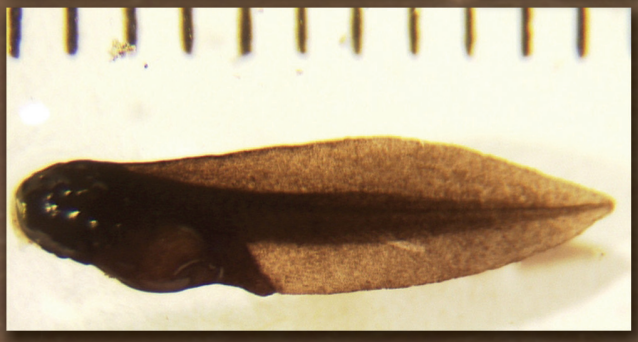
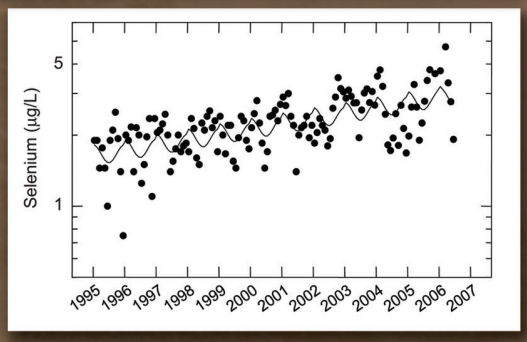
Selenium Status Report 2007

ELK RIVER VALLEY, BC





Prepared by Golder Associates Ltd., for the Elk Valley Selenium Task Force (EVSTF)
DECEMBER 2008

EXECUTIVE SUMMARY

Previous Selenium Status Reports summarized studies conducted through January 2007 regarding elevated selenium concentrations in the Elk River Valley in south-eastern British Columbia. The present Selenium Status Report 2007, produced under the direction of the multi-stakeholder Elk Valley Selenium Task Force (EVSTF), summarizes studies conducted through February 2008, as well as studies currently in progress.

Selenium is a natural element, which is released naturally from selenium-containing rocks by weathering. Coal strata in the Elk River Valley contain selenium, whose release into the environment is accelerated by coal mining. Selenium, although essential for life, can be toxic at higher concentrations and can affect the reproduction of fish, water birds and possibly amphibians that feed in water bodies containing elevated selenium concentrations.

Current efforts in the Elk River Valley are focused on monitoring and management following previous studies indicating that the viability and productivity of fish and water bird populations downstream of the coal mines do not appear to be adversely impacted by selenium, although comprehensive population studies on downstream biota have not yet been conducted to confirm this. Nor does it appear that human health or terrestrial wildlife (i.e., ungulates) are presently being adversely affected.

Continuing management investigations include efforts to: predict future selenium releases under different mining scenarios and management approaches; determine controls on the cycling and conversion of inorganic selenium once it enters the aquatic environment; and integrate present and future information to effectively manage selenium releases from the coal mines. Research is also being conducted by the Elk Valley Coal Corporation (EVCC) into treatment alternatives to reduce selenium loadings to the aquatic environment.

Regional monitoring of water and biota indicates significant, continuing long-term increases in selenium in surface water downstream of the EVCC coal mines. However, monitoring also indicates that selenium concentrations in benthic invertebrates, fish muscle and bird eggs, although elevated, have not increased over the last few years.

Lentic and lotic areas of the Elk River Valley are being mapped to determine relative proportions of these habitat types both related to future selenium studies, and to provide the basis for evaluating the significance of any localized impacts that may occur to the overall health of the Elk River Valley aquatic ecosystem.

The following studies are presently being conducted or planned by the EVSTF:

- Continued monitoring of water and biota in the Elk River Valley; the former will provide early warning of any increased selenium tissue concentrations that could result in adverse biological effects, while the latter will provide information on the efficacy of management actions.
- Preliminary investigations of selenium concentrations in water and biota in Lake Koocanusa, which receives all the selenium inputs from the Elk River Valley.
- A study designed to establish a definitive adverse effects threshold for Westslope cutthroat trout in the Elk River Valley, and to attempt to explain apparent differences between two previous effects studies with this fish species.
- Reanalysis of data from a previous Columbia spotted frog effects study, which may yield more conclusive information than has previously been available.

- An independent, high-level review of selected selenium studies conducted through 2007 in the Elk River Valley. This review, undertaken by four independent US experts, will identify key data gaps and provide recommendations for further work, including a framework for selenium releases, and will also help guide further selenium studies in the Valley.

The overall goal of the EVSTF and of the studies it commissions is to determine if any adverse ecological effects are occurring or could occur due to elevated selenium concentrations in water, sediment and biota in the Elk River Valley. It is expected that the next Selenium Status Report will be released in 2009.

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ACKNOWLEDGEMENTS

This report was prepared by Dr. Peter M. Chapman, Golder Associates, Burnaby, BC. Patti Orr (Minnow Environmental), Stephen Day (SRK), Alan Martin (Lorax Environmental), Chad Wilkinson (UBC), James Elphick (Nautilus Environmental), Stephane Brienne (Teck Cominco), and Sherri McPherson (Interior Reforestation) reviewed sections relevant to studies conducted by their respective firms, and provided useful comments along with photographs, some figures and a table used in this report. Additional photographs were provided by Lee Harding (Sciwrite). An additional table and figures were provided by Golder Associates. Formatting of the document was done initially by Tricia Kersey (Golder Associates) as a Word document for review by the EVSTF, and subsequently by George Gorczynski (Golder Associates) in final format. Useful review comments were provided by members of the Elk Valley Selenium Task Force (EVSTF – **Appendix A**).

I. INTRODUCTION

I.1 BACKGROUND

Selenium (Se) is a metal-like element (a metalloid) discovered in 1818 by the Swedish chemist Berzelius, and named after Selene, the Greek goddess of the moon. It is a naturally-occurring substance, and an essential element required for the health of humans, other animals and some plants.

However, selenium in excess can be harmful. Selenium can be particularly harmful to egg-laying animals, specifically fish, water birds and possibly amphibians that feed in or from water bodies containing elevated selenium concentrations. Inorganic selenium released naturally by weathering of selenium-containing rocks or whose natural release is accelerated by mining, can be modified by bacteria in lakes, ponds, marshes or wetlands into an organic form that can be accumulated by adults of these egg-laying animals from their diet. Selenium can then be transferred to the eggs where, during the development of the embryo, it can substitute for sulphur in the production of proteins, possibly resulting in deformities or even death of the embryos, depending on how much selenium is present in the eggs.

In October 2003 the Elk Valley Mines Environmental Management Committee (EVMEMC), comprised of representatives of the five coal mines in the Elk Valley, published the Selenium Status Report 2003. The purpose of that document was to provide a synthesis of information up to that date relating to investigations of selenium fate and effects in the Elk River Valley and to determine future research priorities. The subsequent Selenium Status Report 2004 and Selenium Status Report 2005/6 were published by a multi-stakeholder group, the Elk Valley Selenium Task Force (EVSTF – see **Section 1.2** and **Appendix A**).

The objective of the present Selenium Status Report 2007 is to summarize new information on selenium in the Elk River Valley that has become available since the last Report, i.e., for the period January 2007 through February 2008. Selenium Status Reports are provided on an approximately annual basis and/or as significant new information becomes available.

We hope that readers find this Report useful. Previous Reports will shortly be available on a dedicated EVSTF website; in the interim, they are available upon request from the Chair. Comments and feedback are appreciated and will be used to improve the next Report.

For copies of this Report, or to provide feedback, you can contact:

Roger Berdusco, Chair
Elk Valley Selenium Task Force
PHONE: (403)-260-9800
E-MAIL: info@elkvalleycoal.ca

I.2 ELK VALLEY SELENIUM TASK FORCE (EVSTF)

Membership of the EVSTF includes representatives (**Appendix A**) from Elk Valley Coal Corporation, Teck Cominco Limited, the BC Ministry of the Environment, the BC Ministry of Energy, Mines and Petroleum Resources, and Environment Canada (**Appendix A**). The overall goal of the EVSTF is to determine if any adverse ecological effects are occurring or could occur due to elevated selenium concentrations in water, sediment and biota in the Elk River Valley. The EVSTF has four specific objectives:

1. Determine if effects are occurring at present;
2. Determine if effects could occur in the future;
3. Provide input to the review of provincial or national guidelines; and
4. Determine site-specific environmental objectives where possible or necessary.

The EVSTF conducts its business via face-to-face meetings (about three per year), teleconferences, and e-mail. Subcommittees are formed as necessary. All work done for the EVSTF is: conducted under the

direct supervision of a Project Manager appointed by the EVSTF; and, when complete and of appropriate quality, approved for publication following review and approval by all members of the EVSTF. The present Selenium Status Report has been approved for publication and release by the EVSTF.

2. SELENIUM STATUS TO JANUARY 2007

The *Selenium Status Report 2003* provides background information on the Elk River Valley, the coal mines, and selenium and its toxicity. Key findings documented in that and the two subsequent Reports are briefly outlined below. A map showing the location of the five coal mines in the Elk River Valley is provided in **Figure 1**.

2.1 SELENIUM RELEASES

Previous studies have determined that coal mining accelerates the natural weathering release of selenium to the aquatic environment. Selenium leaches from waste rock and other coal wastes. Lentic (non-flowing water) areas tend to have the highest water column selenium concentrations. Lotic (flowing water) areas tend to have the lowest water column selenium concentrations.

LOTIC is a term used to describe a flowing water body such as a stream or a river.

LENTIC is a term used to describe a non-flowing water body such as a marsh, pond or lake.

