Expert Report

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Review of Environment Canada's Teck Coal Environmental Assessment and Evaluation of Selenium Toxicology Tests on Westslope Cutthroat Trout in the Elk and Fording Rivers in Southeast British Columbia

(Interim Report: additional data to be included when received)

1.0 Introduction

Selenium pollution in the Fording and Elk Rivers has been a growing environmental issue for many years. Selenium concentrations in surface waters of the Elk River watershed have been increasing since the 1990's as a result of open-pit coal mining activities in the area. Concern about the potential for environmental impacts associated with these increases led to establishment, in 1998, of a joint industry-government committee, the Elk Valley Selenium Task Force (EVSTF). In 2012, a new committee was formed by the British Columbia Government, known as the Selenium Technical Advisory Committee, which functioned through July 2014.

The EVSTF was composed of representatives from the 5 coal mining operations of the Elk Valley Coal Corporation; BC Ministry of Environment; BC Ministry of Energy, Mines, and Petroleum Resources; Teck Cominco (currently Teck Coal); and, Environment Canada. Significant monitoring and research has been undertaken to address the selenium pollution concerns, resulting in many EVSTF-related reports and publications that have substantially advanced the knowledge and understanding of selenium fate and effects in the Elk Valley (e.g., Elphick et al. 2011).

Collectively, the information strongly suggests that dissolved selenium emissions originating from coal mining waste rock are deleterious to resident fish populations, particularly the highly valued Westslope Cutthroat trout. In 2012, under the authority of a General Warrant, Environment Canada collected additional environmental samples and sponsored early life stage bioassay studies to further elucidate sources, cycling, fate, and biological effects of selenium pollution in the Elk River watershed, with emphasis on the Upper Fording River (upstream of Josephine Falls).

A comprehensive draft report providing both summary and detailed results of those efforts has now been produced by Environment Canada titled "Environmental Sampling in Areas Affected by Coal Mining in the Elk and Fording River Watersheds of South Eastern British Columbia – 2012-2014" (Environment Canada 2014).

I was asked by Environment Canada to conduct a technical review of their environmental assessment and its associated selenium toxicology tests. My review is structured to answer 5 key questions that pertain to the scientific rationale, technical quality and interpretive power of Environment Canada's 2012 to 2014 Environmental Assessment:

(1) Is selenium deleterious to fish?*
(2) Was Environment Canada's assessment and test process acceptable?
(3) How do Environment Canada test results compare to other tests/papers?
(4) Does evidence collected by Environment Canada show that selenium is deleterious to westslope cutthroat trout in the Fording River system?
(5) What are the potential implications for the aquatic biota, benthic invertebrates and fish populations in the Upper Fording River, Lower Fording River and Elk River especially in relation to westslope cutthroat trout?

In addition, this review provides a preliminary population impact estimate to support the calculation of economic values of damages to the fisheries in the Fording and Elk Rivers. This review also provides an estimate of the population loss of embryonic westslope cutthroat trout in the Upper Fording River associated with the deleterious effects of the current levels of selenium as measured by the Environment Canada 2012-2014 study.

*Section 34.(1) of the Canadian Federal Fisheries Act, R.C.S., 1985, C F-14, Ammended June 29, 2012 states that "*deleterious substance means (a) any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water*".

2.0 Qualifications

I have spent over 30 years investigating aquatic selenium pollution from coal combustion wastes (CCW), coal mining, and agricultural irrigation. I have extensive experience conducting field and laboratory research on selenium toxicology, primarily involving aquatic cycling, bioaccumulation, and effects on fish. These studies include intensive investigations of the two most damaging cases of selenium pollution that have taken place in the USA; (1) Belews Lake, North Carolina, where 19 species of fish were eliminated due to selenium in CCW, and (2) Kesterson Marsh, California, where hundreds of thousands of aquatic birds and fish were poisoned due to selenium in agricultural irrigation drainage.

My career began in the late 1970's with studies of the landmark pollution event at Belews Lake, which established the fundamental principles of selenium bioaccumulation and reproductive toxicity in fish. In the 1980's, I was a research project manager in the U.S. Fish and Wildlife Service, directing studies that determined impacts of selenium from agricultural irrigation drainage on aquatic life at Kesterson National Wildlife Refuge and in 14 other western states.

In the 1990's, the emphasis of my research shifted to the development of methods and guidelines for hazard assessment and water quality criteria for selenium, which led to the publication of a reference book (see item 42 in the Appendix). This handbook contains the first comprehensive assessment tools for evaluating selenium pollution on an ecosystem scale. I have also published over 50 research journal articles and book chapters on selenium toxicity to fish and wildlife (see Appendix). I have consulted on selenium contamination issues ranging from CCW landfill leachate in Hong Kong to mountaintop removal coal mining in West Virginia. I provide the methods and technical guidance necessary to identify, evaluate, and correct aquatic selenium problems before they become significant toxic threats to fish and wildlife populations. I have devised and applied guidelines for protecting aquatic life in habitats from the Arctic to the tropics, and from high mountain streams to coastal lagoons. I have Masters and Doctorate degrees in biology from Wake Forest University.

3.0 Information Relied Upon

The following information was provided to me by Environment Canada in hard copy and/or electronic form:

(1) Expert witness report "Environmental Sampling in Areas Affected by Coal Mining in the Elk and Fording River Watersheds of South Eastern British Columbia – 2012-2014". Environment Canada 2014.

(2) Fish Capture Data.

(3) Early Life Stage Bioassay Data.

(4) Soloway, A., "Early Life Stage Bioassay and Assessment of Larval Deformities in Cutthroat Trout (*Oncorhynchus clarki lewisi*) Exposed to Selenium at the Teck Fording River Operations and Greenhills Operations Mines in British Columbia's Elk Valley Region", Environment Canada and Dept. of Fisheries and Oceans, Freshwater Institute 2014.

(5) Report "Biological Test Method: Toxicity Tests Using Early Life Stages of Salmonid Fish (Rainbow Trout), EPS 1/RM/28 Second Edition – July – 1998".

(6) Report "Selenium Bioaccumulation in Fish From The Elk River, British Columbia: A Review of Data Collected From 1996 to 2010". McDonald 2013.

(7) Report "Fording River Revisited: A Review of Environmental Projects at Fording Coal Limited's Operations at Fording River Over The Last 25 Years". Wood and Berdusco 1999.

(8) M.S. Thesis by Chad Wilkinson "Sportfish Population Dynamics in An Intensively Managed River System".

(9) Report "Fording River Aquatic Environment Study". Fording Coal Limited 1980.

(10) Various fish population studies conducted by government, industry, academia, and environmental consultants.

In evaluating procedures and results, forming opinions and drawing conclusions, I also relied upon technical data contained in the reports and articles cited in the text and listed in the References section of this review.

4.0 Summary of Opinions

After reviewing the information provided by Environment Canada, which I evaluated both independently and in the context of substantial comparative technical data contained in the Reference documents, I offer the following expert opinions:

(1) Selenium is deleterious to fish when concentrations exceed toxic thresholds in tissue. Excess selenium in eggs causes reduced hatching success and a wide variety of morphological abnormalities and physiological changes in post-hatch survivors. The combination of these effects is expressed as reproductive failure. The end result can be total population collapse and local extinction of species. In the data submitted to me, deleterious impact was evidenced by classical symptoms of selenium poisoning marked by skeletal and craniofacial deformities and edema in samples of embryos and larvae of westslope cutthroat trout collected from the Upper Fording River.

(2) The test methods and evaluation procedures used by Environment Canada are scientifically correct and provide valid answers to the questions being asked. The Environment Canada 2014 report demonstrated the movement of selenium from the waste rock through the environment and into the aquatic food chain, bioaccumulation in fish tissues and expression of selenium poisoning. In addition to measuring environmental conditions and comparing concentrations of selenium in water, food-chain organisms, and fish to known toxic thresholds, Environment Canada chose to go a step further and used early life-stage (embryo-larval) bioassay, measuring survival and mortality coupled with deformity analysis, to do a rigorous site-specific assessment of selenium toxicity.

(3) Environment Canada's test results are very similar to the findings from several other studies of both westslope and Yellowstone cutthroat trout. The Environment Canada studies are technically correct, broad in scope of assessment (in that they include both direct and indirect modes of selenium toxicity), and they conclusively and definitively confirm the types and degree of teratogenic deformity impacts and mortality thresholds for cutthroat trout in the Fording River study area.

(4) All indications are that selenium pollution is having a substantial negative impact on westslope cutthroat trout in the Upper Fording River system. In the samples collected and analyzed by Environment Canada in 2012 and 2014, and submitted to me for review, the waterborne selenium is present at concentrations far above levels that cause bioaccumulation in the aquatic food-chain and excess dietary selenium intake by fish, and cause associated reproductive toxicity in fish (the fish toxic threshold, that is, the concentration at which sensitive species first begin to experience selenium poisoning in habitats favorable for bioaccumulation, is 2 µg/L; measured concentrations in the Upper Fording River system typically ranged from 5-113 µg/L).

Concentrations of selenium in westslope cutthroat trout fish eggs collected from the Upper Fording River in the Environment Canada 2012 study are often far above toxic thresholds (the fish toxic threshold, that is, the concentration at which sensitive species first begin to experience selenium poisoning, is 10-15 µg/g dry weight; measured concentrations in Upper Fording River fish eggs frequently exceeded 60 µg/g dry weight). Strong positive correlations were found between increasing tissue concentrations of selenium in eggs and larvae, and increased mortality and incidence and severity of deformities, particularly, the teratogenic skeletal and craniofacial deformities that are biomarkers of selenium poisoning. These results conclusively and definitively confirm that cutthroat trout in the Upper Fording River study area are experiencing both pre- and post swim-up mortality due to selenium poisoning.

(5) Based on the data provided in the Environment Canada 2012-2014 report, as well as the report "Early Life Stage Bioassay and Assessment of Larval Deformities in cutthroat trout (*Oncorhynchus clarki lewisi*) Exposed to Selenium at the Teck Fording River Operations and Greenhills Operations Mines in British Columbia's Elk Valley Region", Environment Canada and Dept. of Fisheries and Oceans, Freshwater Institute 2014, an estimate of the population mortality of westslope cutthroat trout in the Upper Fording River due to selenium poisoning was determined to be 54.4% of the annual reproductive output or 180,794 fish lost each year. (There was no early life stage bioassay data provided in regards to the impact of other sport fish species such as bull trout, eastern brook trout, rainbow trout, Rocky Mountain whitefish, and non-sportfish species, long nose sucker, dace which are present in the lower Fording and Elk Rivers and this review does not consider the population impacts on these species which would be in addition to the losses estimated for westslope cutthroat trout).

The monetized value of fish lost to selenium poisoning in the Upper Fording River and Elk River each year may be substantial and requires further examination as the monetized replacement cost per fish will be regionally specific. In the United States, the North Carolina Department of Environment and Natural Resources, Raleigh, NC (NCAC 2013) has conducted a replacement cost estimate for various species of fish and indicates a value of $US 24.74 per catchable wild trout 7-13 inches in size (2014 inflation-adjusted dollars).

Losses due to recreational, food/subsistence, aesthetic and other ecological costs require analysis based on regional economic factors.

(6) The Upper Fording River westslope cutthroat trout population is quite small and is isolated by Josephine Falls, which creates a natural barrier to upstream fish movement and has protected this population from hybridization with non-native rainbow trout, making it genetically pure and a high priority conservation target. However, although these fish may benefit genetically from reduced hybridization risk, upper Fording River trout experience much greater extinction risk. Removal of a substantial number of fish, for whatever reason, carries a very high potential for population-level ripple effects that can culminate in an unviable level of reproduction, population collapse, and local extinction. In such a genetically isolated population, if numbers of trout are decreased below a certain level this could result in a genetic bottleneck, whereby genetic heterogeneity is reduced and future generations of fish are less able to respond to environmental change. The implications of removing 54.4% of the annual

reproductive output due to selenium poisoning, as is indicated from the Environment Canada investigations, are extremely serious for the survival of cutthroat in the Upper Fording River. This population of cutthroat merits a fully protective water quality standard, that is, zero mortality from selenium poisoning.

(7) Although coal mining has taken place in the region since the late 1800's, only within the past four decades has large-scale, open pit surface excavation come into play as a dominant mining technique. As these surface mines have expanded, so has the volume of their selenium-laden wastewater discharges to nearby streams and rivers, both from active mine site operations and also from the waste-overburden (tailings) left behind. The increase in water pollution, as evidenced by increasing selenium concentrations, is reflected in the monitoring trends documented by BC Environment, Environment Canada, and several private contractors to the coal mining companies over the past two decades. These trends all point to the same conclusion, that is, the Elk River watershed is now at a tipping point. Selenium toxicity is evident in fish, especially in the Upper Fording River, and further increases in waterborne and fish tissue concentrations can lead to only one outcome.....total population collapse of sensitive species such as westslope cutthroat trout.

(8) Oxbows, or U-shaped bends, in the Upper Fording River present a particularly important ecological scenario with respect to selenium bioaccumulation and toxicity in westslope cutthroat trout, and the associated need for corrective actions to reduce upstream selenium discharges from coal mining. In a river system, oxbows cause a somewhat uncharacteristic reduction in flow and result in an aquatic environment that can be more similar to a lacustrine habitat than the relatively rapid-flow, shallow-water lotic conditions that are present both upstream and downstream. The slowing of water flow rate and increased depth in an oxbow results in enhanced biological primary and secondary productivity, and associated increased biological uptake of waterborne selenium into the aquatic food chain.

Consequently, this increase in food-chain selenium is translated into increased dietary selenium intake by fish, and results in elevated tissue selenium levels in fish that reside in the oxbow environment. The occurrence of these conditions in the Upper Fording River are confirmed by data provided in McDonald 2013 which mirror the values reported in the Environment Canada 2014 report and which clearly show that tissue concentrations of selenium in westslope cutthroat trout are substantially, and toxicologically, greater in oxbow environments that at other sampling locations. The increased biological hazard of incoming waterborne selenium to fish that reside in oxbows and other slow-water, off-channel riverine habitats has been documented in the scientific literature since 1999. The total loss of overwintering habitat in Kilmarnock Creek forces fish to overwinter in the oxbows. Oxbows, therefore, represent an especially valuable and vulnerable aquatic habitat that merits prime focus for monitoring selenium bioaccumulation and toxicological evaluation of fish in the Upper Fording River and elsewhere in the Elk River watershed.

(9) A remnant population of spawning westslope cutthroat trout that produce eggs which either fail to hatch or embryos which exhibit the deleterious effects of severe selenium poisoning remains in the upper Fording River above Josephine Falls. This fact is evident from the review of historical fish population studies and toxicological evaluations provided by the Environment Canada 2014 Report and 5 other university and independent toxicology studies. These reports (which document poisoning that is estimated to cause as much as 54.4% mortality per year in embryos, and some spawns that entirely fail to hatch) and the information provided by five historical fish population studies conducted in the 1970's thru mid-1990's, show that major population declines in the number of spawning-size fish (on the order of 46-67%) and total population densities (on the order of 51-93%) have taken place in the Upper Fording River concurrent with expansion of coal mining operations. Comparative studies conducted elsewhere have documented that complete fish population collapse can occur under these conditions. The toxicology findings, increasing trends in selenium levels, and historic and current population data, all indicate that the Upper Fording River population of westslope cutthroat trout is in a critical downward spiral.

Full recovery of the Upper Fording River population of westslope cutthroat trout to historic numbers and health is only possible through remediation measures that substantially reduce selenium discharges from coal mining. In the case of the Upper Fording River this is particularly critical because it involves an ecologically vulnerable and genetically unique population of fish. The remediation measures must address the higher susceptibility to selenium poisoning of the majority of fish that are forced by the elimination of the Kilmarnock Creek habitat to reside or overwinter in the Upper Fording River oxbows. A toxicologically reasonable water quality target for selenium in the oxbows is 2 µg Se/L based on scientific consensus published in books, peer-reviewed journal articles, and recommendation by BC Environment, US Fish and Wildlife Service, and US Environmental Protection Agency (Peterson and Nebeker 1992, Lemly 1993d, 2002b, Skorupa 1998, BC Environment 2013, USEPA 2014).

5.0 Is Selenium Deleterious to Fish?

Cases of selenium poisoning in fish date back to the 1970's and Belews Lake, NC, where virtually all fish were eliminated from the 1563 ha reservoir due to selenium in coal ash wastewater (Cumbie and Van Horn 1978). Belews Lake is a water body from which the resident fish could not escape and recruitment of new fish was not possible. A coal-fired power plant discharged ash wastewater that contained selenium into the lake. Sampling was conducted and young fish were found to be deformed and in short supply (Figure 1). Over a period of a few years the fish population suffered declines and collapsed due to reproductive failure (Lemly 1985a). Studies of Belews Lake, which could correctly be called the "cradle of aquatic selenium toxicity", formed the cornerstone of selenium ecotoxicology (Lemly 2002a). Subsequent to the Belews Lake case, numerous examples of selenium poisoning have emerged, encompassing a variety of selenium sources. Selenium can be released from agricultural irrigation, petrochemical processing, uranium mining, metal mining and smelting, and especially from coal mining and combustion of coal. These cases have been found in Canada, the USA, and countries around the globe (Lemly 2004). Most recently, a multi-million dollar damage case of selenium poisoning in fish from coal ash wastewater was documented in North Carolina in 2013 (Lemly 2014, Figure 2A, 2B).

Figure 1 (A) Figure 1(B)

Figure 1. Historic photos of abnormal fish (*Gambusia affinis*, A, *Notropis lutrensis*, B) from Belews Lake, NC, showing major V-shaped spinal deformity (kyphosis and lordosis, A) and lateral spine twisting (scoliosis in left individual, B) due to teratogenic effects of selenium poisoning. (Photos by A. D. Lemly, 1980).

Figure 2 (A) Figure 2 (B)

Figure 2. Recent (2013) photos of (A) abnormal bluegill (*Lepomis macrochirus*, top) from Lake Sutton, NC, with deformities that result from teratogenic effects of selenium poisoning. This individual has multiple defects of the mouth (which is less than 20% of its normal size and permanently distended) and other craniofacial structures including "gaping" permanently deformed gill cover. Bottom individual is normal. (B) A deformed bluegill (*Lepomis macrochirus*, top) from Lake Sutton, NC, exhibiting spinal curvature (kyphosis and lordosis) due to teratogenic effects of selenium poisoning. Bottom individual is normal. (Photos by L.P. Lemly, 2013).

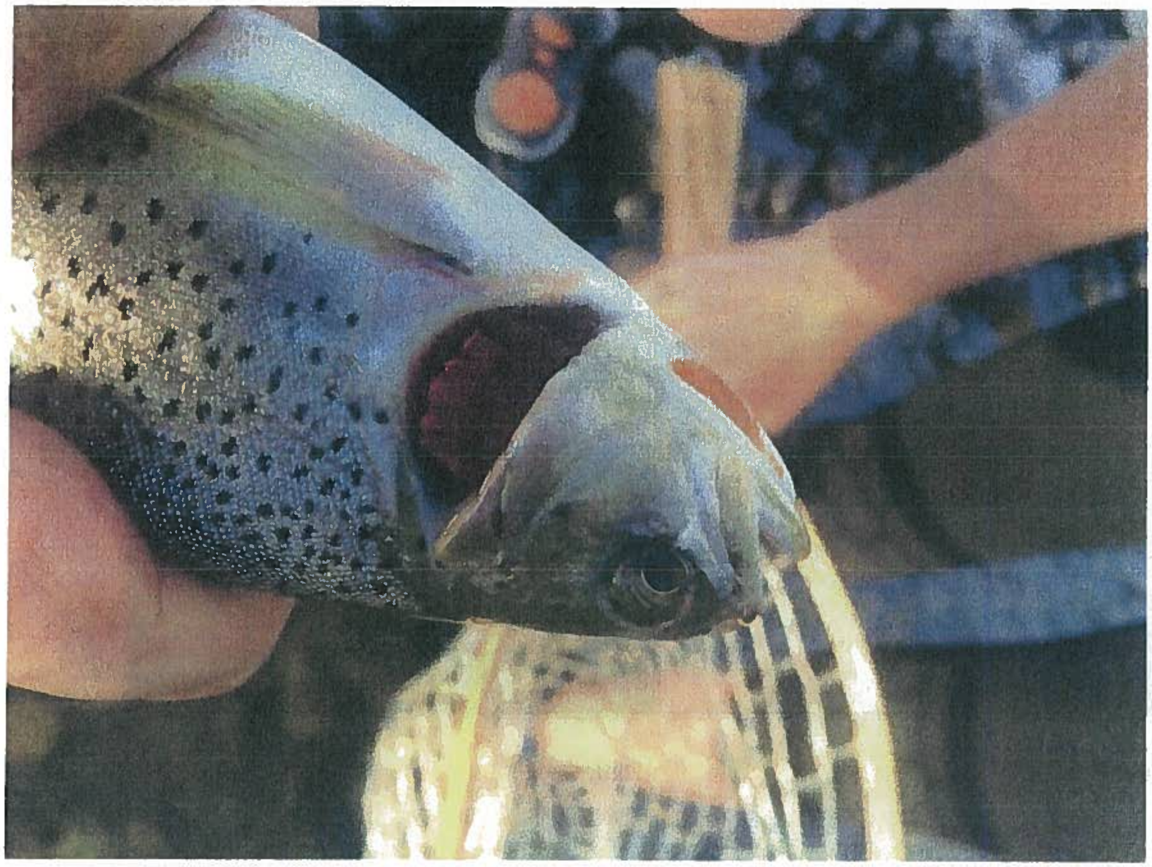


Figure 2 (C). Recent (2014) deformity (missing gill cover) in a westslope cutthroat trout captured in Coal Creek, a tributary emanating from a former coal mine and discharging to the Elk River at Fernie, B.C. Gill cover deformities are a common type of craniofacial abnormality that can be caused by selenium poisoning, and when present in combination with elevated tissue levels of selenium, they are a reliable cause-effect biomarker. These deformities have been documented in many fish species and locations experiencing selenium pollution in North America (see Figures 1A and 2A for example).

5.1 Studies Related to Selenium Toxicity to Fish.

Toxicity is often expressed in terms of weight of toxicant per unit of weight of dry tissue or unit of weight per liter of water. In this report, units will be expressed as follows;

*Tissue - 1.0 µg/g DW = 1 micro gram per gram dry weight or "one part per million based on the dry weight of the tissue" or 1.0 ppm. For conceptual purposes, a part per million may be thought of as "one eye dropper drop in a barrel of water.

**Water - 1.0 µg/L = 1 microgram per liter or "one part per billion" or ppb. For conceptual purposes, a part per billion may be thought of as one eye dropper drop in a thousand barrels of water.

The knowledge base of selenium toxicity to fish has expanded dramatically since the 1970's. Key dates and reports and observations upon which field biologists, research scientists, ecotoxicologists, and regulatory agencies have developed environmental criteria are:

1982-1987 Reports by Lemly (1982, 1985a, 1985b), Gillespie and Baumann (1986), and Woock et al. (1987) concluded that selenium bioaccumulation and poisoning in fish can occur if waterborne selenium exceeds 5 µg/L and egg selenium exceeds 10 µg/g dw.

1992-1998 Reports by Peterson and Nebeker (1992), Hermanutz et al. (1992), Lemly et al. (1993a, 1993b), and Skorupa (1998) concluded that selenium bioaccumulation and toxicity is quite similar in streams and impoundments, that toxic thresholds are 2 µg/L for water, 5.8 µg/g dw for whole-body and about 10 µg/g dw for eggs, and that water containing >2 µg/L should not be used for wetland management on national wildlife refuges.

2003-2005 Reports from Canadian studies by Holm et al. (2003, 2005) revealed toxicity and deformities in salmonids due to selenium from coal mining, and concluded that toxicity thresholds are similar in both cold and warm-water fish.

2006-2009 Reports from Canadian studies by Muscatello et al. (2006, 2008, 2009) provided additional selenium bioaccumulation, toxicity and deformity information for mining waste impacts on cold-water fish, and concluded that toxicity thresholds are similar in both cold and warm-water species.

5.2 Deleterious effects of selenium to fish in the Upper Fording River.

Selenium is deleterious to fish when concentrations exceed toxic thresholds in tissues. Excess selenium causes a wide variety of morphological abnormalities and physiological changes that can be lethal, especially in early life stages, which often causes reproductive failure.

Common morphological abnormalities include: Edema (swelling of tissues by body fluids), spinal (deformed spine due to kyphosis, lordosis, and scoliosis), cranial (misshaped skull, mouth, and gill cover), finfold (deformed or missing fins) and hemorrhage (bleeding of gills or other tissues). The end result of abnormalities and reproductive failure can be total population collapse and local extinction of species.

I examined the photographs and Graduated Severity Index results of the Environment Canada 2014 study and the Ashley Soloway research report and determined that these deformities were present in up to 90 % of the fish hatched from eggs collected in the Upper Fording River study area. EC Report

Figures 4-30 to 4-42, give the prevalence of these abnormalities in samples. Figure 3 (below) shows the appearance of normal characteristics in a westslope cutthroat trout collected in the Upper Fording River by Environment Canada. Sections 5.2.2-5.2.6 (following) illustrate the range and severity of abnormalities caused by selenium poisoning in Upper Fording River westslope cutthroat trout.

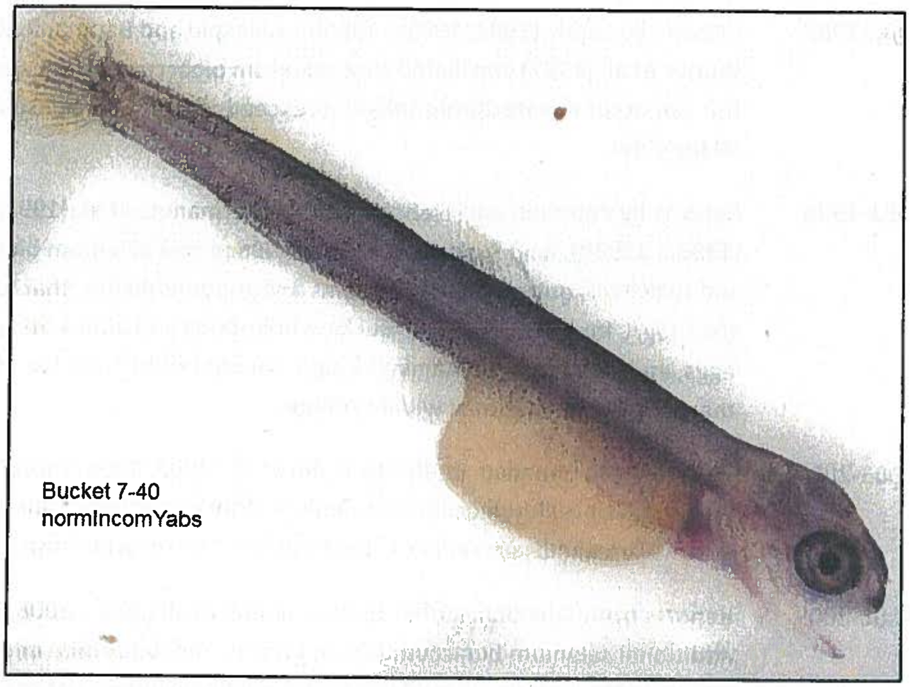


Figure 3. Environment Canada Photo – Upper Fording River westslope cutthroat trout sample Bucket 7-40 exhibits normal characteristics of straight spine, progressively absorbed egg yolk sac, and properly formed head and mouth and fins.

5.2.1 Impact on Eggs

Selenium can have a deleterious effect on eggs by causing abnormal protein formation in the developing embryo and/or expression of oxidative damage to already synthesized tissues. This can result in death of the embryo and failure to hatch.

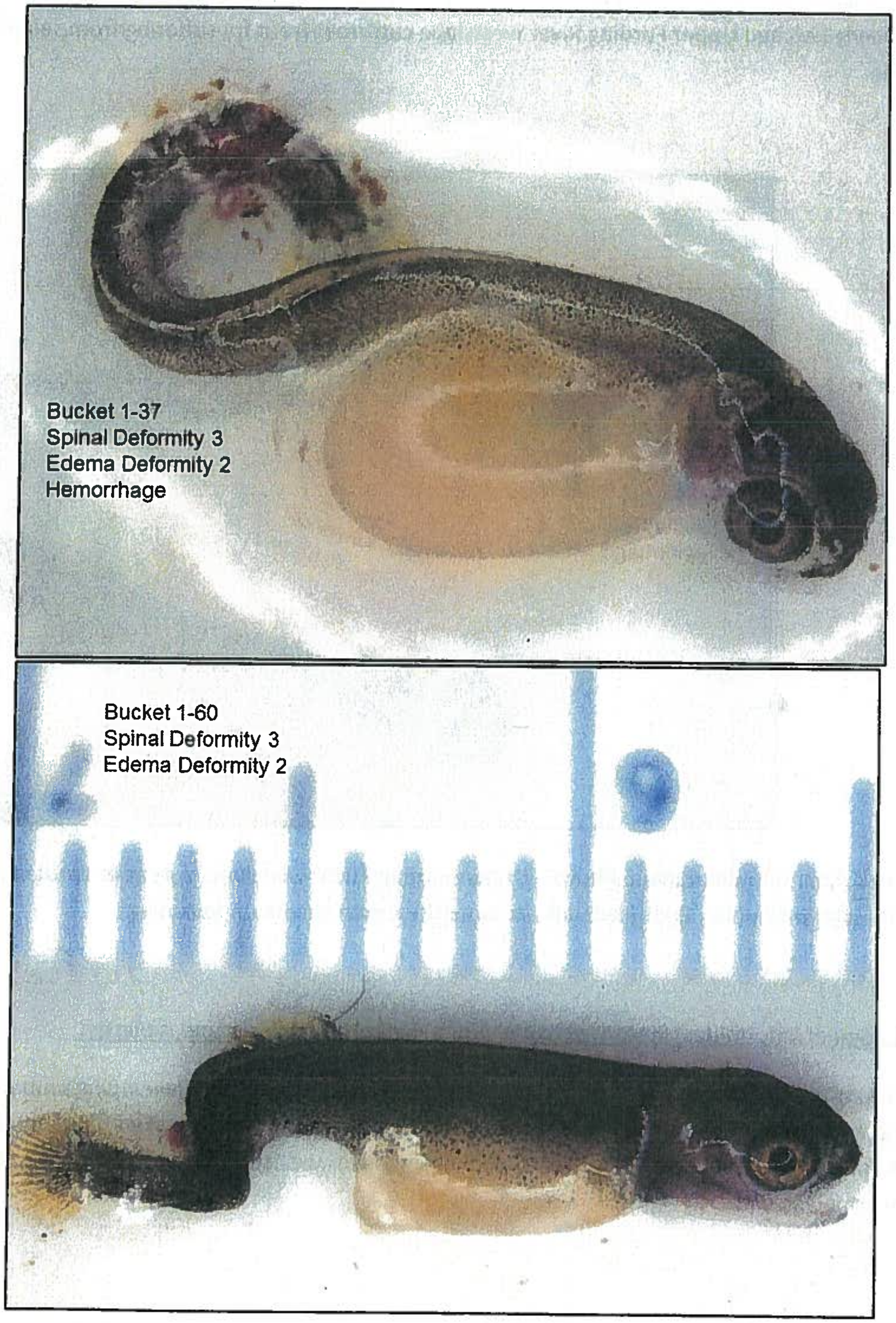
5.2.2 Edema

Selenium-caused edema is often lethal to newly hatched fry. As compared to Figure 3, edema presents as an accumulation of fluid in the abdomen within the yolk sac. This results from inhibition of normal fluid balance and physiological functioning of critical body processes. Figure 4 illustrates the appearance of a newly hatched Upper Fording River westslope cutthroat trout fry suffering from selenium-induced edema.

Figure 4. Environment Canada Photo – Upper Fording River westslope cutthroat trout sample Bucket 2-4 exhibiting distended, fluid-filled yolk sac consistent with selenium poisoning.

5.2.3 Spinal deformities (deformed spine due to kyphosis, lordosis, and scoliosis).

Selenium-caused spinal deformity can have a deleterious effect on the developing embryo and newly emergent fry by inhibiting the ability to swim, feed, and evade predators. Figure 5A and 5B illustrate these abnormalities in newly hatched upper Fording River westslope cutthroat trout fry (as compared to the normal individual in Figure 3).



Figures 5A and 5B. Environment Canada Photos – Upper Fording River westslope cutthroat trout sample Buckets 1-37 and 1-60; presents marked spinal deformities expressed as lordosis, kyphosis, and scoliosis.

5.2.4 Cranial Deformities

Selenium-caused cranial deformities (deformed skull and jaws) can have a deleterious effect on the developing embryo and newly emergent fry by preventing their ability to feed, inhibiting respiration by impairing movement of water over gills, and affecting olfaction (smell). Figure 6 presents this condition in a newly hatched upper Fording River westslope cutthroat trout fry, as compared to a normal individual in Figure 3.

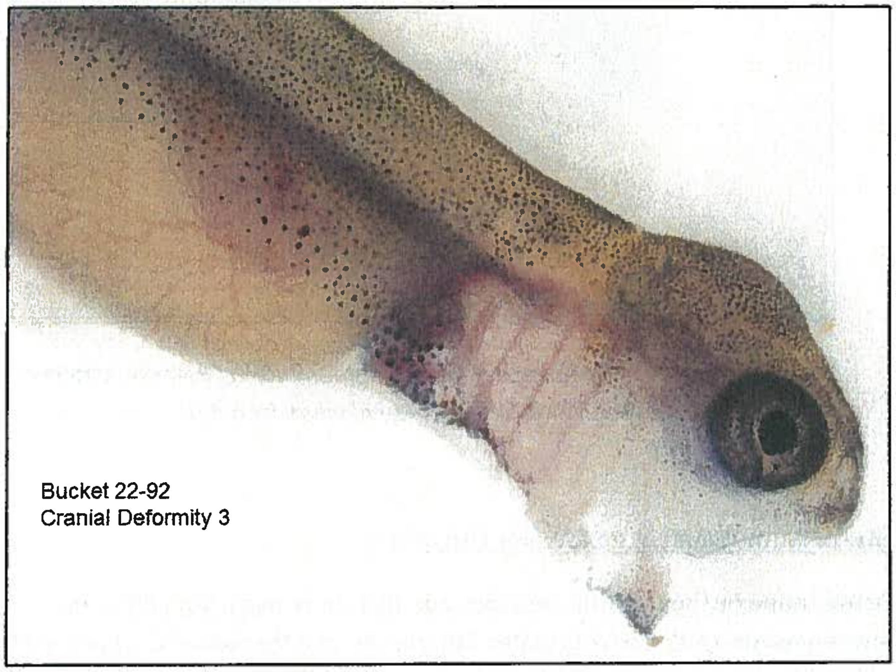


Figure 6. Environment Canada Photo – Upper Fording River westslope cutthroat trout sample Bucket 22-92 exhibits gaping, open mouth that will not close as well as concave cranium above the eye.

5.2.5 Finfold Deformities

Finfold deformities (deformed or missing fins) can have a deleterious effect on the developing embryo and newly emergent fry by retarding free movement and associated body orientation, feeding and evasion of predators. Figure 7 presents this condition in a newly hatched upper Fording River westslope cutthroat trout fry as compared to a normal individual in Figure 3.

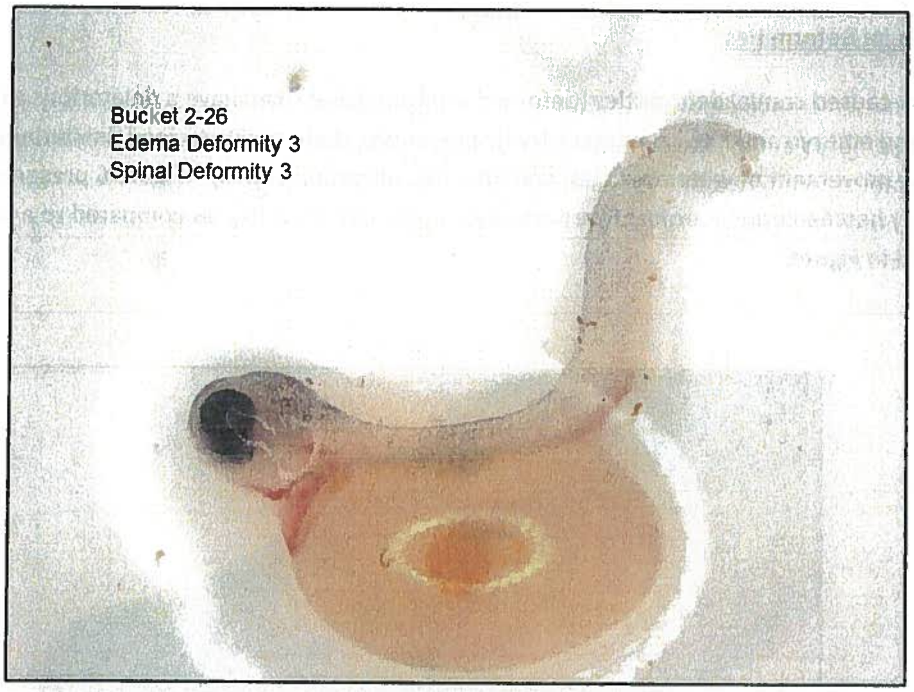


Figure 7. Environment Canada Photo – Upper Fording River westslope cutthroat trout, Bucket 22-92, exhibits finfold deformity of caudal and dorsal fin.

5.3 Sensitivity of Warm-Water vs. Cold-Water Fish Species

One of the issues raised by the scientific research was that there might be a difference in sensitivity to selenium between warm-water and cold water fish species, and that water quality guidelines and pollution-reduction measures implemented to protect warm-water species may be overly protective for cold-water fishes (Chapman 2007). With respect to the warm-water/cold-water question, it has been shown in Canadian studies that the sensitivity of cold-water northern pike and rainbow trout to selenium poisoning is equivalent to that of warm-water centrarchids, i.e., sunfish and bass (Muscatello et al. 2006, Holm et al. 2008). Also, a comprehensive review of tissue-based toxicity thresholds concluded that there is no scientific basis for establishing different toxicity thresholds for warm-water versus cold-water species (Hamilton 2003). As for the difference in sensitivity between cutthroat and rainbow or bull trout, the species sensitivity distribution compiled by Janz (et al. 2010, 2012) shows that cutthroat trout are more sensitive – the threshold EC10 (concentration affecting 10% of the test fish) for larval deformities or alevin mortality is lower for cutthroat trout (17 µg/g dw in eggs) than brown trout (18 µg/g dw in eggs), brook trout (20 µg/g dw in eggs), or rainbow trout (21 µg/g dw in eggs). Moreover, the distribution indicates that cutthroat trout are the most sensitive species to selenium poisoning, and that, as a group, warm-water fish are indistinguishable from cold-water fish because their range of sensitivity (19-22 µg/g dw in eggs) overlaps the sensitivity range of cold-water species (17-21 µg/g dw in eggs).

6.0 Was Environment Canada's Assessment and Test Process Acceptable?

Yes, the test methods and evaluation procedures used are scientifically correct and provide valid answers to the questions being asked. In addition to measuring environmental conditions and comparing concentrations of selenium in water, food-chain organisms, and fish to known toxic thresholds, Environment Canada chose to go a step further and used early life-stage (embryo-larval) bioassay, measuring survival and mortality coupled with deformity analysis, to do a rigorous site-specific assessment of selenium toxicity. Acceptably large quantities of viable eggs were obtained from both reference and test locations and successfully hatched, making the interpretive power of the assessment strong. This test process is correct for three primary reasons.

6.1 The Environment Canada Test Protocol Seeks to Simulate the Conditions Found in the Upper Fording River Environment.

In a real-world setting, selenium pollution from coal mining and other sources imparts toxic impacts to fish populations insidiously, through reproductive impairment brought on by embryo-larval toxicity, not overt acute or direct toxicity to adult fish (Lemly 1985, WVDEP 2010). Acute toxicity is a rapid response to high concentrations of a pollutant, whereas chronic toxicity results from long-term exposure to lower concentrations. Poisoning occurs more slowly, but often with similar symptoms and end results. Selenium from coal mining impacts fish populations in a chronic, gradual way. Selenium does not immediately kill the adult fish, but is transferred from parent fish to offspring through eggs. Therefore, the test protocol must simulate what happens to the eggs once they are laid and fertilized in the gravels of the Fording River. Upon hatching, the metabolized excess selenium exerts a variety of physiological and morphological effects such as teratogenic bone deformities, edema, and hemorrhaging (Janz 2012). The effects on newly hatched fish may be rapid (acute) and severe, even though the parent fish is largely unaffected. The Environment Canada test protocol is designed to simulate these conditions and measure the deformities and physiological effects that cause loss of mobility in young fish and increase their energy expenditures while feeding or fleeing predators. It is entirely appropriate and quite preferable to use embryo-larval bioassay to assess toxicity. I have examined the technique and technical data concerning the early life-stage bioassay provided by Environment Canada and found that it is a scientifically valid and acceptable method for determining selenium toxicity.

6.2 The Environment Canada Protocol Uses a Technique Called Graduated Severity Index (GSI).

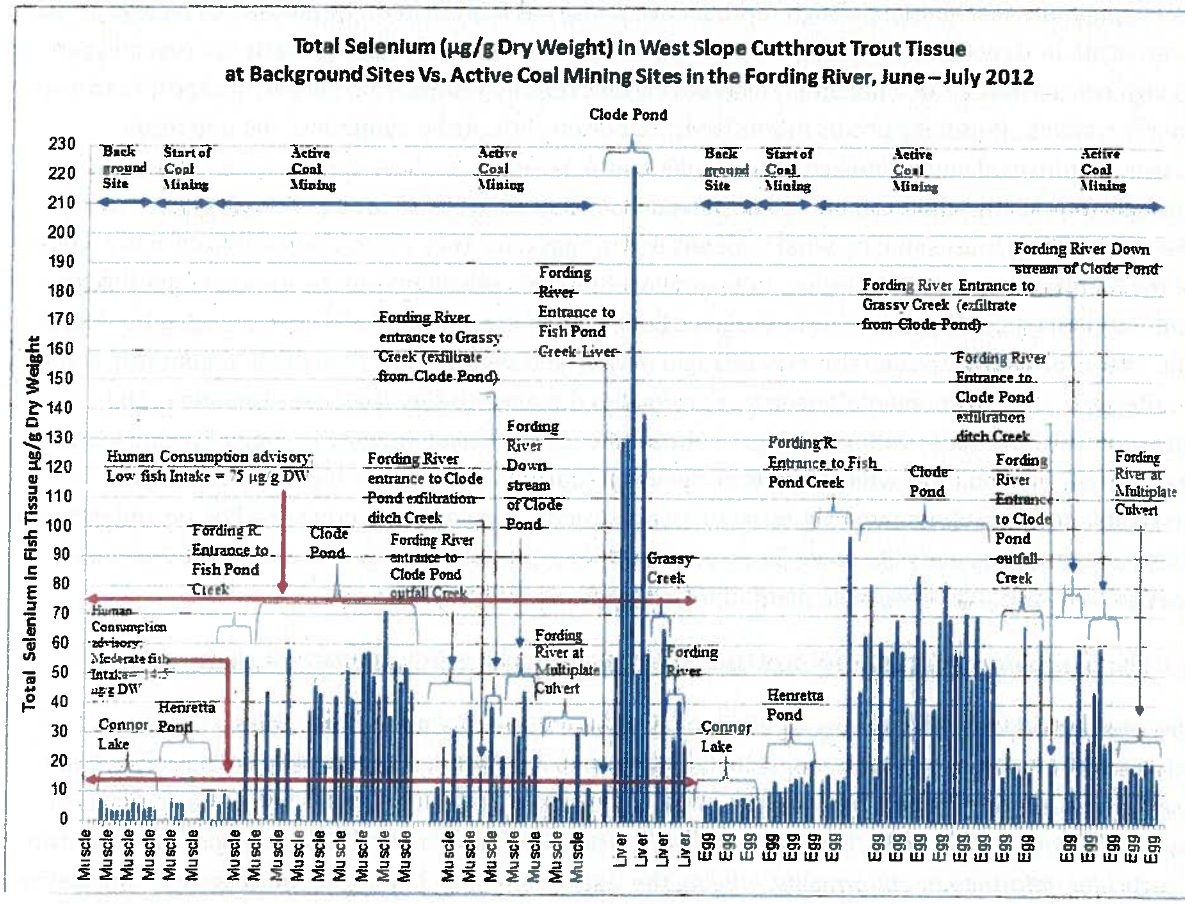
One method of deformity ranking is called the Graduated Severity Index (GSI). GSI is a routine and scientifically accepted procedure for selenium deformity evaluation in young fish, and has often been used previously by Canadian researchers investigating coal mining impacts, including the Fording River issue (Holm et al. 2003, 2005, Elphick et al. 2011). The GSI is based on a 1 to 3 ranking of the severity of a particular deformity or abnormality, 1 being the least severe and 3 being the most severe. The metrics utilized, that is, skeletal/spinal, craniofacial, and edema abnormalities are exactly what need to be assessed in order to obtain valid results. Deformity analysis coupled with rating or ranking the severity of morphological abnormalities is a commonly used technique to assign degree or level of toxic impact in early life stage selenium toxicity tests with fish (Formation 2012).

6.3 The Environment Canada Protocol Compares to Protocol Accepted by Other Jurisdictions.

The embryo-larval bioassay has been the standard assessment method to elucidate selenium toxicity for decades, dating back to the mid-1980s (Gillespie and Baumann 1986, Woock et al. 1987). It is a scientifically valid toxicity assessment method that is accepted by the United States Environmental Protection Agency for use in a variety of regulatory procedural contexts ranging from development of national water quality criteria to litigation in site-specific water pollution cases involving coal mining impacts similar to the Upper Fording River issue (USEPA 2010, 2013).

7.0 How Does Environment Canada's 2012-2014 Environmental Monitoring and Toxicity Test Results Compare to Other Studies/Tests/Papers?

Environment Canada plotted the selenium in egg concentrations in fish tissue from the Upper Fording River and the upper tributaries from the confluence with Henretta Creek, downstream to the Multiplate Culvert in 2012. (Environment Canada Figure 4-28A).

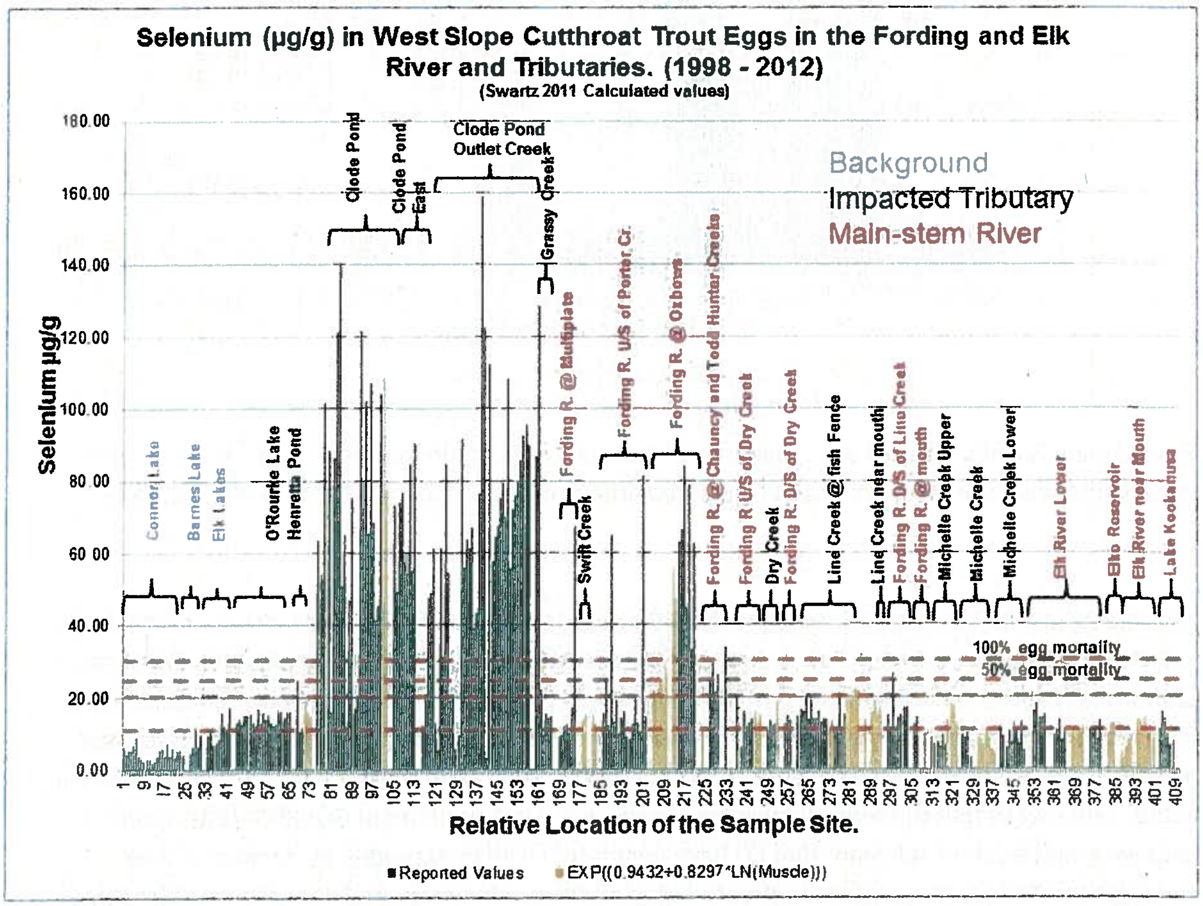


Environment Canada Figure 4-28A. Profile of selenium in egg, liver, and muscle tissue of westslope cutthroat trout in the Upper Fording River and its tributaries in June-July 2012.

