS	NO	8/28/2017	13:55	G	1				x			
GH_CAWS01_50_20170828_1417_FB	RG_GRE-CA01	WS	NO	8/28/2017	14:17	G	1				x			
GH_CAWS02_0_20170828_0924_FB	RG_GRE-CA02	WS	NO	8/28/2017	9:24	G	1				x			
GH_CAWS02_30_20170828_1012_FB	RG_GRE-CA02	WS	NO	8/28/2017	10:12	G	1				x			

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS	RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	DATE/TIME
All metals samples must be shipped to ALS Burnaby for analysis				

NB OF BOTTLES RETURNED/DESCRIPTION					
Regular (default)	x	Sampler's Name	Andy Wight	Mobile #	250-433-1159
Priority (2-3 business days) - 50% surcharge		Sampler's Signature		Date/Time	August 1, 2017
Emergency (1 Business Day) - 100% surcharge					
For Emergency <1 Day, ASAP or Weekend - Contact ALS					

L1982741-COFC

Teck

COC ID:	REP-2017-08-29	TURNAROUND TIME:	

PROJECT/CLIENT INFO				LABORATORY					Excel	PDF	EDD
Facility Name / Job#	Calcite Biological Effects VPO00498621			Lab Name	ALS Burnaby						
Project Manager	Lee Wilm			Lab Contact	Can Dang			lee.wilm@teck.com	x	x	x
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com			teckcoal@equisonline.com			x
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Lougheed Hwy			carla.fraser@teck.com	x	x	x
								andrew.wight@teck.com	x	x	x
City	Sparwood	Province	BC	City	Burnaby	Province	BC				
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada				
Phone Number	250-865-5289			Phone Number	604-253-4188						

SAMPLE DETAILS — ANALYSIS REQUESTED — Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA				
PRESERVATIVE										x			x					
GH_CAWS02_50_20170828_1216	RG_GRE-CA02	WS	NO	8/28/2017	12:16	G	1				x							

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS	RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	
All metals samples must be shipped to ALS Burnaby for analysis			Brian 8/29 6°C	9:47am

NB OF BOTTLES RETURNED/DESCRIPTION					
Regular (default)	x	Sampler's Name	Andy Wight	Mobile #	250-433-1159
Priority (2-3 business days) - 50% surcharge					
Emergency (1 Business Day) - 100% surcharge		Sampler's Signature		Date/Time	August 1, 2017
For Emergency <1 Day, ASAP or Weekend - Contact ALS					

L1982741-COFC

Teck Coal Ltd.
ATTN: Lee Wilm
124-B Aspen Dr
Sparwood BC V0B 2G0

Date Received: 30-AUG-17
Report Date: 11-SEP-17 16:50 (MT)
Version: FINAL

Client Phone: 250-425-8209

Certificate of Analysis

Lab Work Order #: L1983784

Project P.O. #: VPO00517564
Job Reference: CALCITE BIOLOGICAL EFFECTS
C of C Numbers: REP-ECOFISH
Legal Site Desc:

Lyudmyla Shvets, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1983784-1	L1983784-2	L1983784-3	L1983784-4	L1983784-5
	Description	WS	WS	WS	WQ	WQ
	Sampled Date	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17
	Sampled Time	12:05	12:35	13:35	12:05	12:35
	Client ID	DRY-CAWS01_0_20170829_1205	DRY-CAWS01_30_20170829_1235	DRY-CAWS01_50_20170829_1335	DRY-CAWS01_0_20170829_1205_FB	DRY-CAWS01_30_20170829_1235_FB
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	322	307	306		
	Hardness (as CaCO3) (mg/L)	189	185	188		
	pH (pH)	8.38	8.37	8.34		
	ORP (mV)	233	243	242		
	Total Suspended Solids (mg/L)	1.5	4.3	33.9		
	Total Dissolved Solids (mg/L)	203	205	200		
	Turbidity (NTU)	1.14	4.82	25.7		
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0	<1.0	<1.0		
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	165	166	167		
	Alkalinity, Carbonate (as CaCO3) (mg/L)	11.8	10.8	9.0		
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0		
	Alkalinity, Total (as CaCO3) (mg/L)	177	177	176		
	Ammonia as N (mg/L)	0.0144	0.0126	0.0103		
	Bromide (Br) (mg/L)	<0.050	<0.050	<0.050		
	Chloride (Cl) (mg/L)	0.81	0.84	0.80		
	Fluoride (F) (mg/L)	0.094	0.093	0.094		
	Nitrate (as N) (mg/L)	0.847	0.875	0.913		
	Nitrite (as N) (mg/L)	0.0014	0.0011	<0.0010		
	Total Kjeldahl Nitrogen (mg/L)	0.108	0.058 TKNI	0.109		
	Orthophosphate-Dissolved (as P) (mg/L)	0.0070 PEHT	0.0108 PEHT	0.0166 PEHT		
	Phosphorus (P)-Total (mg/L)	0.0158	0.0174	0.0454		
	Sulfate (SO4) (mg/L)	14.0	13.9	13.9		
	Anion Sum (meq/L)	3.91	3.91	3.91		
	Cation Sum (meq/L)	3.78	3.79	3.73		
	Cation - Anion Balance (%)	-1.7	-1.5	-2.3		
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	1.24	1.42	2.39		
	Total Organic Carbon (mg/L)	1.64	1.52	2.28		
Total Metals	Aluminum (Al)-Total (mg/L)	0.0074	0.138	0.138		
	Antimony (Sb)-Total (mg/L)	0.00017	0.00023	0.00022		
	Arsenic (As)-Total (mg/L)	0.00019	0.00031	0.00036		
	Barium (Ba)-Total (mg/L)	0.205	0.214	0.222		
	Beryllium (Be)-Total (ug/L)	<0.020	<0.020	0.025		
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050		
	Boron (B)-Total (mg/L)	<0.010	<0.010	<0.010		
	Cadmium (Cd)-Total (ug/L)	0.0396	0.104	0.116		
	Calcium (Ca)-Total (mg/L)	48.0	48.9	49.4		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

		Sample ID	L1983784-6				
		Description	WQ				
		Sampled Date	29-AUG-17				
		Sampled Time	13:35				
		Client ID	DRY-CAWS01_50_20170829_1335_FB				
Grouping	**Analyte**						
WATER							
Physical Tests	Conductivity (@ 25C) (uS/cm)						
	Hardness (as CaCO3) (mg/L)						
	pH (pH)						
	ORP (mV)						
	Total Suspended Solids (mg/L)						
	Total Dissolved Solids (mg/L)						
	Turbidity (NTU)						
Anions and Nutrients	Acidity (as CaCO3) (mg/L)						
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)						
	Alkalinity, Carbonate (as CaCO3) (mg/L)						
	Alkalinity, Hydroxide (as CaCO3) (mg/L)						
	Alkalinity, Total (as CaCO3) (mg/L)						
	Ammonia as N (mg/L)						
	Bromide (Br) (mg/L)						
	Chloride (Cl) (mg/L)						
	Fluoride (F) (mg/L)						
	Nitrate (as N) (mg/L)						
	Nitrite (as N) (mg/L)						
	Total Kjeldahl Nitrogen (mg/L)						
	Orthophosphate-Dissolved (as P) (mg/L)						
	Phosphorus (P)-Total (mg/L)						
	Sulfate (SO4) (mg/L)						
	Anion Sum (meq/L)						
	Cation Sum (meq/L)						
	Cation - Anion Balance (%)						
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)						
	Total Organic Carbon (mg/L)						
Total Metals	Aluminum (Al)-Total (mg/L)						
	Antimony (Sb)-Total (mg/L)						
	Arsenic (As)-Total (mg/L)						
	Barium (Ba)-Total (mg/L)						
	Beryllium (Be)-Total (ug/L)						
	Bismuth (Bi)-Total (mg/L)						
	Boron (B)-Total (mg/L)						
	Cadmium (Cd)-Total (ug/L)						
	Calcium (Ca)-Total (mg/L)						

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1983784-1	L1983784-2	L1983784-3	L1983784-4	L1983784-5
	Description	WS	WS	WS	WQ	WQ
	Sampled Date	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17
	Sampled Time	12:05	12:35	13:35	12:05	12:35
	Client ID	DRY-CAWS01_0_20170829_1205	DRY-CAWS01_30_20170829_1235	DRY-CAWS01_50_20170829_1335	DRY-CAWS01_0_20170829_1205_FB	DRY-CAWS01_30_20170829_1235_FB
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	<0.00010	0.00081	0.00065		
	Cobalt (Co)-Total (ug/L)	<0.10	0.17	0.19		
	Copper (Cu)-Total (mg/L)	<0.00050	0.00064	0.00071		
	Iron (Fe)-Total (mg/L)	0.023	0.280	0.353		
	Lead (Pb)-Total (mg/L)	<0.000050	0.000234	0.000245		
	Lithium (Li)-Total (mg/L)	0.0102	0.0106	0.0104		
	Magnesium (Mg)-Total (mg/L)	18.3	18.6	18.4		
	Manganese (Mn)-Total (mg/L)	0.00268	0.00942	0.00985		
	Mercury (Hg)-Total (ug/L)	<0.00050	0.00077	0.00138	<0.00050	<0.00050
	Molybdenum (Mo)-Total (mg/L)	0.00113	0.00106	0.00119		
	Nickel (Ni)-Total (mg/L)	<0.00050	0.00128	0.00127		
	Potassium (K)-Total (mg/L)	1.27	1.39	1.43		
	Selenium (Se)-Total (ug/L)	3.33	3.27	3.24		
	Silicon (Si)-Total (mg/L)	3.04	3.32	3.24		
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	0.000013		
	Sodium (Na)-Total (mg/L)	1.20	1.22	1.19		
	Strontium (Sr)-Total (mg/L)	0.0595	0.0600	0.0613		
	Thallium (Tl)-Total (mg/L)	<0.000010	0.000011	0.000016		
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010		
	Titanium (Ti)-Total (mg/L)	<0.010	<0.010	<0.010		
	Uranium (U)-Total (mg/L)	0.000395	0.000428	0.000446		
	Vanadium (V)-Total (mg/L)	0.00068	0.00185	0.00184		
	Zinc (Zn)-Total (mg/L)	<0.0030	0.0040	0.0043		
Dissolved Metals	Dissolved Mercury Filtration Location	LAB	LAB	LAB		
	Dissolved Metals Filtration Location	FIELD	FIELD	FIELD		
	Aluminum (Al)-Dissolved (mg/L)	<0.0030	0.0033	0.0044		
	Antimony (Sb)-Dissolved (mg/L)	0.00015	0.00016	0.00017		
	Arsenic (As)-Dissolved (mg/L)	0.00015	0.00017	0.00020		
	Barium (Ba)-Dissolved (mg/L)	0.195	0.196	0.195		
	Beryllium (Be)-Dissolved (ug/L)	<0.020	<0.020	<0.020		
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050		
	Boron (B)-Dissolved (mg/L)	<0.010	<0.010	<0.010		
	Cadmium (Cd)-Dissolved (ug/L)	0.0280	0.0295	0.0333		
	Calcium (Ca)-Dissolved (mg/L)	44.8	44.9	44.0		
	Chromium (Cr)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010		
	Cobalt (Co)-Dissolved (ug/L)	<0.10	<0.10	<0.10		
	Copper (Cu)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1983784-6				
	Description	WQ				
	Sampled Date	29-AUG-17				
	Sampled Time	13:35				
	Client ID	DRY-CAWS01_50_20170829_1335_FB				
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (ug/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (ug/L)	<0.00050				
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Selenium (Se)-Total (ug/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
Dissolved Metals	Dissolved Mercury Filtration Location					
	Dissolved Metals Filtration Location					
	Aluminum (Al)-Dissolved (mg/L)					
	Antimony (Sb)-Dissolved (mg/L)					
	Arsenic (As)-Dissolved (mg/L)					
	Barium (Ba)-Dissolved (mg/L)					
	Beryllium (Be)-Dissolved (ug/L)					
	Bismuth (Bi)-Dissolved (mg/L)					
	Boron (B)-Dissolved (mg/L)					
	Cadmium (Cd)-Dissolved (ug/L)					
	Calcium (Ca)-Dissolved (mg/L)					
	Chromium (Cr)-Dissolved (mg/L)					
	Cobalt (Co)-Dissolved (ug/L)					
	Copper (Cu)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1983784-1	L1983784-2	L1983784-3	L1983784-4	L1983784-5
	Description	WS	WS	WS	WQ	WQ
	Sampled Date	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17	29-AUG-17
	Sampled Time	12:05	12:35	13:35	12:05	12:35
	Client ID	DRY-CAWS01_0_20170829_1205	DRY-CAWS01_30_20170829_1235	DRY-CAWS01_50_20170829_1335	DRY-CAWS01_0_20170829_1205_FB	DRY-CAWS01_30_20170829_1235_FB
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010	<0.010	<0.010		
	Lead (Pb)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050		
	Lithium (Li)-Dissolved (mg/L)	0.0107	0.0107	0.0107		
	Magnesium (Mg)-Dissolved (mg/L)	17.7	17.8	17.6		
	Manganese (Mn)-Dissolved (mg/L)	0.00140	0.00082	0.00074		
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050	<0.0000050	<0.0000050		
	Molybdenum (Mo)-Dissolved (mg/L)	0.00108	0.00109	0.00117		
	Nickel (Ni)-Dissolved (mg/L)	<0.00050	0.00051	<0.00050		
	Potassium (K)-Dissolved (mg/L)	1.22	1.28	1.30		
	Selenium (Se)-Dissolved (ug/L)	2.98	3.10	2.81		
	Silicon (Si)-Dissolved (mg/L)	2.87	2.99	2.95		
	Silver (Ag)-Dissolved (mg/L)	<0.000010	<0.000010	<0.000010		
	Sodium (Na)-Dissolved (mg/L)	1.28	1.26	1.25		
	Strontium (Sr)-Dissolved (mg/L)	0.0578	0.0586	0.0579		
	Thallium (Tl)-Dissolved (mg/L)	<0.000010	<0.000010	<0.000010		
	Tin (Sn)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010		
	Titanium (Ti)-Dissolved (mg/L)	<0.010	<0.010	<0.010		
	Uranium (U)-Dissolved (mg/L)	0.000384	0.000403	0.000420		
	Vanadium (V)-Dissolved (mg/L)	0.00052	0.00057	0.00066		
	Zinc (Zn)-Dissolved (mg/L)	<0.0030	<0.0030	<0.0030		

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1983784-6				
	Description	WQ				
	Sampled Date	29-AUG-17				
	Sampled Time	13:35				
	Client ID	DRY-CAWS01_50_20170829_1335_FB				
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)					
	Lead (Pb)-Dissolved (mg/L)					
	Lithium (Li)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					
	Manganese (Mn)-Dissolved (mg/L)					
	Mercury (Hg)-Dissolved (mg/L)					
	Molybdenum (Mo)-Dissolved (mg/L)					
	Nickel (Ni)-Dissolved (mg/L)					
	Potassium (K)-Dissolved (mg/L)					
	Selenium (Se)-Dissolved (ug/L)					
	Silicon (Si)-Dissolved (mg/L)					
	Silver (Ag)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
	Strontium (Sr)-Dissolved (mg/L)					
	Thallium (Tl)-Dissolved (mg/L)					
	Tin (Sn)-Dissolved (mg/L)					
	Titanium (Ti)-Dissolved (mg/L)					
	Uranium (U)-Dissolved (mg/L)					
	Vanadium (V)-Dissolved (mg/L)					
	Zinc (Zn)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	Sample was Filtered and Preserved at the laboratory - DOC & Dissolved Metals/Hg

Qualifiers for Individual Samples Listed:

Sample Number	Client Sample ID	Qualifier	Description
L1983784-1	DRY-CAWS01_0_20170829_	WSMT	Water sample(s) for total mercury analysis was not submitted in glass or PTFE container with HCl preservative. Results may be biased low.
L1983784-2	DRY-CAWS01_30_2017082§	WSMT	Water sample(s) for total mercury analysis was not submitted in glass or PTFE container with HCl preservative. Results may be biased low.
L1983784-3	DRY-CAWS01_50_2017082§	WSMT	Water sample(s) for total mercury analysis was not submitted in glass or PTFE container with HCl preservative. Results may be biased low.

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Barium (Ba)-Total	MS-B	L1983784-1, -2, -3
Matrix Spike	Calcium (Ca)-Total	MS-B	L1983784-1, -2, -3
Matrix Spike	Magnesium (Mg)-Total	MS-B	L1983784-1, -2, -3
Matrix Spike	Strontium (Sr)-Total	MS-B	L1983784-1, -2, -3
Matrix Spike	Ammonia as N	MS-B	L1983784-1, -2, -3

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
PEHT	Parameter Exceeded Recommended Holding Time Prior to Analysis
TKNI	TKN result may be biased low due to Nitrate interference. Nitrate-N is > 10x TKN.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ACIDITY-PCT-CL	Water	Acidity by Automatic Titration	APHA 2310 Acidity

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

ALK-MAN-CL	Water	Alkalinity (Species) by Manual Titration	APHA 2320 ALKALINITY

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

BE-D-L-CCMS-VA	Water	Diss. Be (low) in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

BE-T-L-CCMS-VA	Water	Total Be (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

BR-L-IC-N-CL	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

C-DIS-ORG-LOW-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

C-TOT-ORG-LOW-CL	Water	Total Organic Carbon	APHA 5310 TOTAL ORGANIC CARBON (TOC)

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The

Reference Information

carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

CL-IC-N-CL	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-L-PCT-CL	Water	Electrical Conductivity (EC)	APHA 2510B

Conductivity, also known as Electrical Conductivity (EC) or Specific Conductance, is measured by immersion of a conductivity cell with platinum electrodes into a water sample. Conductivity measurements are temperature-compensated to 25C.

EC-SCREEN-VA	Water	Conductivity Screen (Internal Use Only)	APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

F-IC-N-CL	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-D-CVAA-VA	Water	Diss. Mercury in Water by CVAAS or CVAFS	APHA 3030B/EPA 1631E (mod)

Water samples are filtered (0.45 um), preserved with hydrochloric acid, then undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

HG-T-U-CVAF-VA	Water	Total Mercury in Water by CVAFS (Ultra)	EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

IONBALANCE-BC-CL	Water	Ion Balance Calculation	APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-D-CCMS-VA	Water	Dissolved Metals in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-T-CCMS-VA	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NH3-L-F-CL	Water	Ammonia, Total (as N)	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-BC-L-IC-CL	Water	Nitrite-N	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

NO3-BC-L-IC-CL	Water	Nitrate (as N)	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ORP-CL	Water	Oxidation redution potential by elect.	ASTM D1498

Reference Information

This analysis is carried out in accordance with the procedure described in the "ASTM" method D1498 "Oxidation-Reduction Potential of Water" published by the American Society for Testing and Materials (ASTM). Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.

It is recommended that this analysis be conducted in the field.

P-T-L-COL-WP	Water	Phosphorus, Total	APHA 4500 P PHOSPHORUS-L

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorous is determined colourimetrically after persulphate digestion of the sample.

PH-CL	Water	pH	APHA 4500 H-Electrode

pH is determined in the laboratory using a pH electrode. All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SO4-IC-N-CL	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-CL	Water	Total Dissolved Solids	APHA 2540 C

A well-mixed sample is filtered through a glass fibre filter paper. The filtrate is then evaporated to dryness in a pre-weighed vial and dried at 180 – 2 °C. The increase in vial weight represents the total dissolved solids (TDS).

TKN-L-F-CL	Water	Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-L-CL	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, and by drying the filter at 104 deg. C.

TURBIDITY-BC-CL	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
WP	ALS ENVIRONMENTAL - WINNIPEG, MANITOBA, CANADA
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

REP-ECOFISH

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Teck Coal Ltd.
124-B Aspen Dr
Sparwood BC V0B 2G0

Contact: Lee Wilm

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ACIDITY-PCT-CL	**Water**							
Batch R3819603								
WG2608865-6 LCS								
Acidity (as CaCO3)			94.9		%		85-115	02-SEP-17
WG2608865-5 MB								
Acidity (as CaCO3)			<1.0		mg/L		2	02-SEP-17
BE-D-L-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-14 LCS								
Beryllium (Be)-Dissolved			101.9		%		80-120	06-SEP-17
WG2609464-13 MB		**NP**						
Beryllium (Be)-Dissolved			<0.000020		mg/L		0.00002	06-SEP-17
BE-T-L-CCMS-VA	**Water**							
Batch R3821772								
WG2609484-3 DUP		**L1983784-1**						
Beryllium (Be)-Total		<0.000020	<0.000020	RPD-NA	mg/L	N/A	20	06-SEP-17
WG2609484-4 MS		**L1983784-2**						
Beryllium (Be)-Total			95.0		%		70-130	06-SEP-17
Batch R3821866								
WG2609484-2 LCS								
Beryllium (Be)-Total			102.3		%		80-120	07-SEP-17
WG2609484-1 MB								
Beryllium (Be)-Total			<0.000020		mg/L		0.00002	07-SEP-17
BR-L-IC-N-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Bromide (Br)			104.6		%		85-115	30-AUG-17
WG2609497-9 MB								
Bromide (Br)			<0.050		mg/L		0.05	30-AUG-17
C-DIS-ORG-LOW-CL	**Water**							
Batch R3820155								
WG2609029-6 LCS								
Dissolved Organic Carbon			97.6		%		80-120	03-SEP-17
WG2609029-5 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	03-SEP-17
C-TOT-ORG-LOW-CL	**Water**							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-TOT-ORG-LOW-CL	**Water**							
Batch R3820155								
WG2609029-6 LCS								
Total Organic Carbon			97.8		%		80-120	03-SEP-17
WG2609029-5 MB								
Total Organic Carbon			<0.50		mg/L		0.5	03-SEP-17
CL-IC-N-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Chloride (Cl)			100.4		%		90-110	30-AUG-17
WG2609497-9 MB								
Chloride (Cl)			<0.50		mg/L		0.5	30-AUG-17
EC-L-PCT-CL	**Water**							
Batch R3815939								
WG2606035-14 LCS								
Conductivity (@ 25C)			93.3		%		90-110	30-AUG-17
WG2606035-13 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	30-AUG-17
F-IC-N-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Fluoride (F)			96.4		%		90-110	30-AUG-17
WG2609497-9 MB								
Fluoride (F)			<0.020		mg/L		0.02	30-AUG-17
HG-D-CVAA-VA	**Water**							
Batch R3824008								
WG2612561-1 MB		**LF**						
Mercury (Hg)-Dissolved			<0.0000050		mg/L		0.000005	11-SEP-17
HG-T-U-CVAF-VA	**Water**							
Batch R3820826								
WG2609820-2 LCS								
Mercury (Hg)-Total			98.2		%		80-120	06-SEP-17
WG2609820-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	06-SEP-17
MET-D-CCMS-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-14 LCS								
Aluminum (Al)-Dissolved			107.0		%		80-120	06-SEP-17
Antimony (Sb)-Dissolved			96.0		%		80-120	06-SEP-17
Arsenic (As)-Dissolved			108.2		%		80-120	06-SEP-17
Barium (Ba)-Dissolved			106.3		%		80-120	06-SEP-17
Bismuth (Bi)-Dissolved			95.3		%		80-120	06-SEP-17
Boron (B)-Dissolved			92.9		%		80-120	06-SEP-17
Cadmium (Cd)-Dissolved			105.8		%		80-120	06-SEP-17
Calcium (Ca)-Dissolved			99.0		%		80-120	06-SEP-17
Chromium (Cr)-Dissolved			101.3		%		80-120	06-SEP-17
Cobalt (Co)-Dissolved			102.2		%		80-120	06-SEP-17
Copper (Cu)-Dissolved			103.5		%		80-120	06-SEP-17
Iron (Fe)-Dissolved			95.4		%		80-120	06-SEP-17
Lead (Pb)-Dissolved			98.8		%		80-120	06-SEP-17
Lithium (Li)-Dissolved			98.8		%		80-120	06-SEP-17
Magnesium (Mg)-Dissolved			107.2		%		80-120	06-SEP-17
Manganese (Mn)-Dissolved			104.8		%		80-120	06-SEP-17
Molybdenum (Mo)-Dissolved			97.3		%		80-120	06-SEP-17
Nickel (Ni)-Dissolved			108.6		%		80-120	06-SEP-17
Potassium (K)-Dissolved			106.1		%		80-120	06-SEP-17
Selenium (Se)-Dissolved			96.6		%		80-120	06-SEP-17
Silicon (Si)-Dissolved			99.8		%		80-120	06-SEP-17
Silver (Ag)-Dissolved			93.9		%		80-120	06-SEP-17
Sodium (Na)-Dissolved			106.2		%		80-120	06-SEP-17
Strontium (Sr)-Dissolved			102.2		%		80-120	06-SEP-17
Thallium (Tl)-Dissolved			98.7		%		80-120	06-SEP-17
Tin (Sn)-Dissolved			95.5		%		80-120	06-SEP-17
Titanium (Ti)-Dissolved			100.5		%		80-120	06-SEP-17
Uranium (U)-Dissolved			98.6		%		80-120	06-SEP-17
Vanadium (V)-Dissolved			103.5		%		80-120	06-SEP-17
Zinc (Zn)-Dissolved			102.7		%		80-120	06-SEP-17
WG2609464-13 MB		**NP**						
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609464-13 MB		**NP**						
Barium (Ba)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Boron (B)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
MET-T-CCMS-VA	**Water**							
Batch R3821772								
WG2609484-3 DUP		**L1983784-1**						
Aluminum (Al)-Total		0.0074	0.0077		mg/L	3.6	20	06-SEP-17
Antimony (Sb)-Total		0.00017	0.00017		mg/L	1.7	20	06-SEP-17
Arsenic (As)-Total		0.00019	0.00021		mg/L	8.7	20	06-SEP-17
Barium (Ba)-Total		0.205	0.206		mg/L	0.3	20	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821772								
WG2609484-3 DUP		**L1983784-1**						
Bismuth (Bi)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Boron (B)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Cadmium (Cd)-Total		0.0000396	0.0000409		mg/L	3.2	20	06-SEP-17
Calcium (Ca)-Total		48.0	49.3		mg/L	2.7	20	06-SEP-17
Chromium (Cr)-Total		<0.00010	0.00014	RPD-NA	mg/L	N/A	20	06-SEP-17
Cobalt (Co)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Copper (Cu)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	06-SEP-17
Iron (Fe)-Total		0.023	0.024		mg/L	2.2	20	06-SEP-17
Lead (Pb)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Lithium (Li)-Total		0.0102	0.0105		mg/L	2.4	20	06-SEP-17
Magnesium (Mg)-Total		18.3	18.2		mg/L	0.7	20	06-SEP-17
Manganese (Mn)-Total		0.00268	0.00264		mg/L	1.5	20	06-SEP-17
Molybdenum (Mo)-Total		0.00113	0.00121		mg/L	7.1	20	06-SEP-17
Nickel (Ni)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	06-SEP-17
Potassium (K)-Total		1.27	1.26		mg/L	0.2	20	06-SEP-17
Selenium (Se)-Total		0.00333	0.00318		mg/L	4.5	20	06-SEP-17
Silicon (Si)-Total		3.04	3.01		mg/L	1.0	20	06-SEP-17
Silver (Ag)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Sodium (Na)-Total		1.20	1.19		mg/L	1.2	20	06-SEP-17
Strontium (Sr)-Total		0.0595	0.0605		mg/L	1.8	20	06-SEP-17
Thallium (Tl)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Tin (Sn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Titanium (Ti)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Uranium (U)-Total		0.000395	0.000401		mg/L	1.3	20	06-SEP-17
Vanadium (V)-Total		0.00068	0.00070		mg/L	2.6	20	06-SEP-17
Zinc (Zn)-Total		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	06-SEP-17
WG2609484-4 MS		**L1983784-2**						
Aluminum (Al)-Total			88.2		%		70-130	06-SEP-17
Antimony (Sb)-Total			106.3		%		70-130	06-SEP-17
Arsenic (As)-Total			99.7		%		70-130	06-SEP-17
Barium (Ba)-Total			N/A	MS-B	%		-	06-SEP-17
Bismuth (Bi)-Total			92.7		%		70-130	06-SEP-17
Boron (B)-Total			98.4		%		70-130	06-SEP-17
Cadmium (Cd)-Total			100.1		%		70-130	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821772								
WG2609484-4 MS		**L1983784-2**						
Calcium (Ca)-Total			N/A	MS-B	%		-	06-SEP-17
Chromium (Cr)-Total			98.5		%		70-130	06-SEP-17
Cobalt (Co)-Total			94.8		%		70-130	06-SEP-17
Copper (Cu)-Total			93.4		%		70-130	06-SEP-17
Iron (Fe)-Total			95.8		%		70-130	06-SEP-17
Lead (Pb)-Total			91.5		%		70-130	06-SEP-17
Lithium (Li)-Total			90.5		%		70-130	06-SEP-17
Magnesium (Mg)-Total			N/A	MS-B	%		-	06-SEP-17
Manganese (Mn)-Total			93.5		%		70-130	06-SEP-17
Molybdenum (Mo)-Total			98.5		%		70-130	06-SEP-17
Nickel (Ni)-Total			94.6		%		70-130	06-SEP-17
Potassium (K)-Total			91.0		%		70-130	06-SEP-17
Selenium (Se)-Total			105.9		%		70-130	06-SEP-17
Silicon (Si)-Total			95.6		%		70-130	06-SEP-17
Silver (Ag)-Total			100.5		%		70-130	06-SEP-17
Sodium (Na)-Total			88.7		%		70-130	06-SEP-17
Strontium (Sr)-Total			N/A	MS-B	%		-	06-SEP-17
Thallium (Tl)-Total			90.4		%		70-130	06-SEP-17
Tin (Sn)-Total			103.8		%		70-130	06-SEP-17
Titanium (Ti)-Total			95.8		%		70-130	06-SEP-17
Uranium (U)-Total			94.4		%		70-130	06-SEP-17
Vanadium (V)-Total			99.8		%		70-130	06-SEP-17
Zinc (Zn)-Total			95.1		%		70-130	06-SEP-17
Batch R3821866								
WG2609484-2 LCS								
Aluminum (Al)-Total			101.1		%		80-120	07-SEP-17
Antimony (Sb)-Total			106.0		%		80-120	07-SEP-17
Arsenic (As)-Total			98.8		%		80-120	07-SEP-17
Barium (Ba)-Total			98.2		%		80-120	07-SEP-17
Bismuth (Bi)-Total			101.6		%		80-120	07-SEP-17
Boron (B)-Total			96.6		%		80-120	07-SEP-17
Cadmium (Cd)-Total			100.9		%		80-120	07-SEP-17
Calcium (Ca)-Total			101.2		%		80-120	07-SEP-17
Chromium (Cr)-Total			100.8		%		80-120	07-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821866								
WG2609484-2 LCS								
Cobalt (Co)-Total			97.5		%		80-120	07-SEP-17
Copper (Cu)-Total			97.3		%		80-120	07-SEP-17
Iron (Fe)-Total			98.7		%		80-120	07-SEP-17
Lead (Pb)-Total			103.1		%		80-120	07-SEP-17
Lithium (Li)-Total			104.7		%		80-120	07-SEP-17
Magnesium (Mg)-Total			100.6		%		80-120	07-SEP-17
Manganese (Mn)-Total			99.5		%		80-120	07-SEP-17
Molybdenum (Mo)-Total			100.9		%		80-120	07-SEP-17
Nickel (Ni)-Total			98.7		%		80-120	07-SEP-17
Potassium (K)-Total			101.4		%		80-120	07-SEP-17
Selenium (Se)-Total			98.6		%		80-120	07-SEP-17
Silicon (Si)-Total			100.6		%		80-120	07-SEP-17
Silver (Ag)-Total			100.8		%		80-120	07-SEP-17
Sodium (Na)-Total			98.6		%		80-120	07-SEP-17
Strontium (Sr)-Total			102.8		%		80-120	07-SEP-17
Thallium (Tl)-Total			101.3		%		80-120	07-SEP-17
Tin (Sn)-Total			99.7		%		80-120	07-SEP-17
Titanium (Ti)-Total			88.4		%		80-120	07-SEP-17
Uranium (U)-Total			106.0		%		80-120	07-SEP-17
Vanadium (V)-Total			100.9		%		80-120	07-SEP-17
Zinc (Zn)-Total			95.8		%		80-120	07-SEP-17
WG2609484-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	07-SEP-17
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Arsenic (As)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Barium (Ba)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Boron (B)-Total			<0.010		mg/L		0.01	07-SEP-17
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	07-SEP-17
Calcium (Ca)-Total			<0.050		mg/L		0.05	07-SEP-17
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Copper (Cu)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Iron (Fe)-Total			<0.010		mg/L		0.01	07-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821866								
WG2609484-1 MB								
Lead (Pb)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Lithium (Li)-Total			<0.0010		mg/L		0.001	07-SEP-17
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	07-SEP-17
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Potassium (K)-Total			<0.050		mg/L		0.05	07-SEP-17
Selenium (Se)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Silicon (Si)-Total			<0.10		mg/L		0.1	07-SEP-17
Silver (Ag)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Sodium (Na)-Total			<0.050		mg/L		0.05	07-SEP-17
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	07-SEP-17
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Tin (Sn)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	07-SEP-17
Uranium (U)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Vanadium (V)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Zinc (Zn)-Total			<0.0030		mg/L		0.003	07-SEP-17
NH3-L-F-CL	**Water**							
Batch R3821427								
WG2610104-7 LCS								
Ammonia as N			102.3		%		85-115	06-SEP-17
WG2610104-5 MB								
Ammonia as N			<0.0050		mg/L		0.005	06-SEP-17
NO2-BC-L-IC-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Nitrite (as N)			101.8		%		90-110	30-AUG-17
WG2609497-9 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	30-AUG-17
NO3-BC-L-IC-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Nitrate (as N)			100.3		%		90-110	30-AUG-17
WG2609497-9 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-BC-L-IC-CL	**Water**							
Batch R3820515								
WG2609497-9 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	30-AUG-17
ORP-CL	**Water**							
Batch R3817550								
WG2607933-2 CRM		**CL-ORP**						
ORP			215		mV		210-230	31-AUG-17
WG2607933-4 CRM		**CL-ORP**						
ORP			213		mV		210-230	31-AUG-17
P-T-L-COL-WP	**Water**							
Batch R3820333								
WG2608563-14 LCS								
Phosphorus (P)-Total			107.5		%		80-120	03-SEP-17
WG2608563-13 MB								
Phosphorus (P)-Total			<0.0010		mg/L		0.001	03-SEP-17
PH-CL	**Water**							
Batch R3815939								
WG2606035-14 LCS								
pH			6.97		pH		6.9-7.1	30-AUG-17
PO4-DO-COL-VA	**Water**							
Batch R3820320								
WG2609176-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.8		%		80-120	06-SEP-17
WG2609176-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			87.5		%		80-120	06-SEP-17
WG2609176-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
WG2609176-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
SO4-IC-N-CL	**Water**							
Batch R3820515								
WG2609497-10 LCS								
Sulfate (SO4)			101.6		%		90-110	30-AUG-17
WG2609497-9 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	30-AUG-17
SOLIDS-TDS-CL	**Water**							

