# Subject Matter Expert Report: Coal Dust and Sediment Quality.

## Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population.

Prepared for:

Teck Coal Limited

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# EXECUTIVE SUMMARY

In September 2019, population monitoring conducted on behalf of Teck Coal Limited (Teck Coal) determined that the abundance of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WCT) adults and sub-adults (i.e., juveniles) in the upper Fording River (UFR) was significantly lower than observed in the previous monitoring event in September 2017 (Cope 2020). Teck Coal initiated an Evaluation of Cause (EoC) to determine what stressors may have led to, or contributed to, the population decline that occurred sometime between the end of September 2017 and September 2019 ("Decline Window") (Evaluation of Cause Team, EoC 2021).

While there is no record of a spill of coal into the UFR during, or prior to, the Decline Window, there have been anecdotal reports of coal dust in and around the river. Sediment sampling has also documented the presence of coal-associated constituents, specifically metals and polycyclic aromatic hydrocarbons (PAHs), historically and within the Decline Window, although the proportion of those constituents that may be related to coal dust is unknown. At sufficient concentrations some of these constituents have the potential to cause adverse effects to aquatic organisms, including some life stages of WCT.

Azimuth Consulting Group (Azimuth) was retained by Teck Coal to provide support as Subject Matter Expert (SME) to assess the potential for coal-associated constituents in sediment, specifically metals and PAHs, to have caused (Overarching Hypothesis #1) or contributed to (Overarching Hypothesis #2) the WCT population decline. The specific stressor hypothesis examined in consideration of the Overarching Hypotheses in this EoC report is:

*Were concentrations of metals and/or PAHs in sediment present during the Decline Window sufficient to result in adverse effects to WCT that could have caused or contributed to the population decline?*

Azimuth evaluated the evidence that there were changes in sediment quality in the UFR during the Decline Window associated with increased constituent concentrations and that those changes had the potential to result in adverse effects consistent with the WCT population decline. Sediment quality data collected on behalf of Teck Coal as part of studies in the UFR conducted prior to and during the Decline Window, including annual monitoring, sediment quality baseline and supporting studies, and fish monitoring and habitat assessments, were used for this evaluation. Provincial and federal sediment quality guidelines (SQGs) and scientific literature were also relied upon.

The potential for sediment quality to have changed during the Decline Window at concentrations with the potential to cause adverse effects was evaluated by:

1. screening metal and PAH concentrations against SQGs as a conservative assessment of potential for sediment toxicity
2. comparing concentrations of metals and PAHs between the historical and the Decline Window time periods, and
3. assessing the spatial distribution of exceedances of SQGs and/or historical (2011-2017[1]) concentrations of constituents in sediment during the Decline Window.

These three lines of evidence were used to identify where, and to what degree, sediment quality changed during the Decline Window for individual constituents. The potential for these changes in sediment quality to have translated to adverse effects to WCT was evaluated with respect to the bioavailability and nature of potential adverse effects associated with metals and PAHs.

The sediment quality screening indicated that seven metals and eleven PAHs were associated with changes in sediment quality during the Decline Window in one or more of the four river segment groups that were assessed. Constituent concentrations in the upper UFR (Henretta Lake), which has important rearing and overwintering habitat, were similar to historical concentrations and/or had few constituents that exceeded SQGs. In contrast, sediment chemistry data indicated changes in sediment quality for some metals and PAHs in the middle (Segments 6-8) and lower segments (Segments 1-3) of the UFR where there is also important rearing and overwintering habitat.

The potential for these changes in sediment quality to result in adverse impacts to WCT, and specifically to mortality of juveniles and adults, is a function of constituent bioavailability and the toxicity as well as the timing (i.e., life stage) and duration of exposure. Data from site-specific studies and the literature indicate that the bioavailability of metals and PAHs from sediment in the UFR is likely limited. Low bioavailability would limit the exposure of aquatic organisms to metals and PAHs in sediment, which may in turn, reduce the potential for adverse effects indicated by exceedances of SQGs. It is not possible to preclude that sub-lethal effects could have occurred in the UFR if constituents were bioavailable at sufficient concentrations. However, those effects, such as reduced energetic fitness or developmental abnormalities may cause individual mortalities, particularly in the early life stages, but would be unlikely to cause the population level mortality of juveniles and adults observed in the population decline.

[1] Sediment chemistry from 2017 was evaluated as part of the historical dataset, since the WCT population decline was reported in the fall 2017, after the 2017 sediment sampling event in September.

*Based on this assessment, we conclude that concentrations of metals and PAHs in sediment present during the Decline Window were insufficient to result in adverse effects to WCT that could have caused the population decline. However, we cannot preclude the possibility that sub-lethal effects may have reduced individual fitness of WCT in some parts of the UFR which would make them more susceptible to other stressors.*

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| BC | British Columbia |
| BIC | Benthic Invertebrate Community |
| CCME | Canadian Council of Ministers of the Environment |
| COPC | Contaminant of Potential Concern |
| DW | Decline Window |
| ENV | British Columbia Ministry of Environment and Climate Change Strategy |
| EoC | Evaluation of Cause |
| FRO | Fording River Operations |
| GHO | Greenhills Operations |
| HIST | Historical |
| HQ(s) | Historical Quotient(s) |
| ISQG | Interim Sediment Quality Guideline |
| LAEMP | Local Aquatic Effects Monitoring Program |
| LPL | Lowest Practical Level |
| MDL | Method Detection Limit |
| PAH(s) | Polycyclic Aromatic Hydrocarbon(s) |
| PEL | Probable Effects Level |
| QAQC | Quality Assurance Quality Control |
| RAEMP | Regional Aquatic Effects Monitoring Program |
| SARA | Species at Risk Act |
| SME(s) | Subject Matter Expert(s) |
| SQ(s) | Screening Quotient(s) |
| SQG(s) | Sediment Quality Guideline(s) |
| TOC | Total Organic Carbon |
| UFR | Upper Fording River |
| WCT | Westslope Cutthroat Trout |
| WSQG(s) | Working Sediment Quality Guideline(s) |

# READER'S NOTE

## What is the Evaluation of Cause and what is its purpose?

The Evaluation of Cause is the process used to investigate, evaluate and report on the reasons the Westslope Cutthroat Trout population declined in the upper Fording River between fall 2017 and fall 2019.

## Background

The Elk Valley is located in the southeast corner of British Columbia (BC), Canada. It contains the main stem of the Elk River (220 km long) and many tributaries, including the Fording River (70 km long). This report focuses on the upper Fording River, which starts 20 km upstream from its confluence with the Elk River at Josephine Falls. The Ktunaxa First Nation has occupied lands in the region for more than 10,000 years. Rivers and streams of the region provide culturally important sources of fish and plants.

The upper Fording River watershed is at a high elevation and is occupied by only one fish species, a genetically pure population of Westslope Cutthroat Trout *(Oncorhynchus clarkii lewisi)* — an iconic fish species that is highly valued in the area. This population is physically isolated because Josephine Falls is a natural barrier to fish movement. The species is protected under the federal Fisheries Act and the Species at Risk Act. In BC, the Conservation Data Center categorized Westslope Cutthroat Trout as "imperiled or of special concern, vulnerable to extirpation or extinction." Finally, it has been identified as a priority sport fish species by the Province of BC.

The upper Fording River watershed is influenced by various human-caused disturbances including roads, a railway, a natural gas pipeline, forest harvesting and coal mining. Teck Coal Limited (Teck

### Evaluation of Cause

*Following identification of the decline in the Westslope Cutthroat Trout population, Teck Coal initiated an Evaluation of Cause process. The overall results of this process are reported in a separate document (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports.*

*The report that follows this Reader's Note is one of those Subject Matter Expert Reports.*

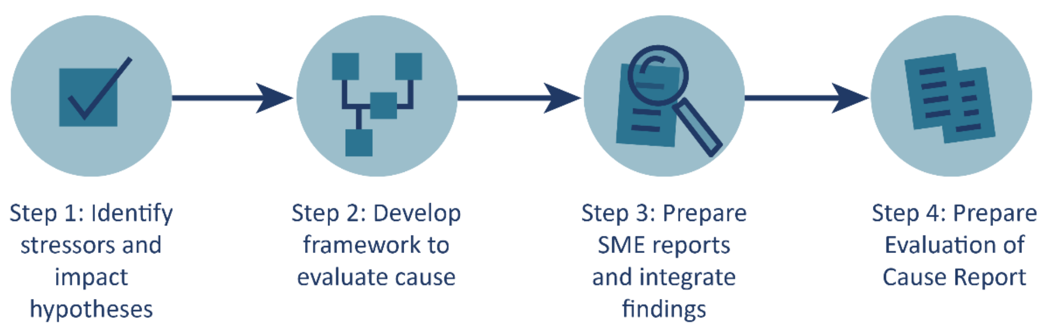
Coal) operates the three surface coal mines within the upper Fording River watershed, upstream of Josephine Falls: Fording River Operations, Greenhills Operations and Line Creek Operations.

Monitoring conducted for Teck Coal in the fall of 2019 found that the abundance of Westslope Cutthroat Trout adults and sub-adults in the upper Fording River had declined significantly since previous sampling in fall 2017. In addition, there was evidence that juvenile fish density had decreased. Teck Coal initiated an *Evaluation of Cause* process. The overall results of this process are reported separately (Evaluation of Cause Team, 2021) and are supported by a series of Subject Matter Expert reports such as this one. The full list of SME reports follows at the end of this Reader's Note.

Building on and in addition to the Evaluation of Cause, there are ongoing efforts to support fish population recovery and implement environmental improvements in the upper Fording River.

## How the Evaluation of Cause was approached

When the fish decline was identified, Teck Coal established an *Evaluation of Cause Team* (the Team), composed of *Subject Matter Experts* and coordinated by an Evaluation of Cause *Team Lead.* Further details about the Team are provided in the Evaluation of Cause report. The Team developed a systematic and objective approach (see figure below) that included developing a Framework for Subject Matter Experts to apply in their specific work. All work was subjected to rigorous peer review.




**Conceptual approach to the Evaluation of Cause for the decline in the upper Fording River Westslope Cutthroat Trout population.**

With input from representatives of various regulatory agencies and the Ktunaxa Nation Council, the Team initially identified potential stressors and impact hypotheses that might explain the cause(s) of the population decline. Two overarching hypotheses (essentially, questions for the Team to evaluate) were used:

Overarching Hypothesis #1: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a single acute stressor[2] or a single chronic stressor[3].

Overarching Hypothesis #2: The significant decline in the upper Fording River Westslope Cutthroat Trout population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced fish numbers, but cumulatively caused the decline.

The Evaluation of Cause examined numerous stressors in the UFR to determine if and to what extent those stressors and various conditions played a role in the Westslope Cutthroat Trout's decline. Given that the purpose was to evaluate the cause of the decline in abundance from 2017 to 2019[4], it was important to identify stressors or conditions that changed or were different during that period. It was equally important to identify the potential stressors or conditions that did not change during the decline window but may, nevertheless, have been important constraints on the population with respect to their ability to respond to or recover from the stressors. Finally, interactions between stressors and conditions had to be considered in an integrated fashion. Where an *impact hypothesis* depended on or may have been exacerbated by interactions among stressors or conditions, the interaction mechanisms were also considered.

The Evaluation of Cause process produced two types of deliverables:

**Individual Subject Matter Expert (SME) reports** (such as the one that follows this Note): These reports mostly focus on impact hypotheses under Overarching Hypothesis #1 (see list, following). A Framework was used to align SME work for all the potential stressors, and, for consistency, most SME reports have the same overall format. The format covers: (1) rationale for impact hypotheses, (2) methods, (3) analysis and (4) findings, particularly

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[2] Implies September 2017 to September 2019.

[3] Implies a chronic, slow change in the stressor (using 2012–2019 timeframe, data dependent).

[4] Abundance estimates for adults/sub-adults are based on surveys in September of each year, while estimates for juveniles are based on surveys in August.

whether the requisite conditions[5] were met for the stressor(s) to be the sole cause of the fish population decline, or a contributor to it. In addition to the report, each SME provided a summary table of findings, generated according to the Framework. These summaries were used to integrate information for the Evaluation of Cause report. Note that some SME reports did not investigate specific stressors; instead, they evaluated other information considered potentially useful for supporting SME reports and the overall Evaluation of Cause, or added context (such as in the SME report that describes climate (Wright et al., 2021).

**The Evaluation of Cause report** (prepared by a subset of the Team, with input from SMEs): This overall report summarizes the findings of the SME reports and further considers interactions between stressors (Overarching Hypothesis #2). It describes the reasons that most likely account for the decline in the Westslope Cutthroat Trout population in the upper Fording River.

## Participation, Engagement & Transparency

To support transparency, the Team engaged frequently throughout the Evaluation of Cause process. Participants in the Evaluation of Cause process, through various committees, included:

Ktunaxa Nation Council

BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development

BC Ministry Environment & Climate Change Strategy

Ministry of Energy, Mines and Low Carbon Innovation

Environmental Assessment Office

[5] These are the conditions that would need to have occurred for the impact hypothesis to have resulted in the observed decline of Westslope Cutthroat Trout population in the upper Fording River.

## Citation for the Evaluation of Cause Report

When citing the Evaluation of Cause Report use:

Evaluation of Cause Team, (2021). *Evaluation of Cause — Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Evaluation of Cause Team.

## Citations for Subject Matter Expert Reports

| Focus | Citation for Subject Matter Expert Reports |
|---|---|
| Climate, temperature, and streamflow | Wright, N., Greenacre, D., & Hatfield, T. (2021). *Subject Matter Expert Report: Climate, Water Temperature, Streamflow and Water Use Trends. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd. |
| Ice | Hatfield, T., & Whelan, C. (2021). *Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd. |
| Habitat availability (instream flow) | Healey, K., Little, P., & Hatfield, T. (2021). *Subject Matter Expert Report: Habitat availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd. |
| Stranding – ramping | Faulkner, S., Carter, J., Sparling, M., Hatfield, T., & Nicholl, S. (2021). *Subject Matter Expert Report: Ramping and stranding. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd. |

| Focus | Citation for<br>Subject Matter Expert Reports |
|---|---|
| Stranding – channel dewatering | Hatfield, T., Ammerlaan, J., Regehr, H., Carter, J., & Faulkner, S. (2021). *Subject Matter Expert Report: Channel dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited by Ecofish Research Ltd. |
| Stranding – mainstem dewatering | Hocking M., Ammerlaan, J., Healey, K., Akaoka, K., & Hatfield T. (2021). *Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd.<br>Zathey, N., & Robinson, M.D. (2021). *Summary of ephemeral conditions in the upper Fording River Watershed. In Hocking et al. (2021). Subject Matter Expert Report: Mainstem dewatering. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. and Lotic Environmental Ltd. |
| Calcite | Hocking, M., Tamminga, A., Arnett, T., Robinson M., Larratt, H., & Hatfield, T. (2021). *Subject Matter Expert Report: Calcite. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd., Lotic Environmental Ltd., and Larratt Aquatic Consulting Ltd. |
| Total suspended solids | Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). *Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd. |
| Fish passage<br>(habitat connectivity) | Harwood, A., Suzanne, C., Whelan, C., & Hatfield, T. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.<br>Akaoka, K., & Hatfield, T. (2021). Telemetry Movement Analysis. In Harwood et al. (2021). *Subject Matter Expert Report: Fish passage. Evaluation of Cause – Decline in upper* |

| Focus | Citation for Subject Matter Expert Reports |
|---|---|
| | *Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Ltd. by Ecofish Research Ltd. |
| Cyanobacteria<br><br>Algae / macrophytes | Larratt, H., & Self, J. (2021). *Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd. |
| Water quality<br><br>(all parameters except water temperature and TSS [Ecofish]) | Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.<br><br>Healey, K., & Hatfield, T. (2021). *Calculator to assess Potential for cryoconcentration in upper Fording River.* In Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. |
| Industrial chemicals, spills and unauthorized releases | Van Geest, J., Hart, V., Costa, EJ., & de Bruyn, A. (2021). *Subject Matter Expert Report: Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd.<br><br>Branton, M., & Power, B. (2021). *Stressor Evaluation – Sewage.* In Van Geest et al. (2021). *Industrial chemicals, spills and unauthorized releases. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. |
| Wildlife predators | Dean, D. (2021). *Subject Matter Expert Report: Wildlife predation. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc. |

| Focus | Citation for Subject Matter Expert Reports |
|---|---|
| Poaching | Dean, D. (2021). *Subject Matter Expert Report: Poaching. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by VAST Resource Solutions Inc. |
| Food availability | Orr, P., & Ings, J. (2021). *Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc. |
| Fish handling | Cope, S. (2020). *Subject Matter Expert Report: Fish handling. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Westslope Fisheries Ltd. |
| | Korman, J., & Branton, M. (2021). *Effects of capture and handling on Westslope Cutthroat Trout in the upper Fording River: A brief review of Cope (2020) and additional calculations.* Report prepared for Teck Coal Limited. Prepared by Ecometric Research and Azimuth Consulting Group. |
| Infectious disease | Bollinger, T. (2021). *Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd. |
| Pathophysiology | Bollinger, T. (2021). *Subject Matter Expert Report: Pathophysiology of stressors on fish. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd. |
| Coal dust and sediment quality | DiMauro, M., Branton, M., & Franz, E. (2021). *Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population.* Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc. |

| Focus | Citation for<br>Subject Matter Expert Reports |
|---|---|
| Groundwater quality and quantity | Henry, C., & Humphries, S. (2021). *Subject Matter Expert Report: Hydrogeological stressors. Evaluation of Cause - Decline in upper Fording River Westslope Cutthroat Trout population.* Report Prepared for Teck Coal Limited. Prepared by SNC-Lavalin Inc. |

## Author Qualifications

- Marianna DiMauro, M.R.M., is an environmental scientist with an applied background in environmental toxicology and wildlife biology. Marianna received her Master's in resource and environmental management in 2018 for her contributions on a project investigating methods to measure biotransformation rates of chemicals in freshwater fish. Since then, she has worked on a range of aquatic monitoring projects and ecological risk assessments at sites across Canada and a site in the United States.
- Maggie Branton, Ph.D., P.Ag., has over 20 years of experience using innovative approaches to assess the response of ecological communities to changes associated with habitat degradation and restoration, historical contamination and oil spills. She has an applied background in ecology, restoration biology, ecological risk assessment and natural resource damage assessment. Dr. Branton has worked extensively in Canada and the United States evaluating the eco-toxicological effects of a broad range of chemicals including oil, polychlorinated biphenyls and other persistent chemicals to aquatic and terrestrial organisms and has studied the response of Pacific salmon to habitat restoration.
- Eric Franz, M.Sc., is an Environmental Scientist with a background in aquatic ecology and expertise in environmental toxicology. Since 2010 he has worked on aquatic monitoring projects such as Environment Effects Monitoring (EEM), large-scale aquatic baseline assessments, and human health and ecological risk assessments. Eric has advanced skills in data interpretation and reporting, including statistical analysis. His work tends to focus on the mining sector, but Eric addresses a wide range of contaminants, most recently the complex mixture of contaminants in biosolids.

# 1 INTRODUCTION

This document is one of a series of Subject Matter Expert (SME) reports that support the overall Evaluation of Cause (EoC) of the upper Fording River (UFR) Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*, WCT) population decline that occurred sometime between the end of September 2017 and September 2019 ("Decline Window") as reported by Cope (2020) (Evaluation of Cause Team, EoC 2021). For general information and context, see the preceding Reader's Note.

Two Overall Hypotheses are being evaluated to support the EoC in these SME reports.

**Overarching Hypothesis #1:** The significant decline in the UFR WCT population was a result of a single acute stressor[6] or a single chronic stressor[7].

**Overarching Hypothesis #2:** The significant decline in the UFR WCT population was a result of a combination of acute and/or chronic stressors, which individually may not account for reduced WCT numbers, but cumulatively caused the decline.

## 1.1 Report-specific Background

Particulates from unburnt metallurgical coal (fugitive coal dust) can enter aquatic environments from erosion of exposed, undisturbed seams, wind-blown dispersal from coal stock piles, and incidental spills and releases during transportation (Ahrens and Morrisey 2005), and mine operations (e.g., blasting). Inputs of coal dust are likely the greatest in the vicinity of storage, loading facilities or where runoff from mining activities occurs (Ahrens and Morrisey 2005). In the absence of spills, coal dust, if present in the aquatic environment, is a component of total suspended solids (TSS) in the water column (Durston *et al*. 2021), with the coal dust eventually settling in sediment in areas of low flow. Coal dust particles may be resuspended or scoured and transported with sediment in daily and seasonal flows such as those associated with freshet and ice movement (USGS 2020; Hatfield and Whelan 2021). Coal also contains metals/metalloids (referred to collectively as metals herein) and PAHs that can be released into the water column,

[6] Implies something that occurred within the September 2017 to September 2019 timeframe.

[7] Implies a long-term exposure to a stressor for which adverse impacts may be cumulative over time (using 2012-2019 timeframe, data dependent).

pore water (i.e., the water in the interstitial spaces of sediment) or accumulate in the sediment as coal particles break down (Davis and Boegly 1981; Ghosh *et al*. 2001; Ahrens and Morrisey 2005; Trowell *et al*. 2020). In this report, metals and PAHs in coal dust and sediment are collectively referred to as “constituents”.

Anecdotal observations and photographs indicate that fugitive coal dust can be visible in the vicinity of the UFR with the potential to enter the aquatic environment, though the amount or frequency of coal dust inputs have not been documented. To our knowledge, no studies have been completed to determine the presence and relative contribution of coal particulate to TSS or embedded sediment in the UFR. However, water and sediment quality monitoring (including chemistry, TSS, and toxicity tests[8]) are routinely conducted (e.g., Fording River Operations Local Aquatic Effects Monitoring Program (FRO LAEMP) studies; Minnow and Lotic 2018, 2019, and 2020). The chemistry data includes the analysis of metals and PAHs, which are associated with coal (Ahrens and Morrisey 2005). While coal dust contributes to an unknown proportion of TSS and coal-associated constituents in water and sediment in the UFR, these monitoring datasets support the assessment of the potential for coal dust associated constituents in sediment to have caused or contributed to the WCT population decline.

## 1.2 Subject Matter Expert Reports Related to Coal Dust

As part of the EoC, a number of SMEs conducted evaluations that relate to the potential for aquatic organisms, including WCT, benthic invertebrates, and periphyton, to be exposed to and impacted by chemical and physical components of coal dust. These are illustrated in **Figure 1-1** and are briefly described below along with cross references to the associated SME reports.

The potential for metals and PAHs in sediment to contribute to the WCT decline is addressed by Azimuth in this document (**Figure 1-1**, A), whereas the potential for metals and PAHs in water to contribute to the WCT decline is addressed in the following SME report:

- Golder (Costa and de Bruyn 2021) assessed the potential for toxicity associated with metals and PAHs in water based on screening concentrations of constituents in water

[8] Teck Coal has been working to understand the potential role of ammonia in sediment toxicity. The study team working on ammonia outside of the EoC recently presented the results of the lotic sediment toxicity testing program to the Environmental Monitoring Committee (EMC) and is incorporating EMC feedback into additional desktop and field-based analysis. The results of this work will inform whether additional work is needed to understand if coal fines or other conditions in the sediment may be contributing to the generation of ammonia or if the ammonia results are an artefact of laboratory conditions. We understand that a lentic sediment toxicity program is also anticipated to begin in 2021.

against water quality guidelines and on site-specific toxicity studies. This report also evaluated the potential for selenium toxicity based on selenium tissue concentrations in fish and benthic invertebrates (**Figure 1-1**, B).

Exposure to TSS, which may contain coal dust, can also cause a number of physical effects on fish, such as smothering of spawning habitat, abrasion to egg and free-swimming life-stages, damage to the gills, changes to gill morphology, impaired feeding due to reduced ability to see prey, consumption of non-nutritional particulates, and clogging of respiratory and feeding organs (Ahrens and Morrisey 2005; Berry *et al*. 2016; Lake and Hinch 1999). Sediment deposition may also impair spawning and early life-stage (i.e., egg and alevin) rearing habitats (Kemp *et al*. 2011; Henley *et al*. 2000). Free-feeding life stages (i.e., fry, juveniles and adults) are most likely to be exposed to coal dust through TSS, when it is present (Ahrens and Morrisey 2005).

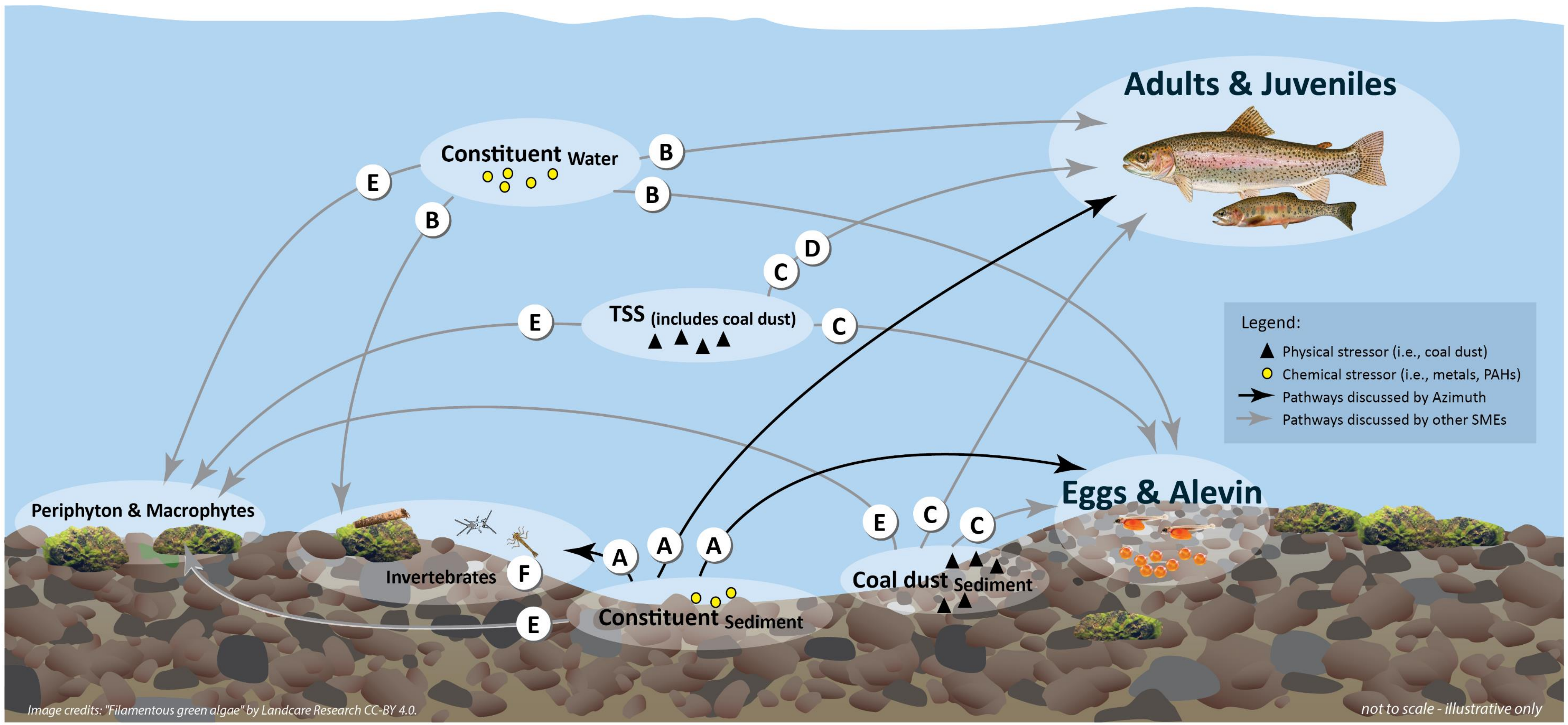
- Ecofish investigated TSS loadings, changes in TSS before and during the Decline Period, and potential TSS related physical impacts to the different life stages of WCT in the UFR (Durston *et al*. 2021). As there are no data available to differentiate between coal dust particles and other suspended sediment particles in the UFR, we assume that the potential for coal dust to cause physical impacts is addressed as part of the TSS matrix (**Figure 1-1**, C).
- Dr. Trent Bollinger (TKB Ecosystem Health Services Ltd.) evaluated the histopathological condition of seven WCT for evidence of gross pathologies (Bollinger 2021; See **Figure 1-1**, D).