Environment Canada compared the selenium in female westslope cutthroat muscle and egg tissue values collected in 2012 in the mining affected portion of the upper Fording River to the values reported for the Fording and Elk Rivers in McDonald 2013. This was done to determine the selenium profile in eggs found in females along the length of the Upper Fording River. McDonald's report contained the data but not the profile in Figure 4-28B. This profile was what highlighted the high selenium concentrations in females in the oxbows. The data in McDonald (2013) was re-organized chronologically and from upstream to downstream and at each reported site and re-plotted. Where only female muscle tissue was provided, Environment Canada 2012-2014 utilized two methods to calculate muscle to egg concentrations;

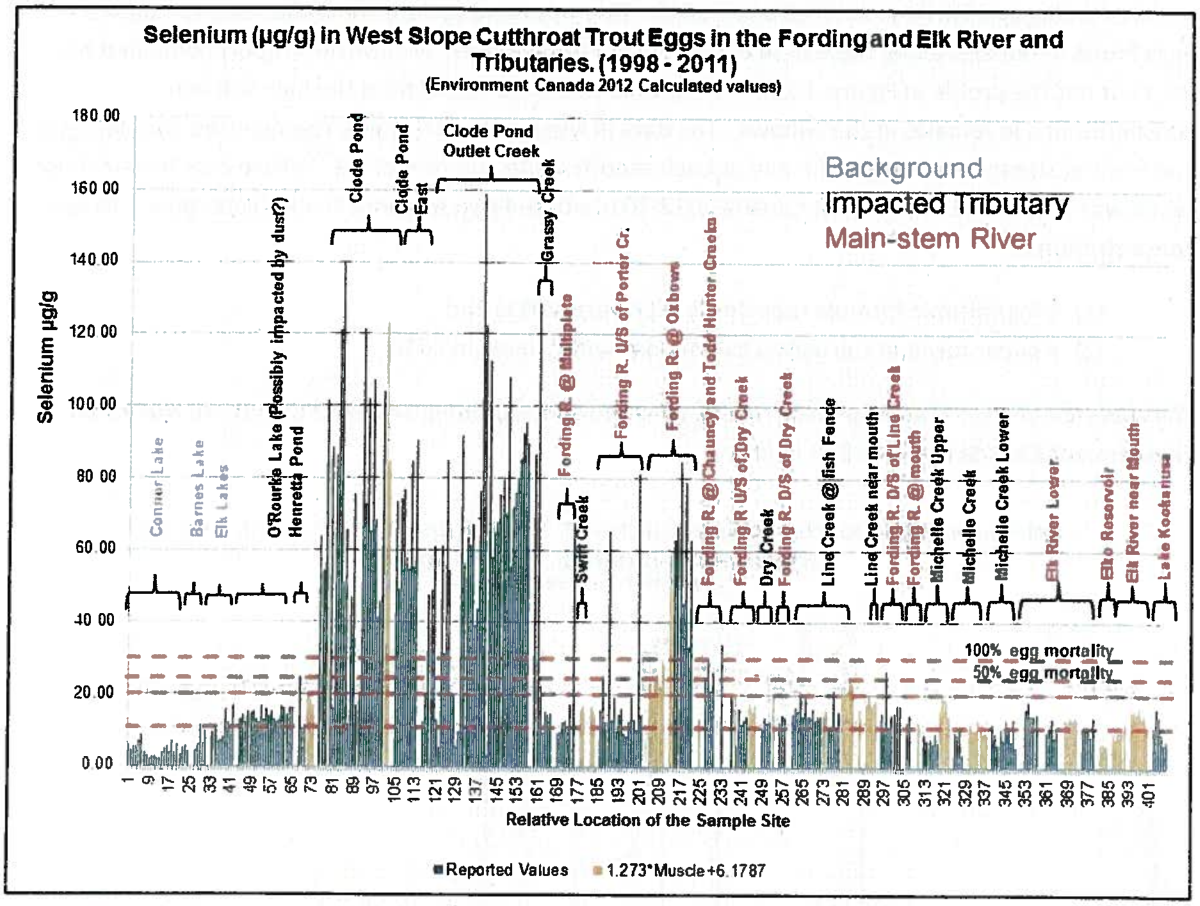
(1) a logarithmic formula reported by Schwarz (2011) and
(2) a linear formula calculated by Environment Canada in 2012.

The reported and calculated selenium in egg concentrations utilizing Schwartz (2011) are illustrated in Environment Canada Figure 4-28B below.



Environment Canada Figure 4-28B. Data from McDonald (2013) with muscle to egg conversion values as calculated using Schwarz (2011) $Egg_{concentration} = EXP((0.9432+0.8297*LN(Muscle)))$.

The reported and calculated selenium in egg concentrations utilizing a linear formula calculated by Environment Canada in 2012 are illustrated in Environment Canada Figure 4-28C below.



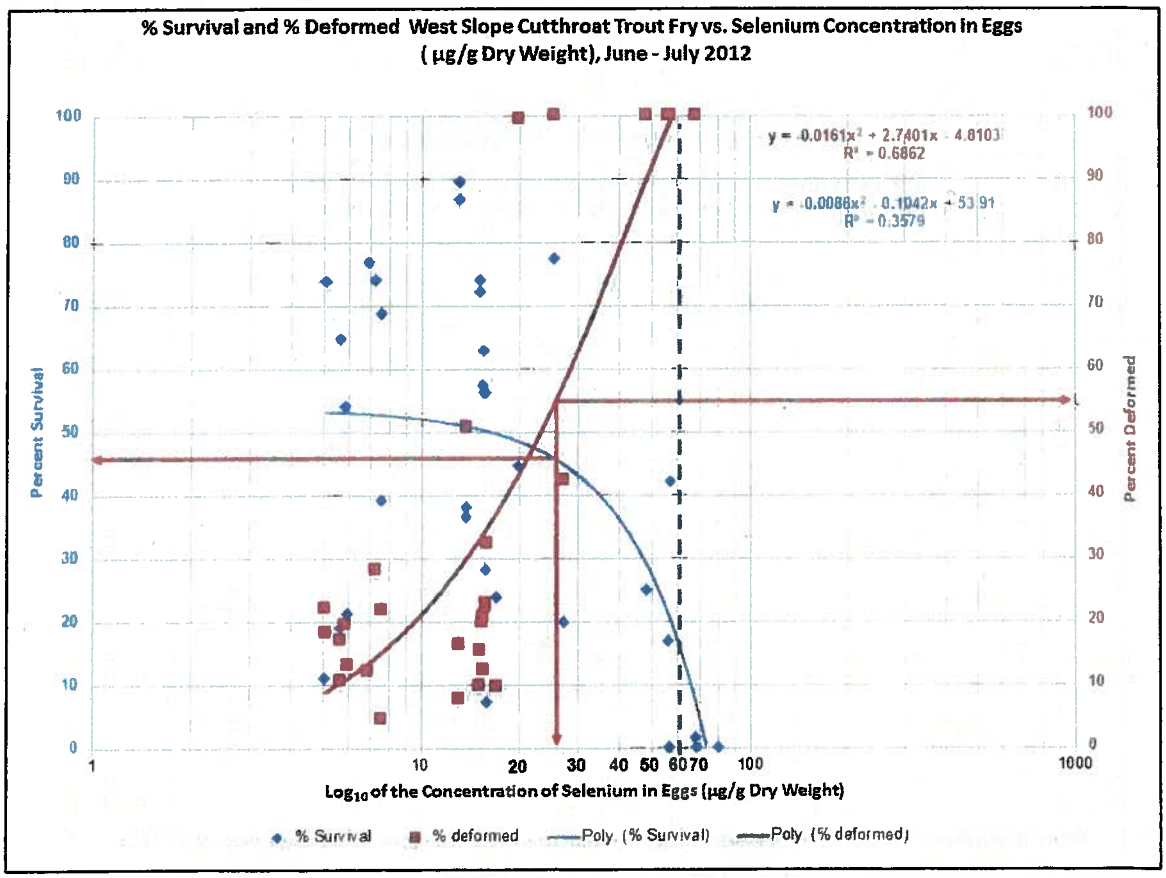
Environment Canada Figure 4-28C. Data from McDonald (2013) with muscle to egg conversion values as calculated using Environment Canada Linear Relationship $Egg_{concentration}$ = 1.273*Muscle + 6.1787.

Monitoring results indicate that the linear formula used by Environment Canada 2012 to calculate the muscle to egg selenium conversion in Figure 2-28C are comparable relative to measurements made in prior investigations. A comparison of monitoring results for 1996-2010 compiled by McDonald (2013) and calculated using the Schwarz (2011) formula shows that Environment Canada's 2012 calculated muscle to egg selenium ratio (EC Figure 4-28C) is slightly higher than those values calculated in EC Figure 4-28B. This means that the reproductive toxicity observed in Environment Canada's tests occurred at environmental levels of selenium that (1) have been confirmed or exceeded by numerous other investigators, and (2) have existed in the study region for several years, and are not a result of some recent unusual spike in selenium concentrations. Moreover, the selenium concentrations in eggs are very similar between Environment Canada 2012 and McDonald 2013, which further indicates a long-term trend of increasing selenium rather than a current event.

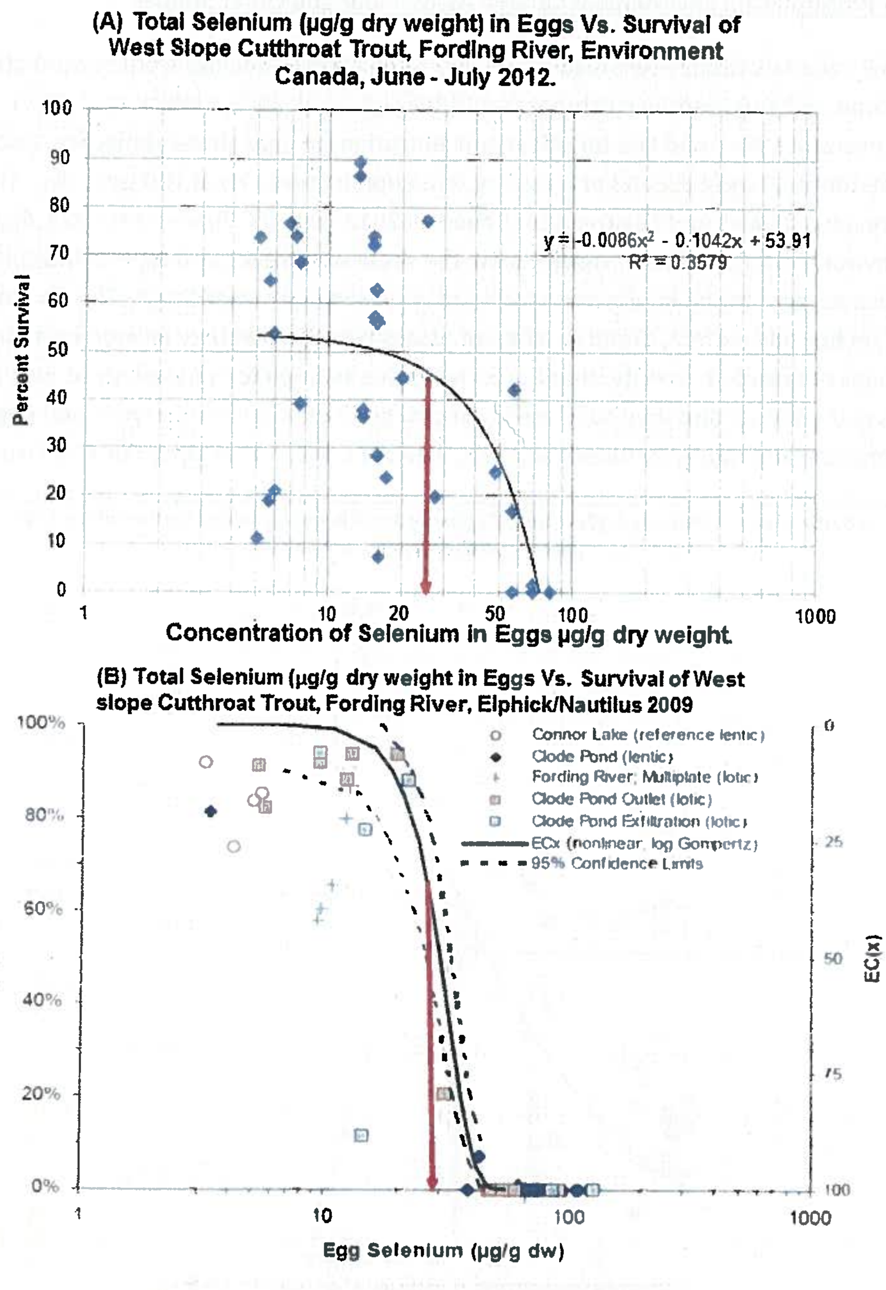
It is important to note that a significant peak in selenium in egg concentrations occurs in the area known as the Upper Fording River oxbows. This area was not sampled by Environment Canada in 2012 but see comments in section 7.4 that address pollution of the oxbow habitats.

7.1 Toxicity Profiles From Environment Canada Assessment and Other Studies.

Environment Canada's toxicity test results are very similar to the findings from several other studies of both westslope and Yellowstone cutthroat trout (Rudolph et al. 2008, Elphick et al. 2011, Formation 2012). For example, the trend line for effect concentrations in eggs shows deflection (mortality) beginning at about 10 µg/g dw and progressing to complete mortality at >50 µg/g dw. This is consistent between previous studies and Environment Canada's 2012 tests (EC Figures 4-43 to 4-46, Figure 9). Also, the Environment Canada test results show the same occurrence and type of morphological abnormalities as were found in previous studies of westslope cutthroat trout. The Environment Canada studies are technically correct, broad in scope of assessment (in that they include both direct and indirect modes of selenium toxicity, that is, mortality due to impaired physiology as well as skeletal deformities and edema), and they conclusively and definitively confirm the types and degree of deformity impacts and mortality thresholds for cutthroat trout in the Upper Fording River study area.

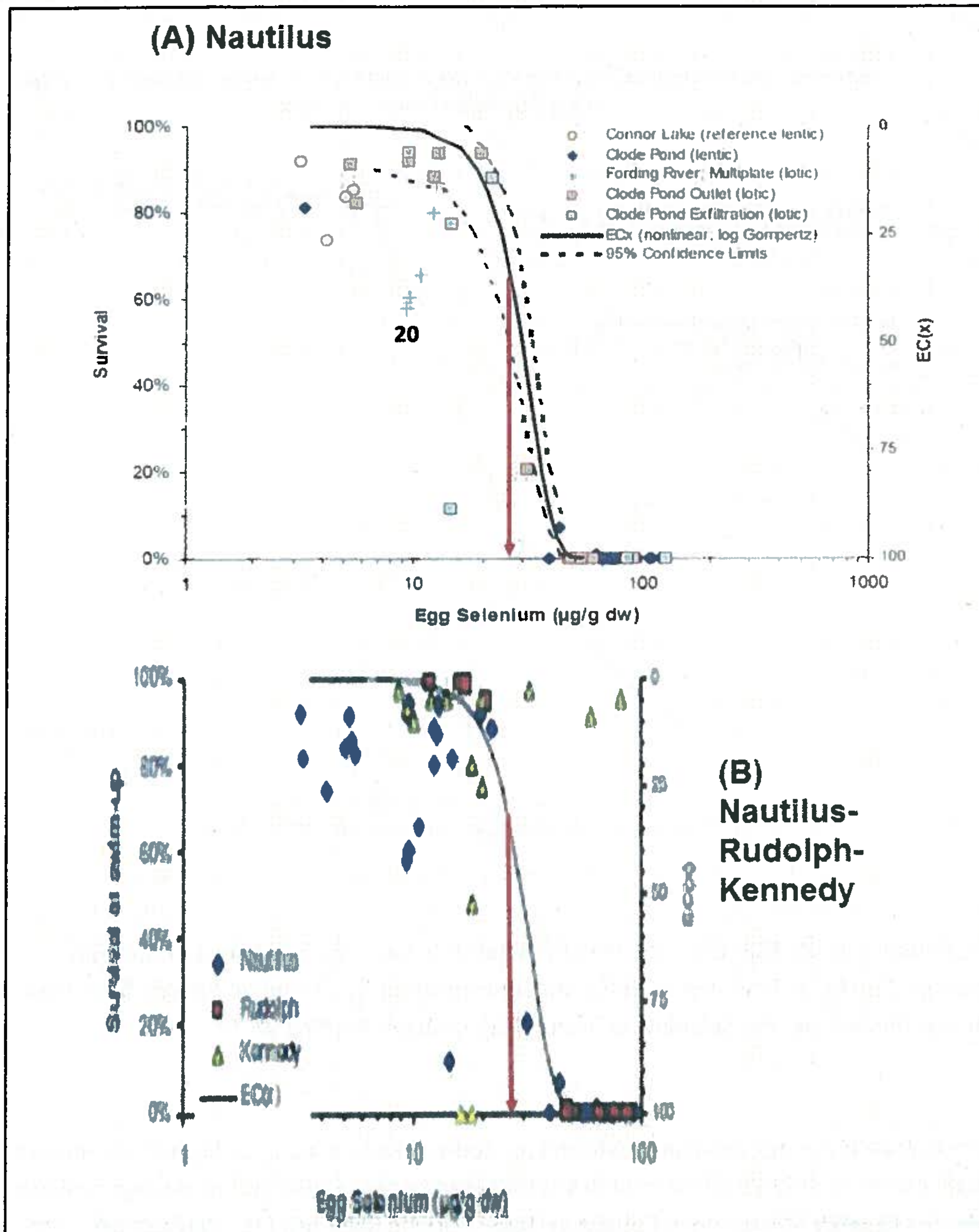


Environment Canada Figure 4 – 43. Percent Survival to Swim-up and Percent Deformity in Westslope Cutthroat Trout Fry vs. Selenium Concentration µg/g, June – July 2012. (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).



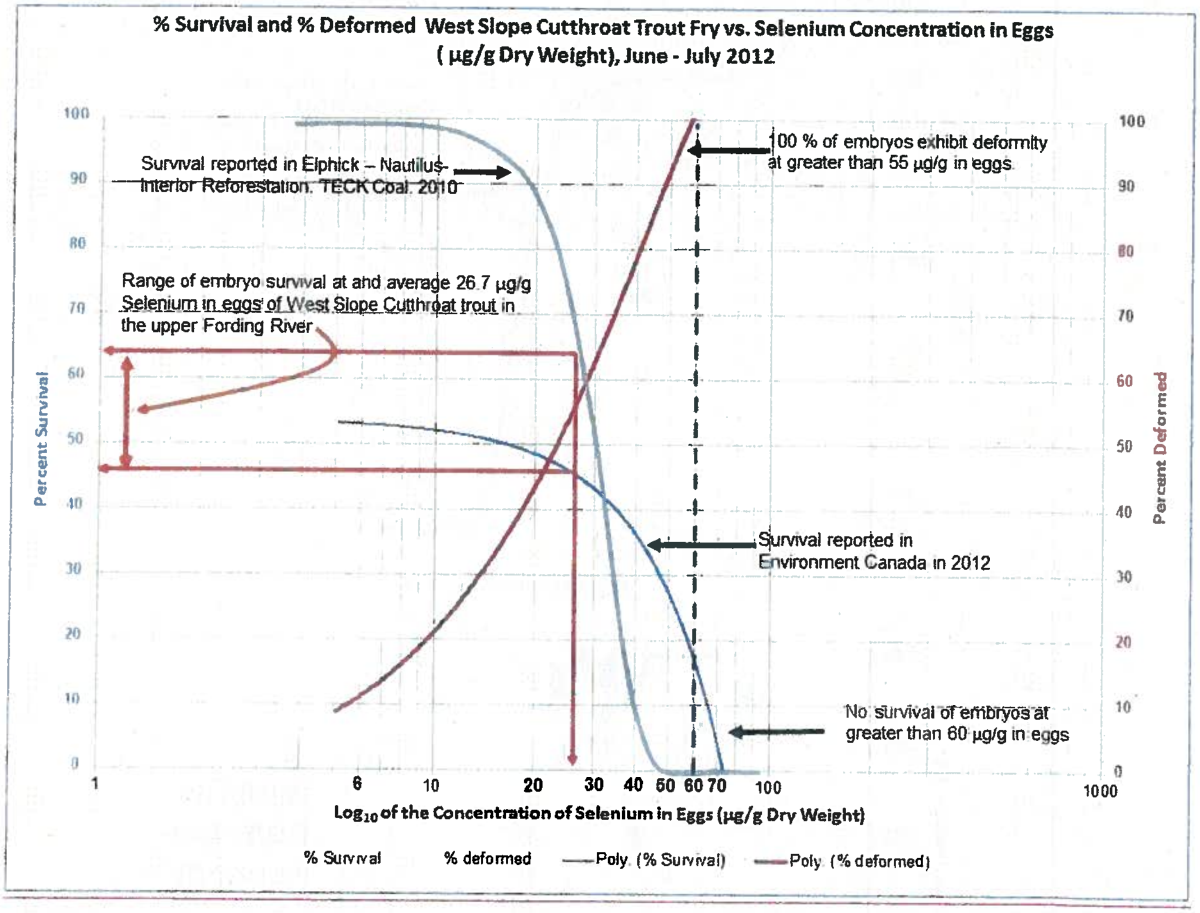
Note: Red Arrow equals mean selenium in egg concentration of 26.7 µg/g in Fording River Fish - 2012

Environment Canada Figure 4-44. (A) Percent Survival to Swim-up vs. Egg Selenium Concentration, Environment Canada 2012; (B) Nautilus Environmental, Teck Coal, Interior Reforestation, "Effect of Selenium on Early Life Stage Development of Westslope Cutthroat Trout", SETAC Poster 2009 and also Elphick et al. 2011 (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).



Note: Red Arrow equals mean selenium in egg concentration of 26.7 µg/g in Fording River Fish - 2012

Environment Canada Figure 4-45. (A) Percent Survival to Swim-up vs. Egg Selenium Concentration, (B) Nautilus Environmental, Teck Coal, Interior Reforestation, Rudolph, Kennedy "Effect of Selenium on Early Life Stage Development of Westslope Cutthroat Trout", SETAC Poster 2009 and Elphick et al. 2011 (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).



Environment Canada Figure 4 – 46. Percent Survival to Swim-up and Percent Deformity in Westslope Cutthroat Trout Fry vs. Selenium Concentration, Environment Canada 2012 (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).

The relationships between egg selenium, deformities, and survival shown in EC Figure 4-46 indicate that a substantial amount of embryo-larval mortality is expected to occur, even at the average concentration of selenium measured by Environment Canada in Upper Fording River fish (26.7 µg/g Se dw). The total cumulative mortality of combined pre-swim-up toxicity and post-swim-up teratogenic deformities is 54.5% when the entire range of selenium concentrations and effects measured by Environment Canada is included (see page 47). If only the average egg selenium concentration of 26.7 µg/g measured in the EC Study is considered, the corresponding cumulative mortality is estimated to be 48% based on a pre-swim-up mortality rate of 8% (54% - 46% estimated from EC polynomial regression line) and a post swim-up deformity rate of about 50% (estimated from EC polynomial regression line), with 80% mortality expected in that group (for a total of 40% deformity mortality, Lemly 1997). This means that at an egg selenium concentration of 26.7 µg/g, teratogenic-caused death may be a greater mortality factor than pre-swim-up toxicity. This relationship changes as selenium concentrations rise, so that when egg selenium reaches 60 µg/g, there are so few post swim-up survivors that virtually all mortality is from pre-swim-up toxicity. The number of embryos lost to selenium poisoning thus varies from 0% at the reference condition of about 5 µg Se/g in eggs, to 48% at the average concentration of 26.7 µg/g measured in Upper Fording River fish, to 100% at about 60 µg/g (Figure 8).

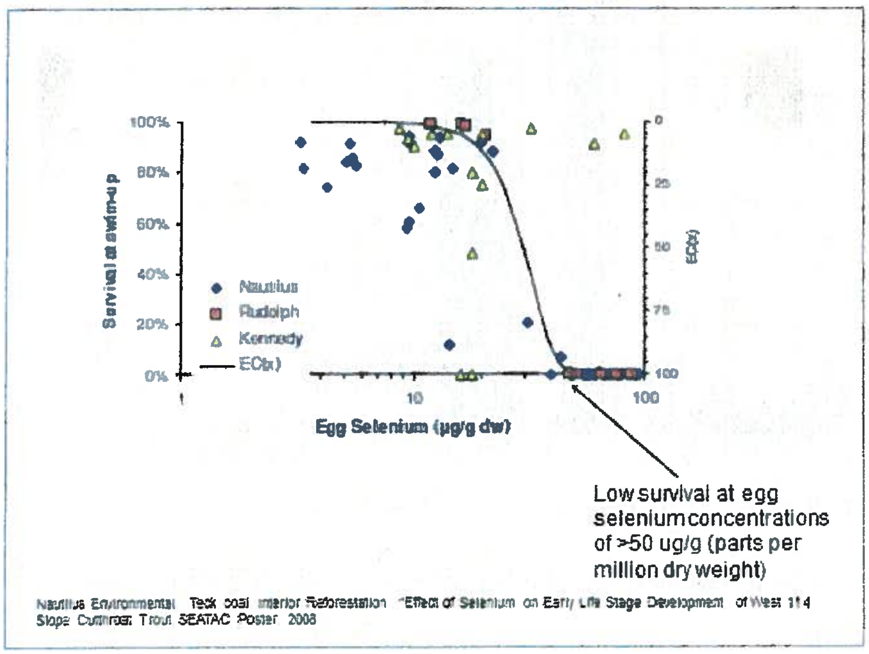
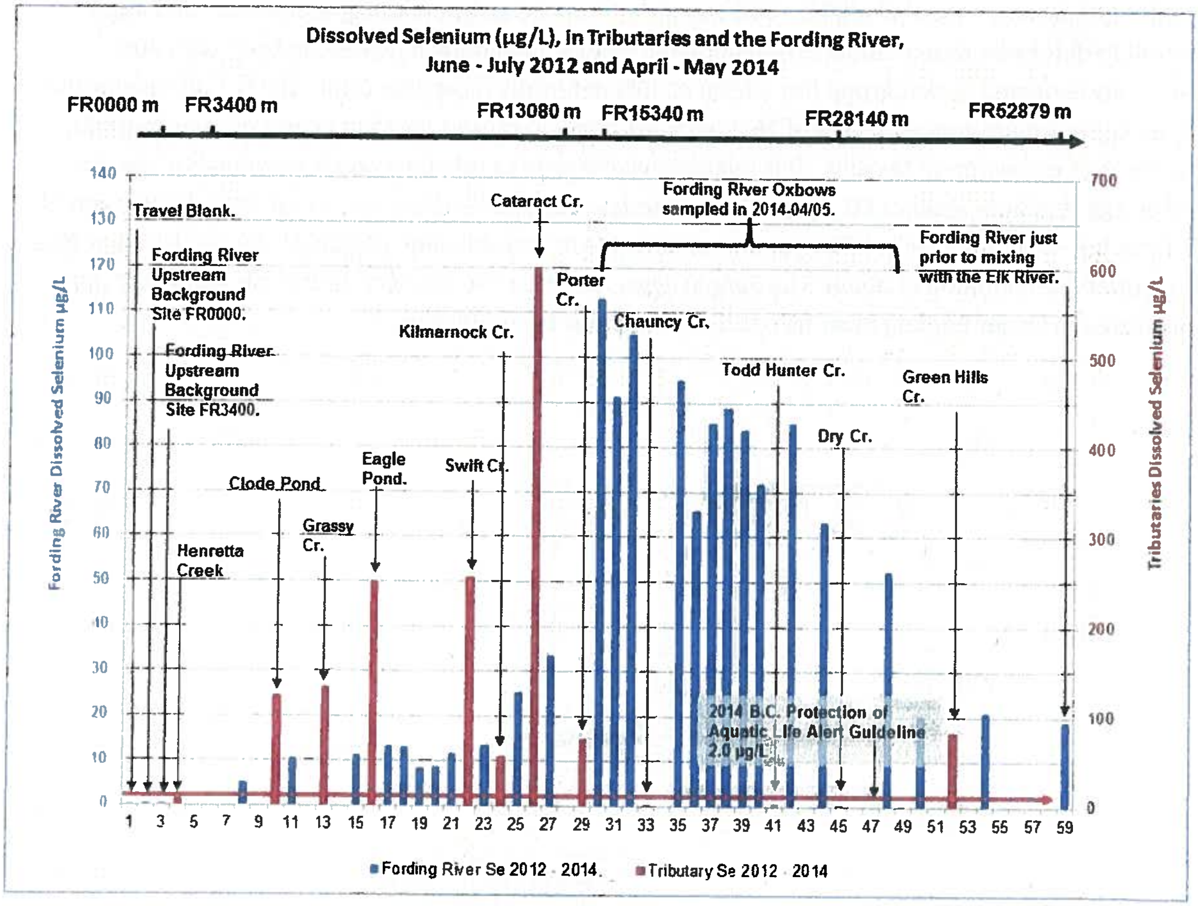


Figure 8. Dose-response curve showing toxicity beginning at about 10 µg/g dw in eggs, progressing to complete mortality at > 50 µg/g dw (Nautilus Environmental, Teck Coal, Interior Reforestation, Rudolph, Kennedy SETAC Poster 2009 and Elphick et al. 2011).

7.2 Comparison of Reference Sites to Coal Mine Impacted Sites

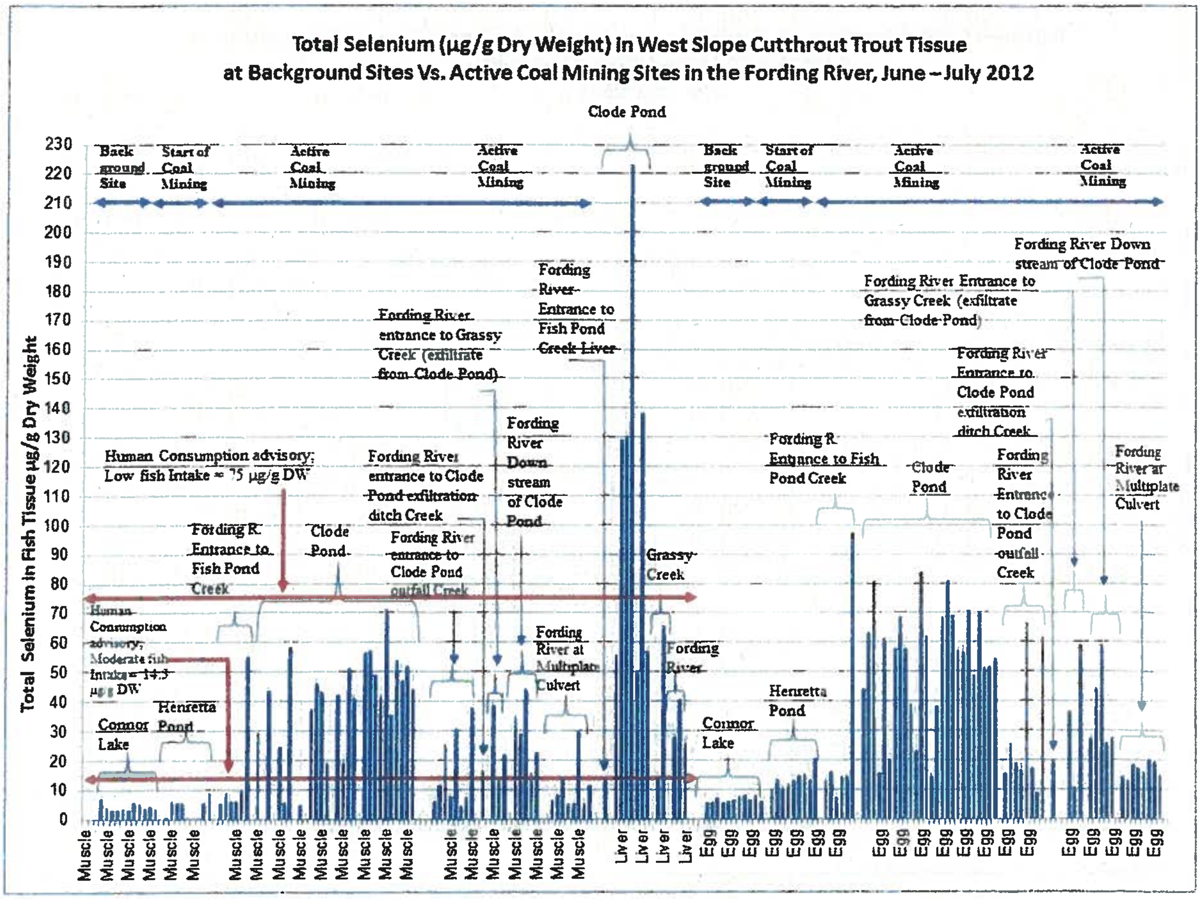
The Environment Canada study uses reference sites to compare against coal mining impacted sites in the Upper Fording River. Comparison with reference sites not influenced by coal mining operations is useful to demonstrate the source and magnitude of impacts. The use of reference sites in combination with sampling of numerous tributary creeks and seeps draining mine tailings provide additional confirmatory evidence of the cause-effect linkage between selenium source (coal mining) and biological impacts on fish. Environment Canada's Figure 4-17B shows the strong influence that tributary inputs have on selenium levels in the Upper Fording River.



Environment Canada Figure 4-17B. Concentrations of selenium in tributary streams and the Upper Fording River.

7.3 Correlations Between Selenium Concentrations in Westslope Cutthroat Trout Tissue and Eggs and Toxic Impacts.

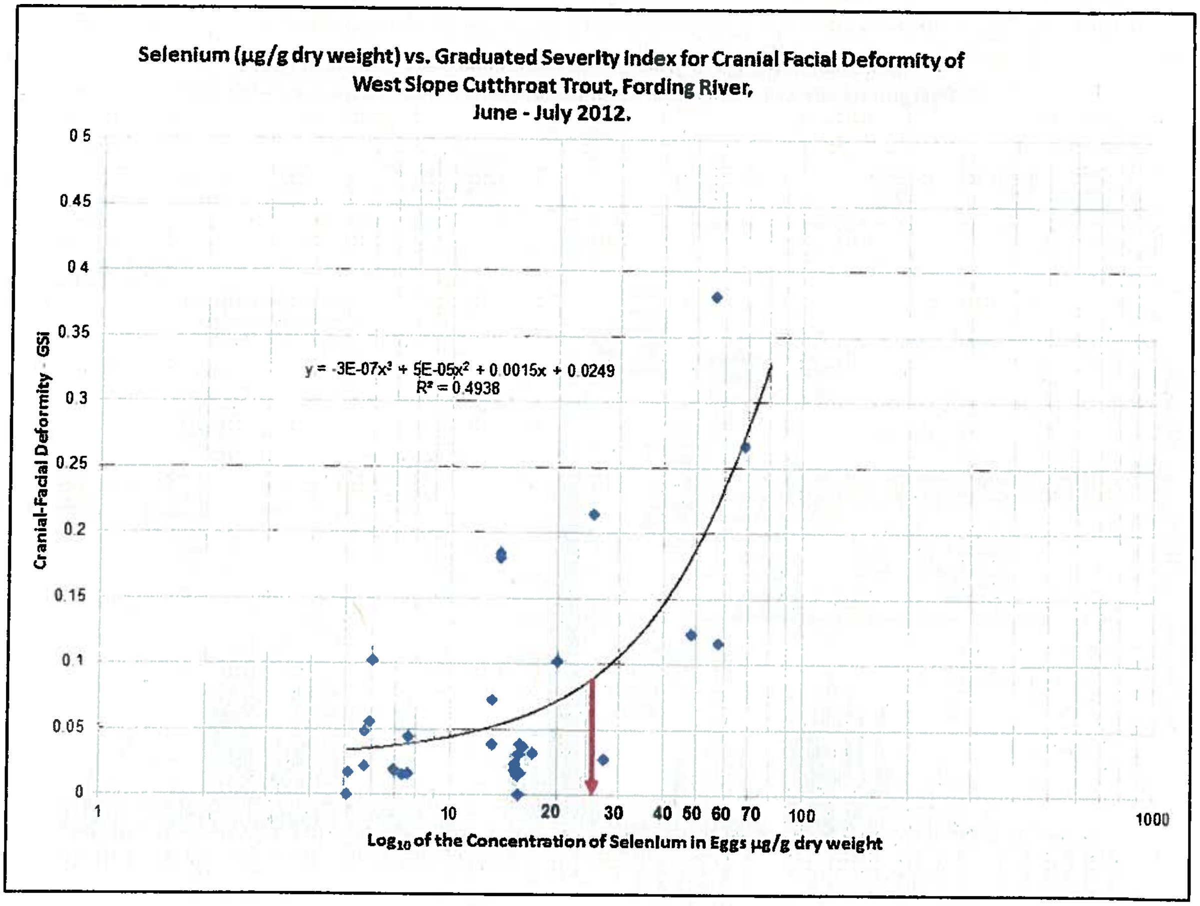
The Environment Canada study found that there were strong positive correlations between increasing concentrations of selenium in tissue (muscle and liver) and eggs and larvae, and increased mortality and incidence and severity of deformities, particularly, the teratogenic skeletal and craniofacial deformities that are biomarkers of selenium poisoning. Environment Canada Figure 4-28A shows the distinct and large site-specific differences in tissue and egg selenium concentration in the study area.



Environment Canada Figure 4-28A. Profile of selenium in egg, liver, and muscle tissue of westslope cutthroat trout in the Upper Fording River and its tributaries.

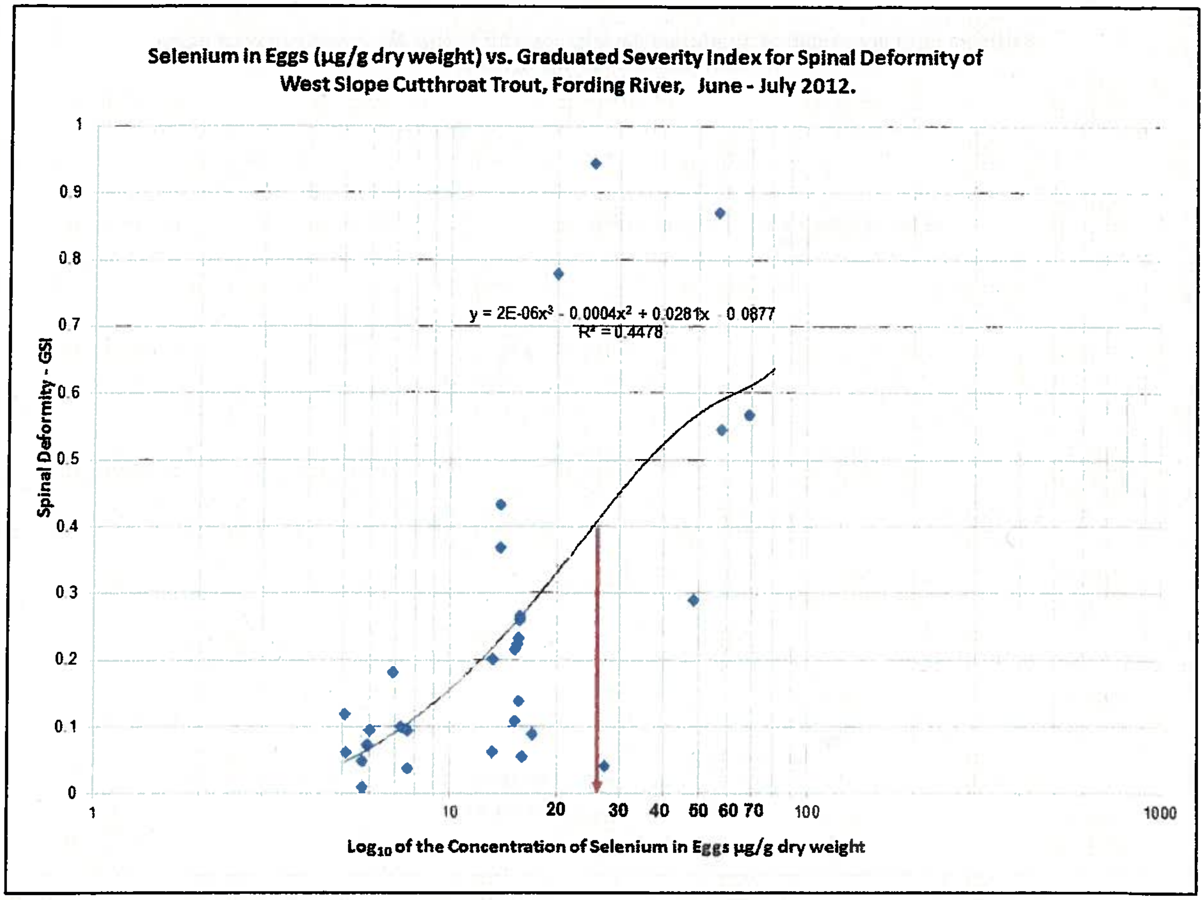
Several important points emerge from EC Figure 4-28A. First, there is a clear and strong trend of substantially elevated selenium levels in fish at sites that are influenced by mining activity, that is, elevated by 5-200 times the concentrations present under non-mining reference conditions. Second, the magnitude of these elevated tissue selenium levels in fish is toxicologically significant for the fish themselves as well as humans, as evidenced by substantial exceedances of the Fish Consumption Advisory Levels for Humans (red arrows) at virtually all active mining locations, and vast exceedance of fish toxicity thresholds for muscle and eggs (toxic thresholds = 8 µg/g Se for muscle, 10 µg/g Se for eggs, 12 µg/g Se for liver, Lemly 1993d, 2002b; measured concentrations reached 70 µg/g for muscle, 98 µg/g for eggs, and 220 µg/g for liver). Third, the scientific literature indicates that these levels of selenium have the potential to completely eradicate fish populations in a local, closed aquatic environment such as the Upper Fording River (Lemly 2002a).

The toxicological significance of these measured environmental concentrations of selenium to fish is further illustrated and explained in the following 5 figures.



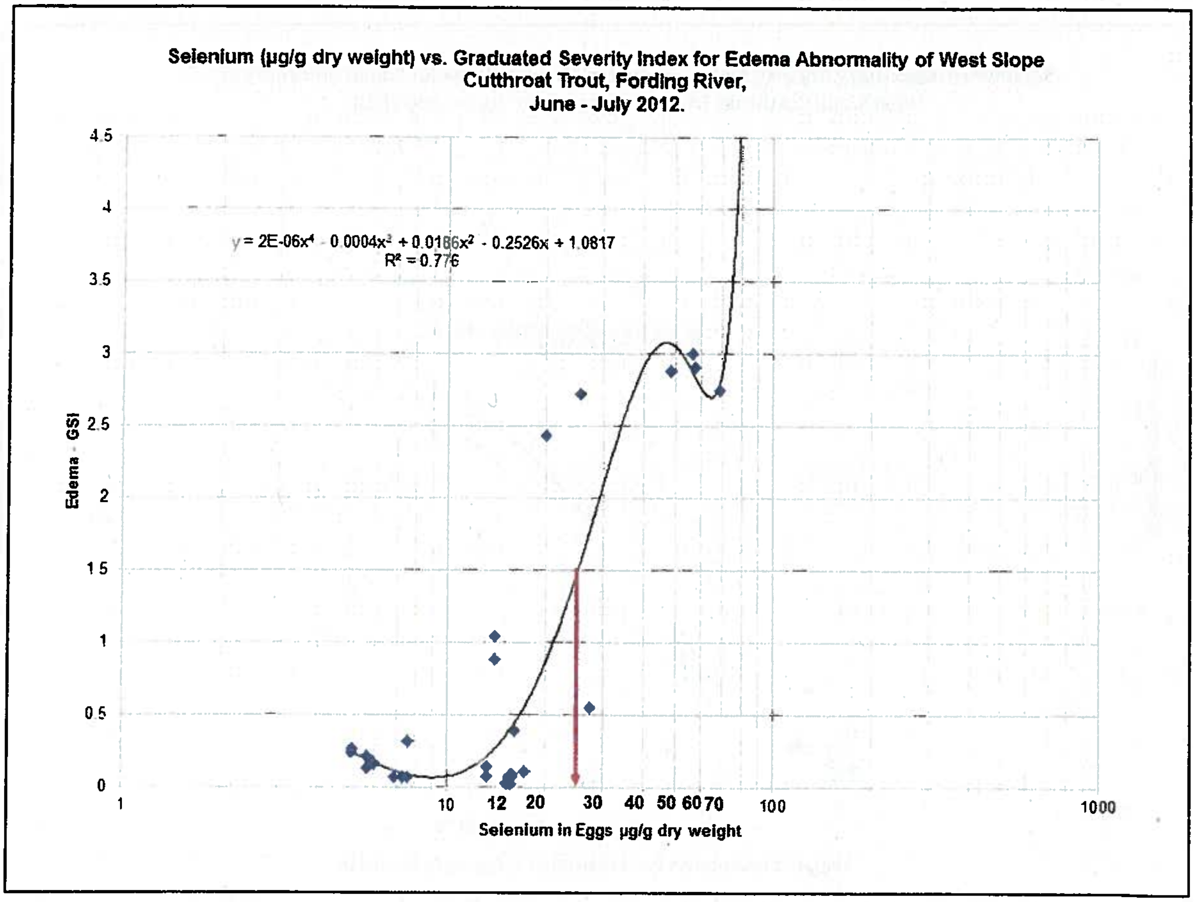
Environment Canada Figure 4-33. Concentration of Selenium in Eggs vs. Cranial Facial Graduated Severity Deformity Index. (Red arrow indicates the mean concentration of selenium in eggs in the Upper Fording River WCT).

The threshold for increased terata that are manifest as craniofacial deformities is about 10 ug/g Se, and ramps up sharply as egg selenium concentrations approach the average level found in Upper Fording River fish (26.7 ug/g Se, red arrow, EC Assessment Fig. 4-33). The severity of these deleterious effects is strongly correlated with egg selenium levels.



