Elk Valley Water Quality Plan

Annex L.2

Drinking Water Evaluation, Preliminary Conceptual Hydrogeological Model and Groundwater Protection Strategy

Teck

SNC·LAVALIN

Elk Valley Groundwater Summary Report

Drinking Water Evaluation, Preliminary Conceptual Hydrogeological Model and Groundwater Protection Strategy

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July 2014

Internal Ref: 615366

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1 INTRODUCTION

The Environment & Water business unit of SNC-Lavalin Inc. (SNC-Lavalin) was retained by Teck Coal Ltd. (Teck) to conduct a Drinking Water Evaluation and Sampling Program in the Elk Valley. The Elk Valley area of interest (AOI) includes locations in the Elk Valley watershed proximate to and downstream of Teck mining operations, shown on attached Drawing 615366-001. This summary report provides a technical summary for the purpose of inclusion in the Elk Valley Water Quality Plan (EVWQP), required under Provincial Ministerial Order No. 113 (the Order). For privacy reasons, detailed results and actual sampling locations have been to members of the Technical Advisory Committee and Interior Health Authority for review as part of EVWQP development; however, have been omitted from this summary. This report also provides a discussion of conceptual regional groundwater understanding and pathways, and how mitigation measures implemented as part of the EVWQP should address groundwater protection objectives.

2 SUMMARY OF DRINKING WATER EVALUATION AND SAMPLING PROGRAM

A drinking water evaluation and sampling program was conducted in the Elk Valley watershed in 2013 and 2014; a summary of the program is provided below.

2.1 Objectives

As a result of ongoing monitoring activities completed by Teck, the potential was identified for drinking water sources in the valley to contain concentrations of Order constituents (cadmium, nitrate, selenium, sulphate) exceeding Health Canada's *Guidelines for Canadian Drinking Water Quality (GCDWQ, Health Canada 2012)*.

Objectives of the evaluation and sampling program were to:

- identify drinking water supplies in the Elk River watershed that may have higher potential to contain mine influenced water and potentially contain elevated concentrations of Order constituents related to mine influences; and
- evaluate whether concentrations of the Order constituents exceed applicable drinking water quality guidelines through completion of a drinking water supply sampling campaign.

The results were also used to inform protection of human health and groundwater components of the EVWQP.

2.2 Background Review, Framework Development, and Desktop Screening

The following describes the desktop steps for screening for the drinking water sampling program.

2.2.1 Background Review

A background review was used to develop a framework for desktop screening and select constituents for testing in the sampling program. The following documents and data sources were reviewed to develop a high-level understanding of surface water and groundwater quality in the Elk Valley:

- *Time Series Plots of Water Quality Data Reduced*, provided by Teck, November 21, 2013.
- *Review of Selenium in Groundwater*, Franz Environmental, #2204-1101; Revised Feb. 28, 2013.
- *District of Sparwood Source Water Protection Plan, Drinking Water Wells*. UMA Engineering Ltd. (UMA), 0764-251-00-02. Report dated January 2008.

- *Origin of Methane in the Elk Valley Coalfield, Southeastern British Columbia, Canada.* Chemical Geology, 195 (2003), 219-227.
- Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. BC Ministry of Water, Land and Air Protection, June 2002.
- *Hydrogeology of a Coal-Seam Gas Exploration Area, Southeastern British Columbia, Canada: Part 1. Groundwater Flow Systems*. Hydrogeology Journal, 8 (2000), p608-622.

<u>*Public Databases*</u>

- *Wells – Ground Water Wells and Aquifer Database.* BC Ministry of Environment. http://www.env.gov.bc.ca/wsd/ (accessed on several occasions between November 2013 and March 2014)
- *Sample History: Sample Parameter Report.* Interior Health Authority. https://www.interiorhealth.ca (accessed April 17, 2014)
- *EcoCat: The Ecological Reports Catalogue.* BC Ministry of Environment. http://www.env.gov.bc.ca/ecocat/ (accessed January 17, 2014)

Water quality data from the BC Environmental Monitoring System (EMS) were reviewed and surface water sampling stations and historical analytical data for the Elk River and Michel Creek in the EMS were relatively similar to the above-mentioned time-series plots. As such, the time-series plots were relied upon.

2.2.2 Assessment Framework Development

The assessment framework development was used to develop screening criteria to support the selection of water well and point of diversion (POD) sample locations for the drinking water sampling program. This was achieved by evaluating existing data and background information to identify criteria for priority areas and water wells or PODs considered to be potentially affected by Teck mining operations. The surface water to groundwater transport pathway was of particular interest as elevated concentrations of the Order constituents, specifically selenium, have been observed in the Elk River and Michel Creek[1]. Groundwater transport pathways from upland areas were not assessed as part of the framework; however, residential properties proximate to and hydraulically down-gradient of operational sites may have been captured in the framework described below.

[1] Elevated concentrations are also observed in the Fording River, however, residential properties and drinking water supplies which may provide drinking water sampling points were not identified near the Fording River.

For pathways related to surface water influence, the BC Ministry of Health (MoH) guidance document Guidance Document for Determining Ground Water At Risk of Containing Pathogens (GARP) Including Ground Water Under Direct Influence of Surface Water (GWUDI), dated April 2012 (BC Ministry of Health, 2012) identified initial criteria used to evaluate water supply sources that may be vulnerable to surface water influence (i.e., potentially hydraulically connected to impacted surface water). The GWUDI screening criteria considers drinking water sources with intakes less than 15 m below ground surface (bgs) and located within a 200-year floodplain of a watercourse. In addition, water sources less than 100 m outside the high water mark or natural boundary of a surface water feature with an intake less than 15 m below the high water level are included in the GWUDI screening (refer to Figures 1 and 2).

Figure 1: Profile showing well in 200-year floodplain with an intake less than 15 m bgs (Source: BC MoH GWUDI Guidance)

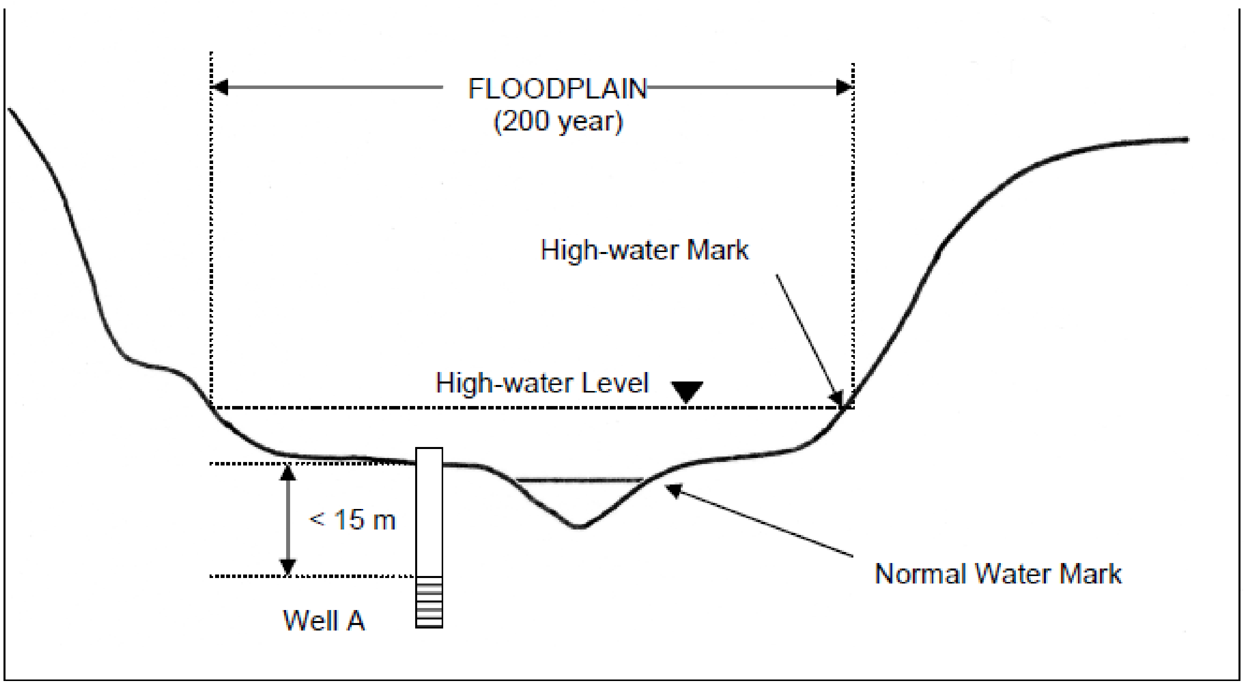
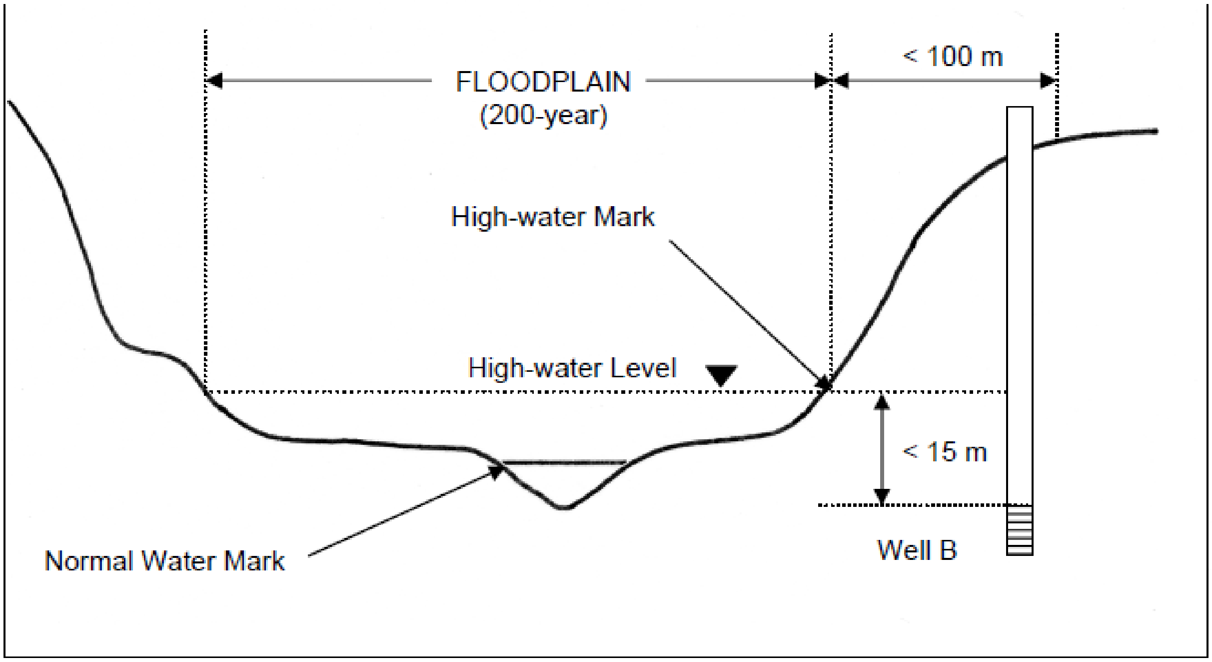


Figure 2: **Profile showing well within 100 m of the high water mark of 200-year floodplain with an intake less than 15 m below high-water level (Source: BC MoH GWUDI Guidance)**



A number of additional criteria were added based on results of the background review; a brief description of additional criteria and/or adjustments to the GWUDI framework is summarized below:

- **Adjustment of the well intake guideline based on District of Sparwood Supply Well #3:** This well was well screened between approximately 18 to 24 m bgs and interpreted to be under the influence of surface water. As such, the well intake depth criterion shown in Figures 1 and 2 was changed from <15 m bgs to ≤ 35 m bgs.