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SOLIDS-TDS-CL	**Water**							
Batch R3821024								
WG2608720-5 LCS								
Total Dissolved Solids			96.3		%		85-115	05-SEP-17
WG2608720-4 MB								
Total Dissolved Solids			<10		mg/L		10	05-SEP-17
TKN-L-F-CL	**Water**							
Batch R3822085								
WG2611329-2 LCS								
Total Kjeldahl Nitrogen			98.6		%		75-125	07-SEP-17
WG2611329-1 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	07-SEP-17
TSS-L-CL	**Water**							
Batch R3821808								
WG2610123-2 LCS								
Total Suspended Solids			90.8		%		85-115	05-SEP-17
WG2610123-1 MB								
Total Suspended Solids			<1.0		mg/L		1	05-SEP-17
TURBIDITY-BC-CL	**Water**							
Batch R3817496								
WG2607014-3 DUP		**L1983784-3**						
Turbidity		25.7	25.9		NTU	0.8	15	01-SEP-17
WG2607014-2 LCS								
Turbidity			99.0		%		85-115	01-SEP-17
WG2607014-1 MB								
Turbidity			<0.10		NTU		0.1	01-SEP-17

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH							
	1	29-AUG-17 12:05	30-AUG-17 13:00	0.25	25	hours	EHTR-FM
	2	29-AUG-17 12:35	30-AUG-17 13:00	0.25	24	hours	EHTR-FM
	3	29-AUG-17 13:35	30-AUG-17 13:00	0.25	24	hours	EHTR-FM
Anions and Nutrients							
Diss. Orthophosphate in Water by Colour							
	1	29-AUG-17 12:05	06-SEP-17 03:23	3	8	days	EHT
	2	29-AUG-17 12:35	06-SEP-17 03:23	3	8	days	EHT
	3	29-AUG-17 13:35	06-SEP-17 03:23	3	8	days	EHT

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1983784 were received on 30-AUG-17 09:00.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Teck

COC ID:	REP-2017-08-29	TURNAROUND TIME:	

PROJECT/CLIENT INFO				LABORATORY			
Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	ALS Burnaby		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Lougheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

	Excel	PDF	EDD
lee.wilm@teck.com	x	x	x
teckcoal@equisonline.com			x
carla.fraser@teck.com	x	x	x
andrew.wight@teck.com	x	x	x

SAMPLE DETAILS / ANALYSIS REQUESTED — Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
PRESERVATIVE										x			x	
DRY-CAWS01_0_20170829_1205	RG_LCDRY-CA01	WS	NO	8/29/2017	12:05	G	7	x	x	x	x	x	x	x
DRY-CAWS01_30_20170829_1235	RG_LCDRY-CA01	WS	NO	8/29/2017	12:35	G	7	x	x	x	x	x	x	x
DRY-CAWS01_50_20170829_1335	RG_LCDRY-CA01	WS	NO	8/29/2017	13:35	G	7	x	x	x	x	x	x	x
DRY-CAWS01_0_20170829_1205_FB	RG_LCDRY-CA01	WQ	NO	8/29/2017	12:05	G	1				x			
DRY-CAWS01_30_20170829_1235_FB	RG_LCDRY-CA01	WQ	NO	8/29/2017	12:35	G	1				x			
DRY-CAWS01_50_20170829_1335_FB	RG_LCDRY-CA01	WQ	NO	8/29/2017	13:35	G	1				x			

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS	RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	DATE/TIME
All metals samples must be shipped to ALS Burnaby for analysis			MM 4°C	30 Aug-17 9:00

NB OF BOTTLES RETURNED/DESCRIPTION

Regular (default)	x	Sampler's Name	Andy Wight	Mobile #	250-433-1159
Priority (2-3 business days) - 50% surcharge		Sampler's Signature		Date/Time	August 1, 2017
Emergency (1 Business Day) - 100% surcharge					
For Emergency <1 Day, ASAP or Weekend - Contact AL					

L1983784-COFC

Teck Coal Ltd.
ATTN: Lee Wilm
124-B Aspen Dr
Sparwood BC V0B 2G0

Date Received: 31-AUG-17
Report Date: 11-SEP-17 16:26 (MT)
Version: FINAL

Client Phone: 250-425-8209

Certificate of Analysis

Lab Work Order #: L1984572

Project P.O. #: VPO00517564
Job Reference: CALCITE BIOLOGICAL EFFECTS
C of C Numbers: REP-2017-08-30
Legal Site Desc:

Lyudmyla Shvets, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-1	L1984572-2	L1984572-3	L1984572-4	L1984572-5
	Description	WS	WQ	WS	WS	WS
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	13:35	12:20	12:00	12:47	14:15
	Client ID	RG_HEN-CA01_WS_50_20170830_1334	RG_HEN-CA01_WS_0_20170830_1220	RG_HEN-CA01_WS_0_20170830_1200	RG_HEN-CA01_WS_30_20170830_1247	RG_HEN-CA02_WS_0_20170830_1415
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	549	555	552	555	549
	Hardness (as CaCO3) (mg/L)	295	299	299	299	301
	pH (pH)	8.31	8.31	8.32	8.32	8.27
	ORP (mV)	264	252	256	229	235
	Total Suspended Solids (mg/L)	7.6	1.0	1.4	2.2	55.6
	Total Dissolved Solids (mg/L)	356	361	366	364	365
	Turbidity (NTU)	3.61	0.58	0.67	0.68	15.7
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	1.1	<1.0	<1.0	<1.0	1.1
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	138	138	135	138	143
	Alkalinity, Carbonate (as CaCO3) (mg/L)	7.0	6.2	6.6	7.2	<1.0
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Alkalinity, Total (as CaCO3) (mg/L)	145	144	142	145	143
	Ammonia as N (mg/L)	0.0126	0.0102	0.0137	0.0098	0.0131
	Bromide (Br) (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Chloride (Cl) (mg/L)	<0.50	<0.50	<0.50	<0.50	<0.50
	Fluoride (F) (mg/L)	0.208	0.212	0.214	0.215	0.215
	Nitrate (as N) (mg/L)	4.75	4.91	4.81	4.89	4.57
	Nitrite (as N) (mg/L)	0.0061	0.0070	0.0064	0.0065	0.0062
	Total Kjeldahl Nitrogen (mg/L)	0.546	0.442	0.482	0.435	0.445
	Orthophosphate-Dissolved (as P) (mg/L)	PEHT <0.0010	PEHT <0.0010	PEHT <0.0010	PEHT <0.0010	PEHT <0.0010
	Phosphorus (P)-Total (mg/L)	0.0029	<0.0020	0.0020	0.0038	0.0054
	Sulfate (SO4) (mg/L)	142	144	142	143	139
	Anion Sum (meq/L)	6.18	6.23	6.14	6.24	6.10
	Cation Sum (meq/L)	5.94	6.03	6.03	6.02	6.06
	Cation - Anion Balance (%)	-2.0	-1.6	-0.9	-1.8	-0.3
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	0.86	0.62	0.83	0.79	1.26
	Total Organic Carbon (mg/L)	0.86	0.79	0.84	0.79	1.26
Total Metals	Aluminum (Al)-Total (mg/L)	0.0281	0.0055	0.0053	0.0066	0.0738
	Antimony (Sb)-Total (mg/L)	0.00014	0.00014	0.00012	0.00012	0.00012
	Arsenic (As)-Total (mg/L)	0.00013	0.00011	0.00012	0.00013	0.00014
	Barium (Ba)-Total (mg/L)	0.0374	0.0368	0.0371	0.0378	0.0385
	Beryllium (Be)-Total (ug/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Total (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (Cd)-Total (ug/L)	0.0292	0.0298	0.0273	0.0248	0.0348
	Calcium (Ca)-Total (mg/L)	74.9	74.7	74.4	74.7	78.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-6	L1984572-7	L1984572-8	L1984572-9	L1984572-10
	Description	WS	WS	WQ	WQ	WQ
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	14:25	14:45	13:35	12:20	12:00
	Client ID	RG_HEN-CA02_WS_30_20170830_1425	RG_HEN-CA02_WS_50_20170830_1445	RG_HEN-CA01_WS_50_20170830_1334_FB	RG_HEN-CA01_WS_0_20170830_1220_FB	RG_HEN-CA01_WS_0_20170830_1200_FB
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	546	548			
	Hardness (as CaCO3) (mg/L)	288	289			
	pH (pH)	8.28	8.29			
	ORP (mV)	252	251			
	Total Suspended Solids (mg/L)	33.8	102			
	Total Dissolved Solids (mg/L)	361	355			
	Turbidity (NTU)	9.78	54.4			
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0	1.0			
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	141	139			
	Alkalinity, Carbonate (as CaCO3) (mg/L)	2.8	2.8			
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0			
	Alkalinity, Total (as CaCO3) (mg/L)	144	142			
	Ammonia as N (mg/L)	0.0118	0.0164			
	Bromide (Br) (mg/L)	<0.050	<0.050			
	Chloride (Cl) (mg/L)	<0.50	<0.50			
	Fluoride (F) (mg/L)	0.214	0.214			
	Nitrate (as N) (mg/L)	4.58	4.59			
	Nitrite (as N) (mg/L)	0.0062	0.0066			
	Total Kjeldahl Nitrogen (mg/L)	0.466	0.466			
	Orthophosphate-Dissolved (as P) (mg/L)	PEHT <0.0010	PEHT <0.0010			
	Phosphorus (P)-Total (mg/L)	0.0091	0.0131			
	Sulfate (SO4) (mg/L)	139	140			
	Anion Sum (meq/L)	6.12	6.08			
	Cation Sum (meq/L)	5.80	5.83			
	Cation - Anion Balance (%)	-2.6	-2.1			
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	0.90	0.98			
	Total Organic Carbon (mg/L)	0.90	1.06			
Total Metals	Aluminum (Al)-Total (mg/L)	0.0610	0.221			
	Antimony (Sb)-Total (mg/L)	0.00012	0.00018			
	Arsenic (As)-Total (mg/L)	0.00015	0.00024			
	Barium (Ba)-Total (mg/L)	0.0373	0.0404			
	Beryllium (Be)-Total (ug/L)	<0.020	<0.020			
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050			
	Boron (B)-Total (mg/L)	<0.010	<0.010			
	Cadmium (Cd)-Total (ug/L)	0.0381	0.0869			
	Calcium (Ca)-Total (mg/L)	75.5	78.6			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-11	L1984572-12	L1984572-13	L1984572-14	
	Description	WQ	WQ	WQ	WQ	
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	
	Sampled Time	12:47	13:35	12:20	12:00	
	Client ID	RG_HEN-CA01_WS_30_20170830_1247_FB	RG_HEN-CA02_WS_0_20170830_1415_FB	RG_HEN-CA02_WS_30_20170830_1425_FB	RG_HEN-CA02_WS_50_20170830_1445_FB	
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	ORP (mV)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Acidity (as CaCO3) (mg/L)					
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia as N (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)					
	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (ug/L)					
	Bismuth (Bi)-Total (mg/L)					
	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (ug/L)					
	Calcium (Ca)-Total (mg/L)					

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-1	L1984572-2	L1984572-3	L1984572-4	L1984572-5
	Description	WS	WQ	WS	WS	WS
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	13:35	12:20	12:00	12:47	14:15
	Client ID	RG_HEN-CA01_WS_50_20170830_1334	RG_HEN-CA01_WS_0_20170830_1220	RG_HEN-CA01_WS_0_20170830_1200	RG_HEN-CA01_WS_30_20170830_1247	RG_HEN-CA02_WS_0_20170830_1415
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	0.00024	0.00010	<0.00010	0.00011	0.00028
	Cobalt (Co)-Total (ug/L)	0.11	<0.10	<0.10	<0.10	0.11
	Copper (Cu)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Iron (Fe)-Total (mg/L)	0.040	0.012	0.012	0.014	0.128
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	0.000096
	Lithium (Li)-Total (mg/L)	0.0087	0.0089	0.0087	0.0089	0.0083
	Magnesium (Mg)-Total (mg/L)	27.7	28.6	28.1	28.6	28.3
	Manganese (Mn)-Total (mg/L)	0.00747	0.00574	0.00579	0.00551	0.0130
	Mercury (Hg)-Total (ug/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Molybdenum (Mo)-Total (mg/L)	0.00113	0.00111	0.00111	0.00107	0.00101
	Nickel (Ni)-Total (mg/L)	0.00147	0.00116	0.00108	0.00118	0.00143
	Potassium (K)-Total (mg/L)	0.870	0.874	0.868	0.874	0.872
	Selenium (Se)-Total (ug/L)	24.2	24.1	24.0	24.3	24.3
	Silicon (Si)-Total (mg/L)	1.62	1.58	1.55	1.61	1.69
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Total (mg/L)	0.677	0.688	0.677	0.676	0.666
	Strontium (Sr)-Total (mg/L)	0.126	0.127	0.125	0.125	0.124
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Total (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Uranium (U)-Total (mg/L)	0.00130	0.00137	0.00131	0.00133	0.00128
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	0.00050
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Dissolved Metals	Dissolved Mercury Filtration Location	LAB	LAB	LAB	LAB	LAB
	Dissolved Metals Filtration Location	LAB	LAB	LAB	LAB	LAB
	Aluminum (Al)-Dissolved (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
	Antimony (Sb)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Arsenic (As)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Barium (Ba)-Dissolved (mg/L)	0.0373	0.0369	0.0377	0.0376	0.0370
	Beryllium (Be)-Dissolved (ug/L)	<0.020	<0.020	<0.020	<0.020	<0.020
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Boron (B)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Cadmium (Cd)-Dissolved (ug/L)	0.0185	0.0221	0.0204	0.0241	0.0216
	Calcium (Ca)-Dissolved (mg/L)	74.2	75.3	75.4	75.8	76.5
	Chromium (Cr)-Dissolved (mg/L)	<0.00010	0.00010	<0.00010	<0.00010	<0.00010
	Cobalt (Co)-Dissolved (ug/L)	<0.10	<0.10	<0.10	<0.10	<0.10
	Copper (Cu)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-6	L1984572-7	L1984572-8	L1984572-9	L1984572-10
	Description	WS	WS	WQ	WQ	WQ
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	14:25	14:45	13:35	12:20	12:00
	Client ID	RG_HEN-CA02_WS_30_20170830_1425	RG_HEN-CA02_WS_50_20170830_1445	RG_HEN-CA01_WS_50_20170830_1334_FB	RG_HEN-CA01_WS_0_20170830_1220_FB	RG_HEN-CA01_WS_0_20170830_1200_FB
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	0.00033	0.00116			
	Cobalt (Co)-Total (ug/L)	0.11	0.33			
	Copper (Cu)-Total (mg/L)	<0.00050	0.00061			
	Iron (Fe)-Total (mg/L)	0.091	0.314			
	Lead (Pb)-Total (mg/L)	0.000078	0.000301			
	Lithium (Li)-Total (mg/L)	0.0085	0.0086			
	Magnesium (Mg)-Total (mg/L)	27.8	28.9			
	Manganese (Mn)-Total (mg/L)	0.0119	0.0389			
	Mercury (Hg)-Total (ug/L)	<0.00050	0.00059	<0.00050	<0.00050	<0.00050
	Molybdenum (Mo)-Total (mg/L)	0.00105	0.00107			
	Nickel (Ni)-Total (mg/L)	0.00140	0.00242			
	Potassium (K)-Total (mg/L)	0.882	0.939			
	Selenium (Se)-Total (ug/L)	24.5	23.9			
	Silicon (Si)-Total (mg/L)	1.67	1.93			
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010			
	Sodium (Na)-Total (mg/L)	0.674	0.683			
	Strontium (Sr)-Total (mg/L)	0.126	0.129			
	Thallium (Tl)-Total (mg/L)	<0.000010	0.000014			
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010			
	Titanium (Ti)-Total (mg/L)	<0.010	<0.010			
	Uranium (U)-Total (mg/L)	0.00129	0.00129			
	Vanadium (V)-Total (mg/L)	<0.00050	0.00101			
	Zinc (Zn)-Total (mg/L)	<0.0030	0.0060			
Dissolved Metals	Dissolved Mercury Filtration Location	LAB	LAB			
	Dissolved Metals Filtration Location	LAB	LAB			
	Aluminum (Al)-Dissolved (mg/L)	<0.0030	<0.0030			
	Antimony (Sb)-Dissolved (mg/L)	<0.00010	0.00011			
	Arsenic (As)-Dissolved (mg/L)	<0.00010	<0.00010			
	Barium (Ba)-Dissolved (mg/L)	0.0369	0.0373			
	Beryllium (Be)-Dissolved (ug/L)	<0.020	<0.020			
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050	<0.000050			
	Boron (B)-Dissolved (mg/L)	<0.010	<0.010			
	Cadmium (Cd)-Dissolved (ug/L)	0.0215	0.0195			
	Calcium (Ca)-Dissolved (mg/L)	72.7	72.9			
	Chromium (Cr)-Dissolved (mg/L)	<0.00010	<0.00010			
	Cobalt (Co)-Dissolved (ug/L)	<0.10	<0.10			
	Copper (Cu)-Dissolved (mg/L)	<0.00050	<0.00050			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-11	L1984572-12	L1984572-13	L1984572-14	
	Description	WQ	WQ	WQ	WQ	
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	
	Sampled Time	12:47	13:35	12:20	12:00	
	Client ID	RG_HEN-CA01_WS_30_20170830_1247_FB	RG_HEN-CA02_WS_0_20170830_1415_FB	RG_HEN-CA02_WS_30_20170830_1425_FB	RG_HEN-CA02_WS_50_20170830_1445_FB	
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (ug/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (ug/L)	<0.00050	<0.00050	<0.00050	<0.00050	
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Selenium (Se)-Total (ug/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
Dissolved Metals	Dissolved Mercury Filtration Location					
	Dissolved Metals Filtration Location					
	Aluminum (Al)-Dissolved (mg/L)					
	Antimony (Sb)-Dissolved (mg/L)					
	Arsenic (As)-Dissolved (mg/L)					
	Barium (Ba)-Dissolved (mg/L)					
	Beryllium (Be)-Dissolved (ug/L)					
	Bismuth (Bi)-Dissolved (mg/L)					
	Boron (B)-Dissolved (mg/L)					
	Cadmium (Cd)-Dissolved (ug/L)					
	Calcium (Ca)-Dissolved (mg/L)					
	Chromium (Cr)-Dissolved (mg/L)					
	Cobalt (Co)-Dissolved (ug/L)					
	Copper (Cu)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-1	L1984572-2	L1984572-3	L1984572-4	L1984572-5
	Description	WS	WQ	WS	WS	WS
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	13:35	12:20	12:00	12:47	14:15
	Client ID	RG_HEN-CA01_WS_50_20170830_1334	RG_HEN-CA01_WS_0_20170830_1220	RG_HEN-CA01_WS_0_20170830_1200	RG_HEN-CA01_WS_30_20170830_1247	RG_HEN-CA02_WS_0_20170830_1415
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Lead (Pb)-Dissolved (mg/L)	<0.000050	<0.000050	<0.000050	<0.000050	<0.000050
	Lithium (Li)-Dissolved (mg/L)	0.0089	0.0095	0.0093	0.0090	0.0090
	Magnesium (Mg)-Dissolved (mg/L)	26.7	27.0	27.0	26.7	26.6
	Manganese (Mn)-Dissolved (mg/L)	0.00029	0.00042	0.00036	0.00034	0.00033
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050	<0.0000050	<0.0000050	<0.0000050	<0.0000050
	Molybdenum (Mo)-Dissolved (mg/L)	0.000971	0.000971	0.000964	0.000967	0.000986
	Nickel (Ni)-Dissolved (mg/L)	0.00108	0.00097	0.00092	0.00095	0.00097
	Potassium (K)-Dissolved (mg/L)	0.839	0.870	0.857	0.866	0.867
	Selenium (Se)-Dissolved (ug/L)	25.8	26.3	25.8	25.9	25.6
	Silicon (Si)-Dissolved (mg/L)	1.43	1.39	1.39	1.42	1.47
	Silver (Ag)-Dissolved (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Sodium (Na)-Dissolved (mg/L)	0.652	0.657	0.654	0.654	0.656
	Strontium (Sr)-Dissolved (mg/L)	0.122	0.126	0.124	0.123	0.127
	Thallium (Tl)-Dissolved (mg/L)	<0.000010	<0.000010	<0.000010	<0.000010	<0.000010
	Tin (Sn)-Dissolved (mg/L)	<0.00010	<0.00010	<0.00010	<0.00010	<0.00010
	Titanium (Ti)-Dissolved (mg/L)	<0.010	<0.010	<0.010	<0.010	<0.010
	Uranium (U)-Dissolved (mg/L)	0.00116	0.00117	0.00115	0.00119	0.00116
	Vanadium (V)-Dissolved (mg/L)	<0.00050	<0.00050	<0.00050	<0.00050	<0.00050
	Zinc (Zn)-Dissolved (mg/L)	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-6	L1984572-7	L1984572-8	L1984572-9	L1984572-10
	Description	WS	WS	WQ	WQ	WQ
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17
	Sampled Time	14:25	14:45	13:35	12:20	12:00
	Client ID	RG_HEN-CA02_WS_30_20170830_1425	RG_HEN-CA02_WS_50_20170830_1445	RG_HEN-CA01_WS_50_20170830_1334_FB	RG_HEN-CA01_WS_0_20170830_1220_FB	RG_HEN-CA01_WS_0_20170830_1200_FB
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010	<0.010			
	Lead (Pb)-Dissolved (mg/L)	<0.000050	<0.000050			
	Lithium (Li)-Dissolved (mg/L)	0.0087	0.0087			
	Magnesium (Mg)-Dissolved (mg/L)	25.9	26.1			
	Manganese (Mn)-Dissolved (mg/L)	0.00027	0.00019			
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050	<0.0000050			
	Molybdenum (Mo)-Dissolved (mg/L)	0.000958	0.000926			
	Nickel (Ni)-Dissolved (mg/L)	0.00099	0.00100			
	Potassium (K)-Dissolved (mg/L)	0.832	0.855			
	Selenium (Se)-Dissolved (ug/L)	27.1	25.6			
	Silicon (Si)-Dissolved (mg/L)	1.42	1.39			
	Silver (Ag)-Dissolved (mg/L)	<0.000010	<0.000010			
	Sodium (Na)-Dissolved (mg/L)	0.639	0.637			
	Strontium (Sr)-Dissolved (mg/L)	0.124	0.123			
	Thallium (Tl)-Dissolved (mg/L)	<0.000010	<0.000010			
	Tin (Sn)-Dissolved (mg/L)	<0.00010	<0.00010			
	Titanium (Ti)-Dissolved (mg/L)	<0.010	<0.010			
	Uranium (U)-Dissolved (mg/L)	0.00112	0.00113			
	Vanadium (V)-Dissolved (mg/L)	<0.00050	<0.00050			
	Zinc (Zn)-Dissolved (mg/L)	<0.0030	<0.0030			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1984572-11	L1984572-12	L1984572-13	L1984572-14	
	Description	WQ	WQ	WQ	WQ	
	Sampled Date	30-AUG-17	30-AUG-17	30-AUG-17	30-AUG-17	
	Sampled Time	12:47	13:35	12:20	12:00	
	Client ID	RG_HEN-CA01_WS_30_20170830_1247_FB	RG_HEN-CA02_WS_0_20170830_1415_FB	RG_HEN-CA02_WS_30_20170830_1425_FB	RG_HEN-CA02_WS_50_20170830_1445_FB	
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)					
	Lead (Pb)-Dissolved (mg/L)					
	Lithium (Li)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					
	Manganese (Mn)-Dissolved (mg/L)					
	Mercury (Hg)-Dissolved (mg/L)					
	Molybdenum (Mo)-Dissolved (mg/L)					
	Nickel (Ni)-Dissolved (mg/L)					
	Potassium (K)-Dissolved (mg/L)					
	Selenium (Se)-Dissolved (ug/L)					
	Silicon (Si)-Dissolved (mg/L)					
	Silver (Ag)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
	Strontium (Sr)-Dissolved (mg/L)					
	Thallium (Tl)-Dissolved (mg/L)					
	Tin (Sn)-Dissolved (mg/L)					
	Titanium (Ti)-Dissolved (mg/L)					
	Uranium (U)-Dissolved (mg/L)					
	Vanadium (V)-Dissolved (mg/L)					
	Zinc (Zn)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	Sample was Filtered and Preserved at the laboratory - DOC & Diss-Metals/Hg

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Barium (Ba)-Dissolved	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Calcium (Ca)-Dissolved	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Magnesium (Mg)-Dissolved	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Strontium (Sr)-Dissolved	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Barium (Ba)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Calcium (Ca)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Calcium (Ca)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Copper (Cu)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Magnesium (Mg)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Magnesium (Mg)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Manganese (Mn)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Manganese (Mn)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Potassium (K)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Potassium (K)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Sodium (Na)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Sodium (Na)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Strontium (Sr)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Strontium (Sr)-Total	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Nitrate (as N)	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7
Matrix Spike	Sulfate (SO4)	MS-B	L1984572-1, -2, -3, -4, -5, -6, -7

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
PEHT	Parameter Exceeded Recommended Holding Time Prior to Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ACIDITY-PCT-CL	Water	Acidity by Automatic Titration	APHA 2310 Acidity

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

ALK-MAN-CL	Water	Alkalinity (Species) by Manual Titration	APHA 2320 ALKALINITY

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

BE-D-L-CCMS-VA	Water	Diss. Be (low) in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

BE-T-L-CCMS-VA	Water	Total Be (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

BR-L-IC-N-CL	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

C-DIS-ORG-LOW-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon

Reference Information

dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

C-TOT-ORG-LOW-CL	Water	Total Organic Carbon	APHA 5310 TOTAL ORGANIC CARBON (TOC)

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

CL-IC-N-CL	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-L-PCT-CL	Water	Electrical Conductivity (EC)	APHA 2510B

Conductivity, also known as Electrical Conductivity (EC) or Specific Conductance, is measured by immersion of a conductivity cell with platinum electrodes into a water sample. Conductivity measurements are temperature-compensated to 25C.

