
Elk Valley Water Quality Plan



Teck

Ensuring the health of the watershed and supporting continued, sustainable mining in the Elk Valley

The Elk Valley Water Quality Plan (the Plan) was developed by Teck with input from the public, First Nations, governments, technical experts and other stakeholders. The purpose of the Plan is to identify a strategy and implement solutions to address increasing selenium and nitrate water concentrations within the Valley, and assess and track levels of cadmium and sulphate in waters; while at the same time allowing for continued sustainable mining in the Valley. The Plan also lays out a strategy to address calcite formation associated with historical and current mining activity.

The Plan was submitted to the British Columbia Minister of Environment for approval on July 22, 2014.

More information about the development of the Plan, including consultation materials, summaries and reports, can be found at www.teck.com/ElkValley.

Executive Summary



Introduction

Developed with input from technical experts, the Elk Valley Water Quality Plan will guide efforts to ensure the health of the watershed, while allowing for continued, sustainable mining

Teck is committed to taking the steps necessary to achieve the objectives of the Plan. Those steps include:

- Implementing water quality mitigation measures (e.g., treatment facilities and diversions)
- Continuing research and development to identify additional sustainable options to manage water quality now and in the future
- Ongoing monitoring to assess water quality and aquatic health during implementation of the Plan, to confirm that the objectives of the Plan are being met, ensure aquatic and human health are protected
- Adaptively managing implementation of the Plan to ensure that new data and information is continually assessed and considered, and actions taken when necessary to meet objectives
- Providing information to the public and other stakeholders on the results of the work undertaken, and continuing to consult and gather feedback throughout the Plan's implementation



Water quality and mining

Steelmaking coal occurs as layers or seams within rock. To access the coal, large quantities of this rock, referred to as waste rock, are mined and placed in piles within and adjacent to the mine pits (Step 1 in Figure 2).

Water from both precipitation and runoff flows through these rock piles and carries selenium and other substances, including cadmium and sulphate as well as nitrate from blasting residue, into the local watershed (Steps 2 and 3 in Figure 2).

Geochemical study indicates waste rock piles continue to release selenium for a very long period of time. Waste rock placed decades ago continues to release selenium at a steady rate today, and is expected to continue doing so for many decades more. This challenge requires a long-term approach to address water quality related to historical mining activity as well as future mining.

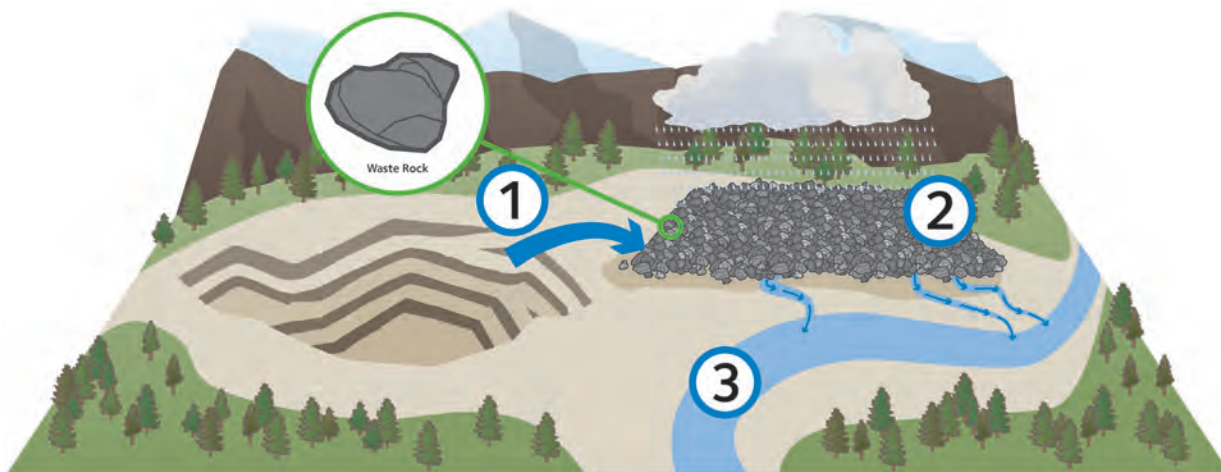


Figure 2: The coal-mining process and water quality

About the Elk Valley Water Quality Plan

The Elk Valley has a long history of mining activity and is currently home to five steelmaking coal operations that are the primary economic driver in the region

Water Quality in the Elk Valley

The Elk Valley is located in the southeast corner of British Columbia and contains the main stem Elk River and many tributaries, including the Fording River. The regional economy of the Elk Valley and surrounding areas is heavily dependent on steelmaking coal mining and related activities, and has a long history of mining activity.

The Valley is currently home to five steelmaking coal mines operated by Teck (See Figure 1), directly employing more than 4,000 people, making Teck the single largest employer in the East Kootenay region. At a provincial scale, including direct and indirect employment and spinoffs, Teck's Elk Valley operations are estimated to support more than 15,000 jobs across B.C. The majority of employees at the Elk Valley operations also live in the Valley and are committed to ensuring the environment is protected for future generations.

Teck has been working with various stakeholders to address water quality challenges related to mining activity, such as issues associated with selenium. This work includes studies, research and development, and construction of water diversions and a water treatment facility at its Line Creek Operations.

Existing studies and monitoring indicate that selenium concentrations and other indicators of water quality within the watershed are at levels that have not affected populations of fish and other sensitive aquatic animals. Regardless of current conditions, action is necessary to ensure that concentrations do not increase to levels that could affect sensitive aquatic populations.



Figure 1: Teck's operations in the Elk Valley watershed

Teck's Approach to Responsible Development

The pursuit of sustainability guides Teck's approach to business and Teck is committed to establishing safe workplaces for its people and collaborative relationships with communities. Teck's sustainability strategy includes a focus on water stewardship and improving biodiversity. This includes reclaiming areas after mining, enhancing habitat, and conserving additional habitat.

See www.tecksustainability.com for more information.

Development of the Elk Valley Water Quality Plan

The Plan was developed through a groundbreaking, area-based process that involved input from the public, First Nations, governments and other stakeholders

In April 2013, the B.C. Minister of Environment required Teck to develop an area-based water quality management plan. The Plan addresses increasing selenium and nitrate water concentrations, as well as cadmium, sulphate levels and calcite formation associated with historical and current mining activity. Teck developed the Plan in consultation with local communities, First Nations and governments.

The Plan is based on extensive research and study into aquatic health in the Valley, and consideration of current and future mining activity. Input was sought through three phases of consultation with the public, governments, First Nations and other stakeholders in the region (see Figure 3).

In addition, a Technical Advisory Committee was formed to provide science-based advice on the Plan. It included representation from the Ktunaxa Nation Council, the provincial government, the government of Montana, the Canadian and U.S. governments, and a third-party independent scientist.

The Plan incorporates a process for ongoing monitoring of the ecological health in the Valley and the effectiveness of the water management options employed. An adaptive management approach will ensure that the Plan evolves in step with changing circumstances, monitoring results, and the outcomes of Teck's research and development program, as well as advances in the science and technology available to manage water quality.

The boundaries of the Designated Area for which the Plan applies are shown in Figure 4.

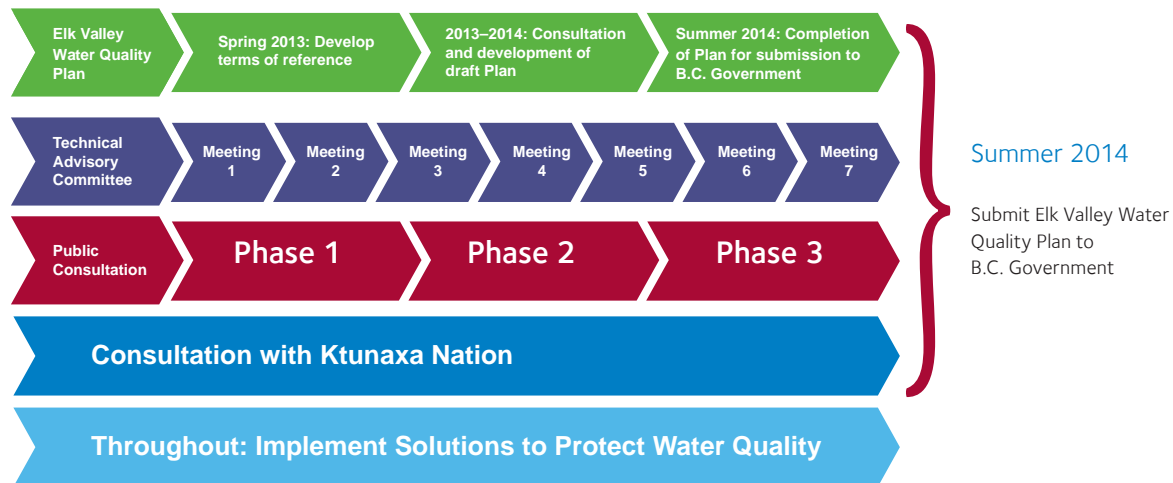


Figure 3: Timeline of the development of the Elk Valley Water Quality Plan

The Purpose of the Plan

The purpose of the Plan is to identify and implement solutions to ensure the ongoing health of the watershed, while allowing for continued sustainable mining in the Valley. To that end, the Plan sets out short-, medium- and long-term water quality targets for selenium, nitrate, sulphate and cadmium as well as targets to address calcite formation. The targets are designed to achieve the following environmental management objectives and outcomes:

- protection of aquatic ecosystem health
- management of bioaccumulation of constituents in the receiving environment (including fish tissue)
- protection of human health
- protection of groundwater

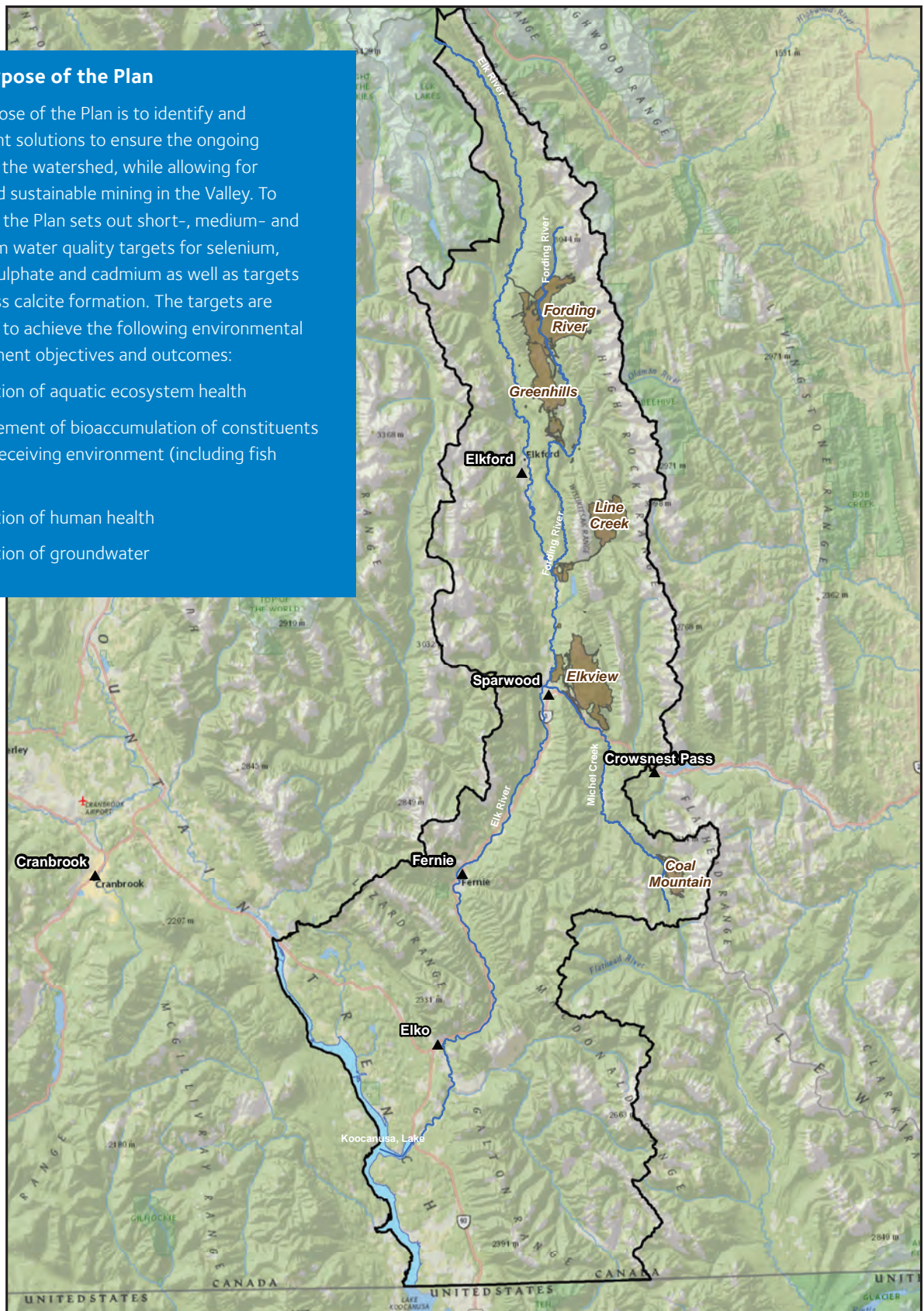


Figure 4: Designated Area boundary



How the Plan is Organized

The Elk Valley Water Quality Plan is organized into 11 chapters. Those chapters are listed below with a brief overview of what they cover and why it's important to the overall Plan.

This summary provides highlights from key chapters of the Plan. For further details, please refer to the specific chapters of the Plan.

