Aquatic Impact Assessment
Burnaby Lake Coal Derailment
Yale Subdivision Mile 122.7

FINAL REPORT

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Acronyms

AEC(s)	Area(s) of Environmental Concern
AIA	Aquatic Impact Assessment
ASTM	American Society for Testing and Materials
BCMOE	British Columbia Ministry of Environment
BSAF	Biota-Sediment Accumulation Factor
BTEX	Benzene, Toluene, Ethylbenzene and Xylenes
CALA	Canadian Association for Laboratory Accreditation
CCME	Canadian Council for Ministers of Environment
CDC	Conservation Data Centre
CN	Canadian National Railway Company
COPC(s)	Chemical(s) of Potential Concern
CP	Canadian Pacific
DO	Dissolved Oxygen
EA	Environmental Assessment
EC	Environment Canada
ICx	Inhibition Concentration (to x% of the test population)
ISQG(s)	Interim Sediment Quality Guideline(s)
K_{OC}	Organic Carbon partition coefficient
LC50	Lethal Concentration (to 50% of the test organisms)
LEL	Lowest Effect Level
MDL	Method Detection Limit
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MOECC	Ontario Ministry of Environment and Climate Change
MSDS	Material Safety Data Sheet
ORP	Oxidation-Reduction Potential
PAH(s)	Polycyclic Aromatic Hydrocarbon(s)
PEL	Probable Effects Level
RDL	Reportable Detection Limit
SD	Standard Deviation
SQG(s)	Sediment Quality Guideline(s)
SQT	Sediment Quality Triad
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TSS	Total Suspended Solids
VEC(s)	Valued Ecosystem Component(s)
WQG(s)	Water Quality Guideline(s)

1.0 Introduction

1.1 Background

On January 11, 2014, a Canadian Pacific (CP) train derailed on the Canadian National Railway Company's (CN) Yale Subdivision, Mile 122.7, in Burnaby, British Columbia. This derailment resulted in the partial release of metallurgical coal from three rail cars in, and adjacent to, Silver Creek. From the derailment site, Silver Creek flows approximately 350 m, before entering Burnaby Lake, 200 m upstream of the Cariboo Dam. From the Cariboo Dam, the Brunette River flows approximately 6 km before entering the Fraser River.

Following the derailment and subsequent spill, CN, in discussions with regulatory agencies (the agencies), opted to follow a 'precautionary principle' risk management approach, and removed the majority of the volume of the coal from the spill site. This was deemed the preferred option, given the urgency expressed by the agencies and the general public, rather than the alternative, which specifically, was to take the time to assess the potential impact of the spill and consider whether or not a clean-up operation was necessary.

In order to implement, and report on, a comprehensive Coal Recovery plan and program, CN retained two environmental services firms: Quantum Murray (Quantum) and Triton Environmental Consultants (Triton). Agency staff from: the British Columbia Ministries of Environment (MOE), Forests, Lands and Natural Resource Operations (MFLNRO), Environment Canada, the City of Burnaby and Metro Vancouver, were - through daily work summaries - apprised of all details related to the various stages of the recovery work. The Coal Recovery program was completed on April 2, 2014, and a summary of the results is available in Triton (2014a). As part of the monitoring conducted during these works, CN prepared and submitted a summary of the water quality monitoring data to Environment Canada, MFLNRO, the City of Burnaby and Metro Vancouver (CN, 2014a, b).

The Coal Recovery program was conducted between March 4 and April 2, 2014. Deposits in Burnaby Lake, lower Silver Creek, and the off-channel habitat in Silver Creek located immediately south of the Cariboo Business Park Driveway, were cleared using a vacuum-truck system and/or hand tools (Triton, 2014a). Coal was removed from the Silver Creek mainstem in the CN right-of-way during the stabilization work in January and February, and during the works conducted during the Coal Recovery program.

A total of approximately 143 tonnes of mixed coal, organic and mineral fines were removed during the program (Triton, 2014a). Based on the performance criteria identified in the field, it was considered impractical to remove additional coal without concomitant removal of significant volumes of native substrates and potential disturbance of riparian habitats.

In order to specifically evaluate any residual impacts from the unrecovered coal downstream of the spill area, CN retained Borealis Environmental Consulting (Borealis) to develop, conduct, and report on an Aquatic Impact Assessment (AIA) of the potentially-affected receiving environments in Silver Creek and Burnaby Lake. A comprehensive work plan, developed based on early drafts, a review meeting, conference calls and written comments from the agencies, was finalized and submitted on May 26, 2014 (Borealis, 2014[1]). This document served as the "road map" to the AIA, reported on herein.

1.2 Aquatic Impact Assessment – Weight-of-Evidence Approach

The investigation and evaluation of the receiving aquatic environment was designed to focus on potential short- and long-term water and sediment impacts. In the AIA work plan (Borealis, 2014[1]), a two-tier evaluation approach was introduced. The approach indicated that, based on a weight-of-evidence assessment, should this initial (*i.e.*, Tier 1) investigation identify significant effects/impacts, a subsequent Tier 2 evaluation would be conducted to understand the extent of any potential impacts to higher trophic levels and/or a greater spatial extent (*i.e.*, Brunette River). The two-tier evaluation approach is discussed briefly below.

1.2.1 Tier 1 Assessment

This Tier 1 of the AIA – which focuses on risks to water and sediment quality, and resident aquatic biota in Silver Creek and Burnaby Lake - utilizes a weight-of-evidence approach to sediment quality, based on the principles of the Sediment Quality Triad (SQT) (Long and Chapman, 1985; Chapman, 1990). The SQT, which has been applied in both marine and freshwater environments for over two decades (*e.g.*, Borgmann *et al.*, 2001; Hall *et al.*, 2005), integrates results from evaluations of: water and sediment chemistry; sediment toxicity and bioaccumulation potential; and, biological community health.

Only the first four of the five above-mentioned lines of evidence (*i.e.*, water/sediment chemistry, and sediment toxicity/bioaccumulation potential) were proposed for implementation in this assessment given the:

- success of the Coal Recovery program in removing the majority volume of the coal (Triton, 2014a);
- results of the water quality program, indicating little to no spill-related impact (CN, 2014a, b); and,

[1]http://www.env.gov.bc.ca/eemp/incidents/2014/pdf/aquatic_impact_assessment.PDF

- the relative time it takes for benthic macroinvertebrate community structure to recolonize and/or respond to disturbance/impacts[2]

The results and conclusions from these lines of evidence (*e.g.*, exceedance/non-exceedance of water and sediment quality guidelines, potential acute or chronic toxicity and/or demonstrated bioaccumulation potential) would provide a basis for whether or not a further evaluation of biological community health or other components tentatively identified in a Tier 2 assessment (described below), may be recommended.

1.2.2 Tier 2 Assessment

If necessary, a Tier 2 assessment - based on the results and conclusions of the Tier 1 assessment - would address any potential impacts to higher trophic levels. This might include (for example):

- additional sediment chemistry/toxicity studies in Burnaby Lake;
- fish population modeling (using toxicity endpoints from acute and chronic toxicity tests with representative fish species), which may be used to predict whether residual impacts of the coal have the potential to impact resident fish populations;
- potential impacts to the Brunette River (and associated receptors) downstream of Burnaby Lake; and/or,
- potential impacts to benthivorous water birds and/or other listed vertebrate species (*e.g.*, Pacific Water Shrew, Red-Legged Frog, Western Painted Turtle)[3].

1.3 Rationale, Purpose and Objectives

Based on the chemical characteristics of the spilled product (*i.e.*, raw, washed, metallurgical coal), <u>the focus of this AIA was on residual (*i.e.*, post-coal recovery) impacts to water, sediment and resident aquatic biota</u>. A weight-of-evidence SQT approach was applied, in order to consider any potential impacts of product constituents (and by-products), through toxicity to water- and sediment-based Valued Ecosystem Components (VECs), which can also indirectly exert effects – via ingestion of lower trophic level organisms - to upper trophic level biota (*e.g.*, amphibians, water birds, and fur-bearing riparian species).

The purpose of this document is to report on the AIA of unrecovered coal for the potentially-affected water bodies (*i.e.*, Silver Creek, Burnaby Lake). The key objectives of the work plan (Borealis, 2014[1]) included the following tasks under a series of hypothesis-based questions:

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[2]Benthic invertebrate life cycles are in the range of months to years (Smith, 2001), so it could be expected that time required for recovery of an impacted community would be comparable, once habitat was restored (Dr. D. Huebert, Aquatic Biologist, AECOM, *personal communication*).
[3] Pacific Water Shrew *(Sorex bendirii);* Red-Legged Frog *(Rana aurora);* Western Painted Turtle *(Chrysemys picta bellii).*

What are the potential agents (chemicals) of effect/impact?

- chemical characterization and environmental fate of the spilled material, including constituents of the metallurgical coal, in addition to any potential breakdown products.

Where at the site can effects/impacts occur?

- delineation of study areas of environmental concern (AECs).

Do chemicals in water and sediment occur at concentrations deemed to result in effects/impacts?

- characterization of the concentrations of chemicals of potential concern (COPCs) in receiving environments; this would include actual reference and exposure area concentrations (where possible), with a comparison of these parameter concentrations to applicable guidelines, objectives and standards (in this case, Provincial and Federal water and sediment quality guidelines).

Will chemicals in water and sediment have adverse effects to resident organisms?

- description of any short- and/or long-term potential biological effects (toxicity) to various aquatic biota (*e.g.*, based on endpoints such as survival and growth), including magnitude, extent and duration of impact (if any).

Will chemicals in water and sediment be taken up by organisms (bioaccumulate) over time?

- description of any short- and/or long-term potential impacts to receiving environment (*e.g.*, based on the bioavailability of contaminants related to the remaining coal impacts and risks to receptor groups), including magnitude, extent and duration of impact (if any).

As indicated above, a weight-of-evidence approach, integrating the potential impact of surface water chemistry, sediment chemistry, sediment and sediment porewater toxicity, and bioaccumulation potential, was employed to evaluate aquatic impact/risk.

2.0 Background on Burnaby Lake

To gain a broader understanding of any potential residual effects of chemicals from the coal on the surface waters and sediments of Silver Creek and Burnaby Lake receiving environments, a background literature review was conducted. Existing information regarding the various characteristics of the aquatic ecosystem of Burnaby Lake (and the surrounding Brunette watershed) was compiled to aid in a more complete understanding of the environmental setting, the various temporal and spatial changes in the lake, and its status in relation to water and sediment quality.

2.1 Burnaby Lake Environmental Setting

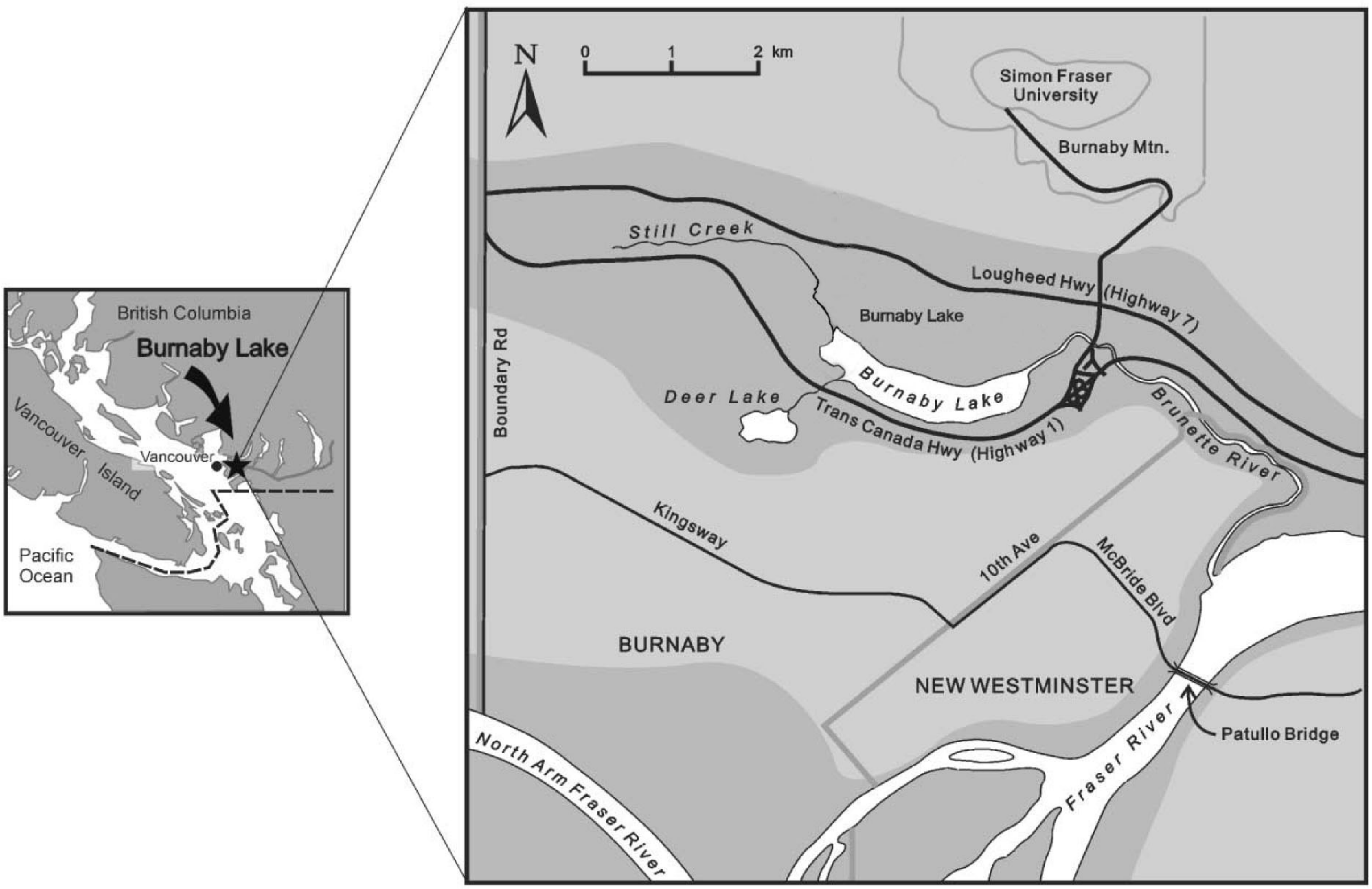
Burnaby Lake is a shallow water body located in Burnaby Lake Regional Park in the City of Burnaby, British Columbia (Hall and Anderson, 1988; Li *et al.*, 2009). It is part of the Brunette Watershed, which comprises: Deer Lake, Still Creek and the Brunette River (ENKON, 2002; Hall and Anderson, 1988; Figure 1 below). Silver Creek - the watercourse into which the derailment occurred - is a first order tributary to Burnaby Lake's northeast shoreline where it transitions into the Brunette River. Most habitat and water quality information regarding Burnaby Lake is discussed in the context of the Brunette Watershed as a whole. The overview focuses on habitat and water quality information involving Still Creek, the Brunette River and Deer Lake, making the assumption that any effects of these connecting water bodies could directly impact Burnaby Lake.

Burnaby Lake comprises various habitats. For example, where Still Creek empties into Burnaby Lake, it is characterized as a riparian corridor (ENKON, 2002; Sampson and Watson, 2004; Golder *et al.* 1977; Zandbergen, 1998). Golder *et al.* (1997) categorized the surrounding area of Burnaby Lake with vegetated habitat types, including:

- mixed forest habitat, including:
  - black cottonwood (*Populus trichocarpa*),
  - red alder (*Alnus rubra*);
  - paper birch (*Betula papyrifera*);
  - Western hemlock (*Tsuga heterophylla*); and,
  - Western red cedar (*Thuja plicata*);
- Grass, fern, and shrub dominant habitat, including:
  - salmonberry (*Rubus spectabilis*);
  - vine maple (*Acer circinatum*); and,
  - lady fern (*Athyrium felix femina*);

- grass-rush wetland, an important habitat for various endangered plant species in British Columbia, which is also part of the Burnaby Lake and Brunette Watershed area (Golder *et al*., 1997). A review of the BC Conservation Data Centre (CDC) database (accessed 2014) indicates historical records (*i.e.,* 1983 and 1999) of the provincially blue-listed[4] species, false pimpernel (*Lindernia dubia* var. *anagallidea),* at Burnaby Lake.

Figure 1
Burnaby Lake and neighbouring water bodies (from Brewer and Belzer, 2001)



[4]Blue-listed species are indigenous species or subspecies of Special Concern (formerly classified as Vulnerable) in British Columbia. Taxa of Special Concern are particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are considered at risk, but are not classified as Extirpated, Endangered or Threatened (Conservation Data Centre, accessed 2014).