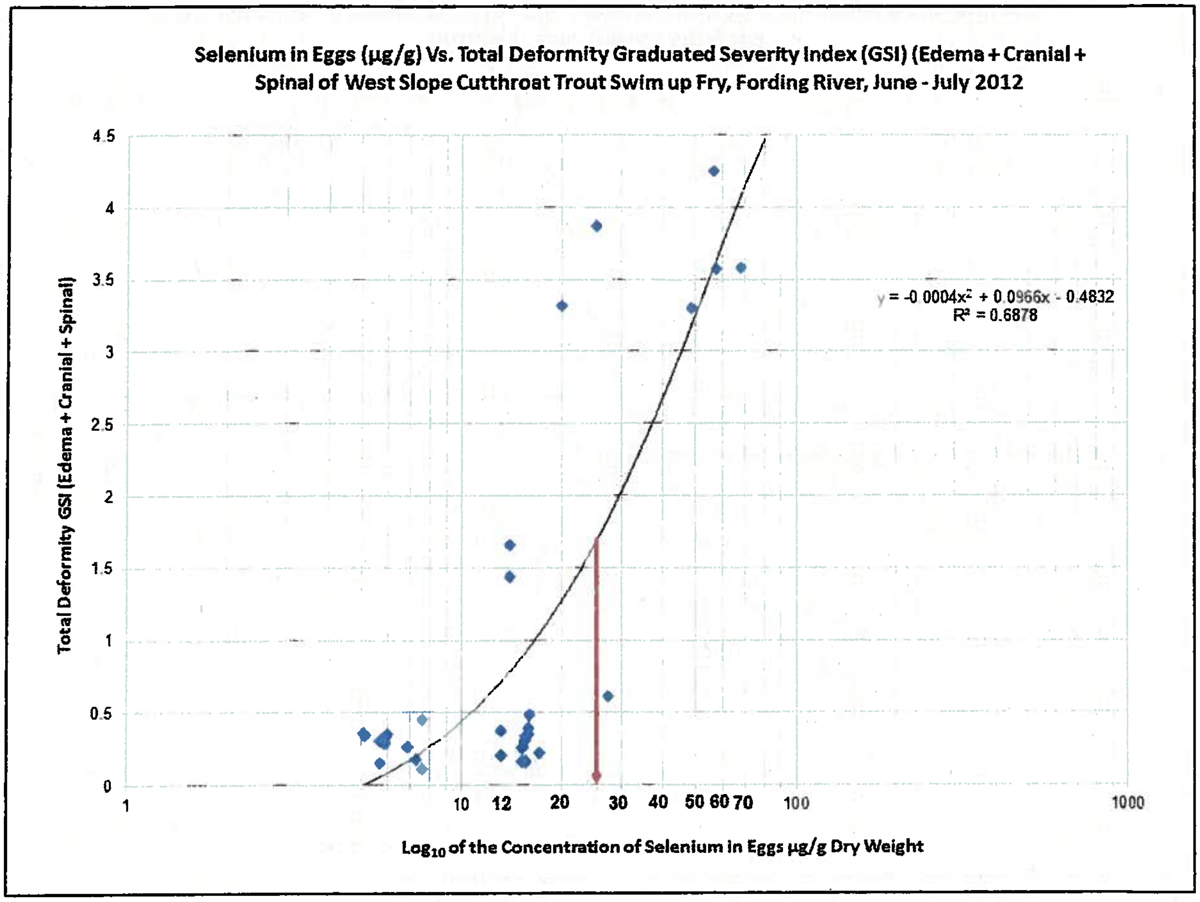
Environment Canada Figure 4-37. Concentration of Selenium in Eggs (dry weight) vs. Spinal Graduated Severity Deformity Index. (Red arrow indicates the average concentration of egg selenium in Upper Fording River WCT).

Similar to the trend for craniofacial abnormalities, the incidence and severity of spinal deformities is strongly correlated to egg selenium levels. The degree of effects that occur at the average egg selenium concentration measured in Upper Fording River fish (26.7 ug/g Se, red arrow) shows a high incidence of severe deformation, which rises rapidly from a threshold level of about 8 ug/g Se in eggs (Environment Canada Figure 4-37).



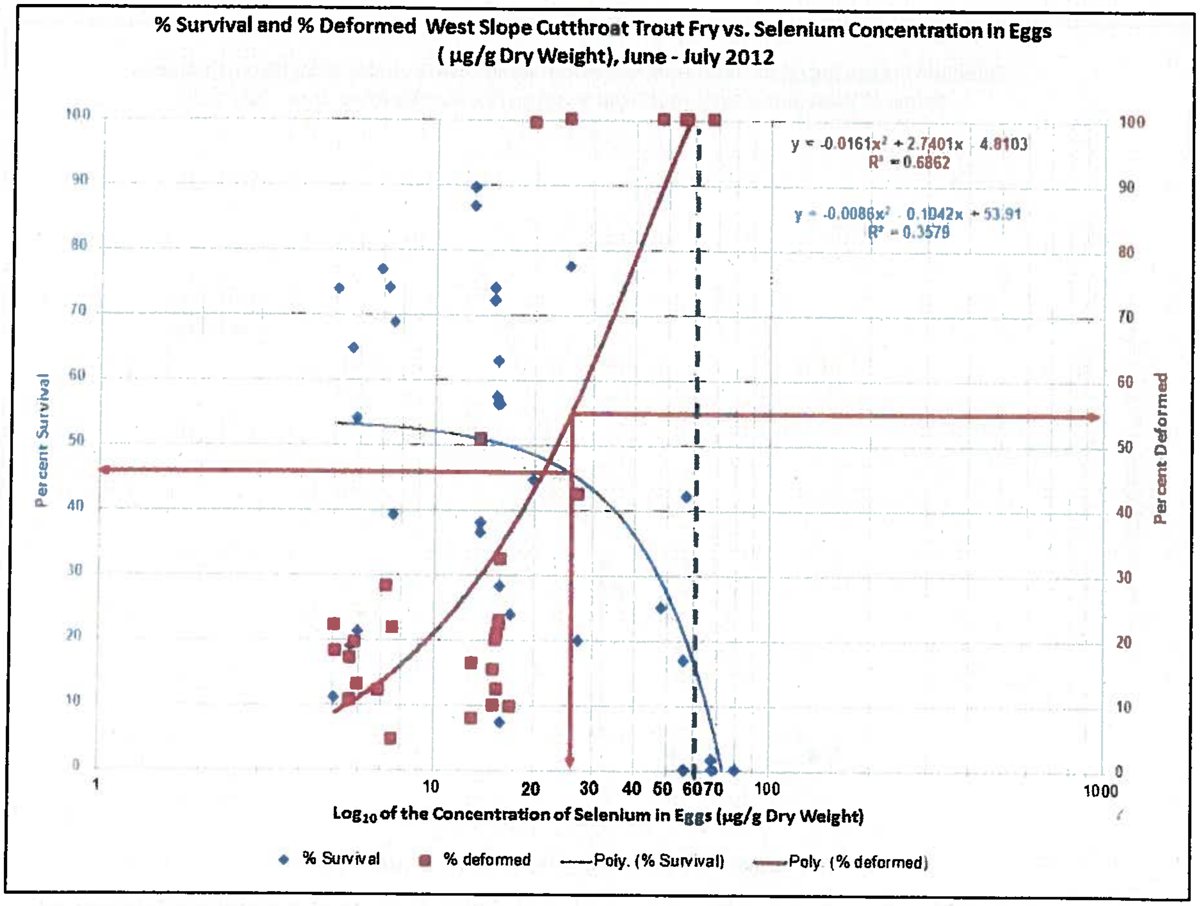
Environment Canada Figure 4-40. Selenium concentration in eggs versus GSI score of edema abnormality. (Red arrow indicates the average egg selenium concentration in Upper Fording WCT)

The finding of a high incidence of edematous larvae (swelling caused by accumulated body fluid) is indicative of acute selenium poisoning (Lemly 1993a, 1997) and this condition has been observed in a variety of fish reproduction studies in both Canada and the USA (Gillespie and Baumann 1986, Woock et al. 1987, Holm et al. 2005, Muscatello et al. 2006, Rudolph et al. 2008, Elphick et al. 2011, Formation 2012). The Environment Canada study (EC Figure 4-40) found a very strong positive correlation between concentration of selenium in eggs and incidence and severity of edema abnormality, beginning at a threshold level of about 11 ug/g Se and rapidly escalating as concentrations approach the average level found in Upper Fording River fish (26.7 ug/g Se, red arrow).



Environment Canada Figure 4-42. Westslope Cutthroat Trout swim-up fry from the Upper Fording River – Total Graduated Severity Index Deformity Score (spinal + cranial-facial + edema deformities). (Red arrow indicates the average concentration of egg selenium in Upper Fording River WCT).

Considering the major morphological categories together yields a clear picture of the strength of correlation between egg selenium and severity of abnormalities. From a threshold level of about 8 µg/g Se, the degree of severity ramps up nearly exponentially as concentrations approach the average that was found in Upper Fording River fish (26.7 ug/g Se, red arrow, EC Figure 4-42).



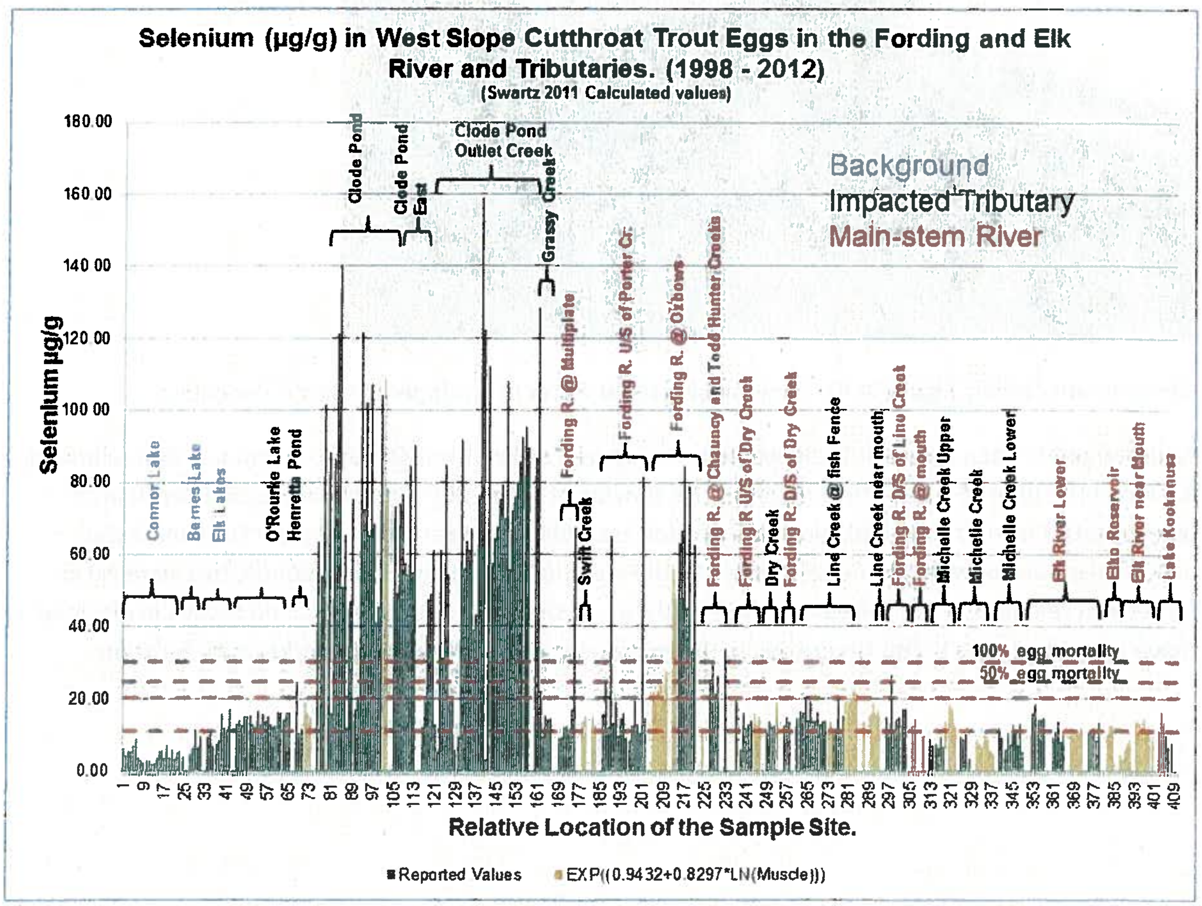
Environment Canada Figure 4-43. Concentration of selenium in westslope cutthroat trout eggs vs. survival to swim-up. (Red arrow indicates the average concentration of egg selenium in Upper Fording River WCT).

In toxicology studies, a common effect measurement is "mortality to swim up", which means the proportion of fish that die just after hatching but before they reach a mobile, free swimming stage. The Environment Canada study determined that the threshold for increased mortality to swim-up is approximately 10 µg/g Se dry weight in eggs (EC Assessment Fig. 4-43). The threshold for deformities seems to be about 7-8 ug/g Se. The egg toxicity thresholds for mortality and deformity in westslope cutthroat trout that were determined in the Environment Canada study are in close agreement with the general fish toxicity threshold level of 10 µg/g Se that has been published in the scientific literature for 2 decades (Lemly 1993b).

Also notable from EC Figure 4-43 is the close congruence of effects levels for mortality and deformity at the average tissue concentration of selenium measured in Upper Fording River fish (26.7 ug/g Se, red arrows). Survival drops to 46% at this average, while the incidence of deformities rises by roughly the same amount (about 50%). The polynomial regression lines describing these two components intersect within that 46-50% window. Additive losses from selenium poisoning manifest in pre-swim up deaths and post-swim-up teratogenic mortality would be expected from these two key components of toxic impacts (Lemly 2002b), which suggests that my estimate of 54.6% total mortality (see page 46) is reasonable and likely conservative.

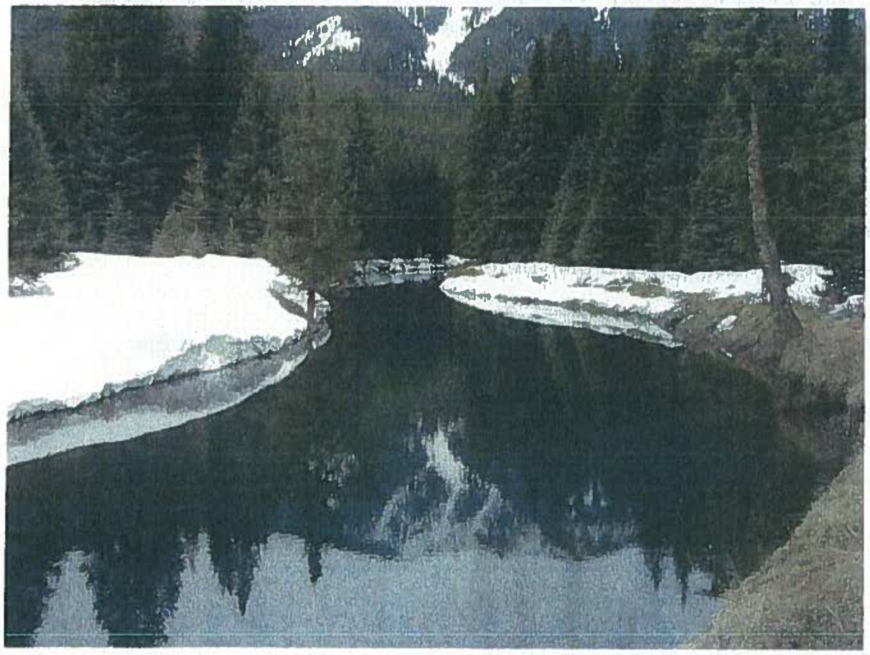
7.4 <u>Toxicological Implications and Assessment of Oxbows in the Upper Fording River.</u>

The McDonald 2013 report reveals a very important point about the pattern and degree of selenium bioaccumulation in the study area. The concentrations of selenium in fish collected from oxbows in the river were consistently greater, usually much greater, than at other collection sites upstream and downstream (20-80 µg/g in eggs of fish in oxbows versus 10-20 µg/g at other sites) with the exception of Clode Pond (Clode pond is an exception because it is an upstream tributary where selenium averaged 122 to 193 µg/L, see EC Figure 4-23B below). This has great toxicological significance with respect to both adult fish and young fish that reside in the main stem river. The oxbow environment results in higher bioaccumulation and associated toxic hazard than other locations.



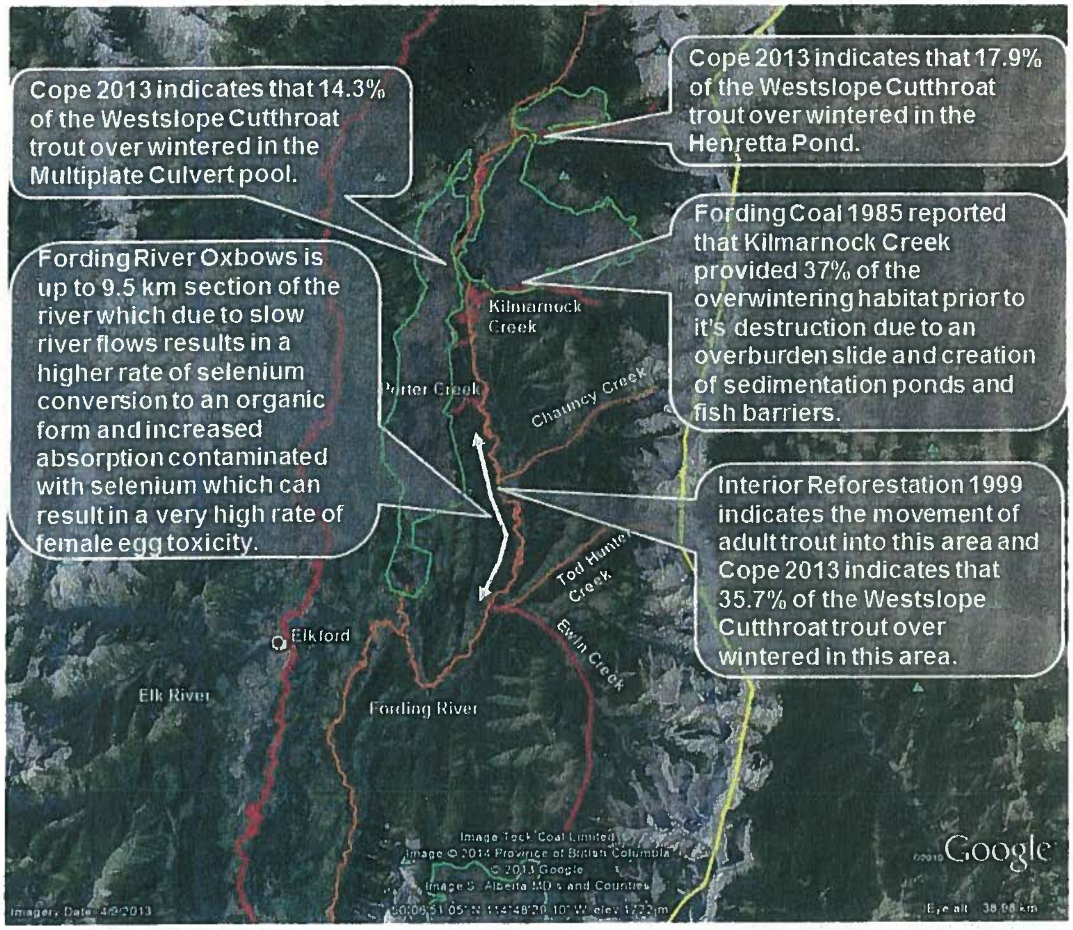
Environment Canada Figure 4-28B. Data from McDonald (2013) calculated by Schwarz (2011) indicating the location of the Upper Fording River Oxbows.

Oxbows, or U-shaped bends, in the Upper Fording River present a particularly important ecological scenario with respect to selenium bioaccumulation and toxicity in westslope cutthroat trout, and the associated need for corrective actions to reduce upstream selenium discharges from coal mining. In a river system, oxbows cause a somewhat uncharacteristic reduction in flow and result in an aquatic environment that can be more similar to a lacustrine habitat than the relatively rapid-flow, shallow-water lotic conditions that are present both upstream and downstream. (See Figure EC 3-30 below)



Environment Canada Figure 3-30. Slow-moving deep water in an Upper Fording River oxbow.

Environment Canada Figure 3-21 shows that the Upper Fording River Oxbows encompass approximately 9.5 km of the upper Fording River habitat. The slowing of water flow rate and increased depth in an oxbow results in enhanced biological primary and secondary productivity, and associated increased biological uptake of waterborne selenium into the aquatic food chain. Consequently, this increase in food-chain selenium is translated into increased dietary selenium intake by fish, and results in elevated tissue selenium levels in fish that reside in the oxbow environment relative to other river locations.



Environment Canada Figure 3-21. Location of the Upper Fording River oxbows.

Not surprisingly, the slow-water oxbows are often sought out and used as a prime feeding location and also as a deep-water refuge during drought or seasonal periods of low flow. During August the oxbows are higher in populations of smaller fish however during the start of the overwintering period in September, the larger fish move into the oxbows. (Interior Reforestation 1999, Figure 9).

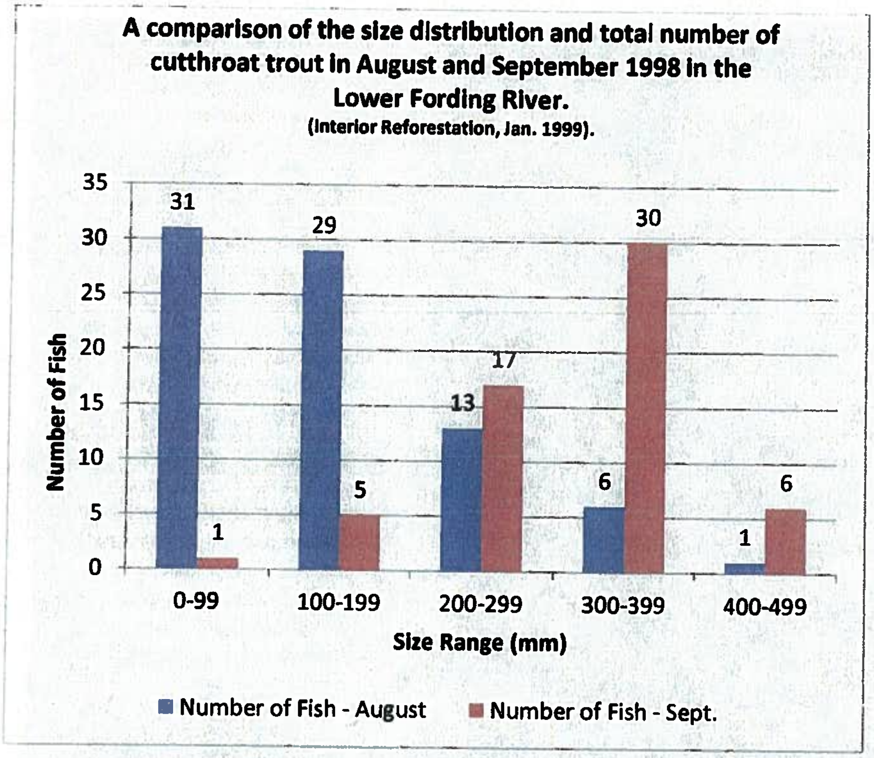


Figure 9. Size Distribution and Total Number of Cutthroat Trout in the Lower Fording River, August and September 1998 (Note: This report refers to the section from the Diversion Channel to the confluence with Tod Hunter Creek/Ewin Cr. as the Lower Fording River) (Interior Reforestation 1999).

This natural seasonal fish movement has been enhanced by loss of overwintering habitat in Kilmarnock Creek, which was estimated in 1985 to hold up to 37% of overwintering fish in the Upper Fording River. As a result of a tailings slide which obliterated the upper portion with the overwintering sites and the conversion of the lower creek into settling ponds which exclude fish passage, this habitat is no longer accessible for warm weather refuge or overwintering. A recent population survey by Cope (2013 page 69-70 and Figure 3-6) states that the majority of fish in the Upper Fording River are now forced to overwinter in only 3 oxbow areas. This has negative ramifications both ecologically and toxicologically. Ecologically, choice sites for occupation by a diverse population in terms of a range of microhabitat and feeding needs are in short supply. This would have the effect of placing additional physiological stress on fish and likely elevate overwinter mortality that can occur due to Winter Stress Syndrome, a condition in which selenium is more toxic to fish in winter because of reduced feeding (Lemly 1993b, 1996).

Toxicologically, oxbows present high hazard because the concentrations of selenium in benthic food organisms of fish are significantly greater in the oxbows than in other riverine habitats (28-62 µg/g dw in oxbows, 6-12 µg/g dw elsewhere, Minnow 2014; threshold level for toxicologically significant bioaccumulation in eggs = 3 µg/g dw, Lemly 1993d, 2002b). Greater dietary selenium intake in oxbow habitats translates to greater concentrations in fish eggs and maximizes the risk of egg mortality, deformed young, and reproductive failure. Figure 10 (below, from Minnow 2014) shows the relationship between river location and selenium concentrations in fish food organisms. Note the strikingly greater selenium concentrations in upper oxbows as compared to other locations.

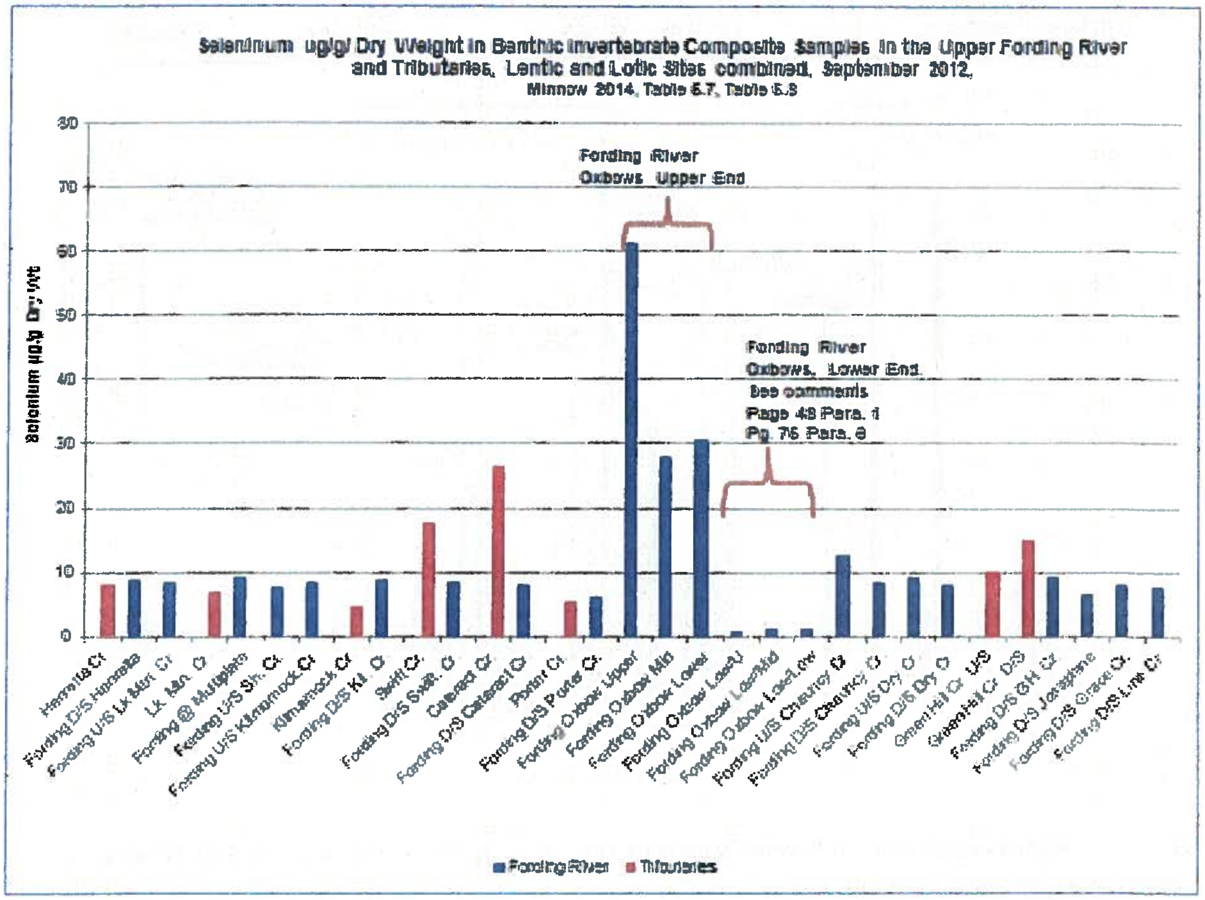


Figure 10. Relationship between river location and selenium concentrations in benthic invertebrates, September 2012 (Minnow 2014).

Figure 11 (below) shows similar findings for selenium in fish food organisms collected by Environment Canada in 2012 and 2014.

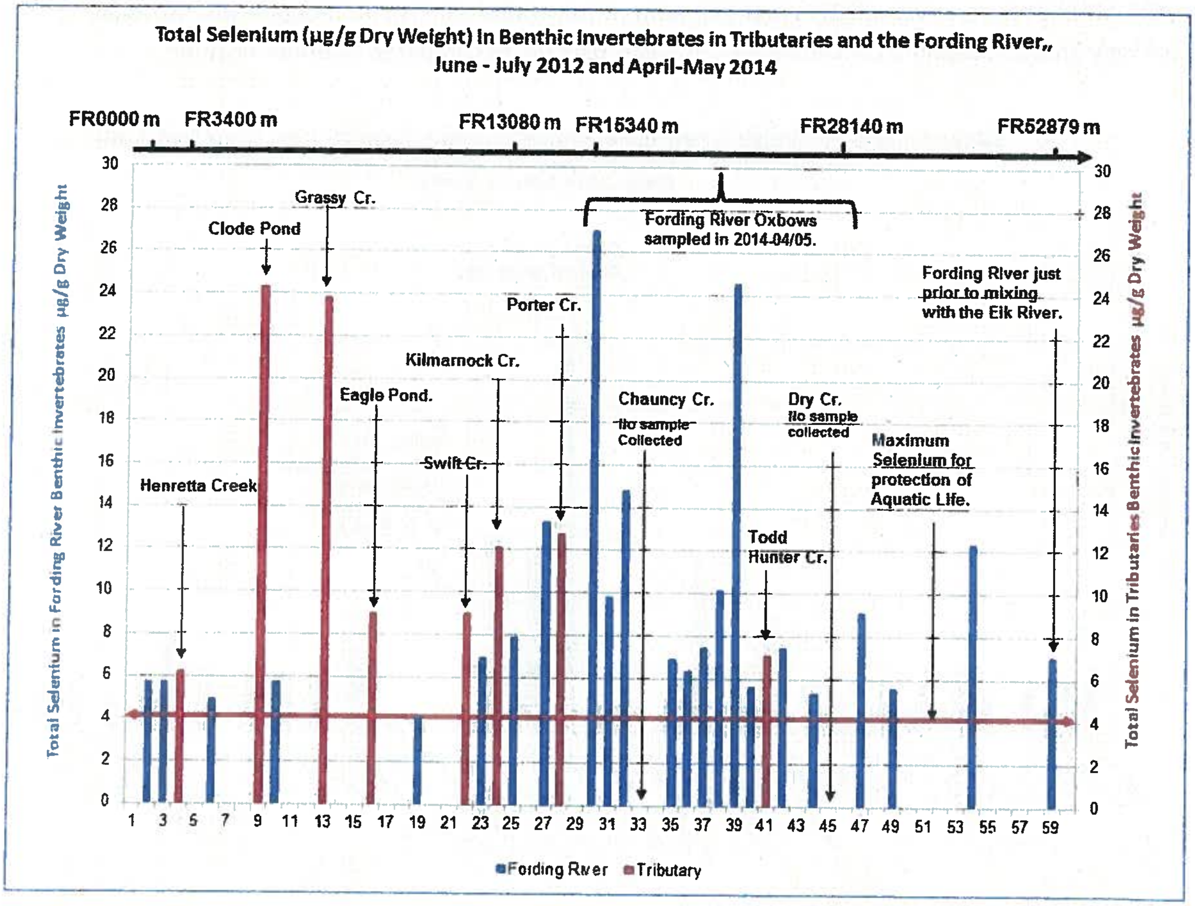


Figure 11. Profile of Selenium in Benthic Invertebrates in the Upper Fording River and its Tributaries. (Environment Canada 2012- 2014, Figure 4-27)

The occurrence of these high selenium exposure conditions in the Upper Fording River is also confirmed by data provided in McDonald (2013) which clearly show that tissue selenium concentrations in westslope cutthroat trout are substantially greater in oxbow environments that at other sampling locations. Greater tissue concentrations means greater hazard toxicologically. The increased biological hazard of incoming waterborne selenium to fish that reside in oxbows and other slow-water, off-channel riverine habitats has been documented in the scientific literature since 1999 (Lemly 1999). Oxbows, therefore, represent an especially vulnerable aquatic habitat that merits prime focus for monitoring selenium bioaccumulation and toxicological evaluation of fish in the Fording River and elsewhere in the Elk River watershed. Importantly, the oxbows represent an ecological and toxicological focal point that brings together large numbers of fish of all ages into an exposure scenario that maximizes the potential for selenium poisoning.

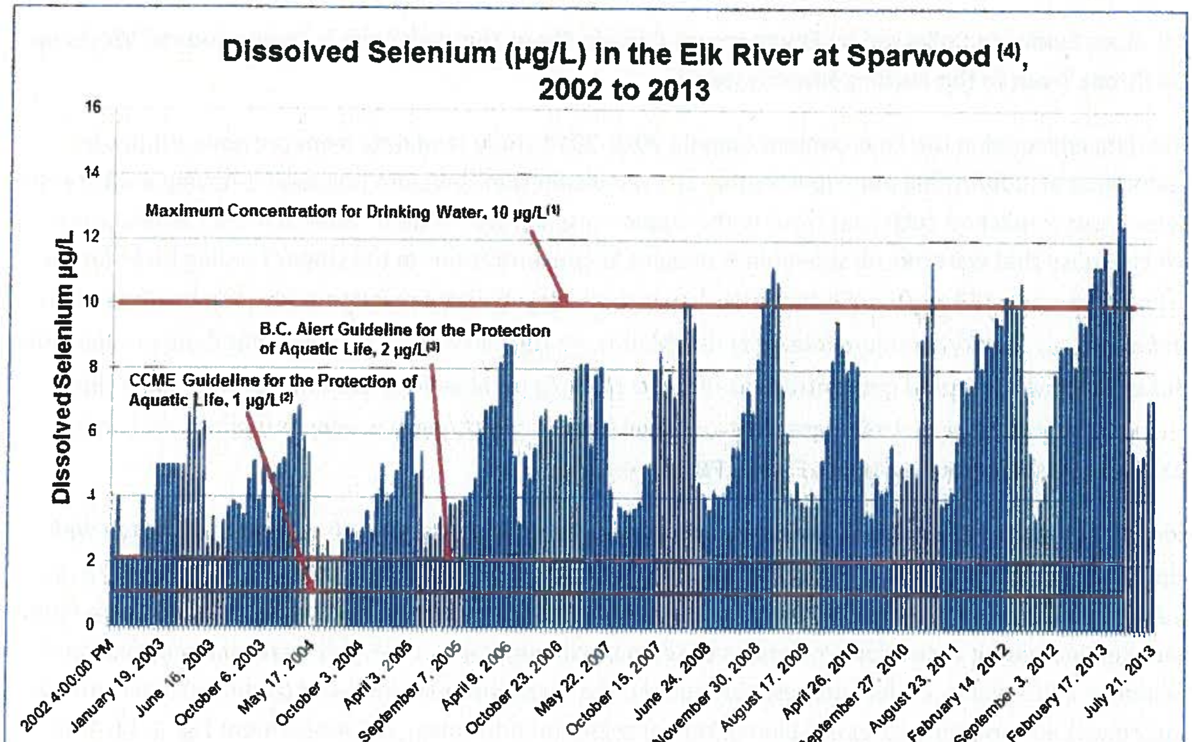
8.0 Does Evidence Collected by Environment Canada Show That Selenium is Deleterious to Westslope Cutthroat Trout in the Fording River System?

The data collected in the Environment Canada 2012-2014 study (and data from previous studies by Rudolph et al. 2006, 2008 and Elphick et al. 2011) indicate that selenium pollution is having a substantial deleterious impact on cutthroat trout in the Upper Fording River system. Environment Canada's data which shows that waterborne selenium is present at concentrations in the Upper Fording River (at the oxbows) at up to 113 µg/L or 55 times the levels that cause bioaccumulation in the aquatic food-chain and an excess dietary selenium intake by fish (that is, ≥2 µg/L in water). Environment Canada's data also shows that the measured concentrations of up to 27 µg/g in those food-chain organisms show that selenium is present at up to 8 times the toxic level (that is, ≥3 µg/g dry weight in food items; Lemly 2002b, EC Assessment Fig. 4-17A, Fig. 4-17B, Fig. 4-27).

Concentrations of selenium in fish tissues and eggs are 5-20 times greater than levels associated with reproductive toxicity in fish (≥ 8 µg/g Se dry weight in muscle, 12 µg/g dry weight in liver, 10 µg/g dry weight in ovary/eggs; Lemly 2002b, EC Assessment Fig. 4-28A). Strong positive correlations were found between increasing tissue concentrations of selenium in eggs and larvae, and increased mortality and incidence and severity of deformities, particularly, the teratogenic skeletal and craniofacial deformities and edema abnormalities that are biomarkers of selenium poisoning. (EC Assessment Fig. 4-34, 4-38, 4-41)

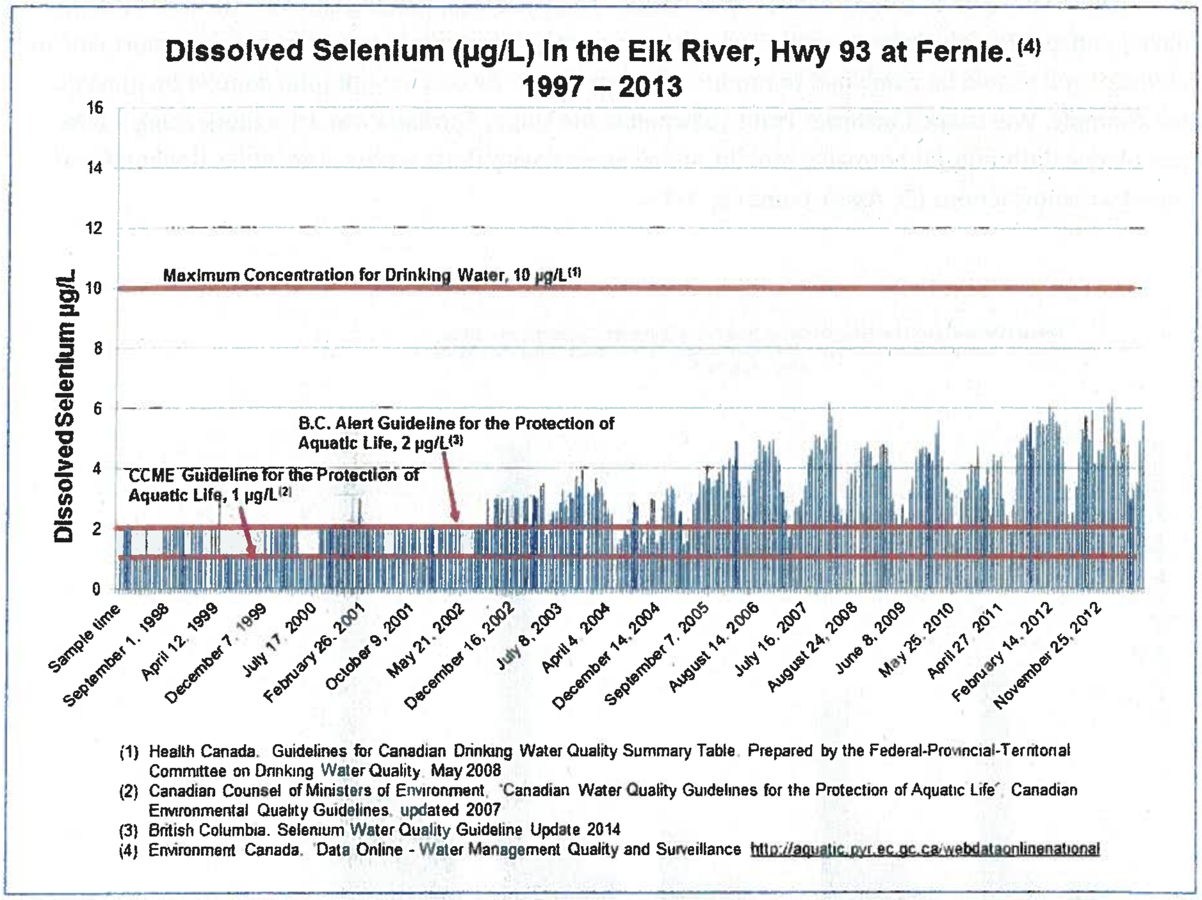
It is my opinion that the results of the Environment Canada study as well as those of Rudolph et.al. (2006, 2008) and Elphick (2011) demonstrate the deleterious impact of selenium on westslope cutthroat trout in the Upper Fording River study area and that westslope cutthroat trout are experiencing both pre- and post swim-up mortality due to selenium poisoning.

In addition to the findings of toxicity, another very important revelation in the Environment Canada assessment is the trend showing that there have been steadily increasing concentrations of waterborne selenium discharged from the Fording River into the Elk River since 1984 (EC Assessment Fig. 5-9, Fig. 5-10).



(1) Health Canada. Guidelines for Canadian Drinking Water Quality Summary Table. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water Quality. May 2008
(2) Canadian Counsel of Ministers of Environment. 'Canadian Water Quality Guidelines for the Protection of Aquatic Life'. Canadian Environmental Quality Guidelines, updated 2007
(3) British Columbia. Selenium Water Quality Guideline Update 2014
(4) Environment Canada. 'Data Online - Water Management Quality and Surveillance http://aquatic.pyr.ec.gc.ca/webdataonlinenational

Environment Canada Figure 5-9. Long term trends in total selenium in the Elk River at Sparwood, which is about 65 km downstream from the mining sources of selenium discharged into the Upper Fording River (Environment Canada - 2012-2014)



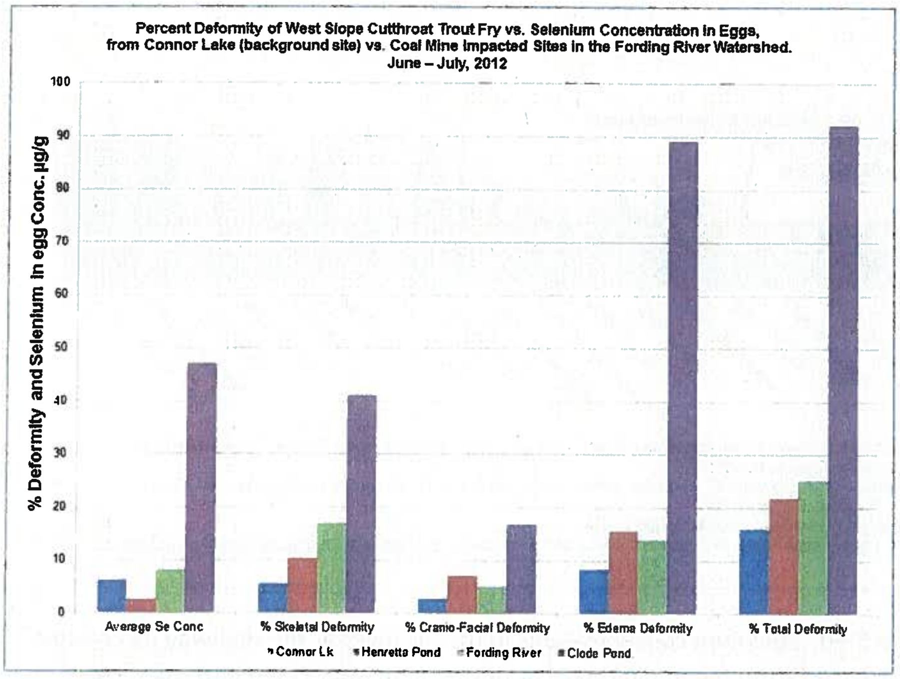
Environment Canada Figure 5-10. Selenium concentrations in the Elk River at the Highway 93 crossing, which is about 95 km downstream from the mining sources of selenium discharged into the Upper Fording River (Environment Canada 2012-2014).

This means that the resultant potential for selenium poisoning to impact fish populations in the Elk and Fording River systems is increasing year-by-year, and has done so for the past two decades. The British Columbia water quality guideline of 2 µg/L is now exceeded by 3-6 times in the Elk River at Sparwood, and resultant impacts on Westslope Cutthroat Trout reproductive success, as demonstrated by pre-and post swim-up mortality conducted by Environment Canada on the Upper Fording River, are substantial.

8.1 Assessment of Abnormalities and Survival in Westslope Cutthroat Trout.

One additional investigative technique that could have been utilized to more fully understand the implications of selenium-induced deformities is the Teratogenic Deformity Index (TDI, Lemly 1997). TDI is used to evaluate impacts of selenium-induced abnormalities on fish populations. This is a useful technique for assessing the real-world biological significance of selenium poisoning on "survivors", that is, those deformed individuals that make it out of the nest or test chamber alive but would be expected

to succumb later due to effects of the abnormalities on physiology, feeding and nutrition, swimming ability and evasion of predators, etc. Post swim-up teratogenic mortality and pre-swim-up mortality are additive, and should be combined to produce the most accurate estimate of total population mortality. For example, Westslope Cutthroat Trout spawned in the Upper Fording River are experiencing a 25% cumulative deformity/abnormality rate, including edema, with the greatest proportion attributable to skeletal malformations (EC Assessment Fig. 4-45).

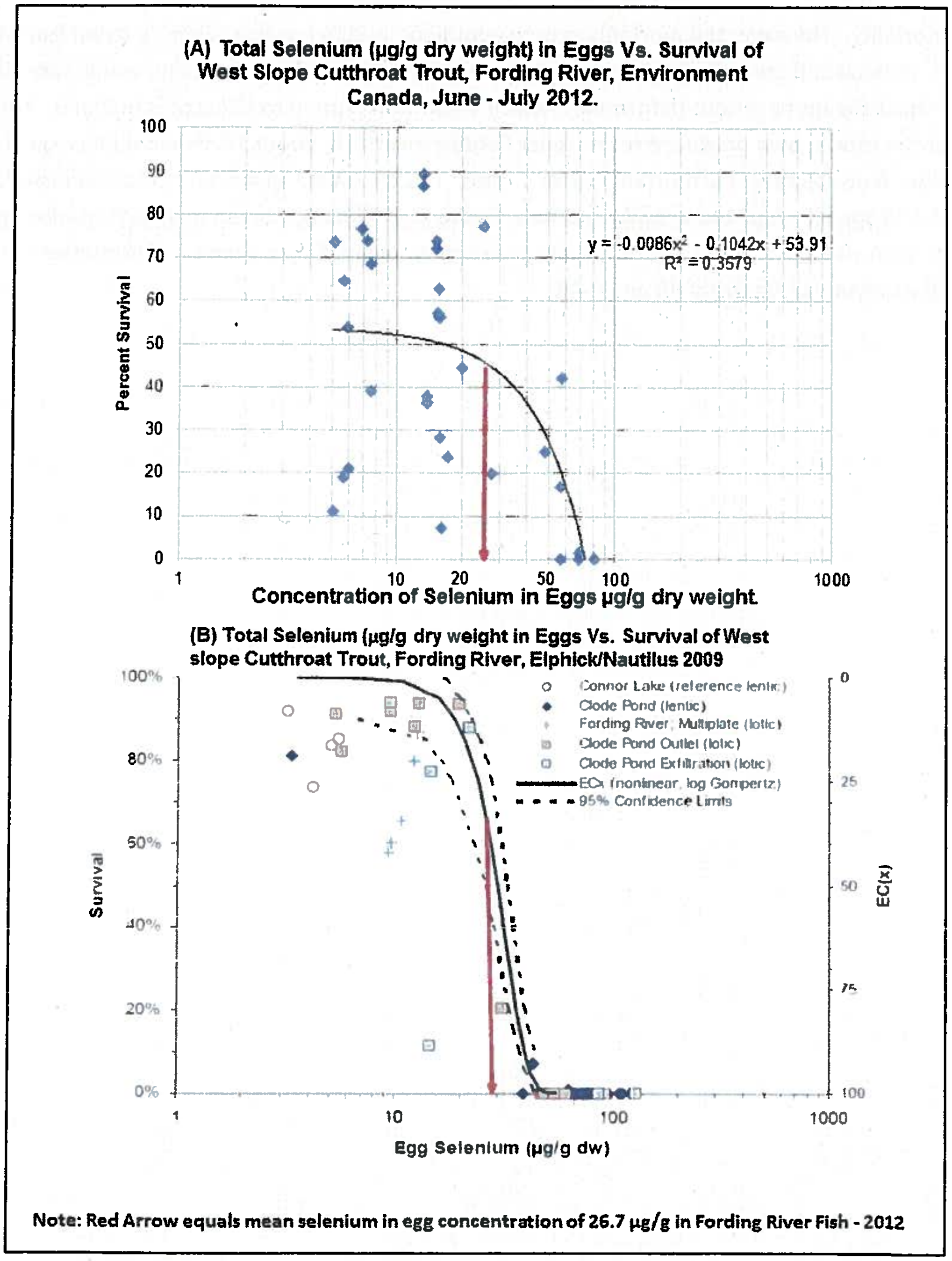


Environment Canada Figure 4-45. Percent skeletal, craniofacial, and edema deformity in fish collected from the Upper Fording River and background sites.