Chapter	Description	Why it's important
1. Introduction	Teck's role in the regional economy and approach to sustainability, and the process for developing the Plan	Background information on the Plan
2. Regulatory Context	Summarizes the legal and regulatory requirements related to water quality relevant to the Plan	Context for the development of the Plan
3. Consultation and Technical Advice	Describes the processes that Teck undertook to receive and incorporate input and advice for the development of the Plan	Consultation and technical input were essential to the development of the Plan
4. Baseline Data	Outlines current conditions in the Elk Valley	Context for development of the Plan and measurement of progress during implementation
5. Protection of Human Health and Groundwater	Results of studies regarding human health and potential health impacts related to water quality	Context for development of the Plan in relation to protecting human health and groundwater quality
6. Development and Selection of Management Options	Explains the assessment process Teck used to select initial water quality management options for the Plan Describes Teck's research and development into future water quality management options	Establishes the water management methods that will be used under the Plan, and how water management will be improved moving forward
7. Calcite Management	Sets out targets for the rate of calcite formation and proposed actions to achieve the targets	A key outcome of the Plan is a plan for managing calcite formation
8. Short-, Medium- and Long-Term Water Quality Targets and Implementation Plan	Sets out short-, medium- and long-term water quality targets and timeframes for selenium, sulphate, nitrate and cadmium, and the process used to develop those targets Describes an initial implementation plan to achieve water quality targets	A key outcome of the Plan is to set out targets and an implementation plan to achieve them
9. Social and Economic Considerations	Examines the anticipated social and economic costs and benefits of the Plan	Implementation plan continues to support the social and economic values in the Valley
10. Monitoring	Outlines the monitoring program that will be undertaken to assess water quality and aquatic health during implementation of the Plan	Monitoring is necessary to confirm that the objectives of the Plan are being met
11. Adaptive Management	Describes the framework that the Elk Valley Water Quality Plan will be implemented within, and outlines the tiered decision-making to allow for refinements of the initial implementation plan	Allows the Plan to adapt through the incorporation of key learnings during implementation

Consultation and Technical Advice

Close to 700 pieces of science-based advice from the Technical Advisory Committee and feedback from three phases of consultation with members of First Nations and other stakeholders contributed to the Plan

The Technical Advisory Committee

Teck received science-based technical advice from a Technical Advisory Committee (TAC) in developing the Plan. The TAC was chaired by the B.C. Ministry of Environment and was composed of representatives from:

- B.C. Ministry of Environment (chair)
- B.C. Ministry of Energy and Mines
- B.C. Environmental Assessment Office
- Government of Canada represented by Environment Canada
- U.S. Federal Government represented by the U.S. Environmental Protection Agency and U.S. Geological Survey
- Montana State Government
- Ktunaxa Nation Council
- An independent third-party qualified professional scientist selected by the TAC
- Teck

The TAC held seven scheduled, multi-day meetings during the development of the Plan. In addition, working groups were established to focus on key development topics: Toxicology, Human Health, Monitoring and Lake Koochanusa. In total, the TAC dedicated more than 200 hours to meetings and discussion on the Plan, and provided close to 700 pieces of science-based advice to Teck.

Consultation

The Plan is also informed by extensive multi-phase consultation. Teck consulted the Ktunaxa Nation Council, local government, the public, governments in Canada and the United States, and other stakeholders.

Local governments, stakeholders and the public were consulted through a three-phase process. Consultation opportunities included in-person meetings in Fernie, Sparwood and Elkford, and online feedback. Notification of consultation phases was broad, including advertising and mailers to all households in the Elk Valley. In total, 213 people attended 11 meetings, and 164 pieces of written feedback were received during the three phases.

The Ktunaxa Nation Council was engaged through a consultation agreement and parallel multi-phase consultation process, which included numerous meetings with leadership and staff, five community presentations, and a mine site tour.

Input received throughout both consultation and input from the TAC has been considered, along with socio-economic information, in the development of the Plan. Teck has documented its consideration of this input in the Plan.

Ongoing Consultation

Teck will continue to undertake consultation with First Nations, communities and other stakeholders during implementation of the Plan. Input received will be considered in the ongoing management and implementation of the Plan.





Water Quality in the Elk Valley

Teck is focused on taking action to address water quality challenges to ensure both human and aquatic health are protected

Water Quality and Aquatic Health

As part of development of the Plan, existing levels of selenium, cadmium, nitrate, sulphate and other constituents were evaluated in the Elk River, Fording River, Lake Koochanusa and tributaries.

Current baseline conditions were examined in surface water, sediments and in tissues of aquatic life to assess the overall health of the aquatic environment. These conditions provided context for the development of the Plan.

Selenium and nitrate are the two constituents observed to most frequently exceed B.C. water quality guidelines and as such, are a primary focus of the initial implementation plan.

Protection of Human Health and Groundwater

Teck conducted a comprehensive evaluation of potential effects on human health and groundwater. This evaluation compared concentrations of selenium and other constituents against conservative health-protective benchmarks for swimming, incidental ingestion, eating fish or drinking groundwater. Results of this analysis concluded that current concentrations of constituents in water, sediment or fish for

activities such as drinking, swimming, or consuming locally caught fish do not present unacceptable human health risks.

Drinking water guidelines for selenium and nitrate are exceeded in some parts of the watershed, meaning that local health authorities should be consulted prior to use of surface water as a drinking water supply. It was also noted that groundwater from a small number (5 of 91) of wells exceeded the guideline for selenium. Further monitoring will be conducted of wells that exceed guidelines, as well as those that are within 30% of guideline.

As groundwater is intrinsically linked to surface water quality in parts of the Elk Valley, it is expected that the actions taken through the Plan to reduce and manage surface water levels of selenium and nitrate will also manage groundwater quality over time.

Water Quality Management Options

Teck launched an extensive research and development program in 2011 to identify the best existing technologies to treat water and to develop new methods to manage water quality

Teck's research has determined that active water treatment and clean-water diversions are the most effective options to stabilize water quality in the short term:

- Active water treatment has been proven to reduce constituents of interest and is necessary to meet water quality targets in the short-term. Active water treatment takes water into a treatment facility, removes unwanted constituents, and returns the water back to the environment (see Figure 5);

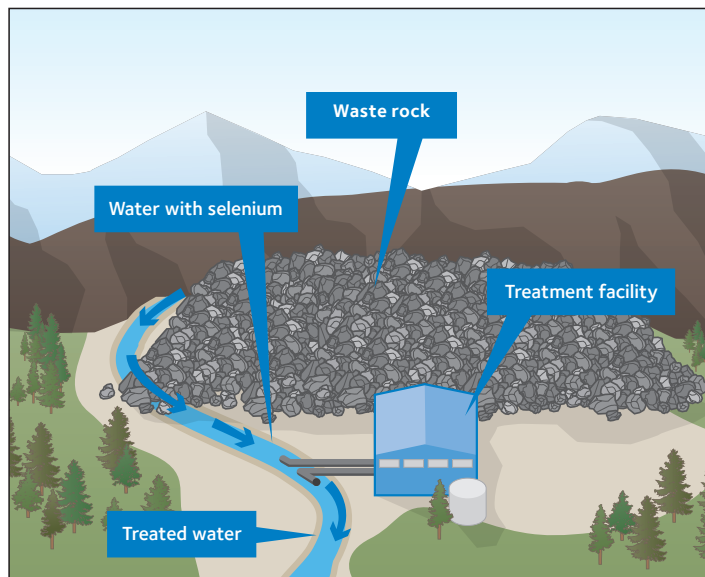


Figure 5: Active-water treatment of mine-affected water

- Clean-water diversions reduce the amount of water that needs to be treated, by keeping clean water clean. Diversions re-route existing water flows away from sources (waste rock) where they would otherwise pick up unwanted constituents, thus keeping clean water clean (see Figure 6).

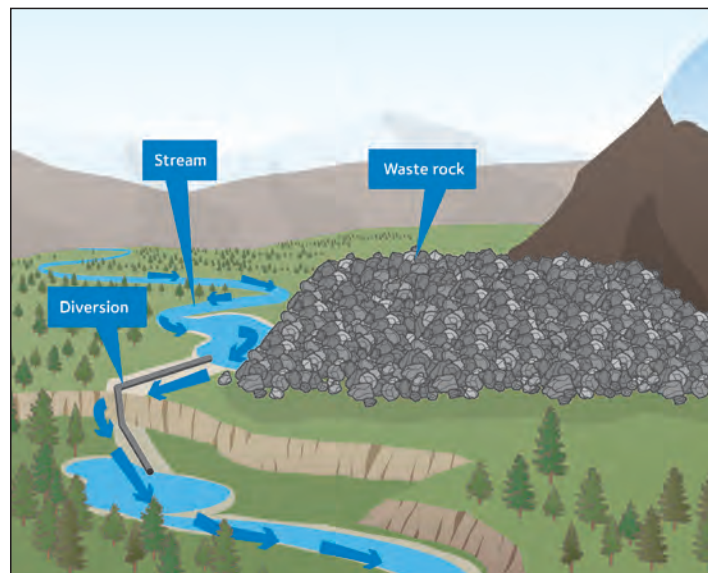


Figure 6: Typical gravity-driven clean-water diversion



Research and Development

Teck's ongoing Research and Development (R&D) program is focused on improving the effectiveness of water treatment technologies and clean-water diversions, while investigating potential long-term solutions that are focused on managing water at source, such as waste rock covers and saturated fills. New technologies and water quality management techniques developed through R&D have the potential to reduce the long-term reliance on active water treatment.

Technologies and techniques evaluated by the R&D program fall into two categories:

- 1. Source control:** investigating the sources of water quality constituents and examining how mine design changes could reduce the release of these substances into the watershed. The source control R&D program depends on rigorous independent research.

As a result, Teck has partnered with several research leaders from Canada and the U.S. The current team includes the University of Saskatchewan, McMaster University, and Montana State University, as well as various consultants with expertise in the field.

- 2. Water treatment technology program:** identifying and evaluating the effectiveness of different water treatment technologies in addition to the water treatment technology already in use by Teck. Testing of technologies can range from small-scale laboratory tests to large-scale pilot projects in the field. Teck is working with various technology providers to evaluate alternative processes.

Setting Short-, Medium- and Long-Term Water Quality Targets

The Plan sets out targets that were derived through a scientifically rigorous process to ensure continued aquatic and human health

Setting Targets

A primary outcome of the Plan was to establish short-, medium- and long-term water quality targets at locations in the Designated Area (see Figure 3).

The long-term targets are set at levels that will ensure continued human and aquatic health. Short-term targets are set with the goal of stabilizing levels of substances at locations where concentrations are expected to exceed long-term targets without mitigation. Medium-term targets are intended to ensure the implementation plan is on track to meet the long-term targets. The targets are a key measure for successful implementation of the Plan, and contribute to determining what water quality mitigation measures may be necessary.

The water quality targets were developed following a comprehensive process. In many locations in the watershed, the existing B.C. Water Quality Guidelines for aquatic health, or their federal government equivalent, have been set as

the long-term water quality targets for selenium, cadmium, nitrate and sulphate.

Where guidelines cannot be met, site-specific targets, which will ensure continued aquatic health, have been set based on:

- Input from the Technical Advisory Committee’s Toxicology Working Group
- Assessment of effects on the most sensitive aquatic species
- Conservative effects assumptions to allow for uncertainty

The chart below (Figure 7) shows where site-specific targets have been identified as necessary in the watershed, and where existing water quality guidelines have been set as the target. Detail on the target levels is found in Chapter 8 of the Plan.

	Fording River	Elk River	Lake Koocanusa	
Selenium	Site-specific target	Site-specific target	WQG	WQG = B.C. Water Quality Guideline CCME Guideline = Federal guideline
Nitrate	Site-specific target	WQG	WQG	
Sulphate	Equivalent to WQG	Equivalent to WQG	WQG	
Cadmium	Level of protection equivalent to CCME Guideline	Level of protection equivalent to CCME Guideline	Level of protection equivalent to CCME Guideline	

Figure 7: Determination of site-specific targets or guideline targets

Calcite Management

Given that calcite poses a concern when it precipitates out of water and forms on the beds of rivers and creeks, setting targets need to be done differently than for constituents such as selenium. Calcite precipitates naturally in some non-mine-affected waters, but its formation can be increased by mining activity. While calcite is not toxic, calcite deposition can negatively affect fish habitat if not controlled.

Surveys of 352 km of streams showed that 89% of mine-affected streams had calcite formation similar to streams not affected by mining. Four streams — Greenhills Creek, Corbin Creek, Dry Creek and Erickson Creek — have been identified as priority streams for calcite management. A long-term target for those locations has been set to achieve a level of calcite formation similar to the upper level in non-mine-affected streams.

Calcite mitigation technologies are being evaluated to determine the most effective method for implementation at a priority stream within three years.

Initial Implementation Plan

Water treatment and clean-water diversions will be part of the initial implementation plan to begin stabilizing and improving water quality in the Valley

Developing the Implementation Plan

Three active water treatment facilities (see Figure 8), combined with diversions, are proposed to reliably and efficiently reduce selenium and nitrate from mine sites in the short term.

Additional water treatment is also contemplated in the Plan, and will be assessed through the Adaptive Management Process as new technologies emerge and monitoring results are analyzed.

Teck developed the Elk Valley Water Quality Planning Model as a regional planning and assessment tool to determine the effectiveness of various mitigation measures, which will be refined and used during implementation. The Model estimates concentrations of selenium, nitrate and sulphate, and was calibrated using existing monitoring data.

More than 700 possible scenarios were evaluated to develop an initial implementation plan to meet the long-term water quality targets for selenium and nitrate.

During implementation, Teck will continue to refine the model based on site-specific investigations of mine-affected water, and new information from monitoring data and Teck's R&D program.