Benthic organisms living on or in the riverbed substrate may be affected by the disturbance of benthic habitat resulting from the deposition of coal particles (Johnson and Bustin 2006). If the benthic environment receives high levels of organic inputs (e.g., coal dust, vegetation debris), anoxic conditions can arise from bacterial consumption of oxygen during degradation of the organic material, which can be detrimental to the benthic community (Johnson and Bustin 2006). Larval or adult forms of aquatic invertebrate groups such as true flies, mayflies, stoneflies, and caddisflies that live in close contact with the sediment tend to make up a significant portion of the WCT diet (Lister and Associates Ltd. and Kerr Wood Leidal Associates Ltd. 1980; Orr and Ings 2021). Detrimental impacts to the benthic community can have ripple effects up the food chain, thus impacting fish and other wildlife that predate on the benthic invertebrates (Johnson and Bustin 2006).

- Larratt Aquatic (Larratt and Self 2021) evaluated the potential for primary producers, specifically periphyton and macrophytes, to stress WCT through changes to stream water chemistry, physical interception of water exchange between the river and its underlying hyporheic zone, and altered biological pathways for metals. (**Figure 1-1**, E).

- Minnow and Lotic (2019, 2020) evaluated benthic invertebrate biomass, density and community composition as part of a regular monitoring program in the UFR. For the EoC, Minnow (Orr and Ings 2021) considered the potential for changes in food supply that could occur if there was reduced biomass and abundance of benthic and terrestrial invertebrates that are a primary component of WCT diet and evaluated the potential effect of reduced food availability leading to loss of energy reserves and starvation as the cause of the WCT population decline. Minnow also directly evaluated fish condition (i.e., the relationship between fish weight and length, **Figure 1-1**, F).

**Figure 1-1. Conceptual diagram of potential physical and constituent (e.g., metals and PAHs) stressor exposure pathways potentially associated with coal dust to aquatic organisms, including Westslope Cutthroat Trout in the upper Fording River, as evaluated in Subject Matter Expert reports[9].**




[9] The circled letters in the diagram refer to different SME reports, and are defined in **Table 1-1**.

**Table 1-1. SMEs addressing coal dust and/or sediment related stressors in the UFR.**

| | Subject Matter Expert | Citation for Subject Matter Expert Reports |
|---|---|---|
| A | **Azimuth Consulting Group Inc.** | DiMauro, M., Branton, M., & Franz, E. (2021). Subject Matter Expert Report: Coal dust and sediment quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by Azimuth Consulting Group Inc. |
| B | **Emily-Jane Costa and Adrian de Bruyn (Golder Associates Ltd.)** | Costa, EJ., & de Bruyn, A. (2021). Subject Matter Expert Report: Water quality. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. |
| C | **Todd Hatfield (Ecofish Research Ltd.)** | Durston, D., Greenacre, D., Ganshorn, K & Hatfield, T. (2021). Subject Matter Expert Report: Total suspended solids. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd. |
| D | **Trent Bollinger (TKB Ecosystem Health Services Ltd.)** | Bollinger, T. (2021). Subject Matter Expert Report: Infectious disease. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by TKB Ecosystem Health Services Ltd. |
| E | **Heather Larratt (Larratt Aquatic Consulting Ltd.)** | Larratt, H., & Self, J. (2021). Subject Matter Expert Report: Cyanobacteria, periphyton and aquatic macrophytes. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd. |
| F | **Patti Orr (Minnow Environmental Inc.)** | Orr, P., & Ings, J. (2021). Subject Matter Expert Report: Food availability. Evaluation of Cause – Decline in upper Fording River Westslope Cutthroat Trout population. Report prepared for Teck Coal Limited. Prepared by Minnow Environmental Inc. |

## 1.3 Description of and Rationale for Impact Hypothesis

While there is no record of a direct spill of coal into the UFR, sediment sampling has documented the presence of coal-associated constituents, specifically metals and PAHs, historically and within the Decline Window throughout the UFR. Metals and PAHs associated with coal dust that may have accumulated in sediment can be an exposure pathway to aquatic organisms including WCT. At sufficient concentrations, some of these constituents have the potential to be toxic to aquatic organisms resulting in mortality or sub-lethal effects.

The objectives of this report are to assess the potential for metals and PAHs in sediment to have caused (Overarching Hypothesis #1) or contributed to (Overarching Hypothesis #2) the WCT population decline. The specific stressor hypothesis examined in consideration of the Overarching Hypotheses in this EoC report is:

*Were concentrations of metals and/or PAHs in sediment present during the Decline Window sufficient to result in adverse effects to WCT that could have caused or contributed to the population decline?*

# 2 APPROACH

To examine the stressor specific hypothesis, we considered the evidence that there were changes in sediment quality in the UFR during the Decline Window and that those changes had the potential to result in adverse effects consistent with the WCT population decline (i.e., mortality of juveniles and adults). Sediment quality was evaluated by (1) screening metal and PAH concentrations against sediment quality guidelines (SQGs) as a conservative assessment of potential for sediment toxicity, (2) comparing concentrations of metals and PAHs between the historical and the Decline Window time periods, and (3) assessing the spatial distribution of exceedances of SQGs and/or historical concentrations of constituents in sediment during the Decline Window. These three lines of evidence were used together to identify constituents of concern that were then assessed in more detail with respect to their bioavailability and the nature of potential adverse effects associated with metals and PAHs.

Azimuth relied upon data collected as part of site-specific studies conducted prior to and during the Decline Window; specifically, sediment sampling programs (Lotic 2013; Minnow 2014, 2016, 2018b; Minnow and Lotic 2018, 2019, 2020) and fish monitoring and habitat assessments (Cope *et al.* 2016; Cope 2020; EoC Team 2021). Provincial and federal sediment quality guidelines, as well as scientific literature on toxicity were also used to conduct this evaluation.

## 2.1 Sediment Quality Guidelines

British Columbia Ministry of Environment and Climate Change Strategy (BC ENV 2020) and the Canadian Council of Ministers of the Environment (CCME 2020) have adopted sediment quality guidelines (SQGs) for the protection of aquatic life. These guidelines provide numerical concentrations of constituents in sediment that represent safe levels of substances meant to protect aquatic life (BC ENV 2020) and would likely result in negligible effects to biota (CCME 2001). Although generally developed based on studies with benthic invertebrates, the SQGs are considered to be protective of other aquatic life including all life stages of fish (BC ENV 2020). All components of the aquatic ecosystem are considered (including fish), dependent on data available (CCME 2001). Both provincial and federal guidelines provide a lower guideline that protects aquatic life from adverse effects from a toxic substance in most situations [i.e., BC ENV's lower Working SQG (WSQG) or CCME's Threshold Effect Level (TEL) or Interim SQG (ISQG)], and an upper guideline representing a concentration likely to cause adverse effects in aquatic life [i.e., BC ENV's upper WSQG or CCME's Probable Effect Level (PEL)] (BC ENV 2020; CCME 2001). These values provide three ranges of concentrations that can be used to assess the potential for adverse biological effects:

- "Concentrations < lower SQG are rarely associated with adverse biological effects;
- Concentrations > lower but < upper SQG are occasionally associated with adverse biological effects; and
- Concentrations > upper SQGs are frequently associated with adverse biological effects." (BC ENV 2020).

It is important to note that an exceedance of an SQG does not indicate that there are unacceptable risks to biota, but that the potential for risks is increased and additional assessment may be required (BC ENV 2020).

Azimuth screened sediment chemistry data from the UFR against the available freshwater BC SQGs (BC ENV 2020) and Canadian SQGs (i.e., ISQG and PEL) (CCME 2020). The available guidelines for metals and PAHs from both BC ENV and CCME, and the lower and upper SQG used to conduct the screening in this report are provided in **Table 2-1** The BC SQGs are the same as the available CCME SQGs; however, for some constituents, no CCME SQGs were available in which case the BC SQGs were used. Selenium does not have provincial or federal SQGs due to inadequate information. Instead, it has a single "alert concentration" that is based on the lowest published toxicity thresholds with no uncertainty factor applied (BC ENV 2019). Due to the uncertainty associated with this alert value, it is used in the screening as both the lower and upper SQG to show the range of potential changes in sediment quality depending on how the value is used. If the concentrations of selenium in sediment exceed the "alert concentration", BC ENV (2014) recommends that other media compartments (e.g., invertebrate and fish tissues) be measured to assess the potential for selenium bioaccumulation.

For the purposes of this assessment, we assumed that the constituents with SQGs are representative of the sediment quality in the UFR. Summary statistics are provided for constituents without SQGs for the Decline Window and historically in **Appendix B**; however, these constituents were not considered further in the screening. There is uncertainty associated with this approach; however, environmental quality guidelines are generally developed on a priority basis, often involving a "risk-based"[10] nomination of substances, concerns and/or direction from task groups, and other committees and jurisdictions (CCME 2001).

When evaluating the results of this screening, it is important to consider that SQG have generally been developed based on studies that evaluated biological effects to benthic organisms in field-based sediment samples with multiple constituents present. Their relevance to non-benthic fish with little direct exposure to sediment, such as WCT, is uncertain. Moreover, concentrations that are considered protective (i.e., lower SQG) or predictive (i.e., upper SQG) of adverse effects are inferred based on the absence or presence of effects; however, this approach assumes that all constituents present may be causing observed effects, when in fact the causative factor is not determined (McGrath *et al*. 2019). This approach provides confidence that effects are unlikely at concentrations below the SQG; however, there is uncertainty whether there would be adverse effects above the SQG. This uncertainty is exacerbated by site-specific sediment characteristics, such as percent organic carbon, grain size, pH, redox conditions, that may influence the bioavailability[11] of constituents, including metals and PAHs (Davis and Boegly 1981; Querol *et al*. 1996; Ahrens and Morrisey 2005; Trowell *et al*. 2020). Of particular relevance to the UFR, the bioavailability of PAHs is reduced in the presence of "black carbon" (i.e., "soot, coke and charcoal-like material") which has a stronger binding affinity for PAHs than natural organic carbon that may come from plants or animals (Talley *et al*. 2002; McGrath *et al*. 2019).

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[10] The Canadian Environmental Protection Act (CEPA) uses a "risk-based" method to make decisions regarding chemical substances. Risk is determined by looking at the harmful properties of chemicals and the level of exposure for humans and the environment (CEPA 1999).

[11] Bioavailability here refers to the fraction of a constituent that is available for uptake by aquatic organisms and thus the relevant exposure dose (Anderson et al. 2008).

Reduced bioavailability may contribute to the conservatism of using the SQGs to characterize sediment quality in the UFR. A study in the Elk Valley, which included sediment collected from study areas within the UFR in 2015, reported low metals bioavailability (Minnow 2016). Site-specific toxicity testing can provide an assessment of sediment related adverse effects that takes into account bioavailability. Teck Coal conducted a sediment toxicity testing program in 2013 as reported in Minnow 2014. Due to the limited number of mine exposed areas sampled in 2013, additional site-specific testing was initiated in 2015 (Minnow 2016). The main objective of the 2015 sediment toxicity supporting study was to evaluate testing methods to determine which methods are the most appropriate for the sediment toxicity in the UFR and surrounding areas. Detailed results from this study are provided in Minnow 2016.These studies were used to help develop the on-going site-specific sediment toxicity testing program, initiated by Teck Coal in 2019. The results of these studies are still under evaluation and a final report is pending therefore they have not been considered in this report (Golder and Minnow 2019, 2020).

Other studies from the UFR (e.g., 2018 and 2019 FRO LAEMP) have demonstrated that sediments with concentrations of constituents exceeding SQGs did not adversely impact the benthic invertebrate community (Minnow and Lotic 2019, 2020; Orr and Ings 2021). This is consistent with the literature that reports limitations associated with using bulk sediment concentrations to predict the potential for adverse effects; concentrations in porewater, by comparison, better represent the concentration that is available for diffusive transport and partitioning into biota (McGrath *et al.* 2019; Mayer *et al*. 2014). In a review of the performance of PAH SQGs, McGrath *et al*. (2019) reported that both protective (i.e., lower SQG) and predictive (i.e., upper SQG) guidelines had high rates of false positives, that is identifying a concentration as toxic based on the guidelines where no toxicity was observed. Specifically, the percentage of false positives for protective guidelines was 63 to 75%, and for predictive guidelines was 20 to 64% (McGrath *et al*. 2019). This reflects the conservative methods and assumptions used to derive SQGs. Notwithstanding these considerations, SQGs provide a conservative screening tool for this EoC to identify constituents present at concentrations below levels of concern and remove them from further assessment. SQGs also provide a method of identifying constituents that are present at potentially toxic concentrations and warrant further consideration with respect to bioavailability and the nature of potential adverse effects to aquatic organisms.

**Table 2-1. Provincial and federal sediment quality guidelines for the protection of freshwater aquatic life and selected guidelines used to screen sediment quality in the UFR.**

| | Freshwater Sediment Quality Guidelines (mg/kg) [1] | | | | | |
|---|---|---|---|---|---|---|
| | BC SQGs | | CCME SQGs | | SQGs used for screening | |
| Constituent | Lower | Upper | ISQG | PEL | Lower | Upper |
| **Metals** | | | | | | |
| Arsenic (As) | 5.9 | 17 | 5.9 | 17 | 5.9 | 17 |
| Cadmium (Cd) | 0.6 | 3.5 | 0.6 | 3.5 | 0.6 | 3.5 |
| Chromium (Cr) | 37.3 | 90 | 37.3 | 90 | 37.3 | 90 |
| Copper (Cu) | 35.7 | 197 | 35.7 | 197 | 35.7 | 197 |
| Iron (Fe) | 21,200 | 43,766 | - | - | 21,200 | 43,766 |
| Lead (Pb) | 35 | 91.3 | 35 | 91.3 | 35 | 91 |
| Manganese (Mn) | 460 | 1,100 | - | - | 460 | 1,100 |
| Mercury (Hg) | 0.17 | 0.486 | 0.17 | 0.486 | 0.17 | 0.486 |
| Nickel (Ni) | 16 | 75 | - | - | 16 | 75 |
| Selenium (Se)[2] | 2 | 2 | - | - | 2 | 2 |
| Silver (Ag) | 0.5 | - | - | - | 0.5 | - |
| Zinc (Zn) | 123 | 315 | 123 | 315 | 123 | 315 |
| **Polycyclic Aromatic Hydrocarbons (PAHs)** | | | | | | |
| 2-Methylnaphthalene | 0.020 | 0.20 | 0.020 | 0.20 | 0.020 | 0.20 |
| Acenaphthene | 0.0067 | 0.089 | 0.0067 | 0.089 | 0.0067 | 0.089 |
| Acenaphthylene | 0.0059 | 0.13 | 0.0059 | 0.13 | 0.0059 | 0.13 |
| Anthracene | 0.047 | 0.25 | 0.047 | 0.25 | 0.047 | 0.25 |
| Benz(a)anthracene | 0.032 | 0.39 | 0.032 | 0.39 | 0.032 | 0.39 |
| Benzo(a)pyrene | 0.032 | 0.78 | 0.032 | 0.78 | 0.032 | 0.78 |
| Benzo(g,h,i)perylene[3] | 0.17 | 2.6 | - | - | 0.17 | 2.6 |
| Benzo(k)fluoranthene[3] | 0.24 | 110 | - | - | 0.24 | 110 |
| Chrysene | 0.057 | 0.86 | 0.057 | 0.86 | 0.057 | 0.86 |
| Dibenz(a,h)anthracene | 0.0062 | 0.14 | 0.0062 | 0.14 | 0.0062 | 0.14 |
| Fluoranthene | 0.11 | 2.4 | 0.11 | 2.4 | 0.11 | 2.4 |
| Fluorene | 0.021 | 0.14 | 0.021 | 0.14 | 0.021 | 0.14 |
| Indeno(1,2,3-c,d)pyrene[3] | 0.20 | 26 | - | - | 0.20 | 26 |
| Naphthalene | 0.035 | 0.39 | 0.035 | 0.39 | 0.035 | 0.39 |
| Phenanthrene | 0.042 | 0.52 | 0.042 | 0.52 | 0.042 | 0.52 |
| Pyrene | 0.053 | 0.88 | 0.053 | 0.88 | 0.053 | 0.88 |

**Notes**

"-" No available sediment quality guideline.

1 BC working sediment quality guidelines (BC ENV 2020) and Canadian Council of Ministers of the Environment interim sediment quality guidelines (CCME 2020) - both for freshwater aquatic life. All guidelines on a dry weight basis (i.e., mg/kg dry weight).

2 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline available due to limited data (BC ENV 2014).

3 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (8.24%). No TOC adjustment required for the lower SQG.

**Acronyms**

SQG = Sediment quality guideline

ISQG = Interim sediment quality guideline

PEL = Probable effects level

TOC = Total organic carbon

## 2.2 Historical Conditions

Historical sediment constituent concentrations measured in the UFR between 2011 and 2017 (see **Section 3.1.1**) were used to represent a baseline sediment quality condition that did not result in adverse population level impacts to WCT. This approach was adopted based on the results of fish monitoring studies conducted between 2013 and 2017 that reported similar WCT abundance and density in the years leading up to and including 2017 (Cope 2020; EoC Team 2021). Although some constituents had concentrations exceeding SQGs during this historical time period (e.g., see **Table 4-3**), based on the population data those concentrations did not appear to have been adversely impacting the WCT population overall[12].

Sediment chemistry data collected during the Decline Window (i.e., 2018 and 2019) were compared with the historical sediment data (i.e., 2011-2017). Sediment concentrations fluctuated over the historical time period, to varying degrees for different constituents. Two exposure scenarios were used to represent a range of historical conditions, the conservative, low-end estimate was based on the mean of the historical dataset, and the 90$^{th}$ percentile was used to represent a high-end potential historical exposure scenario. If a constituents' concentration in the Decline Window was below the historical mean, it was considered to have no explanatory potential for the population decline regardless of whether it exceeded its SQG. If the Decline Window concentrations were higher than reported historically, the constituent was evaluated further in conjunction with the results of the SQG screening.

It is important to note that sediment sampling was generally conducted in August and September[13], just prior to the population monitoring events in the years they co-occurred. Therefore, the 2017 September sediment chemistry data represent the sediment conditions that WCT would have been exposed to immediately prior to the 2017 population monitoring event that reported juvenile and adult WCT abundance and density numbers similar to previous years (Cope 2020; EoC Team 2021). On this basis, the 2017 sediment data are included with the historical time period and not the Decline Window.

[12] This is a simplifying assumption as it is not possible to determine if the population would have had higher abundance than observed if sediment quality or other conditions were different.

[13] Sediment samples were also collected in October 2011 and August 2018, as part of supporting sediment studies (Lotic 2013, Minnow 2018).

## 2.3 Spatial Analysis

Azimuth conducted its evaluation of sediment quality at two spatial scales. The initial screening was conducted using sediment data from the whole UFR, followed by a secondary screening that stratified sediment data into four *river segment groups*[14] (i.e., Henretta Lake, S7-S8, S6, and S1-S3). The river segments are the same as those used in WCT telemetry and monitoring studies (see Cope *et al*. 2016; Cope 2020; EoC Team 2021). Spatial stratification of sediment quality data can be paired with WCT spatial-usage patterns, permitting an assessment of the potential importance of changes in sediment quality in different segments with respect to varying habitat uses by WCT in the UFR. For example, telemetry data collected between 2012 and 2015 indicated that more than 60% of the overwintering WCT population can be found in two general areas of the UFR [S8 (20%) and S6 (40%); see Appendix D, EoC and **Figure 2-2**]. If there were adverse effects to WCT associated with changes in sediment quality in these areas, there could potentially be a disproportionate effect on WCT populations. Alternatively, if changes in sediment quality were found in areas with lower WCT use, such as the lower UFR, they would have a more limited impact on the WCT population.

The river segment groupings used in the spatial analysis correspond generally to the upper-, mid- and lower UFR as described in Cope *et al.* (2016). The general descriptions of each river grouping locations are summarized in **Table 2-2** and all sampling areas and associated number of samples collected in mine-exposed areas in the UFR are provided in **Table A-1**. The general characteristics and habitat use by WCT for these segments are summarized below:

- **Henretta Lake (Upper-UFR)** – Henretta Lake is deep lentic habitat situated 1 km upstream from the confluence of Henretta Creek and the UFR in river segment S9 (62.9 rkm) (Cope *et al*. 2016). It was constructed to be overwintering habitat for WCT as part of the Henretta Creek Channel Reclamation Plan (Cope *et al*. 2016; Pumphrey 2009) and supports a moderate proportion (~11 – 17%, Appendix D, EoC) of WCT overwintering and rearing populations (Cope *et al*. 2016).
- **S7-S8 (Middle-UFR)** – River segments S7 and S8 are located within the Fording River Operations (FRO). These segments meander through open meadows, which were previously clear-cut and described as deficient in fish habitat attributes due to channel

[14] While we adhere to the river kilometer (rkm) descriptions used in Cope *et al*. (2016), we only broadly based our river section groups on the three sections of the upper Fording River described in Cope *et al.* (2016).

disturbances (see Section 3.4 Habitat Mapping, Cope *et al*. 2016). The channels in these segments are also prone to more frequent and extensive dewatering (Cope *et al*. 2016). Despite being previously deficient in fish habitat, telemetry data indicated that 20% of the overwintering WCT population can be found in segment S8 (see Appendix D, EoC).

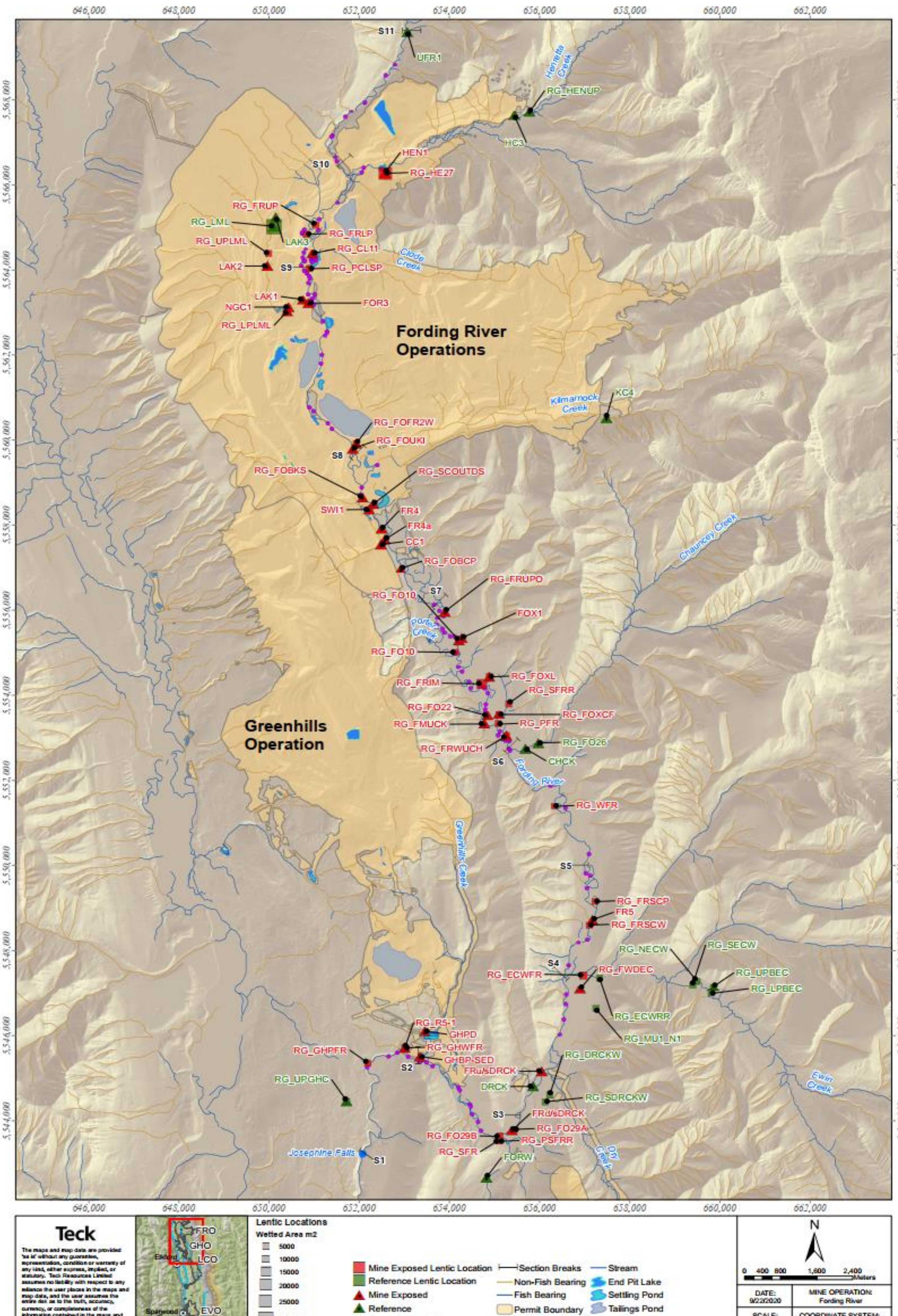
- **S6 (Middle-UFR)** – River segment S6 is made up of a network of oxbows and pools situated from 42 rkm to 48 rkm. S6 has been described as an old growth stream channel with plenty of high quality WCT habitat attributes and provides important spawning, overwintering and juvenile rearing habitat (see Section 3.4 Habitat Mapping in Cope *et al*. 2016). Large aggregations of overwintering WCT (40%) have been reported in S6 (see Appendix D, EoC; Cope *et al*. 2016; Harwood *et al*. 2020).
- **S1-S3 (Lower UFR)** – River segment group S1-S3, described as the Lower-Watershed in Cope *et al.* (2016), extends from segment S1 (24.2 rkm) and ends at segment S3 (30.5 rkm). This segment group occurs within the Greenhills Operations (GHO) area and is characterized by log jams and deep bedrock pools. Cope *et al*. (2016) have suggested the log jams in segment S2 and Greenhills and Dry Creeks are important habitats for overwintering, spawning, and rearing.

**Figure 2-1**, **Figure 2-2** and **Figure 2-3** were created to provide spatial reference for all UFR sediment data/locations given through the references listed in **Table 3-1**. Not all locations mapped were carried through to analysis if they were not applicable (e.g., the location was not accessible to fish, no sediment data was collected at the location). Only data from fish accessible areas in the mine influenced mainstem and tributaries were used for the sediment quality screening and analysis. See **Table A-1** for stations included in the analysis.

In **Figure 2-1**, **Figure 2-2** and **Figure 2-3**, square symbols indicate lentic total area (for those where data was available) and were included to provide a sense of where documented lentic areas are, and their size, in the UFR. Triangles indicate that sediment samples were taken from that location (lentic or lotic). Segments are labeled on the downstream end.

Spawning, overwintering, and rearing locations (in **Figure 2-1**, **Figure 2-2** and **Figure 2-3** respectively) are denoted by points, where each point is one detected fish as per the monitoring done by Cope et al. (2016). For additional information on this telemetry data, see Appendix D of the EoC Report (EoC Team 2021)

**Figure 2-1. Upper Fording River Westslope Cutthroat Trout Population Assessment, Sediment Sampling Stations and Lentic areas.**
2013, 2014, 2015 Telemetry Spawning Locations.