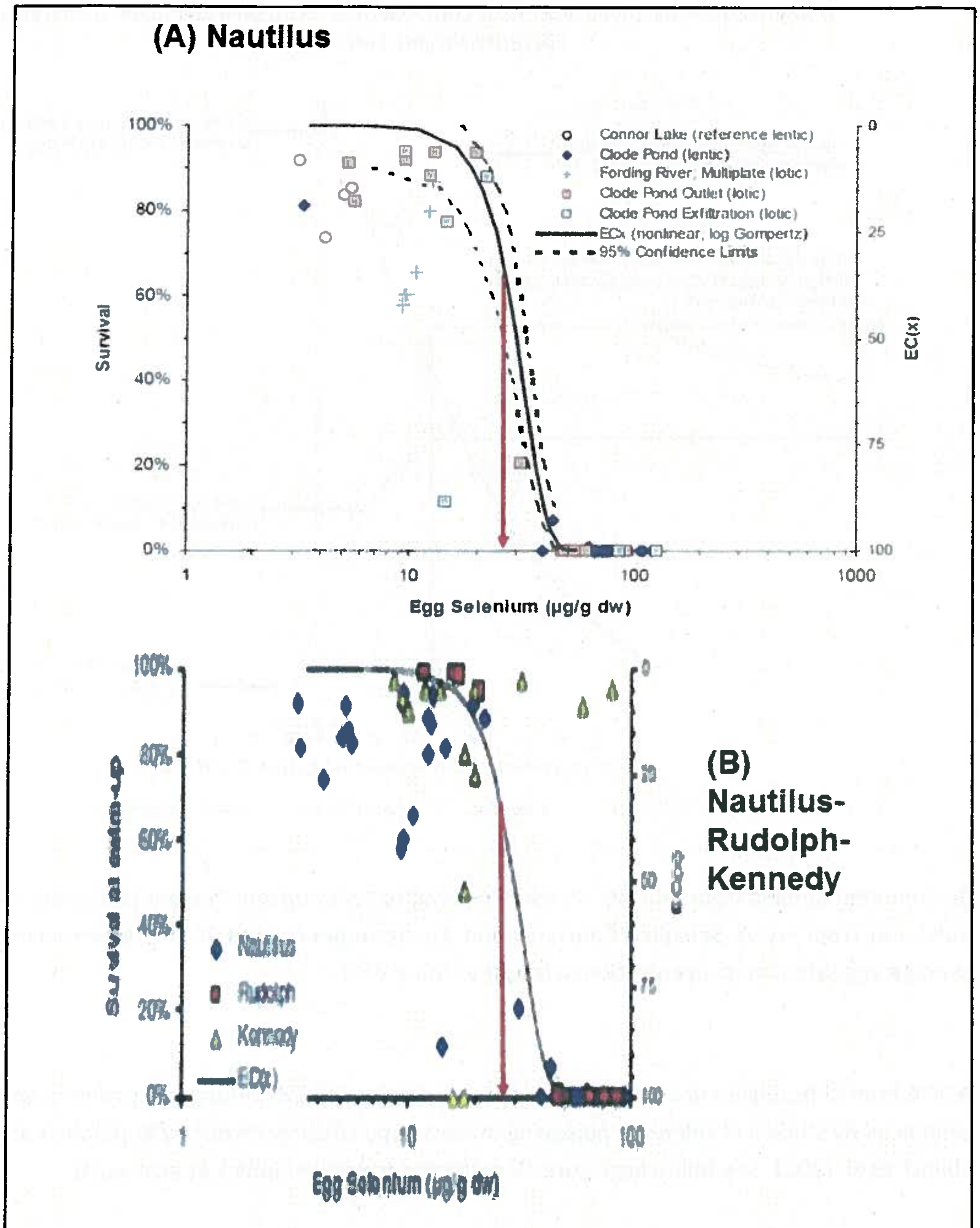
However, TDI applies only to bone and tissue abnormalities, not edema (Lemly 1997). Therefore, one should include only skeletal and craniofacial abnormalities in TDI assessment. Conservatively, one could limit analysis to skeletal defects only, which is about an 18% deformity rate (EC Assessment Fig. 4-34, 4-38). Applying the TDI procedure generates a Level 2 TDI Rating, which means that teratogenic effects alone are having a negative population-level impact on post swim-up fish in the Upper Fording River (in addition to pre-swim-up mortality).

8.2 Estimate of the Mortality of Westslope Cutthroat Trout in the Upper Fording River.

An estimate of the total selenium-induced mortality of westslope cutthroat trout in the Upper Fording River (upstream of Josephine Falls) can be made by determining the mortality due to selenium-related abnormalities and deformities in post swim-up fish and adding that to the pre- swim-up selenium mortality. The expected mortality rate to adulthood is 80% for post swim-up larval fish with terata (that is, skeletal and craniofacial deformities, Lemly 1997). Most of this mortality would take place in fish that exhibit the more serious deformities, which would correspond to GSI scores of 2 or 3. This means that of the total spawn produced from Upper Fording River fish, about 14.4% would be expected to experience teratogenic mortality (80% X 18%). The pre-swim-up mortality rate averaged about 40 % for the 38 spawns depicted in EC Assessment Figure 4-44A (using a baseline of 90% maximum survival and a median survival of 50%). This mortality rate and associated prevalence of deformities is also depicted in EC Assessment Figures 4-45 and 4-46.

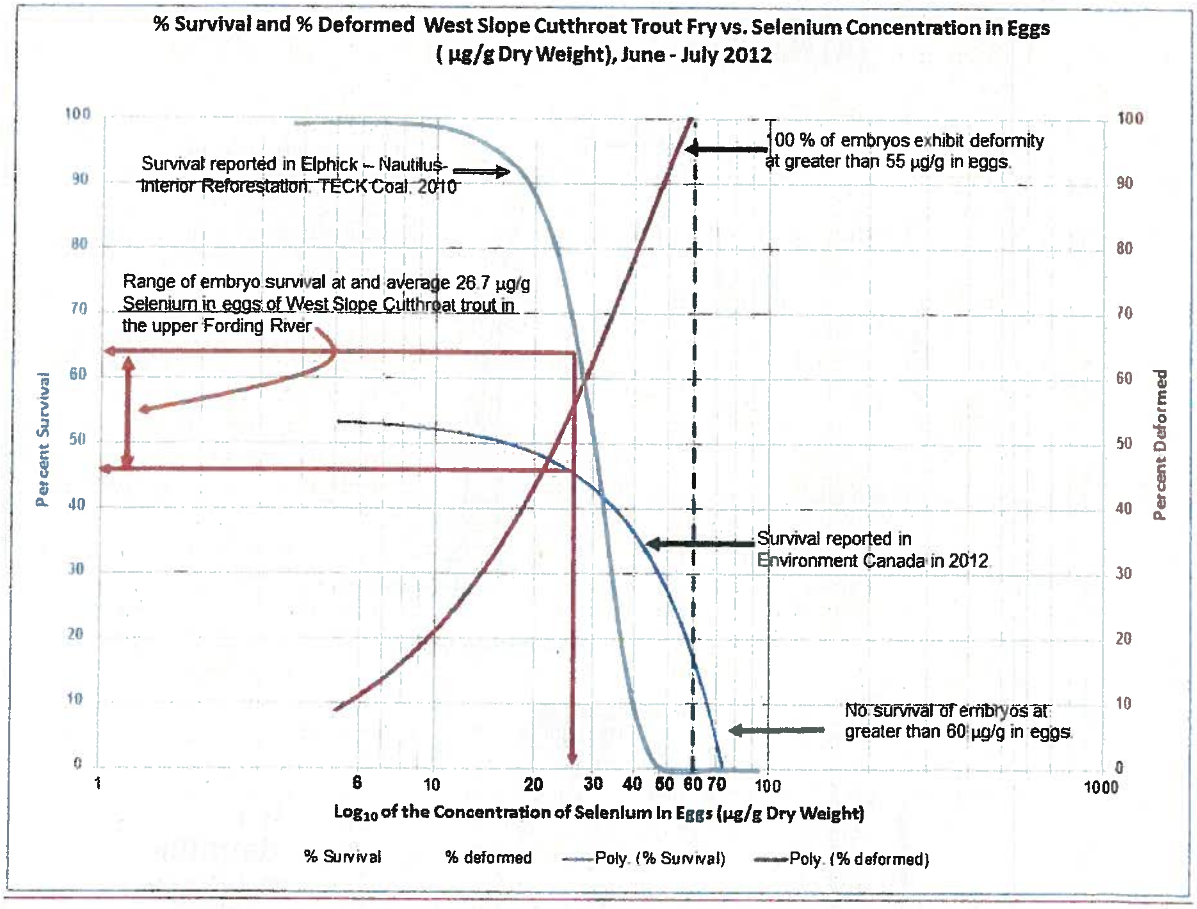


Environment Canada Figure 4-44. (A) Percent Survival to Swim-up vs. Egg Selenium Concentration, Environment Canada 2012 and (B) Nautilus Environmental, Teck Coal, Interior Reforestation, "Effect of Selenium on Early Life Stage Development of West Slope Cutthroat Trout", SETAC Poster 2009 and Elphick et al. 2011. (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).



Note: Red Arrow equals mean selenium in egg concentration of 26.7 µg/g in Fording River Fish - 2012

Environment Canada Figure 4-45. (A) Percent Survival to Swim-up vs. Egg Selenium Concentration, Nautilus , and (B) Nautilus Environmental, Teck Coal, Interior Reforestation, Rudolph, Kennedy "Effect of Selenium on Early Life Stage Development of West Slope Cutthroat Trout", SETAC Poster 2008 and Elphick et al. 2011 (Red arrow indicates the average egg selenium concentration in Upper Fording River WCT).



Environment Canada Figure 4 – 46. Percent Survival to Swim-up and Percent Deformity in Westslope Cutthroat Trout Fry vs. Selenium Concentration, Environment Canada 2014 (Red arrow indicates the average egg selenium concentration in Upper Fording WCT).

A 90% level of baseline maximum survival in low-selenium and/or reference spawns is not unusual, as evidenced by studies of selenium poisoning in westslope cutthroat trout by Rudolph et al. (2008) and Elphick et al. (2011, see following Figure 12 extracted from the Elphick et al. report).

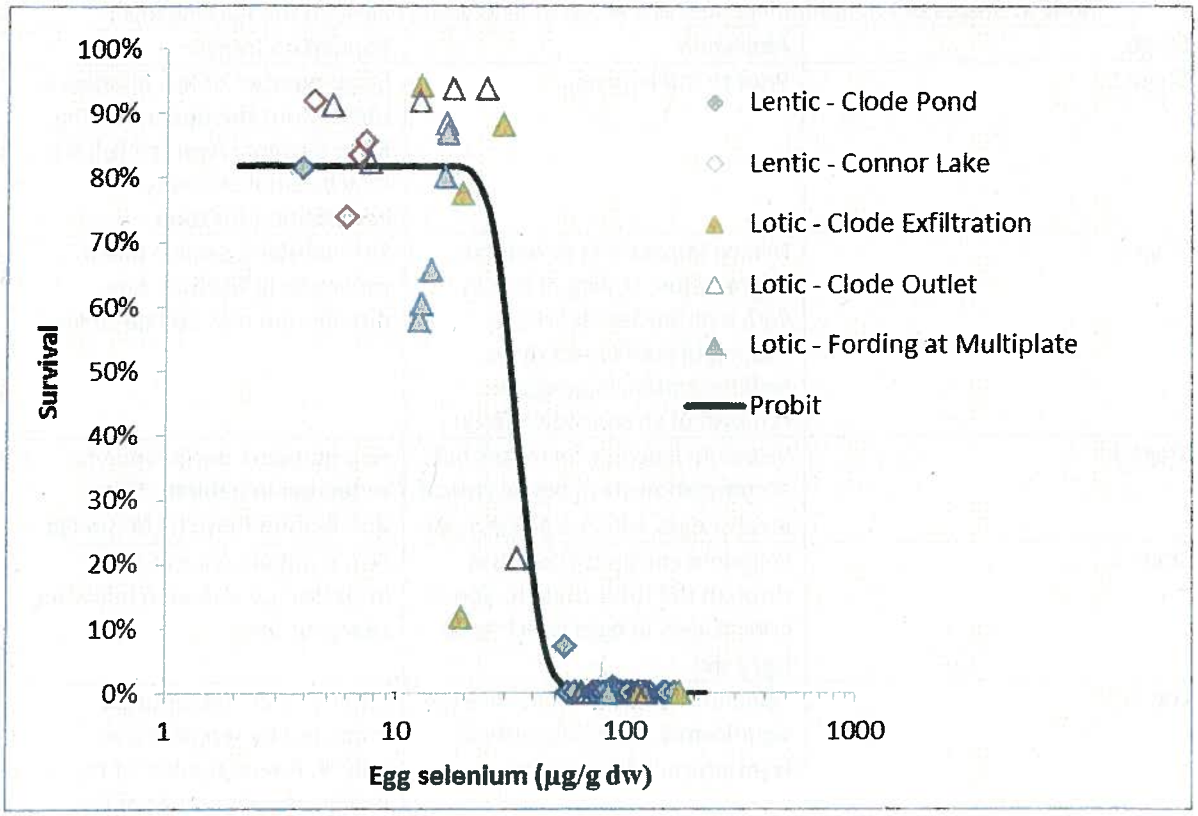


Figure 12. Concentration of selenium in eggs vs. survival in spawns from WCT collected in the Upper Fording River, Elphick et al. 2011.

Applying a pre-swim-up mortality rate of 40% means that about 3.5 times more fish are selenium-poisoned in the pre-swim-up stage than succumb due to teratogenic effects in older life stages. Adding the two numbers together yields a total annual mortality rate of 54.4%.

It is scientifically and toxicologically reasonable to expect that slightly over half of the westslope cutthroat trout eggs spawned in the Upper Fording River each year die due to selenium poisoning. This means that in the absence of selenium pollution, with suitable spawning, feeding, and overwintering habitat present, there could easily be several times as many westslope cutthroat trout in the Upper Fording River than currently exist.

The following table lists the stages of mining impact in the Upper Fording River. It describes how a combination of habitat degradation and selenium pollution affect populations of westslope cutthroat trout over time as pollution levels continue to increase. Based on historical and current information on population trends, habitat conditions, selenium levels, and reproductive toxicity profiles, it is reasonable to conclude that the Fording River as a whole has progressed to Stage 5 impact level and that the Upper Fording River above Josephine Falls is experiencing Stage 6 impacts (Table 1).

Table 1: Stages of Population Impacts as a result of Selenium Toxicity in the Fording River		
Stage	Alteration	Population Impact
Stage 1	Prior to mining impact	Large number of fish distributed throughout the upper Fording River System. Average fish size may be smaller due to competition for food.
Stage 2	Mining impact due to habitat degradation. (Filling of creeks with overburden debris, re-routing of creeks and rivers, sedimentation, logging and removal of streamside habitat	Fish numbers decline due to reduction in habitat. Size distribution may still be similar
Stage 3	Selenium leaching increases but accumulation stays below critical level in eggs which is 10 µg/g dw	Fish numbers decline due to reduction in habitat. Size distribution may still be similar
Stage 4	Selenium concentration rises through the food chain to above critical level in eggs which is 10 µg/g dw	Fish numbers start to be impacted by selenium inhibiting reproduction.
Stage 5	Selenium concentration increase significantly above the critical level which is 10 µg/g dw	Fish numbers increasingly impacted by reproductive failure, fewer number of fry survive, total number of fish starts to decline, the proportion of large fish remaining in the population increases
Stage 6	Selenium concentration continues to increase above the critical level.	High rate of reproductive failure, significant decrease in the population of fry. Large fish have little competition for food so they increase in size and weight and robustness.
Stage 7	High selenium levels are maintained or increasing	Large fish begin to age and are not replaced by younger fish and therefore large fish population begins to die off.
Stage 8	High selenium levels are maintained or increasing over a long period	Extirpation of the population can occur as large fish die off exceeds recruitment of young fish due to continued reproductive failure.
Stage 9	High selenium levels are maintained or increasing over a long period	Upper Fording River Westslope Cutthroat trout population is extirpated.

9.0 Estimate of the Population Loss of Westslope Cutthroat Trout in the Upper Fording, Lower Fording and Lower Elk Rivers.

In addition to knowing the total annual mortality of cutthroat trout due to selenium poisoning it would also be reasonable and prudent for Environment Canada to know the damage value of those lost fish. Having that number would be useful for making cost-benefit analyses that may be needed as regulatory considerations move forward. Loss of fish due to toxic effects of water pollution imparts several well recognized and calculable economic costs. These costs may include ecological, recreational, commercial, subsistence, property, and aesthetic value components (Kopp and Smith 1993).

Each fish carries multiple values and when that fish is lost, all of those values are lost. Thus, one must calculate and add all the value components together to arrive at the true and full monetized negative cost impact (Gentner and Bur 2009, NCAC 2013). Examples of estimated economic losses for (A) replacement value of fish and (B) regional economic impacts for aquatic resources damaged by coal pollution can be found in references such as Lemly and Skorupa (2012).

9.1 Estimate of the Number of Fish Which Must be Replaced due to Selenium Toxicity.

The distribution of native and non-native sport and non-sport fish in the Elk and Fording Rivers are as follows (Heidt 2006) ;

Fording River above Josephine Falls:

1. westslope cutthroat trout (*Onchorhynchus clarki lewisi*)

Fording River below Josephine Falls and Elk River above Elko Dam

1. Native Sport Fish
    a. bull trout (*Salvelinus confluentus*)
    b. mountain whitefish (*Prosopium williamsoni*)
    c. westslope cutthroat trout (*Onchorhynchus clarki lewisi*)
2. Non-native sport fish
    a. eastern brook trout (*Salvelinus fontinalis*)
    b. rainbow trout (*Oncorhynchus mykiss*)
3. Non-sport species
    a. longnose dace (*Rhinichthys cataractae*)
    b. longnose sucker (*Catostomus catostomus*)
    c. largescale sucker (*Catostomus macrocheilus*)
    d. northern pikeminnow (*Ptychocheilus oregonensis*)
    e. sculpin (*Cottus* sp.)

Elk River below Elko Dam and Lake Koocanusa

1. Native Sport Fish
    a. bull trout (*Salvelinus confluentus*)
    b. burbot (*Lota lota*)
    c. mountain whitefish (*Prosopium williamsoni*)

d. westslope cutthroat trout (*Onchorhynchus clarki lewisi*)

2. Non-native sport fish
   a. rainbow trout (*Oncorhynchus mykiss*)
   b. kokanee (*Oncorhynchus nerka*)

3. Non Sport Species
   a. longnose dace (*Rhinichthys cataractae*)
   b. longnose sucker (*Catostomus catostomus*)
   c. largescale sucker (*Catostomus macrocheilus*)
   d. northern pikeminnow (*Ptychocheilus oregonensis*)
   e. sculpin (*Cottus* sp.)

The following is an example of the population loss associated with selenium impacts to fish in the Upper Fording River, in which I limit my analysis to calculating the number of westslope cutthroat trout lost and therefore requiring replacement cost. (Data for other fish species was not provided)

Replacement cost can be determined by multiplying the number of fish poisoned times the monetized value of an individual fish in terms of its physical replacement cost, that is, the cost to collect (via field sites), spawn and grow (via hatchery), , or otherwise obtain and stock a replacement fish in that management jurisdiction.

9.2 Estimate of Potential Productivity of Upper Fording River Westslope Cutthroat Trout.

Standing crop estimates of spawning-size (>200 mm) cutthroat trout in the Upper Fording River were obtained from Cope et al. (2013) which indicate 55 fish/km, or about 2640 fish in total over the entire 48 km of river upstream of Josephine Falls that is deemed to be fish habitat . It is important to note that this population estimate is a current estimate made under the conditions of current selenium pollution. It does not reflect the historical population of the Upper Fording River prior to coal mining impact. Fecundity measurements indicate an average of 495 eggs spawned per female (sex ratio 1.3:1, male to female) and about 65% of adults will successfully spawn (Downs et al. 1997, Peterson et al. 2010). These numbers yield an estimate of

Maximum number of eggs laid;

746 spawning females (1148 X 65%) X 495 eggs/spawn = 369,270 eggs total

Maximum annual number of swim-up fry in the Upper Fording River (EC Assessment Report , Figure 4-46).

369,270 eggs total X 90% maximum survival to swim-up = 332,343 swim-up fry

9.3 Westslope Cutthroat Trout Population Loss Estimates.

Selenium poisoning is expected to remove 54.4% of this potential production;

332,343 swim-up fry X 54.4% = 180,794 westslope cutthroat trout lost each year.

This annual loss estimate is based on the Environment Canada 2012 data which reflects the current Upper Fording River westslope cutthroat trout population and does not include historical population loss estimates prior to the onset of coal mining. It also, does not include impacts on any other species such as bull trout which are also present in the lower Fording River system. Therefore, economic cost estimates must consider these unknowns.

Replacement cost for these lost fish can be calculated using inflation-adjusted numbers for wild trout which may vary from region to region. In the United States, the North Carolina Department of Environment and natural Resources, Raleigh , NC (NCAC 2013) has conducted a replacement cost estimate for various species of fish in that jurisdiction and indicates a value of $US 24.74 per catchable wild trout (Fish that have survived and grown to 7 to 13 inches in size).

9.4 Estimated Population Loss based on Historical Westslope Cutthroat Trout Population Estimates.

Historical (1979-1985) standing crop estimates and population parameters of Westslope Cutthroat Trout in the Upper Fording River are available from studies conducted by D.B. Lister Associates (Fording Coal Limited 1980) and research summaries provided by Wood and Berdusco (1999). The Lister report gives data for summer-fall 1979 population sampling and indicates that age classes 4+ and 5+ years consisted of mature, spawning-size fish (>185 mm (>7 inches)). An average of 0.7-2.6% of "mine area" fish and 9-14% of "above mine area" fish were this age/size, which translates to a grand average of 7.35% of all fish as "spawning size". Combining the densities given in Table 8 of that report for "up", "in", and "below" mining yields an average total density of 14.08 fish per 100m^2, or 1408 fish per km (using mean river width = 10 m). Of these 1408 fish, 7.35% would be spawning size, or 103.48 potential spawners per km. Cope et al. (2013) states there is about 48 km of river upstream of Josephine Falls that is deemed to be fish habitat. Using 103.48 fish per km means that there would be 4,967 spawning size westslope cutthroat trout in the Upper Fording River.

Wood and Berdusco (1999) give September-October fish density for 5 sampling sites which yields a grand mean of 16.96 trout per 100m^2. Estimating that about 10% of fall-sampled westslope cutthroat trout fish are mature (a percentage suggested by Downs et al. 1997 and Cope et al. 2013), there would be about 1.69 potential spawners per 100m^2, or 169 per km (using mean river width = 10 m) X 48 km of river = 8,112 mature trout in the Upper Fording River.

Comparing the population estimate of mature trout from the Lister investigation (4,967) to the Wood and Berdusco report (8,112) and the 2013 Cope et al. study (2,640) suggests that there are currently 46-67% fewer mature westslope cutthroat trout residing in the Upper Fording River than were typically present in 1979-1985. It is important to note that current measures of Population Viability Analysis and Recovery Potential Assessment (Cope 2013) utilize numbers of mature, spawning size fish.

Total densities of westslope cutthroat trout, all ages combined, have dropped as well. For example, Upper Fording River sampling conducted at identical stations in 1979, 1990, and 1995 (Fording Coal Limited 1980, Norecol 1990, Allan 1996) show progressive declines of 51-93% concurrent with the expansion of coal mining operations. Also, Wood (1978) reported that 10,000 westslope cutthroat trout were removed from a 1,220 m section of the Upper Fording River when the channel was diverted to allow for construction of the settling pond (see Figure 13). This is an extremely high density and indicates that there was a tremendous population of trout in the Upper Fording River historically.

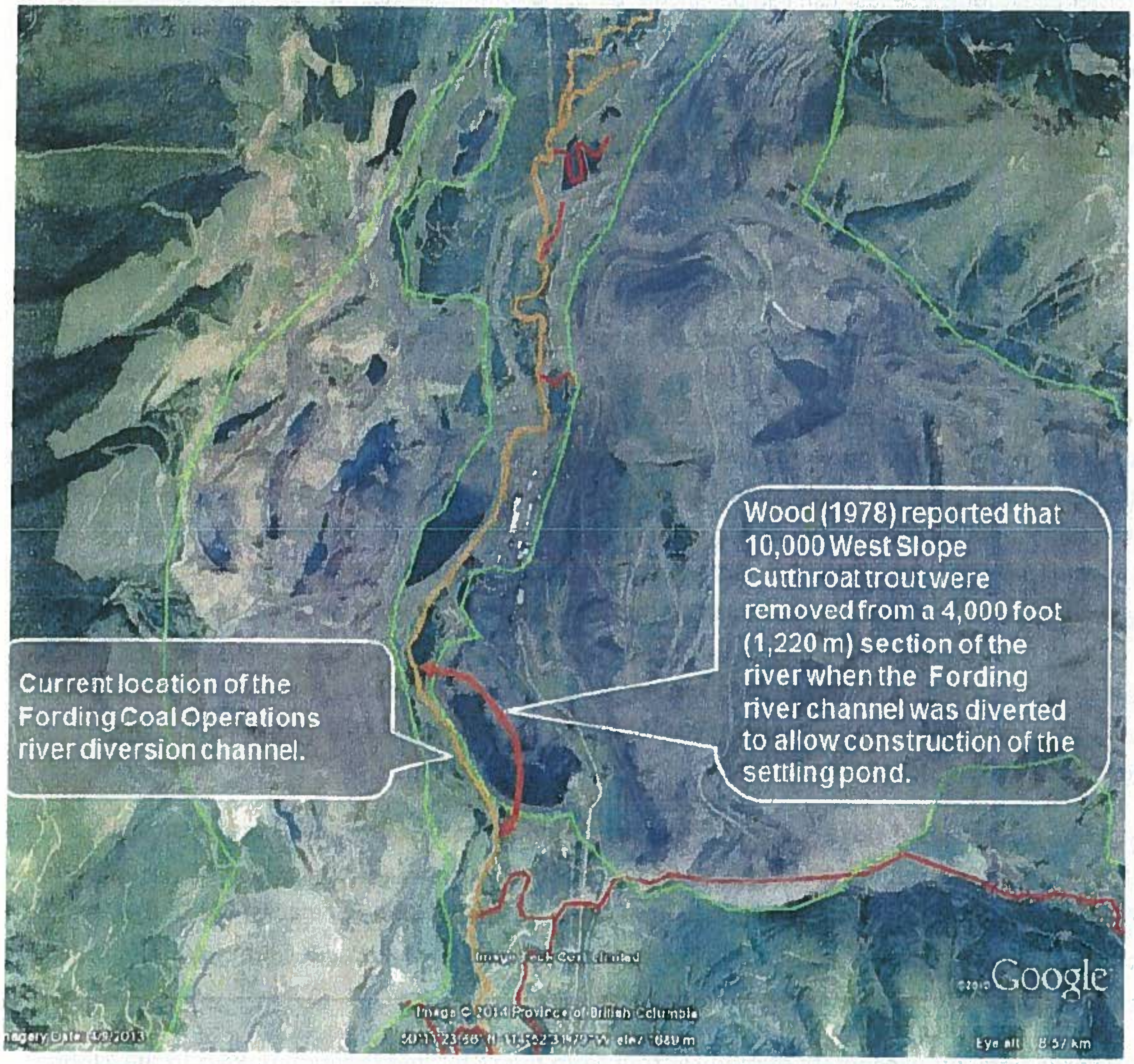


Figure 13. Location of Wood (1978) fish removal relative to river diversion at Fording Coal Operations.

Additional weight of evidence for declining fish populations of all species in the Elk and Fording River watersheds commensurate with escalating coal mining is provided by Interior Reforestation (2010). The report from that study gives both numeric and graphic presentation of dramatic reductions in the abundance of individuals per species and total number of species present over the period 1970-2000. It is highly significant both ecologically and toxicologically that the Shannon's Index of diversity dropped by 27% in the Elk River, and by 80% in the Fording River over this 30 year period as coal mining expanded and selenium concentrations in water and fish tissues steadily increased (see Figure 14 and EC Figure 5-10, also McDonald 2013).

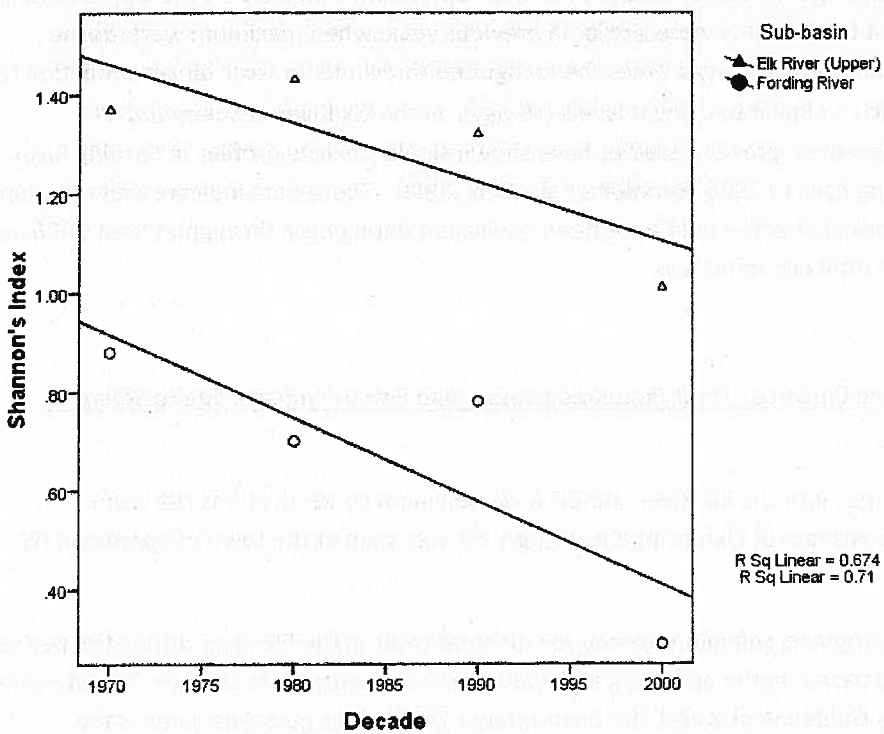


Figure 14. ANCOVA plot of sub-basin par 3 Shannon's Index of fish species diversity by decade (Interior Reforestation 2010).

9.5 Estimate of Total Westslope Cutthroat Trout Population Losses due to Selenium Pollution in the Upper Fording River.

Negative costs of pollution and resultant impacts of "missing fish" on recreational sport fishing, food/subsistence use, aesthetic/property values, and riverine ecology need to be calculated and added

to replacement costs to determine total damage value. These cost estimates must be made utilizing estimates of fish losses and regional economic indicators.

Cope et al. (2013, page iii) stated……

> *"The Fording River is a tributary to the Elk River, which is one of seven major streams and their tributaries in the upper Kootenay River watershed that were designated as Class II Classified Waters in 2005. The classified waters of British Columbia represent 42 highly productive trout streams. The classified waters licensing system was created to preserve the unique fishing opportunities provided by these waters, which contribute significantly to the province's reputation as a world class fishing destination. In 2010, the Province of British Columbia closed the upper Fording River to angling due to uncertainty regarding population status".*

It is scientifically and toxicologically reasonable to infer that reproductive impacts on the Upper Fording River westslope cutthroat trout fishery were similar in previous years when maximum waterborne concentrations of selenium were at least 4 times the recognized threshold for toxic bioaccumulation (2 µg/L, Lemly 2002b), which is similar to current levels (>9 µg/L in the Elk River at Sparwood, EC Assessment Fig. 5-9). Moreover, previous studies have shown similar toxicity profiles in Fording River Basin investigations dating back to 2006 (Rudolph et al. 2006, 2008). Those data indicate that selenium concentrations and biological effects would have been equivalent dating back through at least 2006 and may be used to estimate total economic loss.

<u>9.6 Estimate of Westslope Cutthroat Trout Population Losses and Fishery Impacts due to Selenium Pollution in the Elk River.</u>

The Fording River discharges into the Elk River and Elk River selenium concentrations rise from approximately 1.0 µg/L upstream of Elkford to 8 to 13 µg/L downstream at the town of Sparwood (EC Assessment Fig. 5-9).

Downstream of this convergence, selenium toxicity to cutthroat trout in the Elk River during the period 2006-2013 is highly likely based on the occurrence of waterborne concentrations that are 3-6 times the current BC Water Quality Guideline of 2 ug/L (BC Environment 2013). This guideline value is the threshold at which significant bioaccumulation in food-chain organisms begins to occur and threaten aquatic life, especially fish, due to deformities and reproductive failure.

EC Assessment Figure 5-11 shows a limited number of samples of benthic invertebrates in the Elk River with tissue concentrations of selenium up to 8 µg/g dw. The toxicity to westslope cutthroat trout in the Elk River is also highly likely based on the presence of selenium concentrations in fish food organisms that are over twice the toxic threshold for reduced survival and reproductive effects in fish at 3.0 µg/g dry weight, and also exceed the 4 µg/g dw Alert Concentration of the BC Ministry of Environment (Lemly 2002b, BC Ministry of Environment 2013).

Specific measurements of selenium concentrations in fish eggs are not available for Elk River fish, which makes inferences drawn from measures in water and food organisms, as well comparisons with the Upper Fording River, necessary. EC Assessment Figure 4-28A shows that Upper Fording River cutthroat can attain egg selenium concentrations as high as 50 µg/g dw at sites that have approximately 8 µg/g dw selenium in their food organisms (benthic invertebrates). It is reasonable to assume that cutthroat in the Elk River would attain similar selenium levels in eggs given the food concentrations measured there by Environment Canada in 2012 (8 µg/g dw). EC Assessment Figure 4-43 shows that at 50 µg/g dw selenium in eggs, there is approximately a 60% reduction in fry survival to swim-up. EC Assessment Figures Figs. 4-37, 4-40-42 show that there is a substantial increase in edema abnormalities and deformities of the spine and craniofacial region when egg selenium approaches 50 µg/g dw, which translates into a sharp rise in post swim-up mortality. Collectively, this evidence suggests that the level of selenium poisoning and resulting mortality in Elk River westslope cutthroat trout in the assessment corridor (confluence with Fording River downstream to Highway 93 crossing) may be similar to that in the Fording River proper.

Assuming there are similar standing crops of cutthroat trout in the Elk River (likely a conservative assumption since the Elk River is larger and telemetry studies show strong site fidelity and a high percentage -- 65% -- of non-migratory, in-river spawners, (Westslope Fisheries 2003); also there is some evidence that the Elk River population may exceed 70 adults/km, (Heidt 2006), and knowing that there are similar river distances of selenium-polluted water (approximately 50 km of Fording River, approximately 70 km from Elk-Fording confluence to measurement station at Hwy. 93 crossing) annual population losses for Westslope Cutthroat Trout in the Elk River could easily equal or exceed that for the Fording River*.

*Note: These estimates do not include impacts on bull trout.

Westslope cutthroat trout were not captured during June-July 2012 in the Elk River due to flood conditions. The April-May 2014 sampling focused only on the Upper Fording River oxbows. Environment Canada has received numerous reports of the occurrence of deformities in sport caught fish in the Elk River and its tributaries. The most common report is shortening or absence of the operculum (gill cover). Figure 5-12 shows a westslope cutthroat trout captured in Coal Creek on 2014-07-02 which originates from the former Coal Creek Coal Mine and discharges into the Elk River on the southeast side of Fernie. This creek was not sampled in the 2012 or 2014 sample period.

A vestigial (abnormally small) or missing gill cover is a deformity which can occur due to selenium toxicity and has been documented at selenium-polluted sites in the US (see Figure 2A). This may be a survivable deformity in that it probably does not significantly alter respiration or the streamline characteristics of the fish and may allow regular swimming behavior which allows the fish to feed and/or escape predators. It does leave the gill tissue exposed to mechanical damage and is analogous to missing digits on the hand or foot of a human......not lethal, but certainly not healthy.

Environment Canada has enlisted the assistance of fishing guides and outfitters utilizing the Elk and Fording River watersheds to document, photograph and measure fish which exhibited these types of deformities and were captured during the sport angling season. The results are still being tabulated. As indicated on the cover page, this is an Interim Expert Report, subject to inclusion of additional data as it becomes available. This will include further results of deformities tallied by fishing guides in September and October of 2014, as well as additional selenium concentration biological monitoring by Environment Canada.

Environment Canada 2014 Figure 5-12. Westslope cutthroat trout captured in 2014 from Coal Creek, a tributary to the Elk River at Fernie. This individual is missing its left gill cover, a condition that can be caused by selenium poisoning.

Additional weight of evidence for selenium impacts on fish populations in the Elk River is provided by Interior Reforestation (2011). The results of that study show significant increases in tissue selenium concentrations of longnose dace at sites where waterborne selenium is elevated above the BC Provincial Guideline of 2 µg/L (see Figure 15). Thus, selenium monitoring data for dace suggest that the Elk River fishery as a whole is contaminated to toxic levels (>4 µg/g dw total body selenium), including small species like dace, as well as large sport fish such as westslope cutthroat trout.

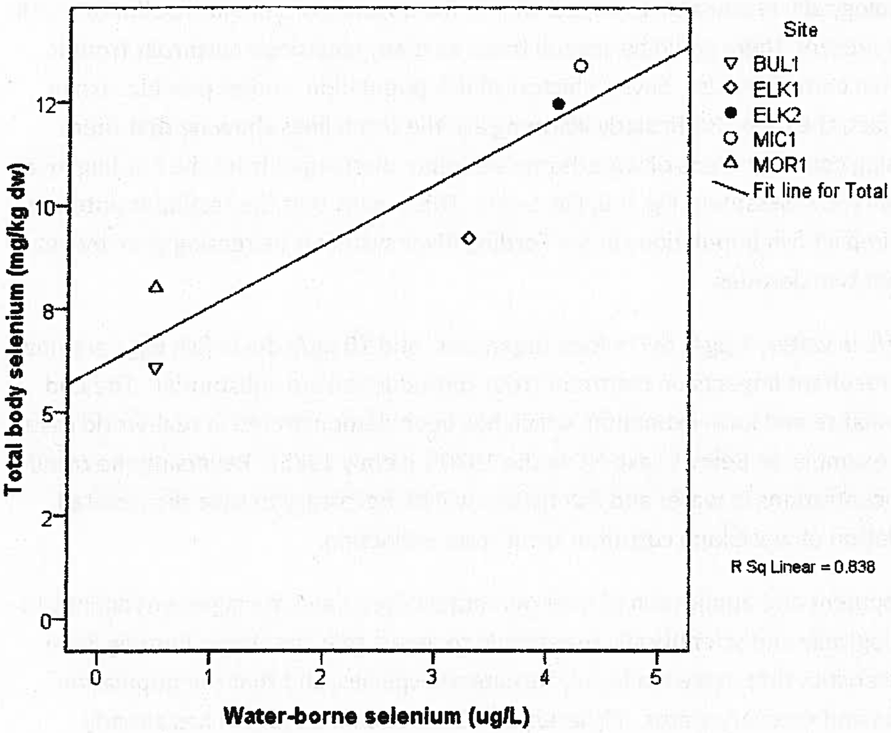


Figure 15. Plot of total body selenium (mg/kg dw) and waterborne selenium for longnose dace (triangles indicate reference sites) (Interior Reforestation 2011).

10.0 What are the potential implications for the Upper Fording River?

10.1 Ecological Consequences.

The Upper Fording River is defined by the portion of the watershed that is upstream of Josephine Falls. Josephine Falls represents a natural barrier to upstream fish movement and this barrier has protected this population from hybridization with non-native rainbow trout; as a result, this population is one of a limited group of populations that have been identified as genetically pure (Cope et al. 2013). However, although these fish may benefit genetically from reduced hybridization risk, Upper Fording River trout experience much greater extinction risk. Reproductively isolated fish populations with relatively small numbers of individuals are essentially "fragmented" from the metapopulation, and consequently, are disproportionately impacted by losses from habitat degradation, water pollution, etc. (Fagan 2002, Fagan et al. 2002). This is exactly the situation that exists in the Upper Fording River.

Removal of a substantial number of fish, for whatever reason, carries a very high potential for population-level ripple effects that can culminate in an unviable level of reproduction, population collapse, and local extinction. Obviously, the implications of removing 54.4% of the annual reproductive output due to selenium poisoning are extremely serious for the survival of westslope cutthroat trout in the Upper Fording River.

It is scientifically and toxicologically reasonable to expect that in the absence of selenium pollution, with otherwise suitable habitat present, there could be several times as many westslope cutthroat trout in the Upper Fording River than currently exist. Several historical fish population studies provide strong evidence that this was, in fact, the case. Particularly alarming are the trend lines showing that there have been steadily increasing concentrations of waterborne selenium discharged from the Fording River into the Elk River since 1984 (EC Assessment Fig. 5-9, Fig. 5-10). This means that the resultant potential for selenium poisoning to impact fish populations in the Fording River system is increasing year-by-year, and has done so for the past two decades.

Toxicity thresholds of 2 µg/L in water, 4 µg/g dw in food organisms, and 10 µg/g dw in fish eggs are now exceeded 5-10 times, and resultant impacts on cutthroat trout reproduction are substantial. The end result can be population collapse and local extinction, which has been demonstrated in real-world case examples for decades, for example, at Belews Lake NC in the 1970's (Lemly 1985). Reversing the trend of increasing selenium concentrations in water and fish tissues will be necessary to save the isolated Upper Fording River population of westslope cutthroat trout from extinction.

With respect to the development and application of environmental criteria and management actions to protect cutthroat, it is ecologically and scientifically reasonable to assert that the Upper Fording River population exhibits characteristics that make it a locally threatened species, and that the population merits priority conservation and recovery status. Fisheries and Oceans Canada (2013) has already established a Canadian precedent by giving special protection status to the Alberta population of westslope cutthroat trout. In the USA, the federal Fish and Wildlife Service gives "full protection under law" to threatened species through the Endangered Species Act, that is, no acceptance or allowance for mortality at any level (USFWS 2013). This means that an LC10 or LC20 effect concentration (levels that kill 10-20% of the fish), which are levels commonly accepted as the "allowable limit" for mortality when regulatory agencies such as Environment Canada and USEPA develop water quality criteria, would not apply. This, in turn, means that a fully protective criterion should be set, which would be below the toxic threshold in order to provide a margin of safety. From both current and previous studies of Fording River westslope cutthroat trout, this threshold was determined to be approximately 10 µg/g dry weight in eggs (EC Assessment Fig. 1-16, Elphick et al. 2011 Fig. 8).

Environment Canada's Teck Coal Environmental Assessment adds substantially to the information base now available from which to draw conclusions about selenium toxicity to westslope cutthroat trout in the Fording River and across the broader affected land area of the Elk River Basin in Canada and the Kootenai River-Lake Koocanusa Basin in the USA.

The extensive monitoring data collected since 1996, as summarized in the McDonald (2013) report, confirms alarming trends of steadily increasing concentrations of selenium in the Elk River basin over the past two decades. This reveals a growing biological hazard that threatens viability of westslope cutthroat trout. The report also confirms that, as described in a discussion of the "hydrologic unit principle" by Lemly (1999), downstream transport of selenium-polluted water in the Elk River is causing contamination and hazardous bioaccumulation in Lake Koocanusa, which spans the Canadian USA border (egg concentrations elevated from less than 5 µg/g to as much as 18 µg/g, McDonald 2013). Selenium levels show that the Elk River basin is at a tipping point toxicologically.

10.2 Water Quality Standard Needed to Protect Westslope Cutthroat Trout.

The key water quality need which must be met in order to (1) ensure survival of the remnant population of westslope cutthroat trout that currently remains in the Upper Fording River, and (2) begin to restore the population of westslope cutthroat trout to historic numbers and health in the Upper Fording River, is that selenium pollution must be eliminated. This requires establishment of a toxicologically appropriate water quality standard and its enforcement through adequate regulatory controls and corrective actions that include substantial, aggressive coal mine wastewater treatment. The large body of scientific literature amassed from study of the Upper Fording River and elsewhere in the Elk River watershed clearly shows that the toxicity profile of selenium in westslope cutthroat trout is predictable and progressing towards a catastrophic outcome. Unless and until there is a dramatic rollback in waterborne selenium, toxicity will continue and advance, year-by-year, according to trends of increasing impact that have been firmly established over the past two decades by multiple investigators.

The toxicity database for selenium from Upper Fording River studies and elsewhere supports a water quality standard of 2 µg Se/L, that is, the maximum allowable water concentration not to be exceeded. This number represents consensus of the scientific research literature, technical reviews, and Canadian provincial and USA national regulatory recommendations across a 2+ decade timeframe (e.g., Peterson and Nebeker 1992, Skorupa 1998, Lemly 2002b, Hamilton 2003, BC Environment 2013, Environment Canada 2014, USEPA 2014). In fact, the USEPA's currently derived selenium criterion for lacustrine and wetland habitats, and other standing or slow-moving waters (such as the oxbows in the Upper Fording River and Lake Kookanoosa, BC-MT) is 1.3 µg Se/L (USEPA 2014). The need for a limit of 2 µg Se/L is especially evident in the oxbow habitats of the Upper Fording River, where selenium bioaccumulation in westslope cutthroat trout food organisms (benthic invertebrates) is greatest (Figure 11). Moreover, oxbows provide critical remnant habitat for overwintering of adults that form the reproductive capacity of the species for the next breeding season. The extensive data presented in EC Figures 4-17B, 4-28B, 4-46, and in Figures 10-11 (see pages 26-27, 37-38, and 46 of this Interim Report) illustrate the tight, indisputable link between waterborne selenium levels, concentrations in benthic invertebrates and fish, and resultant deformities and reproductive failure in westslope cutthroat trout. The patterns and profiles clearly show that when water concentrations rise above 2 ug Se/L, a cascade of cause-effect responses in the food chain and fishery begin to occur, culminating in fish reproductive failure. This sequence of events is unstoppable as long as selenium concentrations remain elevated. I have carefully and thoughtfully considered all current and historical aspects of Upper Fording River ecology and habitat quantity/quality, selenium concentrations/fate and environmental cycling dynamics, and related fish population and toxicology findings. I conclude that long-term survival of westslope cutthroat trout in the Upper Fording River hinges on successful control of selenium pollution, which is, meeting the target of 2 µg Se/L. This is by no means an insurmountable task.....but it will require serious commitment from both government and industry.

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APPENDIX

Publications by A. Dennis Lemly, Ph.D., on selenium ecotoxicology. These reports include toxicity to fish and wildlife, toxicological assessment methods and procedures, and water quality criteria guidelines:

1. Lemly, A.D. 1982. Response of juvenile centrarchids to sublethal concentrations of waterborne selenium: I. Uptake, tissue distribution, and retention. *Aquatic Toxicology* 2: 235-252.

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Interim Expert Witness Report

Environmental Sampling in Areas affected by Coal Mining in the Elk and Fording River Watersheds of South Eastern British Columbia.

2012-2014

By

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For

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Environment Canada Enforcement Division, Pacific and Yukon Region.

Executive Summary.

This report contains a summary of the information and data collected Environment Canada enforcement and technical advisory staff during the environmental assessment of the Elk and Fording Rivers as part of an investigation pursuant to Section 36.3 of the Fisheries Act. The complete report including appendices will be presented upon completion of the investigation.