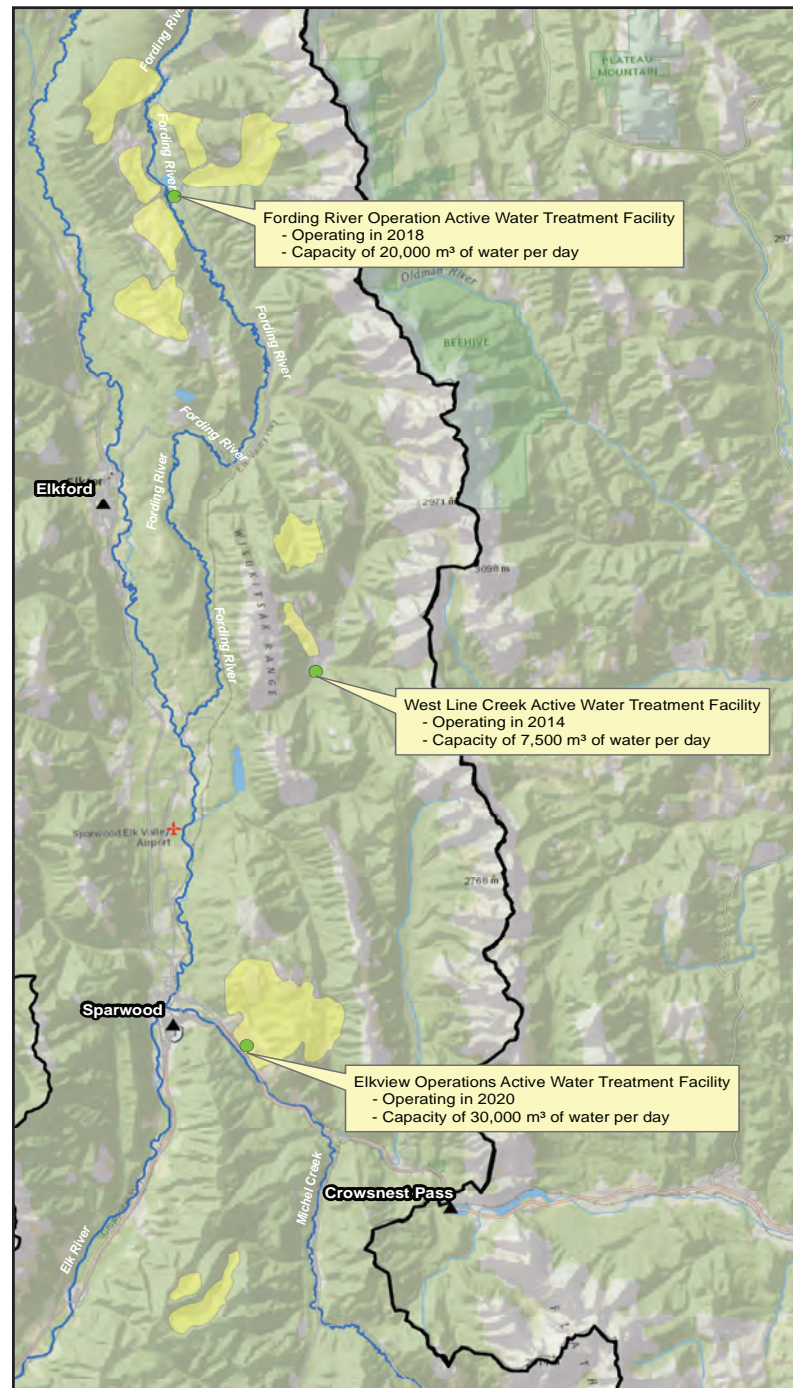


Figure 8: Initial active water treatment facilities

Reductions over the Plan timeframe

The charts below (Figures 9 and 10) were developed using the planning model described above. They show recent and projected levels of selenium (as mitigation measures are implemented) at two representative sites in the Fording and Elk rivers. Order station FR5 is at the mouth of the Fording River, and ER3 is on the Elk River downstream of Michel Creek.

The general pattern is for concentrations to gradually increase until mitigation is in place upstream, following which concentrations decrease.

The green dots represent measured concentrations of selenium from recent years at the Order station. The blue and orange shaded bands represent the range of monthly concentrations of selenium, under high-flow and low-flow conditions, and show the reductions over time as mitigation measures are put in place. The solid red line indicates the long-term selenium target for the Order station (more detail on these graphs can be found in Chapter 8 of the Plan).

The timeframes for stabilizing water quality trends and meeting long-term targets vary depending on the location in the system relative to mitigation measures and the timing with which those measures are implemented.

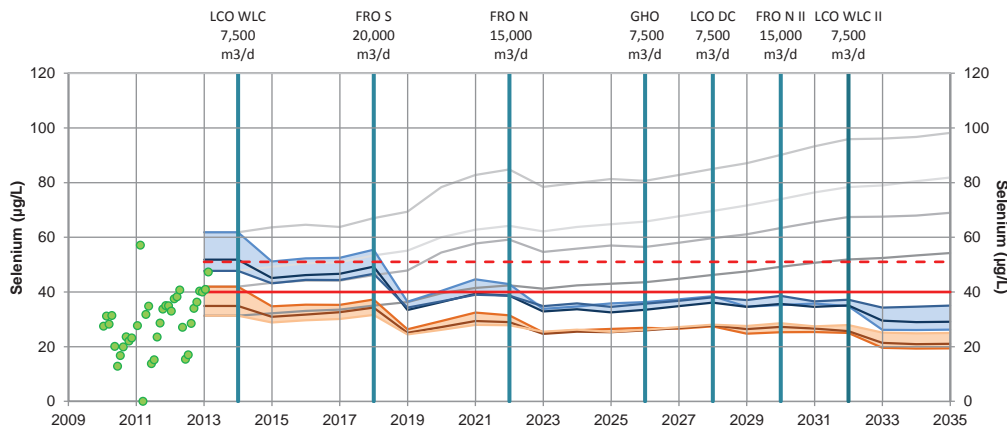


Figure 9: Predicted trend for selenium concentrations at FR5 during Plan implementation

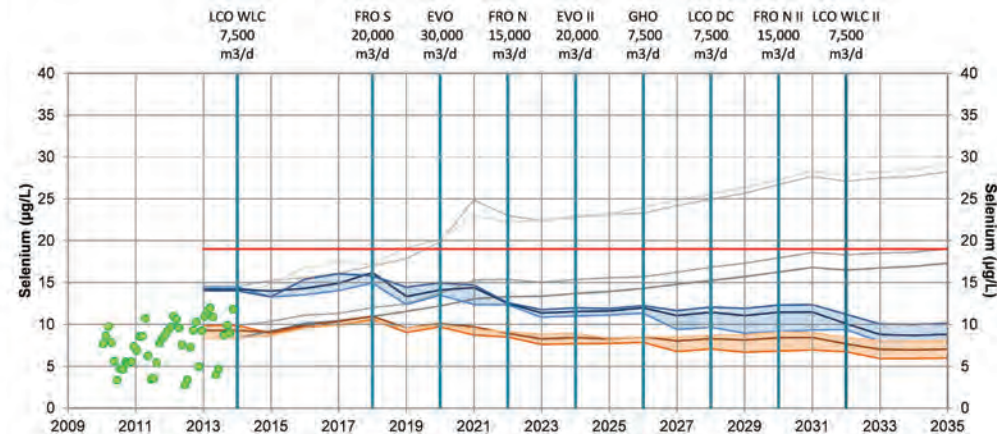
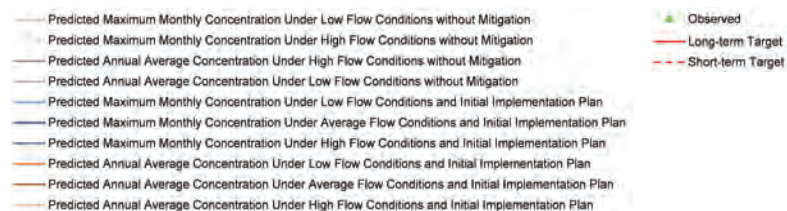


Figure 10: Predicted trend for selenium concentrations at ER3 during Plan implementation



Ongoing Aquatic Monitoring

Teck will continue to conduct extensive monitoring of aquatic health and water quality to ensure the Plan is meeting the objective of protecting aquatic and human health

Monitoring Program

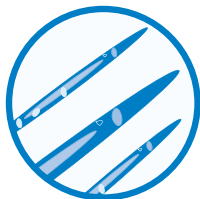
Teck will implement Plan-specific ecosystem monitoring and ecotoxicology assessment programs in parallel with the existing Regional Aquatic Effects Monitoring Program. The monitoring programs will be used to confirm that the Plan is achieving its objectives of protecting aquatic ecosystem health, managing bioaccumulation of constituents and protecting human health and groundwater, and in refining planning tools used in the development of the Plan.

The monitoring programs will include surface water quality, sediment, calcite formation, fish, benthic invertebrates (e.g., insects) and periphyton (e.g., algae and bacteria).

Monitoring results will be provided to government agencies and the Ktunaxa Nation Council, and will be publicly available on the Elk Valley Water Quality Plan website. Surface water quality data will be evaluated and compared to modelled water quality concentrations.

Results of these evaluations will be summarized and made available at www.teck.com/ElkValley. Analysis of the results will be used to inform the adaptive management component of the Plan.

Aquatic Organisms



Periphyton
(algae and bacteria)



Benthic Invertebrates
(small insects)



Birds



Amphibians

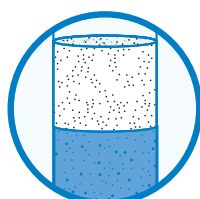


Fish

Environment



Surface water
(creeks, rivers, lakes)



Sediment
(creek, river, lake bottoms)



Groundwater
(wells)

Figure 11: Aspects of the Monitoring Program

Adaptive Management

Through the Adaptive Management process, data from monitoring, results from research and other information will be incorporated into the ongoing implementation of the Plan

Adapting to Monitoring

Teck will be responsive to monitoring data and, as necessary, will adapt the Plan to continue to meet targets and objectives. Adaptive management is a systematic process for reviewing the Plan to ensure that objectives set in the Plan are being met, and to adjust and improve management actions as required to achieve those objectives. Monitoring of water quality, ecosystem health, periphyton, ecotoxicology and groundwater will provide the necessary information to assess results of the initial implementation and to make changes as necessary.

Adapting to R&D

Teck will also adapt the initial implementation plan based on advancements from the R&D program, development of mine plans and a review of other relevant management plans. Advancements in technology from the R&D program may lead to incorporation of new technologies and management approaches. Mine reclamation and closure plans, and changes to future mine plans, will be incorporated into the Plan as they are developed.

The process for assessing and reacting to data and information is shown in the Figure 12 below.

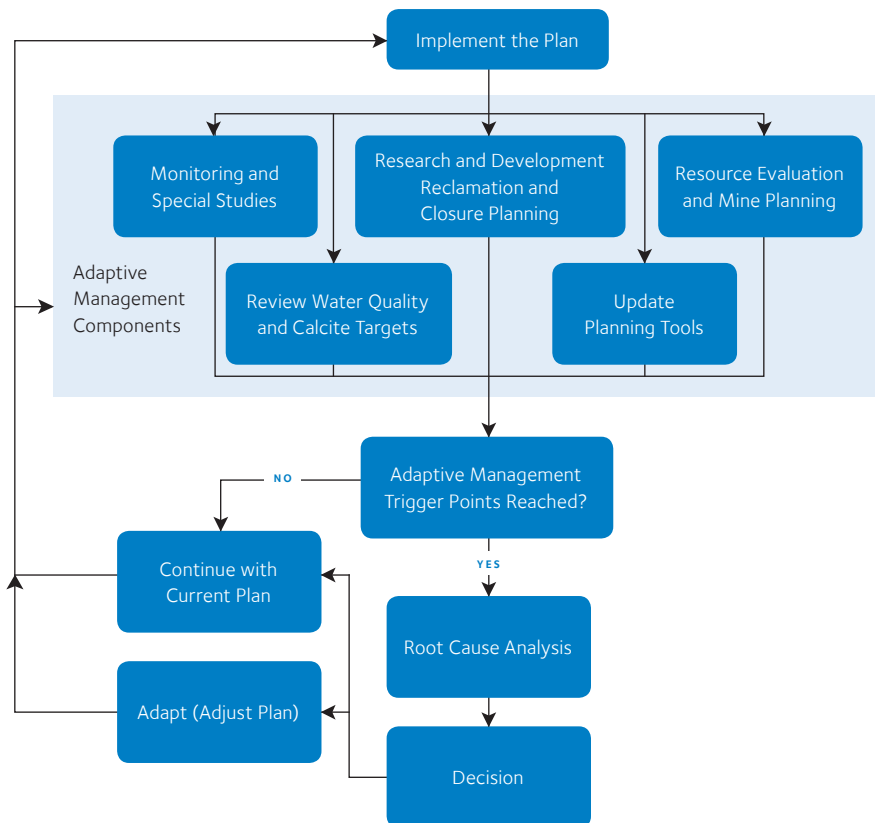


Figure 12: The Adaptive Management process

Conclusion

The Elk Valley Water Quality Plan was submitted to the B.C. Minister of Environment on July 22, 2014. The approved Plan is a public policy document that guides future regulatory applications in the Elk Valley as they relate to water quality.





For more information:

Elk Valley Water Quality Plan

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Annex N	Teck’s Approach to Biodiversity Management
Annex O	Management of Uncertainty in the Selenium Ecological Effects Assessment for the Elk Valley Water Quality Plan

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Glossary of Terms

Active water treatment:	A method of removing constituents of concern from water that requires regular and/or frequent human intervention and management.
Adaptive management:	A systematic process for learning from management actions to confirm that the Plan's objectives are being met and to adjust and improve management actions during implementation.
Adsorption:	The surface retention of a solid, liquid or gas particles by a solid or liquid.
Amphibian:	A cold-blooded, smooth-skinned vertebrate (possessing a backbone) that spend part of their life on land and part in water.
Antiscalant:	A synthetic agent that inhibits precipitation of calcite by changing the molecular properties of ions in water.
Attenuation:	The process of reducing concentrations over time through degradation, dilution or sorption.
Benchmark:	A standard or point of reference against which things may be compared or assessed.
Benthic invertebrates:	Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.
Bioaccumulation:	The accumulation of substances, including both toxic and benign substances, within the tissues of an organism.
Biodiversity:	The variety of plant and animal life in a particular habitat (e.g., plant community or a country). It includes all levels of organization, from genes to landscapes, and the ecological processes through which these levels are connected.
Biological treatment:	A method of treating water through the use of organisms such as bacteria and other microfauna.
Biotic:	The living organisms in an ecosystem.
Calcareous:	Mostly or partly composed of calcium carbonate.
Calcite:	A mineral composed of calcium, carbon and oxygen. Calcite used in this assessment is from the carbonate class of minerals, and has the chemical formula CaCO_3 .
Calcite index:	A numeric expression of the extent and degree of calcite formation; typically given as a range from 0 to 3.00.
Clean-water diversion:	A physical construction that changes the course of water to avoid contamination of the water.