Document Path: \\teckcominco\CGO\Groups\TCGIS\Data\Projects\WCTAssessment\Sediment_Mapping\Fig1_Spawning.mxd

**Figure 2-2. Upper Fording River Westslope Cutthroat Trout Population Assessment, Sediment Sampling Stations and Lentic areas.**
2013, 2014, 2015 Telemetry Overwintering Locations.

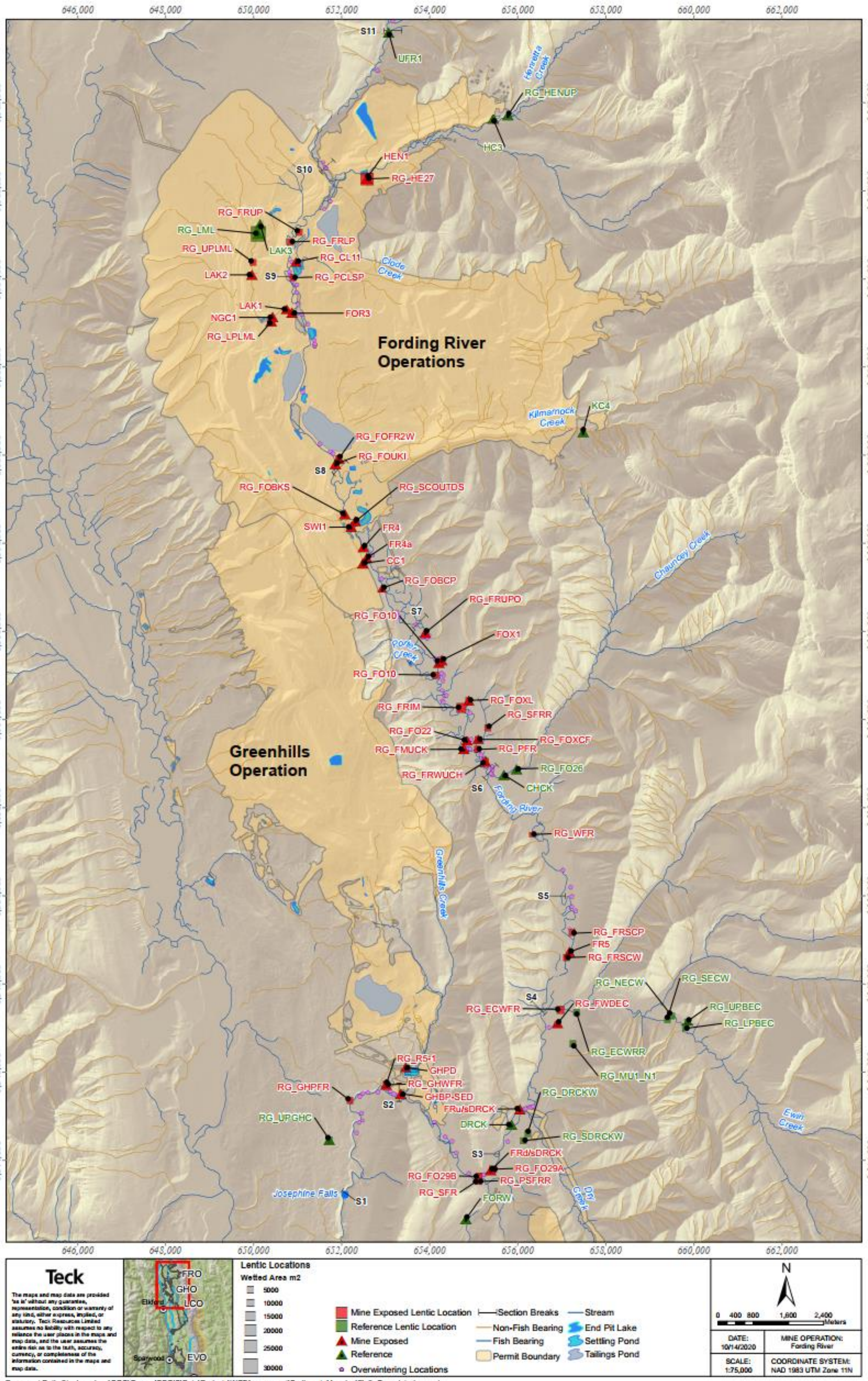


**Figure 2-3. Upper Fording River Westslope Cutthroat Trout Population Assessment, Sediment Sampling Stations and Lentic areas.**

2012 and 2013 Telemetry Rearing Locations.

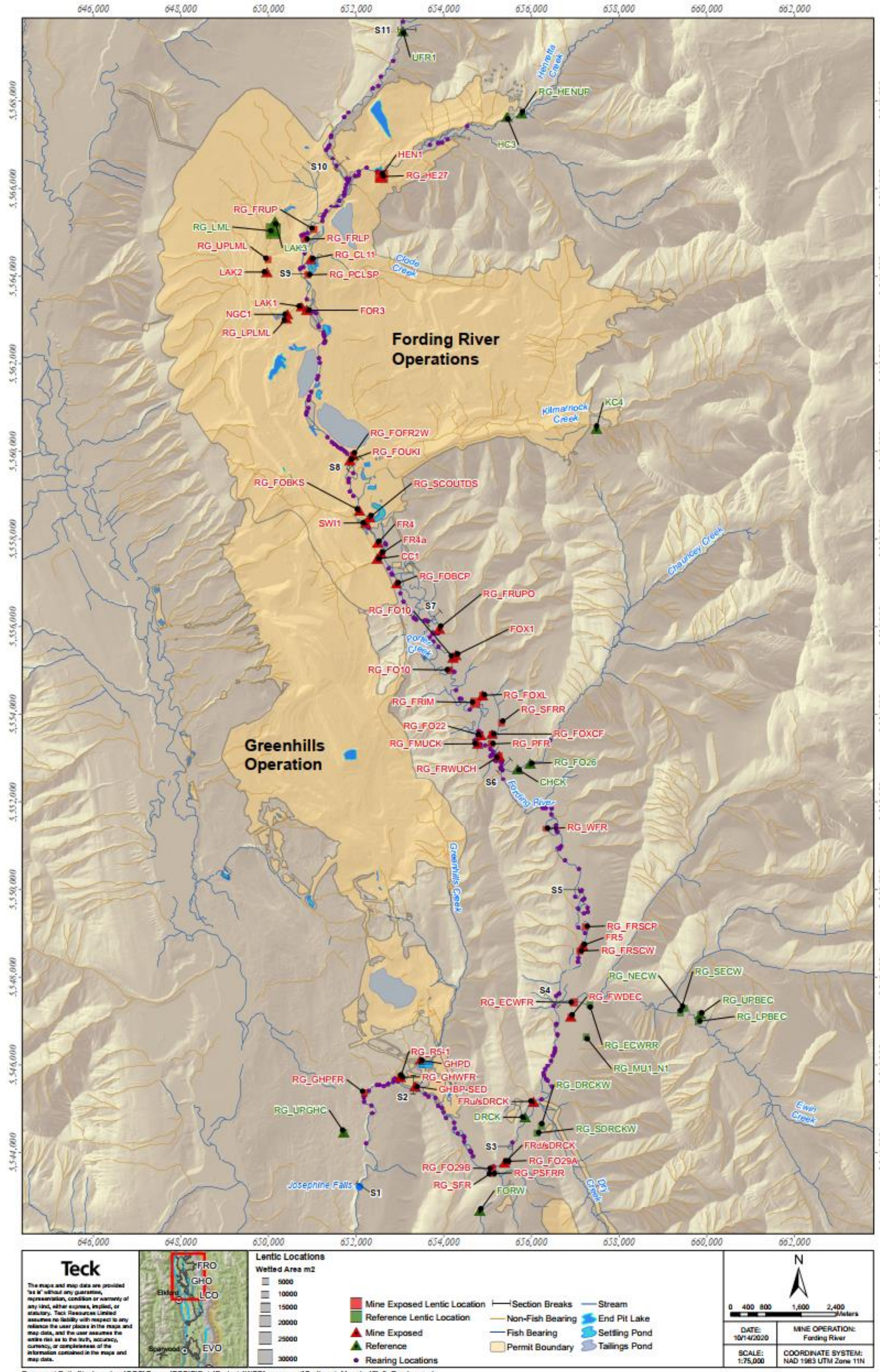


**Table 2-2. Upper Fording River segment groups used for sediment chemistry analysis. River kilometers (rkm) are upstream from confluence with Elk River.** The study area extends from 20.51 rkm at Josephine Falls to ~ 78 rkm.

| River Segment Group [1, 2] | River Segment [3] | River km [4] | Length (km) | Sampling Areas in River Segment [5,6] | Location Description |
|---|---|---|---|---|---|
| S1-S3 | 1 | 20.51–25.00 | 4.49 | RG_R5-1 | Josephine Falls to GHO. Off channel area of Fording d/s Greenhills. |
| | 2 | 25.00-29.00 | 4 | GH_GHBP | Lower Greenhills Creek |
| | 3 | 29.00-33.16 | 4.16 | FR d/s DRCK, FR u/s DRCK, RG_FWDEC | Fording River wetland downstream of Ewin Creek |
| - | 4 | 33.16-37.59 | 4.4 | FR5 | - |
| | 5 | 37.56-41.96 | 4.4 | - | - |
| S6 | 6 | 41.96-48.96 | 7 | RG_FOX1, RG_FMUCK, RG_FO10, RG_FO22, RG_FRUPO | Meadow area u/s Chauncey Creek; u/s Chauncey Creek; Fording River u/s of Porter Creek; Snye along Fording River |
| S7-S8 | 7 | 48.96-54.00 | 5.04 | CC1, FR4, FR4a, RG_FOBCP, RG_FOBKS, RG_SCOUTDS, SWI1 | UFR between Kilmarnock Creek & Swift Creek; d/s of AWTF-S outfall; between Cataract & Porter Creek |
| | 8 | 54.00-59.75 | 5.75 | RG_FOUKI, LAK1 | UFR u/s of Kilmarnock Creek (historically FR_FR2) |
| - | 9 | 59.75-63.40 | 3.65 | FOR3, LAK2, NGC1 | Turnbull Br. to above Henretta |
| - | 10 | 63.40-67.75 | 4.35 | RG_FO26 (Reference) | Reference area on the mainstem of the UFR, upstream of mine influence |
| - | 11 | 67.75-78.00 | 10.25 | - | Headwaters |
| - | Henretta Lake | - | - | RG_HE27, HEN1 | Henretta Lake |

**Notes**

"-" Not applicable

1 River segment groups used for analysis.

2 No sediment data for the Decline Window in river segments 4, 5 and 9.

3 River segments from Cope *et al* . 2016 (Table 2.1.2) and Cope 2020 (Table 2.1) . River segments are not river "reaches" of similar geomorphological characteristics since some segments contain several reaches.

4 Fording River Operations extend from approximately 51 to 65 rkm.

5 Samples collected in 2018 labelled FO10 were actually RG-SAFR (a separate sampling area in the snye along the Fording River). This does not affect this analysis as sampling locations are both within S6.

6 original sample names were retained to be consistent with source materials

**Acronyms**

d/s = downstream

u/s = upstream

FRO = Fording River Operations

GHO = Greenhills Operations

UFR = Upper Fording River

**Table 2-3. The number of sediment sampling areas and samples collected by river segment group in the upper Fording River[15].**

| River Segment | Number of Mine-Exposed Sampling Areas in Each Segment (# Samples) | | | | | |
|---|---|---|---|---|---|---|
| | 2011 | 2013 | 2015 | 2017 | 2018 | 2019 |
| | October | August | August | September | July, September | September |
| Henretta Lake | 1 (10) | 1 (3) | 1 (5) | - | 1 (5) | - |
| S7-S8 | 6 (31) | - | - | 3 (15) | 3 (15) | 4 (20) |
| S6 | 1 (6) | 2 (8) | 2 (10) | 2 (10) | 3 (15) | 2 (10) |
| S1-S3 | 2 (10) | - | 2 (10) | 1 (5) | 2 (10) | 1(5) |
| **Total** | **10 (57)** | **3 (11)** | **5 (25)** | **6 (30)** | **9 (45)** | **7 (35)** |

**Notes**

The list of sampling areas in each river segment are provided in **Table A-1**.

[15] More details on sediment sampling locations provided in **Table A-1**.

## 2.4 Requisite Conditions

Five requisite conditions are incorporated into the EoC to determine the likelihood that a stressor may have been the direct (Overarching Hypothesis #1) or contributory (Overarching Hypothesis #2) cause of the WCT decline (**Table 2-4**). The requisite conditions are conditions that would have to have been present for a stressor to have caused or contributed to the population decline. For the stressor (i.e., one or more coal-associated constituents) to be a likely ***sole cause*** of the decline, at a minimum the stressor would have to be present at a sufficient intensity (i.e., concentration) and duration during the Decline Window in multiple locations throughout the UFR that are known to support a large proportion of the juvenile and adult WCT population. The requisite conditions for a stressor to have ***contributed*** to the decline are less rigorous with respect to the number of locations that the exposure would have had to occur (i.e., intensity and duration of exposures could have been sufficient in only one key location).

The lines of evidence used to evaluate the requisite conditions are summarized in the methods section (**Section 3**) with conclusions with respect to the requisite conditions provided in **Section 4.3**.

**Table 2-4. Requisite conditions.**

| | |
|---|---|
| **Spatial Extent** | Widespread across the UFR (causal) or in some river segments (contributing factor). |
| **Location** | Present in rearing and overwintering habitats. |
| **Duration** | Constituents in sediment are assumed to represent exposure of a sufficient duration to induce adverse effects if intensity is sufficient. |
| **Timing** | Constituent must be elevated during the Decline Window period relative to historical conditions. |
| **Intensity** | Stressors would need to be present at sufficient concentrations to cause adverse effects, be bioavailable and have the potential to cause adverse effects that could result in the population decline (i.e., mortality of juvenile and adult life stages). |

# 3 METHODS

Azimuth relied on data collected as part of site-specific monitoring studies conducted on behalf of Teck Coal in the UFR between 2011 and 2019 to assess sediment quality. A brief background on the source of these datasets and how the data were compiled to support Azimuth's sediment quality assessment is provided below. This section also describes the screening process used to determine if there were changes in sediment quality during the Decline Window.

## 3.1 Data

### 3.1.1 Data Sources

Sediment chemistry data for Azimuth's sediment quality assessment were obtained from annual monitoring reports, baseline and supporting studies which are summarized in **Table 3-1**. Only data from fish accessible areas in the mine influenced mainstem and tributaries were used for the sediment quality screening and analysis.

The UFR is dominated by lotic, high flow habitat with coarse (i.e., cobble and gravel) substrate (IRCL 2008; Minnow 2018). However, the relatively few areas that are lentic (i.e., low flow), from oxbows to small lakes, are recognized as important habitat for the WCT (Cope et al. 2016), in particular for overwintering. Lentic areas tend to be low sinuosity and are characterized by the accumulation of fine sediment (i.e., silt and clay, < 0.063 mm in size) (Minnow 2014, 2016). The focus of the routine sampling was in the lentic depositional areas along the riverbank, dominated by fine sediment and often in locations with habitat structures that could further reduce flow (Minnow 2016). Sediment and benthic invertebrate community samples were collected synoptically with the sediment sampling areas generally within 10 to 100 m from the benthic invertebrate monitoring stations (Minnow and Lotic 2020). Across all compiled sediment samples collected in mine-exposed areas used for screening purposes, the mean concentration of total organic carbon (TOC) was similar between the Decline Window and what was reported historically (i.e., from 2011 to 2017). The mean TOC content was 8.0% historically, 9% in 2018 and 8.1% in 2019.

All sediment quality data from years 2017 through 2019 were collected in September as part of the Fording River Operations Local Aquatic Effects Monitoring Programs (FRO LAEMP) (Minnow and Lotic 2018, 2019 and 2020). Additional sediment quality data is available for years 2017 through 2018, all collected in July or September as part of the Greenhills Creek aquatic baseline and monitoring programs and the Lentic Area Supporting Study (Minnow 2018b, 2019a, b;

Minnow 2020a, b). Some of the sediment sampling areas were consistent across years within each respective sampling program, but not across sampling programs. All sampling areas and associated number of samples collected in the UFR are summarized in **Table A-1**. Sediment samples were collected in mine-exposed areas from the top 1 to 2 cm at five areas in 2017, ten areas in 2018 and six areas in 2019 (Minnow and Lotic 2018, 2019 and 2020). In each sampling area, 3 to 5 sediment samples were collected at locations with sufficient accumulation of sediment for sampling, such as depositional areas along the banks, in back eddies and behind log jams. The sediment sampling locations were in the vicinity of independent and adjacent riffle or glide habitat units that were sampled for benthic invertebrates as part of the FRO LAEMP studies using kick-net sampling. There were no sediment data for the Decline Window in river segments 4, 5, and 9. Detailed sample collection methods are provided in the 2018 -2020 Regional Aquatic Effects Monitoring Program (RAEMP) Study Design as well as the LAEMP reports (Minnow 2018a; Minnow and Lotic 2018, 2019 and 2020).

Sediment sampling areas for the FRO RAEMP were selected based on compliance and order permit stations in particular with respect to water quality. The LAEMP sediment sampling locations were chosen to encompass the areas where treated water from the water quality treatment plant would be entering and possibly influencing water quality in the UFR. The stations were not intended to capture sediment quality throughout the UFR, but rather capture any changes in water quality based on inputs from the new water treatment plant. Nonetheless, the areas sampled for sediment encompass spawning, rearing and overwintering WCT habitat throughout the UFR, including areas identified by Cope *et al*. (2016) known to support a large proportion of the WCT overwintering populations. The sampling areas are therefore considered relevant to the potential exposure conditions for juvenile and adult WCT that were impacted by the population decline.

Historical sediment chemistry data collected between 2011 and 2017 in the UFR were compiled from various supporting studies. Sediment chemistry data from October 2011 were obtained from a study conducted by Lotic Environmental Ltd. (Lotic) to collect sediment quality data downstream of the FRO (Lotic 2013). Although some samples collected for the 2011 study represented the < 0.063 mm fraction, only data representing the < 1 mm fraction were included in the analysis for this report. Sediment was collected in August 2013 at areas selected based on their habitat suitability, accessibility and presence of benthic invertebrates and other aquatic receptors (i.e., fish) (Minnow 2014). A few of the samples collected in 2013 were evaluated for sediment toxicity, although these samples only included one mine influenced area in the UFR (Minnow 2014). In August 2015, sediment was collected as part of Teck's RAEMP and a subset of those areas were later evaluated for sediment toxicity, including one mine influenced area in the

UFR (Minnow 2016). Additional sediment samples were collected in September 2017, 2018, and 2019 at five locations in lower Greenhills Creek to represent sediment quality in the creek (Minnow 2018b, 2019, 2020a).

Sediment samples collected prior to 2011 were not included in this analysis. For example, sediment was collected in 2006 as part of a selenium monitoring study in the Elk River watershed (Minnow et al. 2007). Sediment collected prior to 2011 is not considered representative of recent or current conditions. Furthermore, there were no paired fish population monitoring data for studies preceding 2012.

The sediment sampling areas from 2011-2019 in the UFR are summarized on maps showing the fish-bearing lentic areas and WCT spawning, rearing and overwintering habitat as determined by Cope *et al.* (2016) in **Figure 2-1**, **Figure 2-2** and **Figure 2-3**.

**Table 3-1. Sources of sediment quality data collected in the upper Fording River from 2011 to 2019.**

| Year | Data Format | Report name | Reference |
|---|---|---|---|
| 2011 | PDF | Elk River Watershed Baseline Stream Sediment Collection – Data delivery report. | Lotic 2013 |
| 2013 | PDF | 2013 Sediment Sampling Program for the Coal Mines in the Elk River Watershed, BC. | Minnow 2014 |
| 2015 | PDF | Sediment Toxicity Supporting Study, 2015. | Minnow 2016 |
| 2017 | PDF | FRO LAEMP 2017. | Minnow and Lotic 2018 |
| | PDF | Lower Greenhills Creek Aquatic Baseline. | Minnow 2018b |
| 2018 | PDF | Lower Greenhills Creek Monitoring Program Report - 2018. | Minnow 2019 |
| 2018 | Excel ™ | FRO LAEMP 2018. | Minnow and Lotic 2019; Orr 2020 Pers Comm |
| 2019 | Excel ™ | FRO LAEMP 2019. | Minnow and Lotic 2020; Orr 2020 Pers Comm |
| 2019 | PDF | Greenhills Creek Aquatic Monitoring Program 2019 Report. | Minnow 2020a |
| 2019 | Excel ™ | Lentic Area Supporting Study. | Minnow 2020b; Orr 2020 Pers Comm |

**Notes**

FRO LAEMP = Fording River Operations Local Aquatic Effects Monitoring Program

### 3.1.2 Data Quality Assessment

Sediment data were reviewed to identify results where the concentration of a constituent was reported to be a non-detect (i.e., less than the method detection limit, MDL), but the MDL was higher than the lower SQG. These samples were identified and excluded from further analysis because it would not be possible to determine if the true concentration in that non-detect sample was above or below the SQG. This data quality review resulted in a small number of results being excluded from additional analyses for eight PAHs. In addition, all acenaphthene, and all but one dibenzo(a,h)anthracene samples reported non-detect concentrations below the MDL, which was higher than the SQG therefore, these constituents were excluded from further analysis . All sediment data, including the samples that were omitted due to non-detect concentrations with MDLs above the SGQs are provided in **Appendix C** (**Figure C-1** and **Figure C-2).**

### 3.1.3 Data Compilation

Sediment chemistry data were compiled in an Excel™ database. R software version 3.6.3 (2020-02-29; R Core Team 2020) was used to manage and visualize the data and to calculate summary statistics.

Sediment chemistry data from samples collected in 2011, 2013, 2015, and 2017 were used to represent the range of historical sediment constituent concentrations in the UFR. Sediment chemistry data from 2018 and 2019 represent conditions in the Decline Window.

Several figures and tables (see **Section 4**) are provided to visualize and summarize sediment concentrations of constituents in the UFR. The figures show concentrations by river segment group and by year for the Decline Window. Data summary tables report summary statistics (i.e., mean, minimum, maximum and $90^{th}$ percentiles) of constituent concentrations in sediment. Non-detect results were assigned one-half the detection limit value for calculating summary statistics.

## 3.2 Screening Process

All available metals and PAHs data were compiled from the data sources described in **Section 3.1.1**. Federal and provincial sediment quality guidelines for 12 metals and 16 PAHs were available (see **Section 2.1**). Upper and lower SQGs that were used in the preliminary and secondary screening are presented in **Table 2-1**. Selenium has the same value given that both the lower and upper SQGs are based on the BC ENV alert value (BC ENV 2019, Section 2.1).

### 3.2.1 Preliminary Screening

In the preliminary screening, constituents were separated into those with SQGs and those without SQGs. For constituents with SQGs, if the maximum concentration in sediment reported during the Decline Window anywhere in the UFR did not exceed the lower SQG, meaning that concentration was unlikely to be associated with adverse effects (BC ENV 2020), it was screened out from further evaluation. If the maximum concentration in sediment exceeded the lower SQG, the constituent was retained for secondary screening as described in **Section 3.2.2**. Summary statistics were calculated for constituents without SQGs; however, they were not considered further in the screening or sediment quality analyses (see **Appendix B**).

### 3.2.2 Secondary Screening

Data for all constituents retained after preliminary screening were spatially stratified into *four river segment groups* (i.e., Henretta Lake, S7-S8, S6 and S1-S3) for the secondary screen (see **Section 2.3** for more detailed descriptions of river segment groups). Data for 2018 and 2019 are reported separately to allow the consideration of the exposure scenario for the entire Decline Window as well as in each year of the Decline Window.

For each river segment group, constituents were screened to determine if the concentrations measured during the Decline Window could be associated with adverse biological effects (i.e., based on screening with SQGs) and if they exceeded historical concentrations. The 90$^{th}$ percentile statistic[16] was used to represent the upper range of exposure concentrations that WCT may have been exposed to during the Decline Window (90$^{th}$ percentile$_{DW}$) and the historical time period (90$^{th}$ percentile$_{HIST}$).

The 90$^{th}$ percentile was selected to represent exposure concentrations to ensure that the screening was not skewed to a few samples with high concentrations that may not have represented exposure conditions for WCT throughout the area of interest. Generally, the difference between the maximum and the 90$^{th}$ percentile concentration was small indicating that extreme-high values were rare (**Table B-1**, **Table 4-2** and **Table B-2**). In the few instances where the maximum concentration was substantially higher than the 90$^{th}$ percentile (e.g., Manganese in S6 in 2018, **Table 4-2**), the maximum would have indicated the potential for adverse effects based on an exposure concentration that was likely present in a discrete location (e.g., the riffle where the sample was collected) but would not represent a realistic exposure scenario with respect to the larger population of WCT which is the focus of the EoC.

In the secondary screen constituents were classified into three categories representing how frequently their 90$^{th}$ percentile$_{DW}$ concentrations were associated with adverse effects as follows:

- ***Rarely*** - 90$^{th}$ percentile$_{DW}$ less than the lower SQG,
- ***Occasionally*** - 90$^{th}$ percentile$_{DW}$ between lower and upper SQGs, or

[16] The 90$^{th}$ percentile of a dataset estimates the value that 90% of the datapoints in that dataset fall below.

- ***Frequently*** - 90$^{th}$ percentile$_{DW}$ exceeded the upper SQG associated with adverse effects (see **Section 2.1** for basis of SQGs).

For the comparison with the historical dataset, concentrations of constituents were classified as being:

- ***Less than historical***- 90$^{th}$ percentile$_{DW}$ less than or equal to the mean$_{HIST}$,
- ***Different than historical*** - 90$^{th}$ percentile$_{DW}$ between the mean$_{HIST}$ and the 90$^{th}$ percentile$_{HIST}$, or
- ***More than historical*** - 90$^{th}$ percentile$_{DW}$ exceeded the 90$^{th}$ percentile$_{HIST}$.

Screening quotients (SQ) were calculated for each combination of constituent/year in Decline Window/river segment group, whereby the 90$^{th}$ percentile$_{DW}$ was divided by each of the respective screening values (i.e., upper or, lower SQG, or the mean$_{HIST}$, or 90$^{th}$ percentile$_{HIST}$) (see **Table 3-2**). If the resulting SQ, rounded to two significant figures, was ≤ 1.0 it was classified as a non-exceedance and if it was > 1.0 it was considered an exceedance. The SQ simply indicates if, and by how much, a concentration exceeds the screening value. For the SQG screen, an exceedance indicates the need for additional assessment of that constituent. For the historical screen, the degree of exceedance indicates the magnitude of change from historical conditions.

**Table 3-2. Glossary of screening quotients used in secondary sediment quality screening.**

| Screening Quotient | Acronym | Equation |
|---|---|---|
| Lower SQG screening quotient | $SQ_{lower}$ | $\frac{90^{th}\ \text{percentile}_{DW}\ \text{concentration}}{\text{lower SQG}}$ |
| Upper SQG screening quotient | $SQ_{upper}$ | $\frac{90^{th}\ \text{percentile}_{DW}\ \text{concentration}}{\text{upper SQG}}$ |
| Historical mean screening quotient | $HQ_{mean}$ | $\frac{90^{th}\ \text{percentile}_{DW}\ \text{concentration}}{\text{mean}_{HIST}}$ |
| Historical 90$^{th}$ screening quotient | $HQ_{90th}$ | $\frac{90^{th}\ \text{percentile}_{DW}\ \text{concentration}}{90^{th}\ \text{percentile}_{HIST}}$ |

The results of these analyses were considered in combination using a semi-quantitative approach to represent the evidence that there was a “substantive” (as characterized below) change in sediment quality during the Decline Window. Four categories from ***negligible*** to ***likely*** were used to indicate the likelihood there was a substantive change in sediment quality. If a constituent concentration measured during the Decline Window was not associated with potential for adverse effects based on the SQG screen, or if the same or higher concentration was present prior to the population decline, it would represent a ***negligible*** change in sediment quality. For the ***marginal***, ***probable*** and ***likely*** categories, there were increasing indications of a substantive change in sediment quality based on the potential for toxicity or magnitude of change in concentration compared to historical conditions as described below and illustrated in **Table 3-3**.