The Elk and Fording Rivers originate on the west slope of the Rocky Mountains in South Eastern British Columbia. These waters are waters frequented by fish, namely West Slope Cutthroat trout and other species. The Province of British Columbia manages a Class II sport fishery in these waters which is the second highest quality fishery ranking in the province. Within this watershed there are five coal mines owned and operated by Teck Coal Limited (Fording River Operations, Greenhills Operations, Line Creek Operations, Elkview Operations, and Coal Mountain Operations) which lie within the watershed. These coal mines are open pit and in 2014 estimated to exceed 130 km^2 of disrupted surface and waste rock. (Figure 1-1)

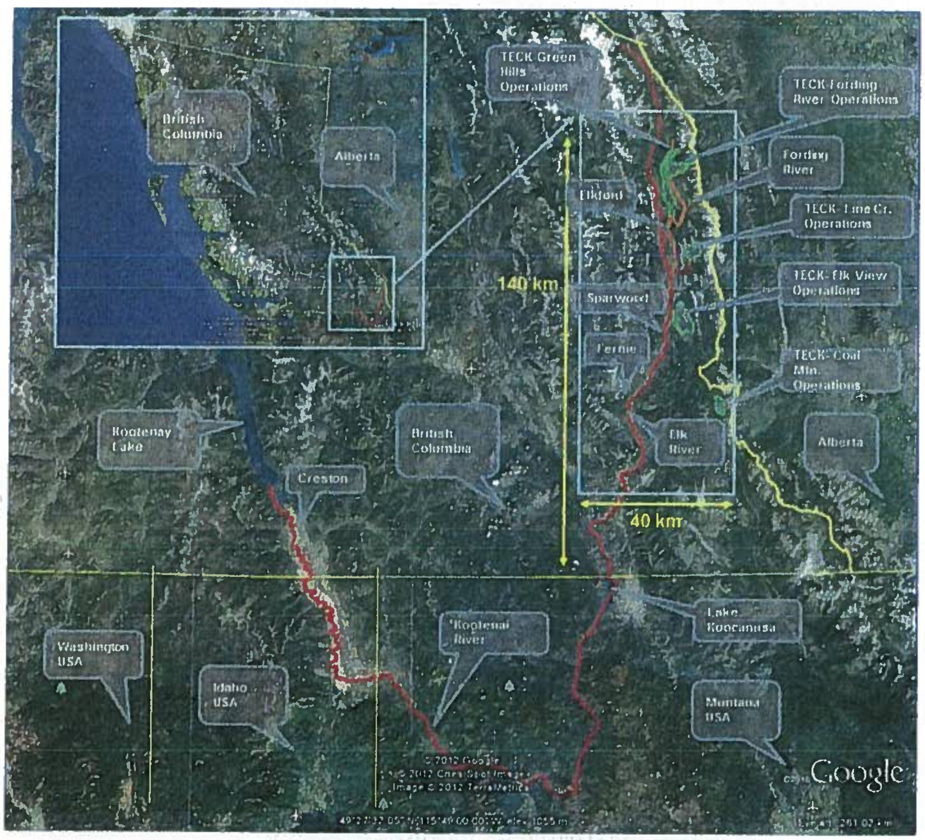

Figure 1-1: Study area in the Elk and Fording River Basins.

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Coal mining has occurred in this area since 1897 (Lussier, 2003) and the mines generate up to 24,000,000 tonnes of coal (TECK, 2013) and up to 140,000,000 tonnes of waste rock annually. (Lussier, 2003) These mines have accrued in excess of 4.0 billion tonnes of waste rock deposits that impact tributary streams and subsequently the Fording and Elk rivers.

Study Overview

In June and July 2012, under the authority of a General Warrant, Environment Canada enforcement staff assisted by authorized experts collected environmental samples from the TECK Fording River Operations and Greenhills Operations coal mines in the upper Fording River watershed and a limited number of samples in the Elk River watershed. The samples were analyzed for selenium and other environmental criteria and an early life stage fish bioassay. In April and May of 2014, Environment Canada enforcement staff and experts collected additional environmental samples in the upper Fording River in a section known as the "Fording River Oxbows" which lie adjacent to and downstream of the Fording Coal and Greenhills Operations. In September to October 2014 Environment Canada enforcement staff will collect additional biological samples and information in the Elk River.

Study Results

These studies found that the Teck Coal Fording Operations, Teck Coal Greenhills Operations in the Fording and Elk River watersheds deposit waste rock onto the land surface adjacent to and into the tributaries of the Elk and Fording Rivers in south western British Columbia. The exposed waste rock deposits contain selenium and calcium, sulphates and other elements that react with incident precipitation, surface water and groundwater and release these substances into these waters. The Fording River and the Elk River and their tributaries were found to be waters frequented by fish which were affected by coal mining.

Impact of Sulphates and Dissolved Mineral Salts (Calcium, Magnesium, Potassium)

Sulphates at up to 1,551 mg/L (parts per million) in tributary streams during the June-July 2012 high flow period were found to exceed the 429 mg/L limits for the protection of Aquatic Life in most coal mining affected tributaries. Sulphates at up to 338 mg/L were found in the Fording River Oxbows during the April-May 2014 winter low flow period.

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Calcium and other mineral salts reach saturation concentration in mine affected streams tributary to the Fording River which results in the precipitation of calcium rich mineral deposits called calcite (or Tufa) in the tributary creeks and the Upper Fording River. The calcite deposits are deleterious substances that result in the initial coating and then consolidation of creek bottom sediments and gravel eventually forming a concrete matrix which in cases such as Kilmarnock creek can only be broken with the force of hammer blows. In cases such as Cataract Creek, the calcite deposits consolidate the creek bottom sands and gravels and form terraces and cause the destruction of aquatic plant life. The calcite deposits are present on the sands and gravels in the Fording River downstream of these tributaries. These calcite deposits can and do result in the harmful alteration and destruction of fish habitat by preventing the fish from spawning and destroying the habitat of fish food organisms. (Figure 1-2)

Figure 1-2: Calcite in Cataract Creek which has killed stream vegetation and cement bottom strata.

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Impact of Dissolved Selenium

Waste Rock from coal mining from the Teck Coal Fording Operations, Teck Coal Greenhills Operations in the Fording and Elk River watersheds contains selenium which is a substance deleterious to fish. Selenium is dissolved from the waste rock by surface and ground water and enters the surface and groundwater of tributaries and directly into the Fording and the Elk Rivers. Dissolved selenium up to 600 µg/L (parts per billion) in tributary streams was found to be 300 times the 2.0 µg/L British Columbia guideline for the protection of aquatic life.

The concentration of selenium in the Elk and Fording Rivers varies with the season due to spring freshet flooding and winter dry seasons. In the Fording River, during the freshet season dissolved selenium at up to 33 µg/L was 16 times higher than the British Columbia guideline of 2.0 µg/L for the protection of aquatic life. During the winter dry season, dissolved selenium at up to 113 µg/L in the area known as the Fording River Oxbows was 55 times higher than the British Columbia guideline for the protection of aquatic life.

Movement of Selenium through the food chain into West Slope Cutthroat Trout

Bacteria, microscopic organisms called protozoa, periphyton/algae and aquatic insects and worms (benthic invertebrates) form an aquatic food chain for fish. Dissolved selenium released from the waste rock is converted by bacteria and protozoa into organo-selenium compounds which are incorporated into the tissue of periphyton/algae concentrating the selenium up to several thousand times. Benthic Invertebrates consume periphyton/algae containing organo-selenium compounds and incorporate those compounds into their tissue further concentrating the selenium. West Slope Cutthroat trout consume the benthic invertebrates and further concentrate selenium into their muscle, liver and egg tissue. In Tributary streams, selenium was found in benthic invertebrates at up to 24 µg/g or 12 times the 2.0 µg/g (parts per million) guideline for the protection of aquatic life. In the Fording River Oxbows selenium was found in benthic invertebrates at up to 27 µg/g or 13 times the 2.0 µg/g (parts per million) guideline for the protection of aquatic life

Deformity and Mortality in Westslope Cutthroat Trout

West Slope Cutthroat trout were captured in the Upper Fording River and Tributaries. (Figure 1-3) These trout consume benthic invertebrates containing organo selenium compounds and incorporate those compounds into their tissue further bio-concentrating the selenium. Mature fish may accumulate selenium in their tissues and not exhibit any visual external deleterious effects. (Figure 1-3)

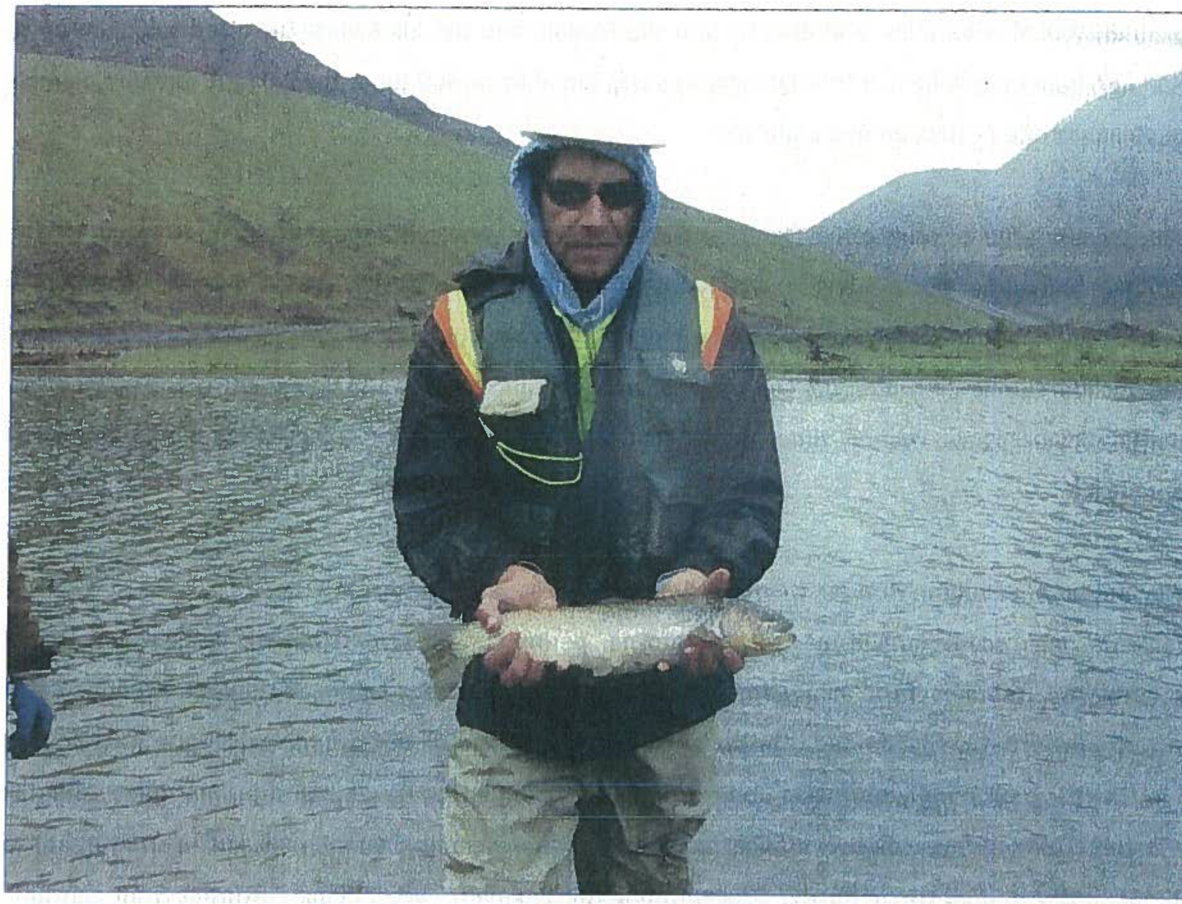

Figure 1-3: Westslope Cutthroat trout in spawning condition captured in Henretta Pond/creek a coal mine affected tributary of the Upper Fording River.

Selenium is known to cause cranial-facial and skeletal deformities and edema (tissue swelling) abnormalities and mortality in the embryonic fish and birds which can be tested by an early life stage bioassay. (Figure 1-4) An early life stage bioassay of West Slope cutthroat trout was conducted in June-July 2012 utilizing fish from the coal mine affected Upper Fording River and a non-mine affected Connor Lake. After fertilization the eggs and emergent fry of Westslope Cutthroat trout containing organo selenium compounds exhibited increasing rates of deformities, abnormalities and mortality at selenium concentrations greater than 20 µg/g (parts per million) dry weight and 100 percent mortality at concentrations greater than 57 µg/g dry weight selenium.

For those eggs which did hatch, the embryonic trout containing organo selenium compounds exhibited increasing rates and degrees of cranial-facial and spinal deformities and increasing rates and degrees of edema (tissue swelling) that impaired feeding and swimming behavior. (Figure 1-4) This test demonstrated that the deposit of selenium from the Teck Fording River Operations and Greenhills Operation coal mines are deleterious to fish.

Figure 1-4: Example of an emergent Westslope Cutthroat trout fry that exhibits multiple deformities due to selenium toxicity.

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Impact of Selenium on Fish Habitat

In June-July 2012, the highest concentrations of selenium in the eggs of Westslope Cutthroat trout captured in the upper Fording River was at the entrance to the tributary spawning streams which indicates that they migrated from other areas downstream. This is consistent with the migration patterns described in Cope 2013 and Cope 2014.

During the winter period, West Slope Cutthroat trout must seek out deep pools of water to survive the winter low temperatures and low water flow. The mining of coal and the placement of waste rock and overburden has caused partial destruction of most tributary streams in the Upper Fording River that lie within the coal mining operations by direct deposit of the overburden or by the generation of waste rock slides into the drainages. Approximately 5 km of Kilmarnock Creek has been totally destroyed as fish habitat by coal mining due to waste rock slides and the construction of settling ponds.

The destruction of Kilmarnock Creek by a coal mining waste rock slide and the construction of downstream settling ponds at the mouth of the creek has removed in excess of 5.0 km of rearing and critical overwintering habitat from the upper Fording River watershed where it had been reported that up to 37% of the trout overwintered. This has forced a large proportion of surviving fish to over winter in the Fording River in a 9 km section known as the Fording River Oxbows which lies adjacent to the Greenhills Operations Coal mine and downstream of the Fording River Operations coal mine.

The Fording River Oxbows have deep slow moving/quiescent water which has been found to accelerate the bio-concentration of selenium in periphyton/algae and the benthic invertebrates upon which the fish feed. Other studies reported that fish sampled in the Fording River Oxbows had concentrations of selenium in eggs significantly in excess of that which caused 100% mortality in eggs and emergent fry. Samples of water, periphyton/algae and benthic invertebrates collected from the Fording River Oxbows during the April-May 2014 period by Environment Canada contained the highest concentrations of selenium in any of the samples collected by Environment Canada in the Fording River. This presents a high mortality risk to the offspring of fish that overwinter in the Fording River Oxbows.

Loading of Selenium and Calcium into the Fording River.

It was found that three tributary streams, Swift Creek, Cataract Creek and Kilmarnock Creek which lie upstream of the Fording River Oxbows contribute 75% of the estimated 27.7 kg/day loading of selenium to the Upper Fording River. These three streams also account for a similar proportion of the loading of calcium which can form Calcite.

Exposure of Fish to Selenium and Deformity and Mortalities in the Upper Fording River.

The samples collected in the Upper Fording River demonstrated that Westslope Cutthroat are exposed to dissolved selenium in the entire section affected by and downstream of coal mining. They also demonstrated that Westslope Cutthroat overwintering in the Upper Fording River Oxbows are exposed to the highest concentrations of dissolved selenium in the Fording and Elk River system. Measurements of algae/periphyton in the Fording River Oxbows confirmed that the food sources for West Slope Cutthroat Trout also contained the highest concentrations of selenium.

There is a significant dose-response (decrease in survival) when selenium in egg concentrations exceed 20 µg/g dry weight and in particular when it exceeds 26.7 µg/g dry weight which was the average concentration of selenium in eggs in West Slope Cutthroat Trout captured in the Upper Fording River by Environment Canada in June-July 2012.

In the absence of selenium, the survival of West Slope Cutthroat Trout Swim up fry is estimated to be 90%. At the average of 26.7 µg/g selenium in eggs the percent survival to swim up of Upper Fording River Westslope Cutthroat Trout fry is estimated to range between 46% to 64%. (Lemly 2014)

For every part per million increase in the average selenium concentration in eggs there is an estimated 4.0 % increase in mortality to swim up for West Slope Cutthroat Trout fry. (In the range of 20 to 40 µg Se/g dry weight)

There was a 100% incidence of deformities and negligible survival of West Slope Cutthroat Trout fry to swim up stage when selenium in egg concentrations exceeded 50 µg/g dry weight.

At the average concentration of 26.7 µg/g selenium in eggs it is estimated that 180,794 Westslope Cutthroat Trout swim up fry are lost in the Upper Fording River each year due to selenium poisoning. (Lemly 2014) (Note, this is at the current adult population estimate, not historical population estimates)

The current cost to replace the 289,610 swim up fry is estimated at $310,000 per year. (Lemly 2014, Klimas 2014) Replacement cost is based on the cost to obtain eggs from wild stock, rear to fry size and transport and release fish. It does not include any other economic costs/values.

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The annual 12% increase in selenium in water due to coal mining presents an increasing risk of mortalities in West Slope Cutthroat Trout swim up fry in the Fording and Elk Rivers.

Remediation of the Upper Fording River.

Remediation of the surface water and groundwater of the tributaries and main stem of the upper Fording River is required to reduce or remove selenium and calcium and other coal mining related contaminants from the tributary streams, especially Swift Creek, Cataract Creek and Kilmarnock Creek and the Upper Fording River. This removal is necessary to protect the declining population of resident Westslope Cutthroat Trout from further degradation.

Any remediation plan must consider;

1) The contribution of surface and groundwater discharge from the tributary streams, especially Kilmarnock Creek, and the year round conditions of the 9 km area of the Fording River known as the Fording River Oxbows which accelerate the uptake of selenium in Westslope Cutthroat Trout.

2) The remediation plan must consider the higher susceptibility of the overwintering trout in the Fording River Oxbows and must be protective to those fish, especially since the uptake of selenium is much greater in the lentic (slow flowing water) environment and the limit on overwintering habitat now available in the Upper Fording River. The protective concentrations of selenium, are dependent on the river environment. Interim levels to be used for estimating the degree of remediation/treatment required will be such that Selenium in egg concentrations in Westslope Cutthroat trout residing in the Upper Fording River Oxbows do not exceed 10.0 to 12 µg/g (see Lemly 2014). An estimate of the degree of treatment and estimated costs will be provided in a separate report regarding due diligence and selenium control and remediation technologies.

3) The re-construction or replacement of fish habitat damaged or destroyed by coal mining especially the Kilmarnock Creek over wintering habitat is recommended whereby compensatory habitat is created in the area that seeks to re-establish the overwintering habitat that was available prior to the waste rock/overburden landslide that destroyed the upper portion of the creek and the construction of settling ponds that destroyed the habitat in the lower portion of Kilmarnock Creek. This may require the construction of new creek channels and holding habitat to utilize water which has been treated to remove selenium to protective concentrations for fish overwintering in the Fording River Oxbows.

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4) Other fish habitat that was lost as a result of infilling of creeks by waste rock or waste rock landslides is still under assessment and may be required to be compensated.

5) Additional evidence is being collected in the Elk River in Sept. and October of 2014 and will be evaluated. This data and any environmental implications will be included in the final report.

Index

Environment Canada Enforcement Division, Pacific and Yukon Region.

Environment Canada Enforcement Division, Pacific and Yukon Region.

1.1 Qualifications

I am the Sr. Enforcement Engineer and National Operational Advisor for the Enforcement Division of Environment Canada and the Project Manager for the INTERPOL Pollution Crimes Forensics Investigations Manual Project.

I am a professional engineer registered to practice chemical and environmental engineering in the Province of British Columbia and have over 30 years of experience in the examination of the use, release and control of toxic chemicals in industrial processes and the environmental assessment of lands and waters affected by those industrial processes.

I have a diploma in chemical and metallurgical technology specializing in the sampling and analysis of chemical, metallurgical and environmental samples from the British Columbia Institute of Technology, and a degree in Chemical Engineering specializing in pollution control from Lakehead University in Thunder Bay Ontario and additional training in groundwater assessment from the Princeton School of Groundwater and additional training in biology and biochemistry from the University of British Columbia.

I have authored or co-authored over 37 articles and reports on the assessment of toxic chemicals in industrial sectors and contaminated sites.

I have conducted more than 40 legal investigations of the release of toxic chemicals.

1.2 Information Relied Upon

The information relied upon for this report include field measurements and observations personally made by me and other enforcement officers during onsite inspections in February 2012, June -July 2012, April-May 2014 and Sept-Oct 2014. Field samples and Laboratory information were supplied by Environment Canada's Pacific Environmental Science Center in North Vancouver and the Department of Fisheries and Oceans Bioassay Laboratory in Winnipeg Manitoba. Appendix XVI provides a complete list of the literature I relied upon.

1.3 Summary of Conclusions

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1.3.1 Setting of the Fording River: The Fording River is divided into two sections, the approximately 36 km upstream of Josaphine Falls (the upper Fording River) and the approximately 19 km downstream of Josaphine Falls (the lower Fording River) Josaphine falls separates the two sections of the river and prevents fish from migrating from the lower section to the upper sections.

In February of 2012, the Elk River was inspected and it was visually confirmed that these waters are waters frequented by fish, namely West Slope Cutthroat Trout and other species. The upper Fording River and its tributaries of Henretta Pond/Creek, Fishpond Creek, Clode Creek, and Grassy Creek were sampled by angling, net and pen traps in June-July 2012 and West Slope Cutthroat trout were captured in these waters confirming that these waters are waters frequented by fish.

The waters and tributaries of the Fording and Elk River are therefore waters frequented by fish and the Province of British Columbia regulates a Class II sport fishery in these waters.

1.3.2 History of industrial activity; The watershed of the Fording River has been significantly altered by industrial activity. Initially the area was affected by logging which impacted tributary streams by the removal of stream side vegetation. With the advent of mining, the removal of overburden and the establishment of waste rock piles exposed rock containing selenium to moisture in the form incident precipitation, surface runoff and groundwater. The mining and waste rock piles of the five mines in the Elk and Fording River watersheds have disrupted an estimated 130 km^2 of surface area which is now exposed to leaching by incident precipitation and groundwater.

During June-July 2012 and April-May 2014 and September – October, 2014 the coal mining operations currently operated by Teck Fording River Operations, Teck Greenhills Operations, Teck Line Creek Operations , Teck Elkview Operations and Teck Coal Mountain Operations, were observed to deposit and continue to deposit hundreds of millions of tonnes of waste rock and over burden into the watershed of the Fording River. The exposed waste rock was sampled and tested and found to contain selenium, calcium and magnesium and other substances.

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1.3.3 Exposure of waste rock to moisture: The exposed waste rock deposits react with incident precipitation, surface water and groundwater and release dissolved mineral salts containing calcium, magnesium, potassium and other minerals (mineral salts) into these waters. These mineral salts are at concentrations which reach saturation concentration and result in the precipitation of calcium rich mineral deposits called calcite (or Tufa) into the tributary creeks and the Fording River. The calcite deposits are deleterious substances that result in the initial consolidation of creek bottom sediments and gravel eventually forming a concrete matrix which in cases such as Kilmarnock creek can only be broken with the force of hammer blows. In cases such as Cataract Creek, the calcite deposits consolidate the creek bottom sands and gravels and form terraces and cause the destruction of aquatic plant life. The calcite deposits are present on the sands and gravels in the Fording River downstream of these tributaries. These calcite deposits can and do result in the alteration and destruction of fish habitat by preventing the fish from spawning and the destroying the habitat of fish food organisms.

1.3.4 Concentration of selenium in the Fording River: The concentration of dissolved selenium in the tributaries and the Fording River upstream of coal mining activity is at the background concentrations of 1.0 µg/L (parts per billion) which is typical of other watersheds in the region which are not impacted by coal mining.

The exposed waste rock deposits in the coal mining affected areas release dissolved selenium which enters surface water and groundwater that discharges from the tributary streams and groundwater into the Fording River.

The concentration of dissolved selenium reached 30 µg/L (parts per billion) in the upper Fording River downstream of the confluence of Porter Creek during the period of June-July 2012 which is 15 times the Level of 2.0 µg/L (parts per billion) to protect aquatic life as specified in the B.C. Water Quality Guidelines. This concentration reflects the typical value during the spring freshet (high runoff) period.

The concentration of dissolved selenium reached 113 µg/L (parts per billion) downstream of the confluence of Porter Creek during the period of April-May 2014 which is 55 times the Level to protect aquatic life as specified in the B.C. Water Quality Guidelines. This concentration reflects the typical value entering the Fording River Oxbows during the winter (low runoff) period.

The rise in the concentration of dissolved selenium in the surface and groundwaters of the tributaries and the Fording and Elk Rivers are due to the deposit of waste rock from the coal mines.

1.3.5 **Loading of Selenium in the Fording River:** The concentration of dissolved selenium increases in the Fording River in direct proportion to quantities of waste rock deposited in the watershed by coal mining and the concentrations of dissolved selenium in the coal mining affected tributaries. During the period of June to July 2012, Kilmarnock Creek was the single largest source of selenium at an estimated 12.9 kg/day, followed by Cataract Cr. at 4.1 kg/day and Swift Creek at 3.6 kg/da. These three creeks accounted for 75% of the estimated surface loading of 27.7 kg/day of selenium deposited into the Fording River not including the quantity which may be discharged via groundwater.

1.3.6 **Concentration of Selenium in the Elk River: The concentration of dissolved selenium in the** Fording River causes the concentration of selenium in the Elk River to increase. During the freshet period of June-July 2012, the discharge of selenium from the Fording River caused the concentration of selenium to increase from 1.0 µg/L to 6.0 µg/L in the Elk River. This increase is consistent with the concentrations observed during the routine water quality monitoring during freshet conducted by Environment Canada in the Elk River at the stations of Sparwood and Elkford.

Over the period from 2002 to 2013, the peak concentration of selenium in the Elk River at Sparwood has increased from 4.0 µg/L to 12 µg/L. Over the same period the peak concentration of selenium in the Elk River at Fernie has increased from 1.0 µg/L to 6 µg/L. The concentration of selenium in the Elk River consistently exceeds the Level of 2.0 µg/L to protect aquatic life as specified in the B.C. Water Quality Guidelines.

The mining of coal and the deposit of waste rock in the watersheds of the Fording River are a cause of the increased dissolved selenium in the Elk River.

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1.3.7 Concentration of Selenium in periphyton/algae: The concentration of dissolved selenium in the tributaries and the Fording River co-relate directly to the concentrations of selenium found in periphyton/algae in those waters. The concentration of selenium in the periphyton/algae is highest in those areas of the watershed with quiescent (Lentic) zones namely Clode Pond and the approximately 9 km section of the upper Fording River known as the Fording River Oxbows. These quiescent (Lentic) zones allow organic carbon materials and fine sediments and selenium to accumulate. The high concentrations of dissolved selenium and organic carbon and the presence of bacteria and protozoa allow the dissolved selenium to be converted by bacteria and protozoa into organo selenium compounds. These organo selenium compounds are incorporated into the tissue of periphyton/algae in those waters. The highest concentrations of selenium in periphyton/algae were sampled in the Fording River Oxbows in April-May 2014.

1.3.8 Concentration of Selenium in benthic Invertebrates: Benthic invertebrates consume periphyton/algae as food. The concentration of dissolved selenium in the tributaries and the Fording River co-relate directly to the concentrations of selenium found in the tissue of benthic invertebrates sampled in those waters. The concentration of selenium in the benthic invertebrates is highest in those areas of the watershed with quiescent (Lentic) zones namely Clode Pond and the approximately 9 km section of the Fording River known as the Fording River Oxbows. The high concentrations of selenium in benthic invertebrates is due to the high concentrations of dissolved selenium in those waters and the corresponding high concentration of selenium in periphyton/algae in those waters.

1.3.9 Concentration of Selenium in West Slope Cutthroat Trout: West Slope Cutthroat Trout consume benthic invertebrates as food. The concentration of dissolved selenium in the tributaries and the Fording River co-relate directly to the concentrations of selenium found in the tissue (muscle, liver and eggs) of West Slope Cutthroat Trout sampled in those waters. The concentration of selenium in the benthic invertebrates is highest in those areas of the watershed with quiescent (Lentic) zones namely Clode Pond and the approximately 9 km section of the Fording River known as the Fording River Oxbows. The high concentrations of selenium in West Slope Cutthroat Trout in the upper Fording River is due to the high concentrations of selenium in the waters and the concentration of selenium in periphyton/algae and benthic invertebrates found in those waters.

1.3.10 **Concentration of Selenium in West Slope Cutthroat Trout Tissues**: West Slope Cutthroat trout were captured in the coal mining impacted tributaries of Henretta Creek, Fish Pond Creek, Clode Pond, Clode Pond Creek, Grassy Creek and the Fording River and the non-mining affected Connor Lake. Tissue samples of muscle, liver and eggs were collected from these fish and analysed for total selenium. The concentration of selenium in these tissues were found to correspond directly in relation to the degree to which each water body is affected by the quantity of waste rock deposited in the water shed by coal mining and the concentration of dissolved selenium in the water emanating from that waste rock. The highest average concentrations in tissues were found in Clode Pond which is a settling pond designed to remove fine particulates. The highest concentration of selenium in eggs from any area was found in a fish that was attempting to migrate from the Fording River into Fishpond Creek to spawn.

1.3.11 **Exceedance of Human Consumption limits for selenium;** Muscle tissue samples analysed for selenium indicated that 1/31 or 3% of fish captured in the Upper Fording River (or migrating out of it to spawn in a tributary) exceeded the 75 µg/g low human consumption limit and 23/31 or 74% exceeded the 14.5 µg/g moderate human consumption concentration limit. (The human consumption limit as specified by the Province of British Columbia and Health Canada fish consumption guidelines).

1.3.12 **Exceedance of limits for selenium in eggs;** Egg samples were analysed from fish captured in the Upper Fording River. Of these fish, 29/31 = 94% exceed 10 µg/g dry weight which as the concentration at which sensitive species first begin to experience selenium poisoning. (Lemly 2014) In the Upper Fording River 12/31 = 39% had Selenium in egg concentrations 20 µg/g dry weight or greater at which point 50% or greater mortality in the emerging fry was evidenced.

1.3.13 **Relationship between selenium in muscle and egg tissue**: The concentration of selenium in egg tissue co-relates to the concentration of selenium in muscle tissue of West Slope Cutthroat trout captured in the upper Fording River and the entrances to its tributaries. The relationship between this co-relation for the samples collected in June-July of 2012 was estimated by the equation;

Selenium in $Egg_{(Enviornment\ Canada\ 2012)} = y = 1.273x + 6.1787\ R^2 = 0.8661$ (Outliers excluded)

This equation is similar but provides a more conservative estimate that the equation derived by Schwarz (2011);

Selenium in $Egg_{concentration}$ = EXP((0.9432+0.8297*LN(Muscle))).

1.3.14 Correlation of Environment Canada Data to other researchers: The analysis of selenium in the eggs of West Slope Cutthroat trout in the Upper Fording River by Environment Canada in June-July, 2012 co-relates directly with results reported by other researchers. Other researchers report that the concentration of selenium in eggs from fish captured in the Fording River Oxbows are among the highest in the Upper Fording River Watershed.

1.3.15 Loss of overwintering areas: Kilmarnock Creek used to provide summer habitat to juvenile and adult west slope cutthroat trout and a sport trout fishery. It was documented to supply overwintering habitat to approximately 37% of the West Slope Cutthroat in the Upper Fording River. Kilmarnock Creek has been damaged by waste rock slides and the construction of two settling ponds which now prevent any fish from the Fording River from entering that stream at any period of the year. This damage is due to waste rock slides which occurred during the periods of ownership prior to the TECK Coal ownership and the operational deposit of waste rock under the current Teck Fording Coal Operations. As a result, West Slope Cutthroat trout can no longer utilize Kilmarnock Creek during the summer high flow or winter low flow periods.

Water still flows in Kilmarnock Creek however now it must pass through the waste rock slides and the two settling ponds and discharge over constructed fish barriers. During the dry/low flow (winter season) the surface water ceases to flow from Kilmarnock Creek overland to the Fording River however groundwater will continue to flow through the alluvial fan (rock/sand/gravel delta) to the Fording River.

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Water from Clode Pond/creek, Grassy Creek, Eagle pond/creek, Swift Creek and Cataract Creek will also enter the Fording River via overland or groundwater discharges.

During the dry/low flow (winter season) the surface water flows in the Fording River will cease in the areas adjacent to the discharges of Swift Creek, Kilmarnock Creek. This decrease in flow during the overwintering period causes West Slope Cutthroat Trout to migrate upstream in the Fording River to the Multiplate Culvert Pond and/or Henretta Creek Pond or downstream into the Fording River Oxbows. The West Slope Cutthroat Trout which migrate into the Fording River Oxbows will feed on the benthic invertebrates found in the Fording River Oxbows and therefore the high concentration of selenium in the muscle and egg tissue of fish sampled in the Fording River Oxbows during the winter period and the high concentration found in fish entering tributary streams in June-July 2012 are likely from fish that overwintered in the Fording River Oxbows.

1.3.16 **Early life stage bioassay:** Eggs and milt from fish captured in June-July 2012 in the Connor Lake site and the Fording River and tributaries were tested in an early life stage bioassay test. The bioassay test showed that;

1) There was a direct co-relation between the increasing concentration of selenium found in the eggs and the increased incidence of cranial-facial and spinal deformities and edema (tissue swelling) abnormalities. The increase in edema abnormalities was the greatest effect.

2) There was a direct co-relation between the increasing concentration of selenium found in the eggs and the decreasing survival rate of newly hatched and swim up fry.

1.3.17 **Movement of Selenium from Waste Rock to fish tissue and toxicity to fish**: Coal mining by the Teck Coal Fording Operations and Teck Coal Greenhills Operations in the Fording and Elk River watersheds deposit waste rock onto the surface adjacent to and into the tributaries of the Elk and Fording Rivers in south western British Columbia.

Waste Rock from coal mining from the Teck Coal Fording Operations, Teck Coal Greenhills Operations in the Fording and Elk River watersheds contains selenium which is a substance deleterious to fish.

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Selenium is dissolved from the waste rock by surface and ground water and enters the surface and groundwater of tributaries to the Fording and Elk Rivers and directly to the waters of the Fording and the Elk Rivers.

Dissolved selenium is converted by bacteria and protozoa into organo-selenium compounds which are incorporated into the tissue of periphyton/algae.

Benthic Invertebrates consume periphyton/algae containing organo-selenium compounds and incorporate those compounds into their tissue.

West Slope Cutthroat trout consume benthic invertebrates containing organo selenium compounds and incorporate those compounds into their tissue. Organo selenium compounds concentrate in the muscle, liver and egg tissue of West Slope Cutthroat Trout.

After fertilization the eggs of Westslope Cutthroat trout containing organo selenium compounds exhibit increasing rates and degrees of cranial-facial and spinal deformities and increasing rates and degrees of edema abnormalities in fry hatched from those eggs.

After fertilization the eggs of Westslope Cutthroat trout containing organo selenium compounds exhibit increasing rates of mortality at selenium concentrations greater than 20 µg/g dry weight and 100 percent mortality at concentrations greater than 60 µg/g dry weight selenium.

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1.4 Summary of Environmental Sampling Results – Fording River

The surface area impacted by the Teck coal mines was estimated using Google Earth Polygon Tool and Earthpoint.us polygon area calculation function and the estimated areas are listed in Table 1.1 and illustrated in Figure 1-1.

Table 1.1 Estimate of Surface Area Impacted by the TECK Coal Mines in South Eastern British Columbia	
Mine	Area (km^2)
Fording Coal Operations (North Pit)	4.8
Fording Coal Operations (South Pit)	22.7
Greenhills Coal Operations	31
Line Creek Coal Operations	19
Elkview Coal Operations	41
Coal Mountain Operations.	11.9
Total	**130 km^2**

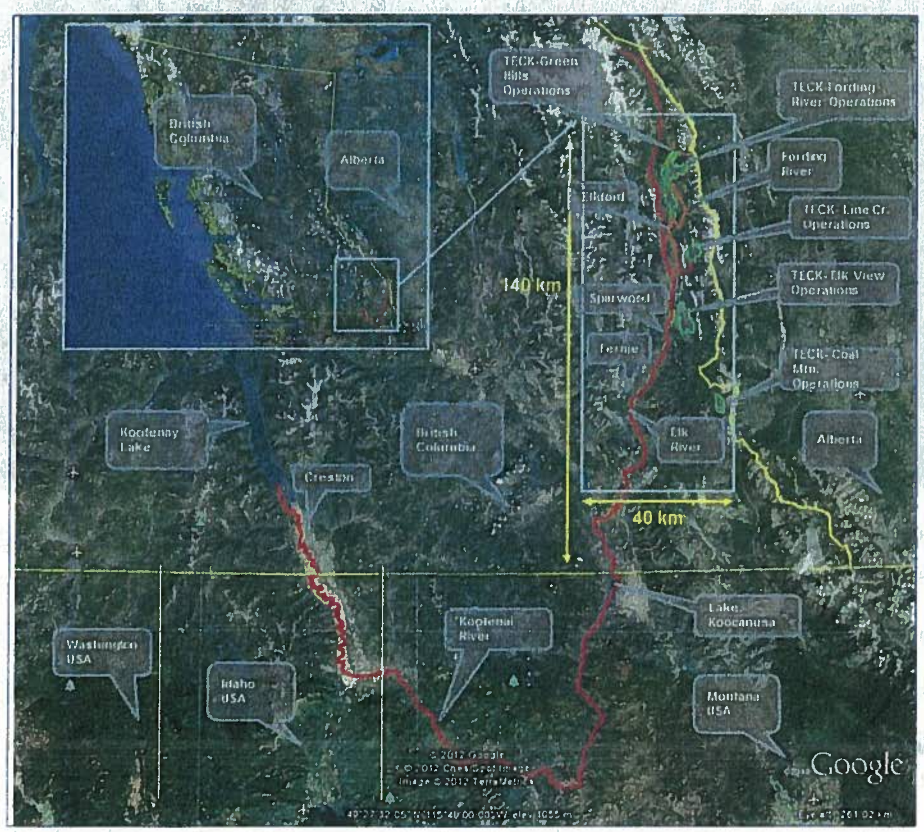

Figure 1-1: Study area in the Elk and Fording River Basins.

In order to assess the environmental impact of Coal Mining in the Elk and Fording River, nine stages of environmental samples were identified from the literature. (Figure 1-2) Field operations were initiated in February 2012, June-July 2012, April-May 2014 and September-October 2014 to collect those samples to illustrate how selenium moves from the source rock into fish muscle, liver and eggs of Westslope Cutthroat trout and the impacts of selenium on the early life stage of fish embryos. (Lemly – 2001, Palace-2004, Orr-2005, Rudolph-2008, Elphick-2009 Minnow-2011)

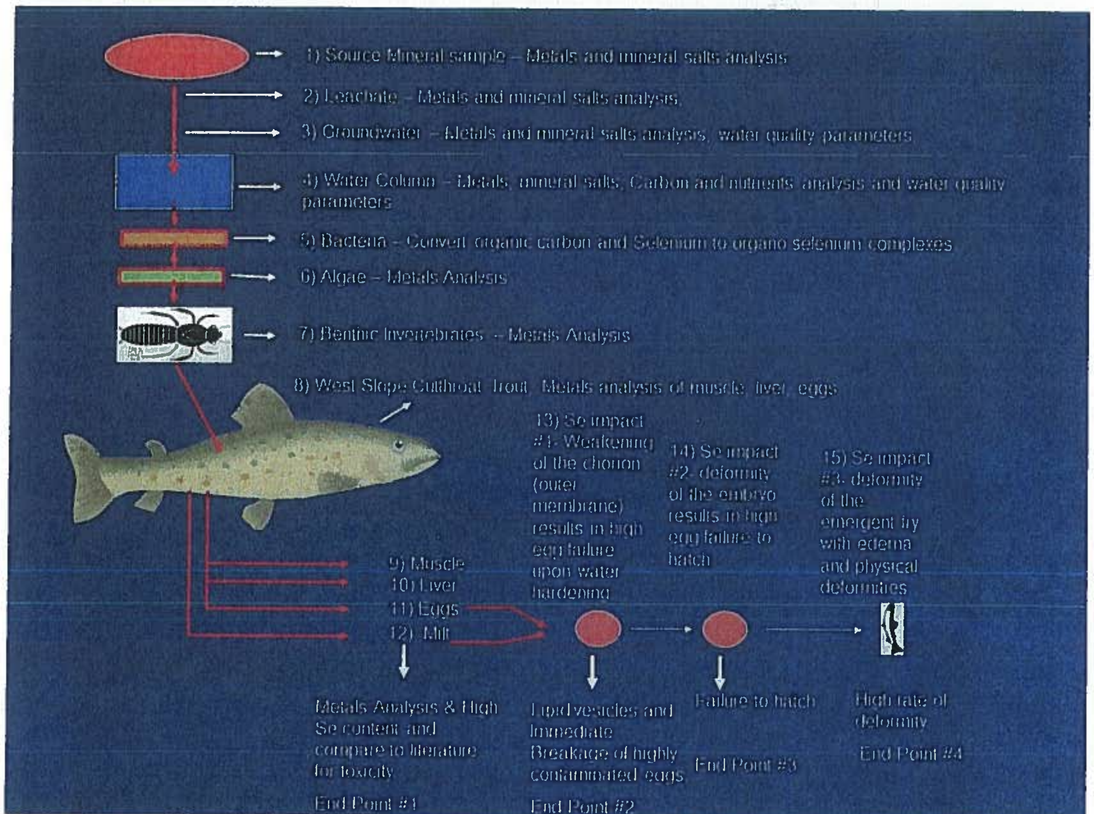

Figure 1-2: General sampling plan to assess the Impact of coal mining on West Slope Cutthroat Trout in the Elk and Fording Rivers.

In June and July 2012, samples were collected in a systematic manner from upstream of coal mining to downstream of the confluence of the Elk and Fording Rivers in south east British Columbia. (Figure 1-3)

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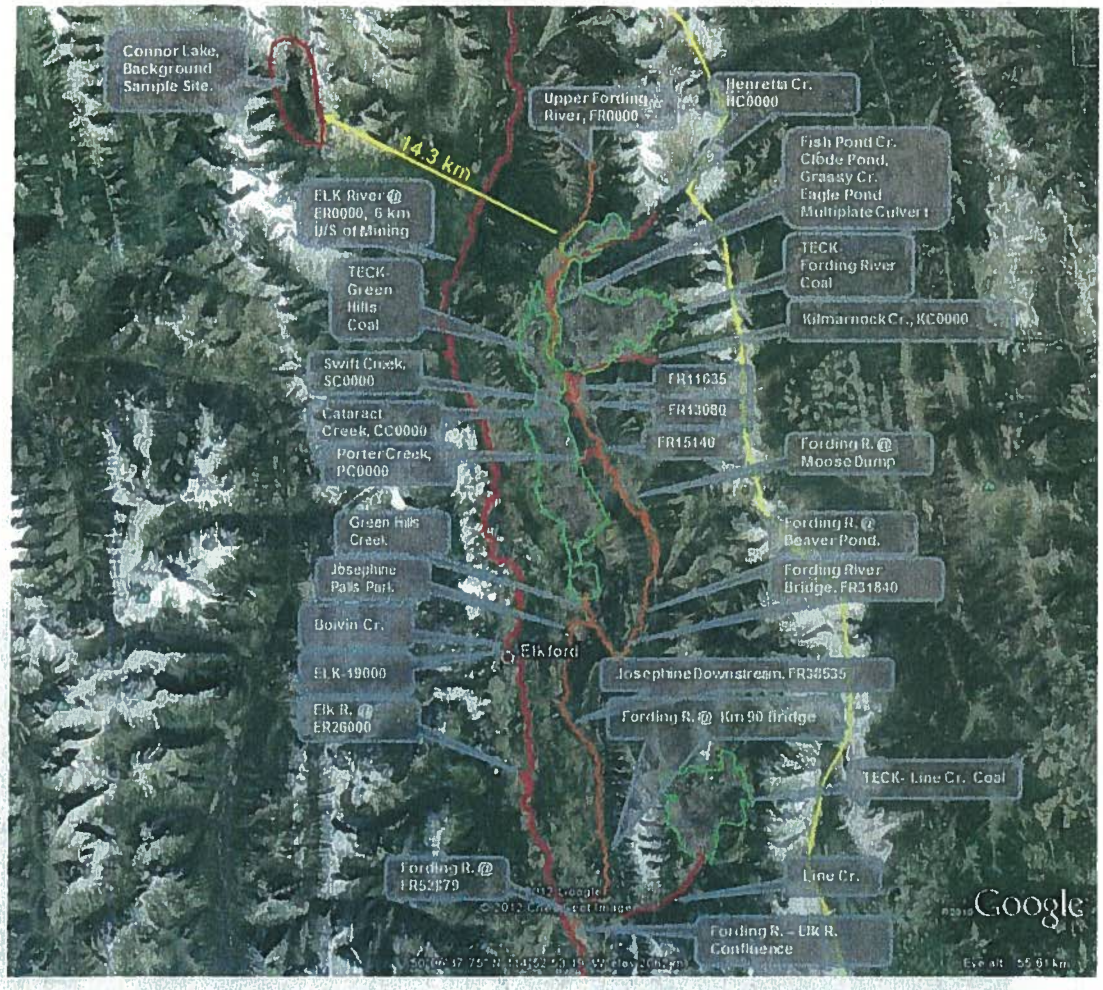

Figure 1-3 Locations of the Major Sampling Sites in the Upper Fording River and Upper Elk River, June-July 2012

The samples included;

1) Source mineral samples from waste rock – Metals and mineral salts analysis

   Leachate – Metals and mineral salts (calcium, magnesium, potassium, sulphates) and nutrients (nitrates, nitrites,) analysis

2) Groundwater – Metals and Mineral Salts analysis and water quality parameters

3) Water Column - Metals and Mineral Salts analysis and water quality parameters

4) Sediment – Metals analysis

   Bacteria – Convert organic carbon and selenium to organo-selenium complexes (not sampled)

5) Algae – which forms benthic invertebrates food source - Metals analysis

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6) Benthic Invertebrates – which forms fish food source – Metals analysis

7) West Slope Cutthroat Trout;

Muscle – metals analysis

Liver – metals analysis

Eggs – metals analysis

Eggs – Lipid vesicles assessment was not performed.

8) West Slope Cutthroat Trout, early life stage bioassay

Selenium concentration vs. percent survival

Selenium concentration vs. skeletal deformity severity index

Selenium concentration vs. cranial-facial deformity index

Selenium concentration vs. edema abnormality index.In April and May 2014, samples were collected in a systematic manner in the area known as the Fording River Oxbows Figure 1-4)

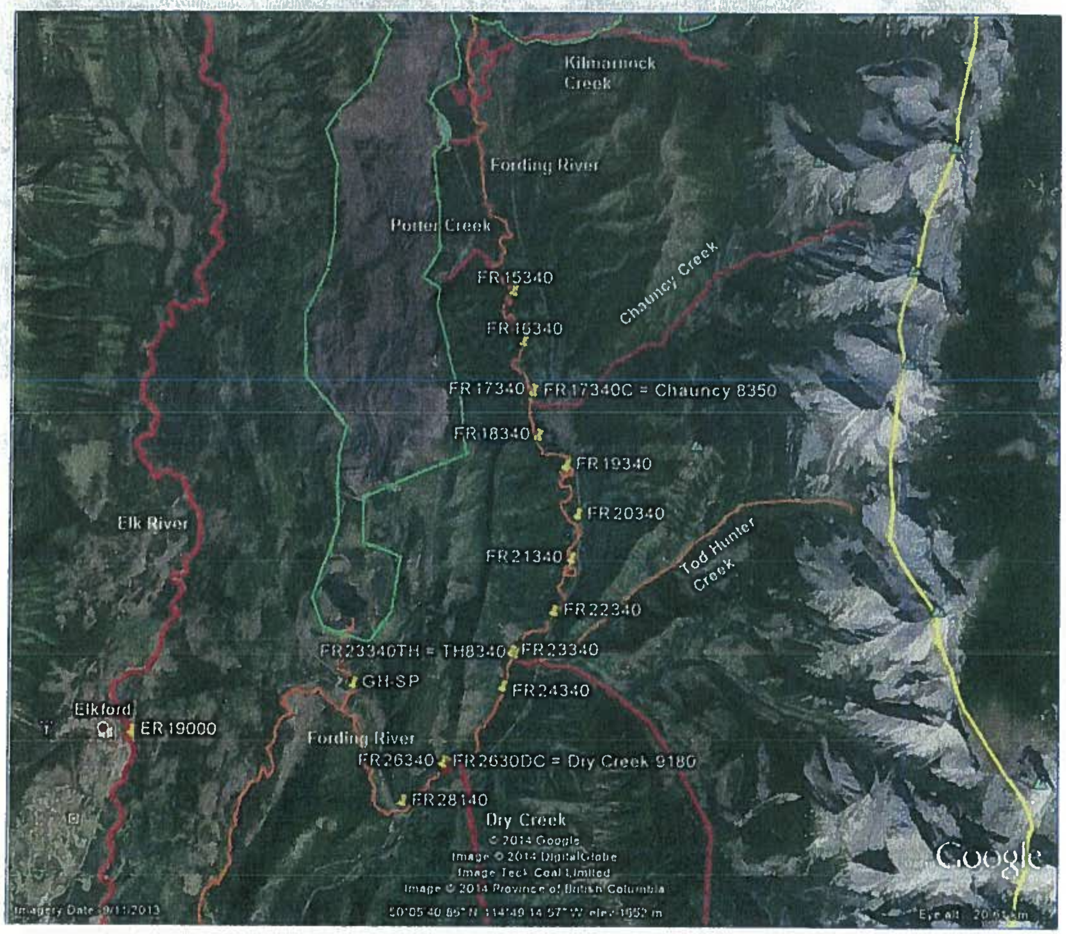

Figure 1-4: Location of sample sites FR15340 to FR24340 which are located at the upstream and downstream ends of the Fording River Oxbows collected April-May, 2014.