2.2 MANAGEMENT

Initial studies focused on the fate and effects of selenium including biological effects and monitoring studies, and determining trends and assessing whether or not selenium releases were adversely affecting resident biota or humans. Management efforts assumed greater importance beginning in early 2006, when studies completed to that date indicated that current selenium concentrations were not adversely impacting either humans or resident biota downstream of mine discharges, with the exception of Westslope cutthroat trout living in an artificial settling pond. However, the possibility of more subtle adverse effects could not be discounted and it was recognized that, if effective management measures were not taken to manage selenium inputs and cycling in the environment, impacts could occur at some point in the future as selenium levels continue to increase in the Elk River **(Figure 2)**. Current management efforts are described in **Section 3.2**.

Previous Effects Studies Have Been Conducted with Long-Nose Sucker

2.3 EFFECTS STUDIES

The results of effects studies conducted through January 2007 are summarized in **Table 1**. Detailed information is available in previous *Selenium Status Reports*.

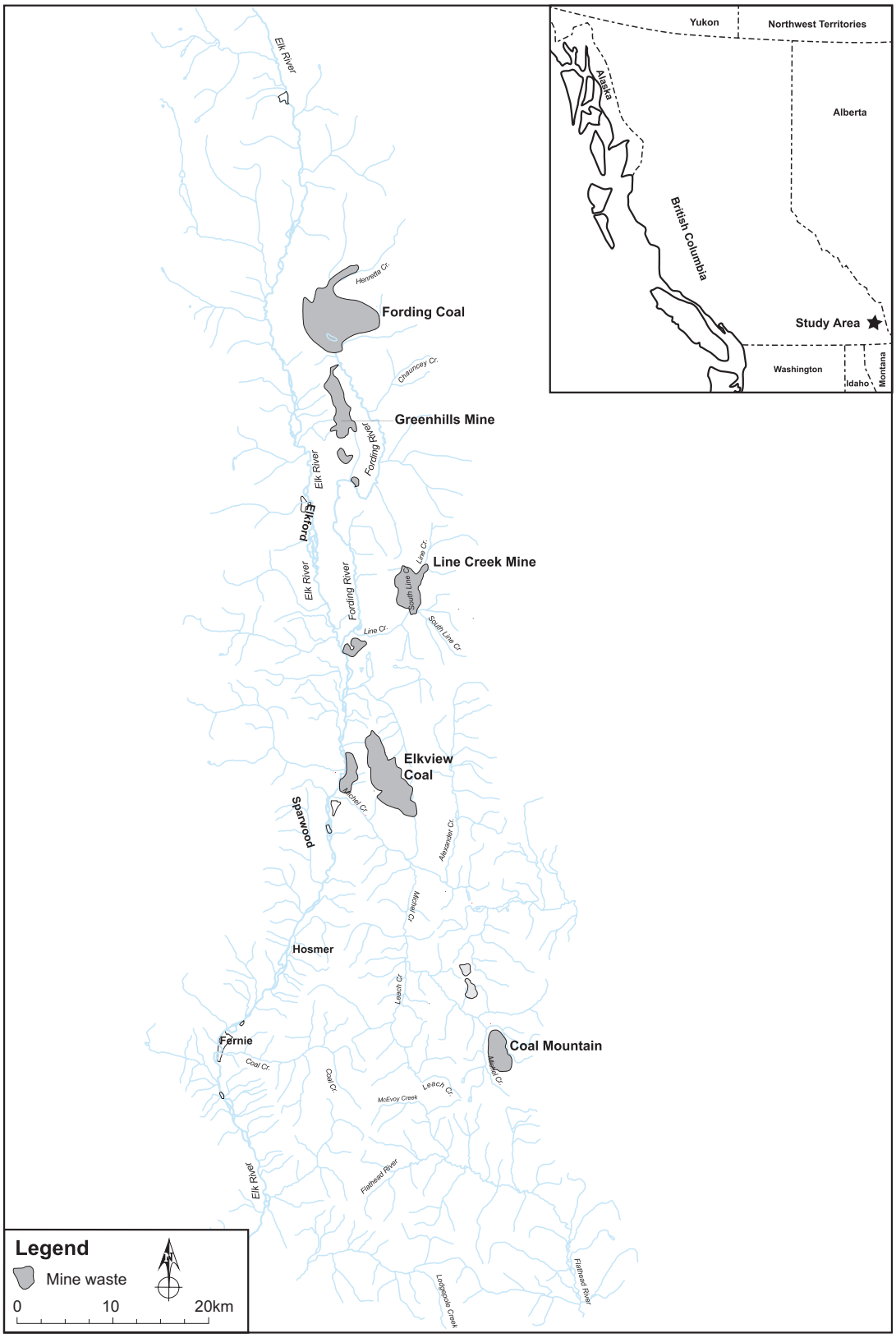


FIGURE I. The Elk River Valley, showing the locations of the five coal mines.
Figure I.1 in Minnow Environmental et al. (2007).

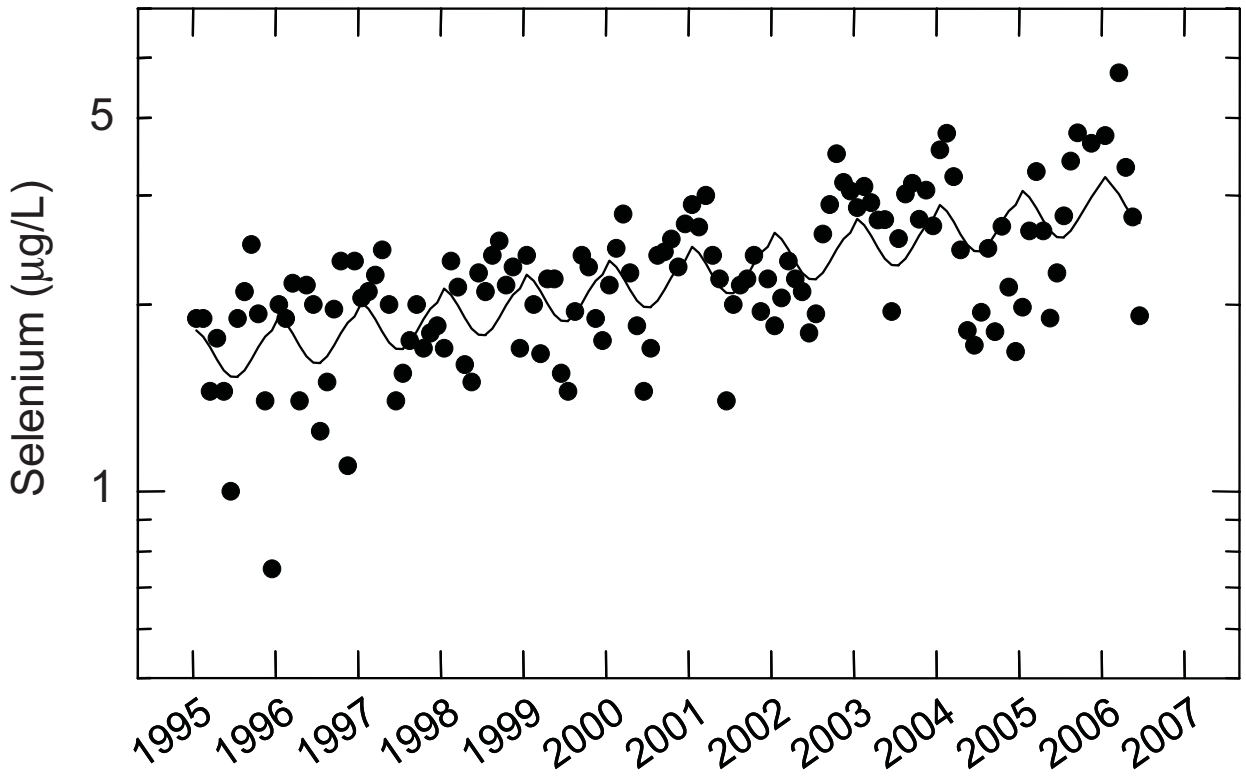


FIGURE 2. Selenium concentrations downstream of the mines at the Highway 93 Federal-Provincial water quality monitoring station. Solid circles are monthly values; the line is a parametric regression. Figure 3.5 in Minnow Environmental et al. (2007).

TABLE I. Summary of effects studies conducted to January 2007.
Based on Table 2 in the Selenium Status Report 2005/2006 with footnote updates.

SPECIES	ADVERSE EFFECT?	POPULATION-LEVEL IMPACT?	COMMENTS
LOTIC			
Cutthroat trout	No	No	Note the findings of lentic studies with this same species below
American dipper	No	No	Significant selenium uptake in exposed areas and sandpiper hatching success slightly depressed but productivity high; no effects to dipper and productivity high
Spotted sandpiper	Yes	No	
LENTIC			
Red-winged blackbirds	No	No	Significant selenium uptake in exposed areas but no significant selenium-related effects and high productivity
Eight species of waterfowl	Inconclusive	No	Significant selenium uptake in exposed areas, but clutch and brood sizes within regional norms. Small sample size; findings not conclusive
Longnose sucker	No	No	Selenium cannot be eliminated as a potential stressor, but other factors appear to contribute to observed embryo and larval mortalities and deformities
Columbia spotted frog	No[a]	No[a]	Selenium appears to be contributing to tadpole mortalities and deformities; however, other unknown factors are also contributing to mortalities and deformities, even in reference populations
Cutthroat trout	Yes[b]	Inconclusive	Studies conducted in lentic areas produced some conflicting results compared to studies conducted previously with this same species in lotic areas; additional studies are being conducted to resolve uncertainties (**Section 3.3.1**)

[a] Data are being reanalyzed using different statistics to determine whether there in fact may be effects or even impacts.

[b] Effects were noted in this lentic effects study but not in the previous lotic effects study, hence the "inconclusive" designation in the previous Status Report. A more conclusive designation is expected when the third study, in progress (cf **Section 3.3.1**), has been completed.

In the case of fish (cutthroat trout, longnose sucker) and frogs (Columbia spotted frogs), effects studies typically involved following the development of fertilized eggs either in the field (in both natural and created environments, including a treatment pond) or in the laboratory and determining end points such as percent hatch, survival following hatching, and levels of deformities compared to reference populations (reference sites located in areas with selenium-containing rocks can also contain elevated selenium concentrations). In the case of water birds (American dippers, spotted sandpipers, red-winged blackbirds) including waterfowl, field studies were conducted to determine any effects of selenium on the productivity of resident bird populations in exposed and reference areas, including any mortalities or deformities associated with hatched eggs.