Closure plans:	Formal documents filed with the provincial government that detail the process of decommissioning a mine.
Community of interest: (COI)	Individuals or groups that may be affected by, have an interest in, or have the ability to influence, a site. These communities are: Indigenous Peoples whose lands or traditional territory are located on or adjacent to Teck's operations and associated infrastructure; academic and thought leaders such as universities, researchers, students and subject matter experts; business partners in joint ventures and customers who purchase materials, applied technology and equipment marketed by Teck; Teck's global employees; governments and regulatory staff at local, national and international levels; industry associations, including commodity-specific associations, sustainability-specific associations and industry sector associations; an investment community of shareholders, potential investors and financial analysts; local communities of remote, rural localities where Teck works; non-governmental organizations that focus on environmental and social issues at local, regional, national and international levels; and suppliers of materials, energy, transportation and services to Teck.
Conceptual model:	A holistic representation of the interplay between point- and non-point sources of constituents and the environment.
Constituents of interest:	An element or ionic compound that may pose a threat to ecological or human health when present at sufficient concentrations; includes Order constituents selenium (Se), cadmium (Cd), nitrate (NO ₃) and sulphate (SO ₄).
Contaminant of Concern:	A chemical that is emitted or released into the environment and poses a potential risk of exposure to humans or ecological receptors.
Critical effect size:	A threshold that indicates that an effect on an organism or community of organisms' performance.
Cumulative effects:	The effects of a development in combination with the effects of other past, present or reasonably foreseeable future developments.
Current baseline:	Represents current or existing conditions (or a temporal period specifically defined to represent baseline [e.g., the year 2010]) and serves as a reference point to which future conditions can be compared. Unless otherwise noted, baseline refers to a surveyed or measured condition, rather than one predicted through the use of models.
Designated Area:	A portion of southeastern British Columbia that contains the Elk Valley and is geographically defined by the Order.
Diversion:	Creation of earthen dykes or other physical barriers and/or pipes or other conduits to route water around mine waste spoils.
Ecotoxicology:	The study of the effects of harmful chemicals on plants, animals and other organisms.
Electrodialysis:	The use of electricity to transport salt ions from one side of a physical barrier (membrane) to the other.
Elk Valley:	The local name for the area of the Elk River valley.
Endpoint:	The completion of a stage of the life history of an organism; common endpoints include reproduction and growth.

Environmental Assessment (EA):	A review of the effects that a proposed development may have on the local and regional environment.
Exposure pathways:	The physical mechanism whereby a constituent of interest comes into contact with an organism; typically includes ingestion and direct contact.
Geomembrane cover:	Synthetic membranes composed of plastic polymers or bituminous (asphalt) materials that provide a waterproof barrier to prevent percolation through wastes.
Groundwater:	That part of the subsurface water that occurs beneath the water table, in soils and geologic formations.
Hardness:	Calculated mainly from the calcium and magnesium concentrations in water; originally developed as a measure of the capacity of water to precipitate soap. The hardness of water is environmentally important since it is inversely related to the toxicity of some metals (e.g., copper, nickel, lead, cadmium, chromium, silver and zinc).
Hazard quotient (HQ):	The ratio of the exposure estimate to an effects concentration considered to represent a “safe” environmental concentration or dose.
Integrated assessment:	A method of incorporating anticipated multiple effects of constituents in the development of long-term water quality targets.
Lentic:	Of or relating to or living in still waters (as lakes or ponds).
Lotic:	Flowing waters.
Management unit:	A portion of the Designated Area specified for water quality management purposes.
Order (the):	A directive issued by the B.C. Minister of Environment in April 2013 requiring Teck to develop the Elk Valley Water Quality Plan.
Order constituent:	Selenium (Se), cadmium (Cd), nitrate (NO ₃) or sulphate (SO ₄).
Order station:	A location specified by the Order to monitor water quality in the Designated Area; for example, the mouth of the Fording River is Order Station FR5.
Percolation:	The movement and filtering of water through porous materials, such as water rock.
Periphyton:	Algae, bacteria and other associated microorganisms attached to any submerged surface.
Plan (the):	The Elk Valley Water Quality Plan, an area-based plan that meets the requirements of Ministerial Order No.M113
Receptor:	The person or organism subjected to exposure to chemicals or physical agents.
Reference stream:	A watercourse that is not affected by point sources of contamination; used to compare the effects of mining activity on constituents of interest and calcite formation.
Reverse osmosis:	A process in which water is purified of solutes by being forced through a semipermeable membrane through which the solvent, but not the solutes, may pass.
Reviewable project:	An industrial activity that requires a government-level examination before a permit is issued to allow the activity to go forward.

Sentinel species:	An organism considered indicative or representative of a larger or ecosystem and suitable for monitoring.
Spoil:	Waste rock from mining processes.
Supersaturation:	A state in which water or another liquid contains more of a dissolved substance than can be dissolved under normal conditions.
Target:	A concentration of a constituent of interest or, in the case of calcite, a calcite index value, in Elk Valley watercourses that the Plan sets; based on water quality guidelines and feasibility.
Technical Advisory Committee:	A nine-member panel established by the Order to guide development of the Plan.
Terms of Reference:	A document produced by Teck and approved by the B.C. Minister of Environment that describes the purpose of the Elk Valley Water Quality Plan and the issues the Plan will address.
Threshold value:	A point along a spectrum of concentrations below which no significant or measurable effect on a receptor is expected.
Toxicity reference (TRV):	For a non-carcinogenic chemical, the maximum acceptable dose (per value unit body weight and unit of time) of a chemical to which a specified receptor can be exposed, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as exposure limit.
Treatment:	The use of a technology to either remove constituents of interest from water, or prevent calcite from precipitating on a streambed.
Valued Component:	Valued components represent biophysical, economic, social, heritage and health properties of the environment that are considered to be important by society.
Waste rock:	Rock moved and discarded in order to access coal resources.
Water management:	Planning, developing, distributing and making optimum use of aquatic resources; includes treatment and diversion, among other technologies.
Water quality guideline (WQG):	The concentration of a constituent of concern developed for the (WQG): protection of ecological or human health; may be federal or provincial.
Wolman Pebble count:	A method of determining the size distribution of gravels and sediment in a streambed; involves the random and periodic sampling of a streambed and analyzing the condition of a pebble or other particles. A modified version of this method is used to measure the extent of calcite formation in a streambed.

Abbreviations

ART	Applied Research and Technology
AWTF	Active Water Treatment Facility
BCMOE	BC Ministry of Environment
BLM	Biotic Ligand Model
BGM	Bituminous geomembrane
CCE	Crown of the Continent Ecosystem
CCME	Canadian Council of Ministers of the Environment
CEAA	Canadian Environmental Assessment Act
CEPA	Canadian Environmental Protection Act
COIs	Communities of interest
CSKT	Confederated Salish and Kootenai Tribes
CSM	Conceptual Site Model
CSR	Contaminated Sites Regulation
DEQ	Montana Department of Environmental Quality
DOC	Dissolved Organic Carbon
DQO	Data Quality Objective
DWPA	Drinking Water Protection Act
EA	Environmental Assessment
EAO	Environmental Assessment Office
EMA	Environmental Management Act
ENGOS	Environmental Non-Governmental Organizations
EPA	US Environmental Protection Agency
ERA	Elk River Alliance
EVWQP	Elk Valley Water Quality Plan
FLNRO	Forests, Lands and Natural Resource Operations
GDP	Gross Domestic Product
HQ	Hazard Quotient
HVE	High Viscosity Emulsion
IBWTA	International Boundary Waters Treaty Act
ISQG	Interim Sediment Quality Guidelines
KNC	Ktunaxa Nation Council
KTOI	Kootenay Tribe of Idaho
LAEMP	Local Aquatic Effects Monitoring Programs
LEL	Lowest Effects Level
MEM	B.C. Ministry of Energy and Mines
MOE	B.C. Ministry of Environment
MRC	Mine Review Committee
MU	Management Unit
PCC	Precipitate Calcium Carbonate
PEC	Probable Effects Concentration
PEL	Probable Effects Level

RAEMP	Regional Aquatic Effects Monitoring Program
SARA	Species at Risk Act
SEL	Severe Effects Level
SLERA	Screening Level Ecological Risk Assessment
SPO	Site Performance Objective
SQGs	Sediment Quality Guidelines
SSD	Species Sensitivity Distribution
SSWQOs	Site-Specific Water Quality Objectives
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
TEC	Threshold Effects Concentration
TEL	Threshold Effects Level
TRVs	Toxicity Reference Values
UL	Tolerable Upper Intake Level
WQGs	Water Quality Guidelines

Chapter 1

Introduction

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1.1 Introduction

The Elk Valley is in the southeast corner of British Columbia and contains the mainstem Elk River and many tributaries, including the Fording River. The regional economy of the Elk Valley and surrounding areas is heavily dependent on steelmaking coal mining and related activities, and has a long history of mining activity. The Valley is currently home to five steelmaking coal mines owned by Teck, which directly employ more than 4,000 people (see Section 1.6.1). Other mining companies have tenure in the Elk Valley but have yet to pursue operations.

Since the mid-1990s, Teck has been working with other stakeholders to address water quality challenges related to mining activity, particularly the challenges associated with increasing concentrations of selenium. Teck participated in various studies of selenium and aquatic health, and helped form the Elk Valley Selenium Task Force in 1998 and the Canadian Industry Selenium Working Group in 2006. In 2010, Teck commissioned an independent Strategic Advisory Panel on Selenium Management, made up of leading experts in the field. The Panel's report included recommendations that led Teck to undertake several large-scale selenium-management activities, including:

- construction of the Kilmarnock and Swift Creek Clean Water Diversions
- pilot testing of active water treatment technology at Line Creek Operations in 2011
- launch of a comprehensive research and development program in 2011 to develop improved methods to manage water quality through mine design and reclamation practices
- construction of a full-scale West Line Creek selenium active water treatment facility at Line Creek Operations, an investment of \$105 million (currently in commissioning).

To date, studies and monitoring conducted by Teck indicate that selenium concentrations generally remain below levels that would affect populations of fish and other sensitive animals in the mainstem of the Elk River and the Fording River below Josephine Falls. In some tributaries selenium concentrations levels are above levels that could affect fish populations. Localized effects on sensitive insect larvae that live on stream bottoms, mainly in the tributaries closest to mining activities, have been detected, but overall larval insect communities throughout the Elk Valley are similar to areas where no mining occurs. However, additional action is necessary to ensure that concentrations do not increase to levels that would affect fish populations within the watershed.

To reduce calcite formation and to manage water quality to stabilize and reverse increasing trends in water contaminant concentrations in the short-term and to set achievable water quality targets over the longer-term for selenium, cadmium, nitrate, and sulphate, in April 2013 the B.C. Minister of Environment's Order M113 directed that an area-based water-quality management plan be developed under Section 89 of the province's Environmental Management Act (Province of British Columbia 2013). Teck was charged with developing the Plan in consultation with local communities, First Nations and governments. In July 2013, the province approved a Terms of Reference (Teck 2013a) that outlines the purpose, scope and process for the development of the Plan.

The process for developing the Plan, called the Elk Valley Water Quality Plan, is based on extensive research and study into aquatic health in the Valley. The Plan takes into account the effect of mining activity, the scientific advice provided by the independent Technical Advisory Committee, and broad consultations. The Plan incorporates a process for ongoing monitoring of water, and ecosystem health in the Valley and the effectiveness of water management. An adaptive management approach will ensure that the Plan evolves in step with monitoring results, technology advances, and the outcomes of Teck's research and development program. As such, the Plan is considered a living document and a process to consider adjustments to target and management actions for example, will be considered during implementation.

1.2 Purpose of the Plan

The Plan will identify a strategy and implement solutions to address increasing selenium and nitrate water concentrations within the Valley, and assess and track levels of cadmium and sulphate in waters, while at the same time allowing for continued sustainable mining in the Valley. To that end, Teck has set proposed short-, medium- and long-term water quality targets to achieve the following environmental management objectives:

- protection of aquatic ecosystem health
- management of bioaccumulation of constituents in the receiving environment (including fish tissue)
- protection of human health
- protection of groundwater.

1.3 Plan Management

Development of the Plan was informed by input obtained in a series of consultations with governments including First Nations, the public and other stakeholders, and a nine-member Technical Advisory Committee (TAC) that provided close to 700 pieces of science-based technical advice to Teck (See Figure 1-1). The Plan was also informed by federal and provincial legislation and international agreements, as detailed in Chapter 2.

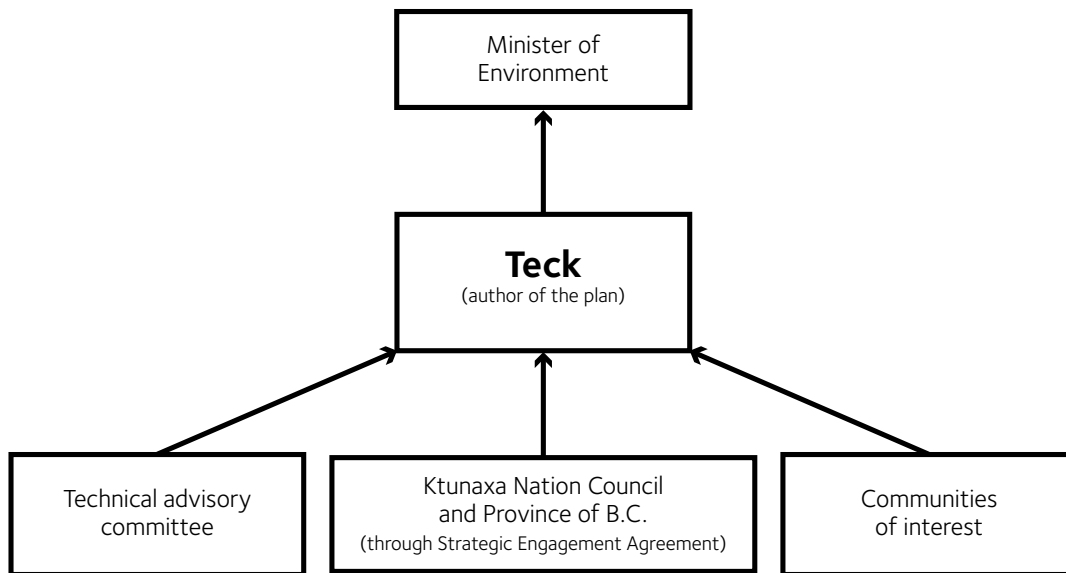


Figure 1-1. Participants and process for development of the Plan.

1.3.1 Technical Advisory Committee

Teck has received science-based technical advice from the TAC in developing the Plan. The TAC is chaired by a B.C. Ministry of Environment representative and is composed of representatives from:

- B.C. Ministry of Environment (MOE) – chair
- B.C. Ministry of Energy and Mines (MEM)
- B.C. Environmental Assessment Office
- Environment Canada
- US Federal Government
- Montana State Government
- Ktunaxa Nation Council
- an independent third-party scientist selected by the TAC
- Teck

The TAC held seven scheduled, multi-day meetings during the development of the Plan. In addition, working groups were established to focus on four key development topics: toxicology, human health, monitoring and Lake Koocanusa. In total, the TAC dedicated over 200 hours to meetings and discussion on the Plan, and provided close to 700 recommendations to Teck. Teck incorporated the majority of TAC recommendations into the analysis informing Plan development and implementation. Annex A includes all TAC recommendations together with how Teck considered each recommendation.