- **Removal of confining unit criteria:** The presence of a relatively thick (~7 m) confining clay unit at Well #3 did not preclude this well from being under the influence of surface water. As such, the GWUDI guidance on confining units (e.g., clay) above the well screen was disregarded.

- **Development of floodplain using LiDAR topography:** Since provincial floodplain mapping in the AOI was incomplete and considered out of date, floodplain mapping and interpretation was qualitatively performed for areas where no floodplain mapping existed, and adjusted where provincial floodplain mapping did not appear to be current and/or correct (i.e., based on comparison with 2013 aerial photos).

The floodplain was conservatively extended to an obvious break in slope in the Elk River valley using LiDAR topography provided by Teck, which provided elevation contours to a one metre accuracy.

- **Inclusion of points of diversion (POD):** Points of diversion with estimated elevations within approximately 5 m of the Elk River floodplain were addressed in the framework to include locations where surface water may be used for drinking water.

2.2.3 Desktop Screening

Based on the framework and criteria described above, SNC-Lavalin completed a desktop screening to delineate areas of interest and potential water source locations for the sampling campaign. Data sources used for the screening are provided above in Section 2.2 (background review), and listed below where used for screening purposes. The screening steps summarizes as follows, and below in Figure 3:

1) AOI Buffer Zone Maps – The first step in the evaluation was the development of a 100 m buffer zone extended out from the defined floodplain of the Elk River and Michel Creek per GWUDI guidance. The buffer zones and floodplain extents are shown on Drawings 615366-102A and 615366-102B.

2) Development of Well and POD Sampling List – Maps showing water wells from the MoE's *BC Water Resource Atlas* and the *WELLS Database* were superimposed on the buffer zones to develop a list of wells that fell within the buffer zones. Similarly, maps showing PODs obtained from *BC Points of Diversion with Water License Information* published by the MFLNRO Water Management Branch were superimposed on the buffers to develop a list of PODs. A total of 211 locations (171 registered groundwater wells and 40 licensed PODs) were identified.

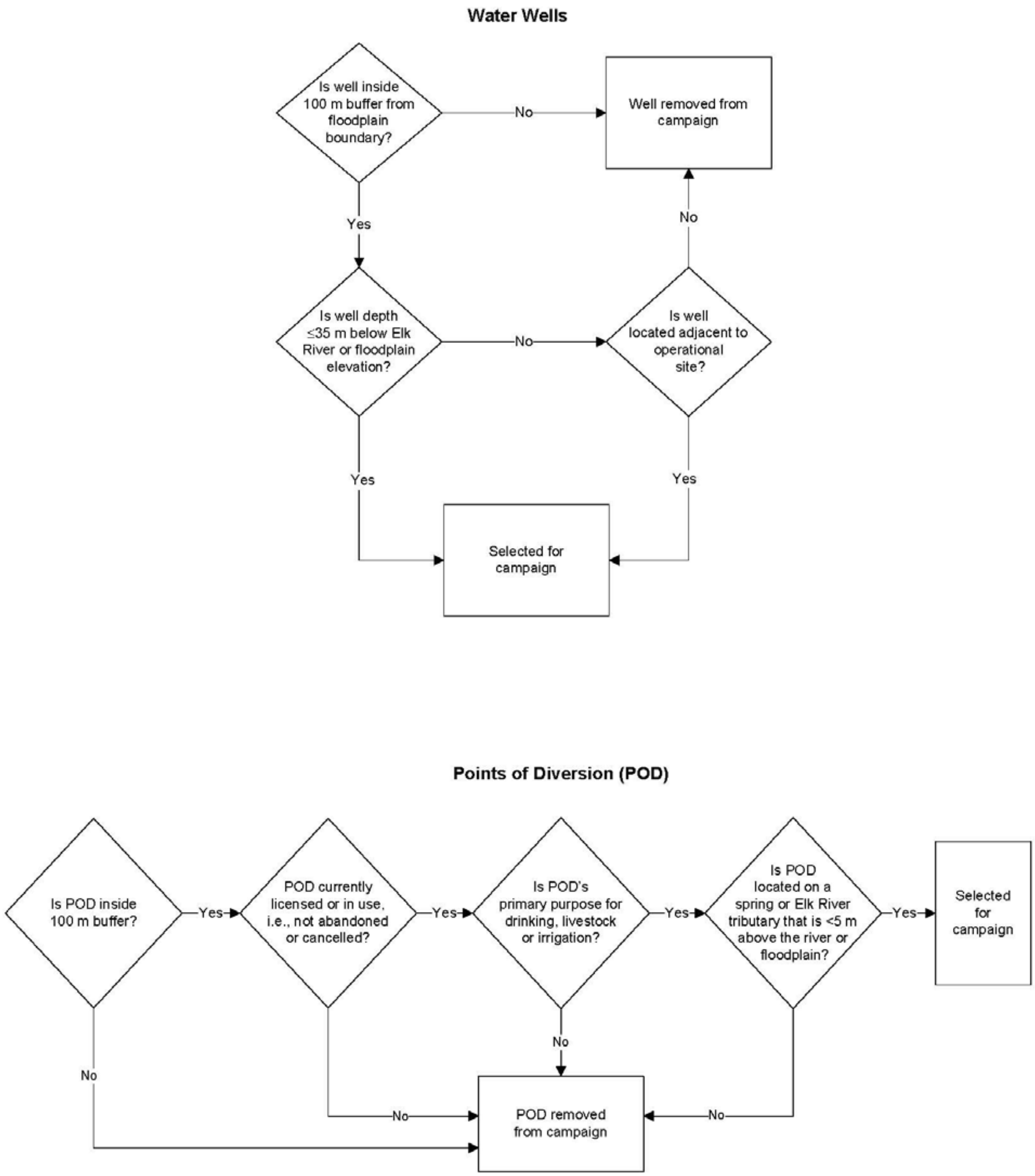
3) Well Screening Based on Depth – The list of initial wells was screened based on a well depth of ≤ 35 m bgs. Exceptions were wells located adjacent to operational sites, which were selected for inclusion regardless of depth.

4) POD Screening Based on Licence Designation or Purpose – The list of PODs was reduced by screening based on licence designations such as abandonment or cancellation. Several of the PODs in the database were listed to have "abandoned" or "cancelled" licences. Several more PODs were also removed from the list as their purpose was not indicative of a drinking or irrigation water use (e.g., overburden disposal, land improvement, sediment control, fire protection and mining-washing coal); the majority of these were owned by Teck.

5) POD Screening Based on Location and Elevation – The list of PODs were further screened based on their location and elevation with respect to the Elk River and its floodplain. Topographic data from LiDAR were used to determine the elevation of PODs. PODs located on springs or Elk River tributaries estimated to be at least approximately 5 metres above the river or floodplain were excluded. Additional screening was completed during field inspections to verify these locations.

6) Non-listed Potential Well/POD Search – Based on SNC-Lavalin's experience and input from the MoE, the Water Resources Atlas does not contain information for all drinking water sources in a particular area. As such, a secondary search of the entire study area (floodplains and 100 m buffer zones) was conducted by searching satellite imagery for homes, buildings or other structures that had potential to use a drinking water source but did not have a source listed in the well or POD databases. To obtain addresses for these locations for follow-up and obtaining water source information, a larger search was conducted of all registered properties whose boundaries intersected any of the buffer zone boundaries. Additional investigation to identify potential non-listed drinking water supplies was conducted during the field program as described below.

Figure 3: **Summary of Screening Framework**



Based on the framework development and desktop screening, 121 sample locations were initially targeted for the sampling campaign, and an additional 61 locations were added based on the extension/adjustment of the Elk River floodplain.

2.3 Field Preparation, Reconnaissance and Sampling Campaign

The following describes the resultant field program based on the desktop screening.

2.3.1 Invitations to Participate in the Sampling Campaign

Invitations to participate in the water supply sampling campaign were sent to owners of properties with water sources selected through the screening process described above, including municipalities with water supply wells within the buffer zones. In general, addresses and contact information were obtained from land title searches completed through BC Online using the parcel identifiers for each property. Included with the invitation packages were consent to access forms and questionnaires requesting additional information on water sources and usage for each property.

2.3.2 Field Reconnaissance

A field reconnaissance and letter drop campaign to attempt to capture water sources not existing in the databases was also completed. The reconnaissance was concurrent with the sampling campaign and targeted areas where known residential properties exist without water source information. Invitations were either sent in an initial mail-out campaign or delivered to locations during field reconnaissance requesting participation in the program. During field reconnaissance, some residents provided a verbal request to Teck to participate in the campaign. Consent to sample was received at that time, and as such, invitations were not mailed/delivered to these locations. Invitations were not mailed for Teck owned water sources, and in some cases where addresses could not be confirmed.

2.3.3 Sample Collection and Site Visits

SNC-Lavalin and Teck personnel (sampling team) checked in with the resident or site contact (or designate) at each sampling location upon arrival, and conducted an inspection of the water system where accessible. The study area was divided into seven segments (six segments numbered from north to south from Elkford to Fernie along the Elk River, and one segment for the area proximate to one of the Operations). Each sample location was given a site identifier number for sample identification which included reference to the segment.