2.4 MONITORING

Water quality around the coal mines is monitored by mine staff under regulatory discharge permits. Water quality downstream of the mines is monitored jointly by the federal and provincial governments at two stations on the Elk River. These stations, including one immediately downstream of Sparwood and another at the Highway 93 bridge, upstream of Lake Koocanusa, are sampled every two weeks (**Figure 2**).

Red-Winged Blackbird Female

Red-Winged Blackbird's Nest With Eggs

Each of the five Elk Valley mines have been conducting routine water quality monitoring since mining operations began at each mine. Each mine is required to meet their approved BC Ministry of Environment (MOE) effluent permit and associated conditions. Those conditions stipulate sampling frequency, sampling location, and the criteria for water quality parameters that must be met. On a quarterly basis, the results of these monitoring activities are reported to the MOE. If the results are unusual or are outside the range of regulated parameters, the MOE is notified and a follow-up investigation is conducted by both the MOE and the mine. The primary purpose of this mine-specific monitoring is to assist environmental managers (both at the mine and with MOE) in determining the potential for any adverse effect from mining activities upon the receiving environment.

Selenium monitoring studies, which began in 1996 (McDonald and Strosher 1998) have consistently reported elevated concentrations of selenium downstream of the mines. However, while selenium water column concentrations are increasing, fish tissue selenium concentrations have not increased between 1996 and 2006 (**Section 3.4.1**).

2.5 OTHER STUDIES

A conservative human health risk assessment (Lawrence and Chapman 2007) found negligible risk and some benefits to humans eating fish from the Elk River Valley that contained selenium.

3. SELENIUM STUDIES JANUARY 2007 TO FEBRUARY 2008

3.1 PUBLICATIONS AND PRESENTATIONS

During the above time period one presentation regarding selenium studies in the Elk River Valley was made at a provincial reclamation symposium (Chapman et al. 2007a) and three were made at a national scientific meeting (Chapman et al. 2007b; Orr et al. 2007; Paine et al. 2007). New publications in the peer reviewed literature directly related to the Elk Valley over the above time period and their major conclusions were:

- Chapman and deBruyn (2007) – the control chart approach is a useful tool that allows for a visual determination of whether or not future data are representative of baseline or background conditions. An application of this approach illustrated the fact that fish (cutthroat trout and mountain whitefish) muscle selenium concentrations have not increased over 10 years despite increased selenium water column concentrations.
- Harding (2007) – absence of selenium impacts to red-winged blackbirds exposed to elevated selenium concentrations in the Valley. Adverse effects were indicated at selenium concentrations > 22 mg/kg dry weight in eggs; however, beneficial effects at low selenium concentrations balance potential toxicity.
- Lawrence and Chapman (2007) – negligible risk of selenium to humans consuming fish from the Elk River; moderate benefits from such consumption.
- Rudolph et al. (2008) – cutthroat trout in lentic environments are more resistant to selenium toxicity than warm-water fish, but show effects at elevated tissue concentrations.

3.2 SELENIUM MANAGEMENT

Three major selenium management efforts were undertaken beginning in 2006: determination of selenium sources including release and water quality predictions; investigations into selenium cycling; and development of a selenium management decision framework. The latter was undertaken by the Elk Valley Coal Corporation (EVCC) and reported to the EVSTF. EVCC has updated its 5-year Plan for selenium research studies and management; this Plan will be discussed with the EVSTF (details of the previous Plan are provided in the *Selenium Status Report 2005/6*).

3.2.1 Selenium Source / Release Studies and Water Quality Predictions

Monitoring of the Elk River and its tributaries in the Elk Valley shows that selenium is discharged to surface waters by the mines. Studies conducted by EVCC (as reported in previous Selenium Status Reports) have shown that, when rain water and snow melt contact rocks disturbed by mining, selenium from minerals leaches into the runoff, which then enters the rivers.

The actual quantity of selenium in the rock is low (generally only a few parts per million), but mining breaks the rocks down and makes the minerals more available for leaching than would occur under undisturbed conditions prior to mining. Some of the selenium minerals only require contact with water to dissolve, while other minerals require oxygen to convert them into a form that dissolves. This process is called oxidation and is similar to the way in which iron rusts. Mine drainage is alkaline due to the natural mineralogy of the area.

Several approaches can be used to reduce the amount of a potential contaminant, such as selenium, in waters from a mine site. One way is to treat the mine water to remove contaminants to an acceptable level. Possible approaches to treatment research and development are being investigated by EVCC (**Section 3.5.1**). However, treatment has many disadvantages which include challenges with collecting the water, operating a treatment plant, disposal of solid and liquid waste by-products, high costs, and the length of time over which treatment is often required. Alternative approaches, known together as "source controls", aim to reduce the amount of contaminants that enter waters discharging to the environment. These approaches may be the best means to reduce selenium loadings to the environment. Such approaches can include applying engineering technologies such as structures to divert water, and cover systems to reduce water and/or oxygen content. The main advantage of these approaches is that, if successful, they may reduce, or in some cases eliminate, the need for water treatment. Treatment and source control are often used in combination to achieve acceptable water quality.

Rain water and snow melt can leach selenium from minerals containing selenium (circled) in rocks exposed by mining activities

In 2007, the EVSTF initiated a project to further investigate selenium sources and mechanisms that control its release. This information will be used to develop a model to predict future selenium releases under difference mining scenarios and management approaches, with the ultimate goal of finding the most effective means of reducing selenium releases from coal mining. Based on the results of this work, it is possible that different types of mine wastes may be amenable to different forms of source control or management approaches.

The project will involve field and laboratory programs using rock and water samples from the mines in the Elk River Valley. Phase 1 of the project involved collecting existing information from each of EVCC's five operating mines in the Valley to determine data gaps and which sites would be suitable for further study. Phase 2 of the project has been initiated, is being refined, and involves the design of specific studies to determine mine waste mineralogy and geochemistry over time and at different scales, as well as additions and enhancements to water quality monitoring programs. This work will be implemented at selected sites in 2008.

3.2.2 Selenium Cycling

Lorax Environmental is leading a project to assess the biogeochemical cycling of selenium in lentic environments. The ultimate goal of this work is to determine the controls for the cycling and conversion of inorganic and organic forms of selenium. This determination will assist in understanding selenium mobility in the environment and its bioavailability to plants and animals, and ultimately may help to predict and prevent selenium-induced toxicity in the aquatic environment of the Elk River Valley. It may also assist in determining opportunities for management intervention to disrupt the cycling of selenium and reduce the amount of organic forms of selenium in the aquatic ecosystem.

The project also involves detailed examination of selenium speciation (the different forms of selenium) in both sediments and their pore waters. Selenium is released from coal mining in an inorganic form but can be converted into organic forms in lentic areas through bacterial activities. These organic forms can then accumulate via the food chain in fish, water birds and amphibians and affect their reproduction.

This project also involves the collaboration of experts in the fields of selenium speciation in water (Dr. Dirk Wallschläger at Trent University and Dr. Nelson Belzile at Laurentian University), selenium speciation in sediments (Dr. Ingrid Pickering, University of Saskatoon), and low-volume pore water analysis (Bert Mueller, Pacific Centre for Geochemical and Isotopic Research, University of British Columbia).

Field surveys were initiated in August 2007 in two lentic environments: Fording River Oxbow (FRO) and Goddard Marsh (GM). Samples were collected of sediment pore waters, sediment cores, dissolved oxygen micro(small-scale)-gradients across the sediment-water interface, and surface water samples. Dialysis arrays ("peepers" – **Figure 3**) that passively sample different layers of sediment bottom waters and pore waters by diffusion were used to collect high-resolution profiles of dissolved selenium across the sediment-water interface. FRO and GM are classic lentic habitats characterized by low flows and fine-grained sediments (**Figure 4**).