2.2 Burnaby Lake Biota

Aquatic (and terrestrial) species – categorized within various ecological niches/guilds and trophic levels - within the watershed, include the following:

Fish. Fish species in Burnaby Lake include: Brassy Minnow, Carp, Cutthroat Trout, Northern Pikeminnow, Peamouth Chub, Prickly Sculpin, Rainbow Trout and Three-spine Stickleback (Golder *et al.*, 1997; Haid, 2005; Metro Vancouver, 2001; FISS, 2014). The Brunette River also supports Chum and Coho Salmon, Steelhead, Coastal Cutthroat Trout and Nooksack Dace (FISS, 2014). A comprehensive list of fish species documented in Burnaby Lake, the Brunette River, Still Creek, Eagle Creek, Massey Creek and Beecher Creek upstream of the Cariboo Dam is provided in Table 1 below.

Table 1
Fish species present in Burnaby Lake, the Brunette River, Still Creek, Eagle Creek, Massey Creek and Beecher Creek*

FISH SPECIES	SCIENTIFIC NAME
Brassy Minnow	*Hybognathus hankinsoni*
Brown Catfish	*Ameiurus nebulosus*
Carp	*Cyprinus carpio*
Chinook Salmon	*Oncorhynchus tshawytscha*
Coastal Cutthroat Trout	*O. clarkii*
Coho Salmon	*O. kisutch*
Chum salmon	*O. keta*
Lamprey	*Lampetra* sp.
Northern Pikeminnow	*Ptychocheilus oregonensis*
Peamouth Chub	*Mylocheilus caurinus*
Perch	*Perca* sp.
Prickly Sculpin	*Cottus asper*
Nooksack dace	*Rhinichthys cataractae*
Rainbow Trout	*O. mykiss*
Redside Shiner	*Richardsonius balteatus*
River Lamprey	*Lampetra ayresii*
Sucker	*Catostomus* sp.
Threespine Stickleback	*Gasterosteus aculeatus*
Yellow perch	*Perca flavescens*

* from Triton (2014a)

Invertebrates. Numerous aquatic macroinvertebrate species in the Brunette watershed have been documented in the literature. Ellis (1969), while studying habitat preferences for grouse-winged backswimmers (*Notonecta undulata*), documented various macrofaunal species in Deer Lake, including diving beetles (Family: Dytiscidae) and water boatmen (Family: Corixidae). As part of the Environmental Assessment (EA) for the Rejuvenation of Burnaby Lake, collections of benthic invertebrates included high densities of: nematodes, tubificid oligochaetes, copepods, cladocerans, and midges (ENKON, 2002). The Still Creek Watershed Biodiversity Conservation Case Study (Haid, 2005) noted that Blue Dasher dragonflies (*Pachydiplax longipennis*), a blue-listed species, were present in Burnaby Lake[5]. Duval (1973) also identified that the main species of zooplankton within Deer Lake were: the water flea, *Daphnia pulex*, and a species of freshwater copepod, *Cyclops scutifers*. As part of the EA for the Rejuvenation of Burnaby Lake, collections of planktonic invertebrates included high densities of populations of several genera, including (predominantly): *Daphnia* spp., *Cyclops* spp., *Diaptomus* spp. and rotifers (*e.g.*, *Felina* sp.) (ENKON, 2002). It should be noted that the above information should be considered with caution, as many of these studies were conducted between 10 and 30 years ago; temporal (and other ecosystem) changes have likely influenced the presence and abundance of these macroinvertebrate populations in the Brunette watershed.

Birds. Many bird species have been sighted in the vicinity of the Brunette Watershed generally, and Burnaby Lake, specifically. These sightings have included common urban bird species, such as: Purple Finch (*Haemorhous purpureus*), Black-capped Chickadee (*Poecile atricapillus*), Mallard (*Anas platyrhynchos*), Great Blue Heron (*Ardea herodias*) and Red-tailed Hawk (*Buteo jamaicensis*) (Sampson and Watson, 2004, Golder *et al.*, 1997, Metro Vancouver, 2001). Moreover, incidental observations of birds during the recent Coal Recovery program (Triton, 2014a) included: Canada Goose (*Branta canadensis*), Great Blue Heron, and Mallard. Of these species, Great Blue Heron *(A. herodias fannini* subspecies) is listed under the Federal *Species at Risk Act* as Schedule 1 - Special Concern.

Mammals. Small mammals have also been observed (and reported on) in the area. Sampson and Watson (2004) established various trapping stations to conduct a biological inventory of Still Creek. Species such as: Deer Mouse (*Peromyscus* spp.), Oregon Vole (*Microtus oregoni*), Black Rat (*Rattus rattus*) and Townsend's Vole (*Microtus townsendii*) were observed in the traps. Coyote (*Canis latrans*) and Short-tailed Weasel (*Mustela ermine*) have also been sighted in the area. COSEWIC (2006) indicates that the Pacific Water Shrew (*Sorex bendirii*) is present in Burnaby Lake Park. Incidental observations of mammals in the area during the Coal Recovery program (Triton, 2014a) included: Beaver (*Castor canadensis*) and North American River Otter (*Lontra canadensis*).

[5] BC CDC (2014) records also indicate observations of Blue Dasher dragonflies (*Pachydiplax longipennis*) from 1996.

Reptiles and Amphibians. Golder *et al.* (1997) documented the presence of various amphibian species, such as: the Long-toed Salamander (*Ambystoma macrodactylum*), Pacific Tree Frog (*Pseudacris regilla*), Bullfrog (*Rana catesbeiana*) and Northwestern Salamander (*Ambystoma gracile*). Reptiles such as the Common Garter Snake (*Thamnophis sirtalis*), the Western Painted Turtle (*Chrysemys picta bellii*), Red-eared Slider *(Trachemys scripta)* and Midland Painted Turtle (*Chrysemys picta marginata*) have also been observed in Burnaby Lake Park. The recent Coal Recovery program report (Triton, 2014a) provides a table (*i.e.*, Table 2-3), which lists wildlife species present in the area, including the blue-listed amphibian, the Red-legged Frog (*Rana aurora*).

2.3 Burnaby Lake Water and Sediment Quality

Historically, the Brunette Watershed has been used as a local water treatment system. Chan (2012) has stated that Still Creek and Burnaby Lake were originally designed and engineered to receive storm water from the surrounding areas. Sewage has also been discharged into the Brunette watershed (McCallum, 1995), however, this is no longer the case. Even though sewage no longer drains into the watershed, the water quality of the lake is still considered to be that of an urban, impacted, eutrophic lake (Sampson and Watson, 2004; Golder *et al*., 1997; McCallum, 1995). A large portion of the areas surrounding Burnaby Lake is categorized as residential and industrial (Hall and Anderson, 1988); for example, Silver Creek runs through the Cariboo Industrial Park, while the eastern end of Burnaby Lake is adjacent to, and just south of it. As a result, there continue to be inputs of storm water into the watershed through run-off from areas such as roadways, roofs and traffic (Li *et al*., 2009). Therefore, there are numerous non-point sources potentially adding a substantial number of chemicals into the watershed.

Dating back to 1986, Hall and Anderson (1988) suggested that storm water was contributing to increasing toxicity of the Brunette system. By studying both Burnaby and Deer Lakes, it was determined that following a storm event, sediment was enriched with elevated concentrations (at times exceeding the guidelines of the day) of metals, such as: copper, iron, lead and zinc (Hall and Anderson, 1988). Moreover, McCallum (1995) examined Burnaby Lake's surface sediment, and reported that various metals in the lake yielded high (often in exceedance of sediment quality guidelines) concentrations of copper, lead, zinc, and cadmium. As part of the EA for the Rejuvenation of Burnaby Lake, ENKON (2002) reported on the sediment quality of the lake, and indicated that, while most metals exceeded Provincial sediment quality guidelines, none of the polycyclic aromatic hydrocarbons (PAHs) exceeded them. More recently, Li *et al.* (2009) examined the Brunette River's water and sediment quality during three storm events between 1999 and 2000; results indicated exceedances of water quality guidelines for both copper and zinc. In addition, recent storm water data collected during a spill observed in Silver Creek (*i.e.*, coming from the municipal outfall) yielded detectable concentrations of toluene, ethylbenzene and xylenes

(CN Rail, *unpublished data*)[6]. Despite the fact that water quality of the Brunette watershed, including Burnaby Lake and its various tributaries, is impacted by anthropogenic activities (as indicated above), it continues to provide habitat for a wide array of terrestrial and aquatic wildlife. Due to the high and increasing levels of urbanization in the vicinity of the lake, including storm water, urban run-off and other inputs, the water and sediments in the lake are not considered to be pristine.

[6]Samples were collected by Triton in January 2014 after an odorous, blue-coloured discharge (visible throughout the water column) was observed at the municipal storm water outfall.
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3.0 Methodology

3.1 Product Chemistry and Spill Characteristics

The first of the hypothesis-based questions was as follows:

"What are the potential agents (chemicals) of effect/impact?

- chemical characterization and environmental fate of the spilled material, including constituents of the metallurgical coal, in addition to any potential breakdown products".

To address this question, available information on the chemical[7] and toxicological characterization of the spilled material (*i.e.*, raw, washed, metallurgical coal) was requested and subsequently obtained from Teck Resources Ltd. in order to provide context for various aspects of the AIA (*e.g.*, profile of PAHs in coal residue).

3.2 Surface Water Chemistry

Another of the hypothesis-based questions was as follows:

"Do chemicals in water occur at concentrations deemed to result in effects/impacts?

- characterization of concentrations of chemicals of potential concern (COPCs) in receiving environments; this would include actual reference and exposure area concentrations (where possible), with a comparison of parameter concentrations to applicable guidelines, objectives and standards (in this case, Provincial and Federal water quality guidelines)".

The objective of this component of the AIA was to evaluate water quality conditions (*e.g.*, concentrations of COPCs and relevant physical parameters) in both reference/upstream and "exposed"/downstream areas in Silver Creek and Burnaby Lake. An understanding of these conditions could help to identify areas of potential residual impact from the spill. Given the timing and robustness of the data set (*i.e.*, the recently-submitted final results from the water quality monitoring program conducted subsequent to the Coal Recovery program (CN, 2014a, b)), it was determined that additional surface water sampling and analysis was not proposed for this AIA (Borealis, 2014); nevertheless, for completeness, the data compiled in CN (2014a, b) have been integrated into the AIA.

[7]Including constituents of the metallurgical coal, in addition to potential breakdown products (*e.g.*, PAHs).

3.3 Study Area

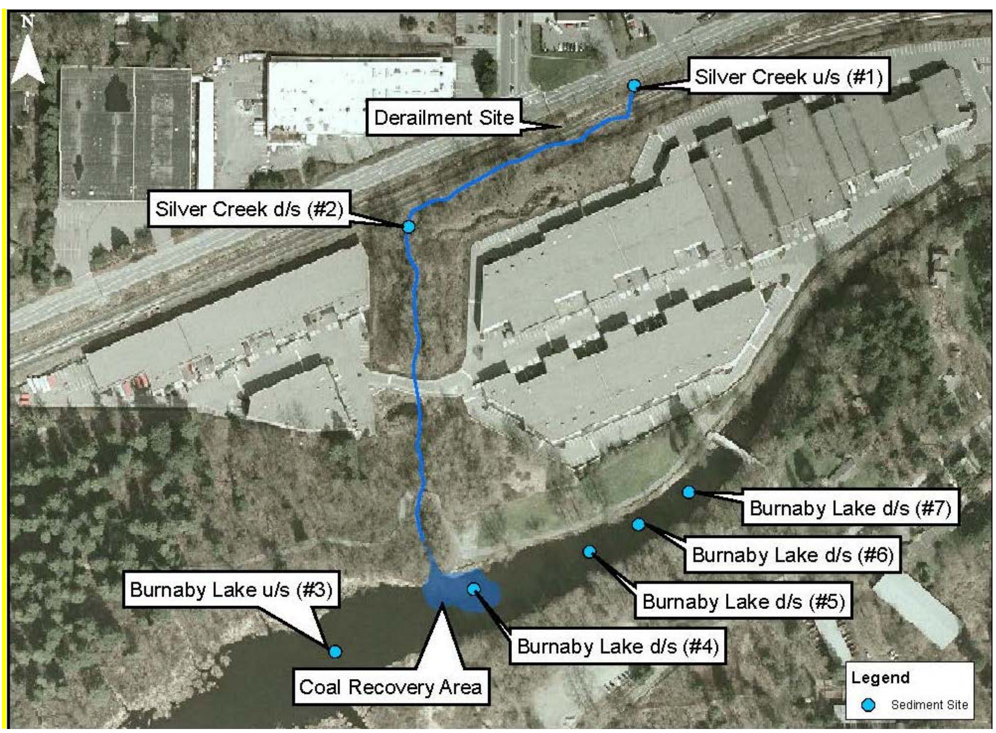
The third of the hypothesis-based questions was as follows:

"Where at the site can effects/impacts occur?

- delineation of study areas of environmental concern (AECs)".

The study area - including the seven (7) sampling stations selected during the development of the AIA work plan (Borealis, 2014) - was based primarily on the location and magnitude of the spill event, and the spatial extent of the Coal Recovery program. Sampling was conducted at upstream (*i.e.*, those areas deemed unimpacted by residual spilled coal), and at downstream (*i.e.*, those areas potentially affected by residual spilled coal) stations. The AIA study area – with the selected sampling stations - is presented in Figure 2, below.

Figure 2
Area of Environmental Concern and Sampling Stations used in the Aquatic Impact Assessment



3.4 Field sampling program

Two approaches are generally used in impact assessments such as this one, specifically:

- using a comparison of before/after (B/A) conditions, or a temporal assessment; and,
- using a comparison of control/impact (C/I) conditions, or a spatial assessment.

Through a review of the available information, it was determined that a B/A comparison could not be made (*i.e.*, water and sediment quality data at or near the same stations before the spill), other than general historical data from Burnaby Lake or the Brunette River watershed (McCallum, 1995; ENKON, 2002; Li *et al*., 2009), all of which are either: (a) not recent enough; and/or, (b) not in the vicinity of the study area, to be temporally relevant.

- McCallum (1995) reported on historical streambed sediment data collected at 33 stations throughout the Brunette River Watershed. Samples were collected between July and September 1993. Only one sampling site, located in Burnaby Lake near the Brunette River, could have been used for comparison, but ultimately, it was determined that data from 1993 were too old to be used.
- ENKON (2002) reports on water and sediment quality data from a water quality monitoring program conducted December 1999 to November 2000. During this program, monthly sampling occurred at 14 sites in Burnaby Lake and one site in Still Creek. These sites were distributed in approximately 500 m intervals along the rowing course on Burnaby Lake. Again, it was determined that data from 1999/2000 were too old to be used.
- Li *et al.* (2009) reports on water quality monitored from “three tributaries and a lake” within the Brunette River Watershed between 1974 and 1998.

Data contained in all three of these studies range from 1974 to 2000 and are considered too old to be used for comparative purposes.

Since the aforementioned historical data were not able to provide a relevant temporal (B/A) comparison, a C/I or, in this case, an upstream/downstream gradient approach, was applied, so that a more relevant comparison could be made. It should be noted that this upstream/downstream approach was proposed and accepted as part of the work plan (Borealis, 2014).

Field sampling was conducted using an Ekman grab at seven (7) stations (Figure 2, above), per the original AIA work plan (Borealis, 2014). Table 2 (below) provides details regarding the sampling stations, with location descriptions, particle size profile and classification, and the SQT analyses conducted for the AIA.

Samples were collected upstream and downstream of spill-affected areas, with multiple samples downstream of the derailment site. This ‘gradient’ approach coincides with the established extent of the dispersion of the coal into the receiving environment (Triton, 2014a, b, c). As indicated above, the selected sampling stations consisted of both reference (*i.e.*, Stn #1 for Silver Creek, and Stn #3 for Burnaby Lake) and ‘exposed’ stations (*i.e.*, Stn #2 for Silver Creek, and Stn #4, #5, #6, and #7 for Burnaby Lake), to allow for spatial comparisons of potentially unimpacted vs. impacted areas[8].

All field sampling was conducted according to relevant guidance provided in the BC Field Sampling Manual (BCMOE, 2003). Sampling was conducted on two dates for logistical reasons[9]: May 30/31, 2014 and June 9, 2014.