1.3.2 Consultation

As part of the development of the Plan, Teck consulted and engaged with a number of groups, including:

- the Ktunaxa First Nation
- Elk Valley residents
- local governments
- the US federal government
- the State of Montana Department of Environmental Quality
- the governments of Canada and B.C.
- the Shuswap First Nation
- the Kootenai Tribe of Idaho
- the Confederated Salish and Kootenai Tribes
- environmental non-government organizations
- other coal companies with interests in the Elk Valley (Coal Valley Resources Inc., Crowsnest Pass Coal Mining Ltd., NWP Coal Canada Ltd., Centermount Coal Ltd. and Centerpoint Resources Inc.).

In addition to ongoing consultation throughout the development of the Plan, three formal consultation phases were held. During this time, Teck made extensive efforts to notify the public and stakeholders, produced consultation materials, and held open houses and small group meetings in communities in the Elk Valley. A separate, parallel consultation process was conducted with the Ktunaxa Nation Council (KNC) in accordance with the KNC-Teck Elk Valley Water Quality Consultation Agreement, which was jointly developed by Teck and the KNC.

In total, 213 individuals participated in meetings and public open houses during the consultation phases, and 164 feedback forms were received. The chair of the TAC attended six open houses and three small group meetings held during Phase 1 and Phase 2, to provide the TAC's perspective on the Plan process. Chapter 3 provides further details on each phase of consultation, and Annex C provides details on the feedback received and how it was addressed in development of the Plan.

1.4 The Elk Valley Designated Area

The area covered by the Plan is defined in Appendix A of the Terms of Reference. The boundaries of the Designated Area, as identified in the Order, are shown below (Figure 1-2).

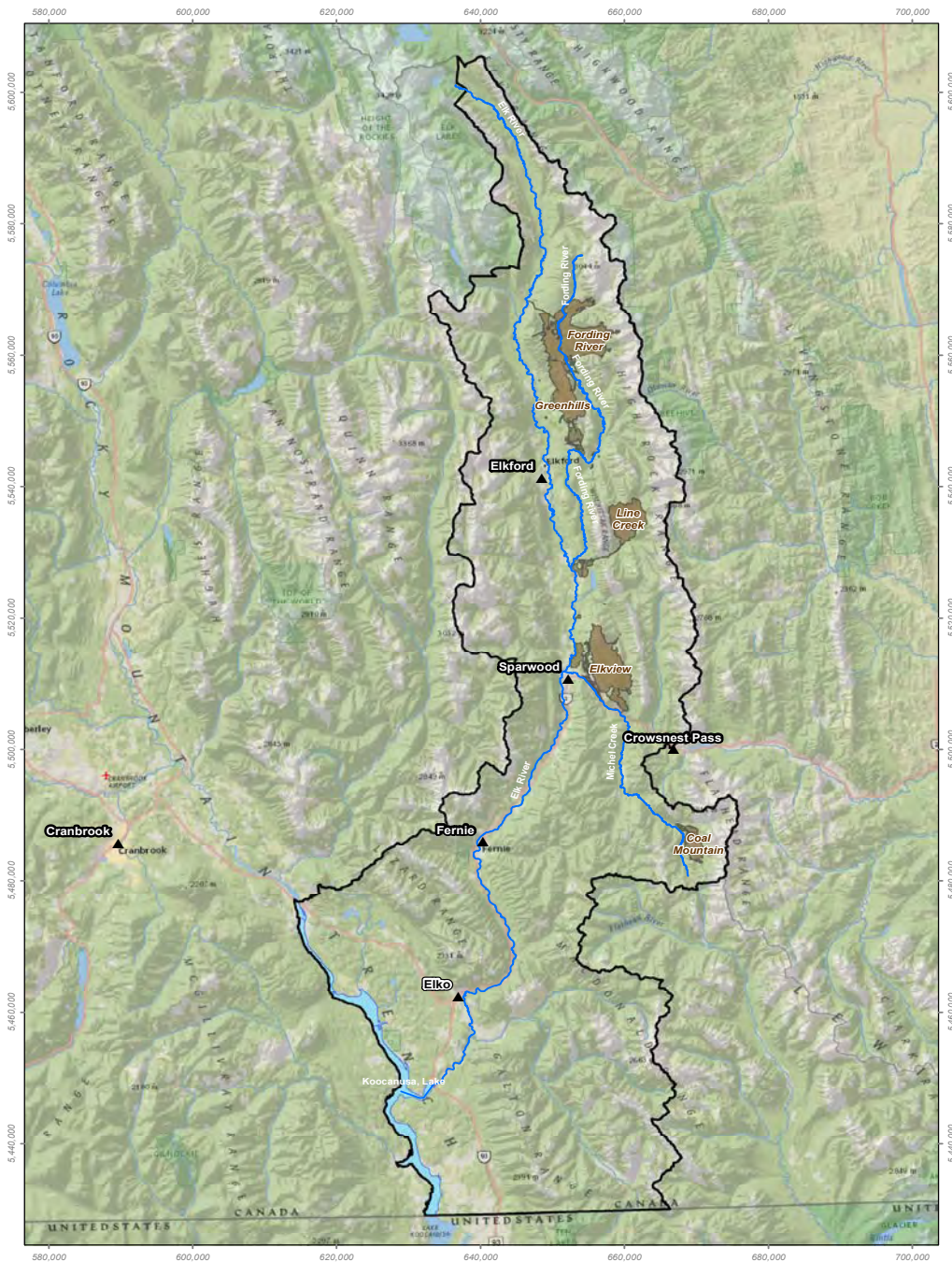


Figure 1-2. Designated Area boundaries.

The East Kootenay Coalfields of southeastern British Columbia lie beneath the Front Ranges of the southern Rocky Mountains. They are divided into three distinct coal deposits: the Elk Valley (also known as the Upper Elk) near the communities of Elkford and Sparwood; the Crowsnest near Fernie; and the Flathead, to the south of Fernie and straddling the U.S. border (Figure 1-2). The Elk Valley Designated Area overlies portions of all three coalfields.

Coal mining has occurred in the Valley since 1897. Most of the coal seams in the Valley are mined for metallurgical purposes (the production of steel). The relatively shallow depth of the seams has led to the use of open-pit mining practices.

The Elk River Watershed and the neighboring Flathead River Watershed comprise the northwest corner of the 7.2-million-hectare Crown of the Continent Ecosystem (CCE), straddling the Continental Divide. The CCE includes headwaters of the Columbia, Missouri-Mississippi and Saskatchewan rivers, making it a dominant element in the larger landscape. In addition, the Flathead and Elk River watersheds represent a critical wildlife connectivity corridor between the Waterton-Glacier International Peace Park on the Alberta-Montana border, and Banff and Jasper national parks on the Alberta-B.C. border.

The Elk River Watershed drains 4,450 km² and includes the communities of Elkford, Sparwood, Hosmer, Fernie and Elko, along with the five steel-making coal mines. Its outlet is the Kootenay River at Lake Koocanusa. It contains the mainstem Elk River and many of its tributaries, including the Fording River and Michel Creek.

1.5 Water quality in the Designated Area

In recent years, much of the attention given to water quality in the Elk Valley involved the element selenium. Teck has been taking steps to understand and address selenium concentrations for several years. Cadmium, nitrate, sulphate and calcite formation have also been identified in the Order as mining-related constituents to be addressed in the Plan. The summaries below are based on studies detailed in Chapter 5.

1.5.1 Selenium

Selenium is a common element in the rocks and minerals of the earth's crust. It is an essential nutrient, meaning trace amounts are necessary for cellular function in many organisms, including plants, animals and people. However, selenium can be harmful when it builds up in an organism's tissues beyond natural levels. When elevated it can interfere with reproductive processes in egg-laying vertebrates. In an aquatic environment, selenium is taken up from water by algae and other microorganisms and transferred through the food web to aquatic invertebrates, fish, birds, and other vertebrates.

1.5.2 Cadmium

Cadmium is a metal that can be harmful at elevated concentrations. As with selenium, mining can accelerate the release of cadmium to the environment by exposing waste rock to air and water. Unlike selenium, however, the primary concern with cadmium is from direct contact with surface waters, rather than bioaccumulation in tissue (CCME 2012).

1.5.3 Nitrate

Nitrate is typically leached from waste rock piles of blasting reagents used in mining (Environment Canada 2003). As with cadmium, the primary concern associated with nitrate is exposure through direct contact with surface water, which in some cases can contribute to eutrophication. Concentrations at the sites identified in the Order have been trending up in recent years.

1.5.4 Sulphate

Sulphate can accumulate to higher levels in mining environments when it interacts with other substances. Concentrations of sulphate in the lower Fording River and Elk River immediately downstream of Michel Creek have remained below the B.C. guideline and have been stable at most monitoring sites identified in the Order since 2000.

1.5.5 Calcite formation

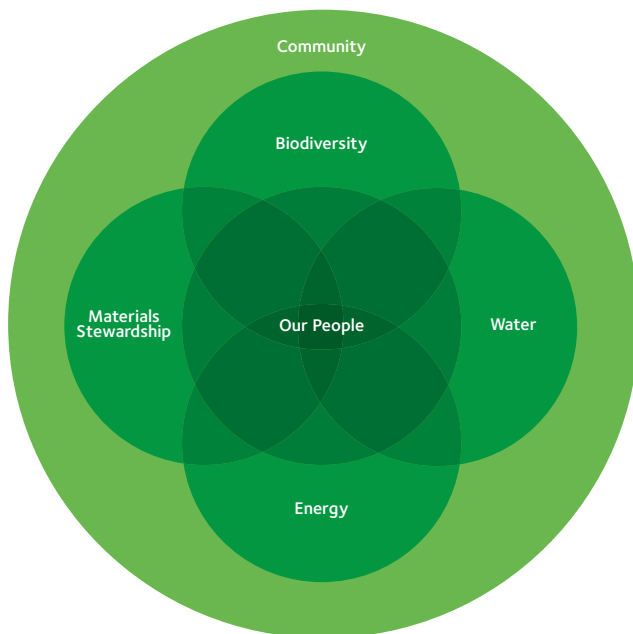
Calcite, in the form of calcium carbonate from the shells of dead marine organisms, is found in sedimentary rocks of the Rocky Mountains. As water travels through the ground or through mining waste rock, calcite can dissolve and then re-crystallize elsewhere in a watercourse. The scaling seen in kettles or hot-water heaters involves a similar chemistry. Increasing rates of calcite buildup have been observed in streams downstream of waste rock dumps. Traces are generally only found on boulders and most watercourse substrates show no evidence of calcite. High calcite buildup does not pose a health threat, but can change the characteristics of the stream substrate by cementing rocks together, adversely affecting habitat for fish and invertebrates.

1.6 About Teck

Teck is Canada's largest diversified resource company, committed to responsible mining and mineral development with business units focused on copper, steelmaking coal, zinc and energy. Headquartered in Vancouver, B.C., Teck owns or has an interest in, 13 mines in Canada, the United States, Chile and Peru, as well as a large metallurgical complex and a wind-power facility in Canada.

Teck's expertise spans a wide range of activities related to exploration, development, mining and mineral processing including smelting and refining, safety, environmental protection, materials stewardship, recycling and research.

1.6.1 Teck's Approach to Sustainability and Biodiversity



In 2011, Teck developed a comprehensive sustainability strategy that set out long-term (to 2030) and short-term (to 2015) goals in six focus areas: Community, Our People, Water, Biodiversity, Energy, and Materials Stewardship (Figure 1-3). These focus areas represent the most significant sustainability-related challenges and opportunities facing the company.

Although water is the focus of the Plan, Teck is also working on the conservation or restoration of biodiversity. These efforts can have a significant impact on water quality and quantity, and relate directly to the protection of aquatic life and the aquatic ecosystem.

Figure 1-3: Teck's sustainability focus areas.

Teck's long-term vision for biodiversity is to achieve a net-positive impact, which equates to leaving the areas where the company operates better off, from a biodiversity perspective, than before mining began. This can be achieved through a number of avenues, including reclamation of disturbed areas, habitat enhancement, and through conserving additional habitat outside the mining area.

This approach is exemplified by Teck's acquisition, in 2013, of several properties of high conservation value close to its areas of operation in the Elk Valley. Teck invested \$19 million to acquire three parcels of land for conservation purposes:

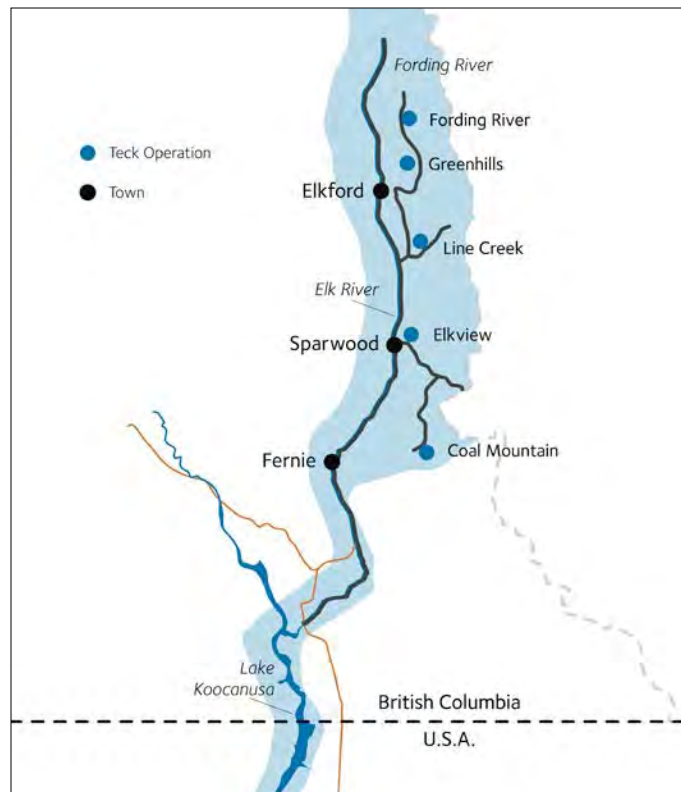
- Grave Prairie (3,059 hectares)
- Alexander Creek (3,098 hectares)
- Flathead Townsite (992 hectares).

These conservation lands lie within a larger ecosystem described by many provincial, national and international organizations as having global significance for biodiversity. The lands preserve key aquatic values such as free-flowing rivers and intact riparian areas that help preserve water quality and influence water temperature. These lands also provide cold-water habitats for native bull trout (a blue-listed species of special concern in B.C.) and westslope cutthroat trout (a blue-listed species in B.C. and a federal species of special concern).