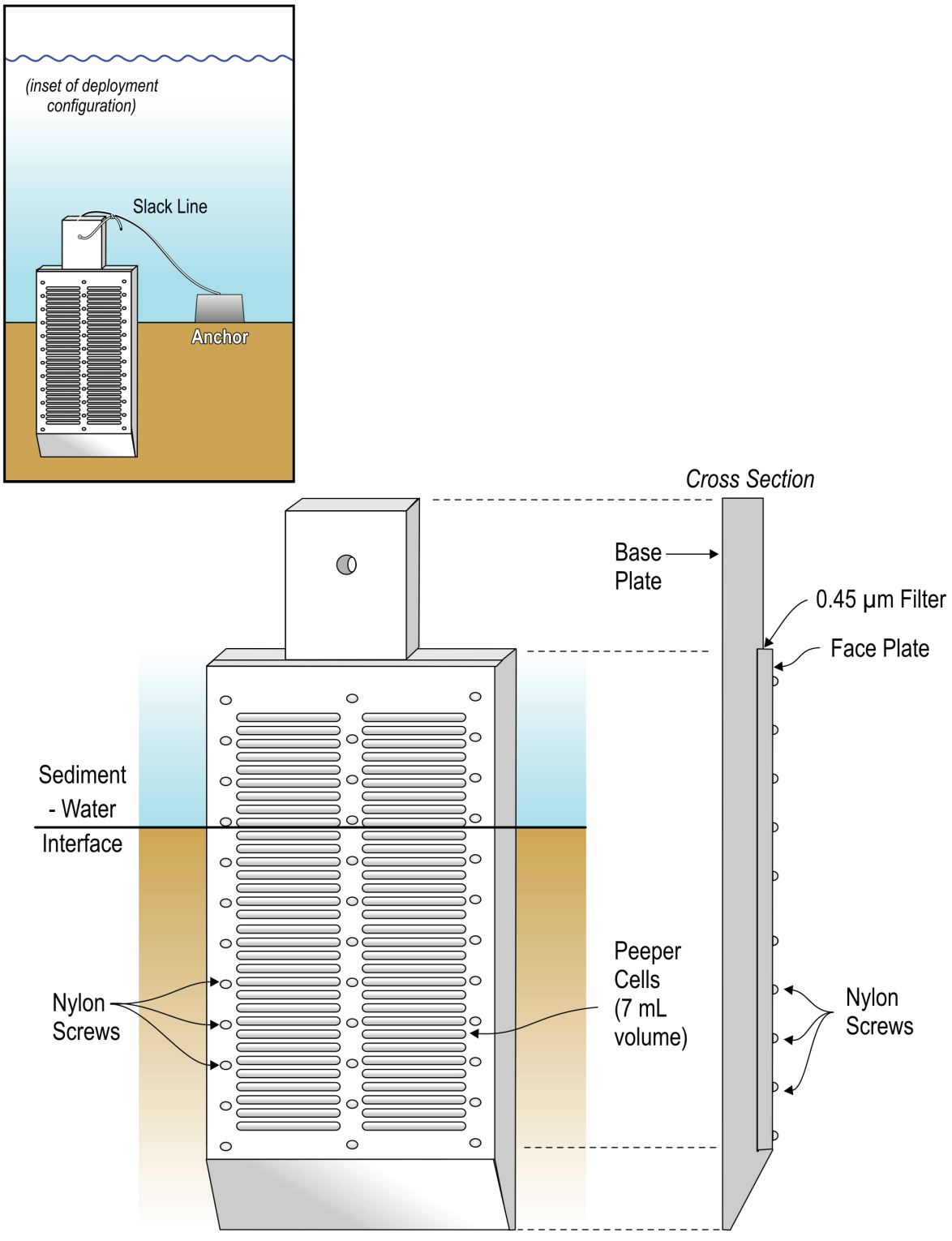


FIGURE 3. Schematic of a dialysis peeper, used to sample water layers above and below the sediment- water interface.
Figure provided by Lorax Environmental.

FIGURE 4. (A) Fording River Oxbow (FRO; downstream of Fording River Operations) (B) Goddard Marsh (GM; downstream of Elkview Operations).

Various state-of-the-art techniques are being used to measure the proportions of various inorganic and organic selenium species in both pore waters and sediments. The data obtained are being used to: 1) determine the biogeochemical controls governing the remobilization and fixation of selenium in lentic sediments; 2) determine the dominant sinks (accumulation pathways) for selenium in sediment; 3) quantify the direction and magnitude of selenium exchanges across the sediment-water interface; 4) help explain temporal and spatial differences in selenium accumulation and toxicity in biological receptors; and 5) develop seasonal and longer-term predictions for both selenium mobility and bioavailability, considering current and future mining scenarios.

The data available to the end of January 2008 indicate that there are important differences in oxygen demand and water circulation between the two sites. FRO is characterized by fully oxygenated bottom waters while in GM oxygen is lacking above the benthic boundary layer. More stagnant conditions at GM and higher abundance of organic matter contribute to a higher oxygen deficit in the water column at this site. Given the sensitivity of selenium to changes in oxygen conditions, the contrasts between these two sites may have important implications with respect to selenium exchanges across the sediment-water interface and selenium bioavailability. Additional data from this study will further explore these implications. A draft report on all aspects of this study is anticipated later in 2008. Key findings will be reported in the next *Selenium Status Report*.

3.2.3 EVCC Decision Framework

A decision framework has been developed by EVCC for managing selenium released from the EVCC coal mines located in British Columbia (BC) and Alberta (AB) and for assessing knowledge gaps and priority issues. The decision framework (detailed in the *Selenium Status Report 2005/6*) will be regularly updated as new site-specific and other relevant knowledge becomes available. The framework is currently being used by EVCC as a guide for determining the basis for future studies, management actions, and monitoring at EVCC coal mines where selenium is a contaminant of potential concern.

3.3 EFFECTS STUDIES

3.3.1 Cutthroat Trout

A cutthroat trout lentic effects study (Rudolph et al. 2007, 2008) was intended to build on the previous cutthroat trout effects study. The latter study, which was conducted in lotic waters (Kennedy et al. 2000), indicated that cutthroat trout in the Elk River Valley were not adversely affected by relatively elevated selenium concentrations. However, Kennedy et al. (2000) were not able to establish a selenium effects threshold for cutthroat trout; only three of the female trout they tested had egg selenium concentrations above levels shown to be toxic in other studies with warm water fish (but no toxicity was observed by Kennedy et al. (2000)).

Although the lotic study generally used the same methodologies as the lentic study, some of the results appeared to be contradictory. Kennedy et al. (2000) demonstrated that eggs with up to 81.3 mg/kg dry weight selenium produced normal fry with no evidence of selenium-related deformities or mortalities. In contrast, in the lentic study when egg selenium concentrations were greater than 46.8 but less than 88.3 mg/kg dry weight (4 females), no viable fry were produced. And when egg selenium concentrations were between 88.3 and 140.0 mg/kg dry weight (4 females), the eggs died before reaching the laboratory.

Because of these apparent contradictions between the earlier (Kennedy et al. 2000) and the later (Rudolph et al. 2007, 2008) cutthroat trout effects studies (the former in flowing waters, the latter in a constructed treatment facility, i.e., lotic versus lentic waters), and the need to establish a tissue threshold for this species, a further cutthroat trout effects study is underway. That study

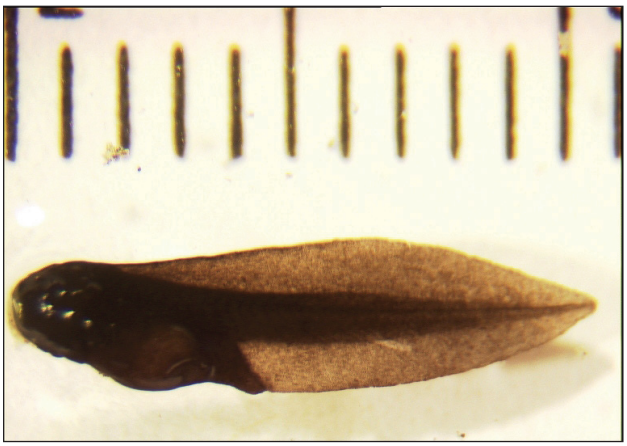
is being led by Nautilus Environmental and includes Hatfield Consultants, Applied Speciation, Interior Reforestation, and Paine Ledge and Associates.

A study design has been developed (Nautilus Environmental 2007) and is being finalized in consultation with the EVSTF. It is hypothesized that the different result between the two previous studies may be due to differences in partitioning and / or speciation of selenium found in trout tissues from lentic compared to lotic waters related to differences in prey and food chain dynamics / structure. In other words, there may be differences in the types of selenium that accumulate in trout depending on where they live and what they feed on.

The study has been designed to test this possibility by collecting, analyzing, and rearing trout from both lentic and lotic habitats. The study's objectives are to provide data to:

1. establish a definitive selenium adverse effects threshold for Westslope cutthroat trout in the Elk River Valley; and
2. explain the differences between the two previous studies.

Effects Studies Have Been Conducted With Columbia Spotted Frogs



3.3.2 Columbia Spotted Frog

A previous effects study with Columbia spotted frog (Minnow Environmental 2006; summarized in the *Selenium Status Report 2005/6*) found that selenium could be contributing to tadpole mortalities and deformities. However, it also indicated that factors other than selenium can have an equal or greater influence.

There have been extensive discussions within the EVSTF regarding the statistical analyses used. As a result, an independent US consultant (Anne Fairbrother, Parametrix) has been retained and is reanalyzing the data. Those findings will be reported in the next *Selenium Status Report*.

3.4 MONITORING

3.4.1 Regional Monitoring of Water and Biota

Regional aquatic monitoring and spatial and temporal analyses of selenium data in water and biota were conducted by a consultant team led by Minnow Environmental and including Interior Reforestation, Paine Ledge and Associates, and Anatum Ecological Consultants. Monitoring included both lotic and lentic habitats in the Elk River Valley. One objective was to evaluate any temporal and spatial trends in selenium concentrations based on routine water quality and flow monitoring data collected by the coal mines

(details of this routine monitoring are provided in the *Selenium Status Report 2004*). A second objective was to determine trends in selenium concentrations in sediment and biota. For the most part, trend assessment was based on three separate years of data collection: 1996, 2001, and 2006.

The findings to date of this regional monitoring program are (Minnow Environmental et al. 2007):

- Selenium was elevated in water, sediment, and biota downstream of the mines compared to upstream reference areas.
- Increased water selenium concentrations at core monitoring stations downstream of the mines can be attributed directly to coal mining activities (**Figure 5**).
- Surface water selenium concentrations are increasing at a rate of about 8% per year at core monitoring stations downstream of the coal mines; this equates to a doubling about every 10 years. Changes of this magnitude or greater have already occurred. Increases are smaller downstream (at the Highway 93 bridge – about 6% increases per year) due to dilution, but generally indicate the same trend (**Figure 2**).
- Selenium concentrations in sediment and fish tissue are elevated both downstream of the mines and in reference areas (i.e., upstream concentrations occasionally exceed BC water and sediment guidelines); in other words, natural selenium concentrations are elevated in some areas, and mining activities are further increasing natural selenium concentrations.
- Sediment selenium concentrations have increased in some areas but not in others; the data are insufficient at present to determine trends (**Figure 6**).
- Benthic (bottom-dwelling) invertebrates (animals without backbones) had higher selenium concentrations near the mine than further away; however, concentrations have not increased over the last ten years (**Figure 7**).
- Selenium in fish tissues is elevated in some, but not at all areas downstream of the coal mines, and selenium concentrations have also not increased over the last ten years (**Figure 8**).
- Similarly, selenium in bird eggs has not increased over the last few years (**Figures 9 and 10**).