All sediment samples were delivered within 24 hours to the:

- analytical chemical laboratory (AGAT Laboratories (AGAT), located in Burnaby, BC). AGAT is a competent environmental analytical laboratory, accredited for laboratory quality systems – according to ISO Standard 17025 - by Canada’s national accreditation body, the Canadian Association for Laboratory Accreditation (CALA); and,
- ecotoxicity laboratory (Nautilus Environmental (Nautilus), also located in Burnaby, BC). Nautilus is a competent ecotoxicity laboratory, also accredited for laboratory quality systems – according to ISO Standard 17025 - by Canada’s national accreditation body, CALA

[8]In the absence of temporal comparisons.
[9]Subsequent to delivery of samples (collected on May 30/31, 2014) to the toxicity laboratory, additional sample volume was requested. In order to ensure that results from sediment chemistry and sediment toxicity tests were concurrent, an additional field sampling trip (on June 9, 2014) was made.

Table 2
Sampling stations, with Location Descriptions, Particle Size Profile and Classification, and SQT Analyses Conducted for the Silver Creek/Burnaby Lake Aquatic Impact Assessment

STATION ID	LOCATION DESCRIPTION	REFERENCE OR EXPOSED SITE?	PARTICLE SIZE PROFILE AND CLASSIFICATION	SQT ANALYSES CONDUCTED
Silver Creek Stn #1*	background/reference Silver Creek (*i.e.*, above the derailment site, ~15 m downstream of the municipal storm water outfall)	Reference (Silver Creek)	% sand – 92.3 % silt - 4 % clay – 3.7 Classification: **Sand**	Sediment Chemistry Sediment Toxicity Bioaccumulation Potential
Silver Creek Stn #2*	Approximately 160 m downstream of the derailment site within Silver Creek	Exposed	% sand - 46 % silt - 44 % clay - 10 Classification: **Sand and Silt/Loam**	Sediment Chemistry Sediment Toxicity Bioaccumulation Potential
Burnaby Lake Stn #3	background/reference Burnaby Lake (*i.e.*, ~100 m upstream of the 'exposed' areas; Coal Recovery Area)	Reference (Burnaby Lake)	% sand - 26 % silt - 49 % clay - 25 Classification: **Loam**	Sediment Chemistry Sediment Toxicity Bioaccumulation Potential
Burnaby Lake Stn #4	within the 'exposed' area (*i.e.*, Coal Recovery Area)	Exposed	% sand – 94.2 % silt – 3.2 % clay – 2.7 Classification: **Sand**	Sediment Chemistry Sediment Toxicity Bioaccumulation Potential
Burnaby Lake Stn #5	in 'exposed' far-field area (*i.e.*, ~100 m downstream of the recovery area)	Exposed	% sand – 95.3 % silt – 2.3 % clay – 2.3 Classification: **Sand**	Sediment Chemistry
Burnaby Lake Stn #6	in 'exposed' far-field area (*i.e.*, ~125, m downstream of the recovery area)	Exposed	% sand - 92 % silt - 4 % clay - 4 Classification: **Sand**	Sediment Chemistry Sediment Toxicity
Burnaby Lake Stn #7	in 'exposed' far-field area (*i.e.*, ~160 m downstream of the recovery area)	Exposed	% sand - 90 % silt – 6.3 % clay – 3.7 Classification: **Sand**	Sediment Chemistry

*Data for these 2 stations are representative of samples from two dates (*i.e.*, May 30/31 and June 9, 2014)

3.5 Sediment Chemistry

Another of the hypothesis-based questions was as follows:

"Do chemicals in sediment occur at concentrations deemed to result in effects/impacts?

- characterization of concentrations of chemicals of potential concern (COPCs) in receiving environments; this would include actual reference and exposure concentrations (where possible), with a comparison of parameter concentrations to applicable guidelines, objectives and standards (in this case, Provincial and Federal sediment quality guidelines).

The objective of this component of the AIA was to evaluate sediment quality conditions (*e.g.*, concentrations of COPCs and relevant physical parameters) in both reference and "exposed" areas in the immediate and downstream receiving environment (*i.e.*, Silver Creek, Burnaby Lake). Overall, an understanding of these conditions will help to identify areas of potential residual impacts from the coal spill.

As indicated above, sediment samples were collected from a total of seven (7) stations (Figure 2 and Table 2, above), located at various distances from the source of the spilled coal material. A minimum of three[10] discrete replicates from each of the sampling stations was collected, in order to reflect the variability of chemicals in sediments at a given station.

Field sampling of sediments for chemical analyses was closely coordinated with the sample collection for sediment toxicity testing (see below), helping to place the results into the context of the ecological conditions. The sediment quality program was inclusive of all applicable parameters and measures outlined in approved monitoring guidance documents (*i.e.*, BCMOE (2012)). For each station, samples were fully homogenized at the laboratory; a sub-sample of the homogenized material was analyzed for a full suite of standard parameters/variables including:

- physical variables: sediment grain size (*i.e.*, particle size distribution), moisture content;
- total organic carbon (TOC);
- metals (total); and,
- PAHs (total and congener-specific).

In order to address any variability associated with sub-sampling, quality control samples (*i.e.*, field duplicates (collected at one station only), lab duplicates, and blanks) were also analyzed.

[10]Due to substrate size, and the efficiency of the sediment grab sampler, greater than three samples were often required in order to meet analytical sample volume requirements.

The results from the sediment quality program were then compared with applicable Provincial and Federal freshwater sediment quality guidelines, as follows:

- Provincial sediment quality guidelines for the protection of aquatic life (BCMOE, 2013); and,
- Federal Interim Sediment Quality Guidelines (ISQGs) and Probable Effect Levels (PEL) (CCME, 2005).

3.6 Sediment and Sediment Porewater Toxicity

Another of the hypothesis-based questions was as follows:

"Will chemicals in site-collected water and sediment have adverse effects to resident organisms?

- description of any short- and/or long-term potential biological effects (toxicity) to various aquatic biota (*e.g.,* based on endpoints such as survival, growth), including magnitude, extent and duration of impact (if any)".

Given that any long-term impacts – if they occur - are likely to be linked to potential chemicals in sediment and/or sediment porewater[11], most resident species likely to be affected/impacted will be associated with sediments (*i.e.,* bottom-dwelling fish, benthic macroinvertebrates, periphyton). Moreover, there is an interest in protecting aquatic organisms from different, representative taxonomic groups, and higher trophic levels. Therefore, an appropriate suite of standardized, approved, and widely-used sediment toxicity tests[12] (all of which are conducted using Environment Canada and/or USEPA/ASTM protocols (see Table 3 below)) was developed and proposed in the AIA work plan document (Borealis, 2014). It should be noted that these tests are generally conducted with aquatic organisms considered to be relatively sensitive to a wide range of chemicals (*e.g.,* for benthic invertebrates (*i.e., H. azteca* and *C. dilutus*) - Phipps *et al*., 1995).

Sediment samples for toxicity testing were collected according to guidelines provided in BCMOE (2003) and Environment Canada (1994). For the purposes of conducting sediment toxicity testing, 10 L of bulk sediment were collected from five of the seven sampling stations (*i.e.*, toxicity testing was not conducted on samples from stations Stn #5 and Stn #7)[13], which were also co-located with sediment chemistry sampling stations. Samples used for sediment toxicity testing were collected

[11]Water that resides in the interstitial spaces among sediment particles.
[12]Based on a review of toxicity testing suites described and outlined in Keddy *et al.* (1995).
[13]During the preparation of the AIA work plan document (Borealis, 2014), it was decided that, due to the extent of the 'exposed' area, 2 of 4 samples would provide sufficient areal coverage in order to establish sediment toxicity potential downstream of the recovery area.

from stations Stn # 3, Stn #4, and Stn #6 on May 30/31, 2014, while samples at Stn #1 and Stn #2 were collected on June 9, 2014[14].

The testing suite comprised five standardized toxicity tests (representing three major trophic levels in freshwater environments, similar to those in Silver Creek and Burnaby Lake), as follows:

- one freshwater fish toxicity test (modified, and using water leached from collected sediments);
- three benthic freshwater invertebrate toxicity tests (using sediment as test medium; one of these tests measured bioaccumulation potential)[15]; and,
- one freshwater plant (unicellular green alga) test (using extracted sediment porewater as the test medium).

Table 3 below outlines the details related to the selected toxicity and bioaccumulation potential tests.

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[14]Subsequent to the delivery of samples (collected on May 30/31, 2014) to the toxicity laboratory, additional sample volume was requested. In order to ensure that results from sediment chemistry and sediment toxicity tests were concurrent, an additional field sampling trip was made on June 9, 2014.

[15]Addressed the hypothesis-based question: ***"Will chemicals in water and sediment be taken up by organisms (bioaccumulate) over time?***

- description of any short- and/or long-term potential impacts to receiving environment (*e.g.*, based on bioavailability of contaminants related to the spill, impacts and risks to receptor groups), including magnitude, extent and duration of impact (if any)."

Table 3

Sediment and sediment porewater toxicity and bioaccumulation potential tests conducted for the Silver Creek/Burnaby Lake Aquatic Impact Assessment

Representative Trophic Level	Test Species	Biological Endpoint	Duration	Method Reference	Notes (including Ecological Relevance)
Freshwater Fish	Rainbow Trout (*Oncorhynchus mykiss*)	Survival	96 hours (acute)	Environment Canada, (July 1990, 1996); EPS 1/RM/9 Environment Canada (2000, 2007); EPS 1/RM/13	Modified; conducted as a ‘leachate’ test (see methodological details provided in the test report (Appendix D)
Benthic Invertebrates	*Chironomus dilutus*	Survival/ Growth	14 days (chronic)	Environment Canada (1997); EPS1/RM/32	Whole sediment test (Note: chironomids have been reported to be resident in Burnaby Lake (ENKON, 2002))
	Hyalella azteca	Survival/Growth	10 days (chronic)	Environment Canada (2013); EPS1/RM/33	Whole sediment test
	Lumbriculus variegatus	Bioaccumulation potential	28 days (chronic)	ASTM International, 2014a,b; E1706-00, E-1688-10	Whole sediment test (Note: freshwater oligochaetes have been reported to be resident in Burnaby Lake (ENKON, 2002))
Freshwater Algae	*Pseudokirchneriella subcapitata*	Growth Inhibition	72 hours (acute)	Environment Canada, 2007; EPS1/RM/25	Sediment porewater test

Sediment, sediment porewater toxicity, and bioaccumulation potential testing was conducted at the Nautilus Environmental’s (Nautilus) ecotoxicity laboratory in Burnaby, BC. Nautilus is accredited according to ISO Standard 17025, by Canada’s national accreditation body, CALA.

The results from the toxicity tests (*i.e.*, reported as various statistical endpoints: LC50[16], and IC25[17], etc.) provide an integrative, ecologically-relevant, site-specific evaluation of both short- and long-term biological effects to aquatic receptors that may be expected in the receiving environment.

[16] LC50 – the concentration of effluent in water that is estimated to be lethal to 50% of the test organisms with a 96-hour exposure (Environment Canada).
[17] IC25 – the effluent concentration where a 25% inhibition is observed in the exposed test organisms (Environment Canada).

4.0 Results

4.1 Product Chemistry and Spill Characteristics

The spilled coal originated from Teck Coal, Line Creek Operations (near Sparwood, BC). Two sources of information were obtained from Teck Resources Ltd. (Teck) to describe the chemical and toxicological nature of the spilled material, as follows (Appendix A):

- Teck's Material Safety Data Sheet (MSDS) for Metallurgical Coal (Teck, 2012); and,
- recently-conducted chemical analyses of a raw metallurgical coal sample from Teck's Line Creek Operations.

Both sources of information are provided in Appendix A and are discussed below.

4.1.1 Coal Composition and Information in the Material Safety Data Sheet for Metallurgical Coal

The chemical element composition of raw bituminous coal - by percentage - is approximately as follows:

- carbon [C], 75–90%
- hydrogen [H], 4.5–5.5%
- nitrogen [N], 1–1.5%
- sulfur [S], 1–2%
- oxygen [O], 5–20%
- ash, 2–10%; and,
- moisture, 1–10%

The Material Safety Data Sheet (MSDS) for Metallurgical Coal (Teck, 2012) (see Appendix A) specifically provides the following text (under the headings "Potential Environmental Effects" and "Ecological Information"):

- "While the solid form of bituminous coal is unlikely to be ecologically hazardous, upon thermal decomposition[18] it is known to liberate hydrocarbon compounds, including PAHs, some of which are considered to be moderately toxic, *e.g.*, pyrene, benzo(a)pyrene, chrysene, phenanthrene. Most PAHs are relatively insoluble in water; they adhere to solid particles such as river and lake sediments. Microorganisms break down PAHs in soil or water after a period of weeks to months. These PAHs are bioaccumulative, in that their

[18]Thermal decomposition (or thermolysis), is a chemical decomposition caused by heat. The decomposition temperature of a substance is the temperature at which the substance chemically decomposes. The reaction is usually endothermic, as heat is required to break chemical bonds in the compound undergoing decomposition.

> concentrations in plants and animals can be much higher than their concentrations in the soil or water they inhabit. Elevated PAH concentrations can be assumed to be significant toxicants to aquatic and terrestrial organisms"

Based on this information, the relative quantities and profile of key COPCs, such as pyrene, benzo(a)pyrene, chrysene, phenanthrene, will be a focus of the evaluation of sediment chemistry (below).

4.1.2 Chemical Analyses of Metallurgical Coal Sample from Line Creek Operations

A sample of metallurgical coal was collected from Teck Coal's Line Creek Operations, and was submitted to Maxxam Analytics in Burnaby, BC. The Certificate of Analysis from this sample is provided in Appendix A.

In order to understand any potential environmental impacts of the chemicals comprising the metallurgical coal[19] that was spilled into Silver Creek (and which subsequently entered Burnaby Lake), it is desirable to compare the results of the clean/washed coal analyses to appropriate environmental guidelines/benchmarks. However, such benchmarks do not exist for a pure product, such as clean/washed coal being transported in rail cars. A highly conservative approach to evaluating potential effects would be to compare these data to available sediment quality guidelines (SQGs). It should be noted, however, that this would not be considered a 'normal' or representative condition, considering that organisms at the study site would be living in a mixture of natural sediment and particles of residual coal and not 100% coal. The comparison of pure product concentrations with the SQGs is provided here for context only.

[19]"Undiluted" form; without sediment/streambed material.

Table 4
Comparison of metal concentrations in Teck Metallurgical Coal Sample with Provincial and Federal Sediment Quality Guidelines*

		Provincial and Federal Sediment Quality Guidelines					
Parameter	RDL	Provincial ISQG[20]	Provincial PEL[21]	Provincial Lowest Effect Level	Federal ISQG[20]	Federal PEL[21]	Clean Coal Sample (Line Creek) (n=1)
Arsenic	0.10	5.90	17.00	-	5.90	17.00	<0.50
Cadmium	0.01	0.60	3.50	-	0.60	3.50	0.296
Chromium	1.00	37.30	90.00	-	37.30	90.00	1.80
Copper	0.20	35.70	197.00	-	35.70	197.00	10.90
Iron	100.00	-	-	21,200	-	-	1,070
Lead	0.10	35.00	91.00	-	35.00	91.30	4.22
Manganese	0.20	-	-	460	-	-	10.30
Mercury	0.01	0.17	0.486	-	0.17	0.486	<0.050
Nickel	0.50	16.00	75.00	-			6.00
Selenium	0.10	2 (single guideline value)		-	-	-	0.87
Silver	0.50	0.5 (single guideline value)		-	-	-	0.072
Zinc	1.00	123.00	315.00	-	123.00	315.00	17.30

* all units expressed in mg/kg.