Prior to collection of samples, the tap or valve at the sample location was opened to purge water for a minimum of five minutes. Once purged, samples were collected into laboratory supplied bottles. Samples for dissolved selenium analysis were field-filtered using a 0.45 µm filter and appropriately preserved in the laboratory-supplied container. Field monitoring for water quality parameters (pH/electrical conductivity/temperature) was completed during sample collection and recorded on a site-specific sample log and a hand-held GPS unit. Nitrile gloves were worn at all times during sampling. A total of 91 samples, plus 8 blind duplicates for Quality Assurance/Quality Control (QA/QC) were collected between February 17, 2014 and April 22, 2014. Samples were placed in ice-chilled coolers, and delivered to the laboratory within required hold-times for analysis.

Based on analytical results obtained during the sampling, additional sampling was proposed for locations where selenium results were either within 20% or exceeding the GCDWQ Maximum Acceptable Concentration (MAC) of 10 µg/L (i.e., locations where total and/or dissolved selenium concentrations were greater than 8 µg/L). Requests for re-sampling were sent to a total of seven locations, and a second set of samples were collected during re-sampling between April 22, 2014 and May 15, 2014 from each of these locations.

Constituents selected for analysis or measured in the field, and associated water quality guidelines, are summarized below in Table A.

Table A: List of Analytical Constituents and Guidelines

Constituent	GCDWQ Guidelines for Drinking Water[1]	BCWQ Guidelines for Livestock[4]
Selenium (total)	10 µg/L (MAC[2])	30 µg/L*
Cadmium (total)	0.005 mg/L (MAC[2])	0.08 mg/L
Sulphate	< than or = to 500 mg/L (AO[3])	1,000 mg/L (dissolved)*
Nitrate as Nitrogen	10 mg/L as N (MAC[2])	100 mg/L as N*
Nitrite as Nitrogen	1 mg/L as N (MAC[2])	10 mg/L as N*
Chloride	< than or = to 250 mg/L (AO[3])	600 mg/L*
Calcium	None	1,000 mg/L (dissolved)
Sodium	< than or = to 200 mg/L (AO[3])	None
Hardness	None	None
Electrical Conductivity (field)	None	1,400 to 4,200 µS/cm (species dependent)
pH (field)	6.5 – 8.5 s.u.	5.0 – 9.5 s.u.*

Notes:

1) Health Canada (2012)
2) MAC – Maximum Acceptable Concentration which is typically health based
3) AO – Aesthetic Objective and generally based on aesthetic considerations such as taste or odour
4) *British Columbia Approved Water Quality Guidelines (Criteria), updated 2014, includes (A Compendium of Working Water Quality Guidelines for BC, 2006).* British Columbia Ministry of Environment (MoE), May 2014. Approved guidelines noted by *, otherwise guideline is a Working guideline.

Samples were also collected from six locations in the Elk River on April 16, 2014 to provide additional Elk River data within the sampling campaign period.. One blind duplicate pair for Quality Assurance/Quality Control was also collected. Surface water samples were collected at locations summarized as follows:

Table B: Summary of Elk River Sample Locations – April 16, 2014

Sample ID	Easting	Northing	Location Description
FR_ELKDSBOIVIN_WP_2014-04-16_NP	649560.2	5543072	Elk River downstream of Boivin Creek confluence
RG_ELKDSFORD_WP_2014-04-16_NP and QA/QC duplicate DUPA-14-416	653174.6	5526900	Elk River upstream of Grave Creek, downstream of Fording River
EV_ER2_WP_2014-04-16_NP	652137.7	5512601	Elk River upstream of Michel Creek confluence
EV_ER1_WP_2014-04-16_NP	651344.6	5511189	Elk River downstream of Michel Creek at Canadian Pacific Railway (CPR) Roadhouse
RG_ELKHOSM_WP_2014-04-16_NP	646792.5	5494617	Elk River at Highway 3 bridge at Hosmer; sample upstream of bridge
RG_ELKFERNIE_WP_2014-04-16_NP	639721.0	5485340	Elk River at Fernie at Highway 3 West Fernie bridge near foot path

The samples were analyzed for the main list of analytical constituents listed above, as well as for dissolved organic carbon. Teck also provided surface water data for the Elk River from routine sampling completed in March 2014 for review and comparison with analytical data from the groundwater well and POD sampling campaign.

2.3.4 Quality Assurance/Quality Control

SNC-Lavalin followed strict QA/QC protocols for all sampling and analysis to ensure samples and data were handled accordingly. The QA/QC program included, but was not limited to, implementation of SNC-Lavalin preferred operating procedures (POPs), adherence to laboratory sampling and analysis protocols (e.g., hold times, sample containers, preservatives, detection limits, approved methodology), and submission of blind field QC duplicate samples at a rate of 10% of total samples.

Upon receipt and review of analytical results from the first several sample submissions, SNC-Lavalin and Teck noted concentrations of dissolved selenium were reported higher than total concentrations for samples collected at the same location. To investigate this anomaly, the following additional QA/QC measures were implemented:

- SNC-Lavalin and Teck contacted the laboratory regarding the results and requested additional information regarding interpretation of the results, and internal laboratory QA/QC protocols;

- Four field blanks were collected by passing distilled water through sampling and filtering equipment, and the samples were analyzed for total and dissolved selenium; and

A subset of 15 samples were collected and analyzed at two laboratories for total and dissolved selenium.

2.4 Results and Interpretation

The following provides a summary of the sampling program and interpretation of the results.

2.4.1 Field Parameters and Analytical Results

A summary of field-measured parameters for each of the sampling segments are provided below in Table C.

Table C: Summary of Field-Measured Parameters

Segment	Field Parameter (units)	Maximum	Minimum	Mean	n[a]
1	pH (s.u.)	8.3	7.7	8.0	10
	Electrical Conductivity (µS/cm)	748	343	435	
	Temperature (°C)	11.4	6.6	8.4	
2	pH (s.u.)	8.5	6.5	7.7	29
	Electrical Conductivity (µS/cm)	1,193	150	489	
	Temperature (°C)	18.4	2.4	7.1	
3	pH (s.u.)	8.2	7	7.7	4
	Electrical Conductivity (µS/cm)	886	399	555	
	Temperature (°C)	9.6	6.9	7.8	
4	pH (s.u.)	8.7	7.1	7.8	22
	Electrical Conductivity (µS/cm)	1,355	273	563	
	Temperature (°C)	12.6	3.1	7.8	
5	pH (s.u.)	8.5	7.5	8.0	13
	Electrical Conductivity (µS/cm)	640	189	459	
	Temperature (°C)	11.8	4	7.6	
6	pH (s.u.)	8.3	6.7	7.9	11
	Electrical Conductivity (µS/cm)	564	370	469	
	Temperature (°C)	13.1	4.2	7.7	
7	pH (s.u.)	8.2	7.3	7.8	2
	Electrical Conductivity (µS/cm)	1,388	465	927	
	Temperature (°C)	5.8	4.7	5.3	

[a] – n denotes sample size

2.4.2 Analytical Results – Residential and Municipal Supply Samples

A summary of results for the residential and municipal supply samples compared to drinking water and livestock watering quality guidelines is as follows:

- Concentrations of total and/or dissolved selenium exceeding the GCDWQ MAC were identified at five locations during the first round of sampling, representing approximately 5.5% of the total locations sampled. The highest selenium concentration measured was 14.3 µg/L.
- Concentrations of total and/or dissolved selenium within 20% or equal to the GCDWQ MAC (i.e., between 8 µg/L and 10 µg/L) were identified at three locations.
- During re-sampling at seven locations where consent to re-sample was received following receipt of results from the first round of sampling, selenium concentrations exceeded GCDWQ at 4 locations.
- Re-sampling results generally indicated similar concentrations to the initial sampling results, with the exception of one location where re-sampling results were substantially less than the original sample (i.e., total selenium concentration of 1.42 µg/L compared to an initial concentration of 9.48 µg/L). Field parameters during re-sampling were generally consistent with measurements obtained during the initial sampling event.
- Higher dissolved selenium concentrations compared to total selenium concentrations were reported in approximately 70% of the samples. SNC-Lavalin relied on the higher concentration for interpretation.
- Concentrations of sulphate exceeding the GCDWQ Aesthetic Objective (AO) of 500 mg/L were measured at one location downslope of one of the Operations during the first sampling event. Concentrations of sulphate were less than the GCDWQ during the re-sampling event.
- Concentrations of sodium exceeding GCDWQ AO were identified at one location. A water softening system was identified at this location, and is interpreted to be the source of the elevated sodium. Concentrations of chloride exceeding GCDWQ AO were identified at one location. A source of chloride was not confirmed; however, based on the low concentrations of main mine-indicator constituents at this location, the elevated chloride is inferred to be associated with a local source and not mining influences.
- Concentrations of the remaining constituents analyzed with drinking water guidelines were less than GCDWQ MAC and AO at all other sample locations.
- Concentrations of all constituents analyzed were less than BCWQG Livestock Watering standards at all sample locations.

- Samples analyzed for DOC during re-sampling at select locations contained concentrations ranging from <0.5 mg/L (05-02) to 2.01 mg/L (02-18).

2.4.3 Elk River Samples

The following provides a summary of the analytical results for samples collected from the Elk River on April 16, 2014, compared to GCDWQ and BCWQG for Livestock Watering.

- Concentrations of dissolved and total selenium exceeded GCDWQ at each location with the exception of location FR_ELKDSBOIVIN, collected in the Elk River downstream of the Boivin Creek confluence and upstream of the confluence with the Fording River. The highest selenium concentration was measured at location RG_ELKDSFORD, collected downstream of the confluence with the Fording River. Concentrations of selenium were less than BCWQG for Livestock Watering.
- Concentrations of the remaining constituents analyzed were less than GCDWQ and BCWQG for Livestock Watering.
- Concentrations of DOC ranged from 1.33 mg/L to 2.16 mg/L, generally higher than DOC concentrations measured in the drinking water sources.

2.4.4 Quality Assurance/Quality Control

Field duplicate samples were submitted on an approximate 10% frequency for analysis, as a QA/QC measure. A total of nine field duplicate sample pairs were analyzed during the sampling program.

SNC-Lavalin's target for RPD value for metals and inorganics concentrations in water is 30%. For the nine duplicate sample pairs analyzed, some RPDs could not be calculated because they were less than five times the method detection limit. The remaining RPDs were less than the 30% target.