This study also compared analyses of non-lethal muscle plugs with analyses from sacrificed fish, which will reduce the number of fish that need to be collected and sacrificed for future monitoring. Changes to the regional monitoring program have been recommended and are being considered by the EVSTF. Both tissue and water quality monitoring will continue, on a 3-5 year cycle, dependent on any changes in measured water or tissue selenium concentrations.

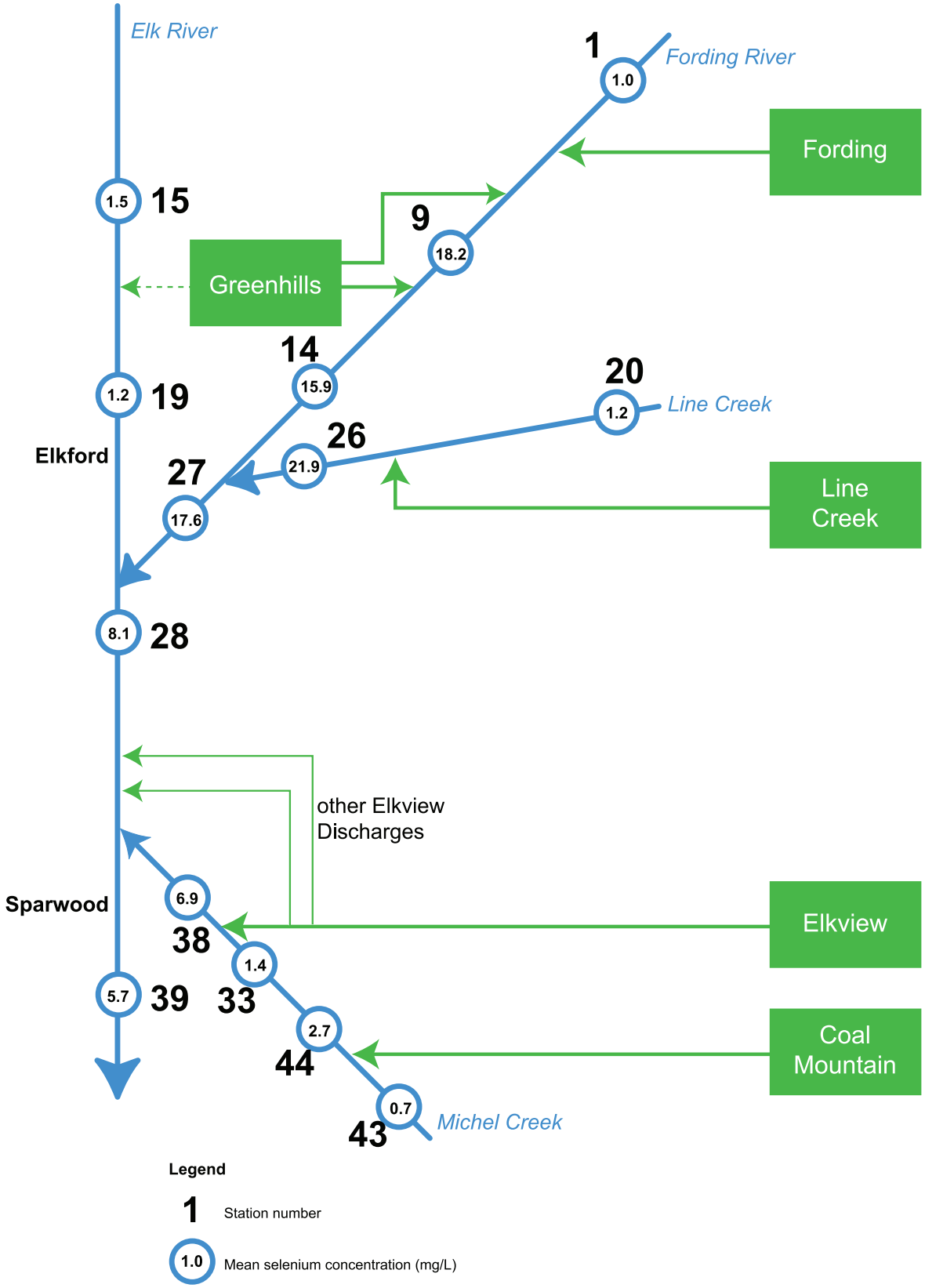


FIGURE 5. Schematic comparing mean selenium concentrations at core monitoring stations, 2004 to mid-2006.
Figure 3.7 in Minnow Environmental et al. (2007).

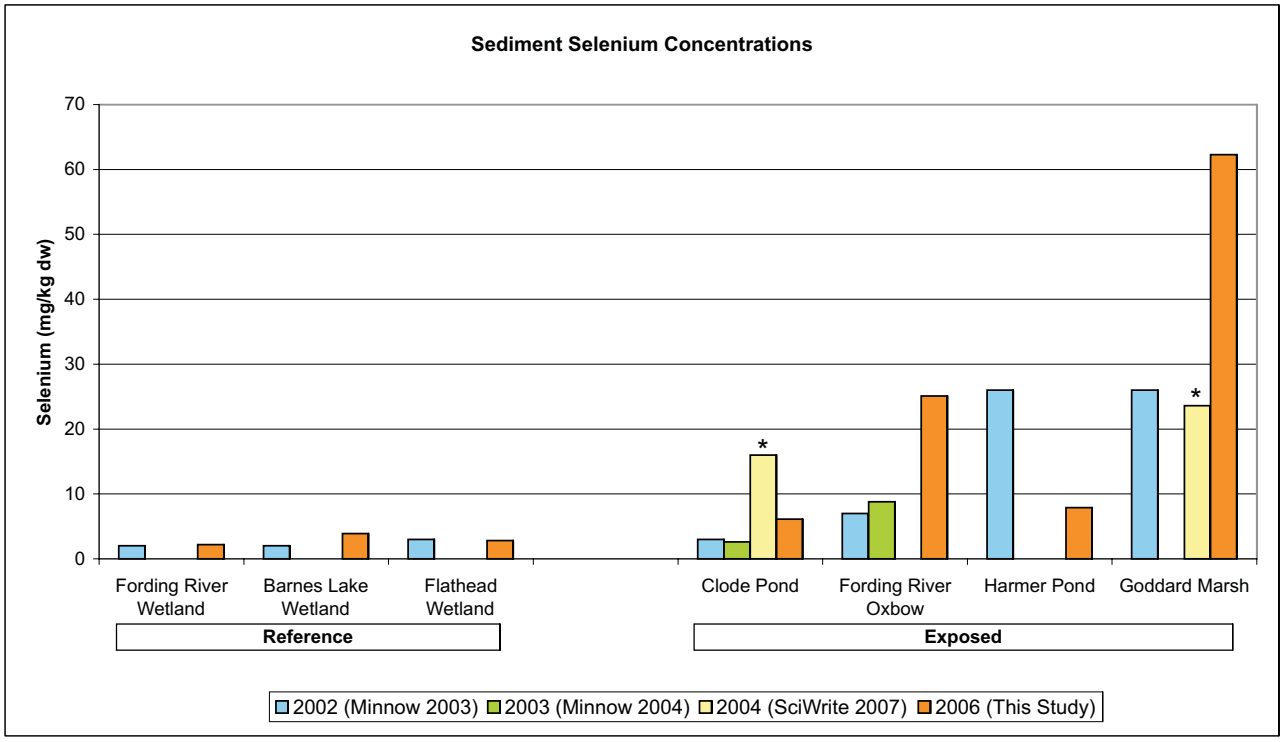


FIGURE 6. Changes in sediment selenium concentrations over time.
Figure 4.1 in Minnow Environmental et al. (2007).

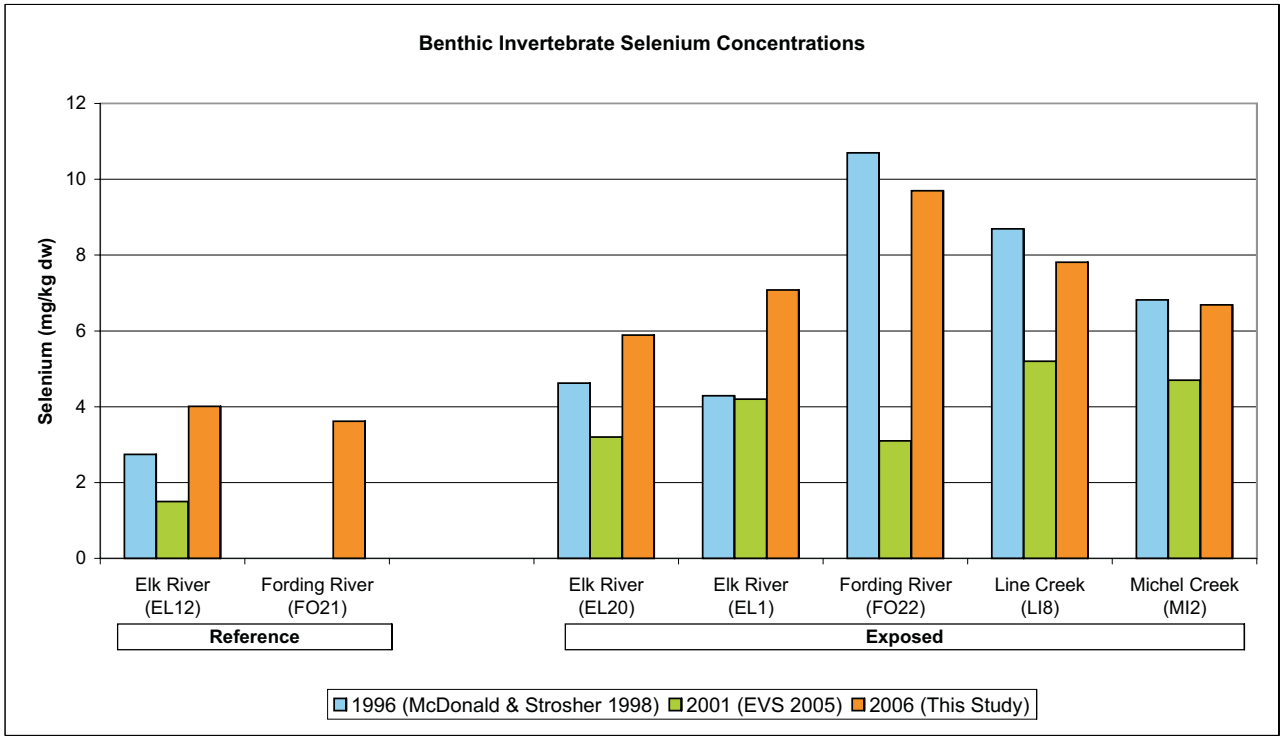


FIGURE 7. Changes in benthic invertebrate selenium concentrations over time.
Figure 4.1 in Minnow Environmental et al. (2007).