Table 5
Comparison of PAH concentrations in Teck Metallurgical Coal Sample with Provincial and Federal Sediment Quality Guidelines*

PAH	RDL	Clean Coal Sample (Line Creek)	BCMOE	CCME ISQG[20]	CCME PEL[21]
Naphthalene	0.050	**2.2**	0.01	0.0346	0.391
2-Methylnaphthalene	0.050	**7.1**		0.0202	0.201
Acenaphthylene	0.050	<0.050		0.00587	0.128
Acenaphthene	0.050	<0.050	0.15	0.00671	0.0889
Fluorene	0.050	**0.96**	0.2	0.0212	0.144
Phenanthrene	0.050	**2.6**	0.04	0.0419	0.515
Anthracene	0.061	<0.061 (1)	0.6	0.0469	0.245
Fluoranthene	0.050	*0.12*	2	0.111	2.355
Pyrene	0.050	*0.23*		0.053	0.875
Benzo(a)anthracene	0.050	*0.13*	0.2	0.0317	0.385
Chrysene	0.050	*0.47*		0.0571	0.862
Benzo(b&j)fluoranthene	0.050	0.2			
Benzo(b)fluoranthene	0.050	0.17	0.3		
Benzo(k)fluoranthene	0.050	<0.050	0.24 (LEL)		
Benzo(a)pyrene	0.050	*0.055*	0.06	0.0319	0.782
Perylene	0.050	<0.050			
Indeno(1,2,3-cd)pyrene	0.050	<0.050	0.2 (LEL)	0.05	5.2
Dibenz(a,h)anthracene	0.050	<0.050		0.00622	0.135
Benzo(g,h,i)perylene	0.050	0.062	0.17 (LEL)		
Total PAH	0.061	14	4 (ERL) 35 (ERM)		

*All units expressed as mg/kg or ppm. *Italics* indicate exceedance of ISQGs; **bold** indicates exceedance of BCMOE or PELs. - BCMOE guidelines for sediment containing 1% organic carbon (http://www.env.gov.bc.ca/wat/wq/BCguidelines/pahs/pahs_over.html)

The comparison indicates that if the sediments in Silver Creek and Burnaby Lake were entirely comprised of coal:

Metals

- there were no exceedances of SQGs for any metals (*i.e.*, BCMOE or CCME sediment quality guidelines);

PAHs

- concentrations of 5 PAHs, specifically: fluoranthene, pyrene, benzo(a)anthracene, chrysene and benzo(a)pyrene, are above Interim Sediment Quality Guidelines (ISQGs)[20] (CCME sediment quality guidelines) and,
- concentrations of 4 PAHs, specifically: naphthalene, 2-methylnaphthalene, fluorene and phenanthrene, are above Probable Effect Levels (PELs)[21] (CCME sediment quality guidelines)

Since the actual composition of the sediments is primarily natural sediment with some residual coal, results of these analyses are considered overestimates to the actual substrate. Of the key COPCs in the clean coal sample analyzed (*i.e.*, pyrene, benzo(a)pyrene, chrysene, phenanthrene), only phenanthrene exceeded PELs. *However, as indicated above, this would not be considered a 'normal' condition, as aquatic organisms are unlikely to live among coal particles exclusively, but rather a mixture of natural sediment and other materials. The comparison of pure product concentrations with the SQG is provided here for context only.*

4.2 Surface Water

Per the AIA Final Work Plan document (Borealis, 2014), surface water quality was not specifically monitored during this study. However, Triton (2014a, b) conducted *in situ* and analytical water quality sampling between February 28 and April 1, 2014 during the Coal Recovery program. Sampling was conducted upstream and downstream of spill-affected areas, as well as inside active recovery areas in Silver Creek and Burnaby Lake (See Figure 3). The discharge from the water treatment system was also monitored as part of the program. *In situ* data were collected with a combination of three (3) Sondes (YSI) Model 556 multi-probe system - 6920-V2 Sonde) and hand-held meters (YSI Professional Plus, Hanna Instruments – Model HI 98129, LaMotte 2020we Turbidimeter) (CN 2014a). The Sondes collected water quality data every 30 minutes and

[20]ISQG - concentration above which adverse effects are rarely expected to occur; recommended for total concentrations of chemicals in shallow sediments [up to 5 cm depth] as quantified by standard analytical protocols for specific chemicals (CCME, 1999)
[21] PELs - concentration above which adverse effects are expected to occur frequently (CCME, 1999).

parameters included: temperature, turbidity, conductivity, pH, dissolved oxygen (DO), salinity and oxidation-reduction potential (ORP). The hand-held meters were used primarily to collect pH and turbidity measurements. The analytical sampling program focused on the following parameters:

- Alkalinity
- Chloride
- Hardness
- Extractable Petroleum Hydrocarbons
- Nutrients (NH_3, NO_3, NO_2, C)
- pH
- PAHs
- Sulphate
- Sulphide
- Total and dissolved metals
- Total dissolved solids (TDS)
- Total suspended solids (TSS)

Triton's (2014a) *in situ* and analytical data compiled were compared with available Provincial and Federal water quality guidelines for the protection of freshwater aquatic life. The resultant data indicated that sampled parameters were within applicable water quality guidelines, with some exceptions (*e.g.,* that were not deemed to be spill-related (CN, 2014a, b)). Selected results are provided in Tables 6 and 7 (metals), 8 (PAHs) below.

Figure 3
Water Quality Sampling Stations (from Triton, 2014a)

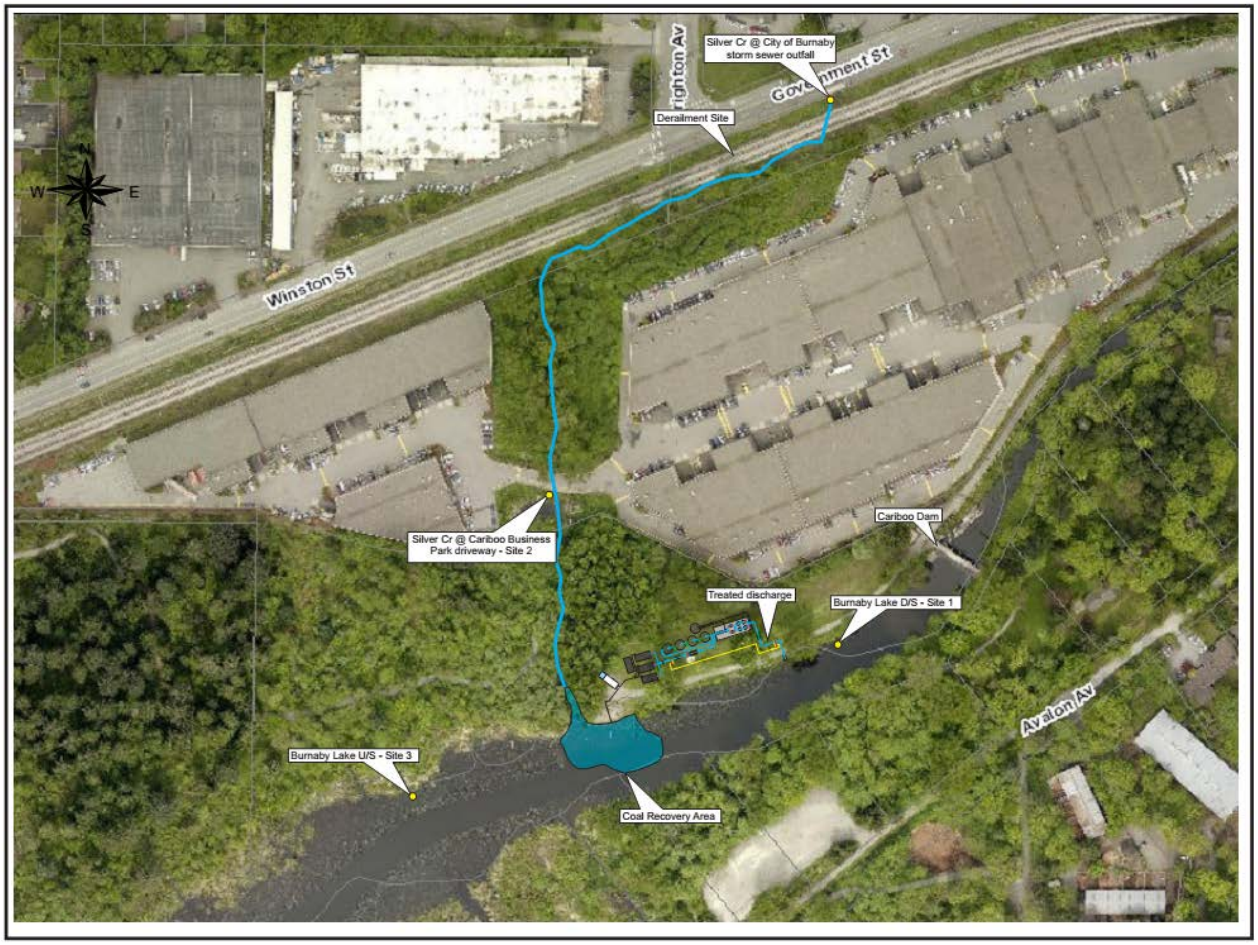


Table 6
Burnaby Lake Coal Recovery Water Quality Data –Average Metals Concentrations February 28 - April 4, 2014*

Sample Description		Provincial and Federal Water Quality Guidelines		Burnaby Lake Site #3	Silver Creek Site #2	Silver Creek Site #2	Burnaby Lake Site #1
Parameter	RDL	BCMOE Approved / Working WQ Guidelines	CCME WQ Guidelines	Mean	Mean	Mean	Mean
Sample				n=5	n=2	n=1	n=9
Aluminum-D***	1	5 @ pH <6.5 (CCME)/ 100 @ pH ≥6.5 (BCMOE/CCME)		40	33	34	34
Iron-D	2	350	-	271	189	210	288
Arsenic-T	0.05	5	5	0.66	0.975	0.45	0.66
Antimony-T	0.05	20	-	0.40	0.5	0.10	0.4
Barium-T	0.1	1,000	-	18.3	52.6	21.9	18.1
Beryllium-T	0.01	5.3	-	0.01	0.03	ND**	0.01
Boron-T	1	1,200	1,500 to 29,000	12	8	5	11
Cadmium-T (H)	0.01	0.01-0.023	0.09-1	0.019	0.174	0.018	0.021
Chromium-T	1	8.9 (CrIII) / 0.1 (CrVI)		0.5	1.4	0.2	0.5
Cobalt-T	0.005	4 to 110	-	0.15	0.37	0.1	0.19
Copper-T (H)	0.2	4.3-8.3	2	3.5	9.1	1.6	3.6
Iron -T	2	1,000	300	490	1,067	333	551
Lead –T (H)	0.1	13.41-49.12	≤1-1.91	0.91	3.77	0.27	1.06
Lithium-T	0.05	11.4 to 870	-	0.35	1.11	0.14	0.32
Manganese-T	0.05	807 to 1,279	-	51.8	51.05	35.3	56.4
Mercury-T	0.01	0.00125-0.02	0.026 (Hg) 0.004 (MeHg)	ND**	0.02	ND**	ND**
Molybdenum-T	0.01	1,000 to 2,000	73	0.60	2.06	2.93	0.75
Nickel-T (H)	0.5	25-65	25-70.58	0.56	0.87	0.25	0.57
Potassium-T	10	373,000 to 432,000	-	1,488	1,428	750	1,381
Selenium-T	0.1	2	1	0.1	0.3	ND**	0.1

Thallium-T	0.004	1.7 to 6.3	0.8	ND**	0.007	ND**	ND**

SAMPLE DESCRIPTION		PROVINCIAL AND FEDERAL WATER QUALITY GUIDELINES		BURNABY LAKE SITE #3	SILVER CREEK SITE #2	SILVER CREEK SITE #2	BURNABY LAKE SITE #1
PARAMETER	RDL	BCMOE APPROVED / WORKING WQ GUIDELINES	CCME WQ GUIDELINES	MEAN	MEAN	MEAN	MEAN
SAMPLE				n=5	n=2	n=1	n=9
Titanium-T	0.2	2,000 to 4,600	-	5.0	23.45	4.50	5.7
Uranium-T	0.001	300 to 500	15 to 33	0.02	0.04	0.01	0.02
Vanadium-T	0.2	6 to 20	-	0.72	1.60	0.50	0.74
Zinc-T (H)	1	33	30	17	57	8	13
pH	0.01 pH units	6.5 to 9	6.5 to 9	6.97	7.35	7.28	7.04
Hardness (Total as $CaCO_3$)	100	N/A	N/A	42.4	-	48.5	40

*All units expressed as μg/L, unless otherwise noted.
**ND – below MDLs
***BCMOE for pH <6.5, Aluminum guideline calculated as $_{e}(1.209 - 2.426 (pH) + 0.286 K)$ where $K = (pH)^2$
H – Hardness-based water quality guideline

Table 7
Burnaby Lake Coal Recovery Water Quality Data –Metals Exceedances - February 28 - April 4, 2014

Location	Cadmium µg/L	Copper µg/L	Iron-T µg/L	Iron-D µg/L	Lead µg/L	Zinc µg/L
Site 1 – Burnaby Lake, D/S of coal recovery area	0.026 / 0.037 / 0.017 / 0.026	3.3 / 4.6 / 2.9 / 3 / 4.4 / 3.3	542 / 518 /401 / 520 / 580 / 666	358	1.5 / 1.48	-
Site 1 – Burnaby Lake, D/S of coal recovery area – *total metals duplicates*	0.016 / 0.028	3 / 4.4 / 3.3	523 / 582 / 626	-	1.46	-
Site 3 – Burnaby Lake, U/S of coal recovery area	0.028 / 0.022	3.6 / 4.5 / 3 / 3.5	564 / 337 / 385 / 602	359	1.09	-
Site 3 – Burnaby Lake, U/S of coal recovery area – total metals duplicate	-	3.5	605	-	1.07	-
Site 2- Silver Creek @ Cariboo Business Park Driveway	0.311 / 0.036	16.3	1,780 / 354	-	7.17	103
Silver Creek @ City of Burnaby Outfall	0.018	-	333	-	-	-
Treated discharge	0.015	2.6	-	-	4.83	-
Treated discharge	0.015	2.6	-	-	4.83	-
Treated discharge - *total metals duplicate*	0.014	-	-	-	4.74	-
BC water quality guidelines	**0.010 to 0.023**	**4.3 to 8.3**	**1,000**	**350**	**13.41 to 49.12**	**33**
CCME water quality guidelines	**0.09 to 1**	**2**	**300**	**-**	**1 to 1.91**	**30**

Note: Cd, Cu, Pb and Zn guidelines calculated on the basis of concurrent hardness at the time of sampling

With respect to metals:

- ***total cadmium*** levels above the Provincial hardness-based guidelines occurred at all sampling stations upstream and downstream of the Coal Recovery area; indicating periodic, naturally-elevated levels (relative to Provincial guideline values);

- ***total copper*** levels exceeded the CCME guideline (2 μg/L at hardness <82 mg/L) at all stations, upstream and downstream of the Coal Recovery area, indicating periodic, naturally-elevated levels (relative to CCME guidelines); one exceedance of the Provincial copper guideline occurred in Silver Creek, March 2, 2104 (rain event). No exceedances of Provincial copper guidelines were noted;

- ***total lead*** levels exceeded the CCME guidelines (1 μg/L at hardness <60 mg/L) at least once in Silver Creek (upstream of the Coal Recovery area), in Burnaby Lake (upstream and downstream of the recovery area) and in the treated discharge. Concentrations of <1 μg/L occurred at all stations ranging from 0.17 μg/L (treated discharge) to 0.95 μg/L (Burnaby Lake d/s station); and,

- ***total zinc:*** one Provincial guideline (33 μg/L at hardness ≤90 mg/L) and federal guideline (30 μg/L) exceedance occurred at Silver Creek during the March 2 rain event (concentration of 103 μg/L). Remaining zinc values were ≤27 μg/L.

Table 8
Burnaby Lake Coal Recovery Water Quality Data – comparison of PAH with available provincial and federal water quality guidelines in Silver Creek Sample
March 2, 2014*

Sample Description		Provincial and Federal Water Quality Guidelines		Silver Creek Site #2 (n=1)
Parameter	**RDL**	**BCMOE Approved / Working WQ Guidelines**	**CCME WQ Guidelines**	
Benzo (a) anthracene	0.01	0.1	0.012	0.02
Benzo (a) pyrene	0.01	0.01 (chronic)	0.015	0.02
Fluoranthene	0.02	4 (chronic) 0.1 (phototoxic)	0.04	0.09
Pyrene	0.02	0.02 (phototoxic)	0.025	0.12

*all units expressed as μg/L.

With respect to PAHs:

- PAHs were not detected at the Burnaby Lake stations and were not detected in the treated discharge. PAHs were detected in only one sample, collected in Silver Creek on March 2, 2014; with one (1) measured exceedance of Provincial and/or CCME guidelines for four (4) PAHs: benzo(a)anthracene, benzo(a)pyrene, fluoranthene and pyrene (Table 8) (CN, 2014a)

EC reviewed the above-mentioned water quality report and assessment and based on the results decided not to take any further action "under the pollution provisions of the *Fisheries Act*" (*personal communication*; e-mail correspondence from Web Kassa, EC to Luanne Patterson, CN; Wednesday, April 30, 2014). The assumption carried forward to the weight-of-evidence assessment of the AIA is that none of the results of the water quality monitoring indicate any potential adverse effects at any of the stations evaluated[22].