F-IC-N-CL	Water	Fluoride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA	Water	Hardness	APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in $CaCO_3$ equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-D-CVAA-VA	Water	Diss. Mercury in Water by CVAAS or CVAFS	APHA 3030B/EPA 1631E (mod)

Water samples are filtered (0.45 um), preserved with hydrochloric acid, then undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

HG-T-U-CVAF-VA	Water	Total Mercury in Water by CVAFS (Ultra)	EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

IONBALANCE-BC-CL	Water	Ion Balance Calculation	APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-D-CCMS-VA	Water	Dissolved Metals in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-T-CCMS-VA	Water	Total Metals in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NH3-L-F-CL	Water	Ammonia, Total (as N)	J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-BC-L-IC-CL	Water	Nitrite-N	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

Reference Information

NO3-BC-L-IC-CL	Water	Nitrate (as N)	EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ORP-CL	Water	Oxidation redution potential by elect.	ASTM D1498

This analysis is carried out in accordance with the procedure described in the "ASTM" method D1498 "Oxidation-Reduction Potential of Water" published by the American Society for Testing and Materials (ASTM). Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.

It is recommended that this analysis be conducted in the field.

P-T-PRES-COL-VA	Water	Total P in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-CL	Water	pH	APHA 4500 H-Electrode

pH is determined in the laboratory using a pH electrode. All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SO4-IC-N-CL	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-CL	Water	Total Dissolved Solids	APHA 2540 C

A well-mixed sample is filtered through a glass fibre filter paper. The filtrate is then evaporated to dryness in a pre-weighed vial and dried at 180 – 2 °C. The increase in vial weight represents the total dissolved solids (TDS).

TKN-L-F-CL	Water	Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-L-CL	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, and by drying the filter at 104 deg. C.

TURBIDITY-BC-CL	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

REP-2017-08-30

Reference Information

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Teck Coal Ltd.
124-B Aspen Dr
Sparwood BC V0B 2G0

Contact: Lee Wilm

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ACIDITY-PCT-CL	**Water**							
Batch R3819603								
WG2608865-6 LCS								
Acidity (as CaCO3)			94.9		%		85-115	02-SEP-17
WG2608865-5 MB								
Acidity (as CaCO3)			<1.0		mg/L		2	02-SEP-17
ALK-MAN-CL	**Water**							
Batch R3819589								
WG2608839-11 LCS								
Alkalinity, Total (as CaCO3)			100.1		%		85-115	01-SEP-17
WG2608839-10 MB								
Alkalinity, Total (as CaCO3)			<1.0		mg/L		1	01-SEP-17
BE-D-L-CCMS-VA	**Water**							
Batch R3821009								
WG2609164-2 LCS								
Beryllium (Be)-Dissolved			104.1		%		80-120	06-SEP-17
WG2609164-1 MB		**LF**						
Beryllium (Be)-Dissolved			<0.000020		mg/L		0.00002	06-SEP-17
Batch R3821856								
WG2609164-4 MS		**L1984572-3**						
Beryllium (Be)-Dissolved			104.2		%		70-130	06-SEP-17
BE-T-L-CCMS-VA	**Water**							
Batch R3821009								
WG2609163-2 LCS								
Beryllium (Be)-Total			100.3		%		80-120	06-SEP-17
WG2609163-1 MB								
Beryllium (Be)-Total			<0.000020		mg/L		0.00002	06-SEP-17
BR-L-IC-N-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Bromide (Br)		<0.050	<0.050	RPD-NA	mg/L	N/A	20	01-SEP-17
WG2610504-10 LCS								
Bromide (Br)			98.6		%		85-115	01-SEP-17
WG2610504-9 MB								
Bromide (Br)			<0.050		mg/L		0.05	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Bromide (Br)			108.0		%		75-125	01-SEP-17
C-DIS-ORG-LOW-CL	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
C-DIS-ORG-LOW-CL	**Water**							
Batch R3822666								
WG2611670-2 LCS								
Dissolved Organic Carbon			103.0		%		80-120	07-SEP-17
WG2611670-6 LCS								
Dissolved Organic Carbon			102.5		%		80-120	07-SEP-17
WG2611670-1 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	07-SEP-17
WG2611670-5 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	07-SEP-17
WG2611670-8 MS		**L1984572-7**						
Dissolved Organic Carbon			114.7		%		70-130	07-SEP-17
C-TOT-ORG-LOW-CL	**Water**							
Batch R3822666								
WG2611670-2 LCS								
Total Organic Carbon			98.7		%		80-120	07-SEP-17
WG2611670-6 LCS								
Total Organic Carbon			106.6		%		80-120	07-SEP-17
WG2611670-1 MB								
Total Organic Carbon			<0.50		mg/L		0.5	07-SEP-17
WG2611670-5 MB								
Total Organic Carbon			<0.50		mg/L		0.5	07-SEP-17
WG2611670-8 MS		**L1984572-7**						
Total Organic Carbon			112.9		%		70-130	07-SEP-17
CL-IC-N-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Chloride (Cl)		<0.50	<0.50	RPD-NA	mg/L	N/A	20	01-SEP-17
WG2610504-10 LCS								
Chloride (Cl)			101.0		%		90-110	01-SEP-17
WG2610504-9 MB								
Chloride (Cl)			<0.50		mg/L		0.5	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Chloride (Cl)			107.9		%		75-125	01-SEP-17
EC-L-PCT-CL	**Water**							
Batch R3819589								
WG2608839-11 LCS								
Conductivity (@ 25C)			98.2		%		90-110	01-SEP-17
WG2608839-10 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	01-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
F-IC-N-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Fluoride (F)		0.212	0.241		mg/L	13	20	01-SEP-17
WG2610504-10 LCS								
Fluoride (F)			95.7		%		90-110	01-SEP-17
WG2610504-9 MB								
Fluoride (F)			<0.020		mg/L		0.02	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Fluoride (F)			108.5		%		75-125	01-SEP-17
HG-D-CVAA-VA	**Water**							
Batch R3821740								
WG2610378-1 MB		**LF**						
Mercury (Hg)-Dissolved			<0.0000050		mg/L		0.000005	07-SEP-17
HG-T-U-CVAF-VA	**Water**							
Batch R3821908								
WG2611091-3 DUP		**L1984572-2**						
Mercury (Hg)-Total		<0.00050	<0.00050	RPD-NA	ug/L	N/A	20	07-SEP-17
WG2611091-2 LCS								
Mercury (Hg)-Total			109.0		%		80-120	07-SEP-17
WG2611091-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	07-SEP-17
WG2611091-4 MS		**L1984572-1**						
Mercury (Hg)-Total			93.0		%		70-130	07-SEP-17
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609164-2 LCS								
Aluminum (Al)-Dissolved			99.0		%		80-120	06-SEP-17
Antimony (Sb)-Dissolved			100.2		%		80-120	06-SEP-17
Arsenic (As)-Dissolved			100.2		%		80-120	06-SEP-17
Barium (Ba)-Dissolved			101.7		%		80-120	06-SEP-17
Bismuth (Bi)-Dissolved			98.4		%		80-120	06-SEP-17
Boron (B)-Dissolved			107.5		%		80-120	06-SEP-17
Cadmium (Cd)-Dissolved			98.8		%		80-120	06-SEP-17
Calcium (Ca)-Dissolved			102.5		%		80-120	06-SEP-17
Chromium (Cr)-Dissolved			95.3		%		80-120	06-SEP-17
Cobalt (Co)-Dissolved			98.0		%		80-120	06-SEP-17
Copper (Cu)-Dissolved			95.9		%		80-120	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609164-2 LCS								
Iron (Fe)-Dissolved			95.9		%		80-120	06-SEP-17
Lead (Pb)-Dissolved			99.5		%		80-120	06-SEP-17
Lithium (Li)-Dissolved			101.8		%		80-120	06-SEP-17
Magnesium (Mg)-Dissolved			101.3		%		80-120	06-SEP-17
Manganese (Mn)-Dissolved			99.3		%		80-120	06-SEP-17
Molybdenum (Mo)-Dissolved			101.7		%		80-120	06-SEP-17
Nickel (Ni)-Dissolved			102.0		%		80-120	06-SEP-17
Potassium (K)-Dissolved			97.1		%		80-120	06-SEP-17
Selenium (Se)-Dissolved			95.4		%		80-120	06-SEP-17
Silicon (Si)-Dissolved			98.3		%		80-120	06-SEP-17
Silver (Ag)-Dissolved			97.2		%		80-120	06-SEP-17
Sodium (Na)-Dissolved			102.2		%		80-120	06-SEP-17
Strontium (Sr)-Dissolved			105.3		%		80-120	06-SEP-17
Thallium (Tl)-Dissolved			102.2		%		80-120	06-SEP-17
Tin (Sn)-Dissolved			98.8		%		80-120	06-SEP-17
Titanium (Ti)-Dissolved			93.0		%		80-120	06-SEP-17
Uranium (U)-Dissolved			101.9		%		80-120	06-SEP-17
Vanadium (V)-Dissolved			99.0		%		80-120	06-SEP-17
Zinc (Zn)-Dissolved			94.1		%		80-120	06-SEP-17
WG2609164-1 MB		**LF**						
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Barium (Ba)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Boron (B)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821009								
WG2609164-1 MB		**LF**						
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Batch R3821856								
WG2609164-4 MS		**L1984572-3**						
Aluminum (Al)-Dissolved			91.1		%		70-130	06-SEP-17
Antimony (Sb)-Dissolved			104.9		%		70-130	06-SEP-17
Arsenic (As)-Dissolved			101.2		%		70-130	06-SEP-17
Barium (Ba)-Dissolved			N/A	MS-B	%		-	06-SEP-17
Bismuth (Bi)-Dissolved			84.9		%		70-130	06-SEP-17
Boron (B)-Dissolved			107.8		%		70-130	06-SEP-17
Cadmium (Cd)-Dissolved			95.6		%		70-130	06-SEP-17
Calcium (Ca)-Dissolved			N/A	MS-B	%		-	06-SEP-17
Chromium (Cr)-Dissolved			94.8		%		70-130	06-SEP-17
Cobalt (Co)-Dissolved			91.4		%		70-130	06-SEP-17
Copper (Cu)-Dissolved			89.3		%		70-130	06-SEP-17
Iron (Fe)-Dissolved			94.0		%		70-130	06-SEP-17
Lead (Pb)-Dissolved			89.7		%		70-130	06-SEP-17
Lithium (Li)-Dissolved			98.6		%		70-130	06-SEP-17
Magnesium (Mg)-Dissolved			N/A	MS-B	%		-	06-SEP-17
Manganese (Mn)-Dissolved			98.5		%		70-130	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821856								
WG2609164-4 MS		**L1984572-3**						
Molybdenum (Mo)-Dissolved			96.5		%		70-130	06-SEP-17
Nickel (Ni)-Dissolved			93.9		%		70-130	06-SEP-17
Potassium (K)-Dissolved			92.7		%		70-130	06-SEP-17
Selenium (Se)-Dissolved			106.3		%		70-130	06-SEP-17
Silicon (Si)-Dissolved			88.5		%		70-130	06-SEP-17
Silver (Ag)-Dissolved			96.8		%		70-130	06-SEP-17
Sodium (Na)-Dissolved			91.5		%		70-130	06-SEP-17
Strontium (Sr)-Dissolved			N/A	MS-B	%		-	06-SEP-17
Thallium (Tl)-Dissolved			90.1		%		70-130	06-SEP-17
Tin (Sn)-Dissolved			98.5		%		70-130	06-SEP-17
Titanium (Ti)-Dissolved			88.0		%		70-130	06-SEP-17
Uranium (U)-Dissolved			92.2		%		70-130	06-SEP-17
Vanadium (V)-Dissolved			96.6		%		70-130	06-SEP-17
Zinc (Zn)-Dissolved			95.4		%		70-130	06-SEP-17
MET-T-CCMS-VA	**Water**							
Batch R3821009								
WG2609163-2 LCS								
Aluminum (Al)-Total			100.2		%		80-120	06-SEP-17
Antimony (Sb)-Total			98.1		%		80-120	06-SEP-17
Arsenic (As)-Total			99.4		%		80-120	06-SEP-17
Barium (Ba)-Total			98.6		%		80-120	06-SEP-17
Bismuth (Bi)-Total			100.1		%		80-120	06-SEP-17
Boron (B)-Total			94.5		%		80-120	06-SEP-17
Cadmium (Cd)-Total			96.3		%		80-120	06-SEP-17
Calcium (Ca)-Total			97.2		%		80-120	06-SEP-17
Chromium (Cr)-Total			97.4		%		80-120	06-SEP-17
Cobalt (Co)-Total			96.2		%		80-120	06-SEP-17
Copper (Cu)-Total			96.3		%		80-120	06-SEP-17
Iron (Fe)-Total			95.2		%		80-120	06-SEP-17
Lead (Pb)-Total			98.4		%		80-120	06-SEP-17
Lithium (Li)-Total			99.4		%		80-120	06-SEP-17
Magnesium (Mg)-Total			103.0		%		80-120	06-SEP-17
Manganese (Mn)-Total			98.8		%		80-120	06-SEP-17
Molybdenum (Mo)-Total			96.2		%		80-120	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821009								
WG2609163-2 LCS								
Nickel (Ni)-Total			101.0		%		80-120	06-SEP-17
Potassium (K)-Total			98.8		%		80-120	06-SEP-17
Selenium (Se)-Total			94.3		%		80-120	06-SEP-17
Silicon (Si)-Total			96.9		%		80-120	06-SEP-17
Silver (Ag)-Total			93.4		%		80-120	06-SEP-17
Sodium (Na)-Total			102.8		%		80-120	06-SEP-17
Strontium (Sr)-Total			104.0		%		80-120	06-SEP-17
Thallium (Tl)-Total			98.0		%		80-120	06-SEP-17
Tin (Sn)-Total			95.1		%		80-120	06-SEP-17
Titanium (Ti)-Total			92.2		%		80-120	06-SEP-17
Uranium (U)-Total			101.3		%		80-120	06-SEP-17
Vanadium (V)-Total			97.7		%		80-120	06-SEP-17
Zinc (Zn)-Total			94.1		%		80-120	06-SEP-17
WG2609163-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	06-SEP-17
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Barium (Ba)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Boron (B)-Total			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Total			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Iron (Fe)-Total			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Total			<0.0010		mg/L		0.001	06-SEP-17
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Total			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Total			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Total			<0.10		mg/L		0.1	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3821009								
WG2609163-1 MB								
Silver (Ag)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Total			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Total			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Total			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Total			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Total			<0.0030		mg/L		0.003	06-SEP-17
Batch R3821866								
WG2609163-1 MB								
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	07-SEP-17
NH3-L-F-CL	**Water**							
Batch R3822753								
WG2611789-14 LCS								
Ammonia as N			90.0		%		85-115	08-SEP-17
WG2611789-13 MB								
Ammonia as N			<0.0050		mg/L		0.005	08-SEP-17
NO2-BC-L-IC-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Nitrite (as N)		0.0070	0.0066		mg/L	5.9	20	01-SEP-17
WG2610504-10 LCS								
Nitrite (as N)			103.1		%		90-110	01-SEP-17
WG2610504-9 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Nitrite (as N)			106.5		%		75-125	01-SEP-17
NO3-BC-L-IC-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Nitrate (as N)		4.91	4.91		mg/L	0.0	20	01-SEP-17
WG2610504-10 LCS								
Nitrate (as N)			102.6		%		90-110	01-SEP-17
WG2610504-9 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-BC-L-IC-CL	**Water**							
Batch R3821340								
WG2610504-9 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Nitrate (as N)			N/A	MS-B	%		-	01-SEP-17
ORP-CL	**Water**							
Batch R3820813								
WG2609803-2 CRM		**CL-ORP**						
ORP			218		mV		210-230	05-SEP-17
P-T-PRES-COL-VA	**Water**							
Batch R3820643								
WG2609268-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			97.2		%		80-120	06-SEP-17
WG2609268-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	06-SEP-17
PH-CL	**Water**							
Batch R3819589								
WG2608839-11 LCS								
pH			7.01		pH		6.9-7.1	01-SEP-17
PO4-DO-COL-VA	**Water**							
Batch R3820320								
WG2609176-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.8		%		80-120	06-SEP-17
WG2609176-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			87.5		%		80-120	06-SEP-17
WG2609176-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
WG2609176-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
SO4-IC-N-CL	**Water**							
Batch R3821340								
WG2610504-11 DUP		**L1984572-2**						
Sulfate (SO4)		144	144		mg/L	0.0	20	01-SEP-17
WG2610504-10 LCS								
Sulfate (SO4)			102.1		%		90-110	01-SEP-17
WG2610504-9 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SO4-IC-N-CL	**Water**							
Batch R3821340								
WG2610504-9 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	01-SEP-17
WG2610504-12 MS		**L1984572-2**						
Sulfate (SO4)			N/A	MS-B	%		-	01-SEP-17
SOLIDS-TDS-CL	**Water**							
Batch R3822658								
WG2609945-2 LCS								
Total Dissolved Solids			99.0		%		85-115	06-SEP-17
WG2609945-1 MB								
Total Dissolved Solids			<10		mg/L		10	06-SEP-17
TKN-L-F-CL	**Water**							
Batch R3823158								
WG2612433-10 LCS								
Total Kjeldahl Nitrogen			109.6		%		75-125	09-SEP-17
WG2612433-9 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	09-SEP-17
TSS-L-CL	**Water**							
Batch R3821901								
WG2611089-2 LCS								
Total Suspended Solids			96.9		%		85-115	06-SEP-17
WG2611089-1 MB								
Total Suspended Solids			<1.0		mg/L		1	06-SEP-17
TURBIDITY-BC-CL	**Water**							
Batch R3819431								
WG2607849-2 LCS								
Turbidity			99.0		%		85-115	02-SEP-17
WG2607849-1 MB								
Turbidity			<0.10		NTU		0.1	02-SEP-17

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH							
	1	30-AUG-17 13:35	01-SEP-17 15:00	0.25	49	hours	EHTR-FM
	2	30-AUG-17 12:20	01-SEP-17 15:00	0.25	51	hours	EHTR-FM
	3	30-AUG-17 12:00	01-SEP-17 15:00	0.25	51	hours	EHTR-FM
	4	30-AUG-17 12:47	01-SEP-17 15:00	0.25	50	hours	EHTR-FM
	5	30-AUG-17 14:15	01-SEP-17 15:00	0.25	49	hours	EHTR-FM
	6	30-AUG-17 14:25	01-SEP-17 15:00	0.25	48	hours	EHTR-FM
	7	30-AUG-17 14:45	01-SEP-17 15:00	0.25	48	hours	EHTR-FM
Anions and Nutrients							
Diss. Orthophosphate in Water by Colour							
	1	30-AUG-17 13:35	06-SEP-17 03:23	3	7	days	EHT
	2	30-AUG-17 12:20	06-SEP-17 03:27	3	7	days	EHT
	3	30-AUG-17 12:00	06-SEP-17 03:27	3	7	days	EHT
	4	30-AUG-17 12:47	06-SEP-17 03:27	3	7	days	EHT
	5	30-AUG-17 14:15	06-SEP-17 03:27	3	7	days	EHT
	6	30-AUG-17 14:25	06-SEP-17 03:27	3	7	days	EHT
	7	30-AUG-17 14:45	06-SEP-17 03:27	3	7	days	EHT

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1984572 were received on 31-AUG-17 09:05.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Teck

L1984572-COFC

COC ID:	REP-2017-08-30	TURNAROUND TIME:

PROJECT/CLIENT INFO / LABORATORY

Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	ALS Burnaby		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Loughheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

Email	Excel	PDF	EDD
lee.wilm@teck.com	x	x	x
teckcoal@equisonline.com			x
carla.fraser@teck.com	x	x	x
andrew.wight@teck.com	x	x	x

SAMPLE DETAILS / ANALYSIS REQUESTED

Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

	Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
PRESERVED											x			x	
1	RG_HEN-CA01_WS_50_1334	RG_HEN-CA01	WS	NO	8/30/2017	13:35	G	7	x	x	x	x	x	x	x
2	RG_HEN-CA01_WS_0_1220	RG_HEN-CA01	WQ	NO	8/30/2017	12:20	G	7	x	x	x	x	x	x	x
3	RG_HEN-CA01_WS_0_1200	RG_HEN-CA01	WS	NO	8/30/2017	12:00	G	7	x	x	x	x	x	x	x
4	RG_HEN-CA01_WS_30_1247	RG_HEN-CA01	WS	NO	8/30/2017	12:47	G	7	x	x	x	x	x	x	x
5	RG_HEN-CA02_WS_0_1415	RG_HEN-CA02	WS	NO	8/30/2017	14:15	G	7	x	x	x	x	x	x	x
6	RG_HEN-CA02_WS_30_1425	RG_HEN-CA02	WS	NO	8/30/2017	14:25	G	7	x	x	x	x	x	x	x
7	RG_HEN-CA02_WS_50_1445	RG_HEN-CA02	WS	NO	8/30/2017	14:45	G	7	x	x	x	x	x	x	x
8	RG_HEN-CA01_WS_50_1334_FB	RG_HEN-CA01	WQ	NO	8/30/2017	13:35	G	1				x			
9	RG_HEN-CA01_WS_0_1220_FB	RG_HEN-CA01	WQ	NO	8/30/2017	12:20	G	1				x			
10	RG_HEN-CA01_WS_0_1200_FB	RG_HEN-CA01	WQ	NO	8/30/2017	12:00	G	1				x			
11	RG_HEN-CA01_WS_30_1247_FB	RG_HEN-CA01	WQ	NO	8/30/2017	12:47	G	1				x			

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS	RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	DATE/TIME
All metals samples must be shipped to ALS Burnaby for analysis				8/31 9:25

NB OF BOTTLES RETURNED/DESCRIPTION					
Regular (default)	x	Sampler's Name	Nicole Wright	Mobile #	250-433-1159
Priority (2-3 business days) - 50% surcharge		Sampler's Signature		Date/Time	August 30, 2017
Emergency (1 Business Day) - 100% surcharge					
For Emergency <1 Day, ASAP or Weekend - Contact ALS					

18°

Teck

COC ID: REP-2017-08-30 TURNAROUND TIME:

L1984572-COFC

PROJECT/CLIENT INFO				LABORATORY			
Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	ALS Burnaby		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Lougheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

	PDF	EDD
	x	x
teckcoal@equisonline.com		x
carla.fraser@teck.com	x x	x
andrew.wright@teck.com	x x	x

SAMPLE DETAILS / ANALYSIS REQUESTED — Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

	Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
PRESERV.											x			x	
12	RG_HEN-CA02_WS_0_1415_FB	RG_HEN-CA02	WQ	NO	8/30/2017	13:35	G	1				x			
13	RG_HEN-CA02_WS_30_1425_FB	RG_HEN-CA02	WQ	NO	8/30/2017	12:20	G	1				x			
14	RG_HEN-CA02_WS_50_1445_FB	RG_HEN-CA02	WQ	NO	8/30/2017	12:00	G	1				x			

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS

All metals samples must be shipped to ALS Burnaby for analysis

RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	

NB OF BOTTLES RETURNED/DESCRIPTION

Regular (default)	x
Priority (2-3 business days) - 50% surcharge	
Emergency (1 Business Day) - 100% surcharge	
For Emergency <1 Day, ASAP or Weekend - Contact ALS	

Sampler's Name	Nicole Wright	Mobile #	250-433-1159
Sampler's Signature		Date/Time	August 30, 2017

Teck Coal Ltd.
ATTN: Lee Wilm
124-B Aspen Dr
Sparwood BC V0B 2G0

Date Received: 01-SEP-17
Report Date: 18-SEP-17 12:19 (MT)
Version: FINAL

Client Phone: 250-425-8209

Certificate of Analysis

Lab Work Order #: L1985025

Project P.O. #: VPO00517564
Job Reference: CALCITE BIOLOGICAL EFFECTS
C of C Numbers: REP-2017-08-31
Legal Site Desc:

Lyudmyla Shvets, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-1	L1985025-2	L1985025-3	L1985025-4	L1985025-5
	Description	WS	WQ	WS	WQ	WS
	Sampled Date	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17
	Sampled Time	09:22	09:22	09:44	09:44	10:54
	Client ID	RG_LCDRY_CA02_WS_0_20170831_922	RG_LCDRY_CA02_WS_0_20170831_922_FB	RG_LCDRY_CA02_WS_30_20170831_944	RG_LCDRY_CA02_WS_30_20170831_944_FB	RG_LCDRY_CA02_WS_50_20170831_1054
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	367		360		359
	Hardness (as CaCO3) (mg/L)	192		193		194
	pH (pH)	8.37		8.39		8.38
	ORP (mV)	248		258		265
	Total Suspended Solids (mg/L)	1.0		47.8		4.2
	Total Dissolved Solids (mg/L)	DLHC 223		DLHC 223		DLHC 218
	Turbidity (NTU)	0.47		24.0		1.13
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0		<1.0		<1.0
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	182		178		183
	Alkalinity, Carbonate (as CaCO3) (mg/L)	58.6		11.4		10.6
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0		<1.0		<1.0
	Alkalinity, Total (as CaCO3) (mg/L)	241		189		194
	Ammonia as N (mg/L)	0.0226		0.0227		0.0577
	Bromide (Br) (mg/L)	<0.050		<0.050		<0.050
	Chloride (Cl) (mg/L)	0.80		0.85		0.83
	Fluoride (F) (mg/L)	0.095		0.099		0.096
	Nitrate (as N) (mg/L)	0.924		0.914		0.920
	Nitrite (as N) (mg/L)	0.0020		0.0014		0.0012
	Total Kjeldahl Nitrogen (mg/L)	0.148		0.113		0.117
	Orthophosphate-Dissolved (as P) (mg/L)	0.0050		0.0043		0.0088
	Phosphorus (P)-Total (mg/L)	0.0069		0.0142		0.0086
	Sulfate (SO4) (mg/L)	14.2		14.2		14.4
	Anion Sum (meq/L)	5.20		4.17		4.27
	Cation Sum (meq/L)	3.92		3.93		3.97
	Cation - Anion Balance (%)	-14.1		-3.0		-3.6
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	1.58		1.60		1.36
	Total Organic Carbon (mg/L)	1.72		1.54		1.49
Total Metals	Aluminum (Al)-Total (mg/L)	0.0040		0.0659		0.0120
	Antimony (Sb)-Total (mg/L)	0.00015		0.00019		0.00017
	Arsenic (As)-Total (mg/L)	0.00015		0.00021		0.00016
	Barium (Ba)-Total (mg/L)	0.217		0.201		0.210
	Beryllium (Be)-Total (ug/L)	<0.020		<0.020		<0.020
	Bismuth (Bi)-Total (mg/L)	<0.000050		<0.000050		<0.000050
	Boron (B)-Total (mg/L)	<0.010		<0.010		<0.010
	Cadmium (Cd)-Total (ug/L)	0.0483		0.0694		0.0444
	Calcium (Ca)-Total (mg/L)	47.6		48.0		46.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-6				
	Description	WQ				
	Sampled Date	31-AUG-17				
	Sampled Time	10:54				
	Client ID	RG_LCDRY_CA02_WS_50_20170831_1054_FB				
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)					
	Hardness (as CaCO3) (mg/L)					
	pH (pH)					
	ORP (mV)					
	Total Suspended Solids (mg/L)					
	Total Dissolved Solids (mg/L)					
	Turbidity (NTU)					
Anions and Nutrients	Acidity (as CaCO3) (mg/L)					
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)					
	Alkalinity, Carbonate (as CaCO3) (mg/L)					
	Alkalinity, Hydroxide (as CaCO3) (mg/L)					
	Alkalinity, Total (as CaCO3) (mg/L)					
	Ammonia as N (mg/L)					
	Bromide (Br) (mg/L)					
	Chloride (Cl) (mg/L)					
	Fluoride (F) (mg/L)					
	Nitrate (as N) (mg/L)					
	Nitrite (as N) (mg/L)					
	Total Kjeldahl Nitrogen (mg/L)					
	Orthophosphate-Dissolved (as P) (mg/L)					
	Phosphorus (P)-Total (mg/L)					
	Sulfate (SO4) (mg/L)					
	Anion Sum (meq/L)					
	Cation Sum (meq/L)					
	Cation - Anion Balance (%)					
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)					
	Total Organic Carbon (mg/L)					
Total Metals	Aluminum (Al)-Total (mg/L)					
	Antimony (Sb)-Total (mg/L)					
	Arsenic (As)-Total (mg/L)					
	Barium (Ba)-Total (mg/L)					
	Beryllium (Be)-Total (ug/L)					
	Bismuth (Bi)-Total (mg/L)					
	Boron (B)-Total (mg/L)					
	Cadmium (Cd)-Total (ug/L)					
	Calcium (Ca)-Total (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-1	L1985025-2	L1985025-3	L1985025-4	L1985025-5
	Description	WS	WQ	WS	WQ	WS
	Sampled Date	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17
	Sampled Time	09:22	09:22	09:44	09:44	10:54
	Client ID	RG_LCDRY_CA02_WS_0_20170831_922	RG_LCDRY_CA02_WS_0_20170831_922_FB	RG_LCDRY_CA02_WS_30_20170831_944	RG_LCDRY_CA02_WS_30_20170831_944_FB	RG_LCDRY_CA02_WS_50_20170831_1054
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	<0.00010		0.00032		0.00018
	Cobalt (Co)-Total (ug/L)	<0.10		<0.10		<0.10
	Copper (Cu)-Total (mg/L)	<0.00050		<0.00050		<0.00050
	Iron (Fe)-Total (mg/L)	0.019		0.128		0.028
	Lead (Pb)-Total (mg/L)	<0.000050		0.000114		<0.000050
	Lithium (Li)-Total (mg/L)	0.0118		0.0115		0.0115
	Magnesium (Mg)-Total (mg/L)	19.3		18.7		19.0
	Manganese (Mn)-Total (mg/L)	0.00308		0.00763		0.00309
	Mercury (Hg)-Total (ug/L)	<0.00050	<0.00050	0.00065	<0.00050	<0.00050
	Molybdenum (Mo)-Total (mg/L)	0.00121		0.00110		0.00116
	Nickel (Ni)-Total (mg/L)	<0.00050		0.00076		<0.00050
	Potassium (K)-Total (mg/L)	1.36		1.32		1.34
	Selenium (Se)-Total (ug/L)	3.02		3.06		3.02
	Silicon (Si)-Total (mg/L)	3.15		3.02		3.00
	Silver (Ag)-Total (mg/L)	<0.000010		<0.000010		<0.000010
	Sodium (Na)-Total (mg/L)	1.22		1.16		1.19
	Strontium (Sr)-Total (mg/L)	0.0617		0.0599		0.0594
	Thallium (Tl)-Total (mg/L)	<0.000010		0.000011		<0.000010
	Tin (Sn)-Total (mg/L)	<0.00010		<0.00010		<0.00010
	Titanium (Ti)-Total (mg/L)	<0.010		<0.010		<0.010
	Uranium (U)-Total (mg/L)	0.000422		0.000432		0.000420
	Vanadium (V)-Total (mg/L)	0.00052		0.00101		0.00058
	Zinc (Zn)-Total (mg/L)	<0.0030		0.0064		<0.0030
Dissolved Metals	Dissolved Mercury Filtration Location	FIELD		FIELD		FIELD
	Dissolved Metals Filtration Location	LAB		LAB		LAB
	Aluminum (Al)-Dissolved (mg/L)	<0.0030		0.0041		<0.0030
	Antimony (Sb)-Dissolved (mg/L)	0.00015		0.00017		0.00014
	Arsenic (As)-Dissolved (mg/L)	0.00015		0.00015		0.00015
	Barium (Ba)-Dissolved (mg/L)	0.204		0.198		0.206
	Beryllium (Be)-Dissolved (ug/L)	<0.020		<0.020		<0.020
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050		<0.000050		<0.000050
	Boron (B)-Dissolved (mg/L)	<0.010		<0.010		<0.010
	Cadmium (Cd)-Dissolved (ug/L)	0.0294		0.0320		0.0314
	Calcium (Ca)-Dissolved (mg/L)	47.1		48.2		47.6
	Chromium (Cr)-Dissolved (mg/L)	<0.00010		<0.00010		<0.00010
	Cobalt (Co)-Dissolved (ug/L)	<0.10		<0.10		<0.10
	Copper (Cu)-Dissolved (mg/L)	<0.00050		<0.00050		<0.00050

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-6				
	Description	WQ				
	Sampled Date	31-AUG-17				
	Sampled Time	10:54				
	Client ID	RG_LCDRY_CA02_WS_50_20170831_1054_FB				
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)					
	Cobalt (Co)-Total (ug/L)					
	Copper (Cu)-Total (mg/L)					
	Iron (Fe)-Total (mg/L)					
	Lead (Pb)-Total (mg/L)					
	Lithium (Li)-Total (mg/L)					
	Magnesium (Mg)-Total (mg/L)					
	Manganese (Mn)-Total (mg/L)					
	Mercury (Hg)-Total (ug/L)	<0.00050				
	Molybdenum (Mo)-Total (mg/L)					
	Nickel (Ni)-Total (mg/L)					
	Potassium (K)-Total (mg/L)					
	Selenium (Se)-Total (ug/L)					
	Silicon (Si)-Total (mg/L)					
	Silver (Ag)-Total (mg/L)					
	Sodium (Na)-Total (mg/L)					
	Strontium (Sr)-Total (mg/L)					
	Thallium (Tl)-Total (mg/L)					
	Tin (Sn)-Total (mg/L)					
	Titanium (Ti)-Total (mg/L)					
	Uranium (U)-Total (mg/L)					
	Vanadium (V)-Total (mg/L)					
	Zinc (Zn)-Total (mg/L)					
Dissolved Metals	Dissolved Mercury Filtration Location					
	Dissolved Metals Filtration Location					
	Aluminum (Al)-Dissolved (mg/L)					
	Antimony (Sb)-Dissolved (mg/L)					
	Arsenic (As)-Dissolved (mg/L)					
	Barium (Ba)-Dissolved (mg/L)					
	Beryllium (Be)-Dissolved (ug/L)					
	Bismuth (Bi)-Dissolved (mg/L)					
	Boron (B)-Dissolved (mg/L)					
	Cadmium (Cd)-Dissolved (ug/L)					
	Calcium (Ca)-Dissolved (mg/L)					
	Chromium (Cr)-Dissolved (mg/L)					
	Cobalt (Co)-Dissolved (ug/L)					
	Copper (Cu)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-1	L1985025-2	L1985025-3	L1985025-4	L1985025-5
	Description	WS	WQ	WS	WQ	WS
	Sampled Date	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17	31-AUG-17
	Sampled Time	09:22	09:22	09:44	09:44	10:54
	Client ID	RG_LCDRY_CA02_WS_0_20170831_922	RG_LCDRY_CA02_WS_0_20170831_922_FB	RG_LCDRY_CA02_WS_30_20170831_944	RG_LCDRY_CA02_WS_30_20170831_944_FB	RG_LCDRY_CA02_WS_50_20170831_1054
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010		<0.010		<0.010
	Lead (Pb)-Dissolved (mg/L)	<0.000050		<0.000050		<0.000050
	Lithium (Li)-Dissolved (mg/L)	0.0104		0.0108		0.0109
	Magnesium (Mg)-Dissolved (mg/L)	18.0		17.6		18.3
	Manganese (Mn)-Dissolved (mg/L)	0.00191		0.00097		0.00144
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050		<0.0000050		<0.0000050
	Molybdenum (Mo)-Dissolved (mg/L)	0.00117		0.00122		0.00124
	Nickel (Ni)-Dissolved (mg/L)	<0.00050		<0.00050		<0.00050
	Potassium (K)-Dissolved (mg/L)	1.25		1.26		1.27
	Selenium (Se)-Dissolved (ug/L)	3.36		3.30		3.28
	Silicon (Si)-Dissolved (mg/L)	2.91		2.92		2.84
	Silver (Ag)-Dissolved (mg/L)	<0.000010		<0.000010		<0.000010
	Sodium (Na)-Dissolved (mg/L)	1.11		1.10		1.19
	Strontium (Sr)-Dissolved (mg/L)	0.0566		0.0588		0.0582
	Thallium (Tl)-Dissolved (mg/L)	<0.000010		<0.000010		<0.000010
	Tin (Sn)-Dissolved (mg/L)	<0.00010		<0.00010		<0.00010
	Titanium (Ti)-Dissolved (mg/L)	<0.010		<0.010		<0.010
	Uranium (U)-Dissolved (mg/L)	0.000387		0.000396		0.000443
	Vanadium (V)-Dissolved (mg/L)	<0.00050		0.00050		0.00051
	Zinc (Zn)-Dissolved (mg/L)	<0.0030		<0.0030		<0.0030

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985025-6				
	Description	WQ				
	Sampled Date	31-AUG-17				
	Sampled Time	10:54				
	Client ID	RG_LCDRY_CA02_WS_50_20170831_1054_FB				
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)					
	Lead (Pb)-Dissolved (mg/L)					
	Lithium (Li)-Dissolved (mg/L)					
	Magnesium (Mg)-Dissolved (mg/L)					
	Manganese (Mn)-Dissolved (mg/L)					
	Mercury (Hg)-Dissolved (mg/L)					
	Molybdenum (Mo)-Dissolved (mg/L)					
	Nickel (Ni)-Dissolved (mg/L)					
	Potassium (K)-Dissolved (mg/L)					
	Selenium (Se)-Dissolved (ug/L)					
	Silicon (Si)-Dissolved (mg/L)					
	Silver (Ag)-Dissolved (mg/L)					
	Sodium (Na)-Dissolved (mg/L)					
	Strontium (Sr)-Dissolved (mg/L)					
	Thallium (Tl)-Dissolved (mg/L)					
	Tin (Sn)-Dissolved (mg/L)					
	Titanium (Ti)-Dissolved (mg/L)					
	Uranium (U)-Dissolved (mg/L)					
	Vanadium (V)-Dissolved (mg/L)					
	Zinc (Zn)-Dissolved (mg/L)					

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	Sample was Filtered and Preserved at the laboratory - DOC,DISSOLVED METALS

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Barium (Ba)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Boron (B)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Calcium (Ca)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Magnesium (Mg)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Manganese (Mn)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Molybdenum (Mo)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Potassium (K)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Sodium (Na)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Strontium (Sr)-Dissolved	MS-B	L1985025-1, -3, -5
Matrix Spike	Uranium (U)-Dissolved	MS-B	L1985025-1, -3, -5

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLHC	Detection Limit Raised: Dilution required due to high concentration of test analyte(s).
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ACIDITY-PCT-CL	Water	Acidity by Automatic Titration	APHA 2310 Acidity

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

ALK-MAN-CL	Water	Alkalinity (Species) by Manual Titration	APHA 2320 ALKALINITY

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

BE-D-L-CCMS-VA	Water	Diss. Be (low) in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

BE-T-L-CCMS-VA	Water	Total Be (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

BR-L-IC-N-CL	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

C-DIS-ORG-LOW-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

C-TOT-ORG-LOW-CL	Water	Total Organic Carbon	APHA 5310 TOTAL ORGANIC CARBON (TOC)

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

Reference Information

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

CL-IC-N-CL | Water | Chloride in Water by IC | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-L-PCT-CL | Water | Electrical Conductivity (EC) | APHA 2510B

Conductivity, also known as Electrical Conductivity (EC) or Specific Conductance, is measured by immersion of a conductivity cell with platinum electrodes into a water sample. Conductivity measurements are temperature-compensated to 25C.

F-IC-N-CL | Water | Fluoride in Water by IC | EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA | Water | Hardness | APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-D-CVAA-VA | Water | Diss. Mercury in Water by CVAAS or CVAFS | APHA 3030B/EPA 1631E (mod)

Water samples are filtered (0.45 um), preserved with hydrochloric acid, then undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

HG-T-U-CVAF-VA | Water | Total Mercury in Water by CVAFS (Ultra) | EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

IONBALANCE-BC-CL | Water | Ion Balance Calculation | APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-D-CCMS-VA | Water | Dissolved Metals in Water by CRC ICPMS | APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-T-CCMS-VA | Water | Total Metals in Water by CRC ICPMS | EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NH3-L-F-CL | Water | Ammonia, Total (as N) | J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-BC-L-IC-CL | Water | Nitrite-N | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

NO3-BC-L-IC-CL | Water | Nitrate (as N) | EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ORP-CL | Water | Oxidation redution potential by elect. | ASTM D1498

This analysis is carried out in accordance with the procedure described in the "ASTM" method D1498 "Oxidation-Reduction Potential of Water" published by the American Society for Testing and Materials (ASTM). Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.

It is recommended that this analysis be conducted in the field.

P-T-PRES-COL-VA | Water | Total P in Water by Colour | APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically

Reference Information

after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-CL	Water	pH	APHA 4500 H-Electrode

pH is determined in the laboratory using a pH electrode. All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SO4-IC-N-CL	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-CL	Water	Total Dissolved Solids	APHA 2540 C

A well-mixed sample is filtered through a glass fibre filter paper. The filtrate is then evaporated to dryness in a pre-weighed vial and dried at 180 – 2 °C. The increase in vial weight represents the total dissolved solids (TDS).

TKN-L-F-CL	Water	Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-L-CL	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, and by drying the filter at 104 deg. C.

TURBIDITY-BC-CL	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

REP-2017-08-31

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Teck Coal Ltd.
124-B Aspen Dr
Sparwood BC V0B 2G0

Contact: Lee Wilm

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ACIDITY-PCT-CL	**Water**							
Batch R3819603								
WG2608865-2 LCS								
Acidity (as CaCO3)			99.4		%		85-115	02-SEP-17
WG2608865-1 MB								
Acidity (as CaCO3)			<1.0		mg/L		2	02-SEP-17
ALK-MAN-CL	**Water**							
Batch R3821754								
WG2610900-3 DUP		**L1985025-5**						
Alkalinity, Total (as CaCO3)		194	186		mg/L	4.2	20	06-SEP-17
WG2610900-2 LCS								
Alkalinity, Total (as CaCO3)			103.8		%		85-115	06-SEP-17
WG2610900-1 MB								
Alkalinity, Total (as CaCO3)			<1.0		mg/L		1	06-SEP-17
BE-D-L-CCMS-VA	**Water**							
Batch R3820091								
WG2608597-2 LCS								
Beryllium (Be)-Dissolved			104.9		%		80-120	05-SEP-17
WG2608597-1 MB		**NP**						
Beryllium (Be)-Dissolved			<0.000020		mg/L		0.00002	05-SEP-17
BE-T-L-CCMS-VA	**Water**							
Batch R3827888								
WG2613842-2 LCS								
Beryllium (Be)-Total			109.7		%		80-120	12-SEP-17
WG2613842-1 MB								
Beryllium (Be)-Total			<0.000020		mg/L		0.00002	12-SEP-17
Batch R3828959								
WG2613842-3 DUP		**L1985025-3**						
Beryllium (Be)-Total		<0.000020	<0.000020	RPD-NA	mg/L	N/A	20	13-SEP-17
BR-L-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Bromide (Br)		<0.050	<0.050	RPD-NA	mg/L	N/A	20	02-SEP-17
WG2610641-10 LCS								
Bromide (Br)			98.0		%		85-115	02-SEP-17
WG2610641-9 MB								
Bromide (Br)			<0.050		mg/L		0.05	02-SEP-17
WG2610641-12 MS		**L1985025-1**						

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BR-L-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-12 MS		**L1985025-1**						
Bromide (Br)			107.8		%		75-125	02-SEP-17
C-DIS-ORG-LOW-CL	**Water**							
Batch R3823472								
WG2612766-23 DUP		**L1985025-3**						
Dissolved Organic Carbon		1.60	1.30	J	mg/L	0.30	1	09-SEP-17
WG2612766-22 LCS								
Dissolved Organic Carbon			110.4		%		80-120	09-SEP-17
WG2612766-21 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	09-SEP-17
C-TOT-ORG-LOW-CL	**Water**							
Batch R3823472								
WG2612766-23 DUP		**L1985025-3**						
Total Organic Carbon		1.54	1.52		mg/L	1.5	20	09-SEP-17
WG2612766-22 LCS								
Total Organic Carbon			111.3		%		80-120	09-SEP-17
WG2612766-21 MB								
Total Organic Carbon			<0.50		mg/L		0.5	09-SEP-17
CL-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Chloride (Cl)		0.80	0.77		mg/L	3.2	20	02-SEP-17
WG2610641-10 LCS								
Chloride (Cl)			102.3		%		90-110	02-SEP-17
WG2610641-9 MB								
Chloride (Cl)			<0.50		mg/L		0.5	02-SEP-17
WG2610641-12 MS		**L1985025-1**						
Chloride (Cl)			111.6		%		75-125	02-SEP-17
EC-L-PCT-CL	**Water**							
Batch R3821754								
WG2610900-3 DUP		**L1985025-5**						
Conductivity (@ 25C)		359	361		uS/cm	0.6	10	06-SEP-17
WG2610900-2 LCS								
Conductivity (@ 25C)			100.3		%		90-110	06-SEP-17
WG2610900-1 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	06-SEP-17
	Water							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
F-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Fluoride (F)		0.095	0.101		mg/L	5.8	20	02-SEP-17
WG2610641-10 LCS								
Fluoride (F)			98.1		%		90-110	02-SEP-17
WG2610641-9 MB								
Fluoride (F)			<0.020		mg/L		0.02	02-SEP-17
WG2610641-12 MS		**L1985025-1**						
Fluoride (F)			111.0		%		75-125	02-SEP-17
HG-D-CVAA-VA	**Water**							
Batch R3820540								
WG2609337-2 LCS								
Mercury (Hg)-Dissolved			107.1		%		80-120	06-SEP-17
WG2609337-1 MB		**NP**						
Mercury (Hg)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
WG2609337-4 MS		**L1985025-3**						
Mercury (Hg)-Dissolved			104.7		%		70-130	06-SEP-17
HG-T-U-CVAF-VA	**Water**							
Batch R3820826								
WG2609820-8 DUP		**L1985025-3**						
Mercury (Hg)-Total		0.00065	0.00062	RPD-NA	ug/L	N/A	20	06-SEP-17
WG2609820-2 LCS								
Mercury (Hg)-Total			98.2		%		80-120	06-SEP-17
WG2609820-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	06-SEP-17
MET-D-CCMS-VA	**Water**							
Batch R3820091								
WG2608597-2 LCS								
Aluminum (Al)-Dissolved			104.6		%		80-120	05-SEP-17
Antimony (Sb)-Dissolved			108.0		%		80-120	05-SEP-17
Arsenic (As)-Dissolved			103.2		%		80-120	05-SEP-17
Barium (Ba)-Dissolved			109.0		%		80-120	05-SEP-17
Bismuth (Bi)-Dissolved			104.6		%		80-120	05-SEP-17
Boron (B)-Dissolved			108.7		%		80-120	05-SEP-17
Cadmium (Cd)-Dissolved			99.8		%		80-120	05-SEP-17
Calcium (Ca)-Dissolved			107.8		%		80-120	05-SEP-17
Chromium (Cr)-Dissolved			100.1		%		80-120	05-SEP-17
Cobalt (Co)-Dissolved			100.2		%		80-120	05-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3820091								
WG2608597-2 LCS								
Copper (Cu)-Dissolved			102.0		%		80-120	05-SEP-17
Iron (Fe)-Dissolved			96.6		%		80-120	05-SEP-17
Lead (Pb)-Dissolved			105.1		%		80-120	05-SEP-17
Lithium (Li)-Dissolved			110.1		%		80-120	05-SEP-17
Magnesium (Mg)-Dissolved			107.2		%		80-120	05-SEP-17
Manganese (Mn)-Dissolved			108.0		%		80-120	05-SEP-17
Molybdenum (Mo)-Dissolved			99.7		%		80-120	05-SEP-17
Nickel (Ni)-Dissolved			102.0		%		80-120	05-SEP-17
Potassium (K)-Dissolved			110.8		%		80-120	05-SEP-17
Selenium (Se)-Dissolved			100.3		%		80-120	05-SEP-17
Silicon (Si)-Dissolved			104.4		%		80-120	05-SEP-17
Silver (Ag)-Dissolved			101.3		%		80-120	05-SEP-17
Sodium (Na)-Dissolved			106.9		%		80-120	05-SEP-17
Strontium (Sr)-Dissolved			107.2		%		80-120	05-SEP-17
Thallium (Tl)-Dissolved			106.0		%		80-120	05-SEP-17
Tin (Sn)-Dissolved			99.3		%		80-120	05-SEP-17
Titanium (Ti)-Dissolved			107.9		%		80-120	05-SEP-17
Uranium (U)-Dissolved			103.3		%		80-120	05-SEP-17
Vanadium (V)-Dissolved			105.5		%		80-120	05-SEP-17
Zinc (Zn)-Dissolved			98.3		%		80-120	05-SEP-17
WG2608597-1 MB		**NP**						
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	05-SEP-17
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Barium (Ba)-Dissolved			<0.000050		mg/L		0.00005	05-SEP-17
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	05-SEP-17
Boron (B)-Dissolved			<0.010		mg/L		0.01	05-SEP-17
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	05-SEP-17
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	05-SEP-17
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	05-SEP-17
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	05-SEP-17
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	05-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3820091								
WG2608597-1 MB		**NP**						
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	05-SEP-17
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	05-SEP-17
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	05-SEP-17
Potassium (K)-Dissolved			<0.050		mg/L		0.05	05-SEP-17
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	05-SEP-17
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	05-SEP-17
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	05-SEP-17
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	05-SEP-17
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	05-SEP-17
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	05-SEP-17
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	05-SEP-17
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	05-SEP-17
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	05-SEP-17
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	05-SEP-17
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	05-SEP-17
Batch R3820821								
WG2608597-1 MB		**NP**						
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	05-SEP-17
MET-T-CCMS-VA	**Water**							
Batch R3827888								
WG2613842-2 LCS								
Aluminum (Al)-Total			112.8		%		80-120	12-SEP-17
Antimony (Sb)-Total			107.1		%		80-120	12-SEP-17
Arsenic (As)-Total			114.2		%		80-120	12-SEP-17
Barium (Ba)-Total			115.6		%		80-120	12-SEP-17
Bismuth (Bi)-Total			109.9		%		80-120	12-SEP-17
Boron (B)-Total			99.7		%		80-120	12-SEP-17
Cadmium (Cd)-Total			111.4		%		80-120	12-SEP-17
Calcium (Ca)-Total			105.7		%		80-120	12-SEP-17
Chromium (Cr)-Total			113.9		%		80-120	12-SEP-17
Cobalt (Co)-Total			111.7		%		80-120	12-SEP-17
Copper (Cu)-Total			111.5		%		80-120	12-SEP-17
Iron (Fe)-Total			105.1		%		80-120	12-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3827888								
WG2613842-2 LCS								
Lead (Pb)-Total			108.9		%		80-120	12-SEP-17
Lithium (Li)-Total			110.7		%		80-120	12-SEP-17
Magnesium (Mg)-Total			113.8		%		80-120	12-SEP-17
Manganese (Mn)-Total			115.1		%		80-120	12-SEP-17
Molybdenum (Mo)-Total			106.5		%		80-120	12-SEP-17
Nickel (Ni)-Total			111.9		%		80-120	12-SEP-17
Potassium (K)-Total			112.8		%		80-120	12-SEP-17
Selenium (Se)-Total			108.3		%		80-120	12-SEP-17
Silicon (Si)-Total			107.0		%		80-120	12-SEP-17
Silver (Ag)-Total			108.7		%		80-120	12-SEP-17
Sodium (Na)-Total			110.4		%		80-120	12-SEP-17
Strontium (Sr)-Total			108.7		%		80-120	12-SEP-17
Thallium (Tl)-Total			109.0		%		80-120	12-SEP-17
Tin (Sn)-Total			112.3		%		80-120	12-SEP-17
Titanium (Ti)-Total			96.2		%		80-120	12-SEP-17
Uranium (U)-Total			108.0		%		80-120	12-SEP-17
Vanadium (V)-Total			113.6		%		80-120	12-SEP-17
Zinc (Zn)-Total			107.2		%		80-120	12-SEP-17
WG2613842-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	12-SEP-17
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Arsenic (As)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Barium (Ba)-Total			<0.000050		mg/L		0.00005	12-SEP-17
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	12-SEP-17
Boron (B)-Total			<0.010		mg/L		0.01	12-SEP-17
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	12-SEP-17
Calcium (Ca)-Total			<0.050		mg/L		0.05	12-SEP-17
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Copper (Cu)-Total			<0.00050		mg/L		0.0005	12-SEP-17
Iron (Fe)-Total			<0.010		mg/L		0.01	12-SEP-17
Lead (Pb)-Total			<0.000050		mg/L		0.00005	12-SEP-17
Lithium (Li)-Total			<0.0010		mg/L		0.001	12-SEP-17
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	12-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3827888								
WG2613842-1 MB								
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	12-SEP-17
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	12-SEP-17
Potassium (K)-Total			<0.050		mg/L		0.05	12-SEP-17
Selenium (Se)-Total			<0.000050		mg/L		0.00005	12-SEP-17
Silicon (Si)-Total			<0.10		mg/L		0.1	12-SEP-17
Silver (Ag)-Total			<0.000010		mg/L		0.00001	12-SEP-17
Sodium (Na)-Total			<0.050		mg/L		0.05	12-SEP-17
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	12-SEP-17
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	12-SEP-17
Tin (Sn)-Total			<0.00010		mg/L		0.0001	12-SEP-17
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	12-SEP-17
Uranium (U)-Total			<0.000010		mg/L		0.00001	12-SEP-17
Vanadium (V)-Total			<0.00050		mg/L		0.0005	12-SEP-17
Zinc (Zn)-Total			<0.0030		mg/L		0.003	12-SEP-17
Batch R3828959								
WG2613842-3 DUP		**L1985025-3**						
Aluminum (Al)-Total		0.0659	0.0716		mg/L	8.2	20	13-SEP-17
Antimony (Sb)-Total		0.00019	0.00020		mg/L	1.8	20	13-SEP-17
Arsenic (As)-Total		0.00021	0.00021		mg/L	1.2	20	13-SEP-17
Barium (Ba)-Total		0.201	0.191		mg/L	5.1	20	13-SEP-17
Bismuth (Bi)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	13-SEP-17
Boron (B)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	13-SEP-17
Cadmium (Cd)-Total		0.0000694	0.0000650		mg/L	6.5	20	13-SEP-17
Calcium (Ca)-Total		48.0	48.4		mg/L	0.7	20	13-SEP-17
Chromium (Cr)-Total		0.00032	0.00032		mg/L	2.0	20	13-SEP-17
Cobalt (Co)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	13-SEP-17
Copper (Cu)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	13-SEP-17
Iron (Fe)-Total		0.128	0.143		mg/L	11	20	13-SEP-17
Lead (Pb)-Total		0.000114	0.000120		mg/L	4.7	20	13-SEP-17
Lithium (Li)-Total		0.0115	0.0118		mg/L	2.0	20	13-SEP-17
Magnesium (Mg)-Total		18.7	17.6		mg/L	6.3	20	13-SEP-17
Manganese (Mn)-Total		0.00763	0.00717		mg/L	6.2	20	13-SEP-17
Molybdenum (Mo)-Total		0.00110	0.00116		mg/L	5.1	20	13-SEP-17