The field blank and subset samples collected to evaluate discrepancies between dissolved and total selenium concentrations indicated sampling equipment and sampling procedures were not contributing to these results. Concentrations of dissolved and total selenium in field blanks were both less than laboratory detection limits. Concentrations of total and dissolved selenium in subset samples (i.e., samples from the same location analyzed by both ALS and Maxxam) were consistent, and within approximately 10% for each subset sample. Maxxam also reported dissolved concentrations higher than total concentrations in approximately 60% of the subset samples. Maxxam and ALS both reported the difference in concentrations were acceptable according to internal laboratory QA/QC protocols. As discussed above, SNC-Lavalin relied on the higher concentrations for results interpretation.

SNC-Lavalin considers that the results of the QA/QC analyses support the reliability of the analytical and sampling program.

2.4.5 Inferred Transport Pathways for Selenium and Groundwater Types

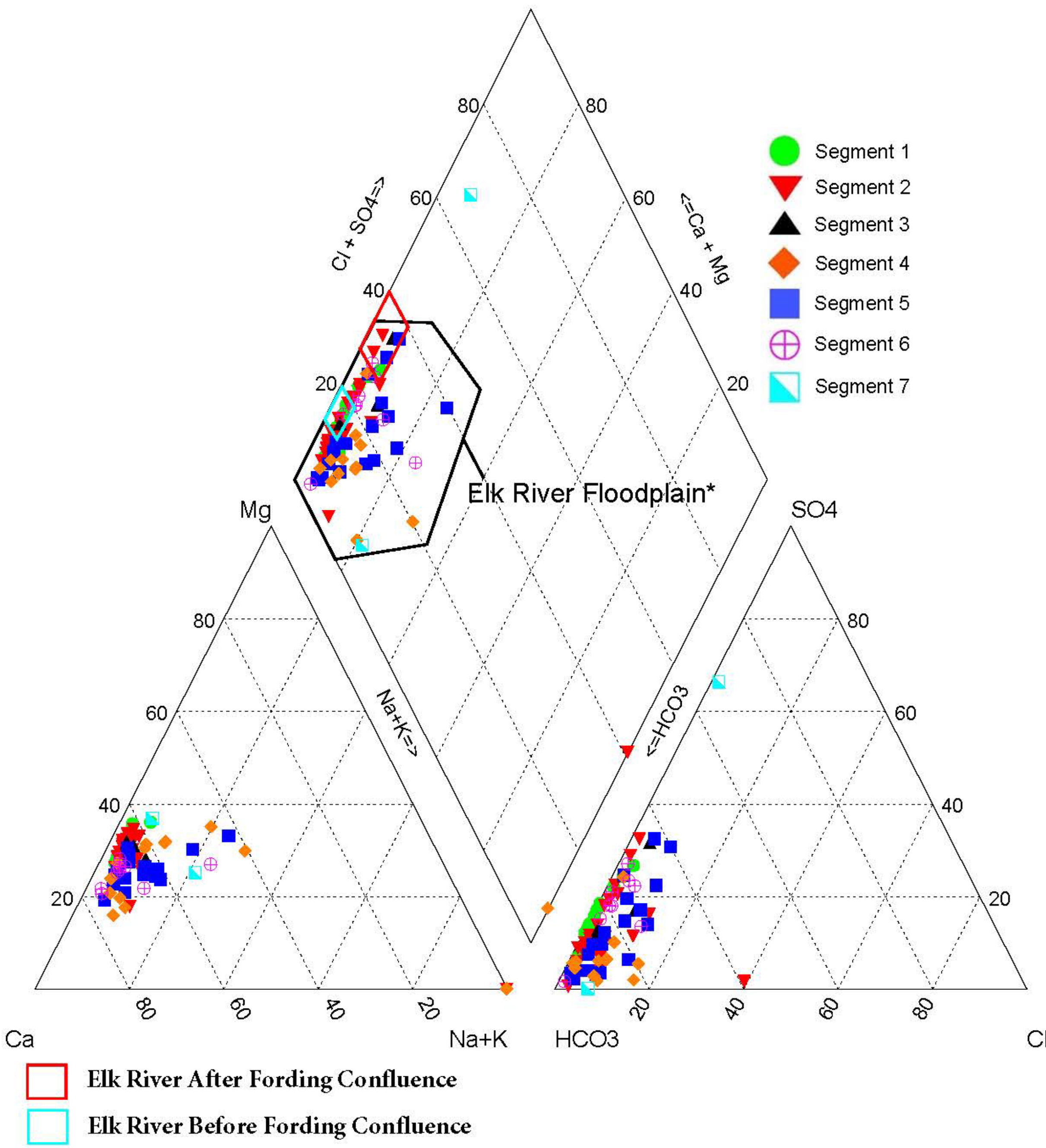
Elevated selenium concentrations were noted downslope of one of the Operations and four locations in the Elk River floodplain. These two areas are in two distinct hydrological settings (i.e., Operations exist in an upland environment vs. the Elk River floodplain); as such, two main transport pathways for dissolved selenium to groundwater appear to be present based on this study:

1) **Source release to groundwater:** assumes selenium is released from source material (e.g., waste rock) and elevated selenium concentrations in groundwater results from leaching and infiltration at up-gradient locations. This transport pathway is expected to occur in the vicinity of and hydraulically down-gradient from the respective Operations; and,

2) **Surface water recharge to groundwater:** assumes surface water is elevated in selenium and elevated selenium concentrations in groundwater results from surface water recharge to groundwater. It is noted that this pathway is considered to be applicable in the floodplain where groundwater has a direct hydraulic connection with surface water.

The major ion chemistry for these two transport pathways appears to be relatively different as sulphate concentrations for the source release pathway appear to be relatively higher. Note that only one location near an operational site exceeded the guideline for selenium and reported relatively higher sulphate concentrations; however, corporate experience at other sampling locations in the vicinity of the operational sites indicates higher sulphate concentrations are present in the upland setting. Piper plots are a good way of characterizing groundwater by major ion chemistry to assess groundwater sources and transformations. There appears to be two distinct water types, as shown in Figure 4, below.

Figure 4: Piper Plot Showing Major Ion Chemistry



* Indicates one sample from the Elk River Floodplain sample subset from Segment 7 (i.e., upland)

These two distinct types appear to be reflective of the two main transport pathways; in the upland setting the groundwater type was Ca-Mg-SO_4-HCO_3, whereas the Elk River floodplain groundwater type was a Ca-Mg-HCO_3 or Ca-Mg-HCO_3-SO_4.

2.4.6 Surface Water-Groundwater Interactions in the Elk River Floodplain

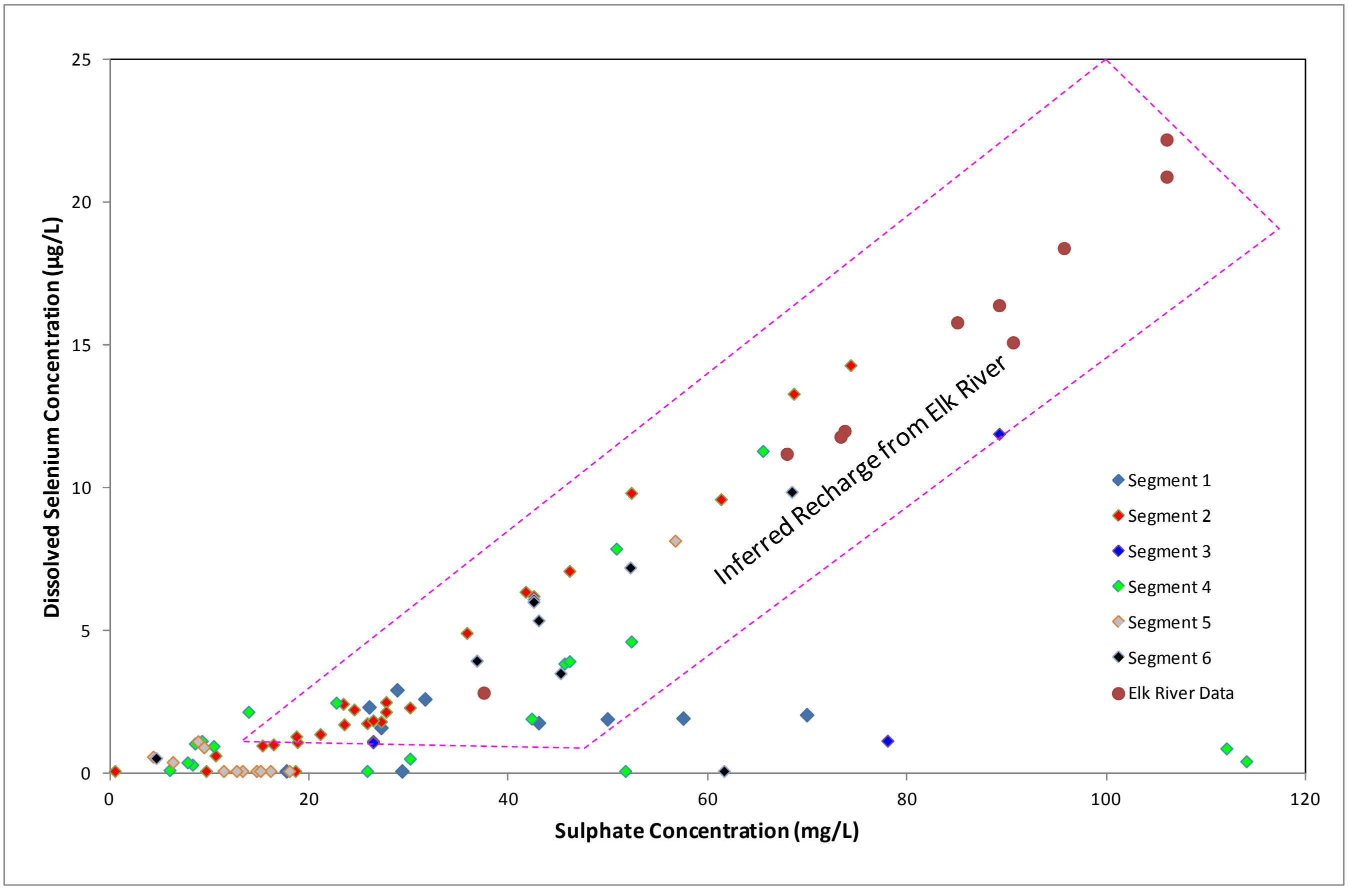
The main focus of this study was the surface water to groundwater transport pathway and most of the drinking water sources are located within the Elk River floodplain; as such, the discussion below is on groundwater quality in the Elk River floodplain. Also, the majority of the discussion below is on selenium as that was the only constituent that exceeded water quality guidelines through transport in groundwater (with the exception of sulphate at one location, and sodium/chloride exceedences inferred to be related to an onsite source).