- **Negligible** – $90^{th}$ $percentile_{DW}$ < either the lower SQG **or** the $mean_{HIST}$
- **Marginal** – $90^{th}$ $percentile_{DW}$ between the lower and upper SQG **and** between the $mean_{HIST}$ and $90^{th}$ $percentile_{HIST}$
- **Probable** – $90^{th}$ $percentile_{DW}$ higher than the upper SQG **or** the $90^{th}$ $percentile_{HIST}$
- **Likely** – $90^{th}$ $percentile_{DW}$ exceeding both the Upper SQG **and** the $90^{th}$ $percentile_{HIST}$

The results of this assessment were used to represent changes in sediment quality across river grouping segments and time.

**Table 3-3. Template for screening sediment quality in the upper Fording River by comparing the 90th percentile concentrations in the Decline Window to SQGs and historical concentrations.**

| | 90th Percentile$_{DW}$ Associated with Adverse Biological Effects | | |
|---|---|---|---|
| | **Rarely** | **Occasionally** | **Frequently** |
| | ≤ Lower SQG | Between Lower & Upper SQG | > Upper SQG |
| 90th Percentile$_{DW}$ ≤ Historical Mean | Negligible | Negligible | Negligible |
| 90th Percentile$_{DW}$ Between Historical Mean and Historical 90th Percentile | Negligible | Marginal | Probable |
| 90th Percentile$_{DW}$ > Historical 90th Percentile | Negligible | Probable | Likely |

# 4 RESULTS

## 4.1 Sediment Quality Screening

### 4.1.1 Preliminary Screening

Sediment quality guidelines were available for 12 of 35 metals and 16 of 24 PAHs. Of the constituents with SQGs, five of 12 metals, and three of 16 PAHs, had maximum concentrations in the UFR that were below their respective lower SQGs and were screened out from further evaluation (**Table 4-1**). Two PAHs with SQGs, acenaphthene and dibenz(a,h)anthracene, were omitted from this screening due to data quality issues (see **Section 3.1.2**). The remaining constituents, which included seven metals (arsenic, cadmium, iron, manganese, nickel, selenium, and zinc), and 11 PAHs (2-methylnaphthalene, acenaphthylene, benz(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, chrysene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene), were retained for the secondary screening.

**Table 4-1. Preliminary screening to identify constituents in which the maximum reported concentrations in the upper Fording River during the Decline Window exceed the lower sediment quality guidelines.**

| Constituent [1] | UFR Maximum > Lower Sediment Quality Guideline |
|---|---|
| ***Metals*** | |
| Arsenic (As) | Yes |
| Cadmium (Cd) | Yes |
| Chromium (Cr) | No |
| Copper (Cu) | No |
| Iron (Fe) | Yes |
| Lead (Pb) | No |
| Manganese (Mn) | Yes |
| Mercury (Hg) | No |
| Nickel (Ni) | Yes |
| Selenium (Se) | Yes |
| Silver (Ag) | No |
| Zinc (Zn) | Yes |
| ***Polycyclic Aromatic Hydrocarbons (PAHs)*** | |
| 2-Methylnaphthalene | Yes |
| Acenaphthylene | Yes |
| Anthracene | No |
| Benz(a)anthracene | Yes |
| Benzo(a)pyrene | Yes |
| Benzo(g,h,i)perylene | Yes |
| Benzo(k)fluoranthene | No |
| Chrysene | Yes |
| Fluoranthene | Yes |
| Fluorene | Yes |
| Indeno(1,2,3-c,d)pyrene | No |
| Naphthalene | Yes |
| Phenanthrene | Yes |
| Pyrene | Yes |

**Notes**

(grey shading) Maximum concentration in upper Fording River during Decline Window exceeds lower sediment quality guideline (SQG).

1 Acenaphthene and dibenz(a,h)anthracene have SQGs however their MDLs were consistently higher than their respective SQGs and were therefore excluded from the screening.

### 4.1.2 Secondary Screening

The results of the secondary screen, including summary statistics and screening quotients, are summarized by river segment group and Decline Window year in **Table 4-2**. Screening quotients, as described in **Section 3.2.2**, were used in the secondary screening to categorize the constituents based on the evidence of potential change in sediment quality in each river segment during the Decline Window. The results are summarized in **Table 4-3** to provide an overview of which constituents had substantive evidence of change in the UFR and followed the template presented in **Table 3-3**. Note that since the only available guideline for selenium is an alert concentration, it was applied as a lower and upper SQG. Therefore, the classifications of changes in sediment quality for selenium are presented as a range (e.g., *marginal* to *probable*) for each river segment group. In general, concentrations of metals and PAHs in Henretta Lake (data available for 2018 only) were consistent with historical concentrations and had few exceedances of lower SQGs, whereas there were indications of substantive changes in sediment quality for some metals and PAHs in S7-S8, S6, and S1-S3 in 2018 and 2019. The results for each river segment group are presented herein and discussed in context of the requisite conditions (**Section 2.4**) and the screening quotients (**Section 3.2.2**).

In **Henretta Lake**, which was sampled in the historical period and 2018, but not 2019, changes in sediment quality were *negligible* for all metals except selenium. Selenium was categorized as having *marginal* to *probable* changes in sediment quality, with a $SQ_{lower}$ and $SQ_{upper}$ of 1.5 and a $HQ_{mean}$ of 1.1 indicating the concentrations were 1.5 times the lower and upper SQGs (i.e., alert concentration) but just above the historical mean, which suggests the concentrations were similar to historical mean concentrations. We consider that the classification for selenium indicating a *marginal* to *probable* change in sediment quality in Henretta Lake in 2018 is very uncertain because of how similar the concentrations were to historical concentrations and the relatively small exceedance of the SQG (<2). Two PAHs, chrysene and benz(a)anthracene, were classified as having *marginal* changes in sediment quality during the Decline Window. Benz(a)anthracene and chrysene had concentrations exceeding their historical means ($HQ_{mean}$ = 1.3 and $HQ_{mean}$ = 1.5, respectively) and had concentrations between the lower and upper SQGs ($SQ_{lower}$ = 1.3 and $SQ_{lower}$ = 3.4, respectively). Acenaphthylene was categorized as having a *probable* change in sediment quality in 2018 ($SQ_{lower}$ = 1.5, $HQ_{mean}$ = 1.9 and $HQ_{90th}$ =1.1). The remaining six metals and eight PAHs in Henretta were classified as having *negligible* changes in sediment quality.

In **river segment group S7-S8,** sediment data were available for 2018 and 2019. The changes in sediment quality were *negligible* for all metals except three in 2018 and one in 2019. Cadmium had *marginal* changes in sediment quality in 2018 ($SQ_{lower}$ = 3.8, $HQ_{mean}$ = 1.1) and *negligible* changes in sediment quality in 2019, with concentrations below both the $SQ_{lower}$ and $HQ_{mean}$. Manganese had *likely* changes in sediment quality in 2018 ($SQ_{upper}$ = 1.1 and $HQ_{90th}$ = 1.3) and *marginal* evidence of substantive change in sediment quality in 2019 ($SQ_{lower}$ = 1.6, $HQ_{mean}$ = 1.2). Selenium had *marginal* to *probable* changes in 2018 ($SQ_{lower}$ and $SQ_{upper}$ = 3.4, $HQ_{mean}$ = 1.8) and *negligible* changes in 2019.

Of the 11 PAHs in the secondary screen, all but two in 2018 and four in 2019 had some indication of changes in sediment quality. Four PAHs were classified as having *likely* changes in sediment quality in 2018 and *probable* changes in 2019: 2-methylnaphthalene, fluorene, naphthalene and phenanthrene. In 2018, these constituents had $SQ_{upper}$ values between 2.6 and 19 and $HQ_{90th}$ values between 1.1 and 1.3. In 2019, these constituents had $SQ_{upper}$ values from 1.3 and 9.0 and each had an $HQ_{mean}$ value of 1.1. Acenaphthylene only had results for 2018, with *probable* changes in sediment quality ($SQ_{lower}$ = 4.7, $HQ_{90th}$ = 1.7). Three other PAHs were classified as having *probable* changes in sediment quality in 2018, benz(a)anthracene, chrysene and pyrene, with $SQ_{lower}$ values from 2.7 and 8.4 and $HQ_{90th}$ values from 1.2 to 1.8. While benz(a)anthracene had *negligible* changes in 2019, chrysene and pyrene had *marginal* changes in sediment quality in 2019 exceeding the lower SQG ($SQ_{lower}$ = 4.8 and 1.6, respectively) and the historical mean concentrations ($HQ_{mean}$ = 1.5 and 1.4, respectively). Benzo(a)pyrene had *marginal* changes in 2018 exceeding the lower SQG ($SQ_{lower}$ = 2.3) and the historical mean concentrations ($HQ_{mean}$ = 2.0) and *negligible* changes in 2019. The remaining two PAHs, benzo(g,h,i)perylene and fluoranthene had *negligible* changes in sediment quality in 2018 and 2019.

In **river segment group S6,** sediment data were available for 2018 and 2019**.** Of the seven metals in the secondary screen, all but zinc had some indication of a change in sediment quality across both years. Arsenic and iron were classified as having *negligible* changes in sediment in 2018 and *probable* changes in 2019 with exceedances of the lower SQG ($SQ_{lower}$=1.1 and $SQ_{lower}$ =1.2) and the historical 90$^{th}$ ($HQ_{90th}$= 1.2 and $HQ_{90th}$ = 1.7) for each metal, respectively. Manganese had *probable* changes in sediment quality in both 2018 and 2019 with all $SQ_{lower}$ values of 1.6 and 1.2 and $HQ_{90th}$ values of 1.5 and 1.1, respectively. Cadmium and nickel had *marginal* changes in sediment quality throughout the Decline Window ($SQ_{lower}$ from 2.1 to 2.4 and $HQ_{mean}$ from 1.1 and 1.3). Selenium concentrations in 2018 exceeded the SQGs ($SQ_{lower}$ and $SQ_{upper}$ = 6.1) and historical mean and 90$^{th}$ concentrations ($HQ_{mean}$ = 3.2, $HQ_{90th}$ = 1.6) resulting in a classification of *probable* to *likely* changes in sediment quality. Concentrations of selenium in 2019 were lower than in 2018, lowering the classification to *negligible* with an exceedance of the SQG ($SQ_{lower}$ and $SQ_{upper}$ = 1.6) but below the historical concentrations ($HQ_{mean}$ and $HQ_{90th}$ < 1.0).

Of the eleven PAHs in the secondary screen, acenaphthylene, benz(a)anthracene, benzo(a)pyrene, benzo(g,h,i)perylene, fluoranthene and pyrene had *negligible* changes in sediment quality in both 2018 and 2019. Chrysene, fluorene and naphthalene, had *marginal* changes in sediment quality in 2018 and 2019 ($SQ_{lower}$ from 1.8 to 6.3 and $HQ_{mean}$ from 1.1 to 1.7). Phenanthrene had *negligible* changes in sediment quality in 2018 and *marginal* changes in 2019 ($SQ_{lower}$ = 11 and $HQ_{mean}$ = 1.1). 2-methylnaphthalene had *probable* changes in sediment quality in 2018 and 2019 with $SQ_{upper}$ values of 3.3 in 2018 and 3.2 in 2019, and $HQ_{mean}$ values of 1.4 in 2018 and 1.3 in 2019.

In **river segment group S1-S3**, sediment data were available for 2018 and 2019. Of the seven metals in the secondary screen, all but iron had some indication of a change in sediment quality in one or both years. Arsenic concentrations in sediment in 2018 and 2019 indicated *negligible* and *probable* changes in sediment quality, respectively. Concentrations of arsenic exceeded the lower SQG ($SQ_{lower}$ = 1.1) in 2019, the historical mean both years ($HQ_{mean}$ = 1.2 in 2018 and 1.6 in 2019) and the historical 90$^{th}$ in 2019 ($HQ_{90th}$ = 1.1). Concentrations of cadmium indicated *probable* (2018) and *negligible* (2019) changes in sediment quality, with exceedances of the lower SQG in both years ($SQ_{lower}$ = 3.8 and 2.3, respectively), and exceedances of the historical mean and 90$^{th}$ percentile in 2018 ($HQ_{mean}$ = 1.6, $HQ_{90th}$ = 1.2). Manganese indicated *probable* changes in sediment quality in 2018 and 2019. Manganese exceeded the lower SQG ($SQ_{lower}$ = 1.3 and 1.2), the historical mean ($HQ_{mean}$ = 2.6 and 2.4) and historical 90$^{th}$ ($HQ_{90th}$ = 1.6 and 1.5) in 2018 and 2019, respectively. Selenium concentrations indicated *marginal* to *probable* changes in sediment quality in 2018 and 2019; the concentrations exceeded the SQGs ($SQ_{lower}$ and $SQ_{upper}$ = 10 and 9.5 in 2018 and 2019, respectively) and the historical mean ($HQ_{mean}$ = 1.1) in both years. Although the exceedance of historical concentrations was slight, the selenium concentration was approximately 10 times higher than the SQGs ($SQ_{lower}$ and $SQ_{upper}$ = 10 and 9.5 in 2018 and 2019, respectively) providing more confidence that there was a change in sediment quality compared to Henretta Lake which had a similar exceedance of historical concentrations but a much lower exceedance of SQGs (i.e., $SQ_{lower}$ and $SQ_{upper}$ = 1.5).

Sediment quality associated with concentrations of nickel was classified as *likely* in 2018 and *probable* in 2019, exceeding the lower and upper SQGs ($SQ_{lower}$ from 8.8 to 6.7, $SQ_{upper}$ from 1.9 to 1.4) and the historical mean and 90$^{th}$ percentile concentrations ($HQ_{mean}$ from 3.1 to 2.4, $HQ_{90th}$ =1.3 in 2018). Zinc concentrations indicated *marginal* and *negligible* sediment quality in 2018 and 2019, respectively, with exceedances of the lower SQG in 2018 ($SQ_{lower}$ = 1.1) and of the historical mean in 2018 and 2019 ($HQ_{mean}$ = 1.2 and 1.1 in 2018 and 2019, respectively).

Of the 11 PAHs in the secondary screen, only benzo(g,h,i)perylene indicated *negligible* changes in sediment quality during the Decline Window and all other PAHs indicated changes in sediment quality between *marginal* and *likely* in one or both years. Changes in sediment quality of the following PAHs were classified as *likely* in 2018 and 2019; 2-methylnaphthalene, fluorene, naphthalene and phenanthrene exceeding the upper SQG ($SQ_{upper}$ from 4.4 to 29 in 2018 and from 3.6 to 22 in 2019) and the historical 90$^{th}$ concentrations ($HQ_{90th}$ from 1.4 to 2.3 in 2018 and 1.2 to 1.8 in 2019). Acenaphthylene only had data from 2018, in which sediment quality changes were classified as *probable* ($SQ_{lower}$ = 5.7, $HQ_{90th}$ = 1.3). Benz(a)anthracene and fluoranthene had *probable* changes in sediment quality in 2018 ($SQ_{lower}$ from 1.1 and 5.5, $HQ_{90th}$ from 1.2 to 1.4) and *negligible* changes in 2019. Benzo(a)pyrene had *probable* changes in sediment quality in 2018, exceeding the lower SQG ($SQ_{lower}$ = 3.4) and the historical 90$^{th}$ percentile ($HQ_{90th}$ = 1.3), whereas in 2019 it was classified as having *marginal* changes ($SQ_{lower}$ = 2.7 and $HQ_{mean}$ = 1.8). Chrysene had *marginal* changes in 2018 and 2019, exceeding the lower SQG ($SQ_{lower}$ = 12 and 10) and the historical mean concentrations ($HQ_{mean}$ = 2.1 and 1.9) in both years. Finally, pyrene had *probable* changes in 2018 and 2019, exceeding the lower SQG ($SQ_{lower}$ = 4.1 and 4.2) and the historical 90$^{th}$ percentile concentrations ($HQ_{90th}$ = 1.3 and 1.4).

**Table 4-2. Sediment chemistry from the upper Fording River, screened against guidelines and historical concentrations (2011/2013/2015/2017) by river segment group. Sample sizes are provided in Table 2-3.**

| | | | | Segments | Henretta Lake [2] | | | | | | Screening Results | | | | Screening Summary |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Concentrations in Sediment (mg/kg) [3] | | | | | | Screening Quotient | | Historical [4] | | |
| | | | Freshwater Sediment Quality Guideline (SQG) [1] | | 2018 | | | Historical [4] | | | 2018 | | | | |
| | Constituent | Units | Lower | Upper | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Lower SQG Quotient [5] | Upper SQG Quotient [5] | $Hist_{Mean}$ Quotient [6] | $Hist_{90th}$ Quotient [6] | 2018 |
| Metals | Arsenic (As) | mg/kg | 5.9 | 17 | 4.3 | 4.3 | 3.7 | 4.3 | 4.1 | 3.5 | 0.73 | 0.25 | 1.2 | 1.1 | Negligible |
| | Cadmium (Cd) | mg/kg | 0.60 | 3.5 | 0.81 | 0.78 | 0.67 | 1.2 | 1.1 | 0.88 | 1.3 | 0.22 | 0.89 | 0.69 | Negligible |
| | Iron (Fe) | mg/kg | 21,200 | 43,766 | 11,800 | 11,440 | 9,952 | 10,200 | 9,748 | 8,769 | 0.54 | 0.26 | 1.3 | 1.2 | Negligible |
| | Manganese (Mn) | mg/kg | 460 | 1,100 | 362 | 354 | 311 | 1,350 | 401 | 366 | 0.77 | 0.32 | 0.97 | 0.88 | Negligible |
| | Nickel (Ni) | mg/kg | 16 | 75 | 20 | 20 | 18 | 25 | 24 | 20 | 1.2 | 0.26 | 0.97 | 0.82 | Negligible |
| | Selenium (Se)[7] | mg/kg | NA | 2.0 | 3.3 | 3.0 | 2.0 | 4.8 | 4.4 | 2.6 | NA | 1.5 | 1.1 | 0.68 | Probable |
| | | mg/kg | 2.0 | NA | 3.3 | 3.0 | 2.0 | 4.8 | 4.4 | 2.6 | 1.5 | NA | 1.1 | 0.68 | Marginal |
| | Zinc (Zn) | mg/kg | 123 | 315 | 77 | 77 | 73 | 113 | 110 | 90 | 0.63 | 0.24 | 0.85 | 0.70 | Negligible |
| Polycyclic Aromatic Hydrocarbons (PAHs) | 2-Methylnaphthalene | mg/kg | 0.020 | 0.20 | 1.2 | 1.1 | 0.93 | 4.2 | 2.5 | 1.5 | 53 | 5.3 | 0.73 | 0.42 | Negligible |
| | Acenaphthylene | mg/kg | 0.0059 | 0.13 | 0.0095 | 0.0087 | 0.0072 | 0.0085 | 0.0077 | 0.0045 | 1.5 | 0.068 | 1.9 | 1.1 | Probable |
| | Benz(a)anthracene | mg/kg | 0.032 | 0.39 | 0.044 | 0.041 | 0.035 | 0.067 | 0.051 | 0.032 | 1.3 | 0.11 | 1.3 | 0.81 | Marginal |
| | Benzo(a)pyrene | mg/kg | 0.032 | 0.78 | 0.026 | 0.024 | 0.019 | 0.026 | 0.025 | 0.016 | 0.74 | 0.030 | 1.5 | 0.93 | Negligible |
| | Benzo(g,h,i)perylene[8] | mg/kg | 0.17 | 2.6 | 0.031 | 0.029 | 0.026 | 0.069 | 0.039 | 0.026 | 0.17 | 0.011 | 1.1 | 0.76 | Negligible |
| | Chrysene | mg/kg | 0.057 | 0.86 | 0.20 | 0.19 | 0.17 | 0.29 | 0.19 | 0.13 | 3.4 | 0.22 | 1.5 | 1.0 | Marginal |
| | Fluoranthene | mg/kg | 0.11 | 2.4 | 0.036 | 0.033 | 0.028 | 0.052 | 0.028 | 0.024 | 0.30 | 0.014 | 1.4 | 1.2 | Negligible |
| | Fluorene | mg/kg | 0.021 | 0.14 | 0.17 | 0.16 | 0.13 | 0.65 | 0.37 | 0.23 | 7.7 | 1.1 | 0.71 | 0.43 | Negligible |
| | Naphthalene | mg/kg | 0.035 | 0.39 | 0.26 | 0.26 | 0.22 | 0.86 | 0.55 | 0.32 | 7.4 | 0.65 | 0.79 | 0.46 | Negligible |
| | Phenanthrene | mg/kg | 0.042 | 0.52 | 0.68 | 0.65 | 0.57 | 2.1 | 1.2 | 0.85 | 16 | 1.3 | 0.77 | 0.55 | Negligible |
| | Pyrene | mg/kg | 0.053 | 0.88 | 0.058 | 0.055 | 0.047 | 0.12 | 0.091 | 0.053 | 1.0 | 0.063 | 1.1 | 0.61 | Negligible |

**Notes**

NA = no data.

1 BC working sediment quality guidelines (BC ENV 2020) and Canadian Council of MInisters of the Environment interim sediment quality guidelines (CCME 2020) - both for freshwater.

2 No data available for this segment in 2019.

3 1/2 detection limit used for non-detects in calculation of 90th percentile and mean concentrations.

4 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

5 SQG Quotient = 90th percentile concentration/SQG (lower or upper).

6 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration; $Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

7 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline due to limited data. Considered protective of most aquatic environments and provides early detection of potential for impacts to aquatic organisms. Key compartments (e.g., tissues) should be measured for Se bioaccumulation if there are exceedances (BC ENV 2014, 2019).

8 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (8.24%). No TOC adjustment required for the lower SQG.

Sediment Quality Guidelines and/or Historical Quotients exceed 1.0.

**Table 4-2 (Continued). Sediment chemistry from the upper Fording River, screened against guidelines and historical concentrations (2011/2013/2015/2017) by river segment group. Sample sizes are provided in Table 2-3.**

| | | | | Segments | S7-S8 | | | | | | | | | Screening Results | | | | | | | | | Screening Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Concentrations in Sediment (mg/kg)[3] | | | | | | | | | Screening Quotient | | | | Historical[4] | | | | | | |
| | | | Freshwater Sediment Quality Guideline (SQG)[1] | | 2018 | | | 2019 | | | Historical[4] | | | 2018 | | 2019 | | 2018 | | 2019 | | | | |
| | Constituent | Units | Lower | Upper | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Lower SQG Quotient[5] | Upper SQG Quotient[5] | Lower SQG Quotient[5] | Upper SQG Quotient[5] | $Hist_{Mean}$ Quotient[6] | $Hist_{90th}$ Quotient[6] | $Hist_{Mean}$ Quotient[6] | $Hist_{90th}$ Quotient[6] | 2018 | 2019 |
| Metals | Arsenic (As) | mg/kg | 5.9 | 17 | 5.5 | 5.3 | 4.5 | 6.0 | 5.6 | 4.2 | 5.6 | 4.8 | 3.9 | 0.90 | 0.31 | 0.95 | 0.33 | 1.3 | 1.1 | 1.4 | 1.2 | Negligible | Negligible |
| | Cadmium (Cd) | mg/kg | 0.60 | 3.5 | 2.5 | 2.3 | 1.8 | 1.8 | 1.6 | 1.4 | 4.6 | 4.4 | 2.1 | 3.8 | 0.65 | 2.7 | 0.47 | 1.1 | 0.51 | 0.76 | 0.37 | Marginal | Negligible |
| | Iron (Fe) | mg/kg | 21,200 | 43,766 | 17,600 | 15,820 | 13,833 | 20,400 | 17,970 | 13,342 | 18,100 | 16,000 | 11,878 | 0.75 | 0.36 | 0.85 | 0.41 | 1.3 | 0.99 | 1.5 | 1.1 | Negligible | Negligible |
| | Manganese (Mn) | mg/kg | 460 | 1,100 | 1,230 | 1,188 | 831 | 934 | 756 | 651 | 1,260 | 898 | 640 | 2.6 | 1.1 | 1.6 | 0.69 | 1.9 | 1.3 | 1.2 | 0.84 | Likely | Marginal |
| | Nickel (Ni) | mg/kg | 16 | 75 | 55 | 53 | 44 | 54 | 51 | 40 | 129 | 120 | 61 | 3.3 | 0.70 | 3.2 | 0.68 | 0.86 | 0.44 | 0.83 | 0.42 | Negligible | Negligible |
| | Selenium (Se)[7] | mg/kg | NA | 2.0 | 8.2 | 6.7 | 4.0 | 3.1 | 2.8 | 2.2 | 9.3 | 6.6 | 3.7 | NA | 3.4 | NA | 1.4 | 1.8 | 1.0 | 0.77 | 0.43 | Probable | Negligible |
| | | mg/kg | 2.0 | NA | 8.2 | 6.7 | 4.0 | 3.1 | 2.8 | 2.2 | 9.3 | 6.6 | 3.7 | 3.4 | NA | 1.4 | NA | 1.8 | 1.0 | 0.77 | 0.43 | Marginal | Negligible |
| | Zinc (Zn) | mg/kg | 123 | 315 | 169 | 158 | 136 | 157 | 131 | 117 | 336 | 322 | 162 | 1.3 | 0.50 | 1.1 | 0.42 | 0.97 | 0.49 | 0.81 | 0.41 | Negligible | Negligible |
| Polycyclic Aromatic Hydrocarbons (PAHs) | 2-Methylnaphthalene | mg/kg | 0.020 | 0.20 | 4.1 | 3.7 | 2.1 | 2.5 | 1.8 | 1.4 | 4.1 | 3.1 | 1.7 | 185 | 19 | 90 | 9.0 | 2.2 | 1.2 | 1.1 | 0.59 | Likely | Probable |
| | Acenaphthylene | mg/kg | 0.0059 | 0.13 | 0.030 | 0.028 | 0.015 | NA | NA | NA | 0.023 | 0.016 | 0.010 | 4.7 | 0.22 | NA | NA | 2.7 | 1.7 | NA | NA | Probable | NA |
| | Benz(a)anthracene | mg/kg | 0.032 | 0.39 | 0.14 | 0.13 | 0.072 | 0.015 | 0.015 | 0.015 | 0.10 | 0.074 | 0.047 | 4.2 | 0.35 | 0.47 | 0.039 | 2.8 | 1.8 | 0.32 | 0.20 | Probable | Negligible |
| | Benzo(a)pyrene | mg/kg | 0.032 | 0.78 | 0.083 | 0.073 | 0.039 | 0.044 | 0.032 | 0.021 | 0.083 | 0.077 | 0.037 | 2.3 | 0.093 | 1.0 | 0.041 | 2.0 | 0.95 | 0.88 | 0.42 | Marginal | Negligible |
| | Benzo(g,h,i)perylene[8] | mg/kg | 0.17 | 2.6 | 0.10 | 0.096 | 0.054 | 0.057 | 0.039 | 0.029 | 0.10 | 0.069 | 0.040 | 0.57 | 0.036 | 0.23 | 0.015 | 2.4 | 1.4 | 0.99 | 0.57 | Negligible | Negligible |
| | Chrysene | mg/kg | 0.057 | 0.86 | 0.56 | 0.48 | 0.28 | 0.37 | 0.27 | 0.21 | 0.38 | 0.30 | 0.19 | 8.4 | 0.56 | 4.8 | 0.32 | 2.6 | 1.6 | 1.5 | 0.91 | Probable | Marginal |
| | Fluoranthene | mg/kg | 0.11 | 2.4 | 0.095 | 0.086 | 0.050 | 0.059 | 0.046 | 0.036 | 0.071 | 0.049 | 0.031 | 0.78 | 0.037 | 0.42 | 0.020 | 2.8 | 1.8 | 1.5 | 0.95 | Negligible | Negligible |
| | Fluorene | mg/kg | 0.021 | 0.14 | 0.55 | 0.50 | 0.27 | 0.33 | 0.24 | 0.19 | 0.75 | 0.45 | 0.22 | 24 | 3.4 | 12 | 1.7 | 2.3 | 1.1 | 1.1 | 0.54 | Likely | Probable |
| | Naphthalene | mg/kg | 0.035 | 0.39 | 1.1 | 1.0 | 0.56 | 0.70 | 0.49 | 0.39 | 1.3 | 0.81 | 0.47 | 29 | 2.6 | 14 | 1.3 | 2.2 | 1.3 | 1.1 | 0.61 | Likely | Probable |
| | Phenanthrene | mg/kg | 0.042 | 0.52 | 2.2 | 2.0 | 1.2 | 1.4 | 0.98 | 0.77 | 2.9 | 1.7 | 0.91 | 48 | 3.9 | 23 | 1.9 | 2.2 | 1.2 | 1.1 | 0.57 | Likely | Probable |
| | Pyrene | mg/kg | 0.053 | 0.88 | 0.16 | 0.14 | 0.084 | 0.12 | 0.085 | 0.064 | 0.21 | 0.12 | 0.060 | 2.7 | 0.16 | 1.6 | 0.097 | 2.4 | 1.2 | 1.4 | 0.72 | Probable | Marginal |

**Notes**

NA = no data.