Preservation of these lands will help to conserve aquatic values over the long-term and are also important for the movement of wildlife that uses the river valleys and high elevations to migrate north, south, east and west over the Rocky Mountains.

1.6.2 Social and Economic Impact of Teck's Elk Valley Operations

The Plan considers the economic importance of mining in the Valley and the social and economic impact of water quality mitigation measures.



In 2008, Teck secured a controlling interest in all five active steelmaking coal mines in the Valley: Fording River, Greenhills, Line Creek, Elkview and Coal Mountain (Figure 1-4). Together, these steelmaking coal operations make Teck the single largest employer in the larger East Kootenay region. Directly or indirectly, they contribute 6,440 jobs to the local economy, or one in five of the 33,000 jobs there.

In 2014, Teck's Elk Valley operations are projected to support more than 15,000 jobs in B.C. and 19,000 jobs in Canada (including direct and indirect employment and spin-offs). For every job at Teck, another 2.7 are created elsewhere in the provincial economy due to the capital-intensive nature of the mining industry. Teck's Elk Valley operations will pay approximately \$525 million in wages and benefits and support a total of \$1.8 billion in wages and benefits across B.C. and \$2.6 billion Canada-wide.

Figure 1-4. Teck's operations in the Elk Valley watershed.

Employment in the mining sector is well-compensated. A report for the Mining Association of B.C. found that average income per employee at B.C. mines, comprising salary and benefits, was more than \$120,000¹. By providing high-paying jobs, Teck's Elk Valley operations contribute to the standard of living across the region. Projected per-capita income — total income divided by the entire population, including children and others who are not working — in 2014 in the East Kootenay is \$44,000², compared to \$40,000 for B.C. and \$41,000 for Canada as a whole.

In 2014, Teck's Elk Valley operations will generate an estimated \$4.5 billion in economic output in B.C., as measured in gross domestic product (GDP). This includes approximately \$1.4 billion in goods and services provided by East Kootenay suppliers. Of that amount, approximately \$600 million will remain in the East Kootenays, generating economic activity. The remainder will flow through to suppliers of equipment and consumables (e.g. diesel fuel or tires).

Teck's Elk Valley mines are a significant source of tax revenue. In 2014, the economic activity from the five steel-making coal operations will contribute approximately \$1.1 billion to federal, provincial and local governments. Key indicators of the economic contribution of Teck's Elk Valley operations are summarized in Table 1-1, and more details are provided in Appendix M, the Ernst & Young report *"Elk Valley Water Quality Plan Socio-economic Analysis."*

Table 1-1. Projected economic impact of Teck's Elk Valley operations.

Indicator	2014 value
Direct Jobs with Teck	4,155
East Kootenay Jobs Supported	6,440
B.C. Jobs Supported	15,240
Wages Generated in B.C.	\$1.8 billion
Total Tax Liabilities Generated ³	\$1.1 billion
East Kootenay Procurement	\$1.4 billion

1.6.2.1 Supply and Demand – Price

Approximately 80% of all of the steelmaking coal produced in B.C. originates at the five Elk Valley operations. The high-quality steelmaking coal mined in the Valley is a major Canadian export to the fast-growing economies of the Asia Pacific region, where it is used to make steel that, in turn, is used in a range of products, from major public infrastructure like buildings, bridges and transit, to everyday items such as appliances and automobiles.

The steelmaking coal industry is a competitive global market with prices established by the market forces of supply and demand. Demand is generated by steel mills that require coal for their blast furnaces. Domestic producers such as Teck face significant competition in the seaborne and export market from producers in Australia, the US, Mozambique, Mongolia and inland China.

Steelmaking coal prices are cyclical. In recent years, producers from all regions increased production to meet the increase in demand, but over-supply has now resulted in steelmaking coal prices falling by close to 70% from 2011.

¹ The Mining Industry in British Columbia 2012.

² Economic impacts are derived using Teck's 2013 Life-of-mine plans and Consensus Economic steelmaking coal prices and foreign exchange rates from its October 2013 forecast. Results may vary based upon actual prices.

³ Total tax liabilities generated is an estimate of Teck's incremental tax liability before adjustments resulting from tax pools.

1.6.2.2 Cost of Production

Currently, Teck’s mines operate sustainably and safely with total costs below today’s price for steelmaking coal. Table 1-2 outlines Teck’s average cost for producing a tonne of coal in 2013.

Table 1-2. Average production costs at Teck operations.

Average cost to produce 1 tonne of coal	2013 Actuals ⁴
Operating costs (blasting, shoveling, and hauling coal and waste rock, processing raw coal, maintaining equipment and infrastructure, environmental management, reclamation and wages)	\$51/tonne
Transportation costs (transporting coal 1,200 km from the Valley to ports and loading it onto ships destined for overseas customers)	\$38/tonne
Capital costs (replacing aging equipment and infrastructure, developing areas of the mine to enable continued production; other investments in the business; and water quality management)	\$30/tonne
Total average cost	\$119/tonne

1.6.2.3 Effect of Water Quality Mitigation on Mine Economics

The mitigation measures considered under the Plan (see Chapter 6) will lead to an increase in two of the above cost categories:

- Capital costs will increase, as water treatment facilities, diversions or other measures are constructed and research and development into future mitigation options continues.
- Operating costs will increase, as water treatment projects are completed and require operation, and as some current mining practices are modified to improve water management.

These increases will reduce Teck’s financial flexibility to maintain production and jobs in a low-price environment, and could also affect the global competitiveness of Elk Valley operations.

An additional impact is the reduction in potential tax and resource revenues for governments, including First Nations, from direct mining activities. Income taxes and the B.C. Mineral Tax are based on income. As costs go up, income is reduced, resulting in less tax income from direct mining activities.

The proposed water quality targets and implementation plan described in the Plan (Chapter 8) are designed to be protective of the environment and human health while taking economic factors into consideration, in order to support continued, sustainable mining in the Valley without affecting mining-related jobs and economic activity in the region.

⁴The average costs are for all of Teck’s production including one mine outside of the Elk Valley. Capital costs include pre-stripping rock, but exclude new mine development.

Chapter 2

Regulatory Context

Chapter Overview

This chapter provides the legal and regulatory context under which the Plan was developed. It summarizes key federal and provincial legislation relevant to selenium, cadmium, nitrate and sulphate in water, and calcite formation, as well as water quality guidelines (WQGs) for the protection of various water uses.

Concordance with Ministerial Order and Terms of Reference

Chapter 2 satisfies Section D of Schedule C of Ministerial Order M113 and Section 3.2 and Section 3.8(a) of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Elk Valley Water Quality Plan developed under B.C.'s *Environmental Management Act*.** The Plan has been developed under an Order of the Minister of Environment via the B.C. *Environmental Management Act*.
- **British Columbian and Canadian legislation provides robust regulatory framework for the Elk Valley Water Quality Plan.** In addition to the *Environmental Management Act*, provincial legislation potentially relevant to the Plan includes the *Environmental Assessment Act*, the *Water Act*, the *Mines Act*, and the *Drinking Water Protection Act*. Potentially relevant federal legislation includes the *Canadian Environmental Assessment Act, 2012*, the *Canadian Environmental Protection Act, 1999*, the *Fisheries Act*, the *Species at Risk Act*, the *Migratory Birds Convention Act, 1994*, the *Canada Water Act* and the *International Boundary Waters Treaty Act*.
- **The Elk Valley Water Quality Plan will serve as a framework for future regulatory decisions.** Once approved, the Plan will provide a framework for decision-makers to consider in future regulatory applications for steelmaking coal mining in the Elk Valley.

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2.1 Introduction

The Plan falls under an Order of the Minister of Environment via the B.C. *Environmental Management Act*. As required by the Order and Section 3.2 of the Terms of Reference, this chapter summarizes the key pieces of legislation relevant to selenium, cadmium, nitrate and sulphate in water, and to calcite formation.

Under Canadian Constitutional law, responsibility for the environment is shared between federal and provincial jurisdictions. Both levels of government exercise regulatory jurisdiction over companies operating in Canada. In terms of the Plan, potentially relevant provincial legislation includes the *Environmental Management Act*, the *Environmental Assessment Act*, the *Water Act*, the *Mines Act*, and the *Drinking Water Protection Act*. Potentially relevant federal legislation includes the *Canadian Environmental Assessment Act, 2012*, the *Canadian Environmental Protection Act, 1999*, the *Fisheries Act*, the *Species at Risk Act*, the *Migratory Birds Convention Act, 1994*, the *Canada Water Act*, and the *International Boundary Waters Treaty Act*.

In addition to legislation, both levels of government have established water quality guidelines (WQGs) for the protection of various water uses, which are described in more detail in Section 2.4.

2.2 B.C. Legislation

2.2.1 Environmental Management Act (EMA)

The EMA prohibits the introduction of waste from prescribed activities into the B.C. environment unless the activity is authorized. Prescribed activities are authorized by a permit, approval, Code of Practice or a regulation. Under the Waste Discharge Regulation, coal mining is prescribed as an activity subject to these prohibitions in the EMA. All of Teck's operations in the Elk Valley have obtained the permits required under the EMA.

Under the Waste Discharge Regulation, the prohibition against the discharge of waste into the environment does not apply to the discharge of coarse coal refuse, waste rock or overburden that is managed in accordance with a permit issued under the *Mines Act*. However, the discharge of these materials is subject to the prohibition in the EMA against causing pollution.

Regulations under the EMA apply to various types of activities or wastes. For example, the EMA and the *Hazardous Waste Regulation* contain detailed requirements for the storage, treatment, handling, disposal and transport of hazardous waste.¹ Many of these requirements do not apply to mine tailings or waste rock facilities.²

The EMA and the *Contaminated Sites Regulation* (CSR) set out the requirements for the identification, investigation and remediation of contaminated sites in B.C. and establish the principles of liability that apply to contaminated sites. The EMA (section 68) and CSR provide the legislative basis for the Site Registry, a publicly accessible database containing information on the status of sites in B.C. relative to CSR requirements. The EMA specifies that a director may not issue a remediation order under the CSR requirements for the core area of a mine except where the land and water use is formally changed from those approved in the Mines Act permit.³ The core area includes areas where waste rock and tailings are placed.⁴

¹ For the definition of hazardous waste, see the Hazardous Waste Regulation.

² Any discharge from the facilities would be subject to the EMA requirements discussed above.

³ A remediation order under the CSR may also be issued at the request of the Chief Inspector of Mines.

⁴ Orders may be issued under the pollution prevention and abatement provisions of the EMA with respect to the core area of a mine. The exemption only applies to CSR requirements.

The EMA also provides authority for the Minister of Environment, if considered advisable for purposes of environmental management, to issue an Order requiring development of an area-based management plan for a specific area, and to establish a process for the development of that plan. Under the EMA, if the Minister of Environment approves an area-based plan, the Minister, by order, may require persons making decisions under the EMA to consider the plan in making those decisions.

The EMA authorizes environmental protection officers to conduct compliance activities including the issuance of advisories, orders, warning letters and administrative monetary penalties. These measures are part of the compliance and enforcement hierarchy. The EMA is administered by the provincial Ministry of Environment (MOE), and thus its authority does not extend beyond the borders of B.C.

2.2.2 Environmental Assessment Act

Under the *Environmental Assessment Act*, the proponent of a “reviewable project” must obtain an environmental assessment certificate before proceeding with the project. To obtain a certificate, an assessment must be completed that typically addresses potential adverse environmental, economic, social, heritage and health effects, as well as any potential adverse effects on First Nations interests. A certificate may be issued only following successful completion of an environmental assessment. The proponent must comply with the terms and conditions of the environmental assessment certificate.

A “reviewable project” is specifically defined. A new coal mine that will have an annual production capacity of 250,000 tonnes or more is a reviewable project. A modification to an existing coal mine is a reviewable project if specific production capacity and land disturbance levels and areas are contemplated in the modification.

The *Environmental Assessment Act* states that provincial and municipal permits and approvals for a reviewable project may not be issued until an environmental assessment certificate is issued for the project. However, the Act allows for concurrent permitting. Section 23 states that if an environmental certificate is granted, the Minister responsible for the Act can require, by order, the issuance of specified approvals within a specified time. In the absence of such an order, the issuance of a certificate does not create an obligation on Government decision makers to issue authorizations under other enactments.

The *Environmental Assessment Act* falls under the jurisdiction of MOE, and is administered by the Environmental Assessment Office.

2.2.3 Water Act

The *Water Act* vests property and the right to the use and flow of all water in any stream in the provincial Crown, except to the extent private rights have been established under licences or approvals given under the Act. For example, a licence may permit diversion or use of water for the purpose specified in the licence.

The *Water Act* contains a number of provisions dealing with groundwater protection, including a prohibition against introducing, or causing or allowing the introduction of, any contaminant into a well in an amount or manner likely to cause a significant adverse impact on the quality of groundwater in the well or the existing uses made of the groundwater in the well.

The new *Water Sustainability Act* received Royal Assent on May 29, 2014. The Act is not yet in force, but will come into force over time by regulation. It is expected that the Act will begin to come into force in the spring of 2015. The new Act makes a number of changes to the management of provincial water resources, including:

- extending the provincial water license regime to groundwater used for anything other than domestic purposes;
- ensuring that environmental flow needs are considered in new water allocation decisions;
- authorizing Cabinet to establish water objectives for a watershed, stream or other area; and
- allowing for the development of water sustainability plans for specified areas.

The *Act* also prohibits the introduction of debris, contaminants and other matter into a stream or areas adjacent to a stream in a manner that would have a significant adverse impact on the stream or its users. This prohibition does not apply to a deposit authorized under the *Water Sustainability Act*, or another act, or to any prescribed activity.

The *Water Act and the Water Sustainability Act* are administered by the Ministry of Forests, Lands and Natural Resource Operations (FLNRO).

2.2.4 Mines Act

The *Mines Act* applies to all mines during exploration, development, construction, production, closure, and reclamation. Before starting any work in or about a mine, a permit must be obtained and a plan filed that outlines the details of the proposed work, a program for the conservation of cultural heritage resources, and measures for the protection and reclamation of land, watercourses and cultural heritage resources affected by the mine. Permit holders are required to provide reclamation security. Detailed projections of reclamation costs must be provided in an application for a *Mines Act* permit, including provisions for long-term monitoring, maintenance and mitigation of environmental impacts. All Teck operations in the Elk Valley have obtained the permits required under the *Mines Act*.