2.4.7 Inferred Groundwater Quality in Comparison to the Elk River

Assuming the water sources are representative of groundwater (i.e., proper well construction and no hydraulic connection to the surface), additional distinctions in water types can be made for the locations with elevated selenium concentrations in the Elk River floodplain. Minor distinctions in water types for groundwater show that all of the exceedences for selenium from the surface water pathway are of Ca-Mg-HCO_3-SO_4 water type. This is the same water type as the Elk River after the confluence with the Fording River. As such, selenium exceedences in the Elk River floodplain appear to result from recharge from the Elk River.

A comparison of dissolved selenium with other constituents was performed to assess the degree to which the elevated selenium concentrations appear to be resultant from the Elk River. Figure 5 below provides a comparison of dissolved selenium to sulphate for Segments 1 to 6 along the Elk River floodplain. The majority of samples from the Elk River plot in the upper right portion of the graph (i.e., where sulphate concentrations are high, dissolved selenium concentrations are high). A number of locations in Segments 1 to 6 exhibit a similar relationship (i.e., plot along a similar line) to the Elk River samples; as such, it is inferred that these locations are related to recharge of groundwater from the Elk River. An outline of which samples may be related to recharge from the Elk River is qualitatively shown in Figure 5.

Figure 5: Comparison of Dissolved Selenium and Sulphate Concentrations for Segments 1-6

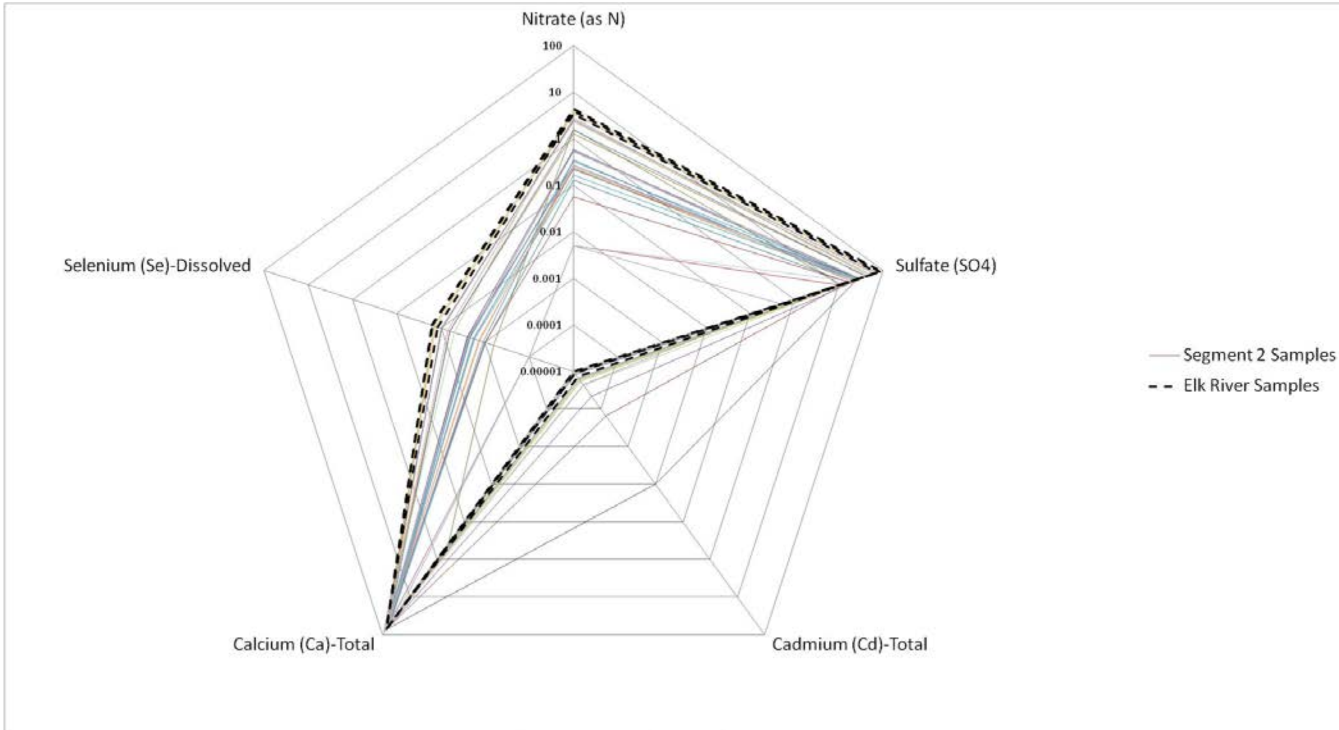


The relationship of nitrate-nitrogen and dissolved cadmium with dissolved selenium in groundwater the Elk River floodplain does not appear to be as strong.

2.4.8 General Spatial Water Quality Trends

Selenium concentrations measured at locations sampled in the floodplain appear to vary spatially by Segment. Segment 2 appears to have the strongest relationship with sulphate and as such it is inferred that a relatively higher component of Elk River recharge occurs in this area. The majority of water supply sample locations with selenium concentrations above 8 µg/L in the AOI were reported from the southern portion of this Segment, after the confluence of the Elk and Fording Rivers. In addition, the relationship between other constituents to the Elk River is stronger in Segment 2. This is illustrated in Figure 6 below, which is a rose diagram showing constituent assemblages for the Elk River surface water samples and water supply locations sampled in Segment 2.

Figure 6: Rose Diagram Including Selected Constituents for Segment 2



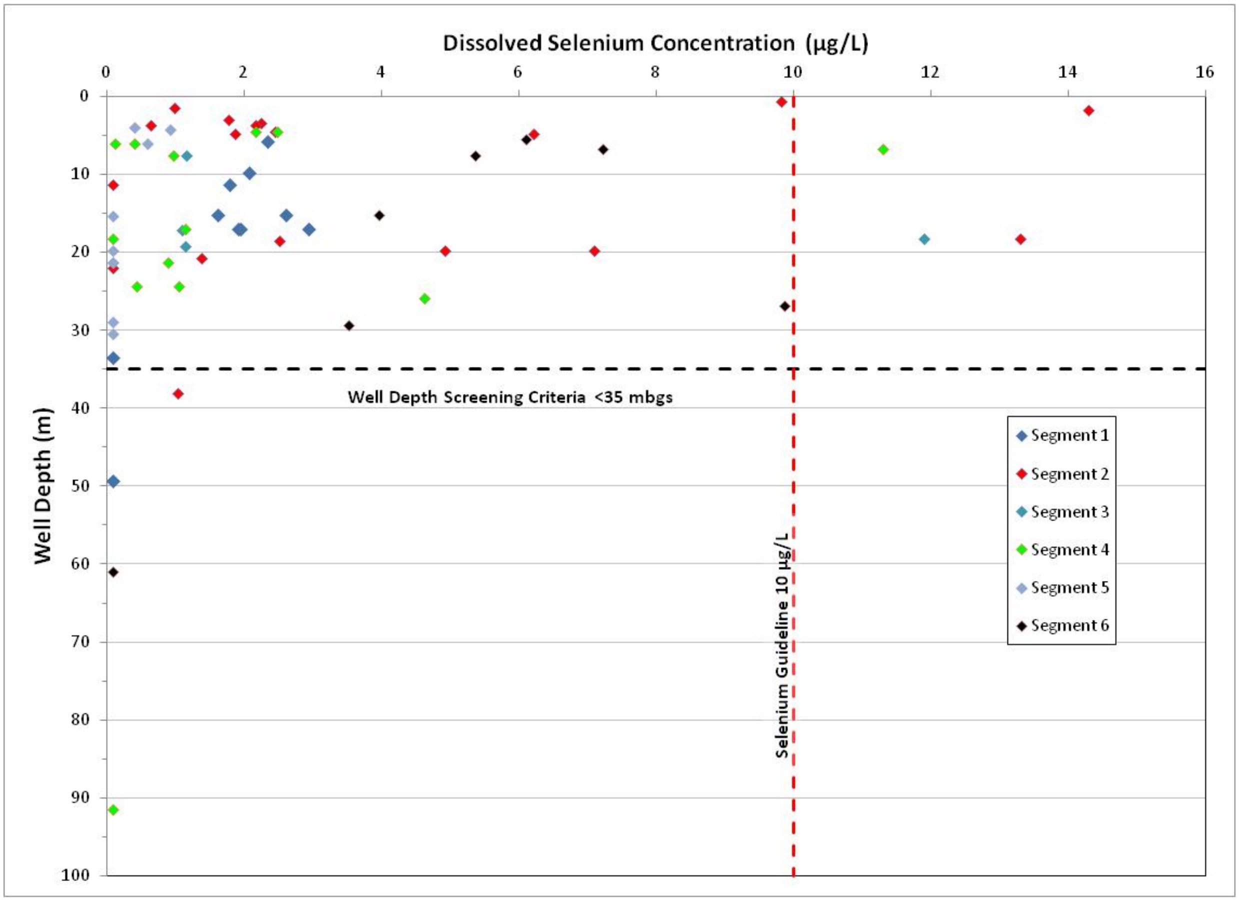
Note: Sodium and Chloride are not included due to bias from other potential sources such as water softeners

The figure above shows concentrations of the constituent assemblages on log axes for the Elk River and Segment 2 samples. Concentrations of each parameter, with the exception of cadmium, are higher in the Elk River as shown in Figure 6 (i.e., the Elk River samples plot on a larger footprint). The relatively similar symmetry of the constituent assemblages between Segment 2 and the Elk River suggests the relative proportions of these constituents are similar; and as such Elk River recharge and subsequent dilution of groundwater from fresh water sources appears to be occurring in Segment 2.

2.4.9 General Vertical Water Quality Trends

In general, there does not appear to be a strong relationship of selenium concentrations with well or POD intake depth (i.e., concentrations drop significantly below a certain depth) across the AOI; however, relatively low selenium concentrations were reported in four samples collected from wells deeper than approximately 35 m bgs as shown in Figure 7 below. The decreasing trend in selenium concentrations with depth provides support for the initial desktop screening, which excluded water wells at depths greater than 35 m bgs.