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The samples included;

1) Water Column - Metals and Mineral Salts analysis

2) Sediments – Metals analysis

2) Nutrients and water quality parameters

3) Periphyton (Algae) – which forms the benthic invertebrate's food source - Metals analysis

4) Benthic Invertebrates – which forms the fish's food source – Metals analysis

1.4.1 Waste Rock as a Source of Selenium – Fording River.

Waste rock is a substance that results from the activity of coal mining and is deposited into areas of the Elk and Fording Rivers adjacent to or into streams which are waters frequented by fish, specifically, West Slope Cutthroat Trout. (Figure 1-5)

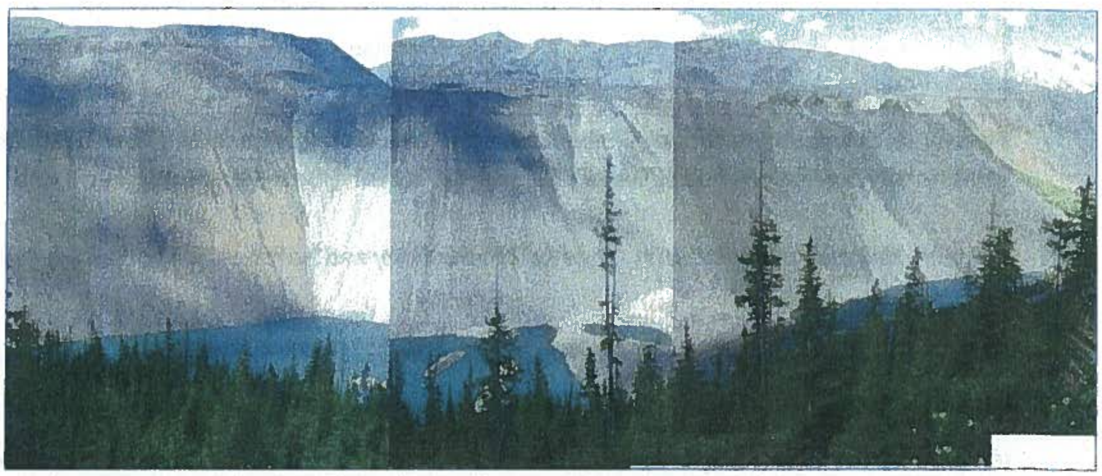

Figure 1-5: Example of Waste Rock from Coal Mining deposited adjacent to and into streams which were previously waters frequented by fish (West Slope Cutthroat Trout)

Source minerals collected from waste rock piles all contained selenium, similar to that as reported by Lussier-2003. In Lussier, the rock types were kept separate whereas in the Environment Canada samples, the rock types were combined into one composite sample for each sampling location. (Figure 1-6)

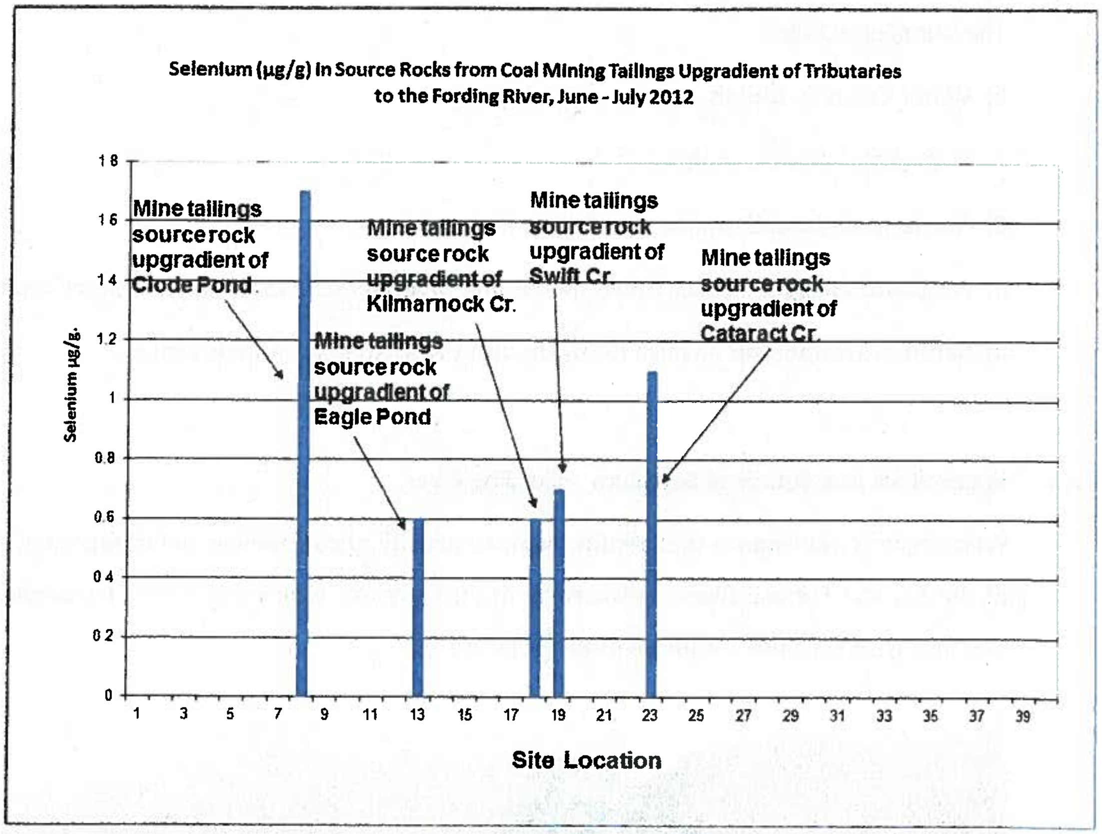

Figure 1-6: Selenium Content of Waste Rock from Coal Mining deposited adjacent to and into streams which were previously waters frequented by fish (West Slope Cutthroat Trout)

1.4.2 Calcium, Magnesium, Potassium, Specific Conductivity and Hardness in the Fording river and the formation of Calcite.

Calcium, magnesium and potassium leach from the waste rock into the water and discharge into groundwater and tributary streams and the Fording River. The upstream to downstream water samples for calcium, magnesium, potassium, conductivity and hardness all show the same concentration profile. Leachate from source rock piles frequently contained calcium and magnesium at over 20 times the background concentrations of areas that were not impacted by coal mining. These high concentrations are reflected in the profile for conductivity and hardness. (Figures 1-7 to 1-11)

The concentrations in the Fording River are lower during freshet (June-July 2012 sampling) and then increase significantly during fall/winter low flow periods when surface runoff subsides and the primary loading from the coal mining affected Clode Pond/Creek, Grassy Creek, Eagle

Pond/Creek, Swift Creek, Kilmarnock Creek, Cataract Creek and Porter Creek. All criteria increase in the Upper Fording River especially during the winter low flow period. (April-May 2014 sampling) The non-coal mining affected streams of Chauncy Creek, Todd Hunter Creek, and Dry Creek provide some dilution of these concentrations after their confluence with the Upper Fording River.

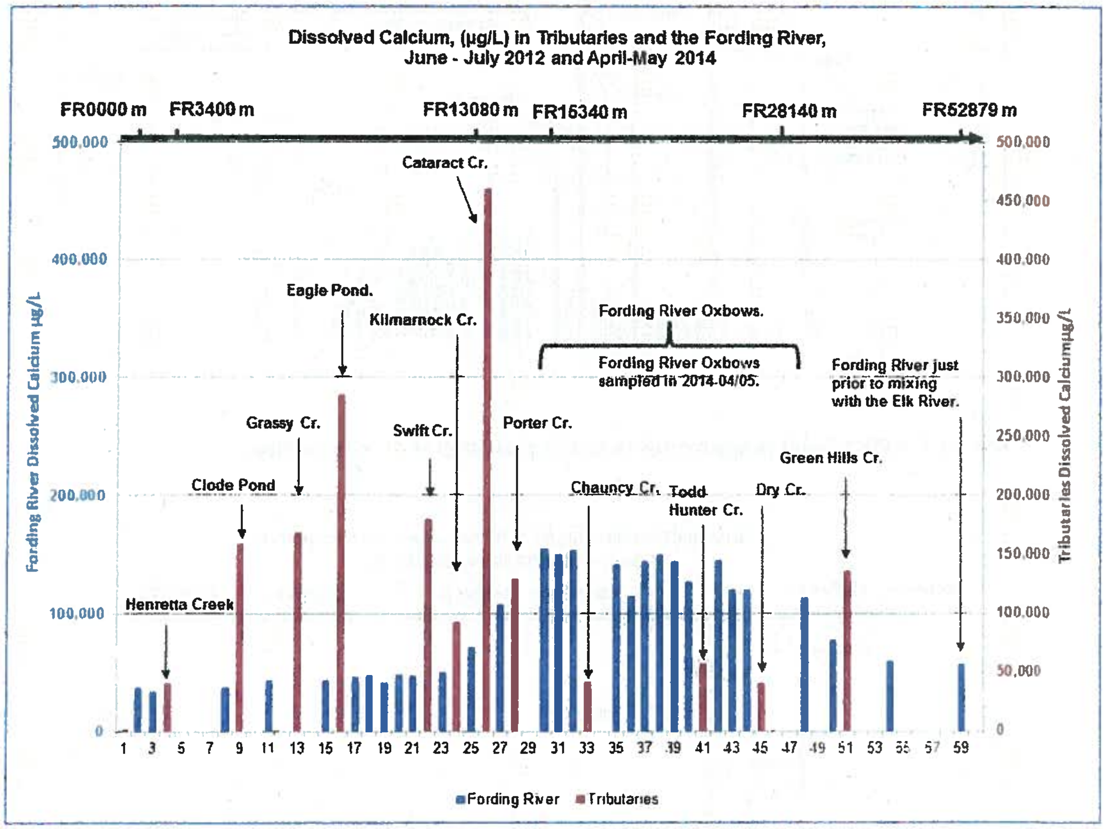

Figure 1-7 Dissolved calcium in tributaries and the Fording River.

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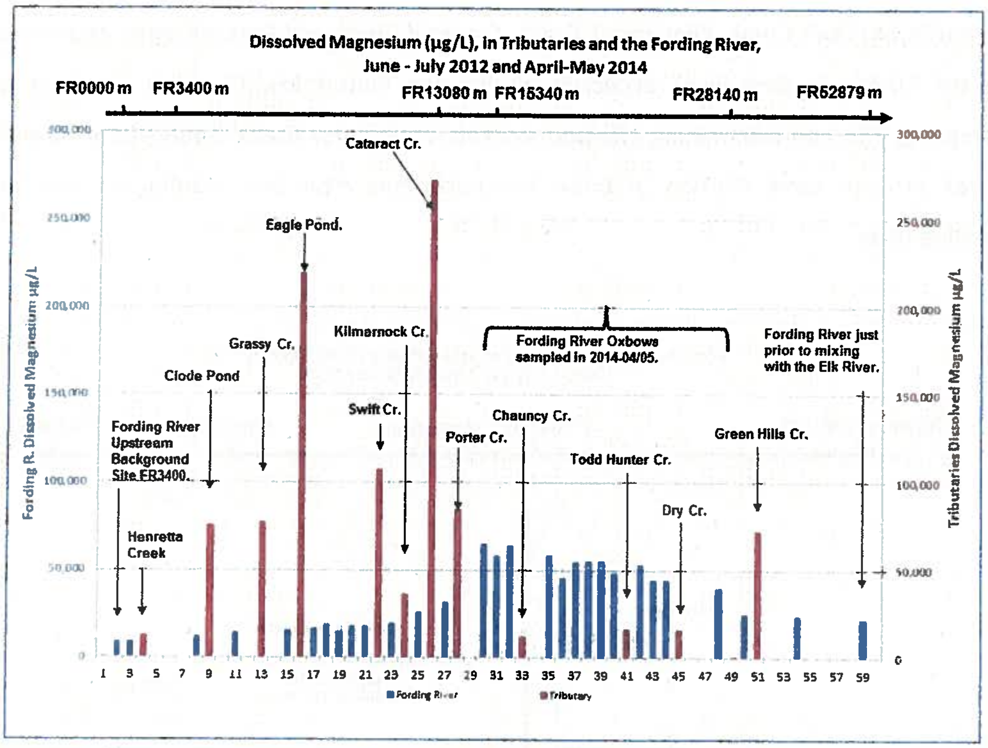

Figure 1-8 Dissolved magnesium in tributaries and the Fording River.

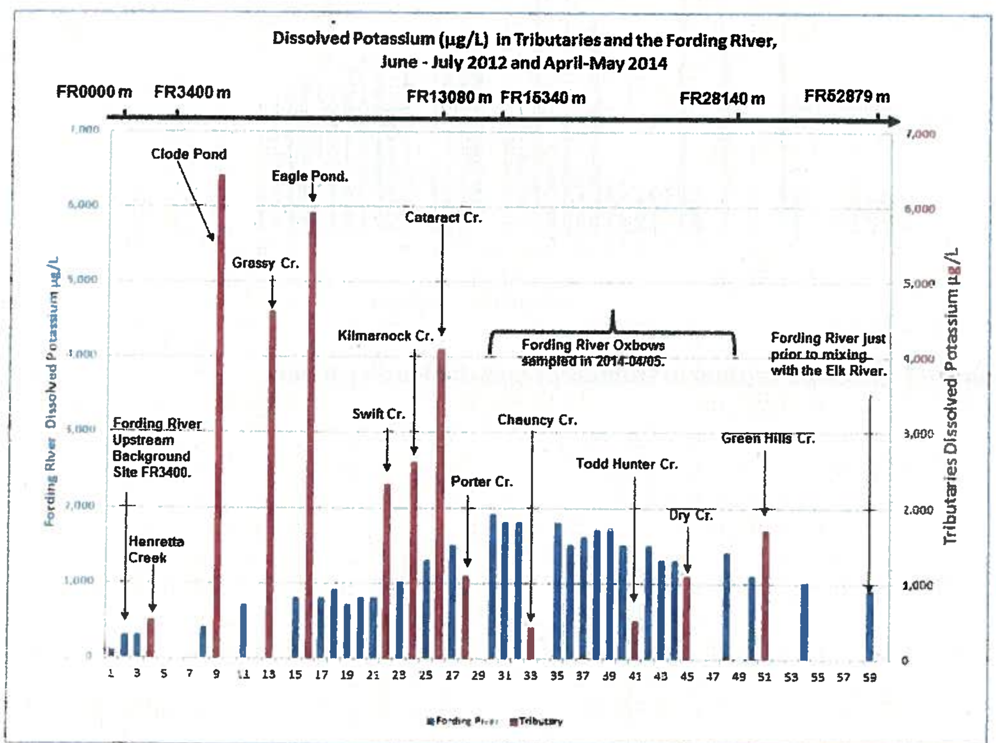

Figure 1-9 Dissolved potassium in tributaries and the Fording River.

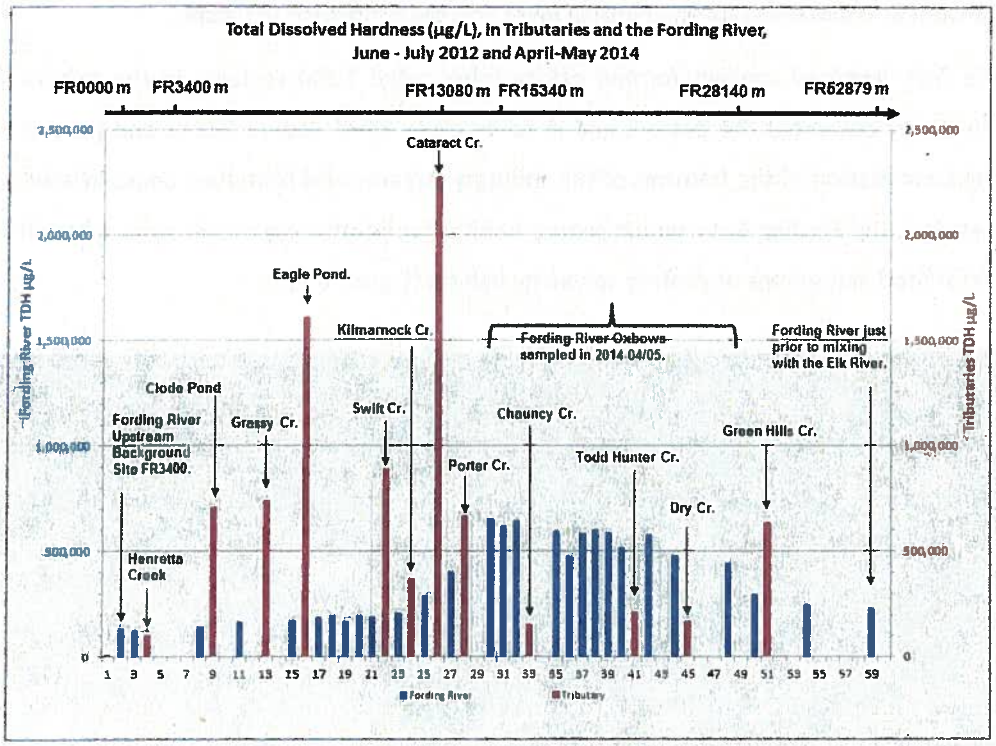

Figure 1-10 Dissolved potassium in tributaries and the Fording River.

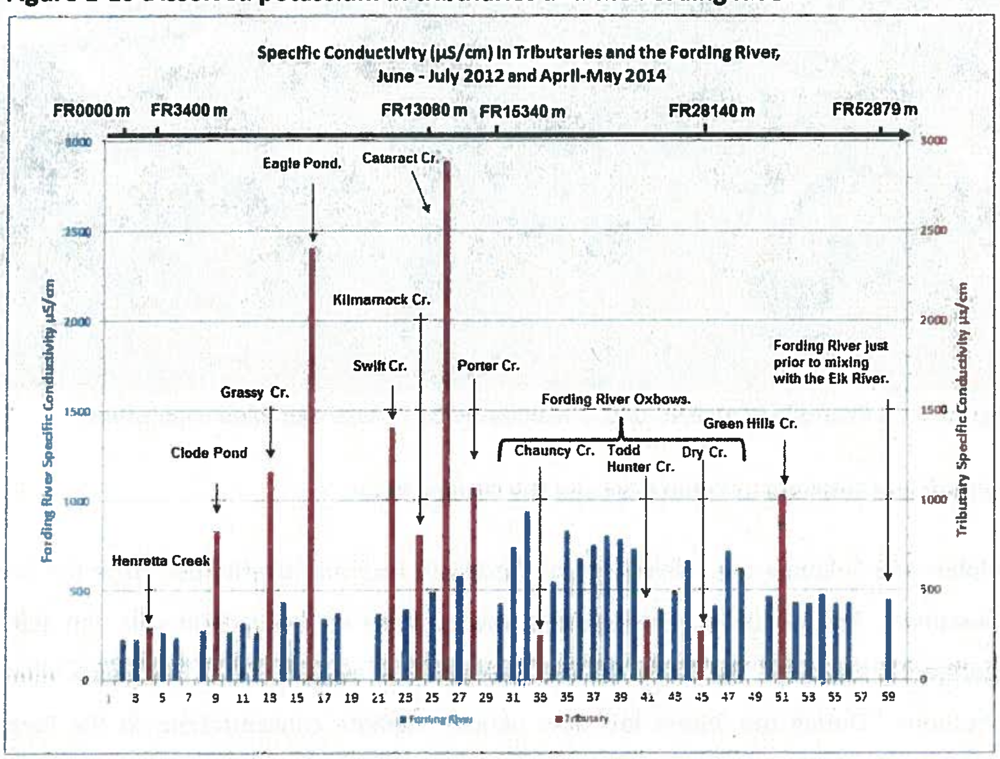

Figure 1-11 Dissolved potassium in tributaries and the Fording River.

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1.4.3 Calcium in Tributaries and the Fording River and the formation of Calcite.

The high levels of calcium formed calcite (also called Tufa) to form in the tributaries which effectively cemented the bottom and in some cases killed aquatic plants and periphyton/algae. The cementation of the bottoms of the tributary streams and continued consolidation of bottom gravels in the Fording River would reduce habitat for benthic organisms upon which fish depend on for food and reduce or destroy spawning habitat (Figure 1-12)

Figure 1-12: Example of stream bed consolidated by Calcite and dead vegetation.

1.4.4 Sulphur and Sulphate in Tributaries and the Fording River.

Sulphur and Sulphate are released from the waste rock and overburden from the coal mining operations. The trends in concentrations mirror those of the mineral salts and sulphate and significantly exceeded the limits for the protection of aquatic life in the major mine affected tributaries. During the winter low flow period, sulphate concentrations in the Fording River

Oxbows increased to concentrations near the limits for the protection of aquatic life. (Figures 1-13 and 1-14)

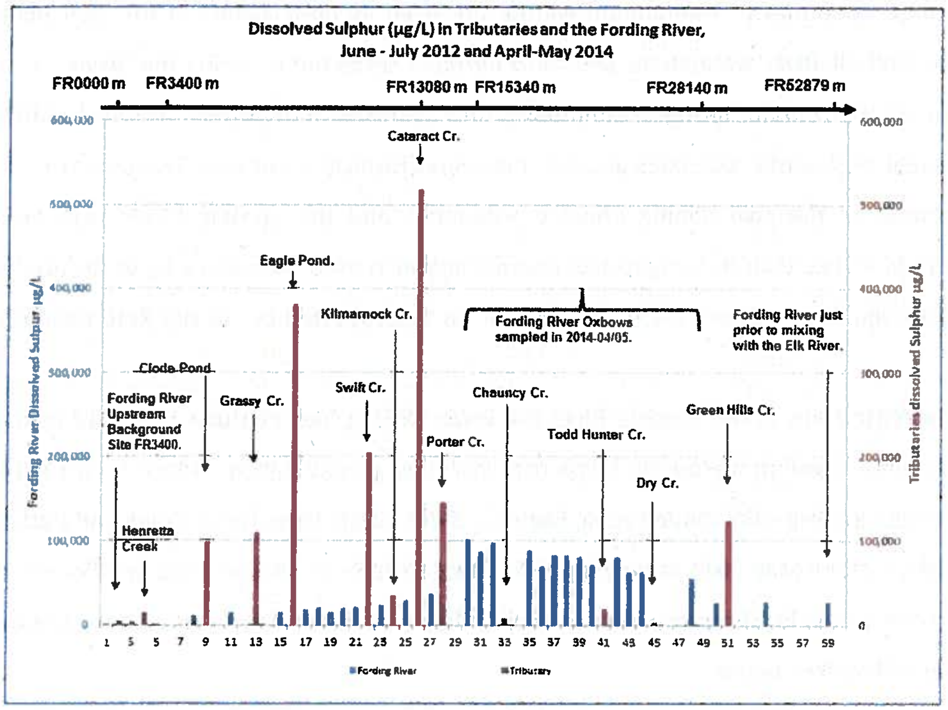

Figure 1-13: Dissolved Sulphur in Tributary Streams and the Fording River.

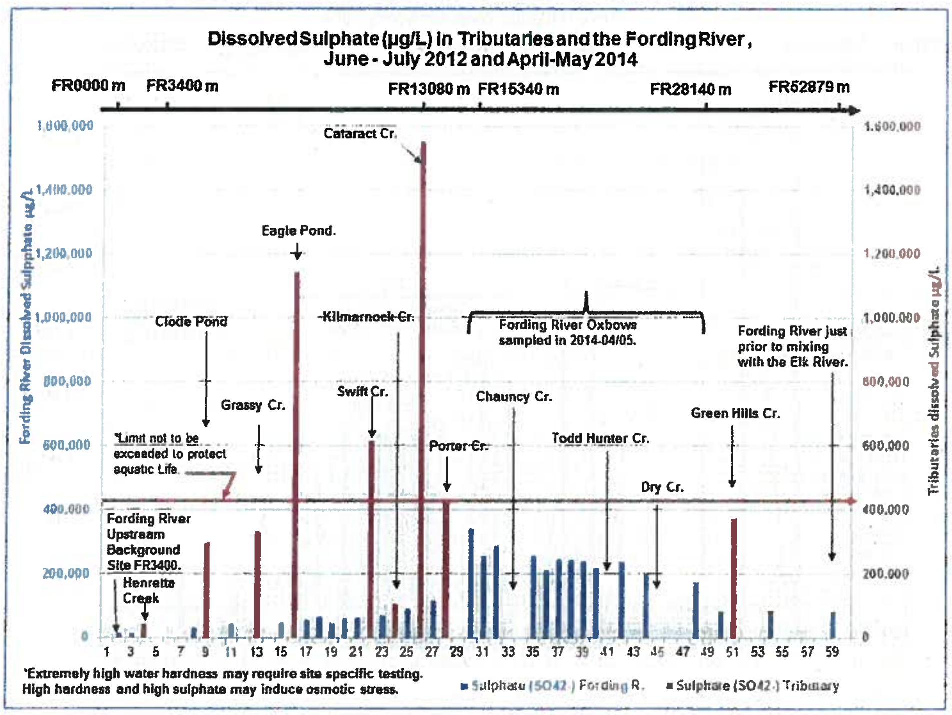

Figure 1-14: Dissolved Sulphate in Tributary Streams and the Fording River.

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1.4.5 Nitrogen and Phosphorus Compounds in Tributaries and the Fording River.

Very large quantities of Ammonium Nitrate are used as blast agents in the coal mines in the Fording and Elk River watersheds and form nitrogen compounds during the blasts. A significant portion of the residual nitrogen compounds are available in dissolved form in runoff from the blast areas and waste rock piles as plant nutrients (Nitrates + Nitrites) The quantity of nitrogen compounds in the coal mining affected tributaries and the Fording River were an order of magnitude higher than in background streams and increased the values by up to ten fold in the upper Fording River. (Figure 1-15) This is similar to that reported by Interior Reforestation 2010.

The concentrations in the Fording River are lower during freshet (June-July 2012 sampling) and then increase significantly during fall/winter low flow periods when surface runoff subsides and the primary loading from Clode Creek, Eagle Cr, Swift Creek, Kilmarnock Creek and Cataract Creek take effect. (April-May 2014 sampling). The concentration of nitrates very significantly exceeded the concentration for the protection of aquatic life, especially in the Fording River Oxbows during the winter low flow period.

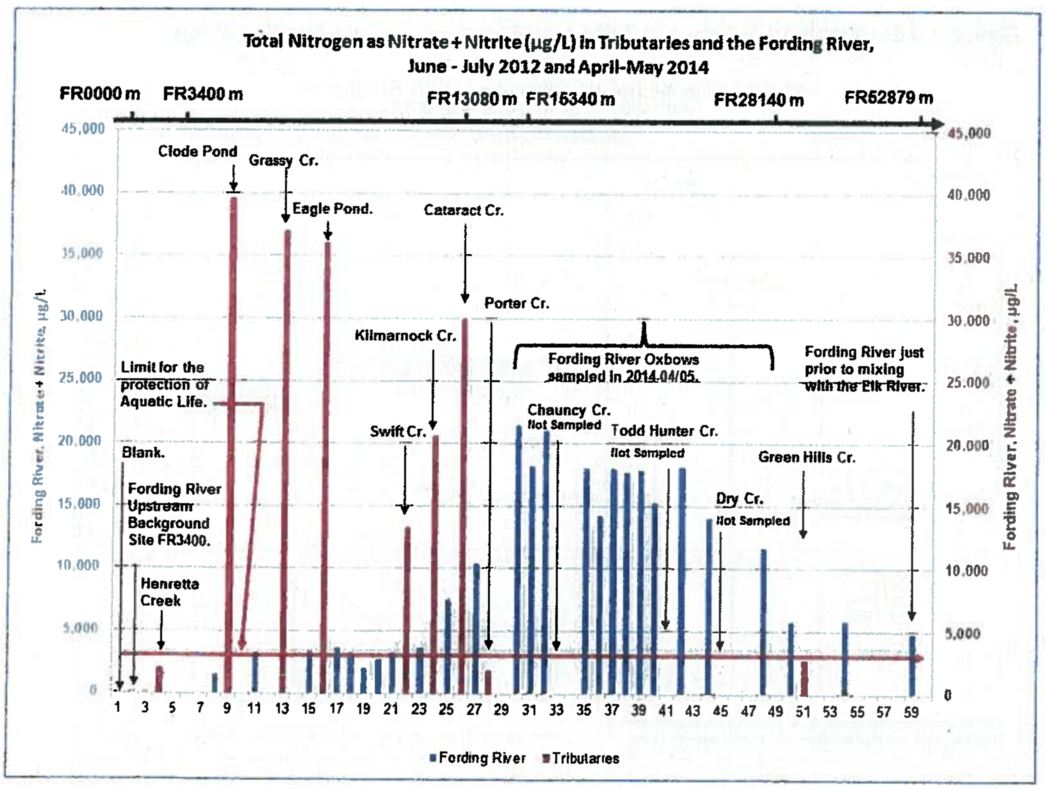

Figure 1-15: Dissolved Nitrogen (Nitrate + Nitrite) in Tributary Streams and the Fording River.

Phosphorus was not associated with the coal mining operation and most of the rocks in the Upper Fording River mining affected tributaries (except for Swift Creek) do not seem to contribute to phosphate in the runoff. The absence of phosphorus likely limits the impact on aquatic vegetation growth which might have been significantly greater in view of the high concentrations of nitrogen compounds. (Figure 1-16)

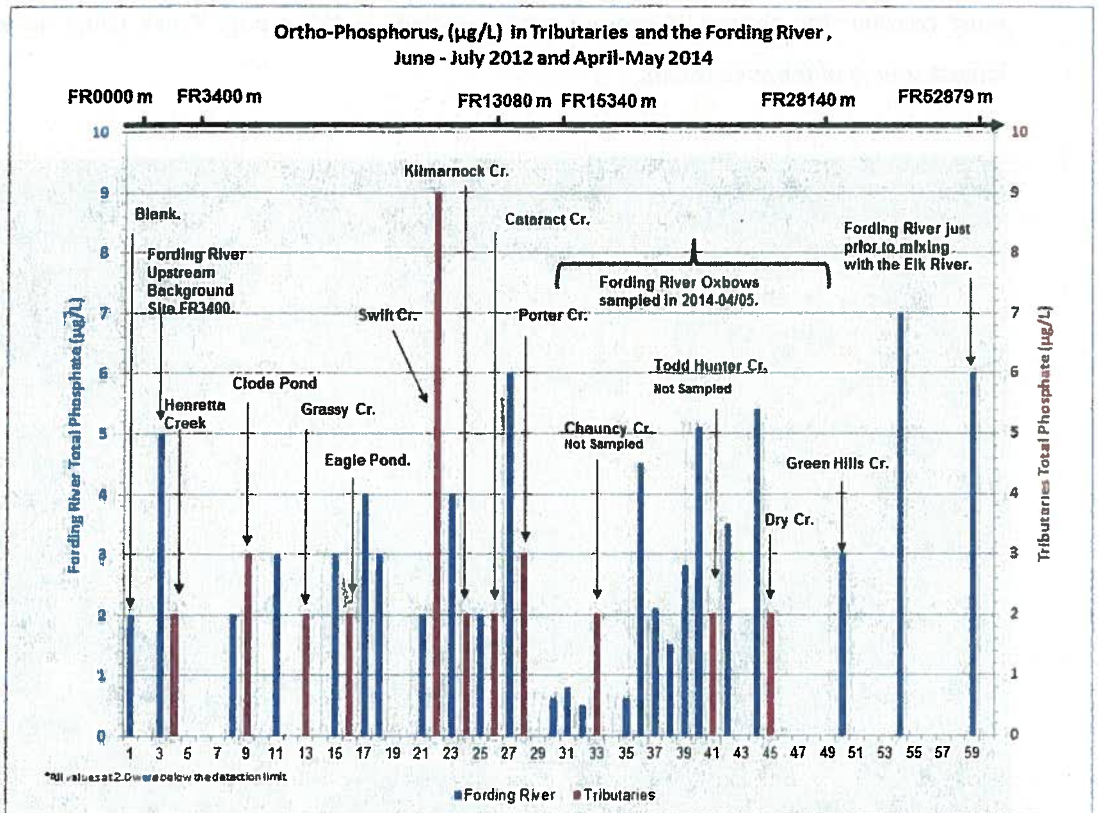

Figure 1-16: Dissolved Ortho-Phosphorus in Tributary Streams and the Fording River.

1.4.6 Groundwater impact in Tributaries and the Fording River.

Surface water which percolates through the broken waste rock will result in both rapid surface runoff during freshet and recharging of groundwater. A limited sampling of shallow groundwater was done down gradient of Kilmarnock Creek settling pond #2. Kilmarnock Creek had created a large alluvial fan composed of large cobble, gravel and sand. Groundwater flowed very rapidly through the settling pond walls and through the substrate to the Fording River.

The mineral salts (calcium, magnesium, potassium) nutrients (nitrogen and phosphorus compounds) and selenium in the groundwater showed the same chemical profiles as leachate and Kilmarnock Creek water for all elements measured in the tributary stream. Groundwater is therefore a significant loading source of these elements into the Fording River. A dye test indicated that the rate of ground water flow to the Fording River from Kilmarnock Creek Pond #2 may be up to 6.9 meters per hour (Figure 1-17 and 1-18). Control of these chemical elements must consider the control of groundwater especially at Kilmarnock Creek which is the single largest source of these elements.

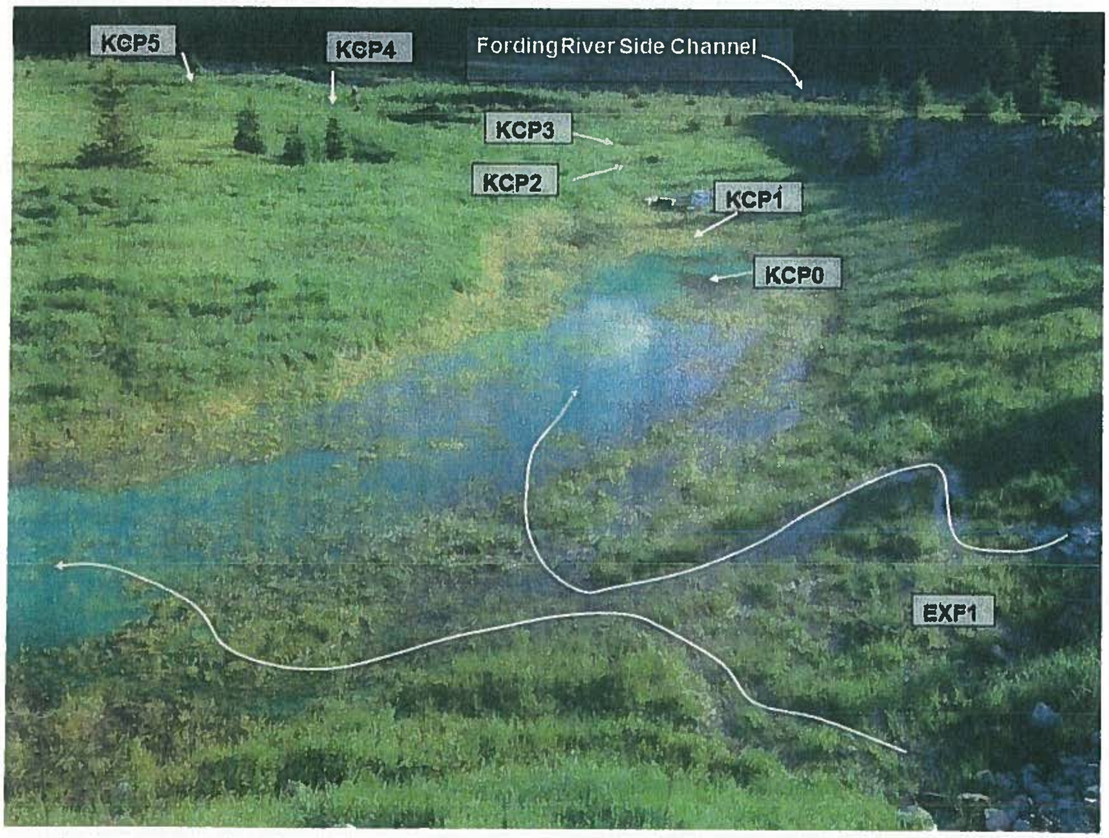

Figure 1-17: Dye test which shows seepage containing selenium that leaks from a storage pond and re-enters groundwater and discharges to the Fording River.

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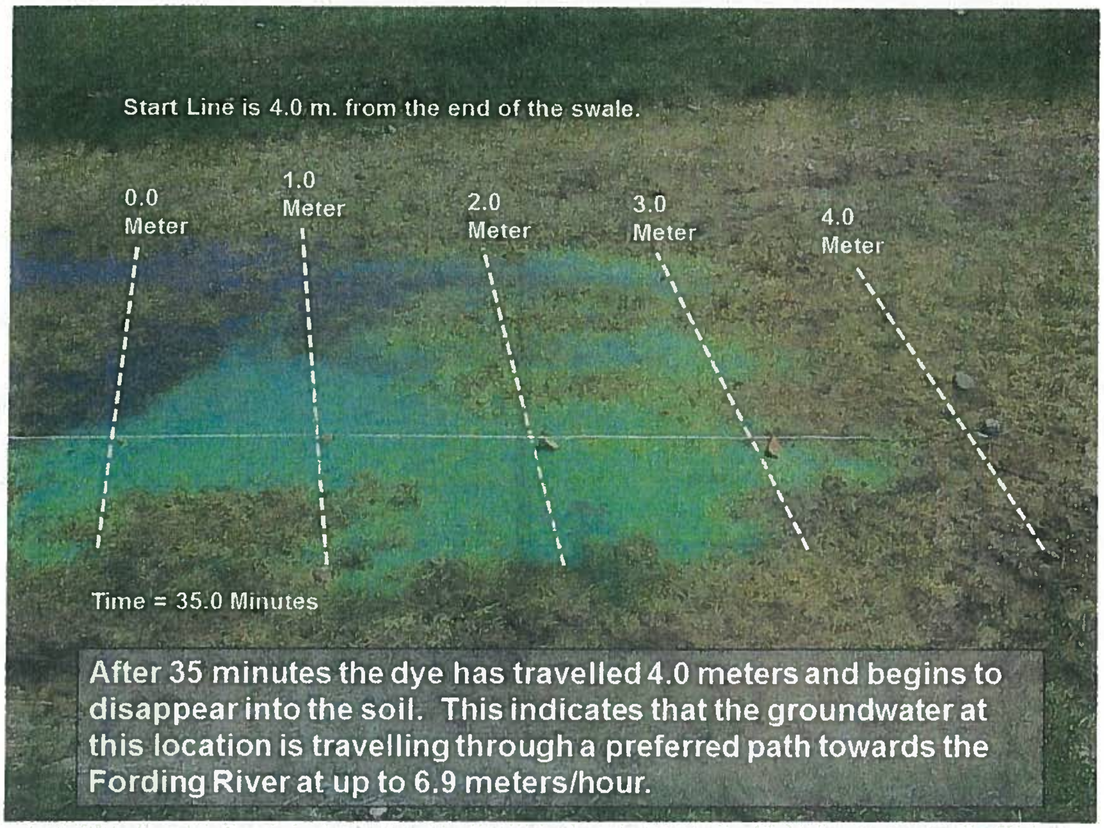

Figure 1-18: Dye test which shows seepage containing selenium re-enters groundwater which moves at up to 6.9 m/hr. and discharges to the Fording River.

1.4.7 Dissolved Selenium and Total Loading of Selenium in Tributaries and the Fording River.

Concentrations of dissolved selenium in tributary streams impacted by coal mining were at up to 400 µg/L to 600 µg/L which is 400 to 600 times the concentration of background sites and 200 to 300 times the guideline concentration of 2.0 µg/L recommended by the B.C. Ministry of Environment. (Figure 1-19)

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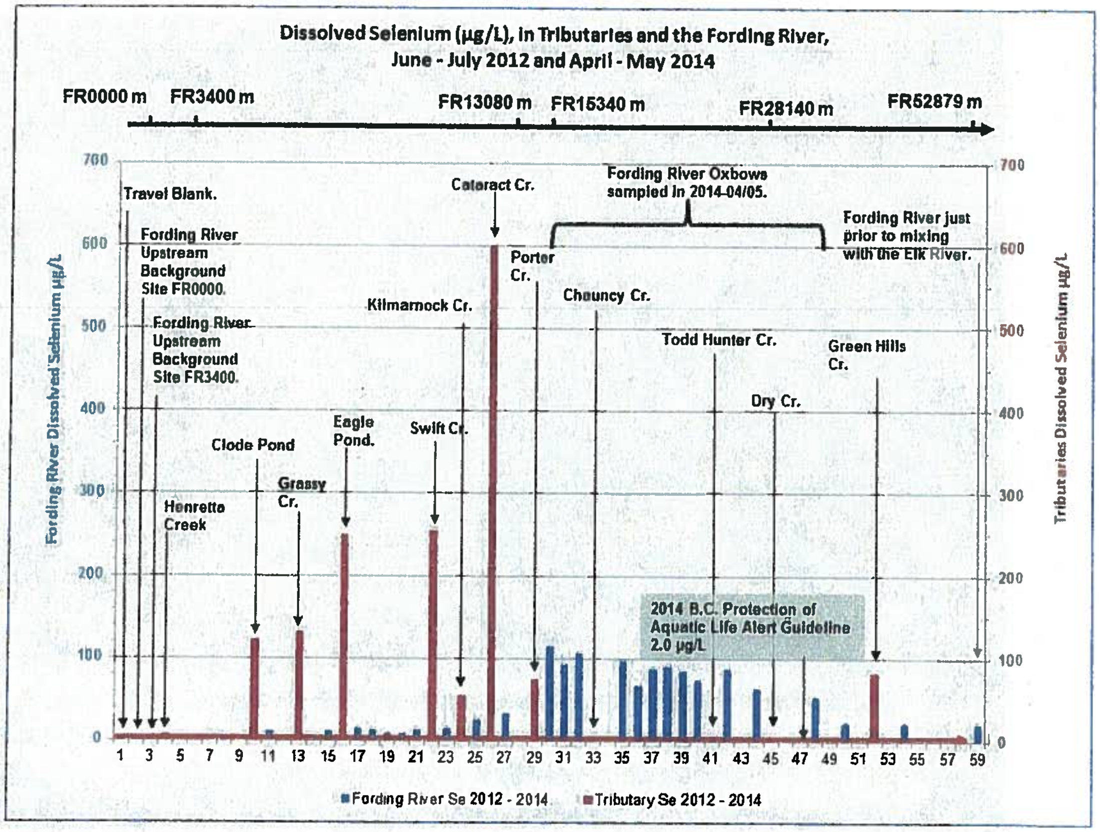

Figure 1-19 Concentration of Dissolved Selenium in Tributaries and the Fording River (equal scale)

The concentration of selenium in the Fording River increased from normal background levels of 1.0 µg/L upstream of coal mining to over 30 times higher in river water during the June-July 2012 freshet period and over 110 times higher than background concentrations during the low flow period of April-May 2014. (Figure 1-20)

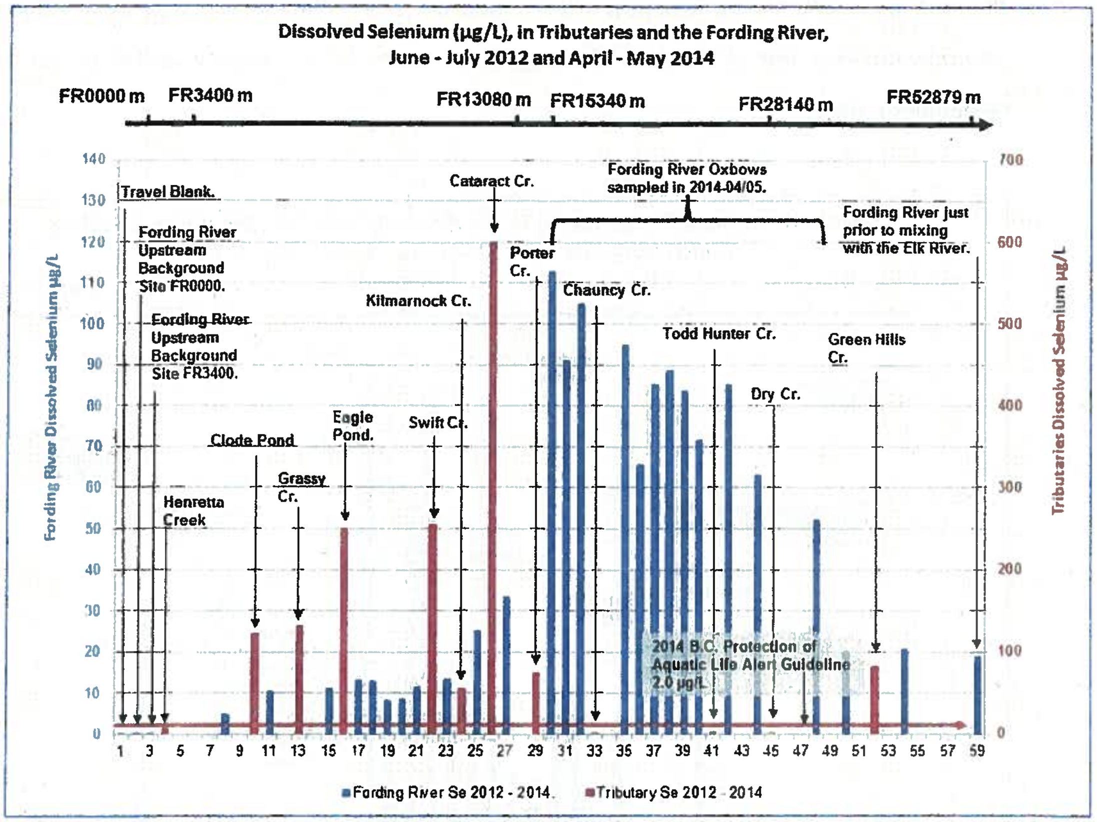

Figure 1-20 Concentration of Dissolved Selenium in Tributaries scale vs. the Fording River scale.

The elevated concentrations of selenium persisted at up to 20 times the background levels downstream of the coal mining areas till the Fording River merged with the Elk River. These values are higher than reported in Minnow-2008 but similar to those reported by McDonald in 2011. (Figure 1-20) During the critical overwintering period for Westslope Cutthroat trout, the concentration of selenium exceeds the 2.0 µg/L guideline by 55 times in the area known as the Fording River Oxbows.