1 BC working sediment quality guidelines (BC ENV 2020) and Canadian Council of MInisters of the Environment interim sediment quality guidelines (CCME 2020) - both for freshwater.

2 No data available for this segment in 2019.

3 1/2 detection limit used for non-detects in calculation of 90th percentile and mean concentrations.

4 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

5 SQG Quotient = 90th percentile concentration/SQG (lower or upper).

6 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration; $Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

7 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline due to limited data. Considered protective of most aquatic environments and provides early detection of potential for impacts to aquatic organisms. Key compartments (e.g., tissues) should be measured for Se bioaccumulation if there are exceedances (BC ENV 2014, 2019).

8 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (8.24%). No TOC adjustment required for the lower SQG.

Sediment Quality Guidelines and/or Historical Quotients exceed 1.0.

**Table 4-2 (Continued). Sediment chemistry from the upper Fording River, screened against guidelines and historical concentrations (2011/2013/2015/2017) by river segment group. Sample sizes are provided in Table 2-3.**

| | | | Segments | | S6 | | | | | | | | | Screening Results | | | | | | | | Screening Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Concentrations in Sediment (mg/kg) [3] | | | | | | | | | Screening Quotient | | | | Historical [4] | | | | | |
| | | | Freshwater Sediment Quality Guideline (SQG) [1] | | 2018 | | | 2019 | | | Historical [4] | | | 2018 | | 2019 | | 2018 | | 2019 | | | |
| | Constituent | Units | Lower | Upper | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Lower SQG Quotient [5] | Upper SQG Quotient [5] | Lower SQG Quotient [5] | Upper SQG Quotient [5] | $Hist_{Mean}$ Quotient [6] | $Hist_{90th}$ Quotient [6] | $Hist_{Mean}$ Quotient [6] | $Hist_{90th}$ Quotient [6] | 2018 | 2019 |
| Metals | Arsenic (As) | mg/kg | 5.9 | 17 | 5.9 | 5.6 | 5.1 | 7.3 | 6.6 | 5.5 | 5.7 | 5.4 | 4.7 | 0.95 | 0.33 | 1.1 | 0.39 | 1.2 | 1.0 | 1.4 | 1.2 | Negligible | Probable |
| | Cadmium (Cd) | mg/kg | 0.60 | 3.5 | 1.7 | 1.4 | 1.2 | 1.5 | 1.5 | 1.2 | 1.6 | 1.4 | 1.2 | 2.3 | 0.39 | 2.4 | 0.41 | 1.1 | 0.97 | 1.2 | 1.0 | Marginal | Marginal |
| | Iron (Fe) | mg/kg | 21,200 | 43,766 | 16,600 | 16,000 | 14,527 | 34,500 | 25,320 | 17,530 | 19,600 | 15,100 | 13,676 | 0.75 | 0.37 | 1.2 | 0.58 | 1.2 | 1.1 | 1.9 | 1.7 | Negligible | Probable |
| | Manganese (Mn) | mg/kg | 460 | 1,100 | 2,450 | 749 | 555 | 590 | 567 | 496 | 598 | 501 | 378 | 1.6 | 0.68 | 1.2 | 0.52 | 2.0 | 1.5 | 1.5 | 1.1 | Probable | Probable |
| | Nickel (Ni) | mg/kg | 16 | 75 | 35 | 33 | 27 | 37 | 34 | 31 | 39 | 34 | 26 | 2.1 | 0.45 | 2.1 | 0.45 | 1.3 | 0.98 | 1.3 | 0.99 | Marginal | Marginal |
| | Selenium (Se)[7] | mg/kg | NA | 2.0 | 15 | 12 | 5.1 | 3.3 | 3.1 | 2.4 | 14 | 7.9 | 3.8 | NA | 6.1 | NA | 1.6 | 3.2 | 1.6 | 0.83 | 0.40 | Likely | Negligible |
| | | mg/kg | 2.0 | NA | 15 | 12 | 5.1 | 3.3 | 3.1 | 2.4 | 14 | 7.9 | 3.8 | 6.1 | NA | 1.6 | NA | 3.2 | 1.6 | 0.83 | 0.40 | Probable | Negligible |
| | Zinc (Zn) | mg/kg | 123 | 315 | 124 | 119 | 103 | 127 | 124 | 111 | 114 | 110 | 101 | 0.97 | 0.38 | 1.0 | 0.39 | 1.2 | 1.1 | 1.2 | 1.1 | Negligible | Negligible |
| Polycyclic Aromatic Hydrocarbons (PAHs) | 2-Methylnaphthalene | mg/kg | 0.020 | 0.20 | 0.95 | 0.66 | 0.42 | 0.70 | 0.65 | 0.45 | 1.1 | 0.86 | 0.49 | 33 | 3.3 | 32 | 3.2 | 1.4 | 0.77 | 1.3 | 0.76 | Probable | Probable |
| | Acenaphthylene | mg/kg | 0.0059 | 0.13 | 0.0063 | 0.0025 | 0.0028 | 0.0025 | 0.0025 | 0.0025 | 0.0090 | 0.0075 | 0.0035 | 0.43 | 0.020 | 0.43 | 0.020 | 0.71 | 0.33 | 0.71 | 0.33 | Negligible | Negligible |
| | Benz(a)anthracene | mg/kg | 0.032 | 0.39 | 0.031 | 0.022 | 0.013 | 0.019 | 0.017 | 0.013 | 0.049 | 0.038 | 0.020 | 0.70 | 0.058 | 0.54 | 0.045 | 1.1 | 0.59 | 0.86 | 0.45 | Negligible | Negligible |
| | Benzo(a)pyrene | mg/kg | 0.032 | 0.78 | 0.013 | 0.0094 | 0.0061 | 0.021 | 0.015 | 0.0090 | 0.027 | 0.023 | 0.0091 | 0.29 | 0.012 | 0.46 | 0.019 | 1.0 | 0.41 | 1.6 | 0.64 | Negligible | Negligible |
| | Benzo(g,h,i)perylene[8] | mg/kg | 0.17 | 2.6 | 0.021 | 0.012 | 0.0075 | 0.022 | 0.018 | 0.011 | 0.034 | 0.028 | 0.015 | 0.068 | 0.0044 | 0.10 | 0.0066 | 0.77 | 0.42 | 1.2 | 0.63 | Negligible | Negligible |
| | Chrysene | mg/kg | 0.057 | 0.86 | 0.15 | 0.10 | 0.070 | 0.14 | 0.11 | 0.086 | 0.15 | 0.14 | 0.092 | 1.8 | 0.12 | 1.9 | 0.12 | 1.1 | 0.73 | 1.2 | 0.77 | Marginal | Marginal |
| | Fluoranthene | mg/kg | 0.11 | 2.4 | 0.030 | 0.020 | 0.011 | 0.022 | 0.020 | 0.013 | 0.062 | 0.037 | 0.023 | 0.18 | 0.0083 | 0.18 | 0.0086 | 0.87 | 0.53 | 0.90 | 0.54 | Negligible | Negligible |
| | Fluorene | mg/kg | 0.021 | 0.14 | 0.096 | 0.065 | 0.038 | 0.087 | 0.079 | 0.056 | 0.10 | 0.090 | 0.047 | 3.1 | 0.45 | 3.8 | 0.55 | 1.4 | 0.72 | 1.7 | 0.88 | Marginal | Marginal |
| | Naphthalene | mg/kg | 0.035 | 0.39 | 0.26 | 0.22 | 0.13 | 0.25 | 0.19 | 0.14 | 0.27 | 0.24 | 0.15 | 6.3 | 0.56 | 5.4 | 0.48 | 1.4 | 0.91 | 1.2 | 0.78 | Marginal | Marginal |
| | Phenanthrene | mg/kg | 0.042 | 0.52 | 0.62 | 0.41 | 0.25 | 0.48 | 0.45 | 0.31 | 0.90 | 0.76 | 0.42 | 9.9 | 0.80 | 11 | 0.87 | 0.97 | 0.54 | 1.1 | 0.59 | Negligible | Marginal |
| | Pyrene | mg/kg | 0.053 | 0.88 | 0.045 | 0.030 | 0.019 | 0.039 | 0.033 | 0.024 | 0.092 | 0.064 | 0.035 | 0.56 | 0.034 | 0.62 | 0.037 | 0.84 | 0.47 | 0.93 | 0.51 | Negligible | Negligible |

**Notes**

NA = no data.

1 BC working sediment quality guidelines (BC ENV 2020) and Canadian Council of MInisters of the Environment interim sediment quality guidelines (CCME 2020) - both for freshwater.

2 No data available for this segment in 2019.

3 1/2 detection limit used for non-detects in calculation of 90th percentile and mean concentrations.

4 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

5 SQG Quotient = 90th percentile concentration/SQG (lower or upper).

6 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration; $Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

7 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline due to limited data. Considered protective of most aquatic environments and provides early detection of potential for impacts to aquatic organisms. Key compartments (e.g., tissues) should be measured for Se bioaccumulation if there are exceedances (BC ENV 2014, 2019).

8 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (8.24%). No TOC adjustment required for the lower SQG.

Sediment Quality Guidelines and/or Historical Quotients exceed 1.0.

**Table 4-2 (Continued). Sediment chemistry from the upper Fording River, screened against guidelines and historical concentrations (2011/2013/2015/2017) by river segment group. Sample sizes are provided in Table 2-3.**

| | | | Freshwater Sediment Quality Guideline (SQG) [1] | | S1-S3 [2] Concentrations in Sediment (mg/kg) [3] 2018 | | | 2019 | | | Historical [4] | | | Screening Results: Screening Quotient 2018 | | 2019 | | Historical [4] 2018 | | 2019 | | Screening Summary | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constituent | Units | Lower | Upper | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Lower SQG Quotient [5] | Upper SQG Quotient [5] | Lower SQG Quotient [5] | Upper SQG Quotient [5] | $Hist_{Mean}$ Quotient [6] | $Hist_{90th}$ Quotient [6] | $Hist_{Mean}$ Quotient [6] | $Hist_{90th}$ Quotient [6] | 2018 | 2019 |
| Metals | Arsenic (As) | mg/kg | 5.9 | 17 | 5.7 | 4.9 | 3.9 | 7.2 | 6.4 | 4.6 | 6.5 | 5.6 | 4.0 | 0.82 | 0.29 | 1.1 | 0.38 | 1.2 | 0.87 | 1.6 | 1.1 | Negligible | Probable |
| | Cadmium (Cd) | mg/kg | 0.60 | 3.5 | 2.4 | 2.3 | 1.6 | 1.5 | 1.4 | 1.2 | 2.0 | 1.9 | 1.5 | 3.8 | 0.66 | 2.3 | 0.39 | 1.6 | 1.2 | 0.93 | 0.72 | Probable | Negligible |
| | Iron (Fe) | mg/kg | 21,200 | 43,766 | 16,600 | 14,080 | 11,380 | 21,400 | 18,720 | 13,170 | 16,200 | 15,840 | 11,810 | 0.66 | 0.32 | 0.88 | 0.43 | 1.2 | 0.89 | 1.6 | 1.2 | Negligible | Negligible |
| | Manganese (Mn) | mg/kg | 460 | 1,100 | 632 | 587 | 295 | 578 | 538 | 435 | 529 | 365 | 224 | 1.3 | 0.53 | 1.2 | 0.49 | 2.6 | 1.6 | 2.4 | 1.5 | Probable | Probable |
| | Nickel (Ni) | mg/kg | 16 | 75 | 144 | 140 | 67 | 112 | 106 | 82 | 119 | 106 | 45 | 8.8 | 1.9 | 6.7 | 1.4 | 3.1 | 1.3 | 2.4 | 1.0 | Likely | Probable |
| | Selenium (Se) [7] | mg/kg | NA | 2.0 | 21 | 20 | 14 | 19 | 19 | 14 | 49 | 34 | 18 | NA | 10 | NA | 9.5 | 1.1 | 0.58 | 1.1 | 0.55 | Probable | Probable |
| | | mg/kg | 2.0 | NA | 21 | 20 | 14 | 19 | 19 | 14 | 49 | 34 | 18 | 10 | NA | 9.5 | NA | 1.1 | 0.58 | 1.1 | 0.55 | Marginal | Marginal |
| | Zinc (Zn) | mg/kg | 123 | 315 | 144 | 139 | 112 | 125 | 125 | 116 | 162 | 137 | 112 | 1.1 | 0.44 | 1.0 | 0.40 | 1.2 | 1.0 | 1.1 | 0.91 | Marginal | Negligible |
| Polycyclic Aromatic Hydrocarbons (PAHs) | 2-Methylnaphthalene | mg/kg | 0.020 | 0.20 | 9.0 | 5.9 | 2.4 | 5.5 | 4.5 | 2.7 | 5.3 | 2.8 | 1.1 | 291 | 29 | 223 | 22 | 5.1 | 2.1 | 3.9 | 1.6 | Likely | Likely |
| | Acenaphthylene | mg/kg | 0.0059 | 0.13 | 0.037 | 0.033 | 0.024 | NA | NA | NA | 0.048 | 0.026 | 0.018 | 5.7 | 0.26 | NA | NA | 1.9 | 1.3 | NA | NA | Probable | NA |
| | Benz(a)anthracene | mg/kg | 0.032 | 0.39 | 0.20 | 0.17 | 0.077 | 0.015 | 0.015 | 0.015 | 0.29 | 0.13 | 0.075 | 5.5 | 0.45 | 0.47 | 0.039 | 2.3 | 1.4 | 0.20 | 0.12 | Probable | Negligible |
| | Benzo(a)pyrene | mg/kg | 0.032 | 0.78 | 0.14 | 0.11 | 0.052 | 0.11 | 0.085 | 0.050 | 0.16 | 0.085 | 0.047 | 3.4 | 0.14 | 2.7 | 0.11 | 2.3 | 1.3 | 1.8 | 1.0 | Probable | Marginal |
| | Benzo(g,h,i)perylene [8] | mg/kg | 0.17 | 2.6 | 0.21 | 0.16 | 0.069 | 0.13 | 0.11 | 0.068 | 0.24 | 0.097 | 0.048 | 0.96 | 0.062 | 0.63 | 0.040 | 3.4 | 1.7 | 2.2 | 1.1 | Negligible | Negligible |
| | Chrysene | mg/kg | 0.057 | 0.86 | 0.84 | 0.67 | 0.30 | 0.73 | 0.59 | 0.36 | 1.6 | 0.69 | 0.32 | 12 | 0.77 | 10 | 0.69 | 2.1 | 0.97 | 1.9 | 0.86 | Marginal | Marginal |
| | Fluoranthene | mg/kg | 0.11 | 2.4 | 0.15 | 0.12 | 0.059 | 0.14 | 0.11 | 0.068 | 0.21 | 0.099 | 0.047 | 1.1 | 0.052 | 1.0 | 0.048 | 2.6 | 1.2 | 2.4 | 1.2 | Probable | Negligible |
| | Fluorene | mg/kg | 0.021 | 0.14 | 0.94 | 0.80 | 0.36 | 0.63 | 0.51 | 0.30 | 0.76 | 0.36 | 0.18 | 38 | 5.5 | 24 | 3.6 | 4.4 | 2.2 | 2.8 | 1.4 | Likely | Likely |
| | Naphthalene | mg/kg | 0.035 | 0.39 | 2.7 | 1.7 | 0.71 | 1.7 | 1.4 | 0.80 | 1.3 | 0.76 | 0.32 | 50 | 4.4 | 41 | 3.6 | 5.4 | 2.3 | 4.4 | 1.8 | Likely | Likely |
| | Phenanthrene | mg/kg | 0.042 | 0.52 | 3.4 | 2.5 | 1.1 | 2.7 | 2.2 | 1.3 | 3.5 | 1.7 | 0.80 | 59 | 4.8 | 52 | 4.2 | 3.1 | 1.4 | 2.7 | 1.2 | Likely | Likely |
| | Pyrene | mg/kg | 0.053 | 0.88 | 0.276 | 0.22 | 0.094 | 0.28 | 0.22 | 0.13 | 0.37 | 0.16 | 0.070 | 4.1 | 0.25 | 4.2 | 0.26 | 3.1 | 1.3 | 3.2 | 1.4 | Probable | Probable |

**Notes**

NA = no data.

1 BC working sediment quality guidelines (BC ENV 2020) and Canadian Council of MInisters of the Environment interim sediment quality guidelines (CCME 2020) - both for freshwater.

2 No data available for this segment in 2019.

3 1/2 detection limit used for non-detects in calculation of 90th percentile and mean concentrations.

4 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

5 SQG Quotient = 90th percentile concentration/SQG (lower or upper).

6 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration; $Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

7 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline due to limited data. Considered protective of most aquatic environments and provides early detection of potential for impacts to aquatic organisms. Key compartments (e.g., tissues) should be measured for Se bioaccumulation if there are exceedances (BC ENV 2014, 2019).

8 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (8.24%). No TOC adjustment required for the lower SQG.

Sediment Quality Guidelines and/or Historical Quotients exceed 1.0.

**Table 4-3. Secondary screening summary by river segment groups in the upper Fording River.**

| | River Segment Group | Henretta Lake | S7-S8 | | S6 | | S1-S3 | |
|---|---|---|---|---|---|---|---|---|
| | Year | 2018 | 2018 | 2019 | 2018 | 2019 | 2018 | 2019 |
| **Metals** | | | | | | | | |
| Metals | Arsenic (As) | | | | | | | |
| | Cadmium (Cd) | | | | | | | |
| | Iron (Fe) | | | | | | | |
| | Manganese (Mn) | | | | | | | |
| | Nickel (Ni) | | | | | | | |
| | Selenium (Se) - Upper SQG | | | | | | | |
| | Selenium (Se) - Lower SQG | | | | | | | |
| | Zinc (Zn) | | | | | | | |
| **PAHs** | | | | | | | | |
| PAHs | 2-Methylnaphthalene | | | | | | | |
| | Acenaphthylene | | | NA - no results | | | | NA - no results |
| | Benz(a)anthracene | | | | | | | |
| | Benzo(a)pyrene | | | | | | | |
| | Benzo(g,h,i)perylene | | | | | | | |
| | Chrysene | | | | | | | |
| | Fluoranthene | | | | | | | |
| | Fluorene | | | | | | | |
| | Naphthalene | | | | | | | |
| | Phenanthrene | | | | | | | |
| | Pyrene | | | | | | | |

| Evidence of Substantive Change in Sediment Quality | | | | |
|---|---|---|---|---|
| | Negligible | Marginal | Probable | Likely |

## 4.2 Bioavailability and Toxicity of Constituents

The sediment quality screening indicated that seven metals and nine PAHs were associated with changes in sediment quality during the Decline Window in one or more of the four river segment groups that were assessed. The potential for these changes in sediment quality to result in adverse impacts to WCT, and specifically to mortality of juveniles and adults, is a function of constituent bioavailability and the toxicity as well as the timing (i.e., life stage) and duration of exposure. Bioavailability and adverse effects associated with metals and PAHs are assessed below using a combination of site-specific data and the scientific literature.

### 4.2.1 Metals

**Exposure pathways and bioavailability** - In general, bulk sediment metal concentrations, as used in the sediment screen (**Section 3.2, Section 4.1**), are not effective in predicting effects to aquatic organisms as they do not reflect bioavailability (Paller and Knox 2013). Moreover, metals bioavailability from sediment may be limited and is determined by a number of site factors including particle size, pH, redox reactions which may change the speciation or solubility of the metal and/or adsorption of metals onto particle surfaces (Affandi and Ishak 2019; Campbell and Tessier 1996; CCME 1999a, b, c). Analytical sediment test methods such as sequential extraction analyses (SEA; e.g., Tessier extractions), acid-volatile sulfides and simultaneously extracted metals analysis (AVS-SEM), and/ or direct measurement of metals concentrations in porewater provide better estimates of the concentration of metals that are available for uptake by aquatic invertebrates and fish compared to concentrations measured in bulk sediment (Tessier *et al.* 1979). SEA is used to indicated total metals in sediment that could be available for uptake in different environmental conditions (refers to the fractions 1-4) and the fraction unlikely to be available (fraction 5) (Tessier and Campbell 1987 and Minnow 2016). SEM-AVS uses a molar ratio to determine whether toxicity would be expected at the concentrations present in the sediment (US EPA 2005).

**Metal toxicity** - Various pathways exist for aquatic organisms to be exposed to metals including aqueous, sediment, and dietary exposure. In the aquatic environment, dissolved metals are thought to be the most bioavailable for uptake by aquatic organisms (Campbell and Tessier 1996; CCME 1999a). The site of acute toxic action during aqueous metal exposures in fish is typically the gill, where metals induce ionoregulatory impairments; the physiological mechanism of toxicity at the gill site typically varies by metal, with disruption of Na/K exchange (by Cu; e.g., Taylor *et al*. 2003) and Ca uptake (by Zn; e.g., Hogstrand *et al*. 1996) as known examples. For cadmium, nickel, manganese, and zinc in sediment to cause acute effects to juvenile and adult WCT, the conditions in the UFR would have needed to favor partitioning of metals from sediment to porewater/surface water at concentrations that were sufficiently high to cause acute effects.

Minnow (2016) conducted a sediment toxicity supporting study in the Elk Valley. The study used two methods, SEA and AVS-SEM, to evaluate metal bioavailability in sediment in order to estimate potential impacts to the benthic invertebrate community. The AVS-SEM test results suggest the concentration of sulfides in the sediment of the UFR exceed the molar ratio of Cu, Cd, Pb, Hg, Ni, and Zn, limiting bioavailability to aquatic organisms in close contact with sediments (Minnow 2016). The sequential extraction test results provided an additional line of evidence showing that the more bioavailable fractions (1-4) of As, Cr, Cu, Fe, Pb, Mn and Zn were less than the lower and upper SQG (Minnow 2016). Both Cd and Ni exceeded the lower SQG for the sum of fractions 1-4, but were less than the upper SQG. The combined SEA and AVS-SEM test results reported by Minnow (2016) suggested that of the metals that had concentrations in bulk sediment that exceeded SQGs, selenium was the only metal where concentrations were high enough in bioavailable fractions in sediment to potentially adversely affect the benthic invertebrate community.

These results, together with those from our screening assessment that identified *probable* to *likely* changes in sediment quality due to concentrations of selenium in the upper (i.e., Henretta Lake), middle (i.e., S7-S8 and S6) and lower (i.e., S1-S3) reaches of the UFR in 2018, indicate the need for further assessment of selenium as a stressor. However, because selenium bioaccumulates into aquatic tissues, selenium concentrations in tissues are more relevant tools than sediment concentrations (BC ENV 2014) to assess the potential for selenium toxicity to cause or contribute to the WCT population decline. Selenium concentrations measured in tissues are evaluated in more detail in the SME Water Quality report (Costa and de Bruyn 2021), and therefore, selenium is not considered further with respect to sediment quality.

### 4.2.2 PAHs

**Exposure pathways and bioavailability** - Aquatic organisms can be exposed to PAHs through dermal exposure, respiration or consumption of contaminated prey or sediment (Varanasi *et al*. 1989). However, teleost fish (including WCT) readily metabolize and excrete PAHs limiting the potential for bioaccumulation (Stegeman 1989; Spies *et al.* 1996; Collier *et al*. 2013). The fraction of PAHs in sediment that are bioavailable is largely determined by the amount of organic carbon present as PAHs sorb to (i.e., are bound to) organic carbon (Meador 1995). Of particular importance in the UFR, PAHs bind strongly to coal particles further reducing their bioavailability from sediment (Ahrens and Morrisey 2005; NRC 2003; McGrath *et al.* 2019). Dissolved constituents are generally more bioavailable to aquatic organisms than those bound to particles in sediment (NRC 2003). The potential for adverse effects associated with PAHs in water have been evaluated in the SME Water Quality report (Costa and de Bruyn 2021).

**PAH Toxicity** - The assessment of sediment quality outlined in **Sections 2** and **3** indicated that there were PAH concentrations in the middle UFR during the Decline Window that exceeded SQG and/or were present at greater concentrations than historically. Notwithstanding the likelihood that coal-associated PAHs have low bioavailability, we consider the potential for exposure to PAHs in sediment to have impacted the WCT population, and specifically for it to have caused the mortality of a large proportion of the WCT population in the UFR. We conducted a review of the toxicity literature specific to fish to assess the types of adverse biological effects typically associated with the exposure of fish to PAHs, either individually or as mixtures[17]. It is important to note that early life stages tend to be more sensitive than adults and are the subject of the vast majority of toxicity tests (Dupuis and Ucan-Marin 2015).

The toxicity of PAHs to fish, has been studied extensively in both laboratory and field studies, which report both lethal and sub-lethal effects. The studies reporting mortality are primarily those conducted using aqueous exposures to determine the concentration lethal to 50% of the population ($LC_{50}$), a common endpoint in toxicity studies (Dupuis and Ucan-Marin 2015). The concentrations used in these studies do not typically reflect environmentally realistic exposure scenarios and, based on the low detection rate of PAHs reported in the SME Water Quality report (Costa and de Bruyn 2021), are not reflective of concentrations in the UFR.

Sub-lethal effects are the subject of the vast majority of toxicity studies for PAHs and adverse effects include altered metabolism, reduced growth rates, neoplasia (i.e., lesions), impaired reproductive success, cardiotoxicity and embryo-larval defects (see reviews in NRC 2003; Lyndal *et al*. 2008; Collier *et al* 2013; Dupuis and Ucan-Marin 2015). Severe developmental abnormalities may be lethal at the early life stages while other sub-lethal defects may result in reduced individual fitness, such as reduced aerobic performance in fish with cardio abnormalities (Hicken *et al*. 2011) or enhanced mortality later in life (Heintz 2007). However, we did not identify any studies in the toxicological literature that would be consistent with sub-lethal effects leading to a mortality event detectable on a population level. These findings are consistent with toxicity studies on model benthic invertebrate species (i.e., not collected from the UFR) conducted as part of the monitoring program in the UFR that reported that although

[17] Much of the toxicity literature that is not focused on individual congeners is associated with petroleum hydrocarbons (e.g., crude, diesel, gasoline). The modes of toxicity and types of adverse effects from these studies are relevant to PAHs associated with coal.

there was a significant correlation between 28-d *Hyallela* survival and phenanthrene, correlations were more common between PAHs (using phenanthrene and pyrene as indicators for the broader suite of PAHs) and growth endpoints (Minnow 2016). Fish condition, which is an endpoint that would be more consistent with sub-lethal effects, was evaluated directly as part of the EoC and found not to have declined during the Decline Window (Orr and Ings 2021).