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3828959								
WG2613842-3 DUP		**L1985025-3**						
Nickel (Ni)-Total		0.00076	0.00077		mg/L	1.2	20	13-SEP-17
Potassium (K)-Total		1.32	1.26		mg/L	4.9	20	13-SEP-17
Selenium (Se)-Total		0.00306	0.00296		mg/L	3.3	20	13-SEP-17
Silicon (Si)-Total		3.02	2.95		mg/L	2.4	20	13-SEP-17
Silver (Ag)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	13-SEP-17
Sodium (Na)-Total		1.16	1.07		mg/L	7.5	20	13-SEP-17
Strontium (Sr)-Total		0.0599	0.0610		mg/L	1.8	20	13-SEP-17
Thallium (Tl)-Total		0.000011	<0.000010	RPD-NA	mg/L	N/A	20	13-SEP-17
Tin (Sn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	13-SEP-17
Titanium (Ti)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	13-SEP-17
Uranium (U)-Total		0.000432	0.000436		mg/L	1.1	20	13-SEP-17
Vanadium (V)-Total		0.00101	0.00100		mg/L	0.5	20	13-SEP-17
Zinc (Zn)-Total		0.0064	0.0047	J	mg/L	0.0017	0.006	13-SEP-17
NH3-L-F-CL	**Water**							
Batch R3823062								
WG2612358-43 DUP		**L1985025-5**						
Ammonia as N		0.0577	0.0563		mg/L	2.5	20	09-SEP-17
WG2612358-8 LCS								
Ammonia as N			102.3		%		85-115	09-SEP-17
WG2612358-7 MB								
Ammonia as N			<0.0050		mg/L		0.005	09-SEP-17
NO2-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Nitrite (as N)		0.0020	0.0014	J	mg/L	0.0006	0.002	02-SEP-17
WG2610641-10 LCS								
Nitrite (as N)			104.7		%		90-110	02-SEP-17
WG2610641-9 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	02-SEP-17
WG2610641-12 MS		**L1985025-1**						
Nitrite (as N)			115.0		%		75-125	02-SEP-17
NO3-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Nitrate (as N)		0.924	0.891		mg/L	3.7	20	02-SEP-17
WG2610641-10 LCS								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO3-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Nitrate (as N)			104.2		%		90-110	02-SEP-17
WG2610641-9 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	02-SEP-17
WG2610641-12 MS		**L1985025-1**						
Nitrate (as N)			110.7		%		75-125	02-SEP-17
ORP-CL	**Water**							
Batch R3824011								
WG2613305-2 CRM		**CL-ORP**						
ORP			219		mV		210-230	06-SEP-17
WG2613305-1 DUP		**L1985025-5**						
ORP		265	268	J	mV	2.5	15	06-SEP-17
P-T-PRES-COL-VA	**Water**							
Batch R3820643								
WG2609268-2 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			97.2		%		80-120	06-SEP-17
WG2609268-1 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	06-SEP-17
PH-CL	**Water**							
Batch R3821754								
WG2610900-3 DUP		**L1985025-5**						
pH		8.38	8.38	J	pH	0.00	0.2	06-SEP-17
WG2610900-2 LCS								
pH			6.96		pH		6.9-7.1	06-SEP-17
PO4-DO-COL-VA	**Water**							
Batch R3817817								
WG2608093-3 DUP		**L1985025-3**						
Orthophosphate-Dissolved (as P)		0.0043	0.0044		mg/L	2.8	20	03-SEP-17
WG2608093-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	03-SEP-17
WG2608093-4 MS		**L1985025-5**						
Orthophosphate-Dissolved (as P)			103.3		%		70-130	03-SEP-17
SO4-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-11 DUP		**L1985025-1**						
Sulfate (SO4)		14.2	13.2		mg/L	7.1	20	02-SEP-17
WG2610641-10 LCS								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SO4-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Sulfate (SO4)			103.3		%		90-110	02-SEP-17
WG2610641-9 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	02-SEP-17
WG2610641-12 MS		**L1985025-1**						
Sulfate (SO4)			112.1		%		75-125	02-SEP-17
SOLIDS-TDS-CL	**Water**							
Batch R3823768								
WG2610569-2 LCS								
Total Dissolved Solids			102.5		%		85-115	07-SEP-17
WG2610569-1 MB								
Total Dissolved Solids			<10		mg/L		10	07-SEP-17
TKN-L-F-CL	**Water**							
Batch R3823158								
WG2612433-10 LCS								
Total Kjeldahl Nitrogen			109.6		%		75-125	09-SEP-17
WG2612433-9 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	09-SEP-17
Batch R3826345								
WG2614706-4 LCS								
Total Kjeldahl Nitrogen			103.2		%		75-125	12-SEP-17
WG2614706-3 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	12-SEP-17
TSS-L-CL	**Water**							
Batch R3823857								
WG2612450-2 LCS								
Total Suspended Solids			92.4		%		85-115	07-SEP-17
WG2612450-1 MB								
Total Suspended Solids			<1.0		mg/L		1	07-SEP-17
TURBIDITY-BC-CL	**Water**							
Batch R3819431								
WG2607849-6 DUP		**L1985025-3**						
Turbidity		24.0	23.8		NTU	0.8	15	02-SEP-17
WG2607849-5 LCS								
Turbidity			99.0		%		85-115	02-SEP-17
WG2607849-4 MB								
Turbidity			<0.10		NTU		0.1	02-SEP-17

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH							
	1	31-AUG-17 09:22	06-SEP-17 14:00	0.25	149	hours	EHTR-FM
	3	31-AUG-17 09:44	06-SEP-17 14:00	0.25	148	hours	EHTR-FM
	5	31-AUG-17 10:54	06-SEP-17 14:00	0.25	147	hours	EHTR-FM

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1985025 were received on 01-SEP-17 09:30.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Teck

L1985025-COFC

COC ID:	REP-2017-08-31	TURNAROUND

PROJECT/CLIENT INFO

Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	A		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Lougheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

	Excel	PDF	EDD
lee.wilm@teck.com	x	x	x
teckcoal@equisonline.com			x
carla.fraser@teck.com	x	x	x
andrew.wight@teck.com	x	x	x

SAMPLE DETAILS — **ANALYSIS REQUESTED** — Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
PRESERV.										x			x	
RG_LCDRY-CA02_WS_0_20170831_922	RG_LCDRY-CA02	WS	NO	8/31/2017	9:22	G	7	x	x	x	x	x	x	x
RG_LCDRY-CA02_WS_30_20170831_944	RG_LCDRY-CA02	WS	NO	8/31/2017	9:44	G	7	x	x	x	x	x	x	x
RG_LCDRY-CA02_WS_50_20170831_1054	RG_LCDRY-CA02	WS	NO	8/31/2017	10:54	G	7	x	x	x	x	x	x	x
RG_LCDRY-CA02_WS_0_20170831_922_FB	RG_LCDRY-CA02	WQ	NO	8/31/2017	9:22	G	1				x			
RG_LCDRY-CA02_WS_30_20170831_944_FB	RG_LCDRY-CA02	WQ	NO	8/31/2017	9:44	G	1				x			
RG_LCDRY-CA02_WS_50_20170831_1054_FB	RG_LCDRY-CA02	WQ	NO	8/31/2017	10:54	G	1				x			

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS

All metals samples must be shipped to ALS Burnaby for analysis

RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	
		brian	9/1 2017 9:30am

NB OF BOTTLES RETURNED/DESCRIPTION

Regular (default)	x
Priority (2-3 business days) - 50% surcharge	
Emergency (1 Business Day) - 100% surcharge	
For Emergency <1 Day, ASAP or Weekend - Contact ALS	

Sampler's Name	Andy Wight	Mobile #	250-433-1159
Sampler's Signature		Date/Time	August 1, 2017

9°C

Teck Coal Ltd.
ATTN: Lee Wilm
124-B Aspen Dr
Sparwood BC V0B 2G0

Date Received: 02-SEP-17
Report Date: 13-SEP-17 15:02 (MT)
Version: FINAL

Client Phone: 250-425-8209

Certificate of Analysis

Lab Work Order #: L1985456

Project P.O. #: VPO00517564
Job Reference: REGIONAL EFFECTS PROGRAM
C of C Numbers: REP-2017-09-01
Legal Site Desc:

Lyudmyla Shvets, B.Sc.
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985456-1	L1985456-2			
	Description	WQ	WQ			
	Sampled Date	01-SEP-17	01-SEP-17			
	Sampled Time	11:00	11:15			
	Client ID	RG__TRIP_WQ_20170901_1100	RG__FBLANK_WQ_20170901_1115			
Grouping	**Analyte**					
WATER						
Physical Tests	Conductivity (@ 25C) (uS/cm)	<2.0	<2.0			
	Hardness (as CaCO3) (mg/L)	<0.50	<0.50			
	pH (pH)	5.76	5.46			
	ORP (mV)	401	394			
	Total Suspended Solids (mg/L)	<1.0	<1.0			
	Total Dissolved Solids (mg/L)	<10	<10			
	Turbidity (NTU)	<0.10	<0.10			
Anions and Nutrients	Acidity (as CaCO3) (mg/L)	<1.0	1.3			
	Alkalinity, Bicarbonate (as CaCO3) (mg/L)	<1.0	<1.0			
	Alkalinity, Carbonate (as CaCO3) (mg/L)	<1.0	<1.0			
	Alkalinity, Hydroxide (as CaCO3) (mg/L)	<1.0	<1.0			
	Alkalinity, Total (as CaCO3) (mg/L)	<1.0	<1.0			
	Ammonia as N (mg/L)	<0.0050	<0.0050			
	Bromide (Br) (mg/L)	<0.050	<0.050			
	Chloride (Cl) (mg/L)	<0.50	<0.50			
	Fluoride (F) (mg/L)	<0.020	<0.020			
	Nitrate (as N) (mg/L)	<0.0050	<0.0050			
	Nitrite (as N) (mg/L)	<0.0010	<0.0010			
	Total Kjeldahl Nitrogen (mg/L)	DLA 2.59	<0.050			
	Orthophosphate-Dissolved (as P) (mg/L)	PEHT <0.0010	PEHT <0.0010			
	Phosphorus (P)-Total (mg/L)	<0.0020	<0.0020			
	Sulfate (SO4) (mg/L)	<0.30	<0.30			
	Anion Sum (meq/L)	<0.10	<0.10			
	Cation Sum (meq/L)	<0.10	<0.10			
	Cation - Anion Balance (%)	0.0	0.0			
Organic / Inorganic Carbon	Dissolved Organic Carbon (mg/L)	<0.50	<0.50			
	Total Organic Carbon (mg/L)	<0.50	<0.50			
Total Metals	Aluminum (Al)-Total (mg/L)	<0.0030	<0.0030			
	Antimony (Sb)-Total (mg/L)	<0.00010	<0.00010			
	Arsenic (As)-Total (mg/L)	<0.00010	<0.00010			
	Barium (Ba)-Total (mg/L)	<0.000050	<0.000050			
	Beryllium (Be)-Total (ug/L)	<0.020	<0.020			
	Bismuth (Bi)-Total (mg/L)	<0.000050	<0.000050			
	Boron (B)-Total (mg/L)	<0.010	<0.010			
	Cadmium (Cd)-Total (ug/L)	<0.0050	<0.0050			
	Calcium (Ca)-Total (mg/L)	<0.050	<0.050			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985456-1	L1985456-2			
	Description	WQ	WQ			
	Sampled Date	01-SEP-17	01-SEP-17			
	Sampled Time	11:00	11:15			
	Client ID	RG__TRIP_WQ_20170901_1100	RG__FBLANK_WQ_20170901_1115			
Grouping	**Analyte**					
WATER						
Total Metals	Chromium (Cr)-Total (mg/L)	<0.00010	<0.00010			
	Cobalt (Co)-Total (ug/L)	<0.10	<0.10			
	Copper (Cu)-Total (mg/L)	<0.00050	<0.00050			
	Iron (Fe)-Total (mg/L)	<0.010	<0.010			
	Lead (Pb)-Total (mg/L)	<0.000050	<0.000050			
	Lithium (Li)-Total (mg/L)	<0.0010	<0.0010			
	Magnesium (Mg)-Total (mg/L)	<0.10	<0.10			
	Manganese (Mn)-Total (mg/L)	<0.00010	<0.00010			
	Mercury (Hg)-Total (ug/L)	<0.00050	<0.00050			
	Molybdenum (Mo)-Total (mg/L)	<0.000050	<0.000050			
	Nickel (Ni)-Total (mg/L)	<0.00050	<0.00050			
	Potassium (K)-Total (mg/L)	<0.050	<0.050			
	Selenium (Se)-Total (ug/L)	<0.050	<0.050			
	Silicon (Si)-Total (mg/L)	<0.10	<0.10			
	Silver (Ag)-Total (mg/L)	<0.000010	<0.000010			
	Sodium (Na)-Total (mg/L)	<0.050	<0.050			
	Strontium (Sr)-Total (mg/L)	<0.00020	<0.00020			
	Thallium (Tl)-Total (mg/L)	<0.000010	<0.000010			
	Tin (Sn)-Total (mg/L)	<0.00010	<0.00010			
	Titanium (Ti)-Total (mg/L)	<0.010	<0.010			
	Uranium (U)-Total (mg/L)	<0.000010	<0.000010			
	Vanadium (V)-Total (mg/L)	<0.00050	<0.00050			
	Zinc (Zn)-Total (mg/L)	<0.0030	<0.0030			
Dissolved Metals	Dissolved Mercury Filtration Location	FIELD	FIELD			
	Dissolved Metals Filtration Location	LAB	LAB			
	Aluminum (Al)-Dissolved (mg/L)	<0.0030	<0.0030			
	Antimony (Sb)-Dissolved (mg/L)	<0.00010	<0.00010			
	Arsenic (As)-Dissolved (mg/L)	<0.00010	<0.00010			
	Barium (Ba)-Dissolved (mg/L)	<0.000050	<0.000050			
	Beryllium (Be)-Dissolved (ug/L)	<0.020	<0.020			
	Bismuth (Bi)-Dissolved (mg/L)	<0.000050	<0.000050			
	Boron (B)-Dissolved (mg/L)	<0.010	<0.010			
	Cadmium (Cd)-Dissolved (ug/L)	<0.0050	<0.0050			
	Calcium (Ca)-Dissolved (mg/L)	<0.050	<0.050			
	Chromium (Cr)-Dissolved (mg/L)	<0.00010	<0.00010			
	Cobalt (Co)-Dissolved (ug/L)	<0.10	<0.10			
	Copper (Cu)-Dissolved (mg/L)	<0.00050	<0.00050			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1985456-1	L1985456-2			
	Description	WQ	WQ			
	Sampled Date	01-SEP-17	01-SEP-17			
	Sampled Time	11:00	11:15			
	Client ID	RG__TRIP_WQ_20170901_1100	RG__FBLANK_WQ_20170901_1115			
Grouping	**Analyte**					
WATER						
Dissolved Metals	Iron (Fe)-Dissolved (mg/L)	<0.010	<0.010			
	Lead (Pb)-Dissolved (mg/L)	<0.000050	<0.000050			
	Lithium (Li)-Dissolved (mg/L)	<0.0010	<0.0010			
	Magnesium (Mg)-Dissolved (mg/L)	<0.10	<0.10			
	Manganese (Mn)-Dissolved (mg/L)	<0.00010	<0.00010			
	Mercury (Hg)-Dissolved (mg/L)	<0.0000050	<0.0000050			
	Molybdenum (Mo)-Dissolved (mg/L)	<0.000050	<0.000050			
	Nickel (Ni)-Dissolved (mg/L)	<0.00050	<0.00050			
	Potassium (K)-Dissolved (mg/L)	<0.050	<0.050			
	Selenium (Se)-Dissolved (ug/L)	<0.050	<0.050			
	Silicon (Si)-Dissolved (mg/L)	<0.050	<0.050			
	Silver (Ag)-Dissolved (mg/L)	<0.000010	<0.000010			
	Sodium (Na)-Dissolved (mg/L)	<0.050	<0.050			
	Strontium (Sr)-Dissolved (mg/L)	<0.00020	<0.00020			
	Thallium (Tl)-Dissolved (mg/L)	<0.000010	<0.000010			
	Tin (Sn)-Dissolved (mg/L)	<0.00010	<0.00010			
	Titanium (Ti)-Dissolved (mg/L)	<0.010	<0.010			
	Uranium (U)-Dissolved (mg/L)	<0.000010	<0.000010			
	Vanadium (V)-Dissolved (mg/L)	<0.00050	<0.00050			
	Zinc (Zn)-Dissolved (mg/L)	<0.0030	<0.0030			

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

Qualifiers for Sample Submission Listed:

Qualifier	Description
SFPL	Sample was Filtered and Preserved at the laboratory - DOC, DISSOLVED METALS

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Mercury (Hg)-Dissolved	MS-B	L1985456-1, -2

Qualifiers for Individual Parameters Listed:

Qualifier	Description
DLA	Detection Limit adjusted for required dilution
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.
PEHT	Parameter Exceeded Recommended Holding Time Prior to Analysis

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
ACIDITY-PCT-CL	Water	Acidity by Automatic Titration	APHA 2310 Acidity

This analysis is carried out using procedures adapted from APHA Method 2310 "Acidity". Acidity is determined by potentiometric titration to a specified endpoint.

ALK-MAN-CL	Water	Alkalinity (Species) by Manual Titration	APHA 2320 ALKALINITY

This analysis is carried out using procedures adapted from APHA Method 2320 "Alkalinity". Total alkalinity is determined by potentiometric titration to a pH 4.5 endpoint. Bicarbonate, carbonate and hydroxide alkalinity are calculated from phenolphthalein alkalinity and total alkalinity values.

BE-D-L-CCMS-VA	Water	Diss. Be (low) in Water by CRC ICPMS	APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

BE-T-L-CCMS-VA	Water	Total Be (Low) in Water by CRC ICPMS	EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

BR-L-IC-N-CL	Water	Bromide in Water by IC (Low Level)	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

C-DIS-ORG-LOW-CL	Water	Dissolved Organic Carbon	APHA 5310 B-Instrumental

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

C-TOT-ORG-LOW-CL	Water	Total Organic Carbon	APHA 5310 TOTAL ORGANIC CARBON (TOC)

This method is applicable to the analysis of ground water, wastewater, and surface water samples. The form detected depends upon sample pretreatment: Unfiltered sample = TC, 0.45um filtered = TDC. Samples are injected into a combustion tube containing an oxidation catalyst. The carrier gas containing the combustion product from the combustion tube flows through an inorganic carbon reactor vessel and is then sent through a halogen scrubber into a sample cell set in a non-dispersive infrared gas analyzer (NDIR) where carbon dioxide is detected. For total inorganic carbon and dissolved inorganic carbon, the sample is injected into an IC reactor vessel where only the IC component is decomposed to become carbon dioxide.

The peak area generated by the NDIR indicates the TC/TDC or TIC/DIC as applicable. The total organic carbon content of the sample is calculated by subtracting the TIC from the TC.
TOC = TC-TIC, DOC = TDC-DIC, Particulate = Total - Dissolved.

CL-IC-N-CL	Water	Chloride in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

EC-L-PCT-CL	Water	Electrical Conductivity (EC)	APHA 2510B

Conductivity, also known as Electrical Conductivity (EC) or Specific Conductance, is measured by immersion of a conductivity cell with platinum electrodes into a water sample. Conductivity measurements are temperature-compensated to 25C.

Reference Information

EC-SCREEN-VA Water Conductivity Screen (Internal Use Only) APHA 2510

Qualitative analysis of conductivity where required during preparation of other tests - e.g. TDS, metals, etc.

F-IC-N-CL Water Fluoride in Water by IC EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

HARDNESS-CALC-VA Water Hardness APHA 2340B

Hardness (also known as Total Hardness) is calculated from the sum of Calcium and Magnesium concentrations, expressed in CaCO3 equivalents. Dissolved Calcium and Magnesium concentrations are preferentially used for the hardness calculation.

HG-D-CVAA-VA Water Diss. Mercury in Water by CVAAS or CVAFS APHA 3030B/EPA 1631E (mod)

Water samples are filtered (0.45 um), preserved with hydrochloric acid, then undergo a cold-oxidation using bromine monochloride prior to reduction with stannous chloride, and analyzed by CVAAS or CVAFS.

HG-T-U-CVAF-VA Water Total Mercury in Water by CVAFS (Ultra) EPA 1631 REV. E

This analysis is carried out using procedures adapted from Method 1631 Rev. E. by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to a purge and trap concentration step and final reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry.

IONBALANCE-BC-CL Water Ion Balance Calculation APHA 1030E

Cation Sum, Anion Sum, and Ion Balance (as % difference) are calculated based on guidance from APHA Standard Methods (1030E Checking Correctness of Analysis). Because all aqueous solutions are electrically neutral, the calculated ion balance (% difference of cations minus anions) should be near-zero.

Cation and Anion Sums are the total meq/L concentration of major cations and anions. Dissolved species are used where available. Minor ions are included where data is present. Ion Balance is calculated as:

Ion Balance (%) = [Cation Sum-Anion Sum] / [Cation Sum+Anion Sum]

MET-D-CCMS-VA Water Dissolved Metals in Water by CRC ICPMS APHA 3030B/6020A (mod)

Water samples are filtered (0.45 um), preserved with nitric acid, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

MET-T-CCMS-VA Water Total Metals in Water by CRC ICPMS EPA 200.2/6020A (mod)

Water samples are digested with nitric and hydrochloric acids, and analyzed by CRC ICPMS.

Method Limitation (re: Sulfur): Sulfide and volatile sulfur species may not be recovered by this method.

NH3-L-F-CL Water Ammonia, Total (as N) J. ENVIRON. MONIT., 2005, 7, 37-42, RSC

This analysis is carried out, on sulfuric acid preserved samples, using procedures modified from J. Environ. Monit., 2005, 7, 37 - 42, The Royal Society of Chemistry, "Flow-injection analysis with fluorescence detection for the determination of trace levels of ammonium in seawater", Roslyn J. Waston et al.

NO2-BC-L-IC-CL Water Nitrite-N EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrite is detected by UV absorbance.

NO3-BC-L-IC-CL Water Nitrate (as N) EPA 300.0

This analysis is carried out using procedures adapted from EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Nitrate is detected by UV absorbance.

ORP-CL Water Oxidation redution potential by elect. ASTM D1498

This analysis is carried out in accordance with the procedure described in the "ASTM" method D1498 "Oxidation-Reduction Potential of Water" published by the American Society for Testing and Materials (ASTM). Results are reported as observed oxidation-reduction potential of the platinum metal-reference electrode employed, in mV.

It is recommended that this analysis be conducted in the field.

P-T-PRES-COL-VA Water Total P in Water by Colour APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Total Phosphorus is determined colourimetrically after persulphate digestion of the sample.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

PH-CL Water pH APHA 4500 H-Electrode

Reference Information

pH is determined in the laboratory using a pH electrode. All samples analyzed by this method for pH will have exceeded the 15 minute recommended hold time from time of sampling (field analysis is recommended for pH where highly accurate results are needed)

PO4-DO-COL-VA	Water	Diss. Orthophosphate in Water by Colour	APHA 4500-P Phosphorus

This analysis is carried out using procedures adapted from APHA Method 4500-P "Phosphorus". Dissolved Orthophosphate is determined colourimetrically on a sample that has been lab or field filtered through a 0.45 micron membrane filter.
Samples with very high dissolved solids (i.e. seawaters, brackish waters) may produce a negative bias by this method. Alternate methods are available for these types of samples.

Arsenic (5+), at elevated levels, is a positive interference on colourimetric phosphate analysis.

SO4-IC-N-CL	Water	Sulfate in Water by IC	EPA 300.1 (mod)

Inorganic anions are analyzed by Ion Chromatography with conductivity and/or UV detection.

SOLIDS-TDS-CL	Water	Total Dissolved Solids	APHA 2540 C

A well-mixed sample is filtered through a glass fibre filter paper. The filtrate is then evaporated to dryness in a pre-weighed vial and dried at 180 – 2 °C. The increase in vial weight represents the total dissolved solids (TDS).

TKN-L-F-CL	Water	Total Kjeldahl Nitrogen	APHA 4500-NORG (TKN)

This analysis is carried out using procedures adapted from APHA Method 4500-Norg D. "Block Digestion and Flow Injection Analysis". Total Kjeldahl Nitrogen is determined using block digestion followed by Flow-injection analysis with fluorescence detection.

TSS-L-CL	Water	Total Suspended Solids	APHA 2540 D-Gravimetric

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, and by drying the filter at 104 deg. C.