4.3 Sediment Porewater

While a specific sediment porewater[23] collection and analysis phase was not conducted as part of this study, it was possible to evaluate the data collected during the toxicity-testing phase of the study as a surrogate.

Metals and PAHs were analyzed for in the sediment 'leachate'[23] from the Rainbow Trout toxicity tests (see section 4.5.1, and Appendix D below). The following are the relevant findings:

- as there were no metal exceedances of sediment quality guidelines, metals in sediment 'leachate' were not assessed; and,
- all PAHs were below method detection limits (MDLs), except for one PAH (*i.e.*, pyrene) from a sample collected at Stn #3 (*i.e.*, reference sample from Burnaby Lake); pyrene was detected after 96 hours (end of the test exposure period) at a concentration of 0.02 µg/L (*i.e.*, at the MDL) (Appendix D).

[22] Note: the locations of the water quality stations differed from those of the sediment AIA study, since:
(i) the goals of the water quality monitoring program differed from that of the AIA; and,
(ii) the spatial nature of water and sediment required a different sampling regime.
However, it is reasonable to assume, based on the design of the AIA, that the results reflect the overall water quality in the area of the sediment quality assessment.

[23] Porewater: Sediment porewater was obtained by centrifuging an aliquot of sediment at 1500 rpm for 15 min under refrigerated conditions. The resulting overlying porewater was carefully decanted and used immediately to conduct the alga test. (Appendix D); 'Leachate': Sediment 'leachate' was generated using under-gravel filters. Prior to toxicity testing, the under-gravel filters were placed at the bottom of each 20 L aquaria and 3 kg of sample was placed on top of the filters (Appendix D).

4.4 Field Observations

Detailed field notes and photographic records were taken during the sampling program and are provided in Appendix B.

4.5 Sediment Chemistry

Sediment samples were submitted to, and analyzed by, AGAT Laboratories in Burnaby, BC; the full analytical reports (including Certificates of Analysis) are provided in Appendix C. A discussion of the results of chemical analyses of the sediments is provided below.

4.5.1 Sediment pH, Total Organic Carbon (TOC) and Particle size

Sediment pH, TOC and particle class results are summarized as follows (and below in Table 9):

pH

- Average sediment pH in Silver Creek ranged from 7.1 at Stn #2, downstream of the derailment to 7.5 at Stn #1 upstream of the derailment

- The average sediment pH in Burnaby Lake (*i.e.*, at Stn #3, upstream of the exposed area) was 6.5. The average pH of the remaining Burnaby Lake samples, all located within the exposed area, was similar: Stn #4 - 6.9; Stn #5 - 7.0; Stn #6 - 7.3; and, Stn #7 - 7.5

TOC

- The average TOC in Silver Creek ranged from 0.51% at Stn #1 to 3.18% at Stn #2

- The average TOC in Burnaby Lake at Stn #3 was 2.79%. The average TOC of the remaining Burnaby Lake samples was as follows: Stn #4 (5.81%), Stn #5 (2.68%), Stn #6 (0.55%) and Stn#7 (4.17%)

Particle Size

- Sieve analysis indicated that ≥98.5% of the samples were within particle size class of >75 microns (0.075 mm):
  - Sand was the dominant fraction at all sites except for Stn #3 which was classified as Loam, and Stn #2 which included a mix of Sand and Silt Loam

Table 9
Summary of Sediment pH, Total Organic Carbon and Particle size

PARAMETER	SILVER CREEK		BURNABY LAKE				
	REFERENCE	*EXPOSED*	*REFERENCE*	*EXPOSED*	*EXPOSED*	*EXPOSED*	*EXPOSED*
	STN #1*	STN #2*	STN #3	STN #4	STN #5	STN #6	STN #7
pH (mean)	7.5	7.1	6.5	6.9	7.0	7.3	7.5
TOC% (mean)	0.51	3.18	2.79	5.81	2.68	0.55	4.17
Sand % (mean)	92.3	46	26	94.2	95.3	92	90
Silt % (mean)	4	44	49	3.2	2.3	4	6.3
Clay % (mean)	3.7	10	25	2.7	2.3	4	3.7
Texture	Sand	Sand-Silt loam	Loam	Sand	Sand	Sand	Sand
Sieve - 2mm (%)	68.4	35.3	-	24.8	-	98.1	-
Sieve - 75 microns (%)	98.6	99	-	99.3	-	99.5	99.5

*Data for Stn #1 and Stn #2 are representative of samples from two sampling dates (May 30 and June 9, 2014).

It is clear from the physical characteristics described above, that Stn #2 and Stn #3 are physically different in comparison to the other stations. The substrate at Stn #3 (upstream of exposed area – near the Coal Recovery area in Burnaby Lake) has very small particulates (and is described as 'loam'), and coal particles were not observed. However, qualitatively, there appeared to be larger pieces of visible coal at Stn #2 in comparison with the other stations (see Photo B-5 in Appendix B). Stn #2 occurred at the first main depositional area downstream of the derailment site, with the combined silts and clays at this location comprising 54% of the substrate, versus the ≤10% combined silts and clays at the remaining "exposed" stations.

4.5.2 Metals

A summary of the results for metals in site sediments is presented below in Table 9. A comparison of the metals data from sediment sampling stations to SQGs (*i.e.*, BCMOE or CCME – ISQGs and PELs) indicates that the only exceedances for metals were cadmium, copper and nickel and these occurred only at Stn #3 (the Burnaby Lake reference site) and these were in comparison with ISQGs. No ISQG exceedances were noted in the exposed sites or the other reference location (*i.e.*, Silver Creek). The results of the sediment chemical analyses against PELs indicate that sediment at neither reference nor exposed stations exceeded their respective guidelines. It should be noted that the profile/relative composition of metals in the metallurgical coal sample (see Table 4, above) did not yield any exceedances of ISQGs or PELs for metals; this supports the assertion that the elevated levels of cadmium, copper and nickel at Stn #3 (Burnaby Lake reference site) must be either natural or originated from a source other than the coal spill.

Table 10
Summary of Sediment Chemistry – Silver Creek and Burnaby Lake, Metals

Sample Description		Provincial and Federal Sediment Quality Guidelines				Stn #1	Stn #2	Stn #3	Stn #4	Stn #5	Stn #6	Stn #7
						Silver Creek		Burnaby Lake				
						Ref	Exposed	Ref	Exposed	Exposed	Exposed	Exposed
Parameter	MDL (µg/g)	Provincial ISQG	Provincial PEL	Federal ISQG	Federal PEL	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Sample size						n=3	n=3	n=3	n=6	n=3	n=3	n=3
Arsenic	0.1	5.9	17	5.9	17	2.6	2.7	3.7	2.2	2.4	1.9	2.2
Cadmium	0.01	0.6	3.5	0.6	3.5	0.2	0.2	***0.8***	0.2	0.2	0.1	0.2
Chromium	1	37.3	90	37.3	90	13	18.7	34.3	9.7	13.0	8.7	10.7
Copper	0.2	35.7	197	35.7	197	16.7	21.4	***57.7***	13.3	11.2	11.1	14.3
Lead	0.1	35	91	35	91.3	7.6	4.5	6.5	10.5	6.5	5.6	7.7
Mercury	0.01	0.17	0.486	0.17	0.486	0.01	0.03	0.06	0.01	0.01	<0.01	<0.01
Nickel	0.5	16	75	16	75	8.5	11.80	***35.0***	6.6	8.4	7.9	8.3
Selenium	0.1	2 (single guideline value)		-	-	0.1	0.23	0.6	0.2	<0.1	0.1	0.2
Silver	0.5	0.5 (single guideline value)		-	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Zinc	1	123	315	123	315	61.3	58.7	95.3	69.2	69.7	50	70.7

Notes: all parameters are reported in µg/g;
Parameters reported as < MDL are treated as the MDL when comparing;
Bold only - exceedance of PEL, BCMOE;
Bold and Italics - exceedance of ISQG.

4.5.3 Polycyclic Aromatic Hydrocarbons (PAHs)

A summary of the results for PAHs in site sediments is presented below in Table 10. PAHs were detected in sediment samples collected from both Silver Creek and Burnaby Lake. However, it is important to note PAHs were *below detection limits* at Stn #3 (reference) and Stn #6 (exposed) in Burnaby Lake. Selected PAHs, including: anthracene, benzo(a)anthracene, dibenzo(a,h)anthracene and indeno(1,2,3-c,d) pyrene were *above detection limits* at ≤2 sampling stations. Average PAH concentrations for individual stations exceeding the BC Approved Sediment Quality Guidelines (MELP, 1993)[24] occurred in exposed areas, as follows:

- benzo(a)anthracene exceeded the 0.54. µg/g guideline at 1 of 5 stations (*i.e.*, Burnaby Lake - Stn#5) [25]; and,
- naphthalene and phenanthrene exceeded their respective guideline ranges of 0.01 to 0.06 µg/g and 0.02 to 0.23 µg/g at 4 of 5 stations (*i.e.*, Silver Creek station Stn #2 and Burnaby Lake stations Stn #4, #5, #7).

Average PAH concentrations exceeding Provincial and/or Federal PEL for detected PAH in exposed areas were as follows:

- benzo(a)pyrene exceeded the Federal and Provincial PEL of 0.782 µg/g at 3 of 5 stations (*i.e.*, Burnaby Lake stations Stn #4, #5, #7);
- dibenzo(a,h)anthracene (only detected at one station, Burnaby Lake station Stn #5) exceeded the Federal and Provincial PEL of 0.135 µg/g;
- fluoranthene and benzo(a)anthracene exceeded their Federal and Provincial PELs of 2.355 µg/g and 0.385 µg/g respectively at 1 of 5 stations (*i.e.*, Burnaby Lake station Stn #5);
- fluorene exceeded the Federal PEL of 0.144 µg/g, but not the Provincial PEL of 0.875 µg/g at 3 stations in Burnaby Lake (*i.e.*, stations Stn #4, #5, #7); and,
- naphthalene, 2-methylnaphthalene and phenanthrene exceeded their respective PELs of 0.391 µg/g, 0.201 µg/g and 0.515 µg/g at 4 of 5 stations (*i.e.*, Silver Creek station Stn #2 and Burnaby Lake stations Stn #4, #5, #7).

Average PAH concentrations in excess of Provincial Approved Sediment Quality Guidelines (Lowest Effect Levels; LELs) for detected PAH in exposed areas were as follows:

- benzo(k)fluoranthene exceeded the Provincial LEL of 0.24 µg/g (*i.e.*, Burnaby Lake station Stn #5);
- indeno(1,2,3)pyrene exceeded the Provincial LEL of 0.2 µg/g (*i.e.*, Burnaby Lake station Stn #5); and,

[24] Table 3: Summary of Aquatic Life and Sediment Criteria for Polycyclic Aromatic Hydrocarbons (PAHs).
[25] Guideline values for parameters with BC *Approved* sediment quality guidelines (*e.g.*, benzo(a)anthracene, naphthalene and phenanthrene) were calculated on the basis of actual % organic carbon at the sampling stations - consistent with guidance in the Ambient Water Quality Criteria for Polycyclic Aromatic Hydrocarbons (PAHs) Overview Report (1993): "*…To protect aquatic life from the harmful effects of PAHs in sediment, it is recommended that PAH concentrations in freshwater and marine sediments containing 1.0% organic carbon should not exceed those shown in* Table 3*. For a sediment with an organic carbon content other than 1.0%, an appropriate criterion can be obtained by multiplying the recommended criterion by the actual organic carbon content of the sediment (e.g. if the sediment had 5% organic carbon you would multiply the sediment guideline value in Table 3 by 5)…*" .http://www.env.gov.bc.ca/wat/wq/BCguidelines/pahs/pahs_over.html

- benzo(ghi)perylene exceeded the Provincial LEL of 0.17 μg/g (*i.e.*, Burnaby Lake station Stn #5).

The conditions under which PAHs are extracted from the coal matrix in the laboratory are not consistent with the way in which these compounds would emerge from surface sediments in Burnaby Lake. In other words, laboratory extraction reflects "worst-case" environmental conditions, resulting in the release of PAHs from the coal matrix that might not occur under natural conditions.

Table 11
Summary of Sediment Chemistry – Silver Creek and Burnaby Lake, PAHs*

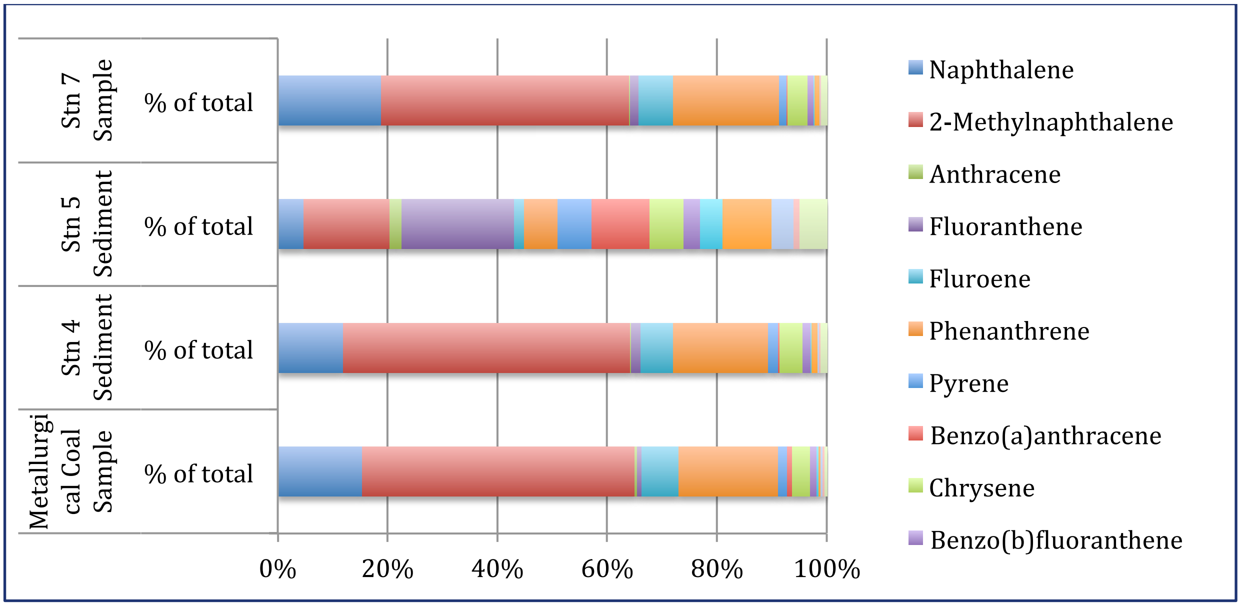
Parameter	RDL	BC Approved Sediment Quality Guidelines**	BC Working Sediment Quality Guidelines		CCME Sediment Quality Guidelines		Stn #1 AVG (n=4)	Stn #2 #2 AVG (n=4)	Stn #4 AVG (n=6)	Stn #5 Avg (n=3)	Stn #7 AVG (n=3)
							Silver Creek		Burnaby Lake		
			ISQG	PEL	ISQG	PEL	Ref	Exposed	Exposed	Exposed	Exposed
Naphthalene	0.01	0.01 to 0.06	-	0.391	0.0346	0.391	<0.01	0.10	1.03	0.60	2.34
2-Methylnaphthalene	0.01	-	0.0202	0.201	0.0202	0.201	0.01	0.57	4.53	1.98	5.59
1-Methylnaphthalene	0.01	-	-	-	-	-	<0.01	0.32	2.44	1.00	2.99
Fluorene	0.02	0.1 to 1.16	-	0.875	0.0212	0.144	<0.02	0.15	0.51	0.23	0.78
Phenanthrene	0.02	0.02 to 0.23	-	0.515	0.0419	0.515	0.02	0.23	1.50	0.77	2.39
Anthracene	0.02/0.04	0.31 to 3.49	-	0.245	0.05	0.245	<0.02	<0.02 / <0.04	<0.02	0.27	<0.02
Fluoranthene	0.05/0.1	1.02 to11.62		2.355	0.111	2.355	0.06	<0.05 / <0.1	0.15	2.59	0.19
Pyrene	0.02	-	0.053	0.875	0.053	0.875	0.05	0.05	0.16	0.79	0.17
Benzo(a)anthracene	0.02/0.04	0.10 to 1.16	-	0.385	0.032	0.385	<0.02	<0.02 / <0.04	<0.02	1.33	<0.02
Chrysene	0.05	-	0.0571	0.862	0.0571	0.862	<0.05	0.11	0.37	0.78	0.45
Benzo(b)fluoranthene	0.02	-	-	-	-	-	0.02	0.04	0.12	0.38	0.14
Benzo(k)fluoranthene	0.02/0.04	0.24 (LEL)	-	-			<0.02	<0.02 / <0.04	0.02	0.52	<0.02
Benzo(a)pyrene	0.05/0.1	0.03 to 0.35	-	0.782	0.032	0.782	<0.05	<0.05 / <0.1	0.09	1.13	0.11
Indeno(1,2,3-c,d)pyrene	0.02/0.04	0.2 (LEL)	-	-	-	-	<0.02	<0.02 / <0.04	0.03	0.50	<0.02
Dibenzo(a,h)anthracene	0.02/0.04	-	0.0062	0.135	0.0062	0.135	<0.02	<0.02 / <0.04	<0.02	0.14	<0.02
Benzo(g,h,i)perylene	0.05/0.1	0.17 (LEL)	-	-	-	-	<0.05	<0.05 / <0.1	0.10	0.63	0.13

* all units expressed as μg/g.
**BC *Approved* sediment quality guidelines: calculated on basis of % carbon at each sample site.