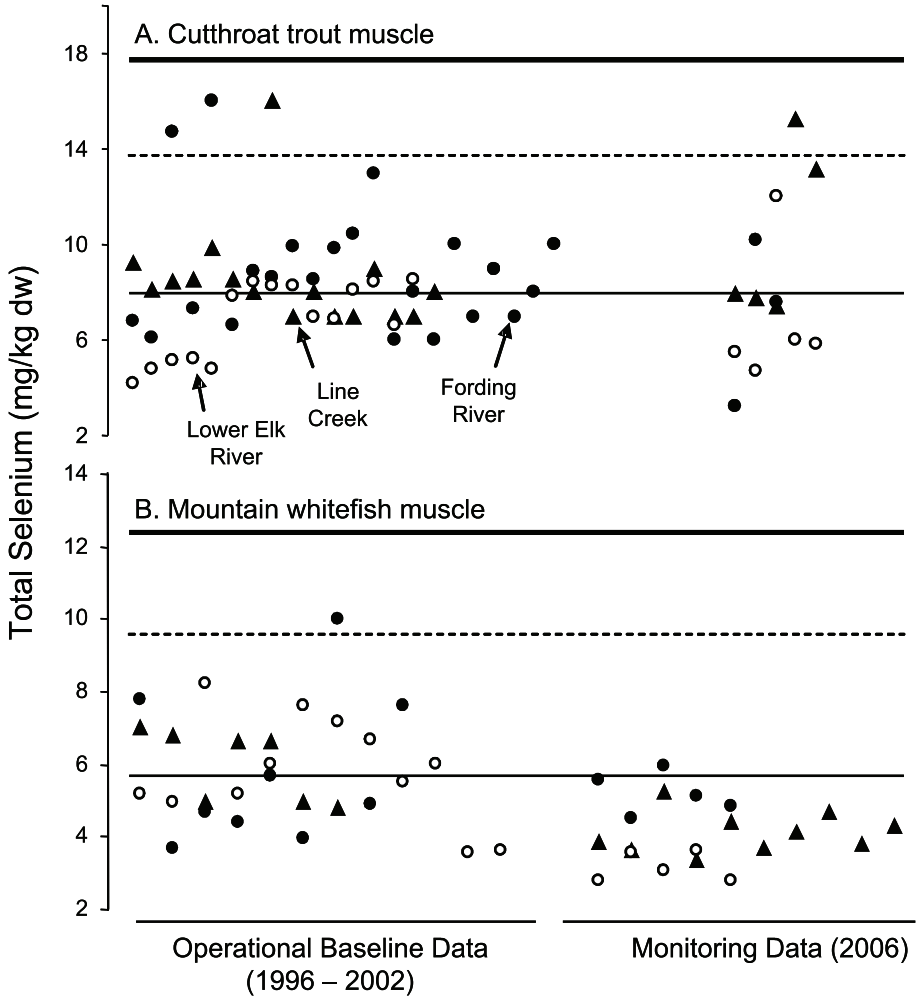
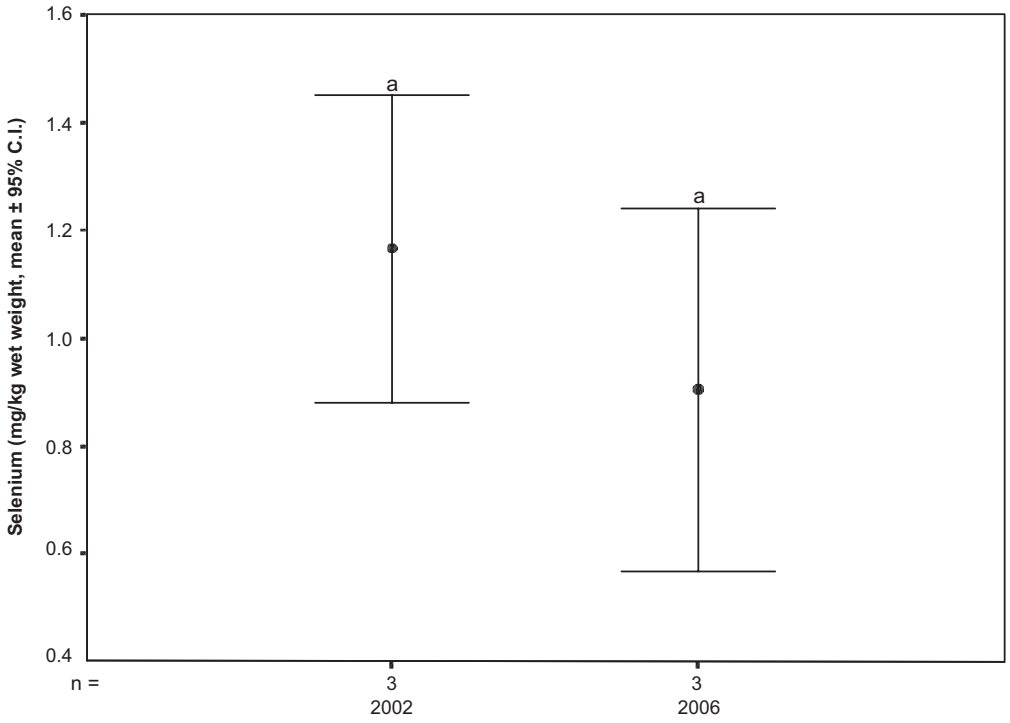


FIGURE 8. A: Cutthroat trout muscle selenium concentrations in three areas of the Elk River Valley in 1996, 2001, 2002, and 2006.
B: Mountain whitefish muscle selenium concentrations in the same three areas of the Elk River Valley in 1996, 2001 and 2006.
Operational baseline data from 1996 and 2001/2002 (left) are compared to 2006 monitoring data (right). Horizontal lines indicate the mean, mean + 2SD (standard deviations), and mean + 3SD. Source: Chapman and de Bruyn (2007).

a) EL20 (minimally exposed)



b) MI2 (exposed)

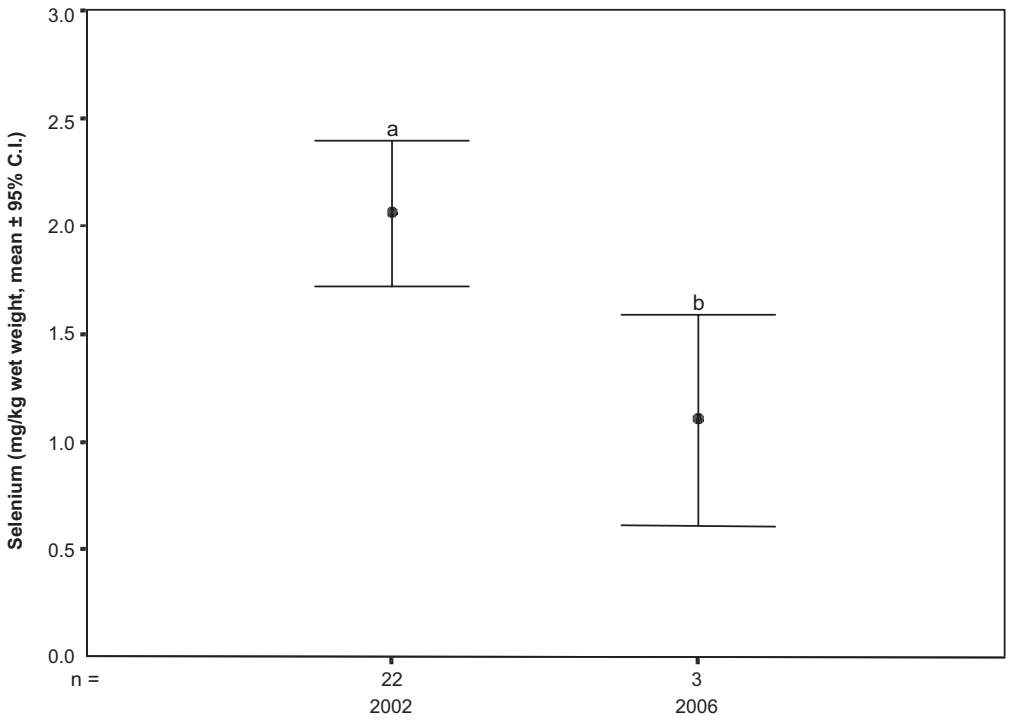


FIGURE 9. Selenium concentrations in sandpiper eggs collected from two selenium-exposed sites in 2002 and 2006.

Figure 8.2 in Minnow Environmental et al. (2007).