TURBIDITY-BC-CL	Water	Turbidity	APHA 2130 B-Nephelometer

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
CL	ALS ENVIRONMENTAL - CALGARY, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

REP-2017-09-01

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Teck Coal Ltd.
124-B Aspen Dr
Sparwood BC V0B 2G0

Contact: Lee Wilm

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
ACIDITY-PCT-CL	**Water**							
Batch R3819603								
WG2608865-2 LCS								
Acidity (as CaCO3)			99.4		%		85-115	02-SEP-17
WG2608865-1 MB								
Acidity (as CaCO3)			<1.0		mg/L		2	02-SEP-17
ALK-MAN-CL	**Water**							
Batch R3821754								
WG2610900-2 LCS								
Alkalinity, Total (as CaCO3)			103.8		%		85-115	06-SEP-17
WG2610900-1 MB								
Alkalinity, Total (as CaCO3)			<1.0		mg/L		1	06-SEP-17
BE-D-L-CCMS-VA	**Water**							
Batch R3821803								
WG2609725-3 DUP		**L1985456-2**						
Beryllium (Be)-Dissolved		<0.000020	<0.000020	RPD-NA	mg/L	N/A	20	06-SEP-17
WG2609725-4 MS		**L1985456-1**						
Beryllium (Be)-Dissolved			96.8		%		70-130	06-SEP-17
Batch R3821842								
WG2609725-2 LCS								
Beryllium (Be)-Dissolved			101.6		%		80-120	06-SEP-17
WG2609725-1 MB		**LF**						
Beryllium (Be)-Dissolved			<0.000020		mg/L		0.00002	06-SEP-17
BE-T-L-CCMS-VA	**Water**							
Batch R3822417								
WG2610497-2 LCS								
Beryllium (Be)-Total			100.9		%		80-120	07-SEP-17
WG2610497-1 MB								
Beryllium (Be)-Total			<0.000020		mg/L		0.00002	07-SEP-17
Batch R3823907								
WG2610497-3 DUP		**L1985456-2**						
Beryllium (Be)-Total		<0.000020	<0.000020	RPD-NA	mg/L	N/A	20	08-SEP-17
WG2610497-4 MS		**L1985456-1**						
Beryllium (Be)-Total			98.8		%		70-130	08-SEP-17
BR-L-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Bromide (Br)			98.0		%		85-115	02-SEP-17
WG2610641-9 MB								

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
BR-L-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-9 MB								
Bromide (Br)			<0.050		mg/L		0.05	02-SEP-17
C-DIS-ORG-LOW-CL	**Water**							
Batch R3824428								
WG2613817-2 LCS								
Dissolved Organic Carbon			109.6		%		80-120	11-SEP-17
WG2613817-1 MB								
Dissolved Organic Carbon			<0.50		mg/L		0.5	11-SEP-17
C-TOT-ORG-LOW-CL	**Water**							
Batch R3824428								
WG2613817-2 LCS								
Total Organic Carbon			103.9		%		80-120	11-SEP-17
WG2613817-1 MB								
Total Organic Carbon			<0.50		mg/L		0.5	11-SEP-17
CL-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Chloride (Cl)			102.3		%		90-110	02-SEP-17
WG2610641-9 MB								
Chloride (Cl)			<0.50		mg/L		0.5	02-SEP-17
EC-L-PCT-CL	**Water**							
Batch R3821754								
WG2610900-2 LCS								
Conductivity (@ 25C)			100.3		%		90-110	06-SEP-17
WG2610900-1 MB								
Conductivity (@ 25C)			<2.0		uS/cm		2	06-SEP-17
F-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Fluoride (F)			98.1		%		90-110	02-SEP-17
WG2610641-9 MB								
Fluoride (F)			<0.020		mg/L		0.02	02-SEP-17
HG-D-CVAA-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
HG-D-CVAA-VA	**Water**							
Batch R3820540								
WG2609337-6 LCS								
Mercury (Hg)-Dissolved			105.5		%		80-120	06-SEP-17
WG2609337-5 MB		**NP**						
Mercury (Hg)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
HG-T-U-CVAF-VA	**Water**							
Batch R3821908								
WG2611091-2 LCS								
Mercury (Hg)-Total			109.0		%		80-120	07-SEP-17
WG2611091-1 MB								
Mercury (Hg)-Total			<0.00050		ug/L		0.0005	07-SEP-17
MET-D-CCMS-VA	**Water**							
Batch R3821803								
WG2609725-3 DUP		**L1985456-2**						
Aluminum (Al)-Dissolved		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	06-SEP-17
Antimony (Sb)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Arsenic (As)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Barium (Ba)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Bismuth (Bi)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Boron (B)-Dissolved		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Cadmium (Cd)-Dissolved		<0.0000050	<0.0000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Calcium (Ca)-Dissolved		<0.050	<0.050	RPD-NA	mg/L	N/A	20	06-SEP-17
Chromium (Cr)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Cobalt (Co)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Copper (Cu)-Dissolved		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	06-SEP-17
Iron (Fe)-Dissolved		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Lead (Pb)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Lithium (Li)-Dissolved		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	06-SEP-17
Magnesium (Mg)-Dissolved		<0.10	<0.10	RPD-NA	mg/L	N/A	20	06-SEP-17
Manganese (Mn)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Molybdenum (Mo)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Nickel (Ni)-Dissolved		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	06-SEP-17
Potassium (K)-Dissolved		<0.050	<0.050	RPD-NA	mg/L	N/A	20	06-SEP-17
Selenium (Se)-Dissolved		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	06-SEP-17
Silicon (Si)-Dissolved		<0.050	<0.050	RPD-NA	mg/L	N/A	20	06-SEP-17
Silver (Ag)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Sodium (Na)-Dissolved		<0.050	<0.050	RPD-NA	mg/L	N/A	20	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821803								
WG2609725-3 DUP		**L1985456-2**						
Strontium (Sr)-Dissolved		<0.00020	<0.00020	RPD-NA	mg/L	N/A	20	06-SEP-17
Thallium (Tl)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Tin (Sn)-Dissolved		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	06-SEP-17
Titanium (Ti)-Dissolved		<0.010	<0.010	RPD-NA	mg/L	N/A	20	06-SEP-17
Uranium (U)-Dissolved		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	06-SEP-17
Vanadium (V)-Dissolved		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	06-SEP-17
Zinc (Zn)-Dissolved		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	06-SEP-17
WG2609725-4 MS		**L1985456-1**						
Aluminum (Al)-Dissolved			95.0		%		70-130	06-SEP-17
Antimony (Sb)-Dissolved			101.4		%		70-130	06-SEP-17
Arsenic (As)-Dissolved			95.0		%		70-130	06-SEP-17
Barium (Ba)-Dissolved			95.8		%		70-130	06-SEP-17
Bismuth (Bi)-Dissolved			98.1		%		70-130	06-SEP-17
Boron (B)-Dissolved			94.3		%		70-130	06-SEP-17
Cadmium (Cd)-Dissolved			97.8		%		70-130	06-SEP-17
Calcium (Ca)-Dissolved			92.9		%		70-130	06-SEP-17
Chromium (Cr)-Dissolved			94.7		%		70-130	06-SEP-17
Cobalt (Co)-Dissolved			96.0		%		70-130	06-SEP-17
Copper (Cu)-Dissolved			97.8		%		70-130	06-SEP-17
Iron (Fe)-Dissolved			94.7		%		70-130	06-SEP-17
Lead (Pb)-Dissolved			98.2		%		70-130	06-SEP-17
Lithium (Li)-Dissolved			92.6		%		70-130	06-SEP-17
Magnesium (Mg)-Dissolved			94.2		%		70-130	06-SEP-17
Manganese (Mn)-Dissolved			95.5		%		70-130	06-SEP-17
Molybdenum (Mo)-Dissolved			92.0		%		70-130	06-SEP-17
Nickel (Ni)-Dissolved			99.9		%		70-130	06-SEP-17
Potassium (K)-Dissolved			94.5		%		70-130	06-SEP-17
Selenium (Se)-Dissolved			95.7		%		70-130	06-SEP-17
Silicon (Si)-Dissolved			94.7		%		70-130	06-SEP-17
Silver (Ag)-Dissolved			102.1		%		70-130	06-SEP-17
Sodium (Na)-Dissolved			100.6		%		70-130	06-SEP-17
Strontium (Sr)-Dissolved			98.9		%		70-130	06-SEP-17
Thallium (Tl)-Dissolved			99.8		%		70-130	06-SEP-17
Tin (Sn)-Dissolved			96.1		%		70-130	06-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821803								
WG2609725-4 MS		**L1985456-1**						
Titanium (Ti)-Dissolved			86.9		%		70-130	06-SEP-17
Uranium (U)-Dissolved			99.3		%		70-130	06-SEP-17
Vanadium (V)-Dissolved			93.8		%		70-130	06-SEP-17
Zinc (Zn)-Dissolved			92.7		%		70-130	06-SEP-17
Batch R3821842								
WG2609725-2 LCS								
Aluminum (Al)-Dissolved			99.3		%		80-120	06-SEP-17
Antimony (Sb)-Dissolved			95.2		%		80-120	06-SEP-17
Arsenic (As)-Dissolved			98.2		%		80-120	06-SEP-17
Barium (Ba)-Dissolved			98.5		%		80-120	06-SEP-17
Bismuth (Bi)-Dissolved			97.4		%		80-120	06-SEP-17
Boron (B)-Dissolved			91.4		%		80-120	06-SEP-17
Cadmium (Cd)-Dissolved			96.8		%		80-120	06-SEP-17
Calcium (Ca)-Dissolved			100.3		%		80-120	06-SEP-17
Chromium (Cr)-Dissolved			95.1		%		80-120	06-SEP-17
Cobalt (Co)-Dissolved			98.1		%		80-120	06-SEP-17
Copper (Cu)-Dissolved			95.5		%		80-120	06-SEP-17
Iron (Fe)-Dissolved			98.3		%		80-120	06-SEP-17
Lead (Pb)-Dissolved			99.3		%		80-120	06-SEP-17
Lithium (Li)-Dissolved			103.6		%		80-120	06-SEP-17
Magnesium (Mg)-Dissolved			100.6		%		80-120	06-SEP-17
Manganese (Mn)-Dissolved			100.4		%		80-120	06-SEP-17
Molybdenum (Mo)-Dissolved			97.9		%		80-120	06-SEP-17
Nickel (Ni)-Dissolved			98.4		%		80-120	06-SEP-17
Potassium (K)-Dissolved			100.7		%		80-120	06-SEP-17
Selenium (Se)-Dissolved			95.7		%		80-120	06-SEP-17
Silicon (Si)-Dissolved			97.7		%		80-120	06-SEP-17
Silver (Ag)-Dissolved			96.7		%		80-120	06-SEP-17
Sodium (Na)-Dissolved			98.8		%		80-120	06-SEP-17
Strontium (Sr)-Dissolved			99.97		%		80-120	06-SEP-17
Thallium (Tl)-Dissolved			98.1		%		80-120	06-SEP-17
Tin (Sn)-Dissolved			96.7		%		80-120	06-SEP-17
Titanium (Ti)-Dissolved			91.1		%		80-120	06-SEP-17
Uranium (U)-Dissolved			101.2		%		80-120	06-SEP-17

ALS Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-D-CCMS-VA	**Water**							
Batch R3821842								
WG2609725-2 LCS								
Vanadium (V)-Dissolved			99.98		%		80-120	06-SEP-17
Zinc (Zn)-Dissolved			93.5		%		80-120	06-SEP-17
WG2609725-1 MB		**LF**						
Aluminum (Al)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Antimony (Sb)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Arsenic (As)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Barium (Ba)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Bismuth (Bi)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Boron (B)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Cadmium (Cd)-Dissolved			<0.0000050		mg/L		0.000005	06-SEP-17
Calcium (Ca)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Chromium (Cr)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Cobalt (Co)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Copper (Cu)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Iron (Fe)-Dissolved			<0.010		mg/L		0.01	06-SEP-17
Lead (Pb)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Lithium (Li)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
Magnesium (Mg)-Dissolved			<0.0050		mg/L		0.005	06-SEP-17
Manganese (Mn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Molybdenum (Mo)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Nickel (Ni)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Potassium (K)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Selenium (Se)-Dissolved			<0.000050		mg/L		0.00005	06-SEP-17
Silicon (Si)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Silver (Ag)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Sodium (Na)-Dissolved			<0.050		mg/L		0.05	06-SEP-17
Strontium (Sr)-Dissolved			<0.00020		mg/L		0.0002	06-SEP-17
Thallium (Tl)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Tin (Sn)-Dissolved			<0.00010		mg/L		0.0001	06-SEP-17
Titanium (Ti)-Dissolved			<0.00030		mg/L		0.0003	06-SEP-17
Uranium (U)-Dissolved			<0.000010		mg/L		0.00001	06-SEP-17
Vanadium (V)-Dissolved			<0.00050		mg/L		0.0005	06-SEP-17
Zinc (Zn)-Dissolved			<0.0010		mg/L		0.001	06-SEP-17
MET-T-CCMS-VA	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3822417								
WG2610497-2 LCS								
Aluminum (Al)-Total			108.5		%		80-120	07-SEP-17
Antimony (Sb)-Total			102.7		%		80-120	07-SEP-17
Arsenic (As)-Total			108.1		%		80-120	07-SEP-17
Barium (Ba)-Total			109.3		%		80-120	07-SEP-17
Bismuth (Bi)-Total			104.7		%		80-120	07-SEP-17
Boron (B)-Total			95.8		%		80-120	07-SEP-17
Cadmium (Cd)-Total			103.2		%		80-120	07-SEP-17
Calcium (Ca)-Total			101.3		%		80-120	07-SEP-17
Chromium (Cr)-Total			107.9		%		80-120	07-SEP-17
Cobalt (Co)-Total			105.2		%		80-120	07-SEP-17
Copper (Cu)-Total			104.8		%		80-120	07-SEP-17
Iron (Fe)-Total			98.9		%		80-120	07-SEP-17
Lead (Pb)-Total			101.8		%		80-120	07-SEP-17
Lithium (Li)-Total			103.4		%		80-120	07-SEP-17
Magnesium (Mg)-Total			110.9		%		80-120	07-SEP-17
Manganese (Mn)-Total			110.7		%		80-120	07-SEP-17
Molybdenum (Mo)-Total			94.7		%		80-120	07-SEP-17
Nickel (Ni)-Total			105.5		%		80-120	07-SEP-17
Potassium (K)-Total			110.5		%		80-120	07-SEP-17
Selenium (Se)-Total			103.8		%		80-120	07-SEP-17
Silicon (Si)-Total			111.3		%		80-120	07-SEP-17
Silver (Ag)-Total			96.4		%		80-120	07-SEP-17
Sodium (Na)-Total			107.7		%		80-120	07-SEP-17
Strontium (Sr)-Total			94.2		%		80-120	07-SEP-17
Thallium (Tl)-Total			102.5		%		80-120	07-SEP-17
Tin (Sn)-Total			103.9		%		80-120	07-SEP-17
Titanium (Ti)-Total			100.2		%		80-120	07-SEP-17
Uranium (U)-Total			100.3		%		80-120	07-SEP-17
Vanadium (V)-Total			107.7		%		80-120	07-SEP-17
Zinc (Zn)-Total			104.1		%		80-120	07-SEP-17
WG2610497-1 MB								
Aluminum (Al)-Total			<0.0030		mg/L		0.003	07-SEP-17
Antimony (Sb)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Arsenic (As)-Total			<0.00010		mg/L		0.0001	07-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3822417								
WG2610497-1 MB								
Barium (Ba)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Bismuth (Bi)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Boron (B)-Total			<0.010		mg/L		0.01	07-SEP-17
Cadmium (Cd)-Total			<0.0000050		mg/L		0.000005	07-SEP-17
Calcium (Ca)-Total			<0.050		mg/L		0.05	07-SEP-17
Cobalt (Co)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Copper (Cu)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Iron (Fe)-Total			<0.010		mg/L		0.01	07-SEP-17
Lead (Pb)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Lithium (Li)-Total			<0.0010		mg/L		0.001	07-SEP-17
Magnesium (Mg)-Total			<0.0050		mg/L		0.005	07-SEP-17
Manganese (Mn)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Molybdenum (Mo)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Nickel (Ni)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Potassium (K)-Total			<0.050		mg/L		0.05	07-SEP-17
Selenium (Se)-Total			<0.000050		mg/L		0.00005	07-SEP-17
Silicon (Si)-Total			<0.10		mg/L		0.1	07-SEP-17
Silver (Ag)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Sodium (Na)-Total			<0.050		mg/L		0.05	07-SEP-17
Strontium (Sr)-Total			<0.00020		mg/L		0.0002	07-SEP-17
Thallium (Tl)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Tin (Sn)-Total			<0.00010		mg/L		0.0001	07-SEP-17
Titanium (Ti)-Total			<0.00030		mg/L		0.0003	07-SEP-17
Uranium (U)-Total			<0.000010		mg/L		0.00001	07-SEP-17
Vanadium (V)-Total			<0.00050		mg/L		0.0005	07-SEP-17
Zinc (Zn)-Total			<0.0030		mg/L		0.003	07-SEP-17
Batch R3822734								
WG2610497-1 MB								
Chromium (Cr)-Total			<0.00010		mg/L		0.0001	08-SEP-17
Batch R3823907								
WG2610497-3 DUP		**L1985456-2**						
Aluminum (Al)-Total		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	08-SEP-17
Antimony (Sb)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17
Arsenic (As)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3823907								
WG2610497-3 DUP		**L1985456-2**						
Barium (Ba)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Bismuth (Bi)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Boron (B)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	08-SEP-17
Cadmium (Cd)-Total		<0.0000050	<0.0000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Calcium (Ca)-Total		<0.050	<0.050	RPD-NA	mg/L	N/A	20	08-SEP-17
Chromium (Cr)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17
Cobalt (Co)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17
Copper (Cu)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	08-SEP-17
Iron (Fe)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	08-SEP-17
Lead (Pb)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Lithium (Li)-Total		<0.0010	<0.0010	RPD-NA	mg/L	N/A	20	08-SEP-17
Magnesium (Mg)-Total		<0.10	<0.10	RPD-NA	mg/L	N/A	20	08-SEP-17
Manganese (Mn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17
Molybdenum (Mo)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Nickel (Ni)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	08-SEP-17
Potassium (K)-Total		<0.050	<0.050	RPD-NA	mg/L	N/A	20	08-SEP-17
Selenium (Se)-Total		<0.000050	<0.000050	RPD-NA	mg/L	N/A	20	08-SEP-17
Silicon (Si)-Total		<0.10	<0.10	RPD-NA	mg/L	N/A	20	08-SEP-17
Silver (Ag)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	08-SEP-17
Sodium (Na)-Total		<0.050	<0.050	RPD-NA	mg/L	N/A	20	08-SEP-17
Strontium (Sr)-Total		<0.00020	<0.00020	RPD-NA	mg/L	N/A	20	08-SEP-17
Thallium (Tl)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	08-SEP-17
Tin (Sn)-Total		<0.00010	<0.00010	RPD-NA	mg/L	N/A	20	08-SEP-17
Titanium (Ti)-Total		<0.010	<0.010	RPD-NA	mg/L	N/A	20	08-SEP-17
Uranium (U)-Total		<0.000010	<0.000010	RPD-NA	mg/L	N/A	20	08-SEP-17
Vanadium (V)-Total		<0.00050	<0.00050	RPD-NA	mg/L	N/A	20	08-SEP-17
Zinc (Zn)-Total		<0.0030	<0.0030	RPD-NA	mg/L	N/A	20	08-SEP-17
WG2610497-4 MS		**L1985456-1**						
Aluminum (Al)-Total			97.3		%		70-130	08-SEP-17
Antimony (Sb)-Total			103.1		%		70-130	08-SEP-17
Arsenic (As)-Total			96.6		%		70-130	08-SEP-17
Barium (Ba)-Total			96.2		%		70-130	08-SEP-17
Bismuth (Bi)-Total			105.3		%		70-130	08-SEP-17
Boron (B)-Total			97.5		%		70-130	08-SEP-17

Environmental

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-T-CCMS-VA	**Water**							
Batch R3823907								
WG2610497-4 MS		**L1985456-1**						
Cadmium (Cd)-Total			97.9		%		70-130	08-SEP-17
Calcium (Ca)-Total			97.8		%		70-130	08-SEP-17
Chromium (Cr)-Total			94.1		%		70-130	08-SEP-17
Cobalt (Co)-Total			96.1		%		70-130	08-SEP-17
Copper (Cu)-Total			98.7		%		70-130	08-SEP-17
Iron (Fe)-Total			97.3		%		70-130	08-SEP-17
Lead (Pb)-Total			101.4		%		70-130	08-SEP-17
Lithium (Li)-Total			100.1		%		70-130	08-SEP-17
Magnesium (Mg)-Total			100.6		%		70-130	08-SEP-17
Manganese (Mn)-Total			97.6		%		70-130	08-SEP-17
Molybdenum (Mo)-Total			94.5		%		70-130	08-SEP-17
Nickel (Ni)-Total			100.2		%		70-130	08-SEP-17
Potassium (K)-Total			98.4		%		70-130	08-SEP-17
Selenium (Se)-Total			94.0		%		70-130	08-SEP-17
Silicon (Si)-Total			93.7		%		70-130	08-SEP-17
Silver (Ag)-Total			101.9		%		70-130	08-SEP-17
Sodium (Na)-Total			99.3		%		70-130	08-SEP-17
Strontium (Sr)-Total			98.4		%		70-130	08-SEP-17
Thallium (Tl)-Total			101.7		%		70-130	08-SEP-17
Tin (Sn)-Total			97.4		%		70-130	08-SEP-17
Titanium (Ti)-Total			105.4		%		70-130	08-SEP-17
Uranium (U)-Total			101.4		%		70-130	08-SEP-17
Vanadium (V)-Total			98.0		%		70-130	08-SEP-17
Zinc (Zn)-Total			96.7		%		70-130	08-SEP-17
NH3-L-F-CL	**Water**							
Batch R3824038								
WG2613337-4 LCS								
Ammonia as N			96.3		%		85-115	11-SEP-17
WG2613337-3 MB								
Ammonia as N			<0.0050		mg/L		0.005	11-SEP-17
NO2-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Nitrite (as N)			104.7		%		90-110	02-SEP-17
WG2610641-9 MB								

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
NO2-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-9 MB								
Nitrite (as N)			<0.0010		mg/L		0.001	02-SEP-17
NO3-BC-L-IC-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Nitrate (as N)			104.2		%		90-110	02-SEP-17
WG2610641-9 MB								
Nitrate (as N)			<0.0050		mg/L		0.005	02-SEP-17
ORP-CL	**Water**							
Batch R3824011								
WG2613305-2 CRM		**CL-ORP**						
ORP			219		mV		210-230	06-SEP-17
P-T-PRES-COL-VA	**Water**							
Batch R3821242								
WG2609616-6 CRM		**VA-ERA-PO4**						
Phosphorus (P)-Total			96.4		%		80-120	07-SEP-17
WG2609616-5 MB								
Phosphorus (P)-Total			<0.0020		mg/L		0.002	07-SEP-17
PH-CL	**Water**							
Batch R3821754								
WG2610900-2 LCS								
pH			6.96		pH		6.9-7.1	06-SEP-17
PO4-DO-COL-VA	**Water**							
Batch R3820320								
WG2609176-2 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			91.8		%		80-120	06-SEP-17
WG2609176-6 CRM		**VA-OPO4-CONTROL**						
Orthophosphate-Dissolved (as P)			87.5		%		80-120	06-SEP-17
WG2609176-1 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
WG2609176-5 MB								
Orthophosphate-Dissolved (as P)			<0.0010		mg/L		0.001	06-SEP-17
SO4-IC-N-CL	**Water**							

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
SO4-IC-N-CL	**Water**							
Batch R3821493								
WG2610641-10 LCS								
Sulfate (SO4)			103.3		%		90-110	02-SEP-17
WG2610641-9 MB								
Sulfate (SO4)			<0.30		mg/L		0.3	02-SEP-17
SOLIDS-TDS-CL	**Water**							
Batch R3822908								
WG2611763-2 LCS								
Total Dissolved Solids			96.1		%		85-115	08-SEP-17
WG2611763-1 MB								
Total Dissolved Solids			<10		mg/L		10	08-SEP-17
TKN-L-F-CL	**Water**							
Batch R3826706								
WG2614809-2 LCS								
Total Kjeldahl Nitrogen			98.6		%		75-125	12-SEP-17
WG2614809-4 LCS								
Total Kjeldahl Nitrogen			106.5		%		75-125	12-SEP-17
WG2614809-1 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	12-SEP-17
WG2614809-3 MB								
Total Kjeldahl Nitrogen			<0.050		mg/L		0.05	12-SEP-17
TSS-L-CL	**Water**							
Batch R3823055								
WG2612334-2 LCS								
Total Suspended Solids			89.0		%		85-115	08-SEP-17
WG2612334-1 MB								
Total Suspended Solids			<1.0		mg/L		1	08-SEP-17
TURBIDITY-BC-CL	**Water**							
Batch R3820338								
WG2608041-2 LCS								
Turbidity			99.5		%		85-115	03-SEP-17
WG2608041-1 MB								
Turbidity			<0.10		NTU		0.1	03-SEP-17

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Quality Control Report

Hold Time Exceedances:

ALS Product Description	Sample ID	Sampling Date	Date Processed	Rec. HT	Actual HT	Units	Qualifier
Physical Tests							
pH							
	1	01-SEP-17 11:00	06-SEP-17 14:00	0.25	123	hours	EHTR-FM
	2	01-SEP-17 11:15	06-SEP-17 14:00	0.25	123	hours	EHTR-FM
Anions and Nutrients							
Diss. Orthophosphate in Water by Colour							
	1	01-SEP-17 11:00	06-SEP-17 03:38	3	5	days	EHT
	2	01-SEP-17 11:15	06-SEP-17 03:42	3	5	days	EHT

Legend & Qualifier Definitions:

EHTR-FM:	Exceeded ALS recommended hold time prior to sample receipt. Field Measurement recommended.
EHTR:	Exceeded ALS recommended hold time prior to sample receipt.
EHTL:	Exceeded ALS recommended hold time prior to analysis. Sample was received less than 24 hours prior to expiry.
EHT:	Exceeded ALS recommended hold time prior to analysis.
Rec. HT:	ALS recommended hold time (see units).

Notes*:
Where actual sampling date is not provided to ALS, the date (& time) of receipt is used for calculation purposes.
Where actual sampling time is not provided to ALS, the earlier of 12 noon on the sampling date or the time (& date) of receipt is used for calculation purposes. Samples for L1985456 were received on 02-SEP-17 08:30.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

Teck

L1985456-COFC

COC ID:	REP-2017-09-01	TURNAROUND T.

PROJECT/CLIENT INFO

Facility Name / Job#	Calcite Biological Effects VPO00517564			Lab Name	ALS		
Project Manager	Lee Wilm			Lab Contact	Can Dang		
Email	lee.wilm@teck.com			Email	can.dang@alsglobal.com		
Address	PO Box 1777, 124B Aspen Drive			Address	8081 Lougheed Hwy		
City	Sparwood	Province	BC	City	Burnaby	Province	BC
Postal Code	V0B 2G0	Country	Canada	Postal Code	V5A 1W9	Country	Canada
Phone Number	250-865-5289			Phone Number	604-253-4188		

	Excel	PDF	EDD
lee.wilm@teck.com	x	x	x
teckcoal@equisonline.com			x
carla.fraser@teck.com	x	x	x
andrew.wight@teck.com	x	x	x

SAMPLE DETAILS

Sample ID	Sample Location	Field Matrix	Hazardous Material (Yes/No)	Date	Time (24hr)	G=Grab C=Comp	# Of Cont.
RG_TRIP_WQ_20170901_1100	RG_TRIP	WQ	NO	9/1/2017	11:00	G	7
RG_FBLANK_WQ_20170901_1115	RG_FBLANK	WQ	NO	9/1/2017	11:15	G	7

ANALYSIS REQUESTED — Filtered - F: Field, L: Lab, FL: Field & Lab, N: None

ANALYSIS	TECKCOAL-ROUTINE-VA	ALS_Package-DOC	ALS_Package-TKN/TOC	HG-T-U-CVAF-VA	HG-D-CVAF-VA	TECKCOAL-MET-T-VA	TECKCOAL-MET-D-VA
			x			x	
RG_TRIP_WQ_20170901_1100	x	x	x	x	x	x	x
RG_FBLANK_WQ_20170901_1115	x	x	x	x	x	x	x

ADDITIONAL COMMENTS/SPECIAL INSTRUCTIONS

All metals samples must be shipped to ALS Burnaby for analysis

RELINQUISHED BY/AFFILIATION	DATE/TIME	ACCEPTED BY/AFFILIATION	DATE/TIME
		brian	9/2 8:30am

NB OF BOTTLES RETURNED/DESCRIPTION

Regular (default)	x
Priority (2-3 business days) - 50% surcharge	
Emergency (1 Business Day) - 100% surcharge	
For Emergency <1 Day, ASAP or Weekend - Contact ALS	

Sampler's Name	Andy Wight	Mobile #	250-433-1159
Sampler's Signature		Date/Time	August 1, 2017

10°C

Appendix G. Supporting Data Collected at LCO Dry Creek for the Spawning Condition Study

LIST OF TABLES

LIST OF FIGURES

Table 1. Substrate size (mm) composition measured at LCO Dry Creek in August/September 2017 to support the spawning condition assessment. Note that b) is a continuation of a).

a)

Substrate Diameter (mm)	LCDRY-CI45-sp [1]	LCDRY-CI48-sp	LCDRY-CI49-sp	LCDRY-CI53-sp	LCDRY-CI55-sp	LCDRY-CI77-ns	LCDRY-CI78-ns	LCDRY-CI80-ns	LCDRY-CI82-ns	LCDRY-CI83-ns
D10	20	21	25	18	24	40	34	42	44	56
D16	25	24	30	21	27	46	40	48	49	65
D40	38	36	42	37	42	59	56	66	67	82
D50	43	40	47	42	49	64	62	72	76	89
D60	49	44	53	48	57	71	70	78	86	101
D84	69	68	76	72	85	89	89	99	133	138
D90	80	78	86	81	605	103	104	113	162	167

D values represent the % grain diameter of a given size in the cumulative GSD

D50: median diameter by mass

[1] Suffix -sp or -ns represent the FHAP units (Buchanan et al. 2016) that were found to have good spawning habitat (sp) and poor spawning habitat (ns).

b)

Substrate Diameter (mm)	LCDRY-CI85-ns [1]	LCDRY-CI88-ns	LCDRY-CI91-ns	LCDRY-CI95-ns	LCDRY-CI115-sp	LCDRY-CI116-sp	LCDRY-CI238-sp	LCDRY-CI271-sp	LCDRY-CI282-sp	LCDRY-CI333-sp
D10	30	37	35	33	33	30	28	23	23	27
D16	35	43	41	39	37	35	33	27	29	33
D40	54	62	60	65	53	52	48	40	43	46
D50	62	68	69	73	60	59	55	44	49	55
D60	72	74	78	81	68	66	63	50	56	63
D84	112	89	119	119	90	91	95	72	81	86
D90	440	106	144	700	105	123	108	88	89	96

D values represent the % grain diameter of a given size in the cumulative GSD

D50: median diameter by mass

[1] Suffix -sp or -ns represent the FHAP units (Buchanan et al. 2016) that were found to have good spawning habitat (sp) and poor spawning habitat (ns).

Figure 1. Summary of CI at additional LCO Dry Creek sites in 2017 to support the spawning condition assessment. Suffix -sp or -ns represent the FHAP units (Buchanan *et al*. 2016) that were found to have good spawning habitat (sp) and poor spawning habitat (ns).

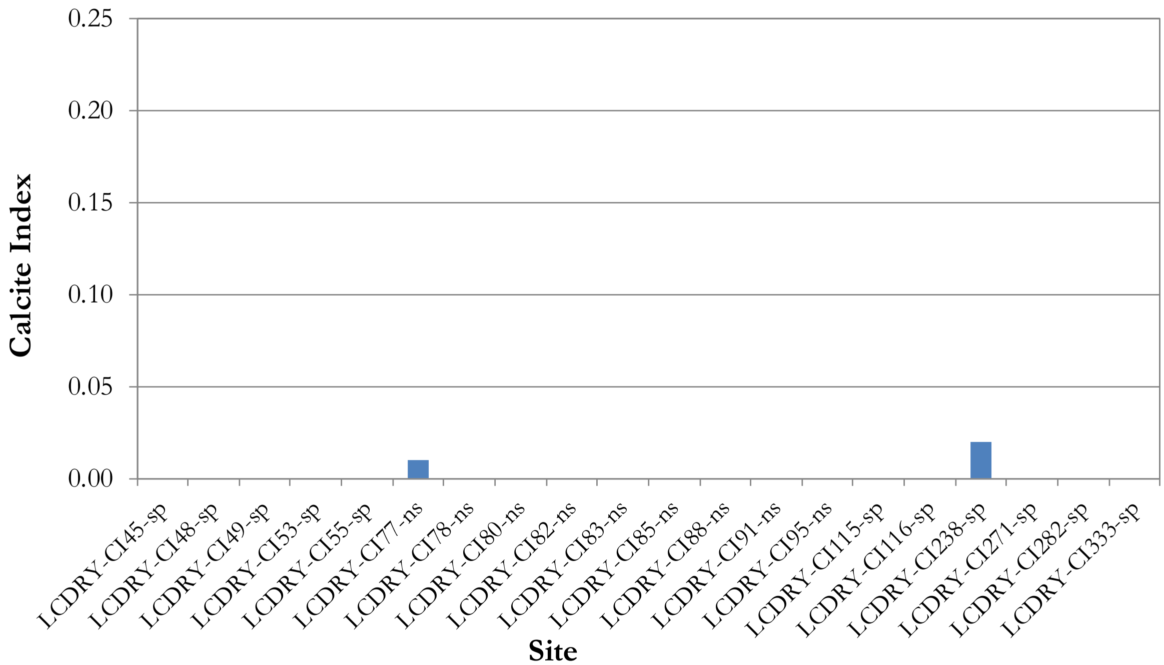


Table 2 Spawning habitat assessment data collected on LCO Dry Creek between August 29 and September 1, 2017.