Figure 7: Dissolved Selenium Concentrations with Well Depth for Segments 1-6



The general decrease in selenium concentrations below 15 m bgs suggests that the majority of recharge to groundwater from the Elk River is relatively shallow and wells screened across deeper intervals are less influenced by the Elk River.

2.4.10 Inferred Hydraulic Gradients

2.4.10.1 Natural Hydraulic Gradients

As discussed above, groundwater in the southern portion of Segment 2 appears to have a relatively strong component of surface water recharge from the Elk River. None of the locations sampled in this area indicated a high degree of domestic water usage (e.g., community water well, industrial use, etc.); as such, based on available information the hydraulic gradient and groundwater flow regime is inferred to be natural and uninfluenced by water extraction. Therefore, elevated selenium concentrations reported in the southern portion of Segment 2 appear to result from Elk River recharge and groundwater transport under a natural hydraulic gradient.

The floodplain in the southern portion of Segment 2 is downstream of the confluence with the Fording River. Downstream of this confluence, the Elk River horizontal gradient increases to approximately 0.007 m/m from approximately 0.0028 m/m. Bedrock is present at the confluence which may locally affect river grade and groundwater recharge. Concentrations in the Elk River were also highest after this confluence. Elevated selenium concentrations were reported in samples from the eastern portion of the floodplain in this area along a minimum length of 2.8 km and a depth of up to 24.4 m bgs. These exceedences may result from the higher river gradient providing more recharge of higher selenium concentrations in the Elk River along this reach.

2.4.10.2 Induced Hydraulic Gradients

In contrast, the elevated selenium concentrations measured at the District of Sparwood Well #3 is likely due to an induced hydraulic gradient from water extraction. This well is pumped on average approximately 3,000 m^3/day (UMA Engineering, 2008) and the capture zone for this well is inferred to be relatively large when compared to the majority of domestic water wells in the Elk Valley; as such, Elk River recharge and therefore elevated selenium can be transported to greater depths.

In general, where individual domestic wells have exceedences and show similar chemistry to the Elk River, a natural gradient similar to the river can be inferred and a more widespread influence of the Elk River is possible. Also in general, where community water wells are present, an induced gradient from pumping and therefore more localized impact can be inferred. Recharge from the Elk River may be able to reach greater depths under an induced gradient.

2.4.11 Limitations, Data Gaps and Uncertainties

The campaign invitations and field reconnaissance were successful in obtaining consent for sampling; however, no water quality data were obtained for locations that did not respond or did not provide consent for sampling and as such water quality for those water sources is unknown. We also note that while reasonable reconnaissance efforts were undertaken, residences with water sources not existing in the database and not captured by reconnaissance likely still exist.

It is noted that the sampling of water wells and PODs provides a relatively high level understanding of groundwater; however, the study did provide an initial assessment of water quality in the valley that is likely sufficient to inform management decisions. The following data gaps are noted:

- There are limited data on the source release to groundwater transport pathway, which consists of groundwater in upland areas that is hydraulically down-gradient from the respective Operations. SNC-Lavalin notes, however, that groundwater monitoring programs at each of the Operational facilities are in progress or under development and will provide additional data related to this pathway;

- There is no seasonal water quality information, with the exception of location 03-04 (i.e., Well #3 at the District of Sparwood which appears to be under direct influence from surface water). Seasonal variations in selenium concentrations have been noted in the Elk River and similarly, they may also vary in groundwater;
- Well yields, pumping information and subsurface lithology are poorly understood; and,
- An assessment of background concentrations of selenium in groundwater in the AOI was not performed.

The following uncertainties on groundwater quality exist:

- The spatial extent was limited to property owners that provided consent for sampling;
- Water well construction and surface seal quality is generally unknown,
- Water wells may be screened over multiple hydrostratigraphic formations; and,
- Water wells and PODs may not be properly maintained.

3 PRELIMINARY REGIONAL CONCEPTUAL HYDROGEOLOGICAL MODEL

SNC-Lavalin has developed a preliminary regional hydrogeological conceptual model for the Elk Valley based on information from the drinking water evaluation, brief review of existing conceptual models and published literature (e.g., references listed in the Background Section and Rivera, 2014), and SNC-Lavalin corporate experience in the Elk Valley. The preliminary conceptual model described below should be considered high-level as no supporting data set is provided.

The Elk and Fording Rivers exist within former glacial valleys carved into bedrock with the majority of surficial deposits present at the base of the Elk Valley. Regionally, two general groundwater hydrogeological settings appear to be present: upland groundwater consisting of groundwater on the adjacent mountain slopes and lowland (e.g., floodplain groundwater), consisting of groundwater present in the valley bottoms.

3.1.1 Upland Groundwater Occurrence and Flow Regime

Slopes of the adjacent mountains are considered to consist of unconsolidated surficial deposits (primarily colluvium) overlying sedimentary bedrock; however, some terraces comprising glacial-related deposits are present. A number of tributary creeks, some ephemeral, exist on the valley slopes. The difference in permeability and hydraulic conductivity between surficial deposits and bedrock may be relatively significant and, as such precipitation (rainfall and snow melt) in the tributary catchments recharges surficial aquifers and discharges into the creeks with limited interaction with the underlying bedrock. Therefore, tributaries would be considered 'gaining' systems (i.e., receiving discharge from groundwater); however, where tributaries flow across thicker, generally unsaturated terraces, surface water recharge to groundwater may be occurring. It is noted that some larger tributaries with more incised valleys may have a deeper component of groundwater that does not daylight.

Groundwater occurrence and flow in bedrock likely occurs along fractures, faults and joints within the bedrock and discharge from bedrock would typically only be from outcropping or sub-cropping of groundwater-bearing fracture or fault zones. Where the Mist Mountain Formation is present, groundwater within bedrock would be generally perched on low permeability coal seams which can control the regional bedrock groundwater flow regime.

3.1.2 Elk River Floodplain (Lowland) Groundwater Occurrence and Flow Regime

In the Elk River floodplain, unconsolidated lithology consists of variable deposits of cobbles, gravel, sand and gravel, sand, silt, clay and till. The expected depositional environment in the floodplain would be alluvial or fluvial, including overbank deposits, overlying deposits of glacial, glaciofluvial and glaciolacustrine origin.

Upstream of the confluence with the Fording River the valley gradient is irregular, and downstream the gradient is more typical of an alluvial slope due to increased river discharge. Geomorphology of the Elk River is a wandering gravel-bed which represents an intermediate condition between meandering and braided rivers (Northwest Hydraulic Consultants, 2006). Groundwater-surface water interactions in wandering rivers can be relatively complex and are highly influenced by local morphology and river gradient, permeability of the underlying materials and seasonality (Driscoll, 1995). Depending on the presence of confining layers, deeper groundwater may not interact with either shallow groundwater or surface water.

Shallow groundwater in a floodplain is typically unconfined. Groundwater flow direction is typically parallel or sub-parallel to the valley as the river provides continuous recharge to the underlying sediments. In steep river valleys such as the Elk River Valley, additional recharge can result from upland tributaries and as such, mounding of the groundwater table in the vicinity of the alluvial fan of the tributary would be expected. Where meanders are oriented perpendicular or semi-perpendicular to the predominant groundwater flow direction (i.e., down-valley), groundwater recharge or discharge may occur. These interactions will likely depend on the elevation of the river vs. adjacent groundwater which may be locally affected by river morphology.

3.1.3 Potential Sources, Transport Pathways and Uses for Groundwater

Based on the drinking water evaluation and sampling program, two main groundwater transport pathways for mine-related constituents were identified, listed below in relation to the preliminary conceptual model:

- **Source release to groundwater:** Groundwater transport from source areas would be expected to occur in the vicinity of and hydraulically down-gradient from respective Operations. In general, the majority of mining Operations exist in the upland setting, with tributaries of the Elk and Fording Rivers flowing into the main stems of those rivers. Groundwater transport of mine-related constituents in tributary catchments in the upland setting would be expected to discharge to surface water unless the valley was highly incised. It is noted that components of certain Operations do exist in the lowland setting (i.e., Elk or Fording floodplains) which may result in transport of mine-related constituents in the floodplain; and,

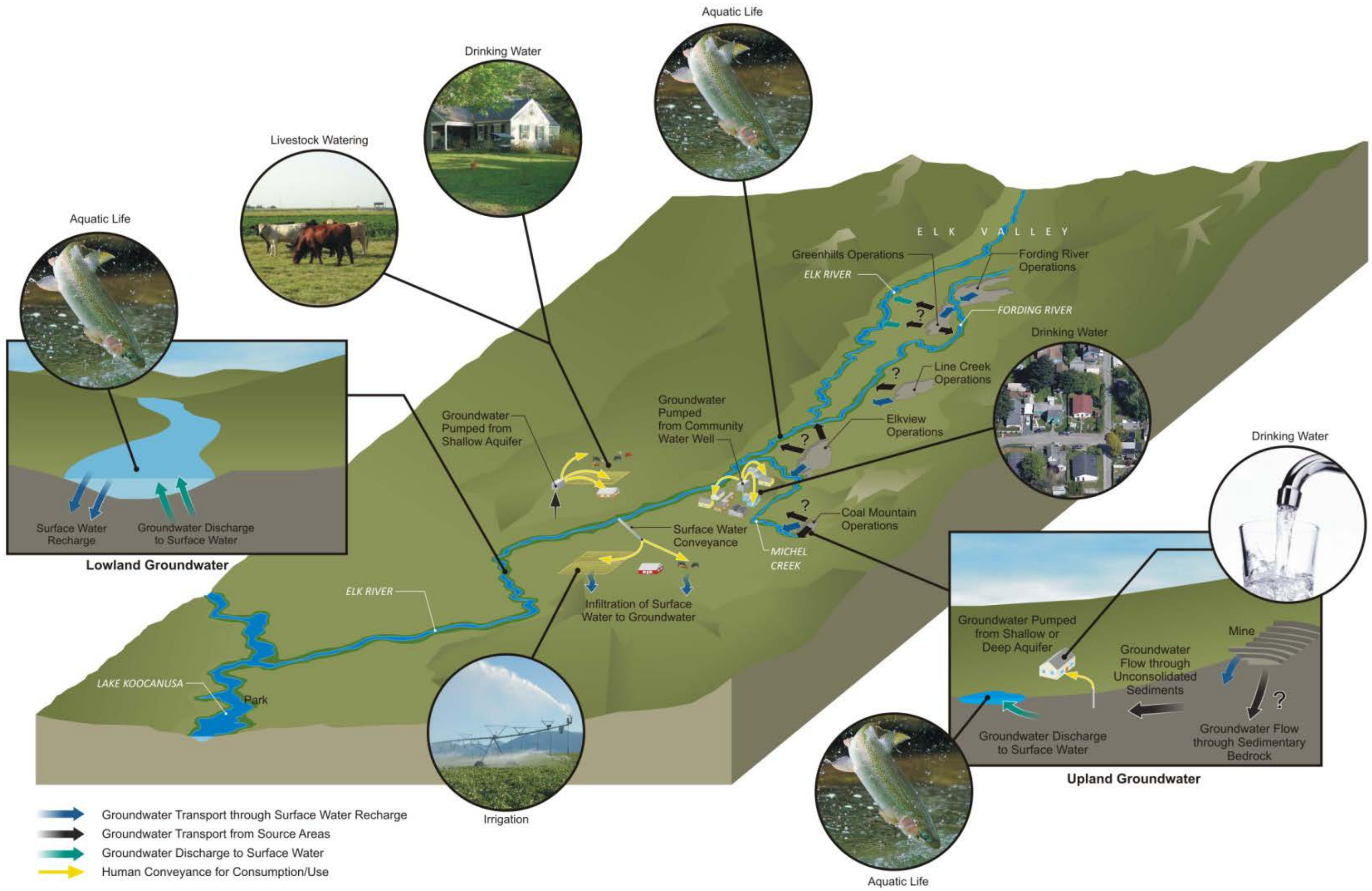
- **Surface water recharge to groundwater:** where constituents are present in surface water, transport of mine-related constituents to groundwater through surface water recharge is expected. Concentrations of mine constituents would therefore be related to surface water concentrations (current and historical) where a hydraulic connection is present.