Historically, mine permit applications have been referred to long-standing, multi-agency Regional Mine Development Review Committees chaired by the Chief Inspector of Mines. Although these committees were inter-agency committees, their focus was the *Mines Act* permit process.

The Province recently made a number of administrative changes to the approval process for major mines. A new Guide to Coordinated Authorizations for Major Mines was released in December 2013. Under Section 9 of the *Mines Act*, the Chief Inspector of Mines is required to establish regional advisory committees to review applications for mine permits. Under this new coordinated authorization process, applications for major mines are referred to a project-specific Mine Review Committee (MRC) chaired by a government representative. The MRC coordinates and reviews all major authorizations for a mining project, including those required under the *Mines Act* and EMA. Members of the MRC include representatives of statutory decision-makers, local government and First Nations, as well as technical advisors from provincial and federal government agencies. At the end of the process, the MRC issues a recommendations report to statutory decision-makers, addressing all the major permit applications for the project.

Applicants for a *Mines Act* permit are generally required to advertise project proposals upon submission of the application and make information available for public review and comment. Additional consultation may be required.

The *Mines Act* is administered by the B.C. Ministry of Energy and Mines (MEM).

2.2.5 Drinking Water Protection Act (DWPA)

The DWPA sets out the requirements to ensure that drinking water operators provide their customers with safe water. It includes requirements for the approval of water system construction proposals, minimum treatment standards, and public notification of water quality problems. The legislation also contains a prohibition against the introduction of anything into a domestic water system, drinking water source, well recharge zone or an area adjacent to a drinking water source that will result or is likely to result in a health hazard. The DWPA is administered by health authorities and the Ministry of Health.

2.3 Federal Legislation

2.3.1 Canadian Environmental Assessment Act, 2012 (CEAA 2012)

Under CEAA 2012, designated projects must undergo an environmental assessment by the Canadian Environmental Assessment Agency, the National Energy Board or the Canadian Nuclear Safety Commission before the project can proceed. In some cases, the Agency may determine that an environmental assessment is not required for a designated project.

Designated projects include new coal mines with a production capacity of 3,000 tonnes/day or more, and the expansion of a coal mine that would increase the area of mine operations by 50% or more, or by 3,000 tonnes/day or more.

An assessment under CEAA 2012 focuses on environmental effects within areas of federal jurisdiction such as migratory birds, aquatic species, species at risk, federal lands and First Nations. At the conclusion of the assessment process, a decision statement is issued that includes the conditions with which the proponent must comply.

The Canadian Environmental Assessment Agency and the B.C. Environmental Assessment Office have entered into a Memorandum of Understanding that establishes the framework under which the provincial environmental assessment process may substitute for the federal assessment process. Substitution requests have been approved for several projects in B.C. to date, including mining projects. Where substitution is approved, both levels of government must still decide whether to approve the project.

2.3.2 Canadian Environmental Protection Act, 1999 (CEPA)

CEPA is one of the primary federal environmental statutes. It contains the legislative framework for the identification and regulation of toxic substances. It also addresses environmental and human health impacts of products of biotechnology, marine pollution, disposal at sea, vehicle, engine and equipment emissions, fuels, hazardous wastes and environmental emergencies.

Schedule 1 to CEPA contains a List of Toxic Substances that including inorganic cadmium compounds. Substances on the list may be subject to various management measures including regulations, and/or a requirement to develop a pollution prevention plan or environmental emergency plan. Some measures have been introduced that include inorganic cadmium compounds (e.g., Notice Requiring the Preparation and Implementation of Pollution Prevention Plans in Respect of Specified Toxic Substances Released from Base Metals Smelters and Refineries and Zinc Plants). However, to date, no specific provisions have been introduced for cadmium discharges from coal mining operations. Selenium, sulphate and nitrate are not listed in Schedule 1 to CEPA.

The *Canadian Environmental Protection Act* is administered by Environment Canada.

2.3.3 Fisheries Act

The *Fisheries Act* protects commercial, recreational and Aboriginal fisheries while safeguarding both fish and fish habitat. It prohibits the unauthorized deposit of any type of deleterious substance in water frequented by fish. "Deleterious substance" includes any substance that would degrade or alter water quality sufficiently to render it deleterious to fish or fish habitat. The Minister may authorize the deposit of a deleterious substance by regulation.

The *Fisheries Act* also prohibits any work, undertaking, or activity that results in serious harm to fish that are part of a commercial, recreational or First Nation fishery or to fish that support such a fishery. "Serious harm to fish" is defined as "the death of fish or any permanent alteration to, or destruction of, fish habitat." The Fisheries Protection Policy Statement indicates that the Department interprets "serious harm to fish" as including a

permanent alteration to fish habitat that is of a spatial scale, duration or intensity that limits or diminishes the ability of fish to use such habitats as spawning grounds or as nursery, rearing or food supply areas, or for migration.

Projects expected to cause serious harm to fish require an authorization to proceed. The *Fisheries Act* sets out factors that must be considered in connection with an application for an authorization, including whether there are measures to avoid, mitigate or offset serious harm to fish. The Policy Statement indicates that any residual serious harm after avoidance and mitigation has been applied should be offset.

The *Fisheries Act* allows for agreements with the provinces for equivalency or delegation of administrative functions. In B.C., an interagency agreement provides for enforcement by the provincial Ministry of Environment.

Administration of the *Fisheries Act* is shared by the Department of Fisheries and Oceans and Environment Canada.

2.3.4 Species at Risk Act (SARA)

SARA identifies and categorizes any species considered at risk, and prohibits specific activities that may harm at-risk species and their habitat. Penalties for prohibited activities include fines and imprisonment. SARA generally applies only on federal lands. However, the protections for aquatic species and migratory birds apply to all lands and waters. Environment Canada is the lead federal agency responsible for administration of SARA. The Department of Fisheries and Oceans takes the lead on the protection of aquatic species that are at risk.

2.3.5 Migratory Birds Convention Act, 1994

The *Migratory Birds Convention Act* implements the Migratory Birds Convention. It prohibits the deposit of a substance that is harmful to migratory birds in waters or an area frequented by migratory birds, or in a place from which the substance may enter such waters or such an area. The Act also prohibits the deposit of a substance that, in combination with one more other substances, results in a substance that is harmful to migratory birds. Penalties for prohibited activities include fines and imprisonment. Environment Canada is the lead federal agency responsible for administration of the *Migratory Birds Convention Act*.

2.3.6 Transboundary Issues

The Canada-US border passes through many waterways. Mechanisms have been developed to facilitate cooperative management of these waters, including treaties and agreements, as well as more informal community-based and cross-border initiatives.

In Canada, the federal government leads national policy and engagement on issues that have an international component. Federal, provincial, and municipal governments in Canada have a history of consultation and coordination to meet Canada's obligations under international treaties and agreements. Two pieces of legislation address Canada's management of waters that cross international boundaries: the *Canada Water Act* (CWA) and the *International Boundary Waters Treaty Act* (IBWTA).

The CWA is federal legislation that provides a framework for federal and provincial cooperation in the conservation, development, and management of Canada's water resources. This includes cooperation on water management programs that may encompass international or boundary waters and that are of significant national interest. A report to Parliament, describing activities conducted under the authority of the CWA, is published at the end of each fiscal year by Environment Canada. This report is a public document.

The IBWTA was enacted to implement the Canada-US International Boundary Waters Treaty of 1909 (Treaty). It establishes principles and outlines mechanisms to assist in the resolution of transboundary water quantity and quality disputes. The Treaty states that water shall not be polluted on one side of the border to an extent that results in harm to health or property on the other side. The International Joint Commission was created by the Treaty to hear disputes arising under the Treaty.

2.4 Water Quality Policy Context

This section summarizes key water policy statements and instruments of the governments of B.C. and Canada that relate to the establishment of water quality targets in the Plan. It includes a summary of the B.C. government policy related to water treatment technologies, and guidance on water quality monitoring.

2.4.1 B.C. Water Quality Policy Statements

Since 1985, MOE's policy has been to develop province-wide WQGs (formerly called water quality criteria) and site-specific water quality objectives (SSWQOs; see Section 2.4.3) for avoiding degradation, upgrading or protecting water quality for a designated use (MOE Policy 6.10.03.03, 1985).

The policy is in place for these reasons:

- to determine the quality of water in important waterways and to detect changes therein that may be significant to the management of the water resource
- to ensure that the quality of the aquatic resource is maintained
- to guide the issuance of permits, licenses and orders related to water quantity and quality
- to assist decision-makers planning for developments that could affect the aquatic resource.

2.4.2 B.C. Water Quality Guidelines

The MOE definition of a WQG is:

A maximum and/or minimum value for a physical, chemical or biological characteristic of water, sediment or biota, applicable province-wide, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions. WQGs are science-based safe levels for physical, chemical, biological characteristics of water, biota or sediment, and thus do not account for social and economic factors. They are developed to protect various water uses, such as aquatic life, wildlife, agriculture, recreation/aesthetic, and source/drinking water. WQGs for the protection of aquatic life and wildlife are intended to protect the most sensitive species and most sensitive life stage indefinitely. As well, they consider all components of the aquatic ecosystems (algae, aquatic plants, invertebrates, amphibians, fish, etc.). For some substances, both a 30-day average (long-term guideline based on a minimum of 5 samples in a 30-day period) and a short-term maximum guideline (set to protect the most sensitive aquatic organism from lethal effects over short-term (96-h or less) exposures) are developed.

WQGs are applicable province-wide and do not account for site-specific factors. B.C. guidelines are generally the basis for the derivation of site-specific water quality objectives, which take local circumstances into account. WQGs are not legally enforceable in B.C., but are approved by the Assistant Deputy Minister of MOE. Once approved, they become official policy that provides direction to those making decisions within MOE that affect water quality (MOE Policy 6.10.03.02, 1991). WQGs are considered in the development of allowable limits in water discharge permits, approvals, plans, or operating certificates.

B.C. WQG reports can be found at: http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html

The status of approved B.C. WQGs for the substances of concern under the Order is:

Nitrate: updated in 2009

Sulphate: updated in 2013

Cadmium: the working guideline is currently being updated

Selenium: updated in 2014

WQG derivation protocol can be found at: <http://www.env.gov.bc.ca/wat/wq/pdf/wq-derivation.pdf>

2.4.3 Site-Specific Water Quality Objectives

In B.C., SSWQOs protect the most sensitive water use at a particular site. Each applies to the site in question and any potentially affected waters downstream of the site, unless otherwise stated.

B.C.-approved WQGs are often adopted for the most sensitive water use as the preliminary WQO for each water quality variable for a site. At sites with atypical water quality characteristics or ecological receptors, the B.C.-approved WQGs may be modified to account for site-specific factors.

Certain conditions must be present before an approach other than direct adoption of the approved B.C. WQGs is considered. For example, any one of the following conditions could justify the development of a WQO that is different from the B.C.-approved WQGs:

- The natural background concentrations of a given variable exceed the B.C.-approved WQG.
- Site-specific circumstances increase or decrease toxicity of the contaminant(s) in question. When toxicity-modifying factors are present, WQOs are based on the natural background concentrations of these factors, not levels that have been altered due to human land use (e.g., water hardness).
- The dataset used to derive the B.C.-approved WQG includes taxonomic groups that do not occur, or do not have the potential to occur, within the water body in question.

Where existing water quality does not suit all desired water uses, and it is feasible to improve quality over time (e.g., legacy impacts from past land use), short-term objectives can be developed to stabilize water quality at a site while the long-term objectives represent the desired future condition (e.g., B.C. WQG levels).

Guidance for developing site-specific WQOs is at: http://www.env.gov.bc.ca/wat/wq/pdf/wqo_2013.pdf

2.4.4 Canadian Water Quality Guidelines

Guidelines issued by the Canadian Council of Ministers of the Environment (CCME) may be adopted by MOE as B.C. Working WQGs, and are considered in the development of approved B.C. WQGs. Regional factors in B.C. may necessitate the adjustment of CCME guidelines to suit provincial circumstances. It is MOE policy that B.C. WQGs take precedence over CCME guidelines.

The current B.C. WQG for cadmium is a Working WQG and is based on an Interim Canadian Water Quality Guideline (CCME 2005). The Interim Canadian Water Quality Guideline for cadmium is being revised and the draft B.C. Cadmium WQG is now posted for public comment.

2.5 Other Regulatory Tools

2.5.1 Manual for Reviewing Environmental Impact Assessments (EIAs)

The Manual for Reviewing Environmental Impact Assessments to Support Effluent Permitting provides guidance for reviewing and conducting EIAs for effluent permitting and waste management plans under the B.C. *Environmental Management Act*. It is intended to be used by EIA biologists and other MOE staff to ensure that a consistent province-wide approach is followed in reviewing EIA reports conducted as part of the waste discharge permitting process.

2.5.2 Site Performance Objective (SPO)

A Site Performance Objective (SPO) is an authorization limit imposed by the statutory decision maker which considers receiving environment information that is derived from scientific data with consideration of other factors. These factors are described in the Effluent Permitting Process: An Overview for Mine Project Applicants. In deriving an SPO, the level of risk is defined and documented. SPOs are set in consideration of the WQGs and/or water quality objectives (WQOs) and social and economic factors. SPOs have relevance to the area based plan because the Order refers to Water Quality Targets, which will be considered Site Performance Objectives if the plan gets approved by the Minister, and the targets, as defined within the Plan, are incorporated into permits or other authorizations.

The factors considered in a SPO decision are described in: http://www.env.gov.bc.ca/epd/industrial/mining_pdf/effluent_permitting_guidance_doc_mining_proponents_apr2013.pdf

2.5.3 Drinking Water Guidelines

WQGs for source drinking water are developed by MOE through consultation with the B.C. Ministry of Health. Health Canada's Guidelines for Canadian Drinking Water Quality for chemical parameters are typically adopted by MOE to reduce risks to drinking water sources.

MOE has approved ambient WQGs for nitrate and sulphate in drinking water sources. The maximum acceptable concentration for nitrate is 10 mg/L (as N) (Nordin and Pommenz 1986). An aesthetic objective of 500 mg/L was adopted for sulphate (Singleton 2000). The current selenium guideline is 0.01 mg/L (Nagpal and Howell, 2001); however, Health Canada has proposed an updated guideline of 0.05 mg/L (Health Canada 2013). MOE has not formally adopted a cadmium source WQG; however, Health Canada's guideline (Health Canada 1986) will be adopted as a working guideline in B.C.