4.5.4 Comparison of PAH profile of Metallurgical Coal and PAHs in Sediment

In order to gain a better understanding of the relative composition of PAHs in Burnaby Lake sediments, and the similarity to PAHs in the metallurgical coal sample analyzed, a semi-quantitative comparison of PAHs (Table 11 above) with the PAH profile of the metallurgical coal sample analyzed (section 4.1.2; Table 5) was made and is presented graphically in Figure 4.

Figure 4
PAH profiles – Burnaby Lake Sediments Analyzed vs. Metallurgical Coal



Based on this comparison, it is evident – qualitatively - that there were similarities in relative proportions between the PAH profile of the metallurgical coal sample and the sediments at Stn #4 and Stn #7, while the sediment at Stn #5 is substantially different. In any case, it is likely that PAHs from sources other than spilled coal are present in Burnaby Lake sediments.

4.5.5 Quality Assurance/Quality Control – Analytical Chemistry

Laboratory duplicates, sampled from the same container, were analyzed throughout the whole analytical process to ensure that suitable precision was achieved. The Relative Percent Difference for the duplicates for all test parameters met the required criteria outlined in the BC British Columbia Environmental Laboratory Manual (2009) and any other reference cited in the test report. Certified Reference Materials were analyzed with each batch of samples and used to verify applicable instrument calibrations and to confirm the accuracy of the analytical procedure. All percent recoveries met the required criteria outlined in the BC MOE Laboratory Manual and any other reference cited in the test report. Method Blanks, analyzed with each batch of samples, did not indicate that any contamination had occurred. Blank Spikes or Matrix Spikes, where appropriate, were analyzed to further confirm the accuracy of the test methods performed and to identify any matrix interferences. All spike recoveries met required criteria, indicating that matrix interference was unlikely. All analytical procedures cited strictly followed the published reference methods indicated in the Method Summary page of the test report. Internal quality control criteria met or exceeded those stated in the reference methods. Finally, all procedures used to generate the data herein have been accredited by the Canadian Association for Laboratory Accreditation (CALA) to the ISO/IEC 17025 international standard. Quality Assurance/Quality Control data are documented within all laboratory reports provided in Appendices C and D.

4.6 Sediment and Sediment Porewater Toxicity

Sediment and sediment 'leachate'/porewater toxicity testing was conducted at Nautilus Environmental (Nautilus), in Burnaby, BC. All test reports for these analyses are provided in Appendix D. A summary and explanation of the results from each test is provided below.

4.6.1 Toxicity Test Results

***Oncorhynchus mykiss* (Rainbow Trout).** Tests with rainbow trout evaluated the survival of fish in leachate from site sediments to ascertain whether sediments were toxic to fish (see full description of procedure in the test report; Appendix D). There was 100% survival in the samples from all stations tested; results are provided below in Table 12, and in the test report (Appendix D). Results from chemical analyses (PAHs) at test initiation and termination is provided in the full reports in Appendix D.

Table 12
Results: 96-h rainbow trout (*Oncorhynchus mykiss)* leachate test

SAMPLE ID	LOCATION IN RELATION TO DERAILMENT/EXPOSURE AREA	SURVIVAL (%)
Control water (laboratory)	N/A	100
Control Sediment (laboratory)	N/A	100
Stn #1 (Silver Creek #1)	Reference*	100
Stn #2 (Silver Creek #2)	Exposed**	100
Stn #3	Reference*	100
Stn #4	Exposed**	100
Stn #6	Exposed**	100

*U/S = upstream of spilled material; **D/S = downstream of derailment

Chironomus dilutus. Tests with *C. dilutus* evaluated both survival and growth of these benthic invertebrates in site sediments. The percent survival in the coal-exposed sediments ranged from

66% - 94%. Only percent survival at station Stn #2 (Silver Creek exposed/downstream) differed significantly from the control sediment and all other samples. With respect to growth, there were no significant differences among all stations and the control sediment. Results are provided below in Table 13 and in the test report (Appendix D).

Table 13
Results: *Chironomus dilutus* survival and growth test

SAMPLE ID	MEAN ± SD	
	SURVIVAL (%)	DRY WEIGHT (MG)
Control Sediment (laboratory)	94.0 ± 8.9	2.27 ± 0.17
Silver Creek #1 (Reference)	86.0 ± 13.4	2.44 ± 0.24
Silver Creek #2 (Exposed)	66.0 ± 11.4*	3.16 ± 0.54
Stn #3 (Reference)	94.0 ± 8.9	2.46 ± 0.40
Stn #4 (Exposed)	88.0 ± 8.4	2.41 ± 0.34
Stn #6 (Exposed)	82.0 ± 11.0	2.29 ± 0.34

(*) Asterisk indicates significantly difference from the control sediment. SD = Standard Deviation.

Hyalella azteca. Tests with *H. azteca* also evaluated both survival and growth of these benthic invertebrates in site sediments. The percent survival in sediment samples ranged from 76% - 100%. Only % survival at station Stn #2 (Silver Creek) differed significantly from the control sediment and from all other samples. With respect to growth, there were no statistically-significant differences among stations and the control sediment.[26] Results are provided below in Table 14 and in the test report, Appendix D.

[26]It was noted that ammonia concentrations in test exposures varied substantially (*i.e.*, by as much as 5-fold) among stations; however, despite this fact, these concentrations were not sufficiently high to cause the observed effect at Stn #2. If ammonia were responsible for the effect observed, there would have been decreased survival with increasing ammonia concentrations. A correlational analysis indicated that there is no correlation between ammonia concentrations with survival and/or growth (*i.e.*, change in dry weight).

Table 14
Results: *Hyalella azteca* survival and growth test

Sample ID	Mean ± SD	
	Survival (%)	Dry Weight (mg)
Control Sediment (laboratory)	98.0 ± 4.5	0.13 ± 0.02
Silver Creek #1 (Reference)	100 ± 0.0	0.14 ± 0.03
Silver Creek #2 (Exposed)	76.0 ± 20.7*	0.13 ± 0.02
Stn #3 (Reference)	90.0 ± 10.0	0.12 ± 0.02
Stn #4 (Exposed)	98.0 ± 4.5	0.13 ± 0.02
Stn #6 (Exposed)	96.0 ± 5.5	0.15 ± 0.03

(*) Asterisk indicates significantly difference from the control sediment. SD = Standard Deviation.

Lumbriculus variegatus. The bioaccumulation of sediment-associated contaminants can best be determined by conducting laboratory bioaccumulation tests with sediments collected from the area of interest (Ingersoll and MacDonald, 2003). The results of the bioaccumulation potential test with the freshwater oligochaete, *L. variegatus*, are presented in Appendix D. The test involved exposing laboratory-reared worms and exposing them to site sediments, in order to determine if – after a period of 28 days - COPCs (in this case, bioaccumulative metals or PAHs) have the potential to be taken up into invertebrate tissue. It should be noted that the test was not conducted to establish a toxicity endpoint related to any adverse biological effect (*e.g.*, survival, growth, reproduction), but rather was applied to specifically address bioaccumulation potential.

The indicator used to evaluate bioaccumulation potential is referred to as the Biota-Sediment Accumulation Factor (BSAF). The BSAF is a ratio, fundamentally calculated by dividing the concentration of a COPC in tissue by the concentration of a COPC in the sediment; this is done differently for inorganic and organic COPCs, as follows:

- For metals and contaminants other than non-ionic compounds[27] (Van Geest *et al.*, 2010), the BSAF is calculated as follows:
    - BSAF = Co / Cs
        - where Co is the concentration of COPC in the organism (ng/g wet weight)[28]; and,
        - Cs is the concentration in the sediment (ng/g dry weight).

[27] A non-ionic compound is a substance comprising atoms held together by covalent bonds, formed by sharing a pair of electrons between two atoms. There are two general types of non-ionic compounds: organic compounds and inorganic compounds.
[28] ng/g = parts per billion

- For most non-ionic organic contaminants[29], the BSAF is defined (Ankley *et al.*, 1992) as:
  - BSAF= (Co / f**l) / (**Cs / f_{SOC})
    - where f**l** is the lipid fraction of the organism (in units of g lipid/g wet weight); and,
    - f_{SOC} is the fraction of the sediment as organic carbon (in units of g organic carbon/g dry weight).

Based on the results of the chemical analyses provided in the bioaccumulation potential test reports (*i.e.*, Tables 2 (PAHs) and 3 (metals), Appendix D)), determinations and comparisons of BSAFs for each COPC ‘type’ (*i.e.*, inorganic and organic), and for each station from which samples were evaluated, were made, as follows (based on draft Ontario Ministry of Environment and Climate Change (MOECC) bioaccumulation testing guidance; *personal communication*, Dr. T. Watson-Leung, MOECC):

- for inorganics (*i.e.*, metals), a BSAF >1 indicates bioaccumulation potential; and,
- for non-ionic organic compounds (*e.g.*, PAHs) and based on the relationship between organic carbon partition coefficients (K_{OC}) and lipid-normalized concentrations in tissue, the maximum BSAF for neutral organic compounds has been calculated to be about 1.7 (ASTM 2001d in Ingersoll and MacDonald, 2003; McFarland and Clarke, 1986), therefore, a BSAF > 1.7 generally indicates that there is bioaccumulation potential. The relative magnitude of the BSAF – and differences in BSAFs among stations - indicates the magnitude of bioaccumulation potential.

Results are provided in Tables 15a (for metals) and 15b (for PAHs), below. It should be noted that only bioaccumulative metals and total PAHs were evaluated in the integrated assessment. The BSAF for metals were ≤0.043. The BSAF for total PAH were ≤2.23; with the majority of values ≤0.15.

[29] Characteristics such as organism lipid content and sediment TOC content greatly influence the bioavailability and partitioning of non-ionic organic contaminants among sediment, porewater, and organism compartments. Normalizing sediment and tissue concentrations for these parameters is the accepted practice to reduce variability (Van Geest *et al*., 2010).

Table 15a
Mean BSAFs of Bioaccumulative Inorganics (Metals)

COPC	Stn #1 Co (ng/g ww)	Cs (ng/g dw)	Stn #2 Co (ng/g ww)	Cs (ng/g dw)	Stn #3 Co (ng/g ww)	Cs (ng/g dw)	Stn #4 Co (ng/g ww)	Cs (ng/g dw)	Stn #1 BSAF	Stn #2 BSAF	Stn #3 BSAF	Stn #4 BSAF
Arsenic	3.01	2600	0.15	2700	3.52	3700	4.93	2200	0.001	0.0001	0.001	0.002
Cadmium	0.67	200	0.428	200	0.574	800	0.462	200	0.003	0.002	0.001	0.002
Lead	10.5	7600	3.48	4500	2.67	6500	5.84	10500	0.001	0.001	0.0004	0.001
Selenium	4.69	100	2.7	200	4.5	600	4.81	200	0.047	0.014	0.008	0.024
Mercury	0.1	10	0.12	30	0.05	60	0.05	10	0.010	0.004	0.001	0.005

*shaded cell indicates bioaccumulation potential;
Note: none of the metals evaluated (via BSAF comparison) were considered to have bioaccumulation potential.

Table 15b
Mean BSAFs of Bioaccumulative Organics (Total PAHs)

Station	C0 (ng/g ww)	fl (g lipid/g ww)	CS (ng/g dw)	fSOC (g OC/g dw)	BSAF
	ng/g	g/g	ng/g	g/g	
Stn #1	19.48	0.01	383.33	0.01	0.05
Stn #2	395.75	0.01	1130.00	0.03	2.23
Stn #3	19.75	0.01	740.00	0.03	0.15
Stn #4	64.89	0.01	8476.67	0.06	0.09

*shaded cell indicates bioaccumulation potential; as indicated above, bioaccumulation potential for bioaccumulative organics is indicated by exceedance of BSAF > 1.7.

While it is evident that the BSAF value for Stn #2 is substantially higher (*i.e.*, an order of magnitude) than the other 3 stations, it is still only slightly higher than the threshold value of 1.7, indicating some, but a relatively low, bioaccumulation potential. A similar comparison has been made for *L. variegatus* in a previous study in which the authors reported an average BSAF for PAHs of 2.87 $\pm$ 0.6, indicating that this value 'was only slightly larger than the 1.7 value expected theoretically' (Kukkonen *et al.*, 2005).

Pseudokirchneriella subcapitata. Tests with *P. subcapitata* evaluated the growth of these sensitive green algal species using the porewater[30] of site sediments. The results from the test indicate that there were no adverse effects observed on cell yield of *P. subcapitata* (see Table 16 below and in Appendix D) in samples tested. The IC25 and IC50 values were all greater than the highest test concentration; in other words, while the endpoint could not be calculated, it is clear that the sediment porewater from these samples (without dilution) did not have any adverse impacts to the growth of these algae.

Table 16
Results: *Pseudokirchneriella subcapitata* growth inhibition test

SAMPLE ID	LOCATION IN RELATION TO DERAILMENT/EXPOSURE AREA	IC25/IC50 (%)
Control water (laboratory)	N/A	>95.2
Control Sediment (laboratory)	N/A	>95.2
Stn #1 (Silver Creek #1)	Reference*	>95.2
Stn #2 (Silver Creek #2)	Exposed**	>95.2
Stn #3	Reference*	>95.2
Stn #4	Exposed**	>95.2
Stn #6	Exposed**	>95.2

*U/S = upstream of spilled material; **D/S = downstream of derailment

4.6.2 Quality Assurance/Quality Control – Toxicity Testing

***Oncorhynchus mykiss* (Rainbow Trout) leachate test.** The toxicity test met acceptability criteria for performance of control organisms with no deviations from the EC protocol. Results for the reference toxicant test used to monitor laboratory performance and test organism sensitivity fell within the range of mean ± two standard deviations of the historical test results. Based on the reference toxicant result, test organisms appear to be of an appropriate degree of sensitivity.

***C. dilutus* and *H. azteca* sediment tests.** The health histories of the test organisms used in the exposures were acceptable and met the requirements of the EC protocols. The tests met all control acceptability criteria and water quality parameters remained within ranges specified in the protocols throughout the tests. Field replicates were not collected and testing was conducted using laboratory replicates. Uncertainty associated with these tests is best described by the SD around the mean. Results of the reference toxicant tests conducted during the testing program fell within the

[30] Sediment porewater was obtained by centrifuging an aliquot of sediment at 1500 rpm for 15 min under refrigerated conditions. The resulting overlying porewater was carefully decanted and used immediately to conduct the alga test. (Appendix D).

range for organism performance of mean and range, based on historical results obtained by the laboratory with these tests. Thus, the sensitivity of the organisms used in the tests was appropriate.

Lumbriculus variegatus. There were no deviations from the ASTM test protocol. Reference toxicant test used to monitor laboratory performance (quality control) and test organism sensitivity were conducted; however, a control chart for this species had not yet been developed by the laboratory due to an insufficient number of historical data points; however, the LC50 value for this test falls midway between the minimum and maximum values obtained in previous tests with this species (*i.e.*, 1.4 and 9.8 g/L, respectively).

Pseudokirchneriella subcapitata. The health history of the test organism used in the exposures was acceptable and met the requirements of the EC protocol. The tests met all control acceptability criteria and water quality parameters remained within ranges specified in the protocol throughout the tests. Uncertainty associated with these tests is best described by the SD around the mean. Results of the reference toxicant test conducted during the testing program fell within the range for organism performance of mean and range, based on historical results obtained by the laboratory with this test. Thus, the sensitivity of the organism used in the tests was appropriate.