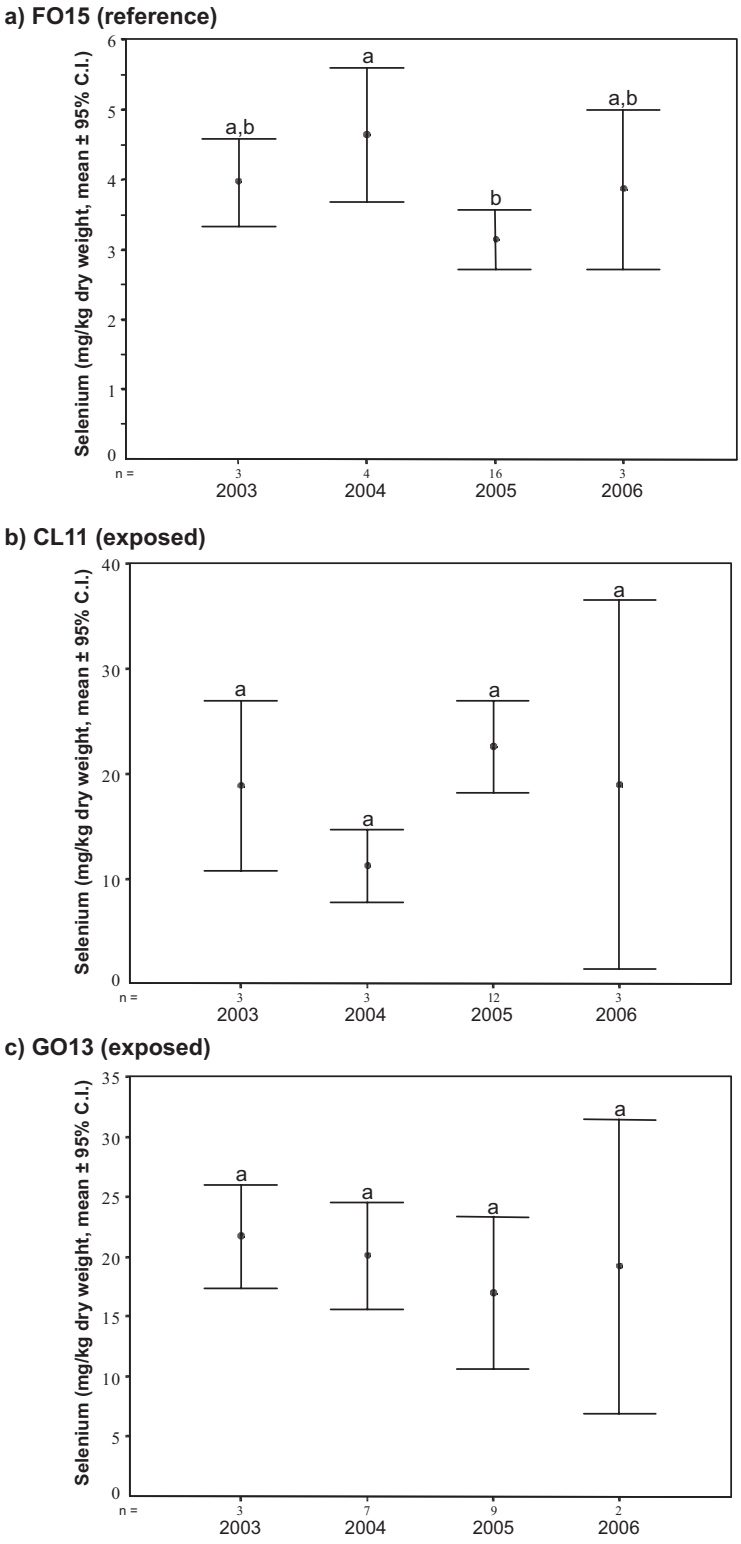


FIGURE 10. Selenium concentrations in red-winged blackbird eggs collected from three sites 2003-2006.
Figure 8.3 in Minnow Environmental et al. (2007).

3.4.2 Resident Fish Communities
Studies Conducted by EVCC, not by the EVSTF

Line Creek Fisheries

Previous *Selenium Status Reports* have provided information regarding the status of Elk River Valley fisheries based on monitoring being conducted in Line Creek, which contains elevated levels of selenium from coal mining activities (in the range of 20 µg/L). This monitoring is continuing. The creek continues to support a resident population of cutthroat trout, a migratory adult spawning bull trout population, a resident juvenile bull trout population that rears in the creek, and a migratory mountain whitefish population that uses the lower portion of the creek for summer feeding.

Bull trout fry removal and measurements, August 2007

In addition to continued monitoring, EVCC initiated a five-year aquatic health monitoring program in Line Creek in 2007. This program, designed and conducted by Interior Reforestation, is intended to provide additional information towards an understanding of the status of aquatic communities in Line Creek in the face of natural variability in their habitat and disturbance to the watershed. This information will assist in separating out any effects of selenium on these fish populations from natural variability. EVCC monitoring results for 2007 can be found in Berdusco and Arnett (2008).

Large-Scale Fisheries Assessment

As noted in the *Selenium Status Report 2005/6*, a larger-scale assessment of the status of fisheries in the Elk River Valley is being conducted by a graduate student from the University of British Columbia with funding assistance from EVCC. This research is investigating the population dynamics of bull and cutthroat trout in the Elk River Valley, specifically the influence on fish species from recreational fishing activities that predominate in the Elk River mainstem (both catch-and-keep and catch-and-release), and coal mining operations in tributary streams.

3.5 OTHER STUDIES

3.5.1 Bacterial Selenium Treatment

Studies Conducted by EVCC, not by the EVSTF

As noted in the *Selenium Status Report 2005/6*, selenium treatment research has been ongoing since 2004 at TeckCominco's Trail (BC, Canada) Applied Research and Technology Group. The goal is to develop a microbial-based selenium removal system by stimulating the growth of indigenous micro-organisms using locally available nutrients as a food source.

Trials are being initiated to determine the ability of seeded bacteria to remove selenium from the water column under field conditions at several sites.

Some of the selenium removal experiments involve continuous columns. Water containing known concentrations of selenium is passed through these columns, which comprise different types of treatment, and the selenium concentration in the water that comes out is determined.

3.5.2 Industry Selenium Working Groups

Relevant, But Not an EVSTF Activity

As also noted in the *Selenium Status Report 2005/6*, in May 2006 EVCC joined with other industries in Canada to form the Canadian Industry Selenium Working Group (CISWG). In November of that same year CISWG members joined with similar industries to form the North American Selenium Working Group (NAISWG). In January 2008 the NAISWG joined the North American Metals Council (NAMC), which is a registered US and Canadian non-profit organization with a solid reputation for conducting research. The NAMC-SWG (Selenium Working Group) is proceeding to fund three research programs of national and international interest, which are also relevant to selenium issues in the Elk River Valley:

1. Development of a review and consensus document on aquatic effects selenium tissue-based thresholds.
2. Preparation of an implementation manual for using a tissue based selenium water quality guideline including site-specific methods for assessing aqueous selenium.
3. Development of a manual delineating appropriate procedures for assessing selenium in water, tissue, sediment, soil and rock.

An update will be provided in the next *Selenium Status Report*.

3.5.3 Mapping of Lentic and Lotic Habitats

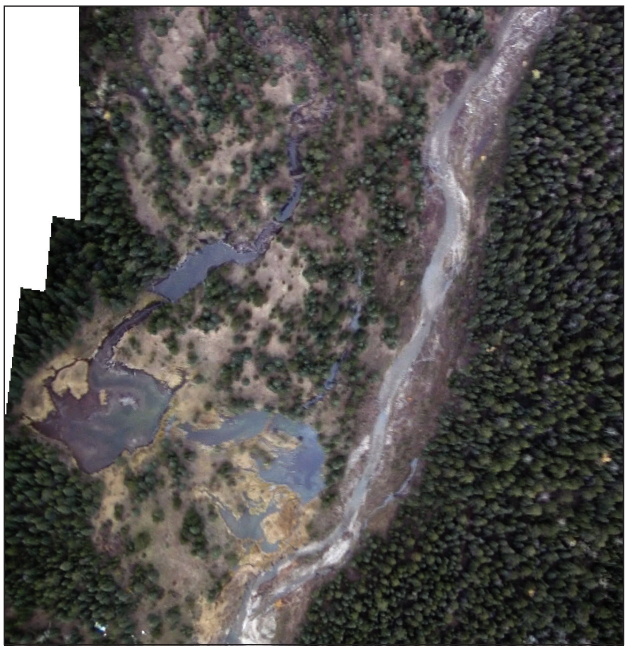
Watershed mapping to determine all lentic areas potentially at risk from selenium (e.g., wetlands, marshes, backwater areas) and the relative proportion of lentic and lotic areas in the Elk River Valley is in progress. This work, conducted by Interior Reforestation, is intended to assist in understanding the overall relative distribution/importance of each type of area downstream of the mines, and will assist in focusing future selenium research and assessments.

Mainstem and tributary areas downstream of the coal mines and within the mines' boundaries were

videotaped from a helicopter. Lentic areas are being distinguished as either:

- Standing water areas (i.e., pond, backwater, relict channel or wetland areas) apparent at base stream flow conditions; or
- Wetlands that were not wetted at base stream flows, but that were expected to be wetted during mid- to high-flow periods for a significant portion of the year. The outlying boundary for these lentic areas is being defined by vegetation, soils and topography visible in the aerial images, from ground-truthing (see below) and, where appropriate and possible, from earlier vintage air photos and other historic information.

Field verification (i.e., ground-truthing) was conducted following the helicopter flights at four sites: upper Fording River, Elk River, lower Fording River and Michel Creek. Data compilation and report preparation are underway. A report for Michel Creek will be prepared for review by the EVSTF prior to completing the report for the entire Elk River watershed.



Michel Creek lotic (flowing) and lentic (ponded) waters

The end products of this work, which will be reported in the next *Selenium Status Report* following review by the EVSTF, will include:

- A 1:250,000 map of the entire study area identifying sub-basins (e.g., Michel Creek), tributary streams, mine locations and other features of interest.
- A map of each individual watershed sub-unit at a scale of 1:20,000 or 1:50,000. These maps will be geo-referenced for use with geographic information systems (GIS).

4. FUTURE STUDIES

4.1 MANAGEMENT

Whether management studies additional to those already underway (**Section 3.2**) are required will be determined based on results from current management and monitoring studies, federal and provincial government requirements, and a high-level, independent expert review.