Date	FHAP Unit[1]	Location[2] (m)	Habitat Type	Spawning Habitat Quality	Redds Detected	Spawning Habitat Comments	Substrate Compaction (Low/Med/ High)	Substrate Embeddedness (Low/Med/ High)	Historical Redd Observations (2016/2017)
29-Aug-17	44	574	Glide	Moderate/Poor	No	Glide tailout.	H	H	None
29-Aug-17	45	580	Glide	Moderate/Poor	No	Habitat may have changed since 2016 when this site was used for spawning. It was previously classified as a riffle.	M	H	3 redds June 2016
29-Aug-17	48	623	Glide	Good	No	Excellent quality spawning habitat.	H	M	1 redd June 2017
29-Aug-17	49	632	Run	Moderate	No		H	M	5 redds June 2016
29-Aug-17	53	693	Glide	Moderate	No	Habitat may have changed, it was classified as a Run in 2016.	L/M	M	1 redd June 2016
29-Aug-17	54	707	Riffle	Moderate	No		H	M	3 redds June 2016
29-Aug-17	55	751	Riffle	Moderate	No	Moderate spawning habitat in side channel.	M	H	1 redd June 2017
01-Sep-17	80	1,251	Riffle	Moderate	No	No obvious redds, but likely some evidence of old redds from previous years.	M	H	None
31-Aug-17	101	1,729	Riffle	Moderate/Poor	No	Small usable area, could be used by 20 cm trout. Some possible old redds observed, but could be Elk tracks.	H	M	1 redd June 2017
31-Aug-17	115	2,097	Riffle	Moderate/Poor	No	Classic spawning location, but lots of fines present. No obvious redds observed, but likely some historic spawning.	M	H	1 redd June 2017
31-Aug-17	116	2,107	Riffle	Moderate/Good	No	Top of riffle. No obvious redds.	M	M	1 redd July 2017
31-Aug-17	238	3,341	Run	Moderate/Good	Yes	2 noticeable redds present.	L	M	2 redds July 2017
31-Aug-17	239	3,357	Run	Moderate/Good	No	Substrate is moderate/good, but hydraulics are not good. Gravel deposition zone.	L	L	None
31-Aug-17	271	3,817	Glide	Moderate/Good	Yes	One noticeable redd, with large substrate underneath the gravel.	M	M	2 redds July 2017
31-Aug-17	275	3,876	Glide	Moderate/Poor	No	Large substrate.	M	M	2 redds June 2016
31-Aug-17	282	3,979	Glide	Moderate	Yes	Redds present. Redds are partially dewatered at low flows.	L	M	2 redds July 2017
31-Aug-17	329	4,549	Run	Moderate/Poor	No	Good hydraulics, some larger substrate. Highly compacted.	M	H	None
31-Aug-17	333	4,591	Riffle	Good	No	Nicest riffle head spawning sites encountered. Particle size a bit large, but excellent hydraulics.	M	H	1 redd June 2017

[1] Fish Habitat Assessment Procedures (FHAP) unit numbers from Buchanan *et al.* 2016.

[2] Distance measured upstream from the Fording River confluence.

Appendix H. Review of other assessment methods

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

In response to EMC advice, we investigated in situ incubation methods for directly assessing egg-to-fry survival in relation to calcite and other variables. The results of our review are described in detail below. Several substantial challenges for studies based on these methods were identified. For example, the substrate will need to be disturbed, which would disturb the calcite layer. There would also be difficulty in teasing out effects of calcite versus effects from water quality on incubation success. Furthermore, in situ incubation methods will not provide insight into other potential effects, such as fry entombment from substrate embeddedness due to fines or calcite. Based on a review of possible techniques, experimental design, permitting challenges, and discussions with the EMC, we recommend not proceeding with the in situ incubation experiments. In the meantime, the program should focus on building the calcite vs. spawning response curve and understanding the outcome of calcite mitigations.

2. PERMITTING REQUIREMENTS AND EGG SOURCE AVAILABILITY

Permitting requirements for use of in situ incubation techniques to assess the impact of calcite effects on incubation success in the Elk Valley were discussed with two Provincial biologists in Cranbrook (Heather Lamson, Fisheries Biologist and Herb Tepper, Habitat Biologist). Fish collection permits from the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD) are required for both experimentation with in situ incubation cassettes loaded with outplanted eggs and the collection of wild emergent fry in emergence traps. An application for a Scientific Fish Collection Permit can be submitted to FrontCounter BC[1] Cranbrook for FLNRORD review.

The Provincial biologists do not support the use of wild Westslope Cutthroat Trout eggs for the incubation study, but would support the use of Westslope Cutthroat Trout triploid eggs from Connor Lake if no live eggs or fry are released back to the wild. These eggs are collected by Bull River Hatchery (Kootenay Trout Hatchery, near Cranbrook) every "even-year" as part of their hatchery program (see section 2 for a description on the triploid process for trout at Bull River Hatchery). The use of triploid eggs and no release minimizes potential adverse effects on wild Fording River Westslope Cutthroat Trout. Triploid progeny are sterile and unable to reproduce. Although success of the triploidy process is very high, it is less than 100% (Benfey 2016). Likewise, spread of pathogens from hatchery to wild is possible despite efforts to disinfect eggs prior to outplanting. Thus, the probability of introgression or pathogen introduction is low, but not zero.

The potential for differences in survival between diploid and triploid eggs was discussed with hatchery management to assess whether results from triploid eggs could be reasonably extrapolated

[1] http://www.frontcounterbc.gov.bc.ca/guides/fish-wildlife/scientific-fish-collection/overview/

to naturally produced diploid eggs. Managers at Duncan Hatchery (Owen Schoenberger and Tristan Robbins) were contacted to discuss whether triploid egg survival is similar to that of diploids. Duncan Hatchery is operated by the Freshwater Fisheries Society of BC (FFSBC) and has been producing triploid trout for several years. They have found that survival of triploid eggs has been up to 5% lower than survival of diploid eggs. Survival was the same for triploid and diploid eggs at the Bull River Hatchery, although there is only one year of data. Thus, existing information suggests that there may be small or no differences in survival between diploid and triploid eggs, suggestion that use of triploid eggs in experiments may represent a reasonable proxy for wild diploid eggs. To address the potential survival difference an in-hatchery control could be setup to compare triploid and diploid egg survival from the same batch of eggs at Bull Hatchery. This type of experimental control was supported by the two Provincial biologists in Cranbrook.

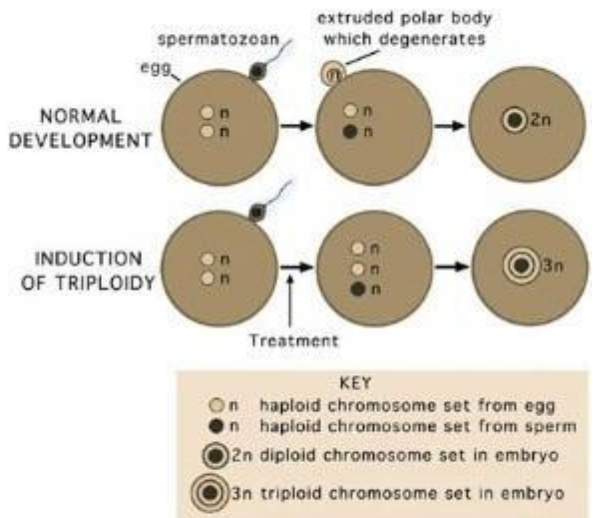
Bull River Hatchery was contacted to discuss the practicalities of obtaining approximately 1000-2000 Connor Lake Westslope Cutthroat Trout triploid eggs for outplanting into incubators to assess incubation survival in the Fording River watershed above Josephine Falls. Currently, eggs are only collected on "even years". To provide Westslope Cutthroat Trout eggs in "odd years", Bull Hatchery staff would need to make a special field trip to collect eggs. The estimated cost to collect 1000-2000 eggs and incubate to the eyed-stage would be up to $10,000 for the helicopter flight and $5,000 for labour. Approval for this special egg collection would be required from FLNRORD.

FLNRORD biologists have provided approval in principal for Bull River Hatchery staff to collect brood from Connor Lake, incubate 1000-2000 triploid eggs to the eyed stage and outplant these in incubators at one or more locations above Josephine Falls in the Fording River watershed. Collecting eggs during "odd years" is feasible to Provincial biologists in Cranbrook, who also mentioned that the hatchery program is under review to determine if Connor Lake Westslope Cutthroat Trout eggs should be collected every year. An application and permit are standard requirements to proceed. FFSBC applies for permits for egg collection and transport from various spawning collection sites to FFSBC hatchery sites and also applies for a transport permit for eggs and fish from hatcheries to lakes, rivers and other hatcheries. FFSBC could include the experimental incubation locations in the upper Fording River watershed on their 2018 permit or permits for other years (see pers. comm. in Section 8). Thus, the triploid egg transfer can be added to Bull River Hatchery's permit for Connor Lake egg collection and shipment to the Fording River egg incubation experimental sites. No other transplant permit is required. Bull River Hatchery is also able to set up a diploid-triploid incubation comparison. This proposed experiment is supported by FLNRORD and the hatchery manager, but some monetary compensation may be required depending on staffing needs.

3. TRIPLOIDING PROCESS FOR TROUT AT BULL RIVER HATCHERY

Triploid trout are created by forcing the egg to retain a chromosome that is normally ejected during egg development (Figure 1). Bull River Hatchery uses the pressure shock treatment method. Fertilized trout eggs, normally a chromosome (N) are kicked out of the egg as a polar body at some stage of development. Using pressure treatment at a specific time in the egg development, the polar body and chromosome is retained. With three chromosomes the fish is sterile and cannot reproduce.

Figure 1. Summary of triploiding process.



Eggs and Milt are collected separately from the respective sexes. The gametes are taken to the fertilization station in groups of approximately 60 ounces of eggs and 10 ml of milt. At timed intervals, each group of eggs is fertilized, rinsed, poured into a metal cylinder (Figure 2), and placed into a holding tank. These eggs will sit in the holding tank for a period of time that is based on water temperature, called a Time Temperature Unit (TTU). This allows the egg sufficient time of development to generate the polar body, but not yet expel it. After this time, the cylinder is placed into a pressure vessel. This usually occurs 37 minutes after fertilization (O. Schoenberger pers.com. 2017). Once the eggs are in and the vessel lid is on, the pressure inside the vessel is increased to 9,500 psi. Eggs remain in the pressure vessel for 5 minutes. During this time, the polar body cannot be ejected due to pressure. After this process the fertilized eggs are loaded into an incubator (Figure 3).

Figure 2. Eggs in metal cylinder being placed into a holding tank.

Figure 3. Fertilized eggs loaded into an incubator.

4. EGG-TO-FRY SURVIVAL ASSESSMENT

Calcite occurs at varying levels in the Elk Valley and there is interest in understanding the effect of calcite on incubation success. A study on the potential effects of calcite on the egg-to-fry survival of Westslope Cutthroat Trout can be conducted by evaluating egg incubation success at different sites with varying levels of calcite (low to high). There are two main types of study approach. The first approach involves outplanting hatchery-sourced fertilized eggs in enclosed containers and measuring egg-to-fry survival. This approach can control for the origin of the eggs and compare a metric of incubation success across different locations. Alternatively, naturally-produced redds can be sampled to estimate the number of fry that successfully emerge. This approach is a more direct observation of realized fry survival, but requires identifying a sufficient number of redds across different habitats and estimating the initial number of eggs in a redd. A number of methods/techniques for studying incubation success and considerations for this type of study are reviewed in the following sections.

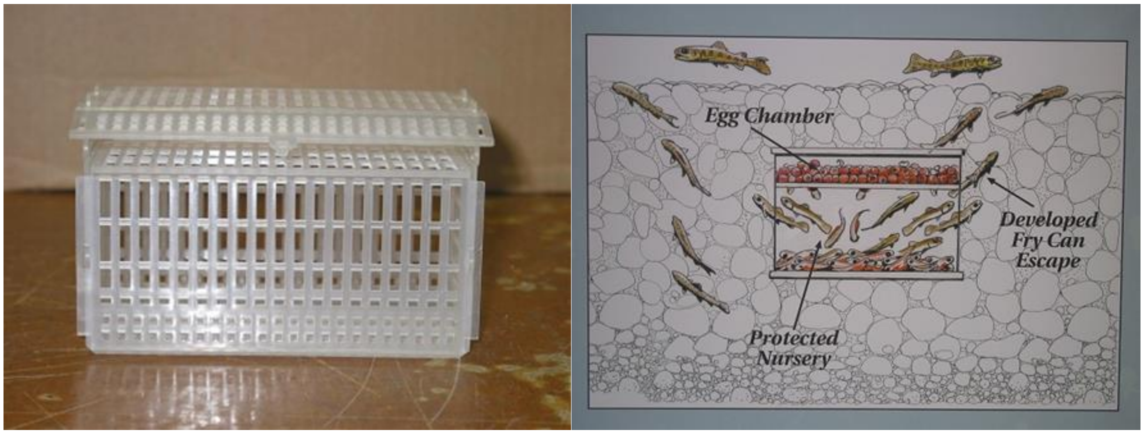
5. USE OF IN SITU INCUBATORS

To avoid some of the challenges inherent in the in situ study of naturally-deposited eggs, various egg incubation devices have been developed that attempt to mimic the conditions experienced by naturally deposited eggs. Several in situ devices have been used in studies for determining the survival of eggs of fluvial spawners and are discussed below. Table 1 summarizes specifications of different devices. These devices have been used to incubate eggs within existing redds and other locations within a stream. It should be noted that the methods assess incubation success but can lead to an over-estimate of fry survival because emergence from the gravel is not assessed. After hatching, fry must find their way into the water column through sediment interstices; fine sediments (or calcite) may create a physical barrier that prevents fry from emerging (Chapman 1988, Crisp 1996, Guerrin and Dumas 2001).

5.1. Whitlock-Vibert Boxes

Whitlock-Vibert boxes have been used in a variety of studies for egg incubation (i.e., Mackenzie and Moring 1988, Garrett and Bennett 1996). The boxes are made of polypropylene and measure 14 × 6.4 × 8.9 cm deep. The slots surrounding the egg chamber are 3.5 × 13 mm on the top and bottom, and 2 × 2 mm on the sides (Figure 4). Eggs are loaded in the top compartment of the box and hatched alevins will fall to the bottom of the box where they can swim out (Figure 4). While the boxes are permeable, they have been found in some studies to be subject to excessive sediment accumulation (Harshbarger and Porter 1979, 1982). Filling the Whitlock-Vibert boxes with gravel improves survival by reducing sedimentation around the eggs, reducing the spread of fungus, and increasing flow within the box. However, since the screen size allows hatchlings to swim out, post-hatch survival cannot be estimated. The loss of numbers from the incubator may be due to swim out or decomposition of eggs or hatchlings. The Whitlock-Vibert box is designed for fry to escape on their own volition; however, a liner can be added to prevent the fry from escaping, thus allowing an estimate of survival. A disadvantage to using this incubator is that a substantial amount of gravel must be excavated for installation of the box.

Figure 4. Whitlock-Vibert Box and sketch of designed use of box.



(http://www.flyfishersinternational.org/Conservation/ProjectsPrograms/Whitlock-VibertBox/tabid/600/Default.aspx)

5.2. <u>Screened PVC Tubes</u>

PVC tube incubators have multiple windows cut along the length of PVC and are covered with mesh. The windows and screen used must allow enough water movement to maintain egg survival. When the screen area is too small or screen size too small, egg survival using PVC tubes egg survival is low. Scrivener (1988) found that capsule screen sizes less than 1000 µm and high egg densities contributed to poor survival; however, good results were found with egg densities of 30 eggs/34 cm^3. Using a similar apparatus, Rubin (1995), also attained good results by using a screen of 1000 µm, a loading density of 30 eggs/108 cm^3, and filling the capsule with gravel from a natural redd.

5.3. <u>Jordan-Scotty Incubator</u>

Jordan-Scotty incubators consist of a pair of loaded plates that are bolted together to create a "unit" designed to hold 200 single eggs or more, depending on species and size of egg. The plates are held together by nylon tie bolts and stainless-steel nuts and can be grouped in up to 5-unit sets (Figure 5). Each unit is 30 cm long, 16.5 cm high, and 3.5 cm wide. The cell for each egg is 3.1 × 1.15 × 1.15 cm or 4.1 cm^3 per egg. Escape holes allow the hatched fry to swim free once they have developed in their protected environment. A single or assembled number of egg units are buried standing upright and perpendicular to the flow of water. Incubator plates are available with varying sizes of escape holes and can also be purchased with openings that prevent fry from escaping (Figure 6).

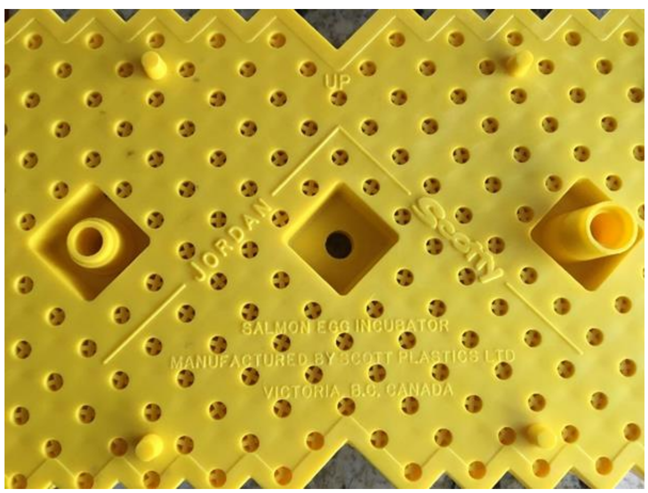
The Jordan-Scotty in-stream incubator can be used as an alternative to the Whitlock-Vibert boxes, where the spread of fungus among eggs can lead to high mortality. Fungus usually establishes itself on dead eggs but can spread to live and healthy eggs. Jordan-Scotty in-stream incubators avoid this issue with small separated chambers for each egg. The interpretation of the observed egg mortality rates in bioassays using Jordan-Scotty incubators is not confused by mortalities due to fungus spread and can therefore be more accurate when testing for differences among treatments of salmonid eggs.

To install the unit, a large depression is dug in the gravel and the incubator is buried. Due to the dimensions of the Whitlock-Vibert box and the Jordan-Scotty incubator it is difficult to place these devices directly into an existing redd without disturbing the redd architecture that can be important for maintaining water flow through the redd (Chapman 1988). However, it would be possible to modify the unit to a smaller size.

Figure 5. Jordan-Scotty incubator with eggs in individual compartments.

(http://scotty.com/wp-content/uploads/2016/07/JordanScotty_IncubatorBrochure.pdf)

Figure 6. Close up view of a Jordan-Scotty box with holes that prevent fry escape.



5.4. Pipe Incubators

Pipe incubators developed by DFO Salmonid Enhancement Program (SEP) for Chinook Salmon incubation studies are 1.9 cm diameter (3/4 inch) perforated metal pipes, 38 cm in length, and equipped with a masonry drill bit at the tip, such that they can be drilled directly into the substrate using a rechargeable battery-powered hammer drill (Figure 7). They were fabricated specifically for applications in deep water (Cowichan River) since they can easily be hammer-drilled into the substrate from an anchored boat. These pipe incubators were modified from the first prototype used at the Puntledge River Bull Island side-channel in 2005. They originally had 3mm perforations and were replaced with a pipe chamber with smaller diameter holes (1600 µm) due to concerns that larvae could escape through 3 mm holes (Figure 8). Each pipe incubator contains 25 eggs mixed with small beads as a substrate (Figure 9).

The key advantage to this technique is the ability to hammer-drill the incubator into an existing redd with little disturbance to the gravel substrate. Additionally, the incubator can be installed from a boat at depths up to 2.5 m. However, the masonry drill bits are prone to rusting and need to be sealed with a non-toxic rust preventive coating. If field staff are able to wade into the locations and are installing egg capsules to a depth of 20 cm or less, other methods can be used, as described by Fitzsimmons (2014), McNeil (1966), and Dumas and Marty (2006). These other methods are less costly and easier to install, and are described below.

Figure 7. Installation of a pipe incubator using a battery-operated drill.

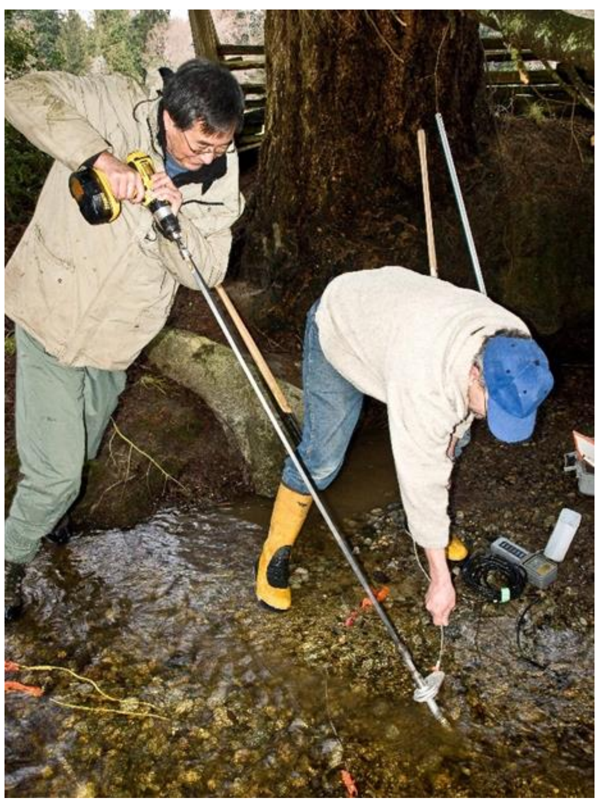


Figure 8. Pipe incubator first prototype.

Figure 9. Contents of a pipe incubator after hatch.

5.5. Egg Capsules

Various versions of egg capsules have also been used to monitor egg-to-fry survival. These units can hold approximately 50 eyed Coho Salmon eggs (i.e., 50 eggs/280 cm^3). The capsules are 6.0 cm in diameter, 10 cm long (but can be made longer), and the screen size is 3937 × 2540 µm. Gravel substrate and eggs are sealed in the cylinder using two plastic end caps (Figure 10). These were recently used in Comox Lake to assess Kokanee egg-to-fry survival along a natural lakeshore spawning area known to support Kokanee spawners (Guimond and Heim 2017). Eyed egg-to-fry survival was +87.9% in eight of the nine incubators installed. Water circulation in the incubator was presumed to be largely dependent on upwelling groundwater flow.

Egg capsules are compact and easy to install; a small hand trowel is used to excavate a depression and bury the unit in the substrate. A smaller screen liner could be used to prevent loss of smaller alevins or fry. Screen liner sizes of 1400 and 1600 µm tested at Duncan Hatchery in January 2018 successfully prevented the escape of all Rainbow Trout alevins and fry ranging in mean weights between 0.124 and 0.160 grams/fry. It is presumed that the larger screen size provided better flow conditions and oxygen levels, which resulted in a larger mean weight of buttoned-up fry.

Figure 10. Egg capsule - perforated cylindrical plastic egg tubes (incubators) empty (left) and loaded with substrate (right) consisting of small gravel (2-16 mm diameter).

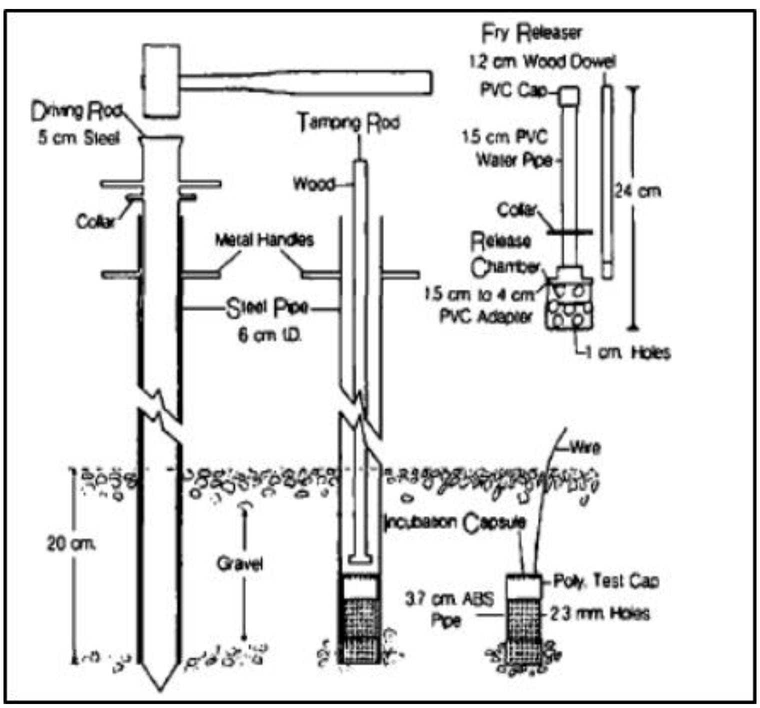
Another version of the egg capsule was developed to reduce the issue of gravel disturbance when placed in natural redds. This egg capsule is almost permeable to water and can be injected directly into redds (Fitzsimons 2014).

The capsule developed by Fitzsimons (2014) consists of a polypropylene mesh tube (5 mm square mesh; 7 cm diameter and 20 cm length) having detachable porous (1,000 µm) end caps. The inside of the capsule is lined with 1,000 µm Nitex mesh to prevent the loss of hatched fry but allow the infiltration of fine sediment. A larger mesh size (i.e., 1,400-1,600 µm) that prevents fry loss could be used depending on the fry emergence size. The larger mesh size is also more desirable because it is less prone to clogging by fines. An egg and gravel mix consisting of 100 hatchery brood stock eggs is added to the capsule, sealed and transported to the river. At the river, a capsule insertion device is driven into the redd to the appropriate depth for naturally spawned eggs, usually 15 to 20 cm (DeVries 1997). The central rod used to drive the capsule insertion device is then removed while the outer tube of the capsule insertion device is held in place providing a void space in the substrate. An individual capsule is then placed into the void space in the outer tube and a rod used to hold the capsule in place while the outer tube is withdrawn from the substrate (Figure 11; Figure 12). Once complete, the capsule is not visible from the surface. Its position can be marked by a coloured tag-line attached to the capsule prior to insertion, allowing it to be readily found and removed at a later date. To assess the effects of holding eggs in the capsule and the transportation effect on egg capsules, a subsample of loaded capsules can be subjected to the same handling as buried capsules, incubated under hatchery conditions, and examined at the same time as capsules are removed from the river.

Scrivener's capsule injection method used in 1988 is very similar to Fitzsimmons' method (2014). The size of these capsules and the insertion tube, which had to be hammered down through the gravel, was considered too big and was thought to disturb gravel and reduce egg survival in natural redds.

Figure 11. Details of a) egg capsule injection device disassembled with a capsule, b) assembled egg capsule injection device (Dumas and Marty 2006).