Current and future uses of groundwater in the Elk Valley are considered to be as follows:

- Human – protection of groundwater for drinking water, irrigation
- Livestock – protection of groundwater for livestock watering
- Aquatic Life and Wildlife – protection of groundwater for discharge to aquatic environments.

Figure 8 below presents a preliminary conceptual model of the general hydrogeological settings (i.e., upland vs. lowland) conceptual groundwater transport pathways, and water uses in the Elk Valley.

Figure 8: Conceptual Model - Groundwater Transport Pathways and Use



4 MANAGEMENT STRATEGIES FOR PROTECTION OF GROUNDWATER

Teck are currently planning and/or implementing management strategies for the reduction and/or mitigation of Order constituents in surface water. Applicable strategies related to protection of groundwater may include: source reduction measures, water treatment, water diversion, ecological risk assessment for protection of aquatic life in river main stems; and human health risk assessment. These measures, or a combination thereof, are anticipated to comprise the main management strategies for the protection of groundwater.

The current understanding and preliminary hydrogeological conceptual model identified two transport pathways for mine-related constituents, listed below with areas and strategies for groundwater protection:

1) Source release to groundwater, where areas/aquifers hydraulically down-gradient of identified source areas may require protection. Conceptually, these areas/aquifers could exist in both upland and lowland hydrogeological settings. At present, the respective Operations are assessing source transport pathways within and adjacent to their property boundaries to improve understanding of groundwater at an operational (local) level. Results of these programs will be used to help improve Teck's understanding of local groundwater in relation to potential mitigation scenarios; and,

2) Surface water recharge to groundwater, where areas/aquifers are subject to surface water losing water to ground and recharging groundwater. Conceptually, these areas typically exist in the floodplain environment, but may also be present in elevated alluvial terraces where tributaries may recharge groundwater. Existing mitigation and management strategies for surface water are anticipated to be applicable to the surface water transport pathway based on the drinking water evaluation, and will also reduce concentrations in groundwater in locations where surface water infiltrates to ground or recharges groundwater (e.g., losing tributaries).

In general, planned or completed mitigation actions to achieve other outcomes outlined in the Order (e.g., protection of aquatic ecosystem health, protection of human health) are ultimately anticipated to reduce constituent concentrations in groundwater and address groundwater protection requirements where surface water recharge to groundwater. Additional actions and management strategies may be required solely for the protection of groundwater, and/or protection of receptors utilizing groundwater, and will be determined through assessment and execution of the groundwater monitoring and management plans at each of the operational facilities currently in progress. If areas are identified where immediate action is warranted to protect groundwater and certain receptors, an approach for protection will be prepared on a case-by-case basis at the operational level, and will outline operational and/or institutional actions necessary to protect groundwater.

5 GENERAL LIMITATIONS AND CONFIDENTIALITY

NOTICE TO READER

This report has been prepared by the Environment & Water business unit of SNC-Lavalin Inc. (SNC-Lavalin) for the exclusive use of Teck Coal Ltd., who has been party to the development of the scope of work for this project and understands its limitations. The methodology, findings, conclusions and recommendations in this report are based solely upon the scope of work and subject to the time and budgetary considerations described in the proposal and/or contract pursuant to which this report was issued. Any use, reliance on, or decision made by a third party based on this report is the sole responsibility of such third party. SNC-Lavalin accepts no liability or responsibility for any damages that may be suffered or incurred by any third party as a result of the use of, reliance on, or any decision made based on this report.

This report is intended to provide information to Teck Coal Ltd. to assist it in making business decisions. SNC-Lavalin is not a party to the various considerations underlying the business decisions, and does not make recommendations regarding such business decisions. In providing this report, SNC-Lavalin accepts no liability or responsibility in respect of the site described in this report or for any business decisions relating to the site, including decisions in respect of the purchase, sale or investment in the site.

The findings, conclusions and recommendations in this report (i) have been developed in a manner consistent with the level of skill normally exercised by professionals currently practicing under similar conditions in the area, and (ii) reflect SNC-Lavalin's best judgment based on information available at the time of preparation of this report. No other warranties, either expressed or implied, are made as to the professional services provided under the terms of our original contract and included in this report. The findings and conclusions contained in this report are valid only as of the date of this report and may be based, in part, upon information provided by others. If any of the information is inaccurate, new information is discovered, site conditions change or applicable standards are amended, modifications to this report may be necessary. The results of this assessment should in no way be construed as a warranty that the subject site is free from any and all contamination.

Any soil and rock descriptions in this report and associated logs have been made with the intent of providing general information on the subsurface conditions of the site. This information should not be used as geotechnical data for any purpose unless specifically addressed in the text of this report. Groundwater conditions described in this report refer only to those observed at the location and time of observation noted in the report.

This report must be read as a whole, as sections taken out of context may be misleading. If discrepancies occur between the preliminary (draft) and final version of this report, it is the final version that takes precedence. Nothing in this report is intended to constitute or provide a legal opinion.

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6 REFERENCES

Driscoll, F., 1995. Groundwater and Wells. Johnson Screens, St. Paul, Minnesota, ISBN 0-9616456-0-1, 1089 pp.

Northwest Hydraulic Consultants, 2006. City of Fernie Elk River Flood Hazard Assessment, prepared for the City of Fernie. March 2006.

Rivera, A. (compiled and edited), 2014. Canada's Groundwater Resources. Fitzhenry and Whiteside, Markham ON, 803pp.

DRAWINGS

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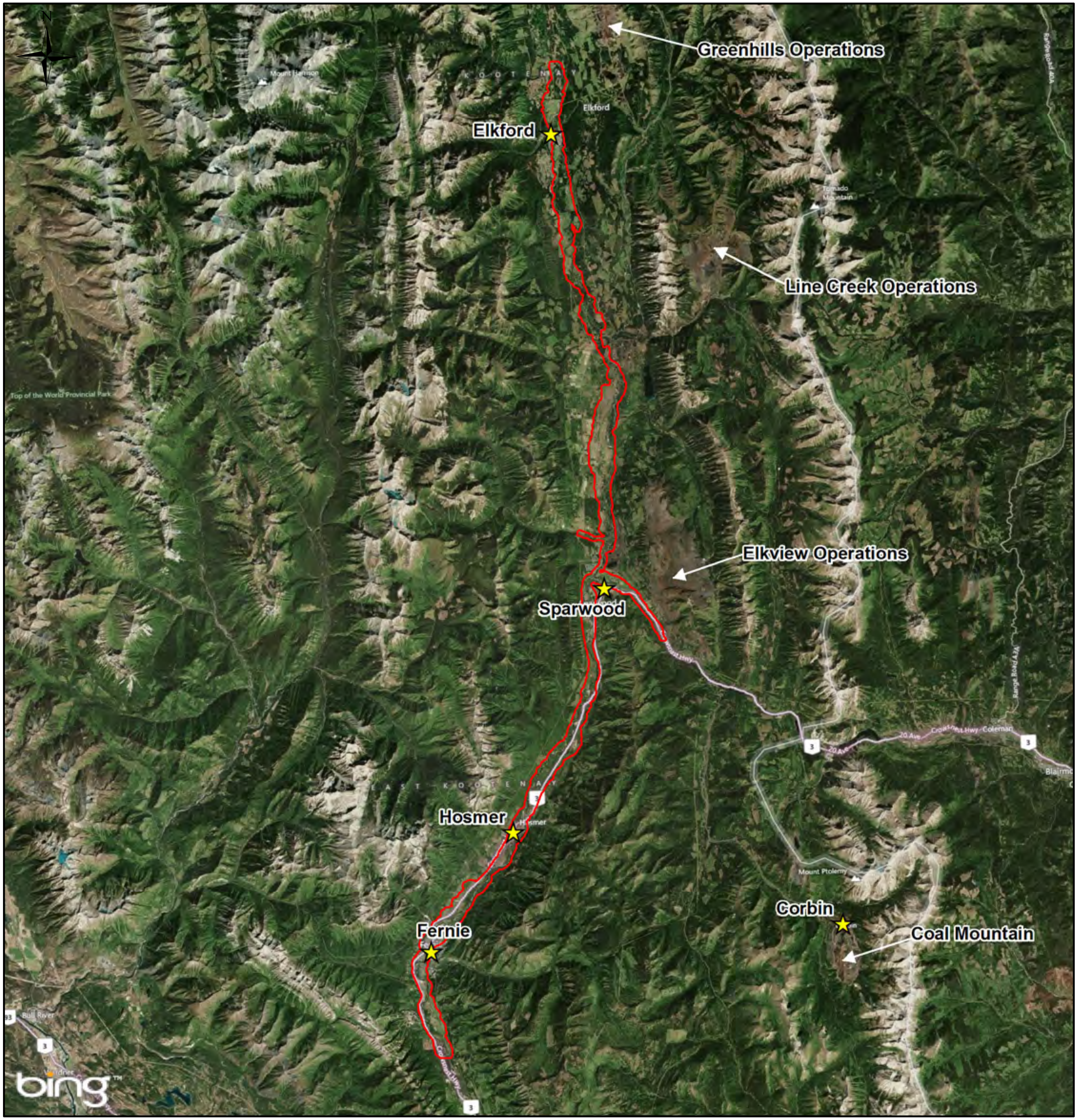
4. 615366-001 Location Plan and Area Of Interest
5. 615366-102A Elk River Floodplain and 100 m Buffer – Elkford to Sparwood
6. 615366-102B Elk River Floodplain and 100 m Buffer– Sparwood to Fernie