4.6.3 Summary of Toxicity and Bioaccumulation Test Results

The level of agreement among the four sediment and sediment 'leachate'/porewater toxicity tests in the suite was quite high. All reference and exposure test sediments at all stations yielded results considered to be 'non-toxic' for all tests (*i.e.*, 100% survival of rainbow trout, no significant differences in growth compared to controls for benthic invertebrates (amphipods and chironomids), IC25/IC50 growth inhibition endpoints > 95.2% for green algae), except for the following:

- sediments collected from Stn #2 (Silver Creek, "exposed"), which yielded a slight, but statistically significant, decrease in survival with both the chironomid, *C. dilutus*, and the amphipod, *H. azteca;* and,
- specifically, using these two freshwater sediment tests, the sediment samples collected at Stn #2 yielded percent survival of 66% and 76% (in comparison to laboratory control [*i.e.*, 94% and 98%, respectively] while reference (not exposed) sediments [*i.e.*, 86% and 100%, respectively]), indicating moderate toxicity.

Moreover, based on the results of the *L. variegatus* bioaccumulation potential test, sediments collected from the two reference stations (*i.e.*, Stn #1 and Stn #3) and the station in the Coal Recovery area (*i.e.*, Stn #4) did not indicate bioaccumulation potential for metals or PAHs, while the sediments collected from the exposed stations, Stn #2 yielded differing bioaccumulation potential, and negligibly exceeding a standard bioaccumulation potential threshold (*i.e.*, 2.23 vs. 1.7; McFarland and Clarke, 1986).

The sediments and sediment porewaters/'leachates' at all but one station did not yield toxicity to fish, invertebrates and algae, the results of the sediment toxicity and bioaccumulation potential tests indicate that sediments from Stn #2 in Silver Creek, downstream of the derailment site, have the potential to affect freshwater invertebrates, and PAHs in sediments from Stn #2 (downstream, Silver Creek) have the slight potential to bioaccumulate in benthic invertebrates. Based on a comparison of COPC exceedances at the various stations, some correlation has been demonstrated between the COPC concentrations and toxicity and/or bioaccumulation potential. However, the highest concentrations of PAHs (and those that exceeded sediment quality guidelines) appear to have been observed at stations Stn #4, #5 and #7, in which no biological effects were observed in any of the toxicity tests in comparison with the reference station sediments. This indicates, overall, that any potential risk is small and localized to within an area approximately 160 m downstream of the derailment site.

Table 17 below provides an integrated summary of the results discussed above.

Table 17
Sediment Toxicity Testing Results – Qualitative Summary of Results[31]

TEST SPECIES	STATION 1 (REFERENCE)	STATION 2 (EXPOSED)	STATION 3 (REFERENCE)	STATION 4 (EXPOSED)	STATION 6 (EXPOSED)
Rainbow trout	-	-	-	-	-
C. dilutus (survival)	-	+	-	-	-
C. dilutus (growth)	-	-	-	-	-
H. azteca (survival)	-	+	-	-	-
H. azteca (growth)	-	-	-	-	-
L. variegatus (bioaccumulation potential)	-	+ (Total PAHs only)	-	-	N/A*
P. subcapitata (growth)	-	-	-	-	-

* Note: Bioaccumulation testing was not conducted with a sample from Station 6.

Legend

No effect observed (based on statistical significance) = "-"
Effect observed (based on statistical significance; exception, bioaccumulation potential test, exceedance of threshold) = "+"

[31]Results reflect statistical comparisons among sites relative to the test exposure controls.

5.0 Discussion

The discussion below is broken down into two main sections:

- the first section provides a background information review, which summarizes the current state-of-science regarding ecological effects of raw, unburnt coal; and,
- the second section discusses the results of this AIA study and puts this Tier 1 assessment into context, and uses a weight-of-evidence evaluation to arrive at conclusions regarding potential risk from the residual coal, subsequent to the Coal Recovery program conducted in Burnaby Lake by CN.

Prior to this discussion, it is important to define the different types of coal, as follows:
- Metallurgical Coal - coal that is used to make steel
- Thermal Coal – coal used for generating electricity

While there is information regarding the effects of different coal types, the focus of this review is on metallurgical coal, which was released during the derailment.

5.1 Background Information Review – Ecological Effects of Coal

Almost a quarter of the world's energy is produced by coal (Baker, 2013; Coal Association of Canada, 2014). Canada is a major producer of metallurgical coal or coking coal, which emanates mainly from bituminous coal[32] (Baker, 2013). Given coal's significance to Canada's resource industry, it is important to understand the impacts that raw or unburnt coal may pose to the surrounding environment. This section presents a review of the effects of unburnt coal on freshwater ecosystems with a focus on bituminous coal.

There a number of ways in which coal can enter aquatic ecosystems, including: erosion of exposed, undisturbed coal seams, losses from coal stockpiles, and, incidental spills of coal during transportation (Gibson *et al.*, 2005). Once the coal is introduced into the environment, various potential effects are possible: physical effects, that can change the use of the natural space; and, chemical effects, that can disrupt the natural functions of aquatic organisms (Gibson *et al.*, 2005). The main factor that determines the impacts of unburnt coal on the freshwater environment is the relative amount of time the coal is exposed, and therefore broken down in the surrounding environment (Gibson *et al.*, 2005). However, there are other important physical and chemical

[32]A detailed classification of different bituminous coal types is provided in a USGS circular: Wood *et al.* [no date provided]; http://pubs.usgs.gov/circ/c891/table1.htm

factors (*e.g.*, abrasion - physical, pH, organic carbon – chemical) that are discussed in greater detail below.

Physical Effects. Physical effects – from particulate material - are the most immediate and obvious ramifications of raw coal entering the aquatic ecosystem. When raw coal first enters a freshwater body or is being moved by the water currents, these modes of movement cause disruptions to the surrounding environment (Gibson *et al.*, 2005; Hyslop and Davies, 1998). This phenomenon has been observed predominantly in marine species. Hyslop and Davies (1998) found, in an experimental study, that the marine chlorophyte alga, *Ulva lactuca* decreased in biomass due to movement of large coal particles by water currents. Unfortunately, there is a paucity of information on physical effects of large particles of coal in general, and comparable examples from freshwater studies do not currently exist; extrapolation of these conclusions to the freshwater ecosystem is therefore not supported. In general, it has been ascertained that increased concentrations of suspended particulate coal in the water column may cause abrasion to animals (*e.g.,* abrasion on the gills of fish) and plants living on the surface (Gibson *et al.*, 2005).

The addition of raw coal to the freshwater environment can also lead to changes to the aquatic sediment, and, depending on the size of coal particles, causing there to be respiratory obstruction (*e.g.,* clogged fish gills) for the surrounding biota (Gibson *et al.,* 2005; Newcombe and MacDonald, 1991). Suspended sediment has also been observed to obstruct respiratory pathways and cause reduction in growth for some invertebrate species, and increase mortality in some fish (Newcombe and MacDonald, 1991). Ahrens and Morrisey (2005) also indicated that with the addition of large coal pieces, greater surface area is added to the environment possibly producing new niches for various aquatic biota (Gibson *et al.*, 2005). This has the potential to shift species and/or population distributions or within aquatic ecosystems (Gibson *et al*., 2005).

Chemical effects. Raw coal contains many organic and inorganic chemicals, all of which can change the composition of the water, under specific environmental conditions. For example, PAHs can be released from raw coal (Gibson *et al*., 2005; Achten and Hoffman, 2009; Laumann *et al.*, 2011) under specific conditions, such as: thermolysis, pH variation, and the presence of organic matter and biosurfactants. The bioavailability of PAHs is also, therefore, dependent on these environmental conditions (Yeom *et al.*, 1996). PAHs released as coal particulates are broken down, thus exposing hydrophobic PAH compounds to other organic matter within the sediments. Therefore, time and physical breakdown of the coal particles to small particulates are the major determining factors (Gibson *et al.* 2005; and Achten & Hofmann, 2009). In natural waters, due to their low water solubility most PAHs are generally of low concern. However, if there is a sufficiently long contact of coal with natural waters, lower molecular weight compounds (*e.g.*, naphthalenes and phenanthrene) may be mobilized and transported by co-eluting humic-like substances derived from the coals (Laumann *et al.*, 2011), and therefore, bioavailability could be influenced by the magnitude of ambient organic carbon levels.

Some PAHs have the potential to be toxic and carcinogenic (Gibson *et al.*, 2005; Laumann *et al.*, 2011). However, effects are only a concern when PAHs become bioavailable, which rarely occurs (Gibson *et al.,* 2005; Achten and Hoffman, 2009; Chapman *et al*., 1996). For example, Gerhart *et al*. (1981) observed that when fathead minnows (*Pimephales promelas*) were exposed to coal particles after an exposure period of 15 days, PAHs were not detected in their tissue. Achten *et al*. (2011) also determined that when PAHs were bound to bituminous coal samples, PAHs degradation by microbes in wet sediment was prevented. The authors concluded that PAHs are of minimal environmental concern if entering a freshwater environment (Achten *et al.*, 2011).

Another effect of raw coal in surrounding water can be an increase in acidity. This effect again depends on the relative exposure time of the coal in the aquatic environment and the coal's sulphur content (Gibson *et al.*, 2005); higher concentrations of sulphur are correlated with high acidity/low pH (Gibson *et al.*, 2005). Scullion & Edwards (1980b) investigated the impacts of coal constituents on macroinvertebrate fauna in a neighboring small river from 1972 to 1973, and measured the cumulative rainfall and pH over a period of two weeks. During periods of higher rainfall, pH in the river was lowered. The researchers observed that particles from a coal stockpile resulted in low pH in the receiving river; during summer months, the range of pH was 2.8 - 2.9 and during winter months, the pH was in the range 3.2 - 4.0. Also, high (*i.e.*, >80%) mortalities of rainbow trout eggs were observed along with a low density of brown trout within the coal particulate-rich water (Scullion & Edwards (1980a). Finally, there was a detectable change in the invertebrate community due to acidic conditions resulting from the presence of the coal particles (Scullion & Edwards, 1980b). These studies concentrated on coal particles emanating from coal stockpiles (*i.e.*, longer residence time, wide range of particle sizes) and this may not be similar to the potential effects of large pieces of unburnt coal. Davis & Boegly (1981) reported a direct correlation between coal particle size and chemical concentrations from leached coal.

In addition, as pH decreases (*i.e.*, acidity increases), trace metals within the coal may leach into the water body (Gibson *et al.*, 2005; Gerhardt, 1993). Trace metals found within unburnt coal include elements such as: zinc, copper, manganese, iron and chromium (Gibson *et al*., 2005; Cheam *et al*., 2000). At elevated concentrations, these metals can be toxic to various aquatic organisms (Gibson *et al*., 2005; Cheam *et al*., 2000). Many studies have linked coal and trace metal concentrations in aquatic ecosystems. However, the mineral composition of the coal, plus the chemical speciation of the trace metals (*e.g.*, cadmium, zinc, nickel) and various ambient conditions like pH, water hardness, influences the availability and therefore the effects that trace metals exert on aquatic organisms (Gibson *et al.*, 2005).

Overall, much of the research has focused on coal subsequent to processing; there is a relative lack of scientific research on the effects of unburnt coal on freshwater ecosystems. Studies on smaller particles have proven useful. Time of contact is a major factor relating to chemical effects due to the presence of unburnt coal (Gibson *et al.*, 2005). With time, the coal breaks down into smaller particles (*i.e.*, greater surface area), increasing the likelihood of chemicals being released into the environment (Davis & Boegly, 1981). Also, a relationship between particle size and the relative release rate of chemicals released by the coal has been established (Davis & Boegly, 1981). The mineralization (*i.e.*, the mineral content of the coal; all of the chemical elements bound within the carbon matrix of the coal), and the characteristics of the surrounding environment (*e.g.*, pH, temperature) can also have an impact on chemical speciation. Bioavailability of the chemicals released from unburnt coal is also heavily influenced by these factors.

5.2 Integration of Results from the Silver Creek/Burnaby Lake Aquatic Impact Assessment

This section reviews and integrates the results of all the elements of the AIA, specifically: water quality, sediment quality, sediment and sediment porewater/'leachate' toxicity, and bioaccumulation potential.

Water Quality. As indicated early, the water quality monitoring effort conducted during the Coal Recovery program yielded results indicating that, overall, chemical parameters measured in the watershed were within applicable water quality guidelines, with some exceptions not deemed to be spill-related (CN, 2014a, b). The conclusion related to this weight-of-evidence assessment of the AIA is that none of the results of the water quality analyses indicate potential adverse effects at any of the stations. This conclusion further indicates that if there are any potential residual impacts from the derailment, they would likely be expected to occur in the sediments, rather than the water column (*i.e.*, any particles or dissolved chemicals of concern that would have been suspended in the water column would have settled out to the bottom of the creek and/or the lake).

Sediment Quality. Based on a review of sediment chemistry data available for Silver Creek and Burnaby Lake sediments collected during this study, the following describes the exceedances of regulatory benchmarks of the chemicals present in the sediments at the various Silver Creek/Burnaby Lake stations:

- Metals:
    - None at any station above PELs; and,
    - cadmium, copper[33], and nickel above the provincial and federal ISQG level – however, only at one station (*i.e.*, Stn #3; upstream Burnaby Lake station)[34].

[33]Note: previously identified as a common COPC in Burnaby Lake.

- PAHs:
    - 7 PAHs above PELs (ranging from 1-4 station coverage, and mainly at stations Stn #2, #4, #5, and #7); and,
    - almost all detected PAHs at all stations at or above the Approved Guidelines and/or the ISQG (except for Acenapthene, which was below the MDL).

This is based on the exceedance of environmental concentrations of these parameters with available sediment quality guidelines, and background/reference area concentrations of theses metals.

Sediment and Sediment Porewater Toxicity. The toxicity test results for the sediment samples collected from Silver Creek and Burnaby Lake sediments, in comparison with clean control laboratory sediment and reference areas, suggest that sediment samples collected in the vicinity of Stn #2 may be potentially toxic to freshwater benthic macroinvertebrates (survival endpoint), but not to fish and algae. Sediments collected from all other areas did not demonstrate toxicity potential, based on the suite of tests conducted.

Bioaccumulation Potential. The freshwater oligochaete bioaccumulation potential test results for the sediment samples collected from Silver Creek and Burnaby Lake sediments, in comparison with laboratory results (*i.e.*, clean sediment) and a reference area (*i.e.*, upstream site), suggest that total PAHs in sediment samples collected in the vicinity of station Stn #2 may be slightly potentially bioaccumulative [35]. Sediments from all other areas/stations did not exhibit bioaccumulation potential to the species exposed.

An illustrative qualitative weight-of-evidence analysis of the various lines of evidence evaluated in this AIA study is presented in Table 18, and AIA conclusions based on an evaluation of the original hypothesis-based questions, is presented in Table 19.

[34]This is consistent with historical sediment quality data in Burnaby Lake (*e.g.*, ENKON, 2002).
[35]While the BSAF calculated (*i.e.*, 2.23) was >1.7 (the bioaccumulation potential threshold), the exceedance is negligible, and likely in the range of experimental and spatial error, in relation to other non-ionic organics.

Table 18
Qualitative Weight-of-Evidence Comparison of the Reference and Exposure Stations, Silver Creek Silver Creek and Burnaby Lake

SQT Aspect	Station 1 Reference	Station 2 Exposure	Station 3 Reference	Station 4 Exposure	Station 5* Exposure	Station 6 Exposure	Station 7* Exposure
Water Quality	-	-	-	-	-	-	-
Sediment Porewater - metals	-	-	-	-	-	-	-
Sediment Porewater - PAHs	-	-	+	-	-	-	-
Sediment Quality - metals	-	-	+	-	-	-	-
Sediment Quality - PAHs	-	+	+	++	++	-	++
Sediment Toxicity – Fish and Algae	-	-	-	-	-	-	-
Sediment Toxicity – Invertebrates	-	+	-	-	N/A*	-	N/A*
Sediment Bioaccumulation Potential- Invertebrates	-	+ (Total PAHs only)	-	-	N/A*	N/A**	N/A*

* Sediment toxicity testing was not conducted with samples from Stn #5 and Stn #7, as it was determined that there would be sufficient areal coverage in order to establish sediment toxicity potential downstream of the recovery area
** Bioaccumulation testing was not conducted with samples from Stn #6 (*i.e.,* PAHs were not detected in sediments and average metals concentrations were below available guidelines at Stn #6).