An independent, high-level review of all selenium studies conducted to date in the Elk River Valley is underway to assist in identifying key uncertainties and recommending future studies. Four expert US reviewers were selected for this review, three consultants and one university / government researcher: Harry Ohlendorf (CH2MHill), Steve Canton (GEI Consultants), Anne Fairbrother (Parametrix), and Denis Lemly (US Department of Agriculture and Virginia Tech).

The researchers were tasked with the following:

- Review selected Elk Valley selenium studies;
- Summarize overall conclusions;
- Identify major data gaps relating specifically to the potential impacts of selenium;
- Recommend studies that would support the identification of toxicity thresholds for selenium; and
- Suggest future selenium monitoring/research.

A workshop was held in Vancouver on February 5-6, 2008. Key findings and recommendations from the independent experts' forthcoming report will be provided in the next *Selenium Status Report*.

4.2 EFFECTS

Whether additional effects studies are required will be determined partly based on on-going monitoring studies as well as on the findings of effects studies currently in progress (**Section 3.3**).

4.3 MONITORING

Site-specific monitoring of selenium and other parameters in discharge water will continue at the five mines as originally outlined in the *Selenium Status Report 2004*. The next cycle of regional monitoring of water and biota (**Section 3.4.1**) will occur in 2009. Monitoring of fish populations and reproduction in Line Creek by EVCC will continue on an annual basis.

4.4 OTHER STUDIES

4.4.1 Lake Koocanusa

Lake Koocanusa, the reservoir formed by the Libby Dam on the Kootenay River in Montana, receives all selenium transported downstream from the Elk River. The EVCC is providing funding to the BC Ministry of Environment (MOE) for the purpose of conducting appropriate sampling and analyses to determine the concentration of selenium in the water column, zooplankton (small animals that live in the water column), and fish (kokanee) eating those zooplankton. Sampling will be conducted upstream and downstream of the confluence with the Elk River. This work will be conducted in 2008, and summarized in the next *Selenium Status Report*.

4.4.2 The Terrestrial Environment

EVCC's five BC mines monitor the health and sustainability of neighbouring and resident wildlife populations. Wildlife surveys are conducted in winter months when wildlife are utilizing their respective winter range and habitat. Information collected during these surveys includes species, sex, age class, size, and overall condition. Typically mine personal are accompanied by a local Environmental Protection Officer who assists in collecting the information and in determining the specific rating criteria for each animal. Information collected is submitted to MOE

annually. Survey information consistently indicates that wildlife populations are maintaining sustainable populations and, in some cases, increasing in numbers. In particular, certain species such as elk are thriving due to successful reclamation efforts at each of the mine sites.

As reported in previous *Selenium Status Reports*, there is currently no reason to believe that selenium from the mines is adversely affecting resident ungulate populations (e.g., elk, sheep). As noted above, annual wildlife surveys undertaken by EVCC indicate that these populations are at least stable and, in some cases, thriving. Accordingly, the only terrestrial studies planned are continued monitoring of the health of the ungulate herds and analysis every 5 years (next cycle in 2011) of selenium concentrations in vegetation.

4.4.3 Aquatic Benthic Invertebrates

Benthic (bottom-dwelling) invertebrates (animals without backbones) are an important part of the food web in water bodies in the Elk River Valley. As noted in the *Selenium Status Report 2005/6*, a graduate student is evaluating any alterations to benthic invertebrate communities below active coal mines in the Elk River Valley.

5. CONCLUSIONS

Based on studies conducted to date, current levels of selenium in the Elk River Valley, although elevated, do not appear to be having large-scale adverse effects or impacts; however, some adverse effects appear to be occurring on a more localized level (see **Table 1**). Although selenium water column concentrations are increasing and selenium concentrations are elevated in water, sediment and biota below mining activities, data presently available indicate that selenium concentrations in benthic invertebrates, fish muscle and water bird eggs have not increased over the last few years. Red-winged blackbirds appear to have an inherent ability to limit selenium accumulation in their eggs to levels that are just barely into the potentially toxic range, regardless of increasing water selenium concentrations. Terrestrial (i.e., ungulate) or human health effects from selenium do not appear to be occurring and are not expected to occur in future.
Increasing selenium surface water concentrations are a concern in the aquatic environment downstream of the Elk Valley coal mines. Thus, management efforts are focusing on managing / minimizing selenium inputs and understanding how to intervene in the selenium cycle once selenium is in the environment (to reduce production of the organic form of selenium).

It is anticipated that the next *Selenium Status Report* will be released in 2009.

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APPENDIX A

EVSTF MEMBERSHIP AS OF FEBRUARY 2008

EVSTF MEMBERSHIP AS OF FEBRUARY 2008
(In alphabetical order by last name)

Lanny Amos	EVCC-Elkview Operations
Julia Beatty	BCMoE-Nelson
Kim Bellefontaine	BCMEMPR
Ricci Berdusco	BCMEMPR
Roger Berdusco	EVCC-Calgary
Peter Chapman	Golder Associates Ltd (Technical Advisor)
Tim Chala	EVCC
Warn Franklin	EVCC-Coal Mountain Operations
Carla Fraser	EVCC-Greenhills Operations
Jody Frenette	BCMoE-Cranbrook
Guy Gilron	Teck Cominco
Ron Jones	EVCC-Calgary
Marc Meyer	EVCC- Elkview Operations
Billie O'Brien	EVCC-Line Creek Operations
Kevin Podrasky	EVCC-Line Creek Operations
Jolene Raggett	BCMoE
Patrick Shaw	Environment Canada
Keith Streeter	EVCC
Mark Strosher	BCMoE-Cranbrook
Greg Sword	EVCC-Fording River Operations

APPENDIX B

LIST OF ACRONYMS AND GLOSSARY

LIST OF ACRONYMS

AB	Alberta
BC	British Columbia
BCGS	British Columbia Geological Survey
BT	Bull Trout
CISWG	Canadian Industry Selenium Working Group
EVCC	Elk Valley Coal Corporation
EVMEMC	Elk Valley Mines Environmental Management Committee
EVSTF	Elk Valley Selenium Task Force
FRO	Fording River Oxbow
GIS	Geographic Information System(s)
GM	Goddard Marsh
MEMPR	Ministry of Energy, Mines and Petroleum Resources
MOE	Ministry of Environment
NAISWG	North American Industry Selenium Working Group
NAMC	North American Metals Council
SD	Standard Deviation
SWG	Selenium Working Group
UBC	University of British Columbia
WCT	Westslope Cutthroat Trout

GLOSSARY

Benthic
Pertaining to the bottom region of a water body, such as a lake or marsh.

Biogeochemical
Of or relating to the partitioning and cycling of chemical elements and compounds between the living and nonliving parts of an ecosystem.

Dialysis
A method of separating particles of different dimensions in a liquid mixture, using a thin semi-permeable membrane.

Dissolution
The process of going into solution, for example dissolving sugar in tea or coffee.

Effect
A change to a valued ecosystem component due to human activities. An effect is not necessarily a negative impact; an effect may be neutral or even positive. For instance, selenium is an essential element required for the health of all animals including humans.

Food chain
The transfer of nutrients and energy from one group of organisms to another, linked together in a series resembling a "chain".

Food web
Food chains interconnecting at various levels.

Hatchability
For animals that lay eggs, such as birds, the proportion of eggs incubated to full term that hatch.

Impact
An adverse (harmful) effect of such magnitude that it affects not just individual organisms, but the health of a population of organisms, for example selenium toxicity that reduces the function and/or productivity of fish or water bird populations. In the case of humans or endangered species an impact would occur not at the population but rather at the individual level because in these cases individuals are protected, not populations.

Invertebrates
A collective term for all animals without a backbone or spinal column (e.g., insects, worms, clams, snails, etc.).

Lentic
Non-flowing (static) water bodies such as lakes, ponds and marshes.

Lotic
Flowing water bodies such as creeks, streams and rivers.

Mean
The arithmetic average of a collection of numbers, computed by adding them up and dividing by their number.

Metalloid
An element whose chemical behaviour can include both metallic and non-metallic aspects, depending on the particular chemical substances in which they exist.

Oxidation
Addition of oxygen, removal of hydrogen, or removal of electrons from an element or compound.

Peeper
A mechanism for sampling water, typically used to collect porewater from sediments.

Porewater
The water contained in the spaces between sediment particles.

Productivity
The ability to produce life (e.g., number of offspring produced by fish, birds or amphibians).

Redd
Fish such as trout and salmon build nests called redds for their eggs. In general, the female digs the redd in the gravel and lays her eggs, which the male then fertilizes. The eggs are then covered with gravel and left to incubate for several months until the hatched juvenile fish are ready to emerge.

Semipermeable
Permitting the passage of only certain molecules.

Source ontrol
The means by which the origin of a substance is controlled to reduce release of that substance.

Standard deviation
A measure of the range of variation from an average or mean of a group of measurements. 68% of all measurements fall within one standard deviation of the mean. 95% of all measurements fall within two standard deviations of the mean. 99.7% of all measurements fall within three standard deviations of the mean.

Standard error
The standard deviation (positive square-root of the variation) of the errors associated with a series of measurements.

Swim-up fry
Fry (juvenile fish) that have absorbed their yolk sac and are ready to start feeding.

Toxic
Poisonous, carcinogenic, or otherwise directly harmful to a living organism.

Trophic level
A functional classification of organisms in an ecosystem according to feeding relationships, from primary producers through herbivores (secondary producers) and carnivores (tertiary producers).

Ungulate
A hoofed animal (e.g., horse, sheep, cow, elk).

Water birds
Birds that frequent water.

Waterfowl
Swimming / diving water birds (e.g., ducks, geese, coots). Wading birds such as sandpipers or songbirds such as dippers or red-winged blackbirds are water birds, but they are not waterfowl.

Weathering
Processes that decay and break up bedrock by a combination of physical fracturing and chemical decomposition.

Zooplankton
Microscopic or small floating animals suspended in the water column of aquatic ecosystems such as lakes.