LEGEND

Area of Interest

Community

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REFERENCES

1. BCGOV ILMB Crown Registry and Geographic Base Branch (CRGB) (data accessed through www.GeoBC.gov.bc.ca)

2. GPS Data Collected using an eTrex. Accuracy expected to be approximately +/- 3.5m.

0 2.5 5 10 15 20 Kilometers

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CLIENT NAME: Teck Coal Ltd.	PROJECT LOCATION: Elk Valley British Columbia

Location Plan and Area of Interest

AUTHOR: DMB	SCALE: 1:400,000
CHK'D: SAH	DATE: 2014/06/05
PROJ COORD SYS: NAD 1983 UTM Zone 11N	REF No: 615366-001 REV: 0

Project Path:

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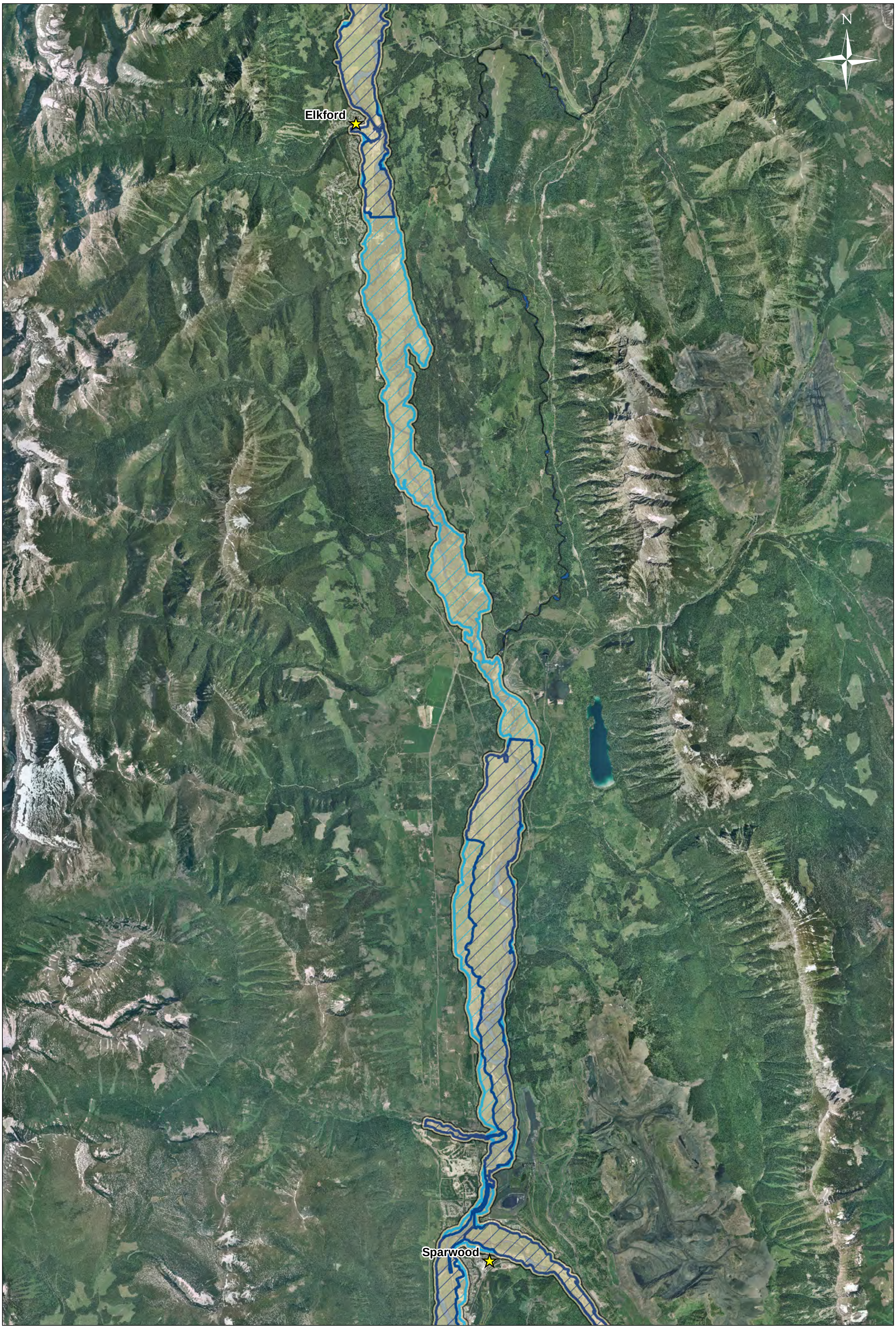

LEGEND

- Approximate Floodplain Extent (Gov BC Data)
- SNC Interpreted Floodplain (Based on Topography)
- 100m Buffer on Floodplain
- ☆ Community

NOTES

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2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
4. Floodplain extent approximated based on BC Floodplain data and LiDAR data provided by Teck Metals Ltd.

REFERENCES

Base imagey provided by Teck Coal Ltd.

0 1 2 4 6 Kilometers

SNC · LAVALIN

CLIENT NAME: Teck Coal Ltd.

PROJECT LOCATION: Elk Valley British Columbia

Elk River Floodplain and 100m Buffer - Elkford to Sparwood

BY:	DB	DATE:	2014/07/15	REF No:	REV: 0
CHK'D:	SAH	SCALE:	1:106,000	615366-102A	

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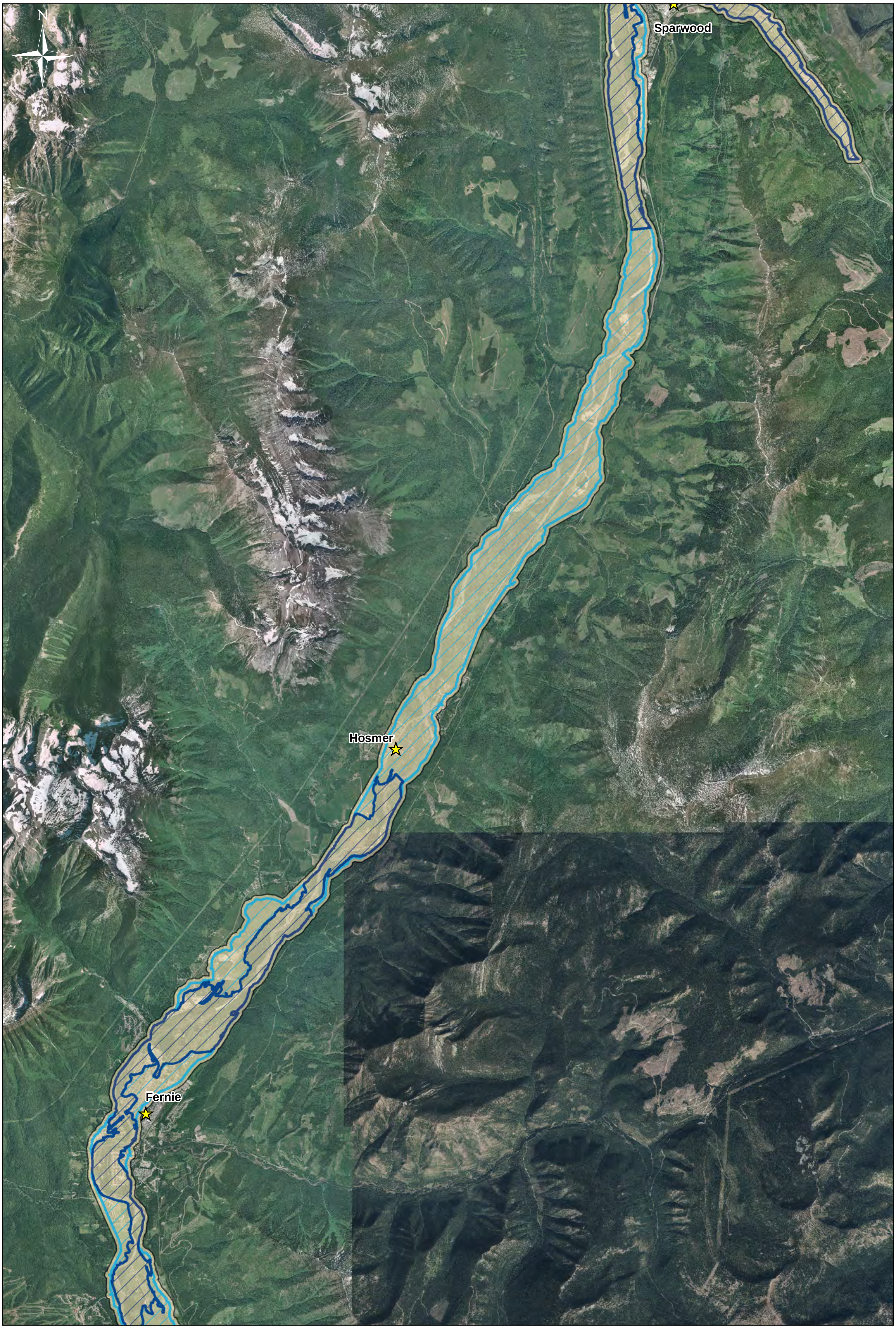

LEGEND

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- SNC Interpreted Floodplain (Based on Topography)
- 100m Buffer on Floodplain
- Community

NOTES

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REFERENCES

Base imagery provided by Teck Coal Ltd.

0 1 2 4 6 Kilometers

SNC · LAVALIN

CLIENT NAME: Teck Coal Ltd.	PROJECT LOCATION: Elk Valley British Columbia

Elk River Floodplain and 100m Buffer - Sparwood to Fernie

BY:	DB	DATE:	2014/07/15	REF No:	REV: 0
CHK'D:	SAH	SCALE:	1:87,000	615366-102B	

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