## 4.3 Conclusions and Evaluation of Cause

As part of the EoC, Azimuth assessed the potential for coal-associated chemicals, specifically metals and PAHs, to have caused or contributed to the WCT population decline. There is strong evidence based on site-specific sediment data that there were changes in sediment quality, but only in the middle and lower reaches of the UFR. There is also strong evidence from site-specific studies and the literature that indicate that the bioavailability of metals and PAHs from sediment in the UFR is limited. Low bioavailability suggests that aquatic organisms' exposure to metals and PAHs in sediment is low relative to measured bulk sediment concentrations, and in turn, the potential for adverse effects indicated by exceedances of SQGs may be lower than indicated by the SQG screen. Moreover, WCT are not benthic associated fish thus limiting their direct exposure to sediment. It is not possible to preclude the possibility that sub-lethal effects could have occurred in the UFR where constituent concentrations were elevated in sediment and bioavailable. However, those effects, such as reduced energetic fitness or developmental abnormalities, may cause individual mortalities, particularly in the early life stages, but would be unlikely to cause the population level mortality of juveniles and adults observed in the population decline. If there were sub-lethal effects that reduced individual fitness, that could have made WCT more susceptible to other stressors. These conclusions are further described below in **Table 4-4** with respect to the requisite conditions for coal dust associated stressors to have caused or contributed to the WCT in the UFR.

**Table 4-4. Requisite conditions for evaluation of stressor to cause or contribute to WCT decline in the UFR.**

| | |
|---|---|
| **Spatial Extent** | ***No-cause; Yes-contribute***. There was limited evidence indicating changes in sediment quality in the upper reaches of the UFR in 2018; (no sediment data were collected in Henretta Lake in 2019) and substantial evidence indicating *probable* changes in sediment quality in the middle and lower reaches (i.e., S7-S8, S6, S1-S3). Data were not available for S4-S5 and S9. Given the distribution of juvenile and adult WCT throughout the UFR and in particular S6 and S8 (EoC Appendix D), this spatial extent meets the requisite condition for a contributing factor that changes in sediment quality were widespread. |
| **Location** | ***Yes***. changes in sediment quality occurred in areas with juvenile rearing habitat and overwintering habitat for juveniles and adults. |
| **Duration** | ***Yes***. Constituent concentrations in sediment were generally consistent between 2018 and 2019 where data were available for both years. On that basis, concentrations of constituents that WCT could be exposed to appear to be somewhat stable during the Decline Window. |
| **Timing** | ***Yes***. There were changes in sediment quality during the Decline Window period relative to historical conditions. |
| **Intensity** | ***No - cause***. Exceedances of SQGs for some constituents but limited bioavailability. Acute effects typically mediated through aqueous exposure, sub-lethal effects unlikely to result in substantial mortality of juveniles and adults.<br>***Yes - contribute***. Sub-lethal effects in early life stages associated with exposure to PAHs and metals could reduce fish condition and increase susceptibility to other stressors, however low bioavailability makes this unlikely. |

*Based on this assessment, we conclude that concentrations of metals and PAHs in sediment present during the Decline Window were insufficient to result in adverse effects to WCT that could have caused the population decline. However, we cannot preclude the possibility that sub-lethal effects in early life stages that could reduce individual fitness of WCT in some parts of the UFR which would make them more susceptible to other stressors.*

## 4.4 Uncertainties

There are a number of uncertainties associated with this assessment, most of which were discussed throughout the document, that are summarized below.

- SQGs are conservative in nature and most likely to overpredict the potential for adverse effects.
- The selenium SQG is based on an "alert value" rather than a guideline due to a lack of data. The alert value was derived based on the lowest published toxicity thresholds and using no uncertainty factor. We used this value as both a lower and an upper SQG to represent that uncertainty.
- A number of constituents did not have SQGs available. For the purpose of this assessment, we assumed that the constituents that do have SQGs were adequate to represent the potential for adverse effects associated with changes in sediment quality.
- Sediment chemistry data for acenaphthene and dibenzo(a,h)anthracene had data quality issues, specifically the MDL was higher than the respective SQG. In addition, a small number of samples for eight PAHs during the historical and Decline Window also had MDLs higher than the SQGs and were therefore excluded from additional analyses. Therefore, it is not possible to draw any conclusions regarding changes in sediment quality associated with these constituents and/or samples.
- There are no site-specific bioavailability data for PAHs. Sediment chemistry data were generally only collected once a year (except in 2018 in which sediment was collected in July and August) therefore it is not possible to determine how long the constituents would have been present at the observed concentrations given the fact that sediment can be dynamic and change daily or seasonally in a system like the UFR.
- We cannot draw conclusions regarding changes in sediment quality in Henretta Lake in 2019 as sediment chemistry were not available. We also cannot draw conclusions regarding S4, S5 and S9 due to a lack of sediment chemistry data. It is very unlikely that reducing these uncertainties would change the conclusions from this assessment.

# 5 REFERENCES


Affandi, F.A., and M.Y. Ishak. 2019. Impacts of suspended sediment and metal pollution from mining activities on riverine fish population—a review. Environmental Science and Pollution Research, pp.1-13.

Ahrens, M.J., and D.J. Morrisey. 2005. Biological Effect of Unburnt Coal in the Marine Environment. Oceanography and Marine Biology: An Annual Review, 43:69–122.

Anderson, K., W. Hillwalker, J. Sven Erik, and F. Brian. 2008. Bioavailability. Encyclopedia of Ecology.

Baran, A. and M. Tarnawski. 2015. Assessment of heavy metals mobility and toxicity in contaminated sediments by sequential extraction and a battery of bioassays. Ecotoxicology, 24(6):1279-93.

BC ENV (British Columbia Ministry of Environment and Climate Change Strategy). 2014. Companion Document to: Ambient Water Quality Guidelines for Selenium Update. Available from: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/bc_moe_se_wqg_companion_document.pdf [Accessed September 2020].

BC ENV. 2019. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture: Summary Report. Available from: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf [Accessed September 2020].

BC ENV. 2020. Working Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture. Water Quality Guideline Series, WQG-07. Victoria, BC. [Accessed September 2020].

Berry, K.L., M.O. Hoogenboom, F. Flores, and A.P. Negri. 2016. Simulated coal spill causes mortality and growth inhibition in tropical marine organisms. Scientific reports, 6:25894.

Bollinger, T. 2021. Subject Matter Expert Report: Disease. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited.

Brown, R.S. 1999. Fall and early winter movements of cutthroat trout, Oncorhynchus clarki, in relation to water temperature and ice conditions in Dutch Creek, Alberta. Environmental biology of fishes, 55(4):359-368.

Buhl, K.J., and S.J. Hamilton. 1991. Relative sensitivity of early life stages of arctic grayling, coho salmon, and rainbow trout to nine inorganics. Ecotoxicology and Environmental Safety, 22(2):184-197.

Campbell, P.G.C., and A. Tessier. 1996. Ecotoxicology of metals in aquatic environments: Geochemical aspects. In: Ecotoxicology: A hierarchical treatment, M.C. Newman and C.H. Jagoe, eds. Lewis Publishers, Boca Raton. FL. Cited in CCME 1999a.

CCME (Canadian Council of Ministers of the Environment). 1999a. Canadian sediment quality guidelines for the protection of aquatic life: chromium factsheet. In Canadian Environmental

Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

CCME. 1999b. Canadian sediment quality guidelines for the protection of aquatic life: arsenic factsheet. In Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

CCME. 1999c. Canadian sediment quality guidelines for the protection of aquatic life: cadmium factsheet. In Canadian Environmental Quality Guidelines. 1999 (plus updates), Canadian Council of Ministers of the Environment, Winnipeg.

CCME. 2001. Canadian sediment quality guidelines for the protection of aquatic life: Introduction. Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

CCME. 2020. Canadian sediment quality guidelines for the protection of aquatic life. Summary Tables. Accessed October 2020.

CEPA (Canadian Environmental Protection Act). 1999. (S.C. 1999, c. 33). Parliament of Canada. Accessed June 2021.

Chapman, G.A. 1978. Toxicities of cadmium, copper, and zinc to four juvenile stages of chinook salmon and steelhead. Transactions of the American Fisheries Society. 107(6):841-7.

Chapman, P.M, M.D. Paine, A.D. Arthur, and L.A. Taylor. 1996. A triad study of sediment quality associated with a major, relatively untreated marine sewage discharge. Marine Pollution Bulletin. 32(1): 47-64.

Collier, T.K., B.F. Anulacion, M.R. Arkoosh, J.P. Dietrich, J.P. Incardona, L.L. Johnson, G.M. Ylitalo, and M.S. Myers. 2013. Effects on fish of polycyclic aromatic hydrocarbons (PAHS) and naphthenic acid exposures. In 'Fish Physiology'. (Eds APF Keith, B. Tierney, and JB Colin.) Vol. 33.

Cope, S., C.J. Schwarz, A. Prince, and J. Bisset. 2016. Upper Fording River Westslope Cutthroat Trout Population Assessment and Telemetry Project: Final Report. Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 266 p.

Cope, S. 2020. Upper Fording River Westslope Cutthroat Trout Population Monitoring Project: Report Prepared for Teck Coal Limited, Sparwood, BC. Report Prepared by Westslope Fisheries Ltd., Cranbrook, BC. 40 p + 1 app.

Costa EJ., and A. de Bruyn. 2021. Subject Matter Expert Report: Water Quality. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Golder Associates Ltd. Draft for discussion.

Davis, E. C., and W.J. Boegly. 1981. A review of water quality issues associated with coal storage. Journal of Environmental Quality, 10:127–133

Dupuis, A., and F. Ucan-Marin. 2015. A literature review on the aquatic toxicology of petroleum oil: An overview of oil properties and effects to aquatic biota. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/007. vi + 52 p.

Durston, D., D. Greenacre, Ganshorn, K and T. Hatfield. 2021. Subject Matter Expert Report: Total Suspended Solids. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Ecofish Research Ltd

Evaluation of Cause (EoC) Team. 2021. Evaluation of Cause — Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited by Evaluation of Cause Team. 2021.

Ghosh, U., J.W. Talley, and R.G. Luthy. 2001. Particle-scale investigation of PAH desorption kinetics and thermodynamics from sediment. Environmental Science & Technology, 35 (17):3468–3475.

Golder and Minnow (Golder Associates and Minnow Environmental). 2019. Fall 2019 Lotic Sediment Toxicity Supporting Study. Prepared for Teck Coal Ltd.

Golder and Minnow. 2020. Fall 2020 Lotic Sediment Toxicity Supporting Study. Prepared for Teck Coal Ltd.

Harwood, A., C. Suzanne, C. Whelan, and T. Hatfield. 2021. Subject Matter Expert Report: Fish Passage. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. by Ecofish Research Ltd.

Hatfield, T., and C. Whelan. 2021. Subject Matter Expert Report: Ice. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. Report Prepared by Ecofish Research Ltd. Draft for discussion.

Heintz, R.A. 2007. Chronic exposure to polynuclear aromatic hydrocarbons in natal habitats leads to decreased equilibrium size, growth, and stability of pink salmon populations. Integrated Environmental Assessment and Management: An International Journal, 3(3), pp.351-363.

Henley, W.F., M.A. Patterson, R.J. Neves, and A.D. Lemly. 2000. Effects of sedimentation and turbidity on lotic food webs: a concise review of natural resource managers. Reviews in Fisheries Science, 8:125–139.

Hicken, C. E., T.L. Linbo, D.H. Baldwin, M.S. Myers, L. Holland, M. Larsen, N.L. Scholz, T.K. Collier, G.S. Rice, M.S. Stekoll, and J.P. Incardona. 2011. Sub-lethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish. Proceedings of the National Academy of Sciences USA, 108:7086–7090.

Hogstrand, C.H., N. Webb, and C.M. Wood. 1998. Covariation in regulation of affinity for branchial zinc and calcium uptake in freshwater rainbow trout. Journal of Experimental Biology, 201(11):1809-15.

Howe, P., H. Malcolm, and S. Dobson. 2004. Manganese and its compounds: environmental aspects. World Health Organization.

IRCL (Interior Reforestation Co. Ltd.). 2008. Lentic and Lotic Mapping of the Elk River Watershed. Prepared for the Elk Valley Task Force and Elk Valley Coal Corporation – Greenhills Operations by Interior Reforestation Co., Ltd., Cranbrook, BC. December.

Johnson, R., and R.M. Bustin. 2006. Coal dust dispersal around a marine coal terminal (1977–1999), British Columbia: The fate of coal dust in the marine environment. International Journal of Coal Geology, 68(1-2):57-69.

Kemp, P., D. Sear, A. Collins, P. Naden, and I. Jones. 2011. The impacts of fine sediment on riverine fish. Hydrological Processes, 25:1800–1821.

Lake, R.G., and S.G. Hinch. 1999. Acute effects of suspended sediment angularity on juvenile coho salmon (Oncorhynchus kisutch). Canadian Journal of Fisheries and Aquatic Sciences, 56(5):862-867.

Larratt, H., and J. Self. 2021. Subject Matter Expert Report: Cyanobacteria, Periphyton and Aquatic Macrophytes. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Limited. Prepared by Larratt Aquatic Consulting Ltd. Draft for discussion.

Lister, D.B. and Associates Ltd. and Kerr Wood Leidal Associates Ltd. 1980. Fording River Aquatic Environment Study. Prepared for Fording Coal Ltd., Elkford, B.C. 77 pp. + app.

Lotic (Lotic Environmental Ltd.). 2013. Elk River Watershed Baseline Stream Sediment Collection – Data delivery report. Cranbrook, BC. Accessed September 2020.

Mayer, P., T.F. Parkerton, R.G. Adams, J.G. Cargill, J. Gan, T. Gouin, P.M. Gschwend, S.B. Hawthorne, P. Helm, G. Witt, and J. You. 2014. Passive sampling methods for contaminated sediments: Scientific rationale supporting use of freely dissolved concentrations. Integrated environmental assessment and management, 10(2), pp.197-209.

McGrath, J.A., N. Joshua, A.S. Bess, and T.F. Parkerton. 2019. Review of polycyclic aromatic hydrocarbons (PAHs) sediment quality guidelines for the protection of benthic life. Integrated environmental assessment and management, 15(4):505-518.

Meador, J. P., J.E. Stein, W.L. Reichert, and U. Varanasi. 1995. Bioaccumulation of polycyclic Aromatic hydrocarbons by marine organisms. In Reviews of Environmental Contamination and Toxicology (ed. G. Ware), pp. 79–165. New York: Springer.

Mebane, C.A., F.S. Dillon, and D.P. Hennessy. 2012. Acute toxicity of cadmium, lead, zinc, and their mixtures to stream-resident fish and invertebrates. Environmental Toxicology and Chemistry, 31(6):1334-1348.

Minnow Environmental Inc., Interior Reforestation Co. Ltd., and Paine, Ledge and Associates. 2007. Selenium Monitoring in the Elk River Watershed, BC (2006). Report Prepared for Elk Valley Selenium Task Force. December 2007

Minnow (Minnow Environmental Inc.). 2014. 2013 Sediment Sampling Program for the Coal Mines in the Elk River Watershed, BC. Georgetown, ON.

Minnow. 2016. Sediment Toxicity Supporting Study, 2015. Prepared for Teck Coal Ltd., Sparwood, BC. Project #2565.

Minnow. 2018a. Draft Study Design for the Regional Aquatic Effects Monitoring Program, 2018 to 2020. Prepared for Teck Coal Ltd., Sparwood, BC. Project #1753.

Minnow. 2018b. Lower Greenhills Creek Aquatic Baseline. Prepared for Teck Coal Ltd., Sparwood, BC. Project #177202.0043.

Minnow. 2018c. Study Design for the Lentic Area Supporting Study, 2018 to 2020. Prepared for Teck Coal Ltd., Sparwood, BC. Project #177202.0053.

Minnow. 2019. Lower Greenhills Creek Monitoring Program Report - 2018. Prepared for Teck Coal Limited, Sparwood, BC. October 2019.

Minnow. 2020a. Greenhills Creek Aquatic Monitoring Program 2019 Report. Prepared for Teck Coal Limited, Sparwood, BC. July 2020.

Minnow. 2020b. Lentic Area Supporting Study Report, 2018 to 2019. Prepared for Teck Coal Limited, Sparwood, BC. November. Project #207202.0016.

Minnow and Lotic. 2018. Fording River Operations Local Aquatic Effects Monitoring Program (LAEMP) Report, 2017. Prepared for Teck Coal Ltd., Sparwood, BC. Project #177202.0022.

Minnow and Lotic. 2019. Fording River Operations Local Aquatic Effects Monitoring Program (LAEMP) Report, 2018. Prepared for Teck Coal Ltd., Sparwood, BC. Project #187202.0022

Minnow and Lotic. 2020. Fording River Operations Local Aquatic Effects Monitoring Program (LAEMP) Report, 2019. Prepared for Teck Coal Ltd., Sparwood, BC. Project #197202.0004.

National Research Council (NRC). 2003. Chapter 5. Biological Effects of Oil Releases in Oil in the Sea III: Inputs, Fates, and Effects. Washington, DC: The National Academies Press.

Orr, P., and J. Ings. 2021. Subject Matter Expert Report: Food Availability. Evaluation of Cause – Decline in Upper Fording River Westslope Cutthroat Trout Population. Report prepared for Teck Coal Ltd. Prepared by Minnow Environmental Inc. Draft for discussion.

Paller, M.H., and A.S. Knox. 2013. Bioavailability of metals in contaminated sediments. In E3S Web of Conferences (Vol. 1, p. 02001). EDP Sciences.

Pumphrey, J.F. 2009. Henretta Creek reclamation project. Report prepared for Teck Coal Ltd. Calgary, AB. Available at: https://open.library.ubc.ca/cIRcle/collections/59367/items/1.0042556 (Accessed September 2020).

Querol, X., R. Juan, A. Lopez-Soler, J. Fernandez-Turiel, and C.R. Ruiz. 1996. Mobility of trace elements from coal and combustion wastes. Fuel, 75:821–838.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Spies, R. B., J.J. Stegeman, D.E. Hinton, B. Woodin, M. Okihiro, R. Smolowitz, and D. Shea. 1996. Biomarkers of hydrocarbon exposure and sublethal effects in embiotocid fishes from a natural petroleum seep in the Santa Barbara Channel. Aquatic Toxicology, 34:195-219.

Stegeman, J. J. 1989. Cytochrome P450 forms in fish: Catalytic, immunological and sequence similarities. Xenobiotica, 19:1093-1110.

Talley, J.W., U. Ghosh, S.G. Tucker, J.S. Furey, and R.G. Luthy. 2002. Particle-scale understanding of the bioavailability of PAHs in sediment. Environmental science & technology, 36(3): 477-483.

Tessier, A., P.G.C. Campbell, and M. Bisson. 1979. Sequential Extraction Procedure for the Speciation of Particulate Trace Metals. Anal. Chem, 51(7): 844-846.

Taylor, L.N., C.M. Wood, and D.G. McDonald. 2003. An evaluation of sodium loss and gill metal binding properties in rainbow trout and yellow perch to explain species differences in copper tolerance. Environmental Toxicology and Chemistry: An International Journal, 22(9):2159-2166.

Trowell, J., G. Gilron, K. Graf, L. Patterson, C. Chan, F. Perelló, and S. Bard. 2020. Potential effects and impacts of a coal spill on sensitive aquatic habitat: a weight-of-evidence sediment quality assessment. Water Quality Research Journal.

US EPA (United States Environmental Protection Agency). 2000. Methods for Measuring Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates. 2nd Edition. Washington, D.C.

US EPA. 2005. Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc). Document # EPA-600-R-02-011, January 2005.

USGS (United States Geological Survey). 2020. River Sediment Dynamics. Available at: https://www.usgs.gov/centers/sbsc/science/fluvial-river-sediment-dynamics?qt-science_center_objects=0#qt-science_center_objects (Accessed September 2020).

Varanasi, U., Stein, J.E. and, M. Nishimoto. 1989. Biotransformation and Disposition of Polycyclic Aromatic Hydrocarbons (PAH) in Fish. Metabolism of Polycyclic Aromatic Hydrocarbons in the Aquatic Environment. CRC Press, Inc., Boca Raton Florida. 1989. p 93-149, 20 fig, 15 tab, 171 ref. NOAA Contract Y 01-CP-40507.

# APPENDIX A: SEDIMENT SAMPLING STATIONS IN THE UFR

**Table A-1. Sediment samples collected in mine-exposed areas of the upper Fording River historically (2011 – 2017) and during the Decline Window.**

| | | | Number of sediment samples collected each year | | | | | |
|---|---|---|---|---|---|---|---|---|
| **River Stretch** [1] | **Area Code** [2, 3, 4, 5] | **Description** | **2011** | **2013** | **2015** | **2017** | **2018** | **2019** |
| Henretta Lake | RG_HE27 | Henretta Lake | - | 3 | 5 | - | 5 | - |
| | HEN1 | | 10 | - | - | - | - | - |
| S8 | RG_FOUKI | Fording River u/s of Kilmarnock Creek | - | - | - | 5 | 5 | 5 |
| | LAK1 | Lake Mountain Creek mouth | 5 | - | - | - | - | - |
| S7 | RG_FOBKS | Fording River between Kilmarnock Creek & Swift Creek | - | - | - | 5 | 5 | 5 |
| | RG_SCOUTDS | d/s of FRO AWTF-S outfall | - | - | - | - | - | 5 |
| | RG_FOBCP | Fording River between Cataract & Porter Creek | 5 | - | - | 5 | 5 | 5 |
| | SWI1 | Swift Creek - Reach 1 (fish bearing) | 6 | - | - | - | - | - |
| | CC1 | Cataract Creek at pond discharge | 5 | - | - | - | - | - |
| | FR4 | Fording River d/s Swift Creek | 5 | - | - | - | - | - |
| | FR4a | Fording River u/s Cataract Creek | 5 | - | - | - | - | - |
| S6 | RG_FRUPO | Fording River u/s of Porter Creek | - | - | - | 5 | 5 | 5 |
| | RG_FO10 | Snye along Fording River | - | 5 | 5 | - | 5 | - |
| | RG_FO22 | u/s Chauncey Creek | - | - | - | 5 | 5 | 5 |
| | RG_FMUCK | Meadow area u/s Chauncey Creek | - | 3 | 5 | - | - | - |
| | FOX1 | Fording River oxbow | 6 | - | - | - | - | - |
| S3 | FRd/sDRCK | Fording River downstream of Dry Creek | 5 | - | - | - | - | - |
| | FRu/sDRCK | Fording River u/s of Dry Creek, d/s of Chauncey Cree | 5 | - | - | - | - | - |
| | RG_FWDEC | Fording River wetland d/s of Ewin Creek | - | - | 5 | - | 5 | - |
| S2 | GHBP | Lower Greenhills Creek | - | - | - | 5 | 5 | 5 |
| S1 | RG_R5-1 | Off channel area of Fording d/s Greenhills | - | - | 5 | - | - | - |
| | | **Total Samples Collected** | **57** | **11** | **25** | **30** | **45** | **35** |

**Notes**

"-" No sediment collected.

1 No sampling areas in segment S4 or S9 during Decline Window, therefore historical sediment chemistry from S4 and S9 were not included in analysis.

2 Mine-exposed areas that are either outside of the UFR watershed or settling ponds were not included in analysis.

3 Areas in which sediment was collected but were not fish bearing and/or accessible were omitted from further analysis, and are not included in this table.

4 Samples collected in 2018 labelled FO10 were actually RG-SAFR (a separate sampling area in the snye along the Fording River). This does not affect this analysis as sampling locations are both within S6.