Total Loading of Selenium was estimated in the mining affected tributaries and the Fording River during freshet in June-July of 2012. (Figure 1-21) Loading is a function of concentration times flow rate therefore Kilmarnock Creek was the single largest source of selenium at an estimated loading of 12.9 kg/day, followed by Cataract Cr. at 4.1 kg/day and Swift Creek at 3.6 kg/da. These three creeks accounted for 75% of the estimated surface loading of 27.7 kg/day of selenium. Remediation measures to control the loading of dissolved selenium to the upper Fording River must contain all these creeks and their associated groundwater over all times of the year especially in the low flow winter months. The contribution of selenium loading via groundwater was not assessed in this report and must be assessed in detail to support any remediation plans.

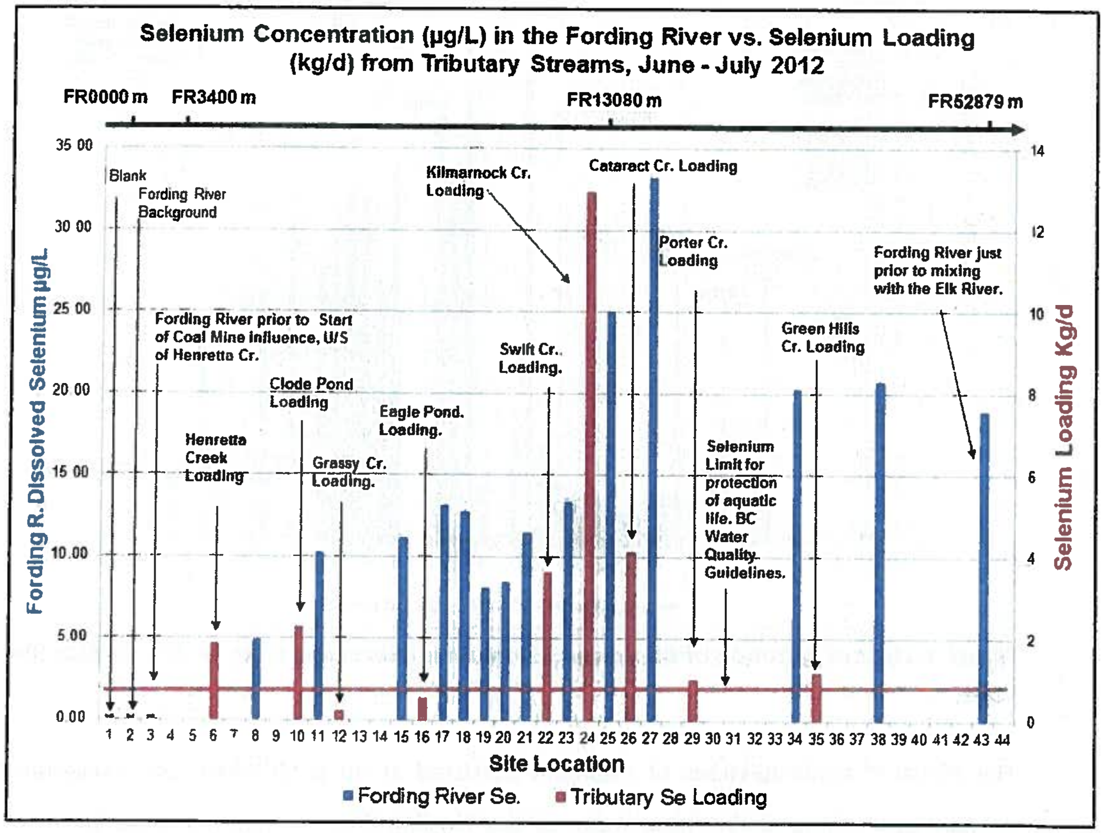

Figure 1-21 Total Loading of Dissolved Selenium in Tributaries and the Fording River.

1.4.8 Total Selenium in Bacteria and protozoa in the Tributaries and the Fording River.

The conversion of dissolved selenium into organo selenium is facilitated by bacteria and protozoa Bacteria and protozoa in the tributaries and the Fording River were not monitored in this study.

1.4.9 Total Selenium (dry weight) in Periphyton/algae in the Tributaries and the Fording River.

Periphyton/algae utilize organo-selenium in their cell structure and subsequently form the food base for benthic invertebrates. (Figure 1-22) The largest bio-concentration of selenium occurs due to Periphyton/algae. Periphyton/algae were sampled for selenium during freshet (June-July

2012) and during winter low flow (April-May 2014) and the profiles were essentially identical to the selenium concentration profile found in the leachate, tributary stream or Fording River.

Periphyton/algae from sites highly impacted by coal mining were up to 8 times higher in selenium than non-impacted sites. These values are generally slightly higher than report by Andrahennadi – 2007 for samples near coal mines in Hinton Alberta. The profile of increases in selenium concentration in periphyton/algae generally followed the increasing concentration in the tributaries containing high selenium and the increases in the Fording River caused by discharge of these tributaries into the main stem of the Fording River.

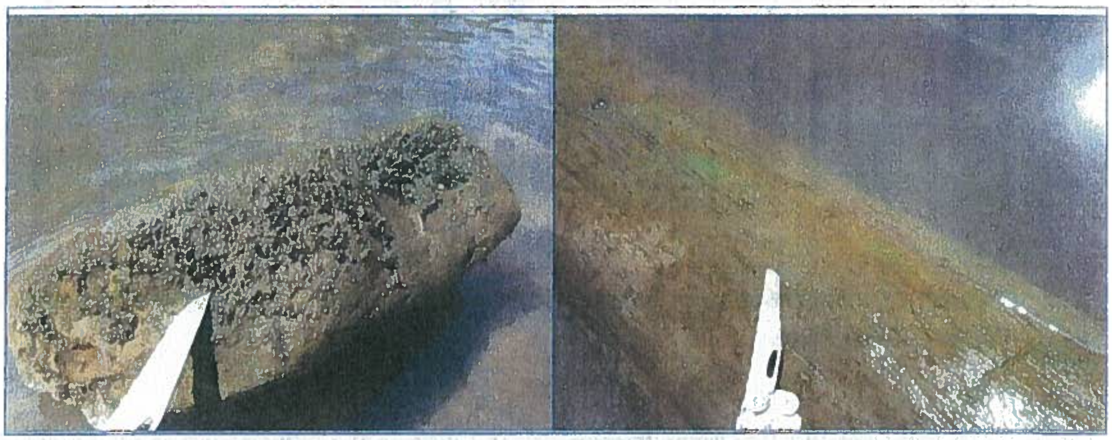

Figure 1-22 Periphyton/algae was found in the Fording River Oxbows.

The highest concentration of selenium in Periphyton/algae was found in the Fording River Oxbows. This is a 9 km portion of the river where the track of the river bed oscillates back and forth across the valley floor resulting in deep pools of slow moving water. These deep pools allow the accumulation of organic compounds which along with bacteria and protozoa facilitate the increased conversion of dissolved selenium into organo selenium. This results in the highest concentrations of selenium in Periphyton/algae (Figure 1-23)

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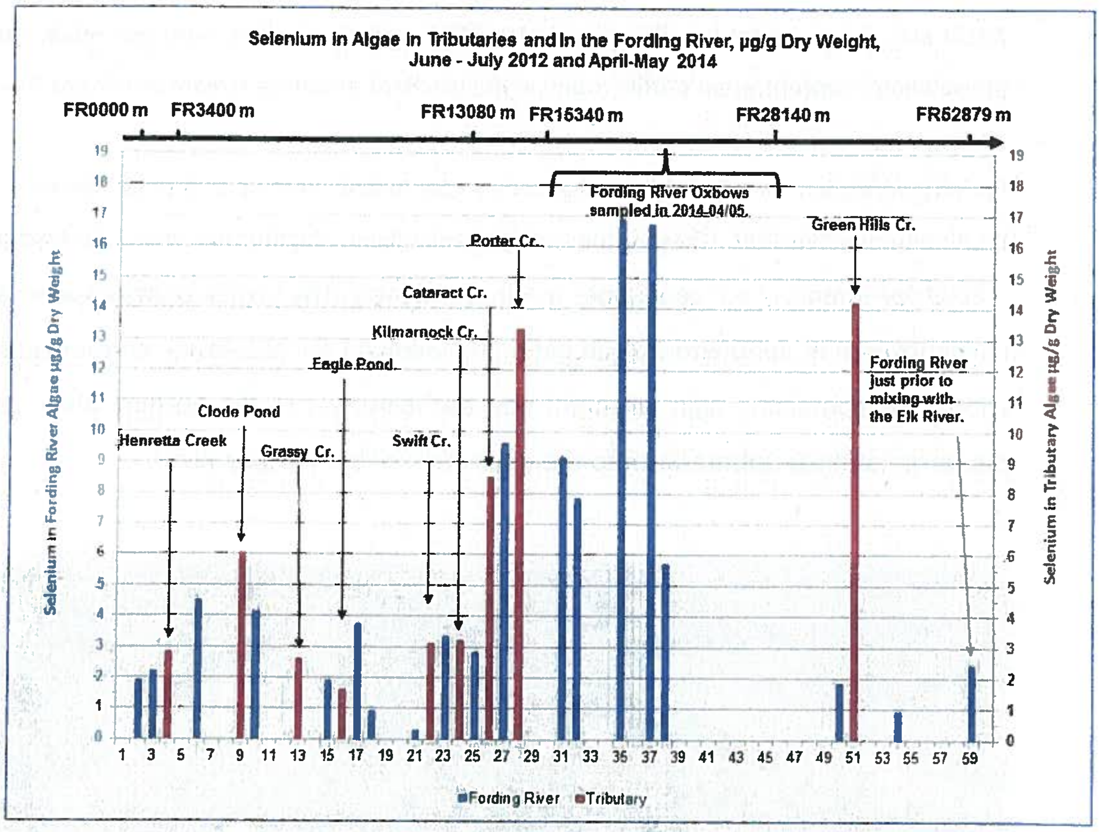

Figure 1-23: Concentration of Selenium in Periphyton/Algae in tributary streams and the Upper Fording River.

1.4.10 Total Selenium (dry weight) in Benthic Invertebrates in the Tributaries and the Fording River.

Benthic invertebrates which feed on algae/periphyton further concentrate the selenium in their tissue. (Figure 1-24) Benthic invertebrates are the primary food supply to West Slope Cutthroat Trout in the Upper Fording River and therefore are the primary route for selenium contamination of the trout.

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Figure 1-24: Benthic Invertebrates in tributary streams and the Upper Fording River.

The profile of increases in selenium concentration in benthic invertebrates generally followed the increasing concentration in the tributaries containing high selenium and the increases in selenium in the Fording River caused by discharge of these tributaries.

The highest concentration of selenium in benthic invertebrates was found in the Fording River Oxbows. This is a 9 km portion of the river where the track of the river bed oscillates back and forth across the valley floor resulting in deep pools of slow moving water. These deep pools allow the accumulation of organic compounds which along with bacteria and protozoa facilitate the increased conversion of dissolved selenium into organo selenium. This results in the highest concentrations of selenium in Periphyton/algae and the benthic invertebrates which feed on them. (Figure 1-25)

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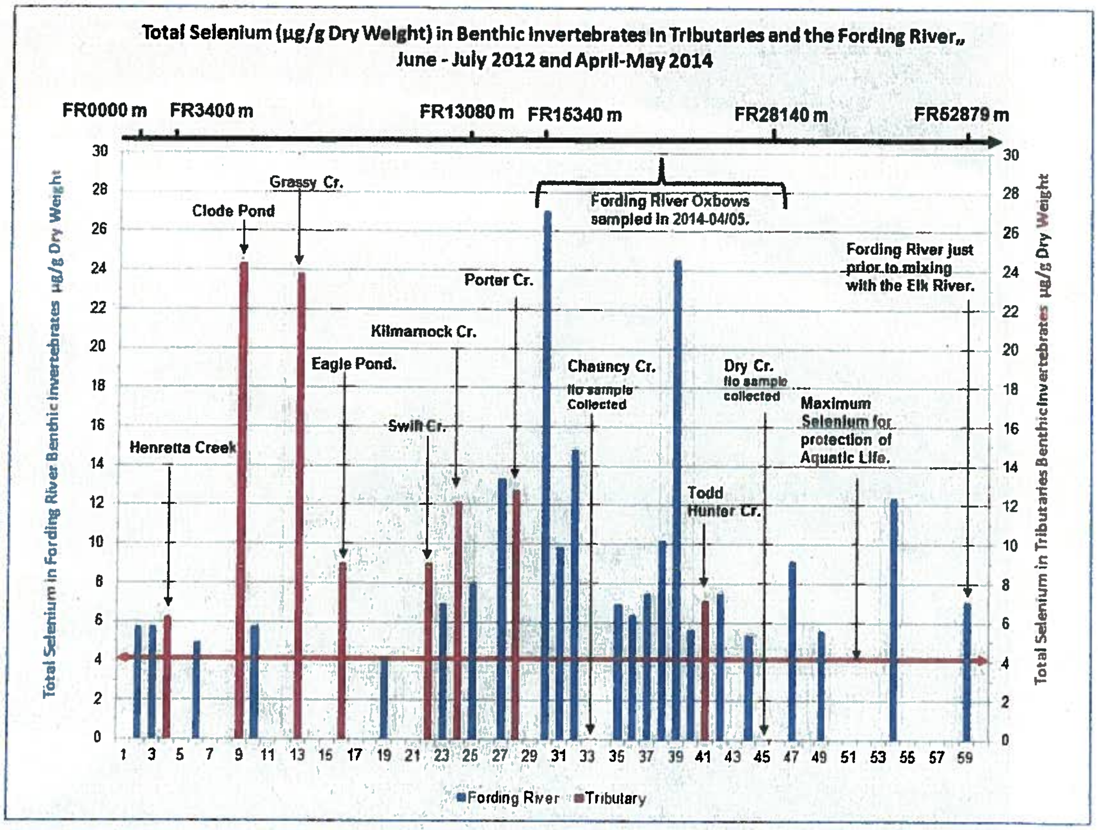

Figure 1-25 Concentration of Selenium in Benthic Invertebrates (Dry Weight) in tributary streams and the Upper Fording River.

1.4.11 Total Selenium (dry weight) in West Slope Cutthroat Trout Tissues in the Tributaries and the Fording River.

The hydrological cycle in the upper Fording water shed results in flooding of the stream channels and entire bed of the Fording River during the spring freshet period. During the winter dry/cold period Kilmarnock Creek and the alluvial fan of Kilmarnock Creek becomes dry on the surface. The portion of the Fording River adjacent to Kilmarnock Creek also becomes dry on the surface. (Subsurface water/groundwater will still flow through the gravels of each watercourse)

West slope cutthroat trout were introduced into the upper Fording River and historically occupied the upper river and portions of most of the tributary streams. During the freshet period, the West Slope Cutthroat trout can migrate all the passable reaches of the upper Fording River and the Tributaries. During the winter low flow winter period the trout have to migrate into overwintering holes which are deeper and contain water of suitable flow and temperature in the Upper Fording River and/or tributary streams.

Of these tributary streams, Kilmarnock Creek was one of the most significant with up to 37% of the overwintering West Slope Cutthroat trout population occupying the deep pools in this stream. Other overwintering habitats included Henretta Pond, the Multiplate hole in the main Fording River and the pools in the Fording River Oxbows. (Lister, 1980, Cope 2013)

The initial industrial impact on the fish habitat in the Upper Fording River was due to logging by removal of streamside trees and shrubs. With the onset of mining the tributaries and the main stem of the Fording River were physically altered, either by re-location of stream beds (such as Henretta Cr for the Henretta Dragline project or the main stem of the Upper Fording for construction of the Coal processing area settling ponds) or infill damage to headwater and main stems of tributary streams by slides from mining waste rock piles which have occurred on all the major tributary streams.

The most significant damage to fish habitat resulted from a massive waste rock slide that infilled over a kilometer of Kilmarnock Creek and cut off all migration from the Upper Fording River into the overwintering pools. The downstream end of Kilmarnock creek was subsequently eliminated from fish habitat by construction of the Kilmarnock #1 and #2 settling ponds totally disconnecting the creek from any fish passage. These ponds were designed to settle out fine particulate but not remove dissolved components such as selenium and have fish barriers to prevent fish in the Upper Fording River from entering the ponds.

Other streams, Swift Creek and Clode Creek also suffered infill slides and alteration that further removed fish habitat. The result of these events is that West Slope Cutthroat trout are now restricted to overwintering in Henretta Pond, the Multiplate hole in the main Fording River and the pools in the Fording River Oxbows. This creates a significant impact on the tissue concentrations of selenium found in the trout.

West Slope Cutthroat trout were captured in June-July 2012 in the Upper Fording River (including the Multiplate Culvert pond), Henretta Pond and Clode pond. Muscle, liver and egg tissue were sampled and analysed for selenium on a dry weight basis. Liver had the highest selenium concentration of 223 µg/g. Selenium in eggs ranged from 3.1 to 96.7 µg/g and was on average 15 times higher at coal mining affected sites over background sites, and muscle was on average 10 times higher at coal mining affected sites over background sites. (Figure 1-26)

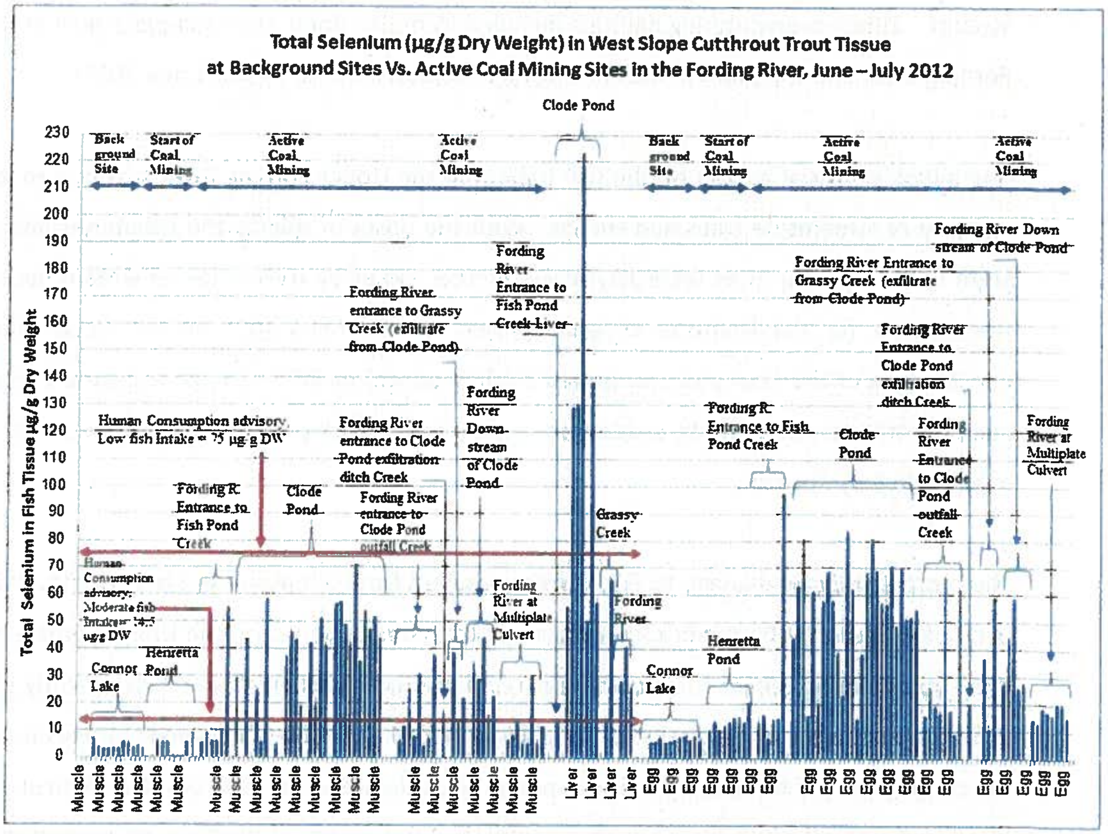

Figure 1-26 Total Selenium (dry weight) in West Slope Cutthroat Trout in the Tributaries and the Fording River.

Fish were captured by angling in the main stem of the Fording River and by wire mesh net pen traps at the entrances to the main spawning streams. The highest concentration of Selenium in eggs at 96.7 µg/g was from a fish that had just exited from the main stem of the Fording River into the trap at the entrance to Fish Pond Creek. This indicated that fish within the Fording main stem may be subject to very high sources of selenium.

Cope 2014 reported an average home range of 13.26 km +/- 2.66 km (95% Confidence Interval) with an outlier range of between 0.68 km and 31.59 km. Fish Pond Creek is approximately 13 km upstream of Environment Canada sample site FR17340 which is equivalent to River section S6 reported in Cope 2014 which is an area known as the Fording River Oxbows.

This means that the fish with the highest selenium captured entering Fish Pond Creek was within the average 13 km migration range of the largest overwintering section in the Oxbows of the Fording River. Environment Canada sampling in 2014 recorded that the highest concentrations of selenium in periphyton/algae and benthic invertebrates were in the section immediately upstream and downstream of FR17340 which is equivalent to River section S6 of Cope 2014 in the Fording River Oxbows. This means that West Slope Cutthroat trout that overwinter in the Fording River Oxbows are subject to utilizing food which contains the highest concentrations of selenium measured in the Upper Fording River.

Selenium in egg and muscle for the Fording and Elk River watersheds are reported in Kuchapski (2008), Deleray (2011) and other sources and are summarized in McDonald (2013). The original data tables for selenium in West Slope Cutthroat Trout data in McDonald (2013) was obtained from the B.C. Ministry of Environment in Cranbrook British Columbia and from Deleray and re-organized chronologically and geographically from upstream to downstream at each reported site. Where only female muscle selenium concentrations were provided, two methods were used to calculate muscle to egg conversion concentrations;

(1) a logarithmic formula reported by Schwarz (2011) (Figure 1-27A) and

(2) a linear formula calculated by Environment Canada in 2014 (Figure 1-27B).

The reported and calculated selenium in egg concentrations utilizing the formula in Schwartz (2011) are illustrated in Figure 1-27A and Environment Canada formula in figure 1-27B. These two figures show that the Environment Canada formula provides selenium in egg estimates that are comparable to just slightly higher than the Schwartz formula.

Figure 1-26 shows that the concentration profile of selenium in West Slope Cutthroat trout collected by Environment Canada in the June-July 2012 samples are essentially the same as those reported in Kuchapski/Deleray/McDonald from upstream of mining downstream to Porter Creek. Downstream of Porter Creek, the Kuchapski/Deleray/McDonald data shows a very significant peak in selenium concentration in the eggs of fish captured in the Fording River Oxbows which is the current major overwintering area. Both plots show that slow moving water (Lentic areas) of Clode Pond and downstream at the Fording River Oxbows have the highest concentration of selenium in fish eggs.

This peak in selenium concentrations in the eggs of West Slope Cutthroat trout corresponds to the peaks in selenium concentration found in the water, sediment, periphyton/algae and benthic invertebrates collected in the Fording River Oxbows area by Environment Canada in April-May 2014. (Figures 1-24 and 1-25)

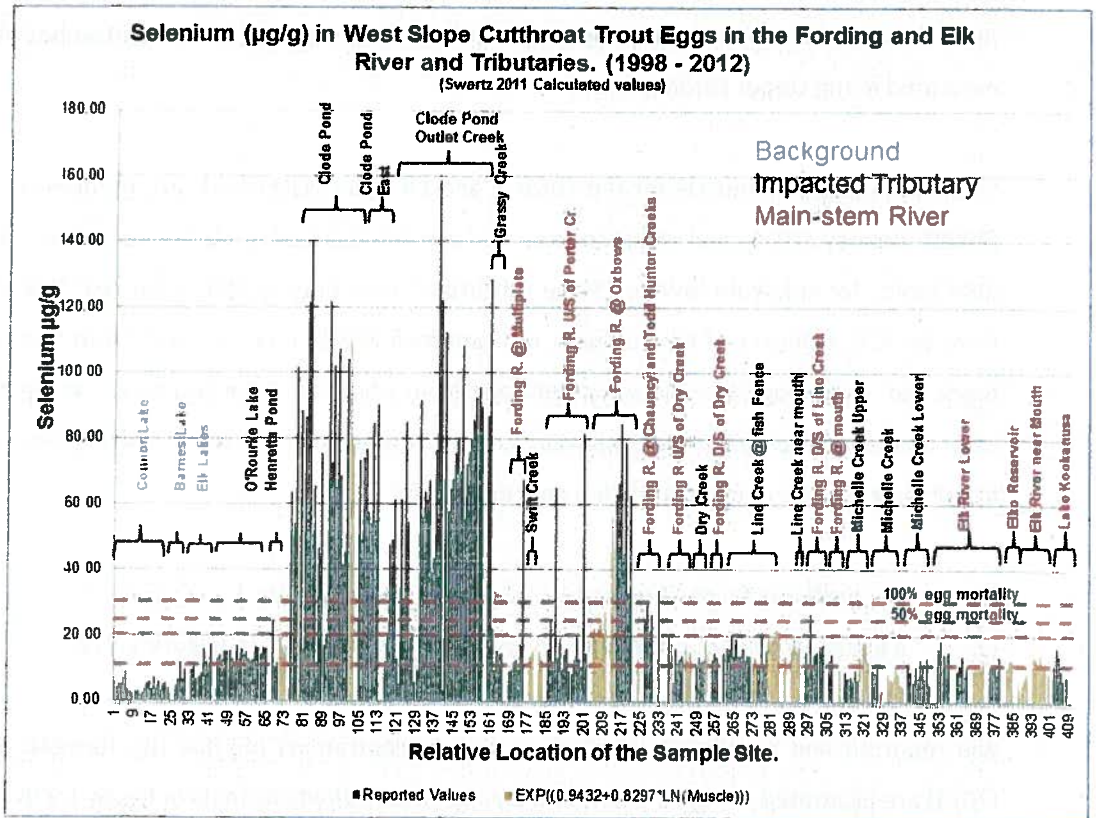

Figure 1-27A: Concentration of Selenium in West Slope Cutthroat Trout muscle, liver, egg (Dry Weight) in tributary streams and the Upper Fording River as reported by Kuchapski (2008), Deleray (2011) and other sources are summarized in McDonald (2013).

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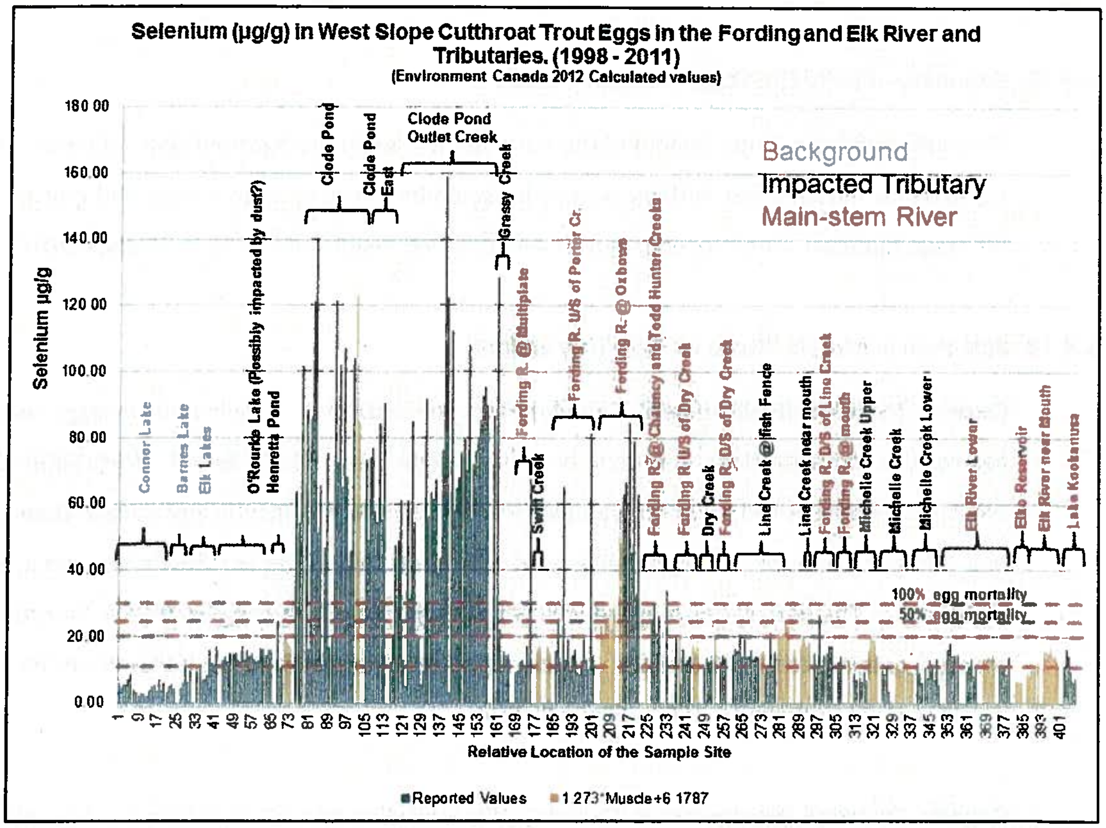

Figure 1-27B: Data from McDonald (2013) with muscle to egg conversion values (Dry Weight) as calculated using Environment Canada Linear relationship Egg$_{concentration}$ = 1.273*Muscle+6.1787.

Muscle tissue samples analysed for selenium in Environment Canada 2014 indicated that;

- 1/31 or 3% of fish captured in the Upper Fording River (or migrating out of it to spawn in a tributary) exceeded the 75 µg/g low human consumption limit.
- 23/31 or 74% exceeded the 14.5 µg/g moderate human consumption concentration limit. (The human consumption limit as specified by the Province of British Columbia and Health Canada fish consumption guidelines, BCMOE 2014).

This indicates that remedial measures required to reduce the concentration of selenium in the upper Fording River must consider the very high uptake rates created by the overwintering conditions in the Fording River Oxbows.

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1.4.12 Summary of Early Life Stage Bioassay Results

Fish collected from Clode Pond and the Fording River and a background site at Connor Lake were sampled for muscle, liver and egg tissues for selenium analysis and for eggs and milt for an early life stage bioassay. The procedures used and detailed results are found in Soloway 2014.

1.4.13 Selenium in Muscle Tissue vs. Eggs (Dry weight)

Outliers Included (Environment Canada): The concentration of selenium in eggs was plotted against the concentrations in muscle on a dry weight basis for 72 female West Slope Cutthroat Trout. The data set included four samples for which there was insufficient muscle tissue resulting in a detection limit of <2.0 µg/g being used which resulted in Egg Se/Muscle Se ratio in the range of 48 to 72. The data set also included seven samples where the Egg Se/Muscle Se ratio was less than 1.0 ranging from 0.68 to 0.99. . When all values considered to be outliers were included, the resulting slope averaged 1.1663. (Figure 1-28A)

Outliers Excluded (Environment Canada): The concentration of selenium in eggs was plotted against the concentrations in muscle on a dry weight basis for 61 female West Slope Cutthroat Trout. The data set excluded the four samples for which there was insufficient muscle tissue resulting in a detection limit of <2.0 µg/g being used which resulted in Egg Se/Muscle Se ratio in the range of 48 to 72. The data set also excluded seven samples where the Egg Se/Muscle Se ratio was less than 1.0 ranging from 0.68 to 0.99. When all values considered to be outliers were excluded, the resulting slope averaged 1.273. (Figure 1-28A)

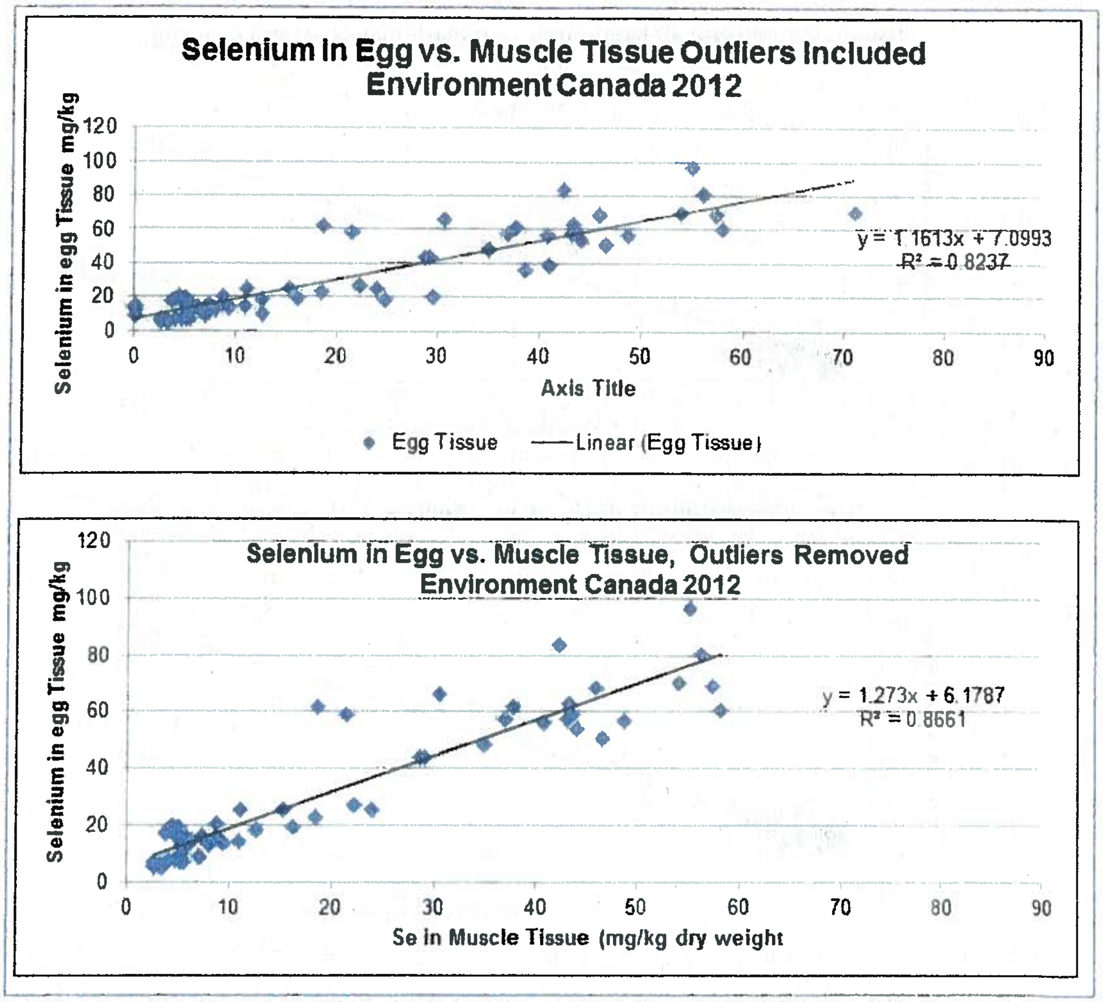

Figure 1-28A: Concentration of Selenium in West Slope Cutthroat Trout Muscle vs. Eggs (Dry Weight) Environment Canada 2012.

Outliers Included (Minnow 2007): The Egg Se/Muscle Se ratio is reported in Figures D7 and D8 of Minnow 2007. The data set included two outliers where the Egg Se/Muscle ratio exceeded 5.0. The concentration of selenium in eggs was plotted against muscle on a dry weight basis and the resulting slope averaged 1.3262. (Figure 1-28B)

Outliers Excluded (Minnow 2007): The Egg Se/Muscle Se ratio is reported in Figures D7 and D8 of Minnow 2007. The concentration of selenium in eggs was plotted against muscle on a dry weight basis with outliers excluded and the resulting slope averaged 1.2616.

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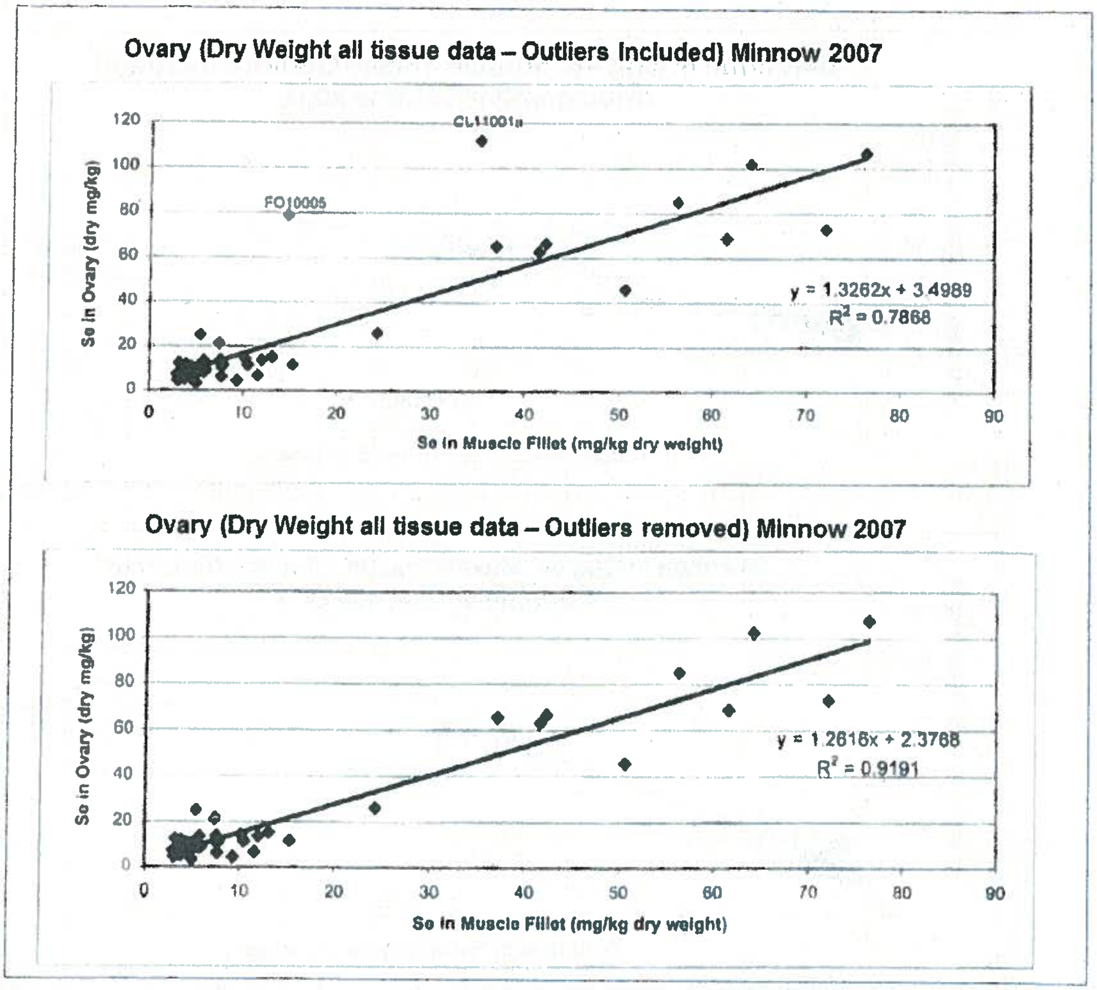

Figure 1-28B: Concentration of Selenium in West Slope Cutthroat Trout Muscle vs. Eggs (Dry Weight) Minnow 2007.

The Outliers excluded graphs from both Environment Canada 2012 and Minnow 2007 indicate a strongly linear relationship between muscle and egg concentrations with very similar slopes but the Environment Canada 2012 Y intercept is higher.

1.4.14 Selenium in Eggs (Dry Weight) Vs. Deformity.

Selenium is known to cause deformities and abnormalities in fish and other vertebrates. In this study, the incidence and type of deformity and abnormality of West Slope Cutthroat trout newly hatched and swim up fry was reported in Soloway 2014. Two types, cranial-facial, spinal-skeletal deformity were measured, and edema (tissue thinning and swelling) abnormalities were scored on a Graduated Severity Index (GSI) which scores deformities on a scale of 0.0 to 3.0. Zero is no deformity/abnormality, 3.0 is severely deformed/abnormal. Microphthalmia (small eyes) deformities were also noted. Increasing selenium concentration in eggs was found to co-relate strongly to increasing deformity and abnormalities in swim up West Slope Cutthroat fry.

1.4.15 Fish demonstrating no Deformities.

A control set of fish were used to establish a GSI score of 0.0 in both types of deformity (Cranial-facial, spinal-skeletal) and edema abnormality and is illustrated in Figure 1-29. Comparison of the degree of deformities is rated against this body structure type.

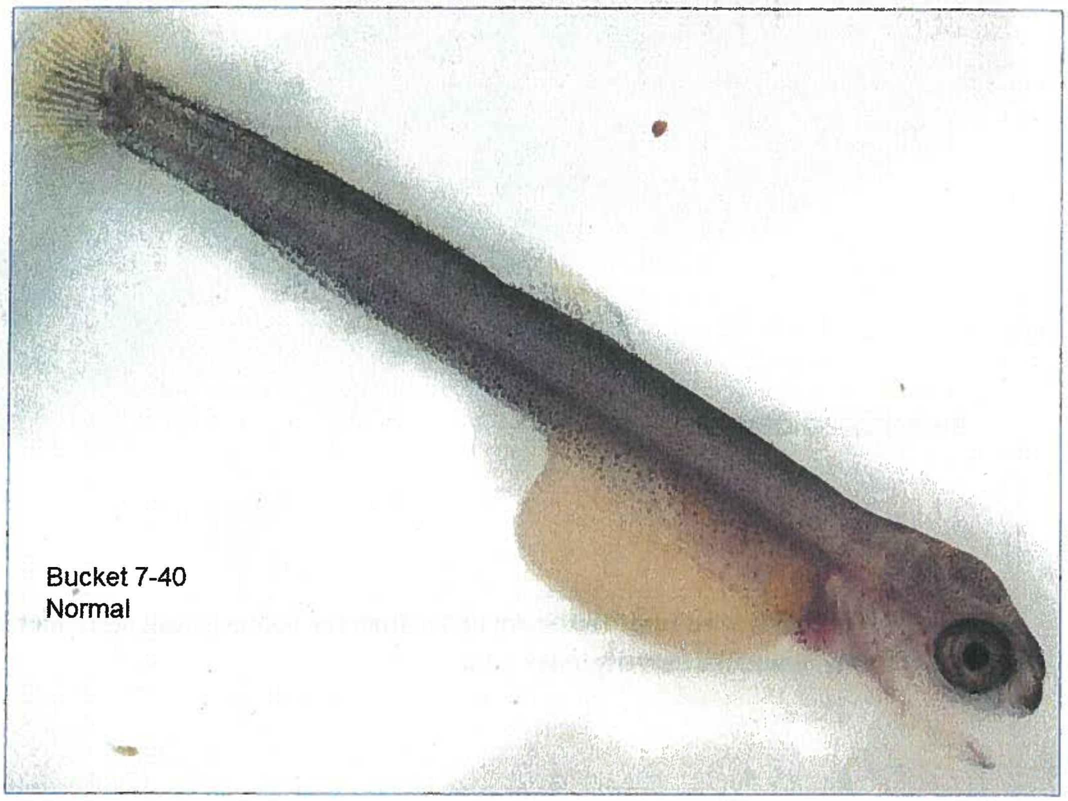

Figure 1-29: West Coast Cutthroat Trout swim up Fry from the Fording River that Scores Deformity GSI = 0 for Cranial Facial, GSI = 0 for Spinal deformity and GSI = 0 for Edema abnormalities.

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1.4.16 Fish demonstrating Cranial-Facial Deformities.

Cranial-facial deformities include the distortion of the scull, jaws and head. (Figure 1-30) This inhibits or prevents efficient or effective feeding. At 20 to 50 µg/g selenium (dry weight) in eggs there was a significant increase in cranial-facial deformities. (Figure 1-31)

Figure 1-30: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Cranial-Facial Deformity, Graduated Severity Index = 3.0

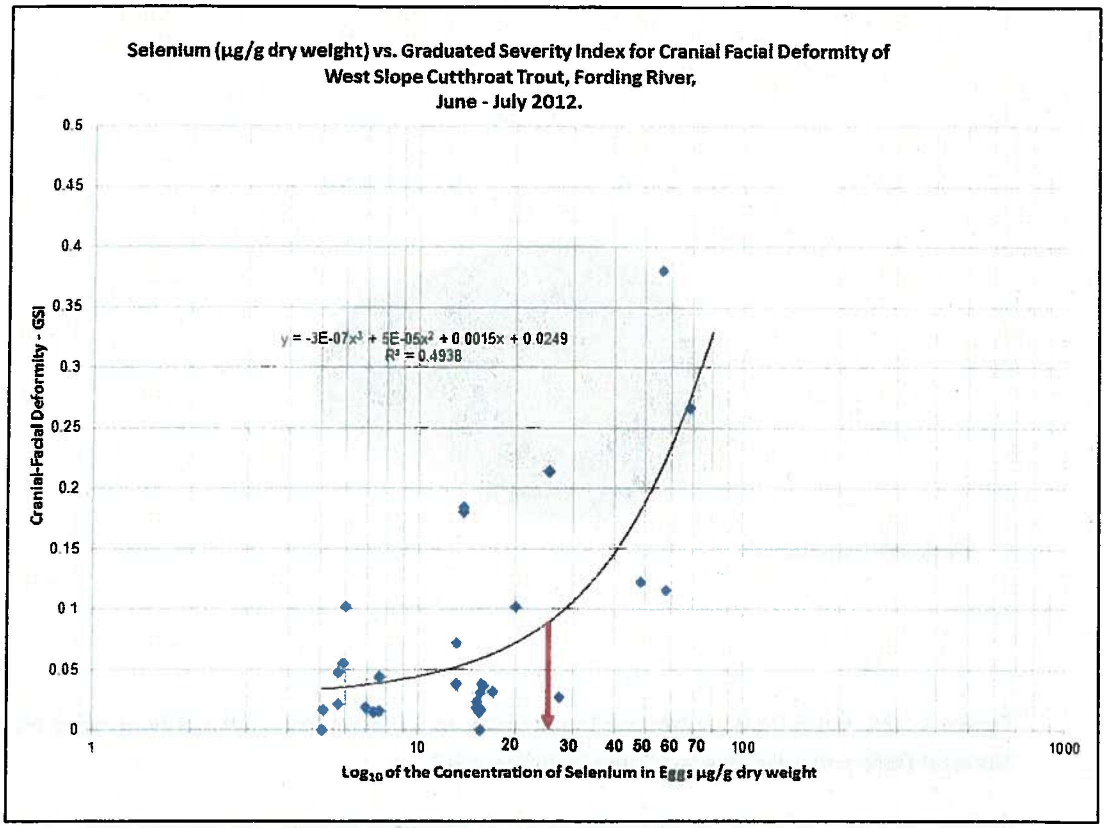

Figure 1-31: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Cranial-Facial Deformity Vs. concentration of selenium in eggs µg/g dry weight. (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured in June-July 2012)

1.4.17 Fish demonstrating Spinal Deformities.

Spinal deformities include the distortion of the spinal column which may be lateral or vertical or coiled. (Figure 1-32 A, B, C) This inhibits or prevents efficient or effective swimming increasing the quantity of energy required and decreasing the ability to pursue prey or avoid predators. At 15 to 50 µg selenium/g dry weight there was a significant increase in spinal deformities. (Figure 1-33)

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Figure 1-32A: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Spinal-Skeletal Deformity, Graduated Severity Index = 3.0

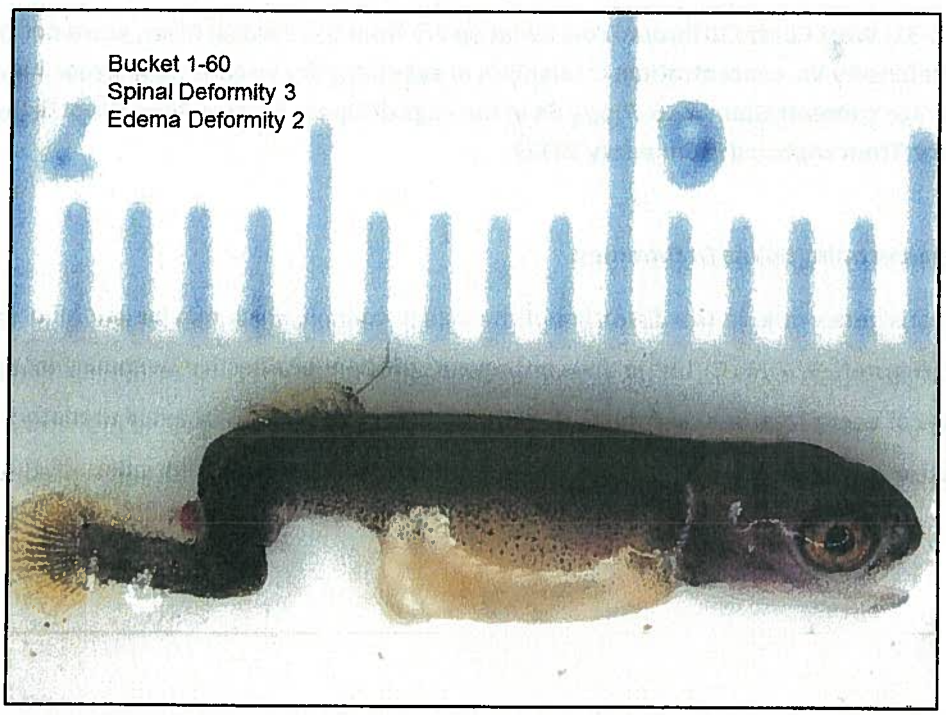

Figure 1-32B: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Spinal-Skeletal Deformity, Graduated Severity Index = 3.0

Figure 1-32C: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Spinal-Skeletal Deformity, Graduated Severity Index = 3.0

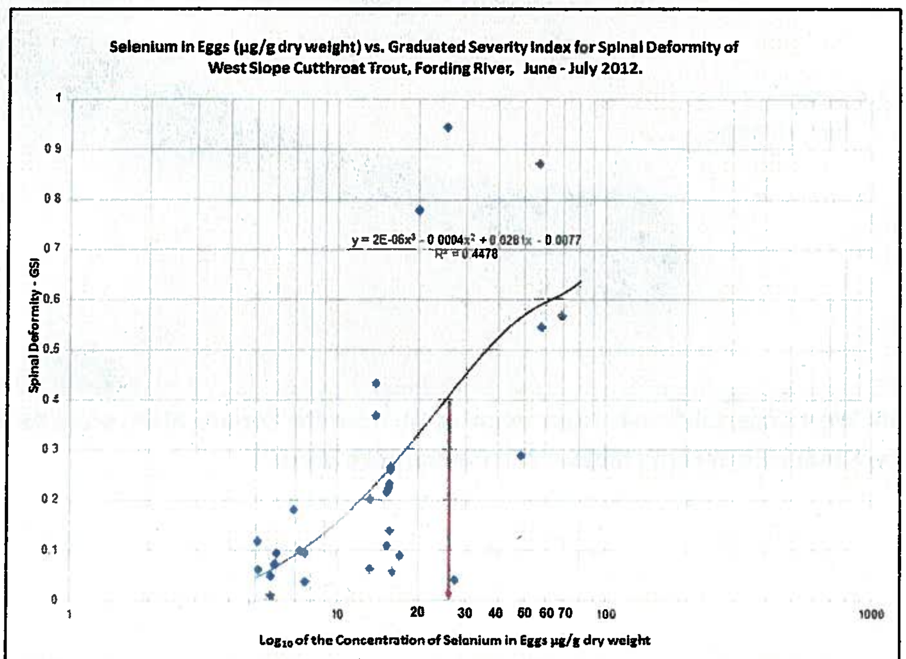

Figure 1-33: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Spinal Vs. concentration of selenium in eggs µg/g dry weight. (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured in June-July 2012)

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1.4.18 Fish Demonstrating Edema Abnormalities.