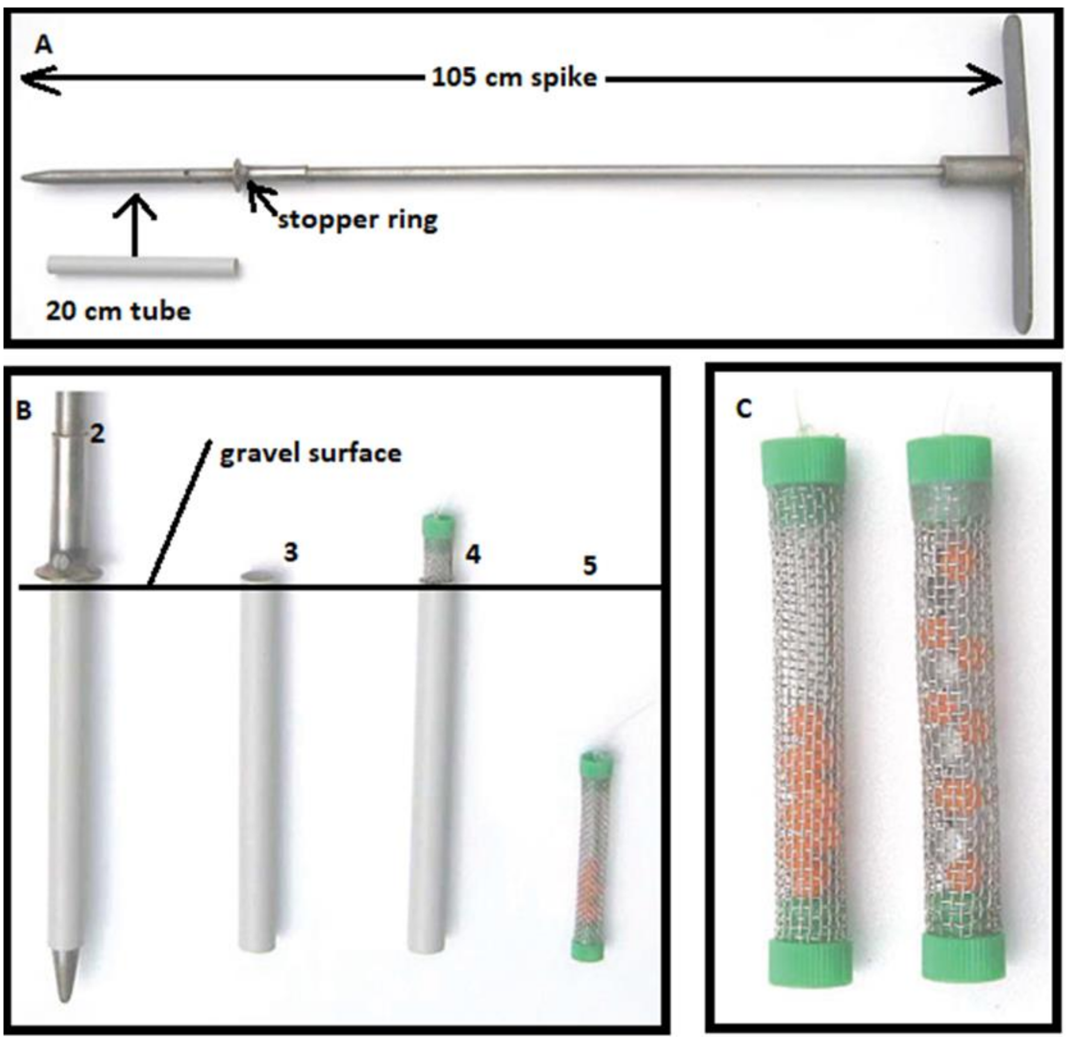
Figure 12. Installation of an egg incubation capsule for salmonids and a diagram of the intragravel fry releaser used at Carnation Creek (top). Also shown are various types of experimental egg incubation capsules (Dumas and Marty 2006) (bottom).



5.6. Miniature Egg Capsule

Dumas and Marty (2006) developed a miniaturized device designed to avoid problems with gravel disturbance (Figure 13). The method allows insertion of one or more small incubation capsules (cylindrical tubes 12 cm^3) directly into the stream bed, without modifying the substrate. The incubation capsules were 9 cm long ×1.4 cm diameter cylindrical tubes made of 1.5 mm mesh stainless steel netting. The two ends of the cylinder were sealed by a plastic stopper leaving a 12 cm^3 and 7.5 cm long volume free for eggs. The incubation capsules were filled with 10 green eggs, and were able to retain alevins. This method was inexpensive, easier, and faster to install than other in situ incubation capsules. The small diameter of the capsules allowed easy insertion with an insertion spike which caused minimal gravel disturbance.

Figure 13. Miniature egg capsule (a) Component and (b) insertion steps for placement of the egg capsules under the gravel of a redd. (c) Arrangement of 10 eggs in the capsule: eggs in a mass (left) or separated by glass balls (right). From Dumas and Marty (2006).



ECOFISH RESEARCH

Table 1. Summary of in situ egg incubators and specifications.

	Whitlock-Vibert Box	Jordan-Scotty Incubators	Pipe Incubator	Egg Capsule	Miniature Capsule
Cost/unit ($)	$4.25 to $4.75	~ $11.00	~ $100.00	~ $4.00	~ $10.00 to $15.00
Incubator dimensions (cm)	14 × 6.4 × 8.9 (egg chamber 14 × 6.4 × 2.0)	30 × 16.5 × 3.5	2.15 diam. × 38 (egg chamber 2.15 diam. × 15)	6.0 diam × 10 (length can vary)	1.4 diam. × 9.0 (length and diameter can vary)
Incubator hole/screen size (mm)	3.5 × 13 (top and bottom), 2.0 × 2.0 (sides), designed for volitional release, screen liner can be added to prevent escape	Various sizes available, can purchase with holes that prevent escape	Manufactured with any hole size needed, 1.6 mm required to prevent escape	3.9 × 2.5, screen liner can be installed to prevent escape	Stainless steel screen can be purchase in various sizes
Space in incubator/ egg (cm^3)	0.578 (egg compartment only, can be loaded with less eggs), 0.875 entire incubator	4.67	2.18, can be adjusted higher or lower	5.66, can be adjusted higher or lower	1.20
Egg loading capacity (no. eggs)	~ 310 (single layer eggs, can be adjusted lower)	200	25	50	10
Screen open area/ egg (cm^2)	Estimate 50% open screen area, 0.418 (egg compartment only), 0.875 (whole incubator)	0.198	0.932 (1.6 mm screen size, 23% open area)	1.152	1.464 (1.5 mm screen, ~ 52% open area)
Installation requirements	Need to excavate hole in gravel for install	Need to excavate hole in gravel for install	Drilled into gravel with little disturbance, install in seconds	Device used to install into substrate, some disturbance of gravel	Device used to install into substrate, very little disturbance of gravel
Additional considerations	Add substrate to separate eggs and prevent spread of fungus, eggs loaded into top compartment, hatched alevins fall into compartment below	Separate egg cubicles prevent spread of fungus, units meet BC Provincial standard for bioassay use	Beads layered into pipe to separate eggs, coat drill bit with rust resistant coating	Can modify solid caps with screened ends, load ends of capsules with small beads to prevent fry from entering dead spots caused by caps	

6. CONSIDERATIONS FOR IN SITU INCUBATOR USE

6.1. Egg Loss/Decay

When eggs are outplanted in incubation devices there is a possibility that some eggs will die and be lost to decomposition. The following is a brief review of egg loss due to decay. Paulwels and Haines (1994) found that the reported rates of decay of non-viable salmonid eggs deposited in streams vary considerably. Some reported little or no decay after 100 days of incubation (using dead Atlantic salmon eggs in a Maine stream). Similarly, after planting dead salmonid eggs (origin unstated) in a stream, no decay of dead eggs was reported after 33 days of incubation. Briggs (1953) planted dead salmonid eggs in a California stream and found that 1% decayed after 30 days, 9% after 60 days, and 13% after 90 days. Gangmark and Broad (1955, 1956) deposited live eggs of Chinook Salmon in a California stream and recovered only about 50% of the planted eggs after 45-58 days of incubation. Hausle and Coble (1976) implanted dead eggs of Brook Trout in a Wisconsin stream and found that, except for some fragments, all of the eggs had disappeared after 133 days. McNeil *et al.* (1964) reported that dead eggs of pink salmon deposited in an Alaska stream decomposed slowly between spawning (October) and fry emergence (March). Studies by Briggs (1953), Gangmark and Broad (1955, 1956), McNeil *et al.* (1964), and Hausle and Coble (1976) were performed in streams with water temperatures ranging from 2 to 13°C. It was stated that temperatures at the high end of this range will increase the rate of decomposition. Loss of dead eggs from Atlantic Salmon redds in Maine has been considered negligible because of the very low incubation temperatures (Paulwels and Haines 1994). However, other data indicate that substantial disintegration of dead Atlantic Salmon eggs can occur even when water temperatures do not rise above 1°C during development. Rubin (1995) found that for up to 250 days, loss of eggs was generally low, but in some cases almost 90% of dead eggs disappeared after that time. Disappearance of dead eggs depended on the physio-chemical characteristics of the substratum, mainly oxygen concentration and presence of saprophytic organisms. When the interstitial oxygen concentration was lower than 6 mg/L, almost all the dead eggs were found in the boxes; when interstitial oxygen concentration increased, particularly when the value reached 10 to 12 mg/l, most of the dead eggs disappeared. Thus, previous studies have found that dead eggs may persist or be decomposed, depending on the environmental conditions.

6.2. Egg Development

One of the key considerations in outplanting studies is the developmental stage of the eggs.

6.2.1. Newly Fertilized Eggs

Presuming that FLNRORD will only allow the use of triploid Westslope Cutthroat Trout eggs for the calcite effects incubation study, the use of triploid fertilized eggs that have only been incubating for 1-2 days would provide the longest period for egg-to-fry incubation survival assessment. Bull River Hatchery staff have successfully transported triploid eggs up to 2 days after fertilization; however, considerable coordination would be required to achieve outplanting within such a short time frame. It may be more feasible to outplant eggs when they are at the eyed stage, as newly-fertilized eggs are shock sensitive and care must be taken when transporting and loading the eggs into the gravel. Sealed buried capsules can be recovered at any stage to estimate survival, but ideally they would be recovered after hatch or around emergence.

Peak oxygen demand for incubating embryos occurs at hatch so the most sensitive period of development to dissolved oxygen conditions is likely to be at this stage. It should be noted that fluvial spawning salmonids select redd sites with physical characteristics that lead to higher embryonic survival and growth (Magee and Moring 1996, Bernier-Bourgault and Magnan 2002) than other sites. Also, females modify the substrate composition during redd construction, such as removal of fine sediments (Chapman 1988).

The sediment composition and water quality of randomly selected incubation sites may differ considerably from that of a redd built by a spawning female. For many fluvial spawning salmonids, a number of habitat factors, such as water velocity, water temperature, ground water seepage, sedimentation, and bottom substrate composition influence survival and growth of embryos in a redd (Chapman 1988, Curry *et al.* 1994, 1995, Bernier-Bourgault and Magnan 2002). Therefore, the incubation methods are best considered for assessing relative success among sites, rather than absolute measures.

All of the above egg incubator assessment methods (that use an enclosed capsule) will not provide insight on the influence of fines or substrate embeddedness on fry emergence.

7. MEASURING INCUBATION SUCCESS ON NATURAL REDDS

The following provides a brief review of methods that can be used to measure incubation success on naturally occurring redds.

7.1. Emergence Traps

Estimates of survival from egg deposition (fertilization) to emergence has been measured using redd caps or emergence traps. Emergence traps can be used to assess egg-to-fry survival when placed on wild redds or human-made redds with a known number of deposited eggs. A comparison of emergence traps used on natural versus human-made redds is provided in Table 2. These devices consist of a solid hoop that when laid flat on the gravel bed covers a wider area than the egg pocket and is buried approximately 10 cm into the substrate to prevent emerging fry from escaping. The hoop is usually made of metal or plastic, with a removable sealed net or screen on top and a tapered net oriented downstream (Figure 14). A screened bottle is attached at the end (similar to a plankton net) and is used to collect fry emerging from the redd (Figure 15). As fry emerge from the redd they drift or swim downstream into the tapered funnel and bottle, which can then be emptied and the contents examined and enumerated. Fraley *et al.* (1986) found that the traps were nearly 100% effective at capturing emerging fry, and fry mortality in the bottles was nil if the trap was checked weekly. Using a similar type of trap made of nylon netting, Phillips and Koski (1969) also found that trap efficiency was 100%, but mortality of captures was 1.5% when the trap was checked three times a week (Figure 16).

To estimate egg-to-fry survival, the numbers of eggs in the redd must be estimated. This can be done by measuring or estimating the length of the spawning female to determine fecundity. It is generally assumed that the female deposited all of the eggs at this location and no other female spawned in the immediate area. These may or may not be valid assumptions.

Table 2. Comparison of emergent trap use on natural versus human-made redds for egg-to-fry survival studies.

Consideration	Natural Redd	Man-Made Redd
Permitting	Need a Provincial sampling permit	Need a Provincial sampling permit
Egg Deposition	Egg deposition based on female length vs. fecundity	Plant a known number of eggs
Redd Marking	Metal rods driven into gravel to discourage other female spawners	Metal rods driven into gravel to discourage other female spawners
Estimation of Fry Emergence Timing	Based on time of egg deposition and river temperature or subsurface water temperature from buried temperature probe accessible from standpipe	Based on time of egg deposition and river temperature or subsurface water temperature from buried temperature probe accessible from standpipe
Sampling Timing	Trap installed prior to emergence	Trap installed prior to emergence
Emergence Trap Security	Must ensure emergent fry cannot escape over entire emergence period. Trap must withstand flooding, vandalism and large mammal disturbance	Must ensure emergent fry cannot escape over entire emergence period. Trap must withstand flooding, vandalism and large mammal disturbance
Trap Servicing	Fry collection tube needs to be emptied every day to every 3 days for approximately one month	Fry collection tube needs to be emptied every day to every 3 days for approximately one month
Estimate of Egg-to-Fry Survival	Can be estimated. Estimate will have errors due to retained eggs and eggs dislodged during spawning or flood events	More accurate estimate. Estimate will have errors due to eggs dislodged during flood events
Emergence Loss	Estimate of egg-to-fry survival takes into account losses associated with emergence through the gravel	Estimate of egg-to-fry survival takes into account losses associated with emergence through the gravel

Figure 14. Conceptual drawing of a fry emergence trap.

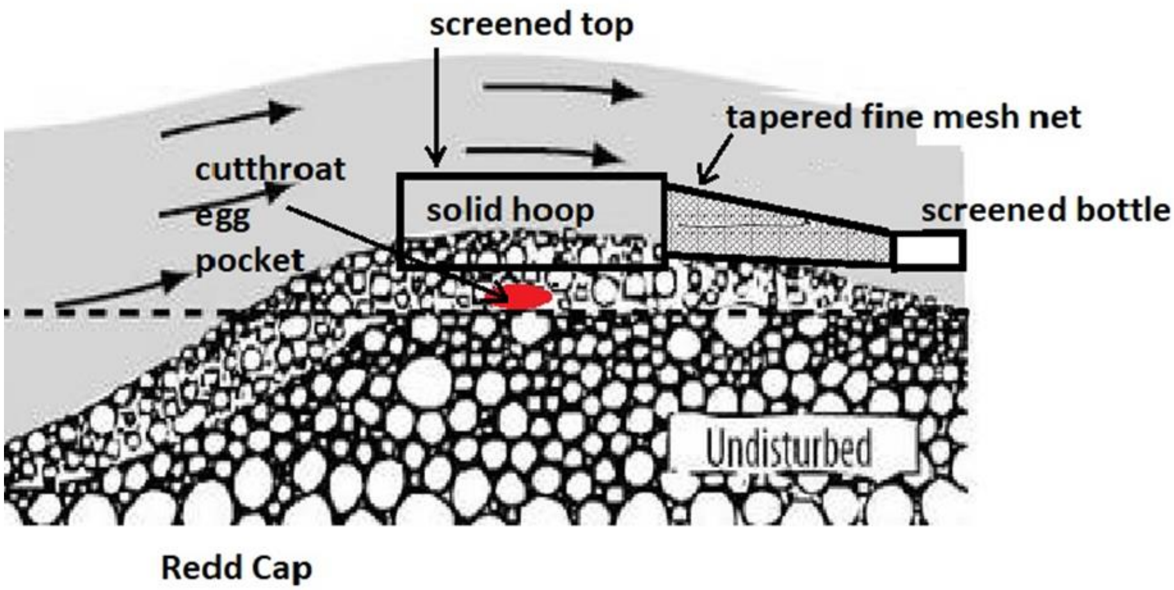


Figure 15. End of tapered fine mesh net and bottle (Michaels *et al.* 2005).

Figure 16. Emergent fry trapping with a trap net covering the whole redd. A lens-shaped cap (2.5 mm mesh net) is maintained off the bottom by a 2.1 m long by 1.2 m wide metal frame, and bordered by a 40 cm wide skirt buried in the peripheral substratum and maintained by metal stakes; at the downstream end, a zipper-equipped pocket collects the emerging fry (Phillips and Koski 1969).

7.2. Hydraulic Sampling

Hydraulic sampling is a field procedure that can be used to estimate total survival of wild salmonid eggs from egg deposition to the time of sampling; this method requires sampling prior to the onset of fry emergence. Survival estimates are based on estimates of female fecundity and the abundance of live eggs, alevins, or pre-emergent fry. Unaccounted-for sources of mortalities include loss of eggs due to egg retention in the body cavity, water velocity during egg deposition, gravel scouring during flood events, and/or predation and decomposition. Care must also be taken to only sample one redd at a time during the field assessment. Table 3 provides a comparison of hydraulic sampling to assess egg-to-fry survival in natural versus human-made redds.

The redd is marked during spawning and then hydraulic sampled at later date, usually after the eyed egg stage. A 1.5" diameter steel pipe probe is used to inject air and water into the substrate to displace and lift the buried embryos which are then captured in a cylindrical wire mesh collection basket. The basket is open at both ends, and a net bag is attached to the side of the basket and pointed downstream to recover eggs or alevins lifted from the gravel. The probe is inserted into the basket and pushed into the substrate which hydraulically works its way into the redd and lifts fine sediment, eggs, alevins, and fry into the basket (Figure 17). The suspended material floats downstream with the current and is collected in the net bag. The contents are emptied into a basin and washed to remove large organic material, and the eggs/alevins are then counted (Figure 18).

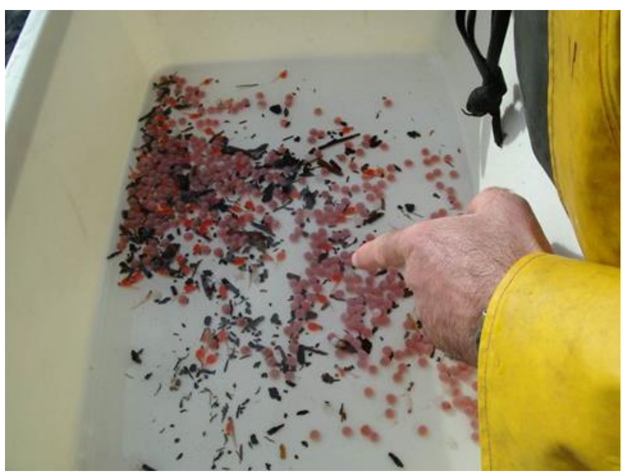
An experienced hydraulic sampler can effectively recover 93% of the contents of a redd in approximately 5-15 minutes with little egg/alevin/fry damage. McNeil (1964) estimated 0.24% mortality and found good agreement between hydraulic sampling survival and fry downstream trapping. However, in situations where the percent fines content and compaction in the gravel substrate is high, hydraulic sampling may be more difficult and corresponding survival less reliable (Bowerman *et al.* 2014, Franssen *et al.* 2012).

Table 3. Comparison of hydraulic sampling on natural redds versus human-made redds to assess egg-to-fry survival.

Consideration	Natural Redd	Man-Made Redd
Permitting	Need approval from Province	Need approval from Province. Should be considered low risk to wild Westslope Cutthroat Trout
Egg Deposition	Egg deposition based on female length vs. fecundity	Plant a known number of eggs
Redd Marking	Metal rods driven into gravel to discourage other female spawners	Metal rods driven into gravel to discourage other female spawners
Estimation of Fry Emergence Timing	Based on time of egg deposition and river temperature or subsurface water temperature from buried temperature probe accessible from standpipe	Based on time of egg deposition and river temperature or subsurface water temperature from buried temperature probe accessible from standpipe
Sampling Timing	Sampling conducted prior to emergence	Sampling conducted prior to emergence
Estimate of Egg-to-Fry Survival	Can be estimated. Estimate will have errors due to retained eggs and eggs dislodged during spawning or flood events	More accurate estimate. Estimate will have errors due to eggs dislodged during flood events
Emergence Loss	Estimate of egg-to-fry survival does not take into account losses associated with emergence through the gravel	Estimate of egg-to-fry survival does not take into account losses associated with emergence through the gravel

Figure 17. Hydraulic sampling probe, collection basket (left) and water pump on raft (right).

Figure 18. Contents of sampling basket after hydraulic sampling.



7.3. Site Selection for Emergence Traps

River flow conditions are an important consideration when choosing study sites; reaches with high river discharge should be avoided. Stable river flow conditions prior to and during the predicted fry emergence period allows for redd caps to be properly installed and remain sealed and functional until emergence is complete. After fry emergence, it is important to ensure that the redd cap is adequately sealed and maintains flow conditions inside the cap that are safe for the fry.

There are a number of challenges associated with the use of redd caps and fry emergence traps. These techniques are labour intensive, can have inherent inaccuracies associated with assumptions of female spawner fecundity, redd superimposition, egg loss during redd construction, trap efficiency (loss of fry that escape from the trap net), surface sedimentation caused by the trapping device, and high flows and debris damaging the trap (Bradford 1994, Radtke 2008, Fitzsimmons 2014). In addition, emerging fry may escape capture by moving laterally through the gravel. Lateral movements within gravel can be extensive in large uniform substrate, but would be negligible in substrates with high proportion of fines. For eggs buried 25 cm within the substrate, lateral movement by Coho Salmon, Brown Trout and Pink Salmon was found to be no more than 23 cm (Phillips and Koski 1969).

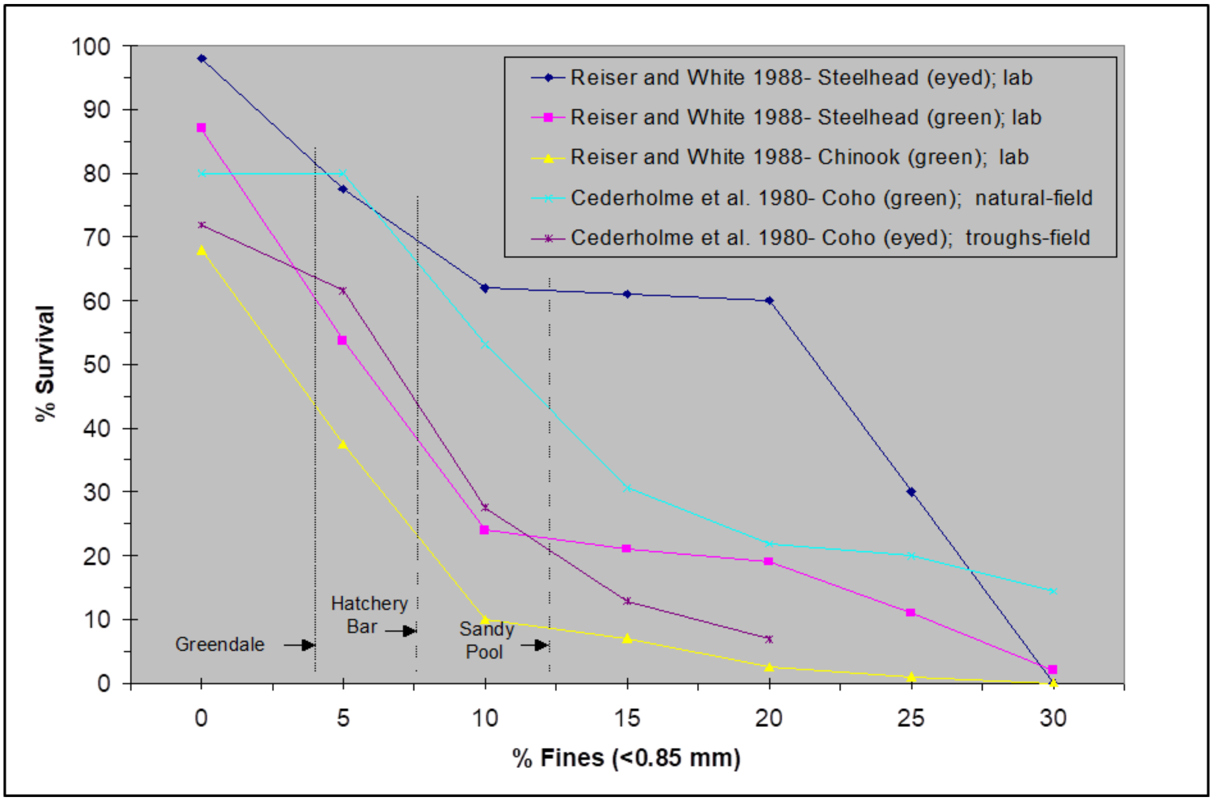
7.4. Sediment Size and Fry Emergence Success

Varying levels of fine sediment in the spawning substrate can have a dramatic effect on emergence success (Weaver and Fraley 1993, Jensen *et al.* 2009, Koski 1966). The fry can be fully developed in the gravel but are entombed by fine sediment and cannot emerge (Bowerman *et al.* 2014, Franssen *et al.* 2012, Burt and Ellis 2006). In an incubation study conducted by DFO biological support staff in the 1980s, Coho Salmon eggs incubated in artificial upwelling incubators with only sand substrate all survived and were fully developed, but none were able to emerge (Lofthouse, pers. comm. 2017).

Koski (1966), studying Coho Salmon incubation survival in three Oregon streams, found that much of the mortality in redds was caused by the inability of fry to emerge from the gravel. Numerous dead fry were found at a depth of 20 cms in one of the redds, with no survival to emergence. The fry were completely buttoned-up, but emaciated and apparently unable to penetrate through the interstices of the gravel. Dead eggs were not recovered in the redd indicating that perhaps a high percentage developed successfully to the fry stage before starving and decomposing. A similar situation was found in a redd that was not trapped. Approximately 260 fry were dead several inches below the surface of the gravel. Where Atlantic Salmon had spawned in gravel with extensive sand, 80% of the eggs were dead and 20% had produced fry which were unable to emerge through the compact layer. Numerous entombed fry were found in redds even where there was assumed to be good gravel. It is generally accepted that fry survival and fitness are lowered when the spawning gravels become filled with fine sediments less than 6 mm in diameter. In laboratory studies on Coho Salmon egg-to-fry emergence, materials finer than 0.85 mm were the most detrimental to Coho Salmon embryo survival. A relationship of a 2% reduction in survival to emergence for each 1%

increase in fines (<0.85 mm) over natural levels (which was 10% for the Clearwater River, Washington) was reported (Figure 19; Cederholm *et al.* 1980).

Figure 19. Relationship between steelhead, Chinook, and Coho Salmon fry survival to emergence and % fine sediment (modified from Reiser and White, 1988 and Cederholme *et al.* 1980, by Burt and Ellis 2006).



Kondolf (2000) reviewed and critiqued literature that assessed spawning gravel quality and incubation success and his findings support much of what has been found by Cederholm *et al.* (1980). Kondolf found that the gravel requirements of salmonids differ with life stage as the role of the gravel changes. The interstitial sediments finer than about 1 mm (or <0.83 mm) reduce the permeability of the gravel and can prevent intragravel flow from providing sufficient oxygen to embryos and removing metabolic wastes, while sediments in the 1 –10 mm size range are known to block fry emergence through intragravel spaces. He concluded that in order to achieve 50% emergence, the percentage of sediments finer than 1 mm could not be greater than about 12-14%. To achieve 50% emergence in coarser sediment, the percentage of sediments finer than both 3.35 mm and 6.35 mm should not exceed about 30%.

When studying the emergence success of Westslope Cutthroat Trout fry, Weaver and Fraley (1993) found a significant inverse relationship ($r^2=0.72$, $P<0.005$, $V=17$) between fry emergence success, as measured by fry emergence traps, and the percentage of substrate materials less than 6.35 mm in diameter. Mean fry emergence success was 76, 55, 39, 34, 26 and 4%, in cells containing 0, 10, 20, 30, 40, and 50% substrate materials less than 6.35 mm, respectively.

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8. PERSONAL COMMUNICATIONS

Lofthouse, D. 2017. DFO SEP Vancouver Headquarters Support Biologist. Communications to Mel Shang.

On Dec 19, 2017, at 8:23 AM, Schoenberger, Owen <Owen.Schoenberger@gofishbc.com> wrote:

Hi Mel,

The comparison of 2N and 3N to button up sounds OK to me. We would likely track the additional time spent to do all the necessary work and seek compensation for that. Collecting eggs in an off year is possible for us but means adding an entire egg collection program to that year's operating plan. So unless FLNRORD wants us to collect eggs every year for lake stocking, we would ask for compensation for the entire program.

Connor Lakes are in the Height of the Rockies Provincial Park northwest of Elkford. The outlet of the largest lake flows down Forsythe Creek into the Elk River. The elevation is close to 6000 feet with the closest road access being about 5km away to the west at Maiyuk Creek; hence the need for a helicopter to operate the station.

As far as a permit goes, each year FFSBC applies for permits for egg collection and transport from any of our spawning sites to whatever destination they are going to (usually a hatchery). In addition, a transport permit is needed for egg/fish transport from our facility to their final destination (lake, river, facility etc.). We would just include your final site in the application for the transport permit.

As for standalone operating costs, in our off years we would probably try to collect the eggs in as short a time as possible (two days?). That would keep cost down and have much less impact on us carrying out our other programs.

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