5 original sample names were retained to be consistent with source materials

**Acronyms**

AWTF = active water treatment facility
d/s = downstream
u/s = upstream
FRO = Fording River Operations
UFR = Upper Fording River

# APPENDIX B: ADDITIONAL SCREENING

**Table B-1. Sediment chemistry screening using data from samples collected at mine-exposed areas from the upper Fording River during the Decline Window (2018, 2019) and historically.**

| | | | | Freshwater Sediment Quality Guidelines [2] | | 2018 Sediment Concentration (mg/kg) [3] | | | 2018 Screening Results | | 2019 Sediment Concentration (mg/kg) [3] | | | 2019 Screening Results | | Historical [4] Sediment Concentration (mg/kg) [3] | | | Historical [4] Screening Results | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Constituent [1] | Units | Detection Limit | Lower | Upper | Maximum | $90^{th}$ Percentile | Mean | Maximum > Lower SQG | Maximum > Upper SQG | Maximum | $90^{th}$ Percentile | Mean | Maximum > Lower SQG | Maximum > Upper SQG | Maximum | $90^{th}$ Percentile | Mean | Maximum > Lower SQG | Maximum > Upper SQG | Lower SQG Historical Quotient [5] | Upper SQG Historical Quotient [5] |
| Metals | Arsenic (As) | mg/kg | 0.10 | 5.9 | 17 | 5.9 | 5.5 | 4.5 | - | - | 7.3 | 6.0 | 4.6 | X | - | 6.5 | 5.2 | 4.2 | X | - | 0.89 | 0.31 |
| | Cadmium (Cd) | mg/kg | 0.020 | 0.60 | 3.5 | 2.5 | 2.2 | 1.4 | X | - | 1.8 | 1.6 | 1.3 | X | - | 4.6 | 1.9 | 1.4 | X | X | 3.1 | 0.54 |
| | Chromium (Cr) | mg/kg | 0.50 | 37 | 90 | 35 | 23 | 15 | - | - | 15 | 14 | 10 | - | - | 31 | 19 | 13 | - | - | 0.51 | 0.21 |
| | Copper (Cu) | mg/kg | 0.50 | 36 | 197 | 19 | 17 | 13 | - | - | 22 | 17 | 12 | - | - | 23 | 16 | 13 | - | - | 0.45 | 0.081 |
| | Iron (Fe)* | mg/kg | 50 | 21,200 | 43,766 | 17,600 | 15,960 | 13,088 | - | - | 34,500 | 20,040 | 14,514 | X | - | 19,600 | 15,600 | 12,099 | - | - | 0.74 | 0.36 |
| | Lead (Pb) | mg/kg | 0.50 | 35 | 91 | 11 | 9.7 | 7.8 | - | - | 12 | 9.6 | 7.6 | - | - | 16 | 10 | 8.2 | - | - | 0.29 | 0.11 |
| | Manganese (Mn)* | mg/kg | 1.0 | 460 | 1,100 | 2,450 | 984 | 562 | X | X | 934 | 736 | 576 | X | - | 1,350 | 779 | 412 | X | X | 1.7 | 0.71 |
| | Mercury (Hg) | mg/kg | 0.0050 | 0.17 | 0.49 | 0.094 | 0.064 | 0.045 | - | - | 0.083 | 0.048 | 0.041 | - | - | 0.094 | 0.064 | 0.049 | - | - | 0.38 | 0.13 |
| | Nickel (Ni)* | mg/kg | 0.50 | 16 | 75 | 144 | 65 | 41 | X | X | 112 | 65 | 44 | X | X | 129 | 70 | 37 | X | X | 4.4 | 0.94 |
| | Selenium (Se)[6]* | mg/kg | 0.20 | 2.0 | NA | 21 | 14 | 6.3 | X | - | 19 | 9.1 | 3.9 | X | - | 49 | 14 | 6.2 | X | - | 6.8 | NA |
| | Silver (Ag)* | mg/kg | 0.10 | 0.50 | NA | 0.27 | 0.21 | 0.16 | - | - | 0.26 | 0.20 | 0.16 | - | - | 0.37 | 0.25 | 0.18 | - | - | 0.50 | NA |
| | Zinc (Zn) | mg/kg | 2.0 | 123 | 315 | 169 | 146 | 113 | X | - | 157 | 130 | 115 | X | - | 336 | 129 | 116 | X | X | 1.0 | 0.41 |
| Polycyclic Aromatic Hydrocarbons (PAHs) | 2-Methylnaphthalene | mg/kg | 0.01 - 0.035 | 0.020 | 0.20 | 9.0 | 3.7 | 1.5 | X | X | 5.5 | 2.2 | 1.3 | X | X | 5.3 | 2.7 | 1.2 | X | X | 136 | 14 |
| | Acenaphthylene | mg/kg | 0.005 - 0.018 | 0.0059 | 0.13 | 0.037 | 0.023 | 0.010 | X | - | 0.0025 | 0.0025 | 0.0025 | - | - | 0.048 | 0.017 | 0.0079 | X | - | 2.9 | 0.13 |
| | Anthracene | mg/kg | 0.004 - 0.024 | 0.047 | 0.25 | 0.015 | 0.010 | 0.0045 | - | - | 0.012 | 0.0058 | 0.0038 | - | - | 0.034 | 0.020 | 0.0072 | - | - | 0.42 | 0.080 |
| | Benz(a)anthracene | mg/kg | 0.01 - 0.12 | 0.032 | 0.39 | 0.20 | 0.14 | 0.047 | X | - | 0.019 | 0.017 | 0.013 | - | - | 0.29 | 0.089 | 0.040 | X | - | 2.8 | 0.23 |
| | Benzo(a)pyrene | mg/kg | 0.01 - 0.035 | 0.032 | 0.78 | 0.14 | 0.076 | 0.028 | X | - | 0.11 | 0.040 | 0.022 | X | - | 0.16 | 0.069 | 0.025 | X | - | 2.2 | 0.088 |
| | Benzo(g,h,i)perylene[7]* | mg/kg | 0.01 - 0.035 | 0.17 | 2.6 | 0.21 | 0.096 | 0.039 | X | - | 0.13 | 0.053 | 0.029 | - | - | 0.24 | 0.067 | 0.032 | X | - | 0.39 | 0.025 |
| | Benzo(k)fluoranthene[7]* | mg/kg | 0.01 - 0.035 | 0.24 | 110 | 0.020 | 0.016 | 0.0087 | - | - | 0.017 | 0.0090 | 0.0067 | - | - | 0.025 | 0.025 | 0.015 | - | - | 0.10 | 0.00023 |
| | Chrysene | mg/kg | 0.01 - 0.035 | 0.057 | 0.86 | 0.84 | 0.48 | 0.20 | X | - | 0.73 | 0.34 | 0.19 | X | - | 1.6 | 0.33 | 0.18 | X | X | 5.8 | 0.39 |
| | Fluoranthene | mg/kg | 0.01 - 0.035 | 0.11 | 2.4 | 0.15 | 0.086 | 0.037 | X | - | 0.14 | 0.059 | 0.034 | X | - | 0.21 | 0.050 | 0.031 | X | - | 0.45 | 0.021 |
| | Fluorene | mg/kg | 0.01 - 0.035 | 0.021 | 0.14 | 0.94 | 0.44 | 0.19 | X | X | 0.63 | 0.30 | 0.17 | X | X | 0.76 | 0.39 | 0.16 | X | X | 18 | 2.7 |
| | Indeno(1,2,3-c,d)pyrene[7]* | mg/kg | 0.01 - 0.035 | 0.20 | 26 | 0.064 | 0.018 | 0.011 | - | - | 0.052 | 0.018 | 0.0091 | - | - | 0.076 | 0.025 | 0.017 | - | - | 0.13 | 0.00095 |
| | Naphthalene | mg/kg | 0.01 - 0.035 | 0.035 | 0.39 | 2.7 | 1.0 | 0.41 | X | X | 1.7 | 0.59 | 0.38 | X | X | 1.3 | 0.76 | 0.32 | X | X | 22 | 1.9 |
| | Phenanthrene | mg/kg | 0.01 - 0.035 | 0.042 | 0.52 | 3.4 | 1.8 | 0.77 | X | X | 2.7 | 1.2 | 0.72 | X | X | 3.5 | 1.5 | 0.74 | X | X | 36 | 2.9 |
| | Pyrene | mg/kg | 0.01 - 0.035 | 0.053 | 0.88 | 0.276 | 0.14 | 0.060 | X | - | 0.28 | 0.11 | 0.063 | X | - | 0.368 | 0.11 | 0.054 | X | - | 2.0 | 0.12 |

**Notes**

NA = No available sediment quality guideline (SQG).

"-" = No exceedance.

"X" = Exceedance.

"*" = no federal guidelines available, only BC SQG.

1 Acenaphthene and dibenz(a,h)anthracene excluded from SQG screening, since the majority of values were below detection limits. See Section 3.1.2 for more details.

2 BC working SQG (BC ENV 2020) and Canadian Council of Ministers of the Environment interim SQG (CCME 2020) - both for freshwater aquatic life. All guidelines on a dry weight basis (i.e., mg/kg dry weight).

3 1/2 detection limit used for non-detects in calculation of summary statistics (e.g., maximum, $90^{th}$ percentile and mean concentrations).

4 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

5 SQG Quotient = $90^{th}$ percentile concentration/SQG (lower or upper).

6 Alert concentration, previously a provincial interim sediment quality guideline. This is the only Canadian federal and provincial sediment quality guideline due to limited data. Considered protective of most aquatic environments and provides early detection of potential for impacts to aquatic organisms. Key compartments (e.g., tissues) should be measured for Se bioaccumulation if there are exceedances (BC ENV 2014; BC ENV 2019).

7 Upper working sediment quality guidelines adjusted for total organic carbon (TOC) content by multiplying the guideline by the mean % organic carbon content of the sediment (7.46%). No TOC adjustment required for the lower SQG.

**Acronyms**

SQG = Sediment quality guideline

TOC = Total organic carbon

**Table B-2. Sediment chemistry from the upper Fording River for constituents with sediment quality guidelines screened against historical concentrations (2011/2013/2015/2017).**

| | | | Segment Groups | Across UFR | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Concentrations in Sediment (mg/kg) | | | | | | | | | Historical Screening Results | | | |
| | | | | 2018 | | | 2019 | | | Historical [1] | | | 2018 | | 2019 | |
| | Constituent [4,5] | Units | Detection Limit | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] |
| Metals | Aluminum (Al) | mg/kg | 50 | 10,500 | 7,788 | 6,205 | 8,980 | 7,994 | 6,019 | 11,100 | 8,100 | 6,439 | 1.2 | 0.96 | 1.2 | 0.99 |
| Metals | Antimony (Sb) | mg/kg | 0.10 | 0.94 | 0.69 | 0.57 | 0.84 | 0.71 | 0.54 | 1.2 | 0.68 | 0.57 | 1.2 | 1.0 | 1.2 | 1.0 |
| Metals | Barium (Ba) | mg/kg | 0.50 | 290 | 229 | 196 | 305 | 244 | 195 | 396 | 255 | 195 | 1.2 | 0.90 | 1.3 | 0.96 |
| Metals | Beryllium (Be) | mg/kg | 0.10 | 0.72 | 0.62 | 0.50 | 0.81 | 0.63 | 0.51 | 0.88 | 0.68 | 0.54 | 1.1 | 0.91 | 1.2 | 0.93 |
| Metals | Boron (B) | mg/kg | 5.0 | 15 | 8.9 | 7.5 | 14 | 12 | 8.0 | 16 | 14 | 9.1 | 0.98 | 0.64 | 1.3 | 0.87 |
| Metals | Calcium (Ca) | mg/kg | 50 | 229,000 | 157,200 | 77,580 | 266,000 | 73,180 | 60,929 | 202,000 | 151,000 | 78,401 | 2.0 | 1.0 | 0.93 | 0.48 |
| Metals | Cobalt (Co) | mg/kg | 0.10 | 11 | 7.3 | 5.7 | 8.4 | 7.3 | 6.0 | 9.7 | 7.0 | 5.4 | 1.4 | 1.0 | 1.3 | 1.0 |
| Metals | Lithium (Li) | mg/kg | 2.0 | 16 | 13 | 8.6 | 12 | 10 | 8.1 | 17 | 14 | 10 | 1.3 | 0.92 | 1.0 | 0.72 |
| Metals | Magnesium (Mg) | mg/kg | 20 | 51,300 | 28,640 | 15,095 | 16,400 | 15,380 | 11,295 | 37,200 | 30,500 | 13,751 | 2.1 | 0.94 | 1.1 | 0.50 |
| Metals | Molybdenum (Mo) | mg/kg | 0.10 | 3.2 | 1.7 | 1.4 | 1.7 | 1.5 | 1.2 | 3.6 | 1.8 | 1.4 | 1.2 | 0.97 | 1.1 | 0.86 |
| Metals | Phosphorus (P) | mg/kg | 50 | 1,840 | 1,646 | 1,290 | 1,980 | 1,858 | 1,295 | 1,840 | 1,660 | 1,226 | 1.3 | 0.99 | 1.5 | 1.1 |
| Metals | Potassium (K) | mg/kg | 100 | 2,450 | 1,844 | 1,448 | 1,950 | 1,712 | 1,335 | 3,450 | 2,110 | 1,618 | 1.1 | 0.87 | 1.1 | 0.81 |
| Metals | Sodium (Na) | mg/kg | 50 | 200 | 137 | 96 | 97 | 87 | 73 | 361 | 182 | 118 | 1.2 | 0.75 | 0.73 | 0.48 |
| Metals | Strontium (Sr) | mg/kg | 0.50 | 117 | 101 | 71 | 116 | 85 | 67 | 256 | 95 | 77 | 1.3 | 1.1 | 1.1 | 0.89 |
| Metals | Sulfur (S) | mg/kg | 1,000 | 9,300 | 4,210 | 2,367 | 3,600 | 2,750 | 1,800 | 3,900 | 3,550 | 2,550 | 1.7 | 1.2 | 1.1 | 0.77 |
| Metals | Thallium (Tl) | mg/kg | 0.050 | 0.31 | 0.23 | 0.18 | 0.22 | 0.21 | 0.16 | 0.47 | 0.24 | 0.20 | 1.1 | 0.96 | 1.0 | 0.85 |
| Metals | Titanium (Ti) | mg/kg | 1.0 | 34 | 23 | 15 | 23 | 20 | 14 | 44 | 32 | 19 | 1.2 | 0.70 | 1.1 | 0.61 |
| Metals | Uranium (U) | mg/kg | 0.050 | 6.2 | 1.9 | 1.4 | 1.9 | 1.2 | 0.98 | 3.8 | 2.4 | 1.3 | 1.4 | 0.76 | 0.96 | 0.51 |
| Metals | Vanadium (V) | mg/kg | 0.20 | 43 | 33 | 27 | 35 | 32 | 24 | 50 | 34 | 27 | 1.2 | 0.98 | 1.2 | 0.94 |
| Metals | Zirconium (Zr) | mg/kg | 1.0 | 4.4 | 3.6 | 2.3 | 1.3 | 1.2 | 1.1 | 4.4 | 2.9 | 1.9 | 1.8 | 1.2 | 0.64 | 0.43 |
| PAHs | 1-Methylnaphthalene | mg/kg | 0.01 - 0.035 | 4.7 | 2.1 | 0.84 | 3.0 | 1.3 | 0.77 | 2.1 | 1.9 | 1.1 | 1.9 | 1.1 | 1.2 | 0.68 |
| PAHs | Benzo(b&j)fluoranthene | mg/kg | 0.01 - 0.035 | 0.45 | 0.21 | 0.095 | 0.34 | 0.12 | 0.071 | 0.49 | 0.18 | 0.087 | 2.4 | 1.1 | 1.4 | 0.66 |
| PAHs | Benzo(b+j+k)fluoranthene | mg/kg | NA | NA | NA | NA | 0.36 | 0.13 | 0.078 | 0.51 | 0.25 | 0.10 | NA | NA | 1.3 | 0.53 |
| PAHs | Benzo(e)pyrene | mg/kg | 0.01 - 0.035 | 0.47 | 0.21 | 0.095 | 0.36 | 0.13 | 0.077 | 0.26 | 0.23 | 0.14 | 1.5 | 0.92 | 0.93 | 0.56 |
| PAHs | Perylene | mg/kg | 0.01 - 0.035 | 0.35 | 0.12 | 0.068 | 0.043 | 0.038 | 0.027 | 0.012 | 0.012 | 0.012 | 9.9 | 9.9 | 3.2 | 3.2 |

**Notes**

NA = No data available, or all data below detection limits.

1 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

2 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration;
$Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

3 No 2019 data available for this segment.

4 No data from the Decline Window for Bismuth, Tin and Benzo(b)fluoranthene so these constituents are not presented in this table.

5 No data historically for Tungsten and Quinoline so these constituents are not presented in this table.

Historical Quotients exceed 1.0.

**Table B-3. Sediment chemistry from the upper Fording River for constituents without sediment quality guidelines screened against historical concentrations (2011/2013/2015/2017) by river segment group.**

| | | | Segment Groups | Henretta Lake [4] | | | | | | | | S7-S8 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Concentrations in Sediment (mg/kg) | | | | | | Historical Screening Results | | Concentrations in Sediment (mg/kg) | | | | | | | | | Historical Screening Results | | | |
| | | | | 2018 | | | Historical [1] | | | 2018 | | 2018 | | | 2019 | | | Historical [1] | | | 2018 | | 2019 | |
| | Constituent [4,5] | Units | Detection Limit | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] |
| Metals | Aluminum (Al) | mg/kg | 50 | 7,150 | 6,910 | 5,670 | 7,340 | 6,752 | 5,677 | 1.2 | 1.0 | 6,620 | 6,316 | 5,238 | 7,480 | 7,146 | 5,366 | 8,760 | 7,748 | 5,533 | 1.1 | 0.82 | 1.3 | 0.92 |
| | Antimony (Sb) | mg/kg | 0.10 | 0.43 | 0.43 | 0.40 | 0.80 | 0.58 | 0.47 | 0.90 | 0.74 | 0.65 | 0.64 | 0.54 | 0.77 | 0.70 | 0.50 | 0.71 | 0.67 | 0.52 | 1.2 | 0.95 | 1.3 | 1.0 |
| | Barium (Ba) | mg/kg | 0.50 | 137 | 132 | 120 | 209 | 168 | 138 | 0.96 | 0.79 | 239 | 230 | 206 | 244 | 221 | 175 | 274 | 234 | 194 | 1.2 | 0.98 | 1.1 | 0.95 |
| | Beryllium (Be) | mg/kg | 0.10 | 0.54 | 0.52 | 0.43 | 0.57 | 0.48 | 0.43 | 1.2 | 1.1 | 0.57 | 0.51 | 0.45 | 0.66 | 0.59 | 0.46 | 0.64 | 0.61 | 0.50 | 1.0 | 0.83 | 1.2 | 0.97 |
| | Boron (B) | mg/kg | 5.0 | 8.3 | 8.3 | 6.7 | 8.7 | 6.5 | 5.6 | 1.5 | 1.3 | 8.4 | 8.1 | 6.8 | 14 | 13 | 8.9 | 9.8 | 9.0 | 7.2 | 1.1 | 0.90 | 1.8 | 1.5 |
| | Calcium (Ca) | mg/kg | 50 | 220,000 | 216,000 | 181,000 | 165,000 | 153,900 | 122,778 | 1.8 | 1.4 | 120,000 | 107,240 | 80,507 | 74,700 | 71,780 | 59,090 | 184,000 | 130,300 | 91,895 | 1.2 | 0.82 | 0.78 | 0.55 |
| | Cobalt (Co) | mg/kg | 0.10 | 4.6 | 4.6 | 4.1 | 8.4 | 5.9 | 5.0 | 0.91 | 0.77 | 7.1 | 6.6 | 6.0 | 7.9 | 7.0 | 5.9 | 6.9 | 6.5 | 5.4 | 1.2 | 1.0 | 1.3 | 1.1 |
| | Lithium (Li) | mg/kg | 2.0 | 16 | 15 | 13 | 17 | 17 | 14 | 1.1 | 0.88 | 9.5 | 8.9 | 7.3 | 12 | 10 | 7.9 | 15 | 13 | 8.6 | 1.0 | 0.71 | 1.2 | 0.84 |
| | Magnesium (Mg) | mg/kg | 20 | 51,300 | 47,020 | 36,400 | 37,200 | 36,070 | 30,067 | 1.6 | 1.3 | 30,000 | 15,860 | 14,058 | 15,700 | 14,090 | 11,057 | 16,700 | 12,580 | 10,260 | 1.5 | 1.3 | 1.4 | 1.1 |
| | Molybdenum (Mo) | mg/kg | 0.10 | 1.2 | 1.2 | 1.1 | 1.8 | 1.3 | 1.1 | 1.1 | 0.91 | 2.3 | 1.7 | 1.5 | 1.7 | 1.6 | 1.2 | 1.8 | 1.8 | 1.3 | 1.3 | 0.99 | 1.2 | 0.89 |
| | Phosphorus (P) | mg/kg | 50 | 1,150 | 1,134 | 1,032 | 1,000 | 979 | 884 | 1.3 | 1.2 | 1,550 | 1,350 | 1,227 | 1,650 | 1,538 | 1,168 | 1,760 | 1,337 | 1,148 | 1.2 | 1.0 | 1.3 | 1.2 |
| | Potassium (K) | mg/kg | 100 | 1,810 | 1,730 | 1,430 | 2,060 | 1,864 | 1,526 | 1.1 | 0.93 | 1,620 | 1,446 | 1,205 | 1,720 | 1,642 | 1,222 | 2,260 | 1,832 | 1,353 | 1.1 | 0.79 | 1.2 | 0.90 |
| | Sodium (Na) | mg/kg | 50 | 200 | 197 | 153 | 160 | 143 | 115 | 1.7 | 1.4 | 129 | 96 | 83 | 88 | 83 | 68 | 104 | 86 | 76 | 1.3 | 1.1 | 1.1 | 0.97 |
| | Strontium (Sr) | mg/kg | 0.50 | 117 | 116 | 109 | 100 | 96 | 84 | 1.4 | 1.2 | 86 | 81 | 72 | 94 | 87 | 69 | 129 | 87 | 76 | 1.1 | 0.92 | 1.2 | 1.00 |
| | Sulfur (S) | mg/kg | 1,000 | 1,000 | 1,000 | 1,000 | 3,200 | 2,750 | 2,220 | 0.45 | 0.36 | 1,500 | 1,500 | 1,330 | 1,500 | 1,450 | 1,250 | 3,900 | 3,900 | 3,380 | 0.44 | 0.38 | 0.43 | 0.37 |
| | Thallium (Tl) | mg/kg | 0.050 | 0.16 | 0.16 | 0.14 | 0.20 | 0.19 | 0.17 | 0.93 | 0.84 | 0.31 | 0.24 | 0.18 | 0.20 | 0.18 | 0.15 | 0.28 | 0.26 | 0.19 | 1.3 | 0.94 | 0.94 | 0.70 |
| | Titanium (Ti) | mg/kg | 1.0 | 26 | 24 | 19 | 44 | 40 | 30 | 0.80 | 0.61 | 20 | 16 | 12 | 18 | 18 | 13 | 34 | 27 | 13 | 1.2 | 0.60 | 1.3 | 0.66 |
| | Uranium (U) | mg/kg | 0.050 | 0.88 | 0.88 | 0.80 | 1.0 | 0.95 | 0.86 | 1.0 | 0.92 | 1.2 | 1.1 | 0.98 | 1.1 | 1.0 | 0.86 | 2.0 | 1.8 | 1.2 | 0.94 | 0.60 | 0.87 | 0.56 |
| | Vanadium (V) | mg/kg | 0.20 | 25 | 24 | 21 | 26 | 25 | 21 | 1.1 | 0.95 | 30 | 30 | 25 | 30 | 29 | 22 | 38 | 32 | 24 | 1.2 | 0.94 | 1.2 | 0.91 |
| | Zirconium (Zr) | mg/kg | 1.0 | NA | NA | NA | NA | NA | NA | NA | NA | 2.8 | 2.8 | 2.8 | 1.1 | 1.1 | 1.1 | NA | NA | NA | NA | NA | NA | NA |
| PAHs | 1-Methylnaphthalene | mg/kg | 0.01 - 0.035 | 0.77 | 0.70 | 0.60 | NA | NA | NA | NA | NA | 2.4 | 2.1 | 1.2 | 1.5 | 1.1 | 0.85 | NA | NA | NA | NA | NA | NA | NA |
| | Benzo(b&j)fluoranthene | mg/kg | 0.01 - 0.035 | 0.089 | 0.085 | 0.075 | 0.12 | 0.12 | 0.068 | 1.2 | 0.73 | 0.22 | 0.19 | 0.11 | 0.13 | 0.093 | 0.066 | 0.18 | 0.13 | 0.083 | 2.4 | 1.5 | 1.1 | 0.74 |
| | Benzo(b+j+k)fluoranthene | mg/kg | NA | NA | NA | NA | 0.12 | 0.12 | 0.068 | NA | NA | NA | NA | NA | 0.14 | 0.10 | 0.071 | NA | NA | NA | NA | NA | NA | NA |
| | Benzo(e)pyrene | mg/kg | 0.01 - 0.035 | 0.086 | 0.083 | 0.074 | NA | NA | NA | NA | NA | 0.23 | 0.21 | 0.12 | 0.14 | 0.099 | 0.071 | NA | NA | NA | NA | NA | NA | NA |
| | Perylene | mg/kg | 0.01 - 0.035 | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |

**Notes**

NA = No data available, or all data below detection limits.

1 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

2 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration; $Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

3 No 2019 data available for this segment.

4 No data from the Decline Window for Bismuth, Tin and Benzo(b)fluoranthene so these constituents are not presented in this table.

5 No data historically for Tungsten and Quinoline so these constituents are not presented in this table.

Historical Quotients exceed 1.0.

**Table B-3 (Continued). Sediment chemistry from the upper Fording River for constituents without sediment quality guidelines screened against historical concentrations (2011/2013/2015/2017) by river segment group.**

| Segment Groups | | | | S6 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Concentrations in Sediment (mg/kg) | | | | | | | | | Historical Screening Results | | | |
| | | | | 2018 | | | 2019 | | | Historical [1] | | | 2018 | | 2019 | |
| | Constituent [4,5] | Units | Detection Limit | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] |
| Metals | Aluminum (Al) | mg/kg | 50 | 7,880 | 7,554 | 6,467 | 8,980 | 8,449 | 7,209 | 8,400 | 7,796 | 6,737 | 1.1 | 0.97 | 1.3 | 1.1 |
| | Antimony (Sb) | mg/kg | 0.10 | 0.69 | 0.64 | 0.57 | 0.64 | 0.61 | 0.57 | 0.69 | 0.68 | 0.59 | 1.1 | 0.95 | 1.0 | 0.90 |
| | Barium (Ba) | mg/kg | 0.50 | 290 | 214 | 198 | 305 | 303 | 212 | 331 | 227 | 202 | 1.1 | 0.94 | 1.5 | 1.3 |
| | Beryllium (Be) | mg/kg | 0.10 | 0.64 | 0.63 | 0.55 | 0.64 | 0.62 | 0.56 | 0.87 | 0.72 | 0.59 | 1.1 | 0.88 | 1.0 | 0.87 |
| | Boron (B) | mg/kg | 5.0 | 8.9 | 8.4 | 7.5 | 7.8 | 7.2 | 6.3 | 9.2 | 9.0 | 7.9 | 1.1 | 0.93 | 0.91 | 0.79 |
| | Calcium (Ca) | mg/kg | 50 | 58,100 | 57,260 | 47,280 | 51,800 | 49,910 | 45,440 | 55,000 | 48,660 | 40,109 | 1.4 | 1.2 | 1.2 | 1.0 |
| | Cobalt (Co) | mg/kg | 0.10 | 6.3 | 5.9 | 5.4 | 6.9 | 6.5 | 5.6 | 7.4 | 6.5 | 5.5 | 1.1 | 0.91 | 1.2 | 1.0 |
| | Lithium (Li) | mg/kg | 2.0 | 9.3 | 8.9 | 8.0 | 9.2 | 9.1 | 8.5 | 11 | 11 | 9.2 | 0.97 | 0.84 | 0.99 | 0.85 |
| | Magnesium (Mg) | mg/kg | 20 | 17,600 | 16,800 | 13,440 | 16,400 | 16,220 | 13,970 | 16,500 | 14,380 | 11,632 | 1.4 | 1.2 | 1.4 | 1.1 |
| | Molybdenum (Mo) | mg/kg | 0.10 | 2.1 | 1.4 | 1.3 | 1.7 | 1.5 | 1.4 | 1.7 | 1.5 | 1.3 | 1.1 | 0.92 | 1.2 | 0.98 |
| | Phosphorus (P) | mg/kg | 50 | 1,840 | 1,690 | 1,495 | 1,980 | 1,953 | 1,664 | 1,840 | 1,746 | 1,488 | 1.1 | 0.97 | 1.3 | 1.1 |
| | Potassium (K) | mg/kg | 100 | 1,910 | 1,844 | 1,581 | 1,870 | 1,798 | 1,510 | 2,180 | 2,008 | 1,650 | 1.1 | 0.92 | 1.1 | 0.90 |
| | Sodium (Na) | mg/kg | 50 | 91 | 90 | 80 | 88 | 87 | 80 | 110 | 94 | 85 | 1.1 | 0.96 | 1.0 | 0.93 |
| | Strontium (Sr) | mg/kg | 0.50 | 70 | 70 | 62 | 73 | 69 | 64 | 73 | 66 | 59 | 1.2 | 1.1 | 1.2 | 1.0 |
| | Sulfur (S) | mg/kg | 1,000 | 1,300 | 1,260 | 1,133 | NA | NA | NA | 3,400 | 3,080 | 2,300 | 0.55 | 0.41 | NA | NA |
| | Thallium (Tl) | mg/kg | 0.050 | 0.23 | 0.22 | 0.20 | 0.22 | 0.21 | 0.19 | 0.24 | 0.23 | 0.21 | 1.1 | 0.94 | 1.0 | 0.90 |
| | Titanium (Ti) | mg/kg | 1.0 | 17 | 16 | 13 | 23 | 22 | 16 | 41 | 27 | 18 | 0.89 | 0.59 | 1.3 | 0.83 |
| | Uranium (U) | mg/kg | 0.050 | 1.2 | 1.2 | 1.1 | 1.0 | 1.0 | 0.99 | 1.3 | 1.2 | 1.0 | 1.1 | 1.0 | 0.98 | 0.87 |
| | Vanadium (V) | mg/kg | 0.20 | 36 | 34 | 30 | 35 | 34 | 30 | 39 | 34 | 30 | 1.1 | 1.0 | 1.1 | 1.0 |
| | Zirconium (Zr) | mg/kg | 1.0 | NA | NA | NA | 1.3 | 1.3 | 1.1 | NA | NA | NA | NA | NA | NA | NA |
| PAHs | 1-Methylnaphthalene | mg/kg | 0.01 - 0.035 | 0.58 | 0.41 | 0.26 | 0.44 | 0.40 | 0.28 | NA | NA | NA | NA | NA | NA | NA |
| | Benzo(b&j)fluoranthene | mg/kg | 0.01 - 0.035 | 0.056 | 0.041 | 0.029 | 0.049 | 0.045 | 0.034 | 0.13 | 0.10 | 0.051 | 0.80 | 0.39 | 0.90 | 0.43 |
| | Benzo(b+j+k)fluoranthene | mg/kg | NA | NA | NA | NA | 0.053 | 0.048 | 0.039 | 0.14 | 0.12 | 0.067 | NA | NA | 0.72 | 0.40 |
| | Benzo(e)pyrene | mg/kg | 0.01 - 0.035 | 0.057 | 0.039 | 0.027 | 0.053 | 0.051 | 0.037 | NA | NA | NA | NA | NA | NA | NA |
| | Perylene | mg/kg | 0.01 - 0.035 | 0.028 | 0.025 | 0.020 | 0.043 | 0.038 | 0.027 | NA | NA | NA | NA | NA | NA | NA |

**Notes**

NA = No data available, or all data below detection limits.