Edema abnormalities include the thinning of various tissues and distortion of the body and bulging of eyes from the eye sockets (Figure 1-34 – A, B) This inhibits or prevents efficient or effective swimming, feeding, vision and increasing the quantity of energy required for mobility and decreasing the ability to pursue prey or avoid predators. At 15 to 40 µg/g selenium/g dry weight in eggs there was a significant increase in edema. Edema was the most prevalent impact showing the highest level of 3.0 on the Graduated Severity Index (GSI) (Figure 1-35).

Figure 1-34A: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Edema Abnormality, Graduated Severity Index = 3.0, Hemorrhage present.

Figure 1-34B: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Edema Abnormality, Graduated Severity Index = 3.0

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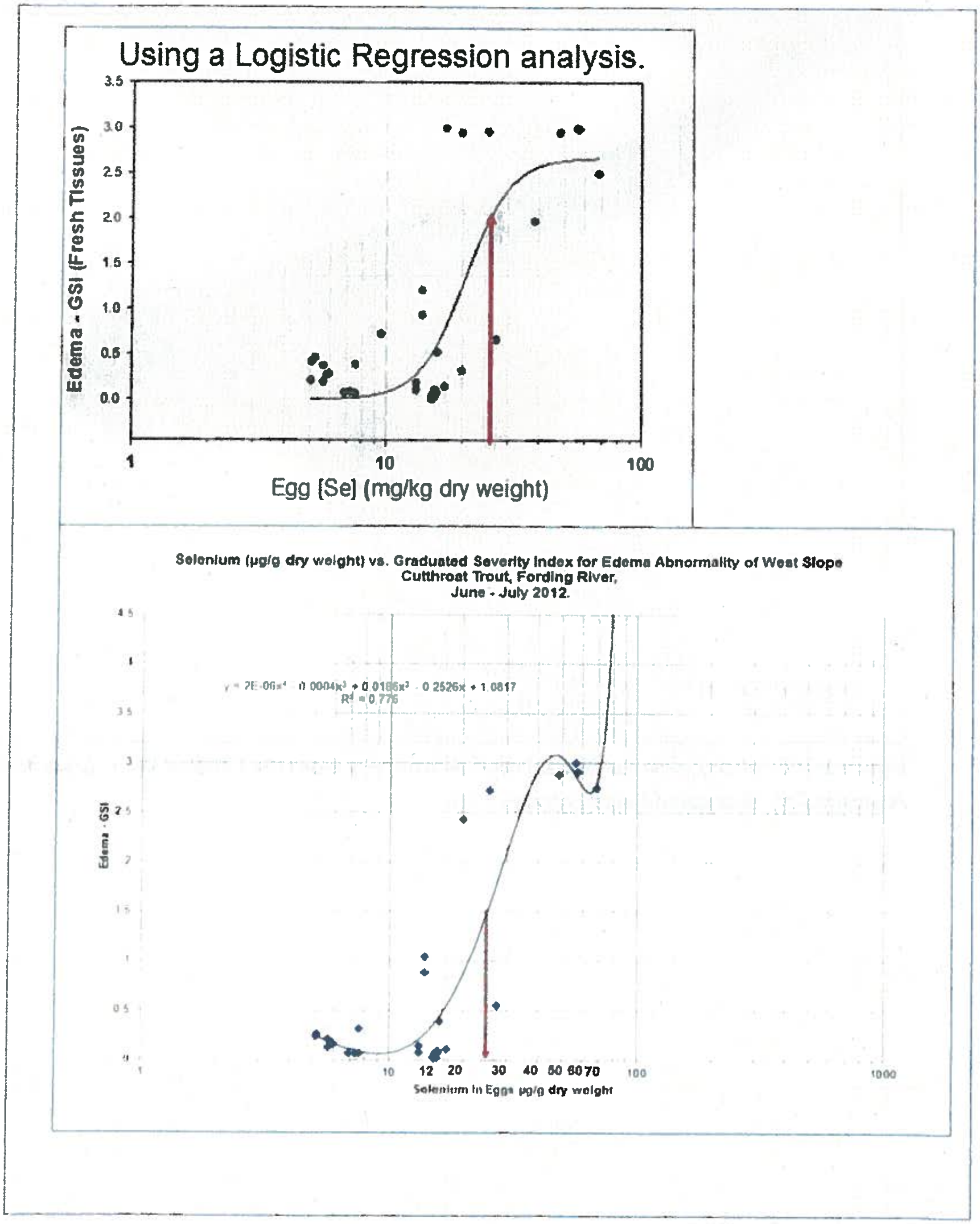

Figure 1-35: West Coast Cutthroat Trout swim up Fry from the Fording River, score for Edema Vs. concentration of selenium in eggs µg/g dry weight. (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured in June-July 2012)

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1.4.19 Fish demonstrating multiple deformities.

At the higher selenium in egg concentrations, fish demonstrated multiple deformities, cranial-facial + spinal + microphthalmia (small eyes) and edema abnormalities. These fish would rarely survive to the swim up stage and therefor had a very high mortality. (Figure 1-36A, 1-36B) These results are similar to those reported by Rudolph – 2008 and Elphick-2009. The total deformity score (cranial-facial + spinal + edema) is dominated by the incidence of edema. (Figure 1-37)

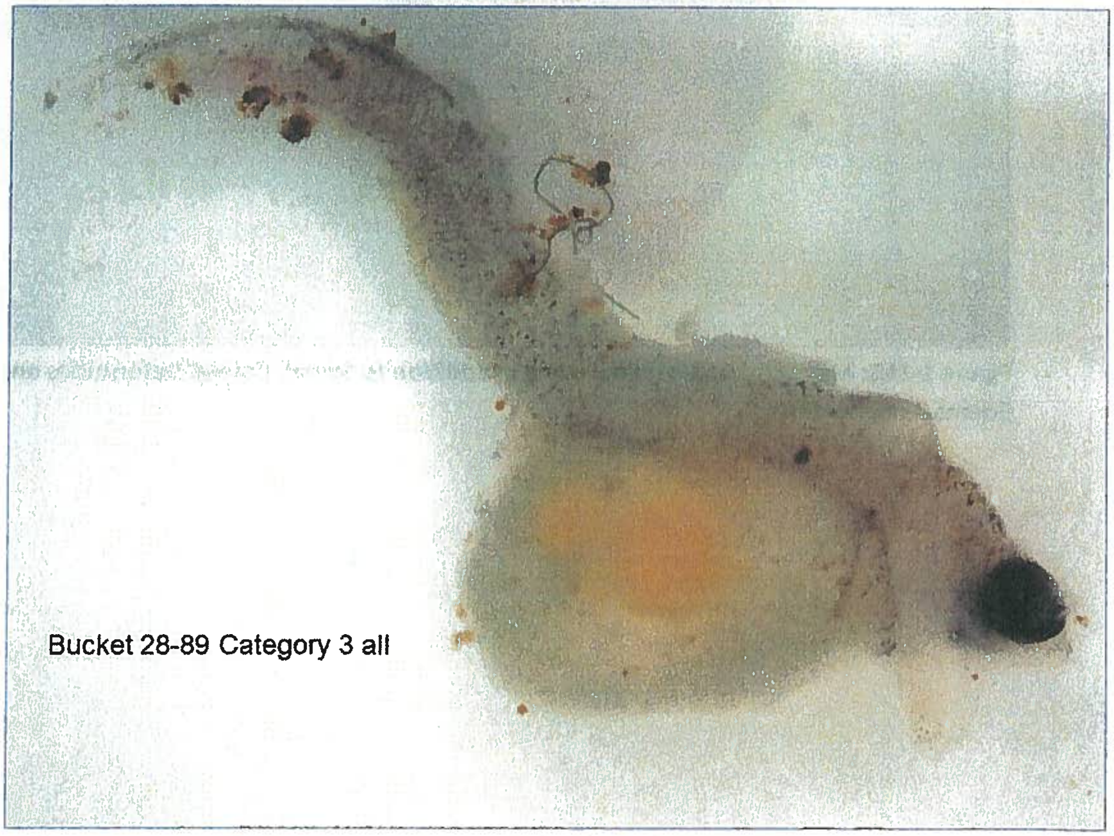

Figure 1-36A: Cranial-Facial Deformity GSI = 3 + spinal-skeletal Deformity GSI = 3 + Edema Abnormality GSI = 3.0, for a GSI Total Score = 9.0.

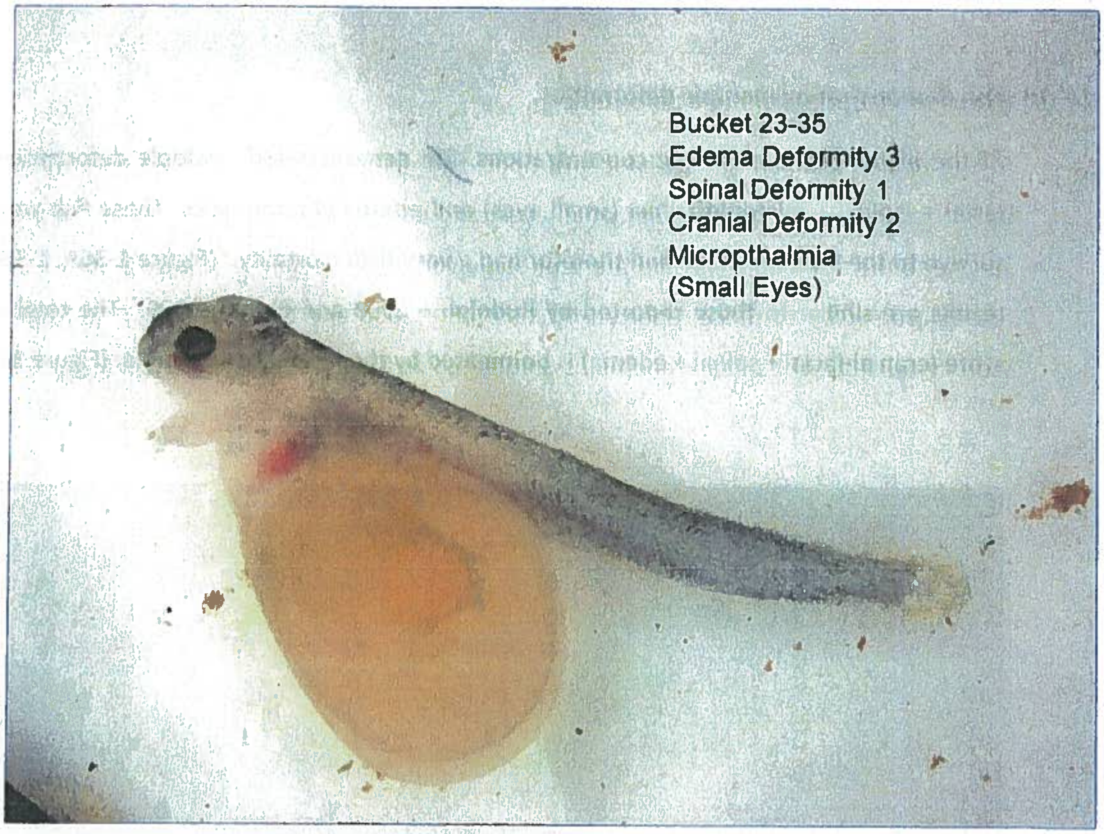

Figure 1-36B: Microphthalmia (small eyes) in addition to Spinal, Cranial Deformities and Edema Abnormalities.

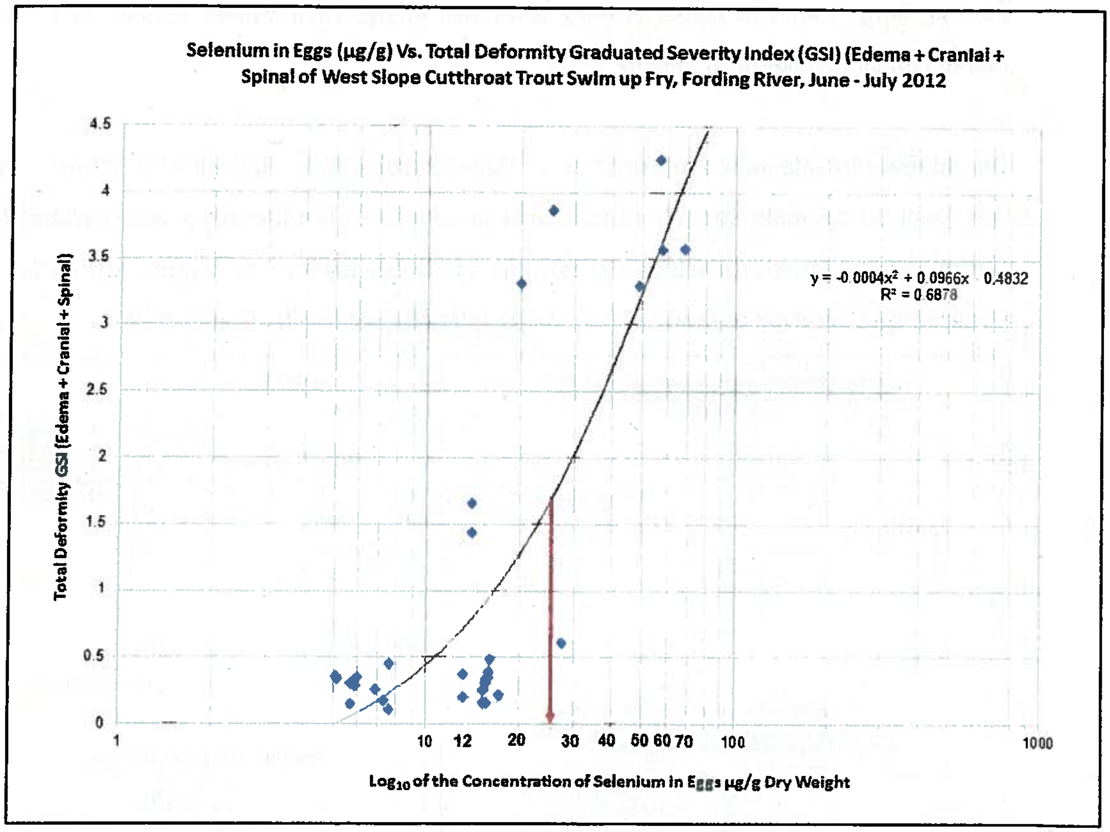

Figure 1-37: Average ((fresh + preserved)/2) total GSI Score (Spinal + Cranial + Edema) Deformities Vs. the concentration of Selenium in Eggs (Dry Weight). (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured in June-July 2012)

For all deformities, there was no significant difference in the scores of fish that were assessed as fresh (no preservative) and those which were assessed after they had been preserved. (Soloway 2014)

1.4.20 Co-relation between Percent Survival and Percent Deformity Vs. Selenium Concentration in Eggs.

A comparison of the percent survival of swim up fry versus the concentration of selenium in eggs (dry weight) as reported by Environment Canada in 2012 and other researchers (Kennedy, Rudolph, Elphick) in earlier studies was made . The figures from Kennedy, Rudolph and Elphick were scaled to compare with the Environment Canada 2012 data. The average concentration of

26.7 µg Se/g found in Upper Fording River fish in the Environment Canada 2012 study was marked on all the diagrams. (Figure 1-38)

The increase in selenium concentration in Upper Fording River Westslope Cutthroat Trout eggs was found to co-relate strongly to decreases in survival in fertilized eggs with a sharp decline in survival when eggs contained 20 µg Se/g dry weight or higher. At higher than 60 µg Se/g, no fertilized eggs survived to swim up (i.e. 100 % mortality occurred). (Figure 1-38)

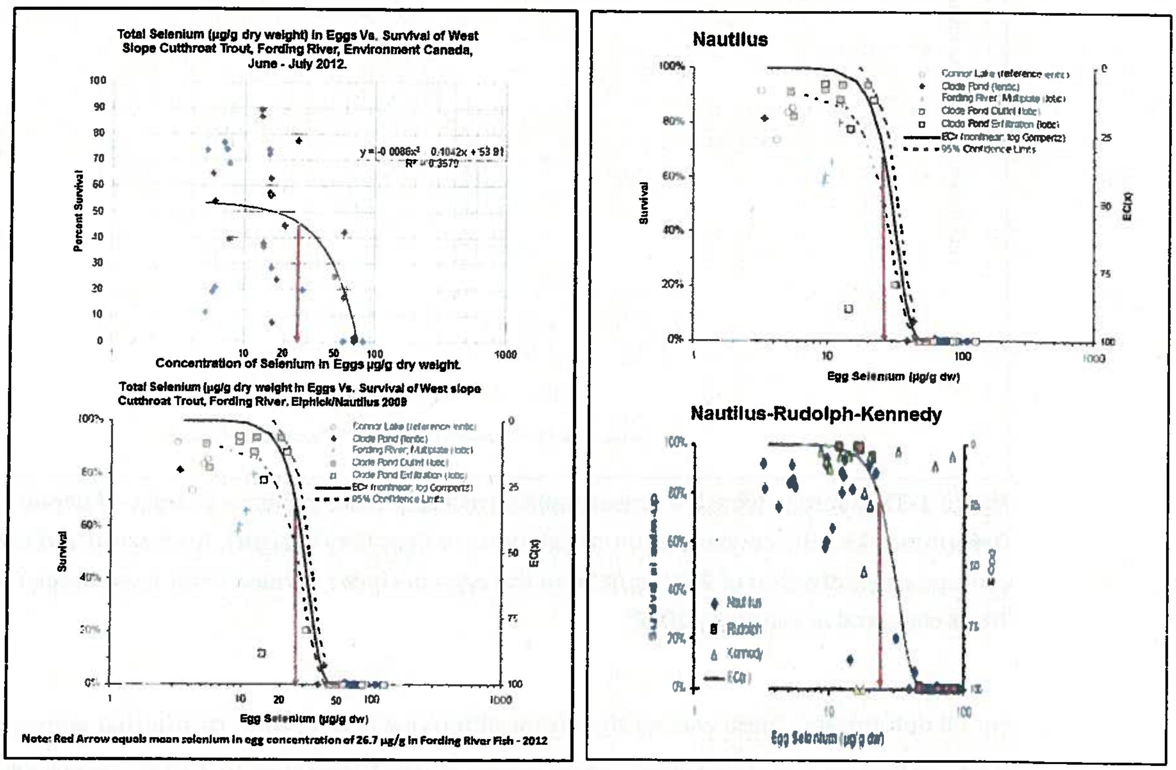

Figure 1-38: Egg Selenium Concentration Vs. Survival - Environment Canada 2012, Nautilus Environmental, Teck coal, Interior Reforestation, "Effect of Selenium on Early Life Stage Development of West Slope Cutthroat Trout", SEATAC Poster, 2009, Rudolph 2008, Kennedy 2000 (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured In June-July 2012)

Figure 1-39 illustrates the co-relation of survival and deformities in the Environment Canada 2012 study and indicates that;

- the average concentration of Selenium in Westslope Cutthroat Trout eggs in the Upper Fording River is 26.7 µg/g.

- 55% of the fry which hatched showed at least one type of deformity at 26.7 µg/g Selenium in eggs dry weight.
- 100% of the fry which hatched from individual fish showed at least one type of deformity at 20 to 57 µg/g Selenium in eggs dry weight
- 100% mortality of the fry occurred in fish at greater than 57 µg/g Selenium in eggs dry weight (Soloway 2014)

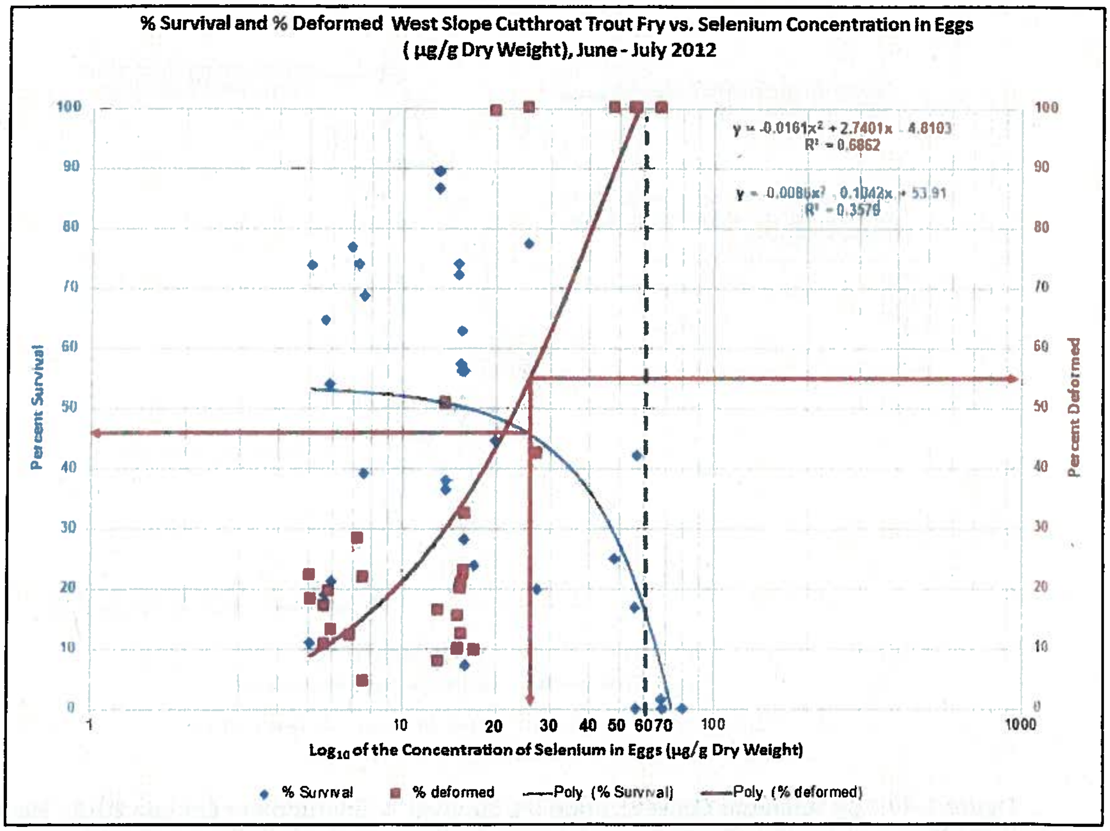

Figure 1-39: Egg Selenium Concentration Vs. Survival - Environment Canada 2012, Nautilus Environmental, Teck coal, Interior Reforestation, "Effect of Selenium on Early Life Stage Development of West Slope Cutthroat Trout", SEATAC Poster, 2009, Rudolph 2008, Kennedy 2000 (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured in June-July 2012)

In Figure 1-40, the Nautilus-Rudolph-Kennedy data is graphically mapped onto the Environment Canada 2012 data and provides an estimate of the range of survival of swim up fry at the average of 26.7 µg/g Selenium in eggs found in the Environment Canada study.

The combined **Environment Canada +Nautilus and Nautilus-Rudolph-Kennedy** data of Figure 1-40 shows that at the average of 26.7 µg/g selenium in eggs the percent survival to swim up of Upper Fording River Westslope Cutthroat Trout fry is estimated to range between 46% to 64%. For an estimate on the potential population impact of the loss of 36% to 54% of the swim up fry due to selenium toxicity see Lemly 2014. For an estimation of the potential economic impact, see Klimas 2014.

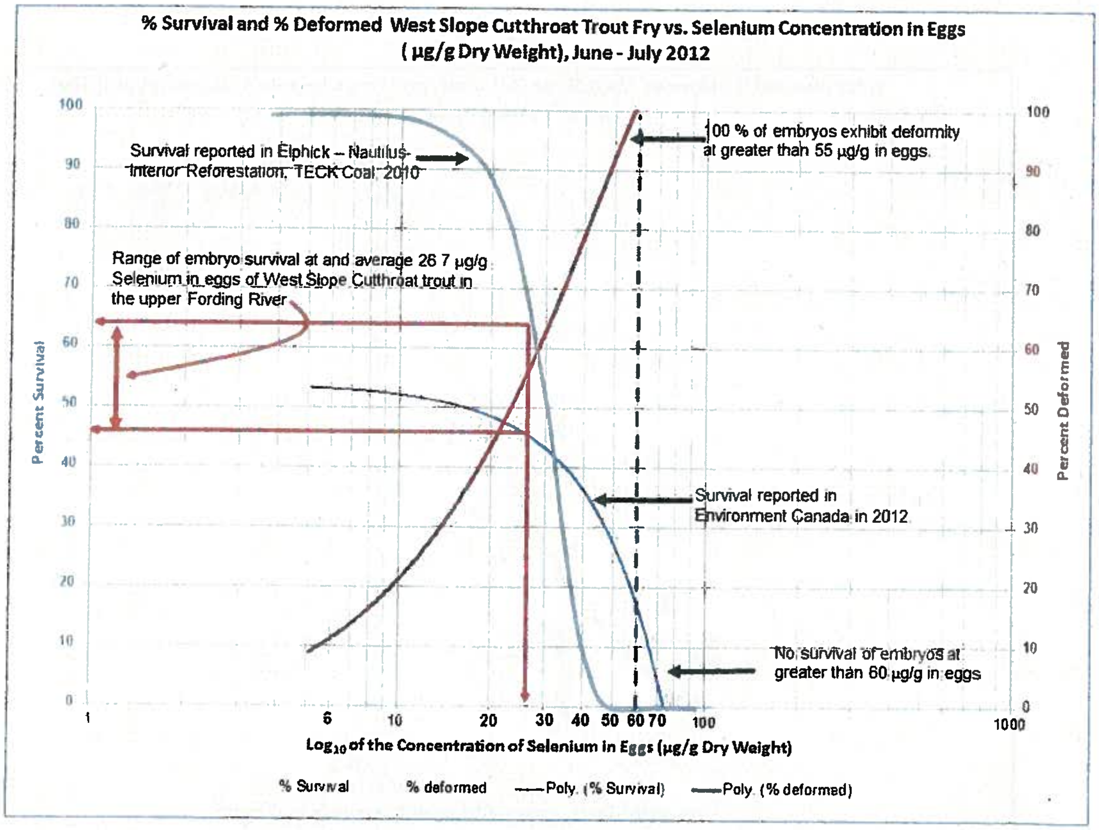

Figure 1-40: Egg Selenium Concentration Vs. Survival - Environment Canada 2012, Nautilus Environmental, Teck coal, Interior Reforestation, "Effect of Selenium on Early Life Stage Development of West Slope Cutthroat Trout", SEATAC Poster, 2009, Rudolph 2008, Kennedy 2000 (Red arrow indicates the average concentration of 26.7 µg/g Se in the eggs of Upper Fording River West Slope Cutthroat Trout captured In June-July 2012)

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1.5 Summary of Environmental Sampling Results – Elk River.

The study collected a limited number of samples in the Upper Elk River 19 km upstream of the town of Elkford to 7 km downstream of its confluence with the Fording River. (Figure 1-41) Additional samples will be collected in September – October 2014.

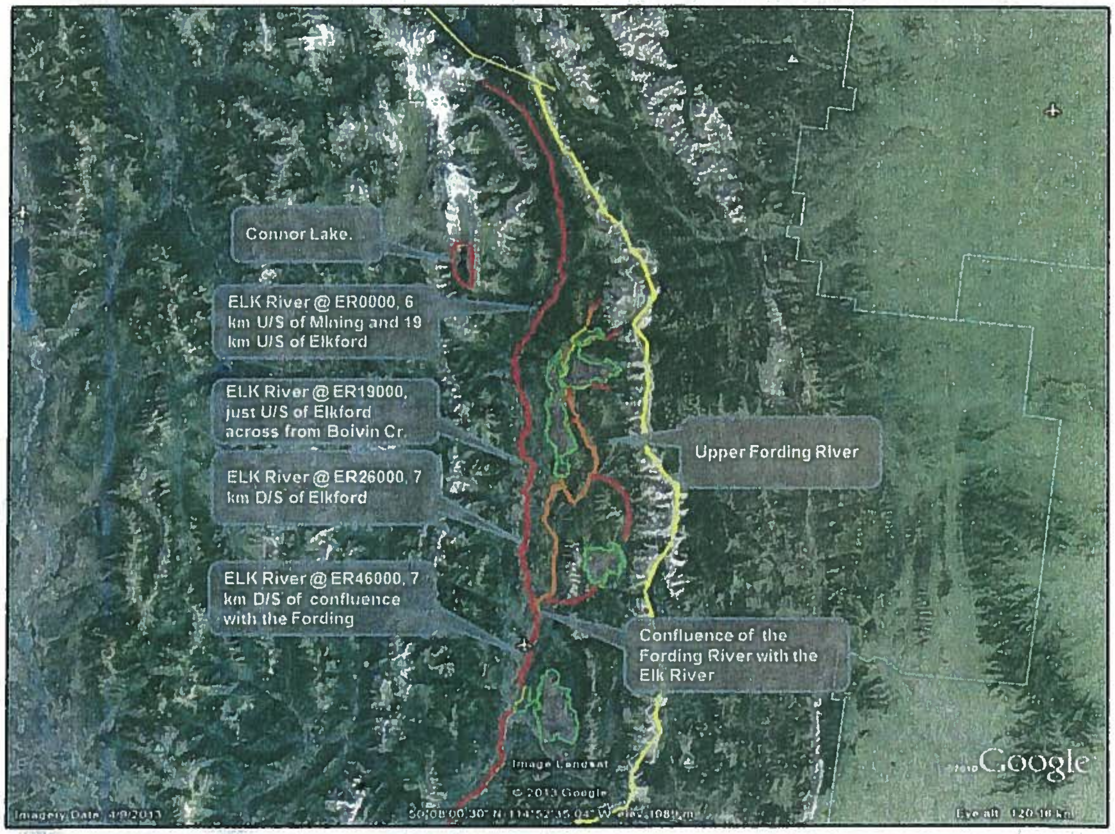

Figure 1-41: Study area in the Upper Elk River Basin.

1.5.1 Concentration of Selenium in the Elk River and Impact of the Fording River.

The study found that dissolved selenium concentrations in the upper Elk River were at the background concentrations of <1.0 µg/L 19 km upstream of the town of Elkford to 1.0 µg/L at the town of Elkford. The increasing deposition of waste rock from the Greenhills mine into the upper Elk River Valley is likely to increase the selenium loading as tributary drainages continue to receive increasing amounts of leachate/runoff from the rock piles.

Selenium concentrations in the Fording River just prior to confluence with the Elk River were at 20 µg/L during the June-July 2012 freshet sampling period and 50 µg/L during the April-May winter dry period. During the June-July 2012 sampling period, selenium concentrations in the central Elk River increased from 1.0 µg/L at Elkford to 6.0 µg/L when measured 7.0 km downstream of confluence with the Fording River. This indicates that the flow in the Elk River is approximately three times that of the Fording River at a time when both rivers were in high flood at freshet. (Figure 1-42)

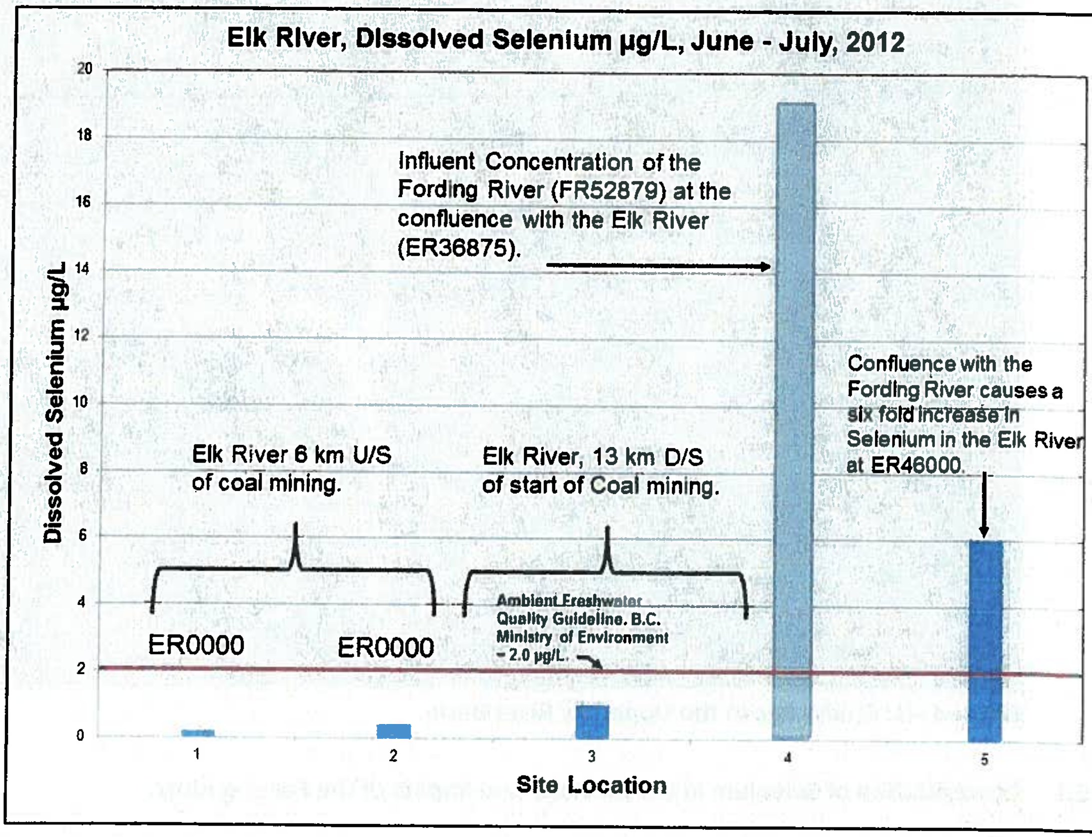

Figure 1-42: Selenium trends measured in the Elk River, June – July, 2012

These trends co-relate to the long term selenium concentration trends measured in the Elk River at Sparwood (Figure 1-43) and at the Highway 93 crossing (Figure 1-44) which show steadily increasing selenium concentrations over time. At Sparwood, the long term trend concentrations always exceeds the CCME guidelines of 1.0 µg Se/L and the British Columbia protection of aquatic life concentrations of 2.0 µg Se/L and during low flow periods exceeds the Health Canada guidelines of 10.0 µg Se/L for drinking water. (Figure 1-43)

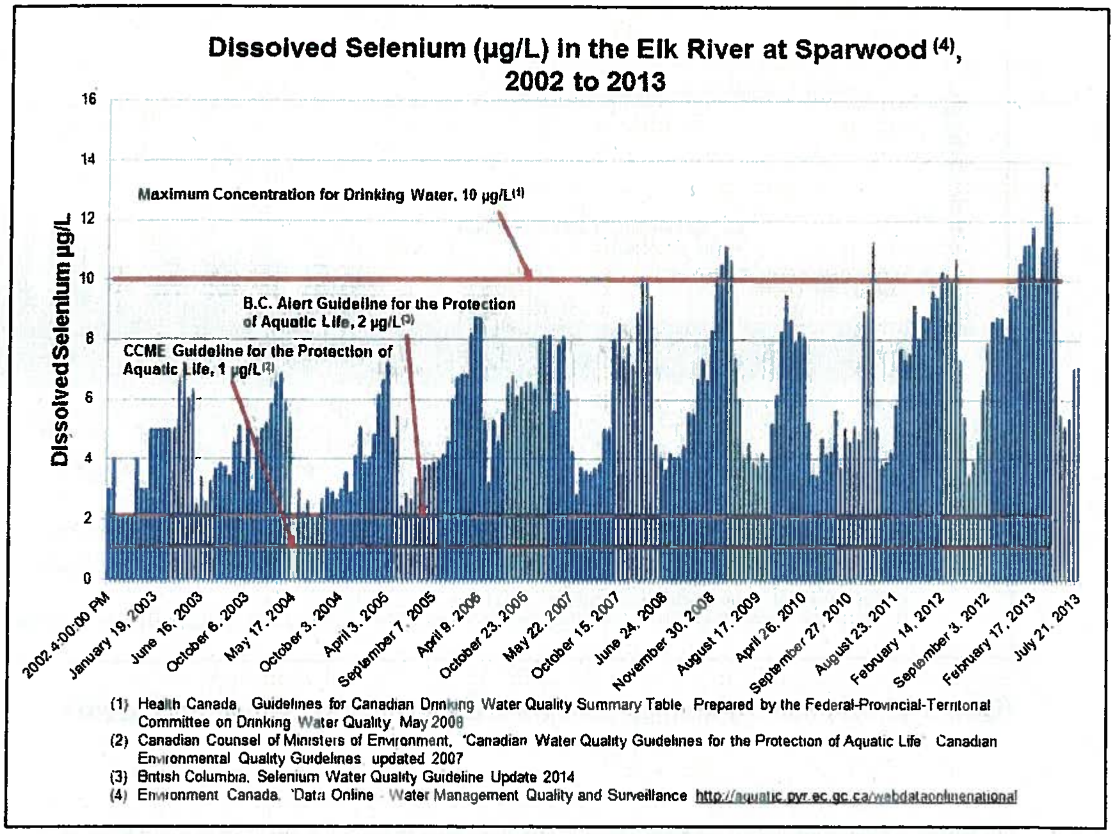

Figure 1-43: Selenium trends measured in the Elk River, at Sparwood, 2002 to 2013

Downstream of Elkford, additional non coal mining impacted tributaries dilute the selenium in the Elk River. At Fernie, the long term trend concentrations always exceeds the CCME guidelines of 1.0 µg Se/L and the British Columbia protection of aquatic life concentration of 2.0 µg Se/L. During low flow periods selenium concentrations in the Elk River at Fernie are one half the Health Canada guidelines of 10.0 µg Se/L for drinking water. (Figure 1-44)

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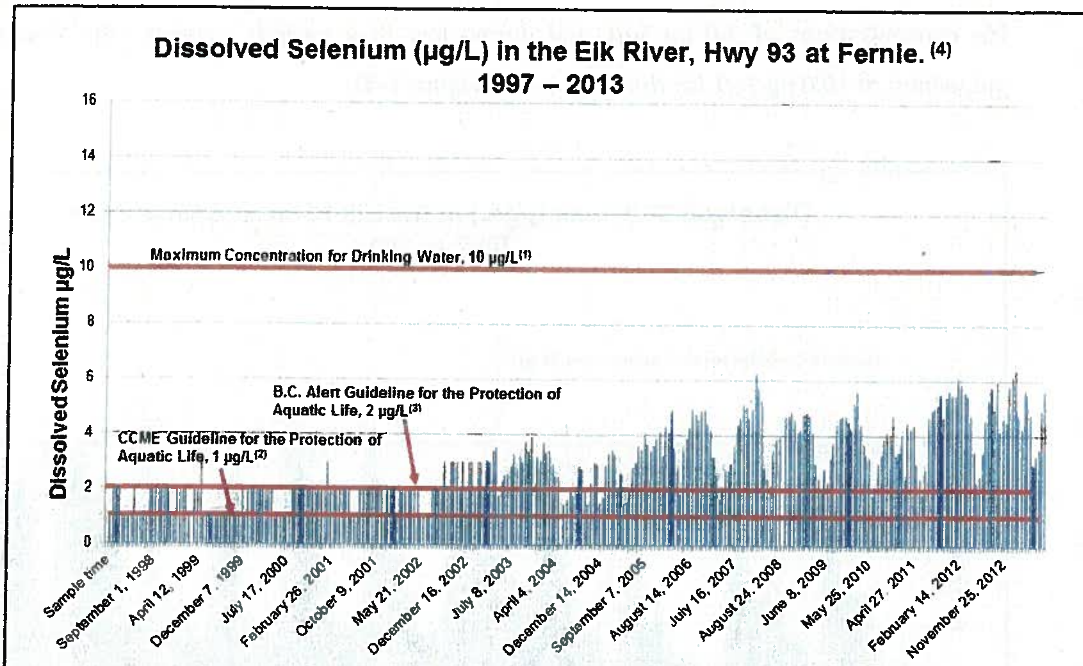

(1) Health Canada, Guidelines for Canadian Drinking Water Quality Summary Table, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water Quality, May 2008
(2) Canadian Counsel of Ministers of Environment, "Canadian Water Quality Guidelines for the Protection of Aquatic Life", Canadian Environmental Quality Guidelines, updated 2007
(3) British Columbia Selenium Water Quality Guideline Update 2014
(4) Environment Canada, 'Data Online - Water Management Quality and Surveillance http://aquatic.pyr.ec.gc.ca/webdataonlinenational

Figure 1-44: Selenium trends measured in the Elk River, at Sparwood, 1984 to 2013

1.5.2 Elk River – Concentration of Selenium in Periphyton/Algae and Benthic Invertebrates.

Only one algae sample was collected and the three benthic invertebrate samples were collected in the Elk River in June-July 2012. Even though there were only three benthic invertebrate samples collected they showed an increasing concentration of selenium that corresponded to the trend in selenium concentrations in Elk River water. (Figure 1-45)

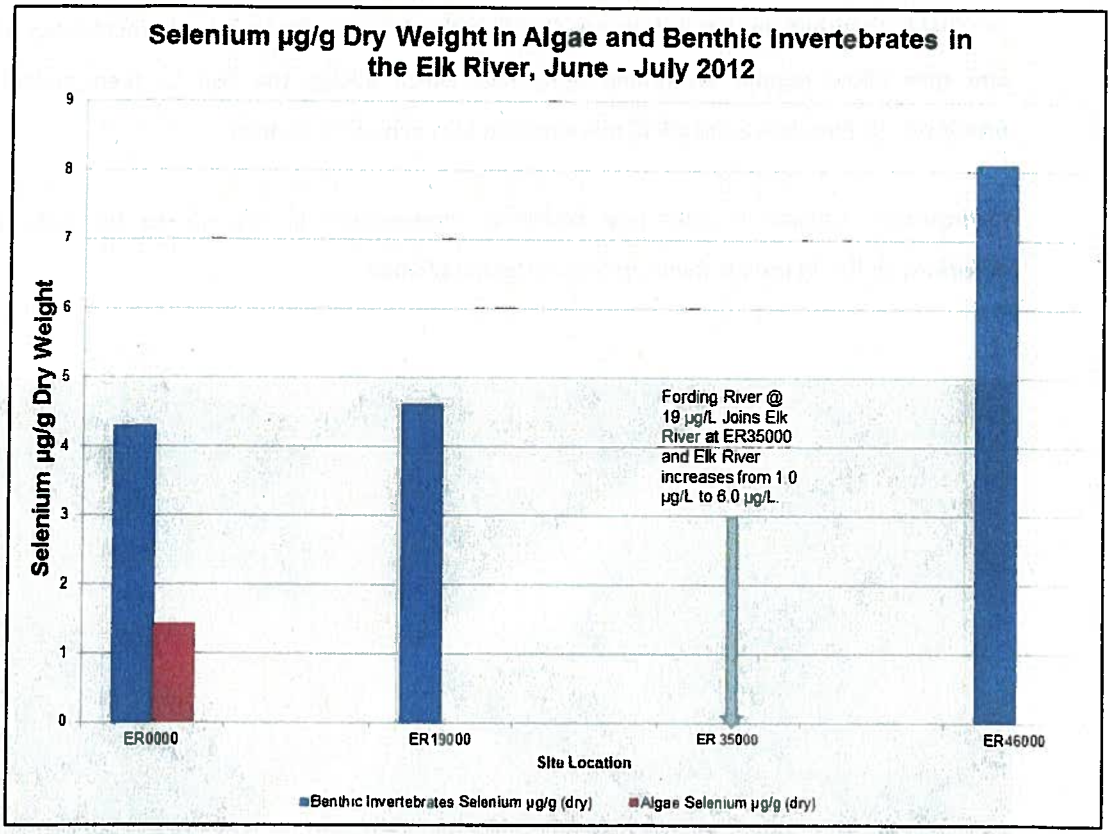

Figure 1-45: Selenium trends measured in Elk River Algae and Benthic Invertebrates, June – July 2012

Fish muscle, liver and egg samples were not collected in the Elk River in June-July 2012 due to limits in time and flood conditions making access and fish capture unsafe.

1.5.3 Incidence of Deformities in Fish in the Elk River

Environment Canada has received numerous reports of the incidence of deformities in sport caught fish in the Elk River and its tributaries. The most common report is shortening or absence of the operculum (gill cover). Figure 1- 46 shows a West Slope Cutthroat trout captured in Coal Creek on 2014-07-02 which originates from the former Coal Creek Coal Mine and discharges into the Elk River on the southeast side of Fernie. This creek was not sampled in the 2012 or 2014 sample period.

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The missing gill cover is a deformity which can occur due to selenium toxicity. This may be a survivable deformity in that it does not significantly alter the stream line characteristics of the fish and may allow regular swimming behaviour which allows the fish to feed and/or escape predators. It does leave the gill plates exposed to mechanical damage.

Environment Canada is collecting additional information in regards to the prevalence of deformity in fish in the Elk River system in the fall of 2014.

Figure 1-46: West Slope Cutthroat Trout captured in Coal Creek, a tributary to the Elk River at Fernie

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