Legend
No effect observed (based on statistical significance) = "-"
Moderate Effect observed (based on statistical significance or exceedance of ISQG) = "+"
Probable Effect observed (based on statistical significance or exceedance of PEL) = "++"

Table 19
AIA Conclusions based on an Evaluation of Original Hypothesis-based Questions

HYPOTHESIS-BASED QUESTION	TASK DESCRIPTION	AIA CONCLUSIONS
What are the potential agents (chemicals) of effect/impact?	chemical characterization and environmental fate of the spilled material, including constituents of the metallurgical coal, in addition to any potential breakdown products	Based on analyses of raw coal: • Metals do not appear to be significant in terms of potential effect/impact; and, • For two categories of PAHs: o Potential (above ISQGs): fluoranthene, pyrene, benzo(a)anthracene, chrysene and benzo(a)pyrene More Likely (above PELs): naphthalene, 2-methylnaphthalene, fluorene and phenanthrene **NOTE:** *As indicated above, this would not be considered a 'normal' condition, as aquatic organisms are unlikely to live among coal particles exclusively, but rather a mixture of natural sediment and other materials. The comparison of pure product concentrations with the SQG is provided here for context only.*
Where at the site can effects/impacts occur?	delineation of study areas of environmental concern (AECs)	Based on the Work Plan: • Between the derailment site (*i.e.*, Silver Creek) and ~160 m downstream of Coal Recovery area (*i.e.*, just above the Cariboo Dam).
Do chemicals in water and sediment occur at concentrations deemed to result in effects/impacts?	characterization of concentrations of chemicals of potential concern (COPCs) in receiving environments; this would include actual reference and exposure concentrations (where possible), with a comparison of parameter concentrations to applicable guidelines, objectives and standards (in this case, Provincial and Federal water and sediment quality guidelines)	Based on analyses of site sediments: • Metals: • Potential (above ISQGs): Cadmium, Copper, Nickel (although these were noted only at a reference site, *i.e.*, Stn #3 in Burnaby Lake) • PAHs: • Various PAHs above ISQGs: ~6-8 exceedances, in Silver Creek and Burnaby Lake downstream of derailment site • Various PAHs above PELs): 4 - 6 exceedances (above ISQGs and PELs), in Silver Creek, as well as Burnaby Lake in and downstream of Coal Recovery area
Will chemicals in water and sediment have adverse effects to resident organisms?	description of any short- and/or long-term potential biological effects (toxicity) to various aquatic biota (*e.g.*, based on endpoints such as survival, growth), including magnitude, extent and duration of impact (if any)	Based on results of toxicity testing with site sediments: • Potential toxicity to benthic macroinvertebrates in a localized area - Silver Creek, roughly 160 m downstream of the derailment site (Stn #2)

Will chemicals in water and sediment be taken up by organisms (bioaccumulate) over time?	description of any short- and/or long-term potential impacts to receiving environment (*e.g.*, based on bioavailability of contaminants related to the remaining coal impacts and risks to receptor groups), including magnitude, extent and duration of impact (if any)	Based on results of bioaccumulation potential testing with site sediments: • Some bioaccumulation potential to benthic macroinvertebrates in a localized area – Silver Creek, roughly 160 m downstream of the derailment site (Stn #2)

6.0 Conclusions and Recommendations

6.1 Conclusions

In this AIA, a commonly-applied weight-of-evidence approach – the Sediment Quality Triad or SQT – was used to evaluate impacts to aquatic habitats from unrecovered coal downstream of the derailment area. The potential impacts of residual coal were evaluated subsequent to the completion of recovery efforts (*i.e.*, the Coal Recovery program) conducted by CN[36]. Four major study elements, indicating potential for aquatic impact, namely: water quality, sediment quality, sediment and sediment 'leachate'/porewater toxicity and bioaccumulation potential, were evaluated.

Water Quality. Based on monitoring conducted during and subsequent to the Coal Recovery program, water quality was deemed to be generally consistent with Provincial and/or Federal guidelines protective of aquatic life, which is especially positive, given the relative aquatic health status of the Brunette watershed.

Sediment Quality. Site sediment concentrations of three metals (cadmium, copper and nickel; only at the reference area) and various PAHs (mainly downstream of the Coal Recovery area) exceeded freshwater sediment guidelines and background/reference area concentrations. While exceedance of these guidelines indicates the potential for adverse effects, additional analyses in the form of laboratory toxicity tests (with site-collected sediments) provided more specific information regarding the bioavailability of these parameters, and the potential for biological impact.

Sediment and Sediment Porewater Toxicity. The sediment toxicity test results for the fish, invertebrate and algae tests conducted with Silver Creek/Burnaby Lake sediment samples in comparison with both laboratory control samples and reference areas indicate that samples were non-toxic to all species tested in most areas, with the exception of Stn #2 (Silver Creek, 160 m downstream of the derailment site), at which samples yielded marginal, but statistically-significant effects on the survival of benthic macroinvertebrates (*i.e.*, midges and amphipods).

Bioaccumulation Potential. The bioaccumulation potential test results for invertebrates (*i.e.*, represented by freshwater oligochaetes) conducted with Silver Creek/Burnaby Lake sediment samples, in comparison with both laboratory control samples and reference areas,

[36] It should be noted, however, that during the Emergency Response, Triton collected total suspended solids (TSS) and turbidity samples, as well as *in situ* pH data,. This information was outlined in *Summary of in situ and analytical water quality data collected as part of the Burnaby Lake coal recovery program (updated to April 4, 2014)*- Submitted to Environment Canada, April 9, 2014.

indicate that PAHs present in specific areas downstream of the derailment site (*i.e.*, Stn #2) have the slight potential to accumulate in benthic invertebrates resident in those areas.

This result, combined with the toxicity potential of these sediments (in the form of the sediment toxicity test results, reported above) support a correlation between the presence of PAHs in sediment, sediment toxicity and bioaccumulation potential in a localized area, roughly 160 m downstream from the derailment site.

6.2 Recommendations

Based on the conclusions of the weight-of-evidence evaluation, specifically, the fact that there potentially are minor impacts in the study area, and that these are likely restricted to a very small localized area within Silver Creek and Burnaby Lake, the following recommendations are provided:

- given that the residual coal in sediments is of a low volume in relation to the volume of the coal spilled during the derailment, that these sediments be left in place to undergo natural attenuation;

- further mitigation of these sediments is not recommended, as any removal of residual coal mixed with sediments would likely pose greater risks to environmental receptors, through:

  - further habitat disturbance; and,
  - re-suspension and transport of any residual coal particles over a broader area

- additional study in the form of a Tier 2 assessment (as discussed above) is not required for the following reasons:

  - it is not anticipated that higher trophic levels would experience any significant adverse effects; and,
  - there are unlikely to be impacts beyond the spatial extent assessed during the AIA (*i.e.,* downstream of the Coal Recovery area, beyond the Cariboo Dam, and into the Brunette River).

Although the results of this study do not indicate a Tier 2 assessment is required, it is recommended that a focused, follow-up monitoring program be completed to further evaluate the area of concern and determine if sediment chemistry, toxicity, and bioaccumulation has altered since the 2014 study. The details are provided in section 7.0, below.

7.0 Proposed Monitoring Plan for 2015

7.1 Objectives

This section outlines the proposed monitoring plan for 2015, which will comprise sediment chemistry and toxicity and bioaccumulation testing. The objective of this component of the 2015 monitoring plan will be to re-evaluate sediment quality conditions (*e.g.*, concentrations of COPCs and relevant physical parameters, toxicity and bioacccumulation potential) in both background/reference and “exposed” areas with a more intensive focus on Silver Creek, downstream of the derailment site.

This will help to identify whether, in areas downstream of the spill, residual impacts have: worsened, stayed the same, or improved, since the 2014 sampling program.

7.2 Proposed Sampling Stations

Based on the information and data collected in 2014, field sampling will be conducted at a combination of old and new sampling stations (Figure 5), as follows:

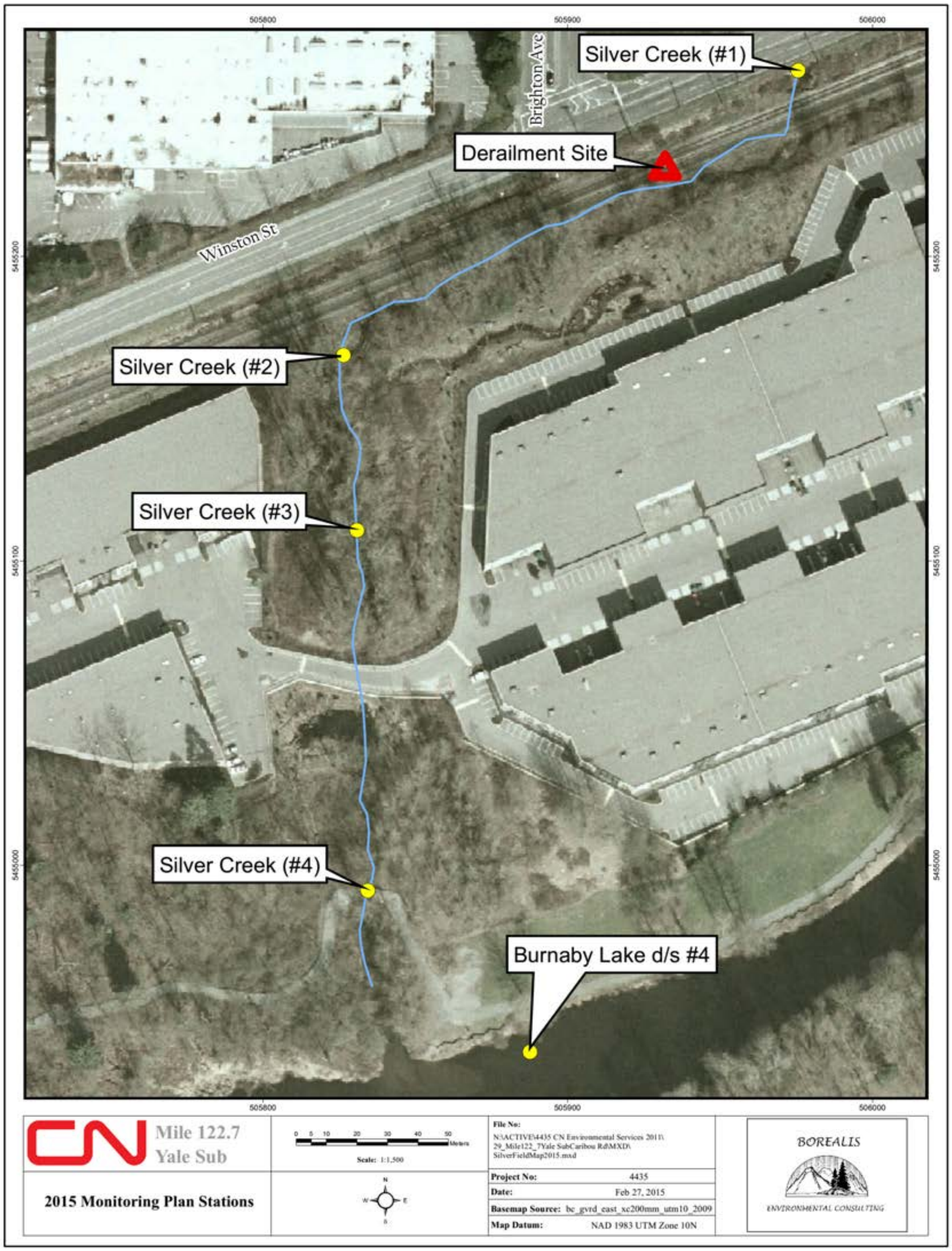
Silver Creek

- background/reference (*i.e.*, above the derailment point) (Silver Creek u/s Stn #1);
- 160 m downstream of the derailment (Silver Creek d/s Stn #2);
- *New station*~220 m downstream of the derailment (Silver Creek d/s #Stn SC-3); and,
- *New station*~320 m downstream of the derailment (Silver Creek d/s #Stn SC-4 –located at pedestrian bridge over Silver Creek in the Park.

Burnaby Lake

- ‘exposed’ far-field (*i.e.*, inside the coal recovery area) (Burnaby Lake d/s Stn #4).

Figure 5
Proposed Sampling Stations for 2015 Monitoring Plan



This 'gradient' approach will coincide with the established extent of dispersion of the sediments into the receiving environment (from recovery plans; Triton, 2014 a, b). As indicated above, selected sampling stations will consist of a gradient of both background/reference and 'exposed' stations, to allow for spatial comparisons of:

- pre- and post-spill conditions; and,
- in addition for this program, 2014 and 2015 conditions (temporal assessment).

7.3 Sediment Chemistry

7.3.1 Field Sampling

The sampling program will tentatively be implemented around the week of May 25, 2015 (to coincide as closely as possible with the 2014 program), with analytical work being conducted immediately thereafter. Per the 2014 program, all sampling will be conducted according to BCMOE (2003) Field Sampling Manual. All chemical analyses will be conducted at AGAT Laboratories (AGAT), in Burnaby, BC. AGAT is a competent environmental laboratory, accredited – according to ISO Standard 17025 - by Canada's national accreditation body, the Canadian Association for Laboratory Accreditation (CALA). The sediment quality program will be inclusive of all of the applicable parameters and measures outlined in approved monitoring guidance (*i.e.*, BCMOE (2012), per the 2014 program.

Sediment samples will be collected from a total of 5 stations (Figure 5; see list above), located at varying distances from the source of the spilled coal material (*i.e.*, the derailment site). A minimum of three discrete replicates from each of the sampling stations will be collected, in order to reflect the variability of chemicals in sediments at a given station.

Samples will be fully homogenized at the laboratory, and a subsample of the homogenized sample will be analyzed for a full suite of standard parameters/variables, including: grain size (*i.e.*, particle size distribution), moisture content, total organic carbon, total metals, and polycyclic aromatic hydrocarbons (PAHs). In order to address variability associated with subsampling, duplicates and blanks will also be analyzed.

7.4 Sediment Toxicity and Bioaccumulation Testing

Based on the results of the 2014 results, which indicated that there was no toxicity to fish or algae, sediment toxicity tests using benthic macroinvertebrates will be applied. An appropriate suite of sediment toxicity tests (based on the 2014 program) has been proposed for the 2015 monitoring plan (see Table 20, below).

7.4.1 Field Sampling and Laboratory Testing

For the purposes of conducting sediment toxicity testing 10 L of bulk sediment will be collected from the five stations, co-located with sediment chemistry sampling stations (as above). These samples will also be collected according to BCMOE (2003) and Environment Canada (1994). The testing suite will comprise the same three benthic freshwater invertebrate toxicity tests from the 2014 program (using sediment as test medium; one of these tests will also measure bioaccumulation potential). Table 20 below outlines relevant details related to the selected toxicity tests.

Table 20
Toxicity tests proposed for the Silver Creek/Burnaby Lake 2015 Monitoring Plan

Representative trophic level	Test species	Biological endpoint	Duration	Method reference	Notes
Benthic Invertebrates	*Chironomus* sp.	Survival/ Growth	14 days (chronic)	Environment Canada (1997); EPS1/RM/32	Whole sediment test
	Hyalella azteca	Survival and growth	10 days (chronic)	Environment Canada (2013); EPS1/RM/33	Whole sediment test
	Lumbriculus variegatus	Bioaccumulation potential	28 days (chronic)	ASTM International, 2014a,b; E1706-00, E-1688-10	Whole sediment test

Sediment toxicity testing will be conducted at Nautilus Environmental (Nautilus), in Burnaby, BC. Nautilus is a competent ecotoxicity laboratory, accredited – according to ISO Standard 17025 - by Canada's national accreditation body, CALA.

7.5 Proposed Schedule

Table 21 below outlines the details of the proposed schedule of the 2015 Monitoring Plan.

Table 21
Proposed Schedule for 2015 Monitoring Plan, Silver Creek/Burnaby Lake

Milestone	Date	Completion	Notes
Field Sampling	Week of May 25, 2015	May 29, 2015	
Laboratory Analyses			
Chemical Analyses	Week of June 8, 2015	Week of June 15, 2015	
Toxicity Tests	Week of June 8, 2015	Week of July 13, 2015	Oligochaete bioaccumulation potential test is the longest test (28 days).
Statistical Analyses/Interpretation		July 27, 2015	
Draft Report		September 7, 2015	Allow for review and comment period.
Final Report		October 31, 2015	Subsequent to revisions made based on comments received on Draft Report.

8.0 References

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