1 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

2 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration;
$Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

3 No 2019 data available for this segment.

4 No data from the Decline Window for Bismuth, Tin and Benzo(b)fluoranthene so these constituents are not presented in this table.

5 No data historically for Tungsten and Quinoline so these constituents are not presented in this table.

Historical Quotients exceed 1.0.

**Table B-3 (Continued). Sediment chemistry from the upper Fording River for constituents without sediment quality guidelines screened against historical concentrations (2011/2013/2015/2017) by river segment group.**

| | | | Segment Groups | S1-S3 | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Concentrations in Sediment (mg/kg) | | | | | | | | | Historical Screening Results | | | |
| | | | | 2018 | | | 2019 | | | Historical [1] | | | 2018 | | 2019 | |
| | Constituent [4,5] | Units | Detection Limit | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | Maximum | 90th Percentile | Mean | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] | $Hist_{Mean}$ Quotient [2] | $Hist_{90th}$ Quotient [2] |
| Metals | Aluminum (Al) | mg/kg | 50 | 10,500 | 9,852 | 7,531 | 8,910 | 8,422 | 6,254 | 11,100 | 9,484 | 7,607 | 1.3 | 1.0 | 1.1 | 0.89 |
| Metals | Antimony (Sb) | mg/kg | 0.10 | 0.94 | 0.84 | 0.67 | 0.84 | 0.80 | 0.64 | 1.2 | 0.88 | 0.69 | 1.2 | 0.96 | 1.2 | 0.91 |
| Metals | Barium (Ba) | mg/kg | 0.50 | 268 | 233 | 215 | 265 | 257 | 239 | 396 | 310 | 236 | 0.99 | 0.75 | 1.1 | 0.83 |
| Metals | Beryllium (Be) | mg/kg | 0.10 | 0.72 | 0.68 | 0.55 | 0.81 | 0.75 | 0.57 | 0.88 | 0.69 | 0.57 | 1.2 | 0.97 | 1.3 | 1.1 |
| Metals | Boron (B) | mg/kg | 5.0 | 15 | 12 | 8.7 | 9.4 | 9.2 | 8.1 | 16 | 14 | 11 | 1.1 | 0.88 | 0.83 | 0.66 |
| Metals | Calcium (Ca) | mg/kg | 50 | 229,000 | 148,900 | 66,930 | 266,000 | 206,000 | 99,260 | 202,000 | 195,800 | 96,733 | 1.5 | 0.76 | 2.1 | 1.1 |
| Metals | Cobalt (Co) | mg/kg | 0.10 | 11 | 11 | 6.3 | 8.4 | 8.3 | 7.1 | 9.7 | 8.5 | 5.8 | 1.9 | 1.3 | 1.4 | 0.97 |
| Metals | Lithium (Li) | mg/kg | 2.0 | 15 | 13 | 9.7 | 11 | 10 | 7.7 | 13 | 13 | 10.0 | 1.3 | 1.0 | 1.0 | 0.80 |
| Metals | Magnesium (Mg) | mg/kg | 20 | 12,900 | 12,810 | 8,479 | 8,210 | 7,906 | 6,902 | 11,000 | 9,740 | 7,709 | 1.7 | 1.3 | 1.0 | 0.81 |
| Metals | Molybdenum (Mo) | mg/kg | 0.10 | 3.2 | 2.7 | 1.5 | 1.5 | 1.4 | 1.1 | 3.6 | 3.0 | 2.1 | 1.3 | 0.89 | 0.67 | 0.47 |
| Metals | Phosphorus (P) | mg/kg | 50 | 1,650 | 1,596 | 1,208 | 1,440 | 1,384 | 1,066 | 1,560 | 1,480 | 1,049 | 1.5 | 1.1 | 1.3 | 0.94 |
| Metals | Potassium (K) | mg/kg | 100 | 2,450 | 1,955 | 1,621 | 1,950 | 1,790 | 1,436 | 3,450 | 2,258 | 2,000 | 0.98 | 0.87 | 0.90 | 0.79 |
| Metals | Sodium (Na) | mg/kg | 50 | 165 | 145 | 108 | 97 | 91 | 81 | 361 | 324 | 181 | 0.80 | 0.45 | 0.50 | 0.28 |
| Metals | Strontium (Sr) | mg/kg | 0.50 | 105 | 76 | 63 | 116 | 98 | 67 | 256 | 251 | 113 | 0.67 | 0.30 | 0.87 | 0.39 |
| Metals | Sulfur (S) | mg/kg | 1,000 | 9,300 | 8,660 | 4,233 | 3,600 | 3,090 | 2,075 | 2,600 | 2,560 | 2,100 | 4.1 | 3.4 | 1.5 | 1.2 |
| Metals | Thallium (Tl) | mg/kg | 0.050 | 0.24 | 0.23 | 0.18 | 0.22 | 0.22 | 0.18 | 0.47 | 0.30 | 0.25 | 0.95 | 0.78 | 0.87 | 0.72 |
| Metals | Titanium (Ti) | mg/kg | 1.0 | 34 | 28 | 20 | 13 | 13 | 11 | 33 | 32 | 18 | 1.5 | 0.86 | 0.73 | 0.41 |
| Metals | Uranium (U) | mg/kg | 0.050 | 6.2 | 5.1 | 2.8 | 1.9 | 1.8 | 1.4 | 3.8 | 3.2 | 2.4 | 2.2 | 1.6 | 0.76 | 0.56 |
| Metals | Vanadium (V) | mg/kg | 0.20 | 43 | 39 | 28 | 32 | 30 | 23 | 50 | 37 | 30 | 1.3 | 1.1 | 0.98 | 0.81 |
| Metals | Zirconium (Zr) | mg/kg | 1.0 | 4.4 | 3.8 | 2.3 | NA | NA | NA | 4.4 | 2.9 | 1.9 | 1.9 | 1.3 | NA | NA |
| PAHs | 1-Methylnaphthalene | mg/kg | 0.01 - 0.035 | 4.7 | 3.1 | 1.3 | 3.0 | 2.4 | 1.5 | 2.1 | 1.9 | 1.1 | 2.9 | 1.7 | 2.3 | 1.3 |
| PAHs | Benzo(b&j)fluoranthene | mg/kg | 0.01 - 0.035 | 0.45 | 0.38 | 0.19 | 0.34 | 0.28 | 0.16 | 0.49 | 0.28 | 0.18 | 2.2 | 1.4 | 1.6 | 0.98 |
| PAHs | Benzo(b+j+k)fluoranthene | mg/kg | NA | NA | NA | NA | 0.36 | 0.29 | 0.17 | 0.51 | 0.34 | 0.20 | NA | NA | NA | NA |
| PAHs | Benzo(e)pyrene | mg/kg | 0.01 - 0.035 | 0.47 | 0.39 | 0.19 | 0.36 | 0.29 | 0.18 | 0.26 | 0.23 | 0.14 | 2.8 | 1.7 | 2.1 | 1.3 |
| PAHs | Perylene | mg/kg | 0.01 - 0.035 | 0.35 | 0.26 | 0.13 | NA | NA | NA | 0.012 | 0.012 | 0.012 | 22 | 22 | NA | NA |

**Notes**

NA = No data available, or all data below detection limits.

1 Historical includes sediment chemistry data from 2011, 2013, 2015 and 2017.

2 $Hist_{Mean}$ = 90th percentile concentration in 2018 or 2019 / mean historical concentration;
$Hist_{90th}$ = 90th percentile concentration in 2018 or 2019 / 90th percentile historical concentration.

3 No 2019 data available for this segment.

4 No data from the Decline Window for Bismuth, Tin and Benzo(b)fluoranthene so these constituents are not presented in this table.

5 No data historically for Tungsten and Quinoline so these constituents are not presented in this table.

Historical Quotients exceed 1.0.

# APPENDIX C: SEDIMENT CHEMISTRY FIGURES

**Figure C-1. Metals concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

**Figure C-1 (Continued). Metals concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Selenium guideline is an "alert concentration" and is treated as an upper sediment quality guideline in this report (see **Section 2.1**). Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

**Figure C-2. Selected low molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

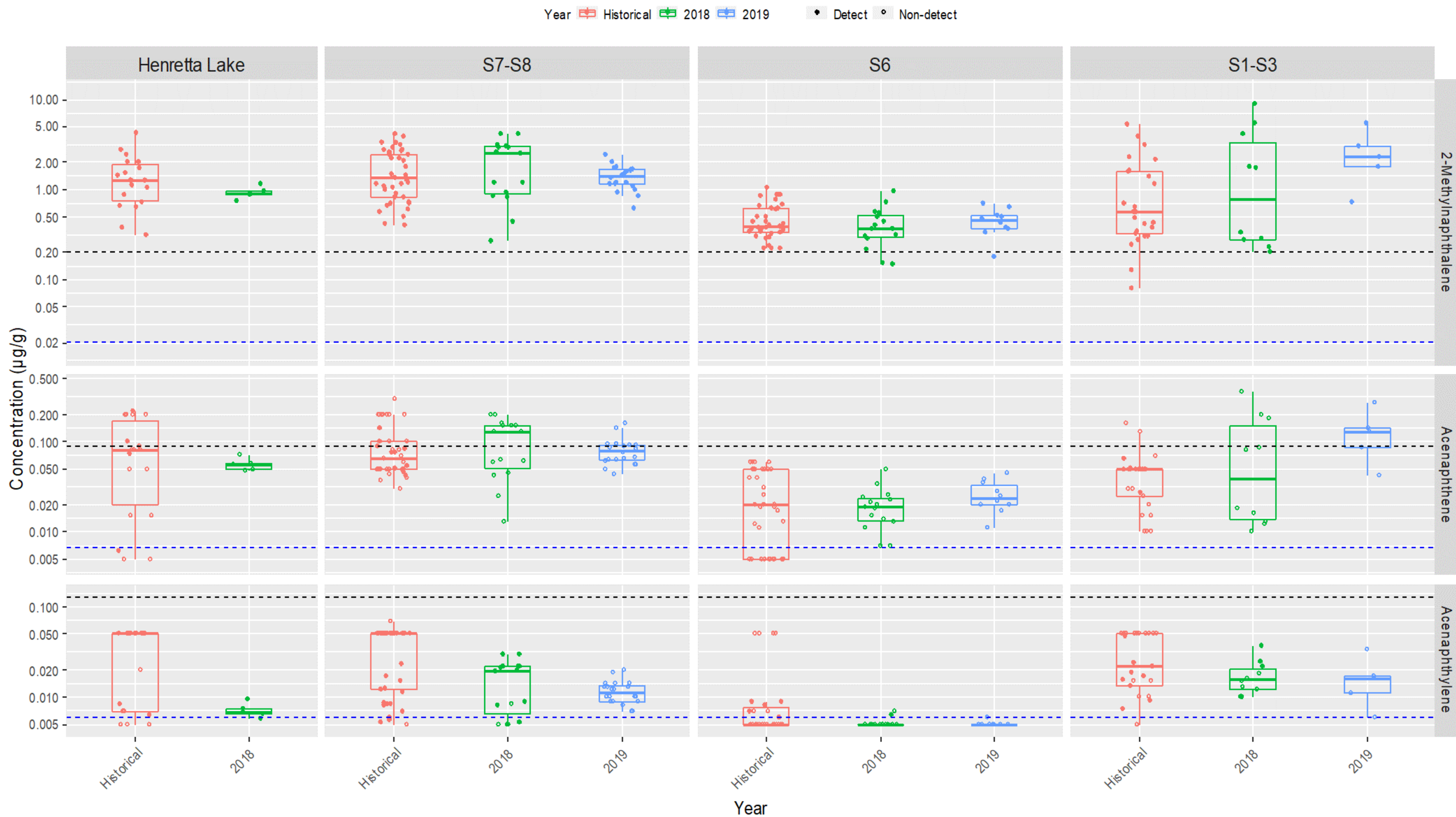


**Figure C-2 (Continued). Selected low molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

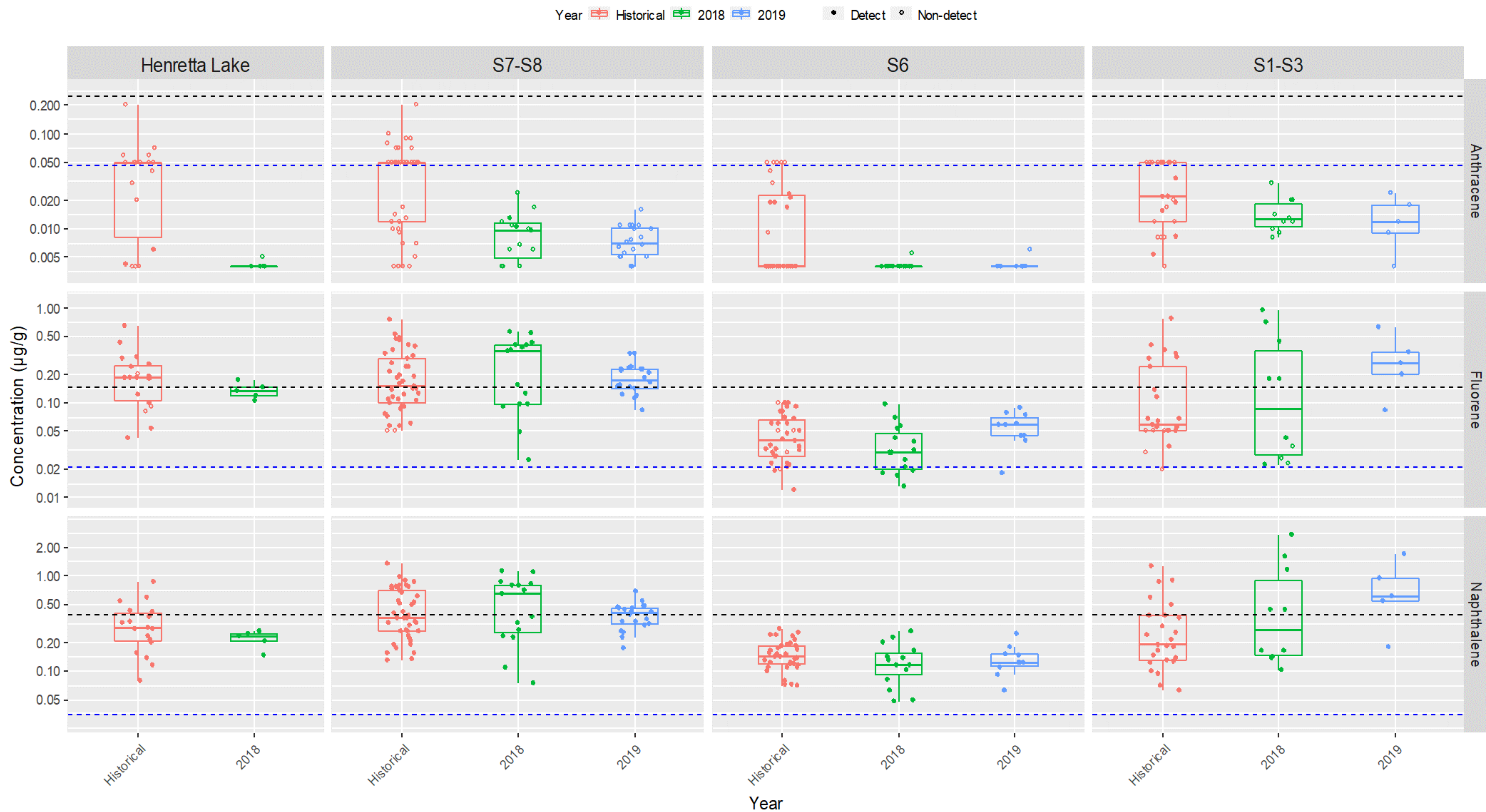


**Figure C-2 (Continued). Selected high molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

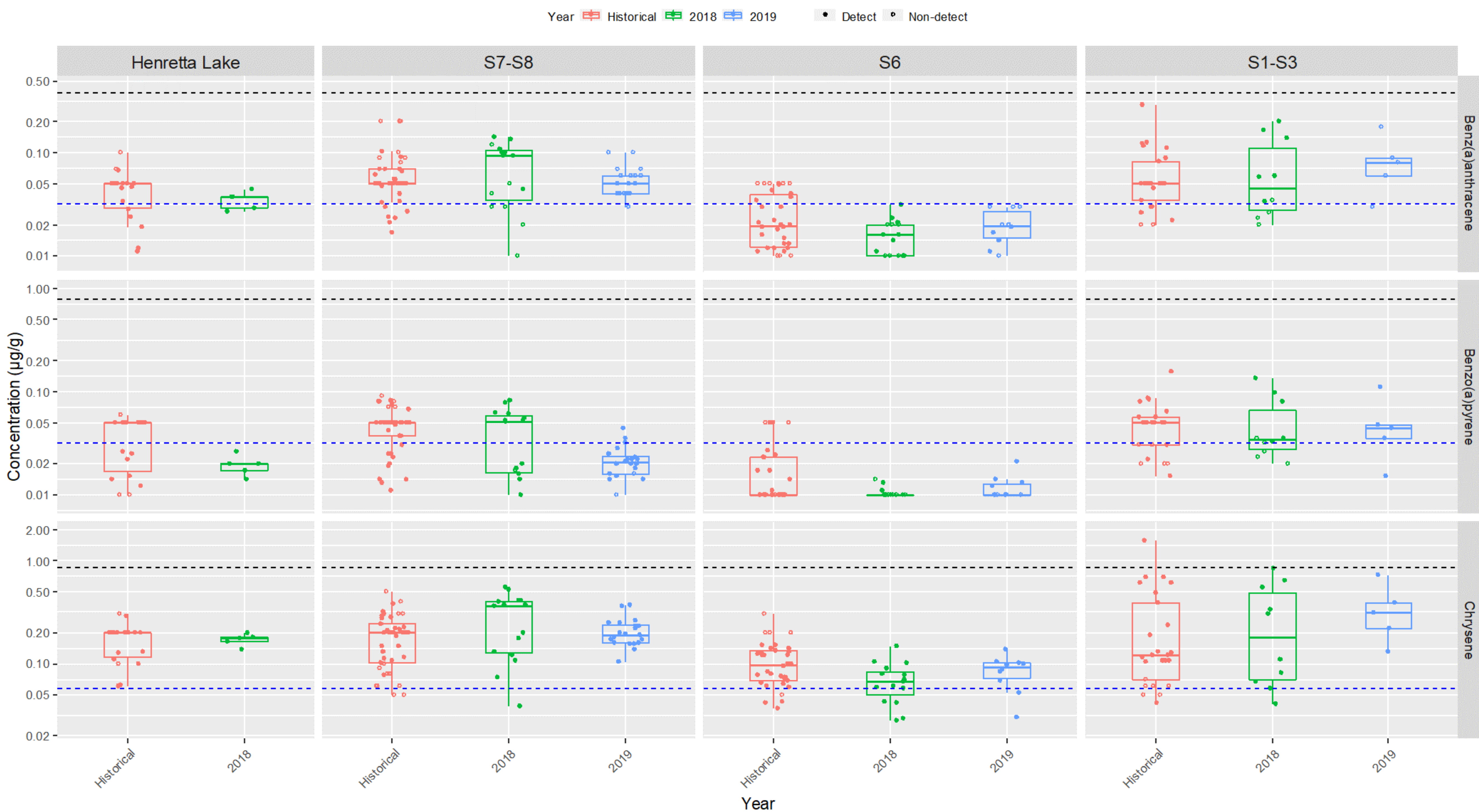


**Figure C-2 (Continued). Selected high molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

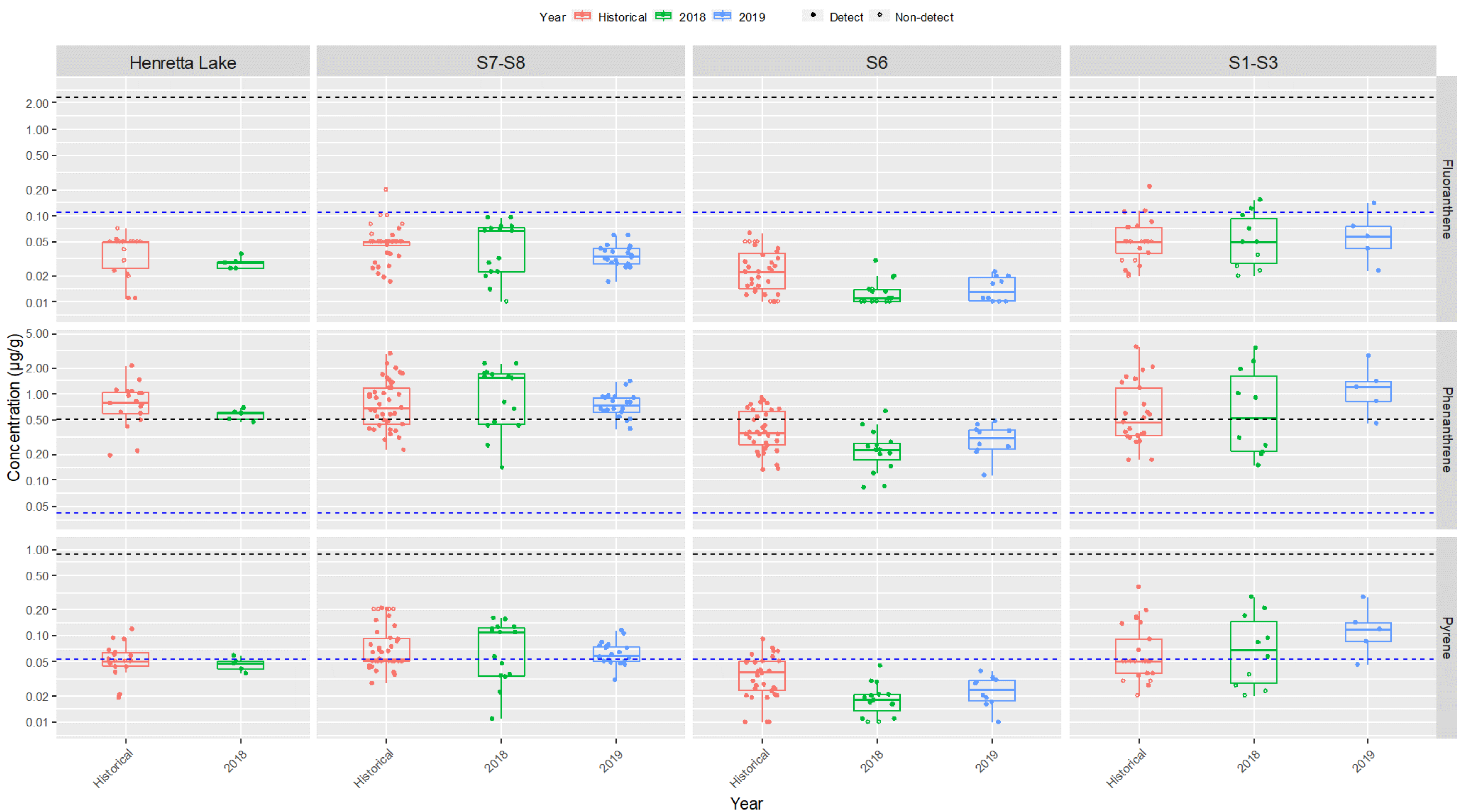


**Figure C-2 (Continued). Selected high molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.

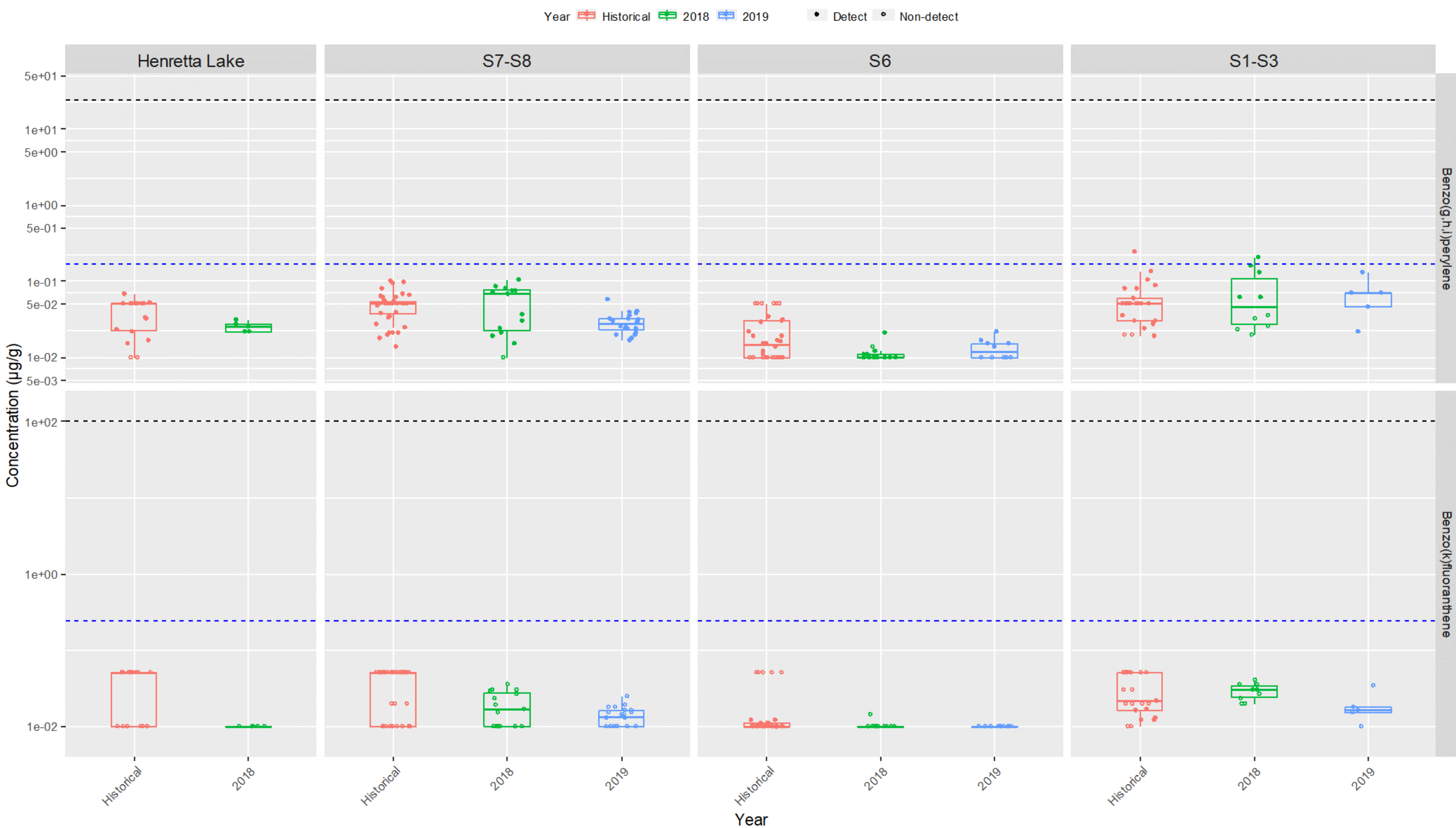


**Figure C-2 (Continued). Selected high molecular weight PAH concentrations (mg/kg) in sediment samples collected from the upper Fording River Study Area (historical, 2018 and 2019).**

Notes: Analyses done on the 1 mm sediment fraction. See **Table 2-2** for the stations within each river segment group and area. The lower and upper working sediment quality guidelines are represented by the blue and black lines, respectively. Historical refers to sediment data from years 2011, 2013, 2015 and 2017.