2.6 Other Guidance Tools

2.6.1 Determining Best Achievable Technology (BAT) Policy

This policy provides guidance for setting waste discharge standards by using BAT standards, and thus encourages significant reduction of waste discharges to the environment. In the policy, BAT "means the technology that can achieve the best waste discharge standards and that has been shown to be economically feasible."

2.6.2 B.C. Field Sampling Manual

The 2003 edition of the B.C. Field Sampling Manual sets out the sampling procedures, protocols and equipment that applicants are normally expected to use when doing monitoring required by MOE.

2.6.3 B.C. Laboratory Methods Manual (2009)

This policy identifies the approved laboratory methods to be followed by laboratories for B.C. clients in order to be acceptable for permit-related sampling. It is important to ensure the current version is used, since this manual is updated frequently.

2.6.4 Monitoring Guidance Document for Mine Proponents and Operators

MOE's Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators is designed to outline and define the baseline study requirements and information considerations necessary to propose a mineral development project in of B.C. The document describes minimum baseline requirements and associated acceptable methods and rationale, and provides sources of information and examples. The topics covered by this document include;

- air quality
- water quality and quantity (surface and groundwater)
- hydrology
- hydrogeology
- sediment quality
- aquatic life information requirements
- geological conditions.

Although developed specifically for the mining industry, much of the information on sampling methodologies and tools for impact assessment applies to other types of effluent permitting.

2.6.5 Guidelines for Designing a Monitoring Program and Interpreting Data (B.C.)

These two manuals present guidelines for designing a water quality program and interpreting water quality data in B.C. They cover the minimum requirements to ensure that a sampling program effectively addresses all concerns regarding potential impacts to a fresh water body and that data are reliable. This is accomplished through the development of a structured approach to program design, data collection, and data interpretation that can be widely applied. Given the variability of the natural conditions as well as man-made inputs, these manuals are limited to providing guidance rather than specific protocols.

Chapter 3

Consultation and Technical Advice

Chapter Overview

The development of the Plan included two processes for receiving and incorporating input from outside of Teck: the establishment of an independent Technical Advisory Committee (TAC) to provide scientific advice and review; and a consultation process with communities, First Nations and governments.

Concordance with Ministerial Order and Terms of Reference

Chapter 3 satisfies Section 2(c) of Schedule B and Schedule D of Ministerial Order M113 and Section 4.0, 5.1, 5.2, 5.4, and 5.5 and 5.9 of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Scientific advice from the TAC:** Teck received close to 700 pieces of science-based advice from the nine-member TAC, which included representatives of the provincial and federal governments, Ktunaxa Nation Council, US federal government, Montana state government, an independent third-party qualified scientist and Teck. Teck participated in over 200 hours of meetings with the TAC and sub-groups between September 2013 and July 2014. Annex A includes all TAC recommendations together with how Teck considered each recommendation.
- **Extensive multi-phase consultation:** Teck fulfilled the requirements of Ministerial Order M113 through consultation with the Ktunaxa First Nation, local government, the public, governments in Canada and the United States, and other stakeholders.
 - **Local government, stakeholders and the public:** Local governments, stakeholders and the public were consulted through a three-phase process. Opportunities included in-person meetings in Fernie, Sparwood and Elkford, and online consultation. Notification of the consultation phases was broad, including advertising and mailers to all households in the Elk Valley. In total, 213 people attended 11 meetings and open houses, and 164 pieces of written feedback were submitted.
 - **Ktunaxa First Nation:** The Ktunaxa First Nation was engaged through a consultation agreement and multi-phase consultation process that included numerous meetings with leadership and staff, five community presentations, and a mine site tour.
- **Input considered in development of the Plan:** Inputs received from the TAC and other entities was considered, along with socio-economic information, in the development of the Plan, as documented in Annex A (Advice Table) and Annex C.8 (Considerations Memo).
- **Consultation to continue:** Teck will continue to undertake consultation at key milestones during implementation of the Plan. Inputs will be considered in the adaptive management of the Plan.

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3.1 The Technical Advisory Committee

The TAC provided technical, science-based advice to Teck and shared this advice with the public during development of the Plan by guiding, reviewing and commenting on its various work packages and components. The advice focused on the science used in the development of the Plan. This included assessing and making recommendations on the scientific methodologies for development of the water-quality concentration targets and assessing potential aquatic health impacts of proposed targets. The Committee provided advice on existing scientific reports and literature relevant to the technical issues to be addressed in the Plan. It reviewed, assessed and made recommendations on the scientific and technical aspects of studies undertaken by Teck before and during development of the Plan.

The chair of the TAC attended six open houses and three small group meetings held during Phase 1 and Phase 2, providing TAC's perspective on the Plan process to attendees.

The goal of the TAC was to provide advice to Teck through consensus among members. Members presented and discussed advice at meetings. Advice was then organized into an advice table and incorporated in the official TAC meeting minutes. Teck reviewed all advice received from the TAC and responded on how each piece of advice was considered in the Plan. These responses are included in Annex A.

The committee included representatives from:

- B.C. Ministry of Environment (MOE) – chair
- B.C. Ministry of Energy and Mines (MEM)
- B.C. Environmental Assessment Office
- Environment Canada
- US Federal Government
- Montana State Government
- Ktunaxa Nation Council
- an independent third-party scientist selected by the TAC
- Teck.

Selection of the independent scientist was made by MOE with input from the TAC.

The TAC held seven scheduled meetings during the development of the Plan. In addition, working groups were established to focus on four key development topics: toxicology, human health, monitoring and Lake Koochanusa. In total, the TAC dedicated more than 200 hours to meetings and discussions on the Plan.

Agendas and meeting notes from TAC meetings are available at www.elkvalleytac.com.

3.2 Consultation

As required by the Order, Section 4.0 of the Terms of Reference for the Plan outlined requirements for consultation under which Teck would consult with, or notify as appropriate, the following groups identified in the Order:

- the public
- the Government of B.C.
- the Government of Canada
- local governments
- the US federal government and the State of Montana Department of Environmental Quality
- B.C. First Nations that assert interests in the Designated Area
- the Kootenai Tribe of Idaho, and the Confederated Salish and Kootenai Tribes
- environmental non-government organizations
- other resource companies including Coal Valley Resources, Crowsnest Pass Coal Mining, NWP Coal Canada, Centermount Coal and Centerpoint Resources.

In addition, the Terms of Reference directed a separate process for consultation on the Plan between Teck and the Ktunaxa Nation Council, described in Section 3.2.4

Teck undertook three phases of formal consultation during the 12-month period to develop the Plan, in which 213 individuals participated in meetings and public open houses, and 164 feedback forms were received.

In addition to notification of the general public through advertising and direct mail, Teck reached out specifically to the above-listed stakeholders to engage them in the consultation process. A dedicated website, www.teck.com/elkvalley, provided the public and stakeholders with access to all information and public materials related to consultation. Separate from the public consultation process, other outreach – including notification, bilateral meetings and group meetings – was conducted with a number of identified stakeholders, including the Ktunaxa Nation Council, B.C. Government, Government of Canada, US federal government, State of Montana, and the Kootenai Tribe of Idaho and the Confederated Salish and Kootenai Tribes.

Before the three formal rounds of consultation, Teck held three public information sessions in Elkford, Fernie and Sparwood, and in June–July 2013 introduced the Plan process at local events, including more than a dozen local community markets throughout the region. Teck also accepted feedback throughout the development period via the website, a toll-free feedback number and email.

Each round of consultation was facilitated by Kirk & Co., an independent consultant with extensive experience in public consultation:

- **Phase 1 (Oct. 28–Nov. 29, 2013):** In the first round, Teck provided information regarding the process to develop the Plan and sought input regarding current and potential water treatment and water quality management approaches. Teck also provided information on ongoing mitigation strategies and the supporting socioeconomic impact analysis.
- **Phase 2 (April 9–May 5, 2014):** During the second round, Teck provided an update on progress made in developing the Plan, including information about research into ecologically protective levels for the substances of concern. Input was sought regarding the short-, medium- and long-term approaches to be included in the Plan, and how communities and the public would like to be consulted about adaptive management of the Plan after it has been implemented.
- **Phase 3 (June 13–July 4, 2014):** In the final round, Teck provided draft Plan content on the Plan website, and sought public comment.

Feedback received through the consultation was summarized after each round by Kirk & Co. in a report that was posted on the public website. Following the final consultation round, all input from the three rounds was collected into a consideration report, detailing how key feedback – along with environmental, technical and financial information – was considered in the development of the final Plan (Annex C.8).

3.2.1 Phase 1 Consultation

Teck took a number of steps to notify the public and stakeholders listed in the Terms of Reference of the opportunity to participate in the Phase 1 consultation, including:

- placing newspaper, radio and online advertisements in local and regional media
- mailing approximately 8,500 postcard invitations to residences and businesses in the Elk Valley
- sending out approximately 300 emails
- making approximately 100 telephone calls to identified stakeholders.

Feedback was collected through an online feedback form, written feedback forms and through open houses and small group meetings.

The open houses and small group meetings, held in Elkford, Sparwood and Fernie, attracted 107 attendees and resulted in 94 feedback forms being submitted. Annex C.1 provides a detailed report on the notification undertaken, the materials and methods Teck used to facilitate information dissemination and consultation, and the feedback received.

3.2.1.1 Feedback Summary

Ninety-two per cent of Phase 1 consultation participants who provided feedback forms approved of the key steps in developing the Plan, with 4% disagreeing and the remainder expressing no opinion. A similar proportion (89%) reported that they somewhat or strongly agreed with current and future water treatment and quality management measures undertaken by Teck. Support for the scope of the Plan's socio-economic impact analysis was also at 89% among those providing feedback.

3.2.1.2 Key Themes

Many participants in the Phase 1 consultation expressed support for the proposed steps in developing the Plan. Some suggested that a broader water use plan be developed for the Elk Valley, including activities beyond mining. Some participants wanted to know what consideration had been given to testing well water, and some wanted to know how existing B.C. drinking water guidelines would be factored into the development of targets for the Plan. Participants also wanted to know more about the water treatment and water quality management options that Teck had proposed, and requested that Teck ensure monitoring and reporting of water quality once the Plan was completed. In general, participants recognized the importance of Teck's continued investment in research and development of the Plan, and were supportive of proposed mitigation measures.

The participants also generally recognized the economic importance of steelmaking coal mining in the Elk Valley and were in agreement with the proposed scope of the socio-economic impact analysis. Annex C.2 provides a detailed report on issues raised and comments provided by participants during Phase 1.

3.2.2 Phase 2 Consultation

Teck took a number of steps to notify the public and stakeholders listed in the Terms of Reference of the opportunity to participate in Phase 2 consultation, including: placing newspaper, radio and online advertisements in local and regional media; two mail-outs of approximately 8,500 postcard invitations each to residences and businesses in the Elk Valley; mailing approximately 8,500 newsletters with information on consultation; sending out approximately 300 emails; and, making follow-up telephone calls to identified stakeholders. Feedback was collected through an online feedback form, written feedback forms and through open houses.

The open houses in Elkford, Sparwood and Fernie attracted 84 attendees and resulted in 45 feedback forms being submitted. Annex C.3 provides a detailed report on the notifications given, the materials and methods Teck used to facilitate information dissemination and consultation, and the feedback received.

3.2.2.1 Feedback Summary

A high proportion of participants who provided feedback in the Phase 2 consultation period were supportive of the short-, medium- and long-term water quality approaches proposed by Teck. Participants were asked how they would prefer to be notified and consulted about ongoing monitoring and adaptive management of the Plan. Most respondents preferred to obtain information and provide feedback via a website (76.7%), direct notification (62.8%), and by attending a community information session (55.5%).

3.2.2.2 Key Themes

Annex C.4 provides a detailed report on issues raised and comments provided by participants during the Phase 2 consultation.

Some participants suggested that Mitigation measures proposed for the medium- and long-term also be considered as part of the short-term approach. Participants wanted to know more about the effects of selenium on aquatic life and how site-specific benchmarks are derived. Some asked how the potential for selenium in drinking water would be addressed through the Plan. Some participants wanted to know how other future industrial activity in the Elk Valley would be addressed within the context of the Plan; how drinking water quality is being addressed within the Plan; the geology of the areas being mined and how that relates to selenium release; and how long selenium would be released from waste rock piles. For a detailed report on issues raised and comments provided by participants during Phase 2 please refer to Annex C.4.

3.2.3 Phase 3 Consultation

Phase 3 consultation were primarily conducted online, with Teck making content from the draft Plan available at www.teck.com/elkvalley and collecting feedback online and through written submissions. Teck took a number of steps to notify and encourage the public and stakeholders listed in the Terms of Reference to participate in the Phase 3 consultation, including:

- placing newspaper, radio and online advertisements in local and regional media
- a mail-out of approximately 8,500 informational pamphlets to residences and businesses in the Elk Valley
- sending out approximately 460 emails
- making 25 telephone calls to identified stakeholders.

A group stakeholder feedback and discussion meeting was held on June 24, 2014, in Sparwood and Fernie. Notification was by emails and follow-up phone calls. Annex C.5 presents a discussion guide for the third phase of consultation.

The Phase 3 consultation resulted in 25 of pieces of written feedback being submitted, and 22 people participated in the feedback meeting. Annex C.6 provides a detailed report on the notification undertaken and the feedback received.

3.2.3.1 Key Themes

Participants at small group meetings were interested in how the Plan would address future industrial proposals, and whether they would have to meet the targets outlined in the Plan. Many were interested in Teck's plan for monitoring, including how often monitoring would be undertaken and whether results would be publicly available.

Several participants who provided submissions were in agreement with the Plan and water quality targets outlined in the Phase 3 discussion guide. Other respondents suggested that monitoring data should be provided to the BC government and the public at regular intervals. Several respondents were interested in how active water treatment facilities and other mitigation measures would be maintained following the end of mining activities, while others were supportive of Teck's leadership role in addressing water quality concerns and the amount of work that Teck has put into developing the Plan.

For a detailed report outlining issues and comments provided by Phase 3 consultation participants, please see Annex C.6.

3.2.4 Ktunaxa Nation Consultation

The Ktunaxa Nation Council (KNC) was consulted throughout the development of the Plan, and Teck is committed to continuing to consult and work with KNC leadership and staff throughout its implementation.

As outlined in the Terms of Reference, Teck consulted with the KNC in accordance with a KNC-Teck Elk Valley Water Quality Consultation Agreement, jointly developed pursuant to the existing KNC-Teck Consultation Protocol. Annex C.7 provides details on this agreement. Specific consultation included the following activities:

- KNC Community consultation meetings were held in February, April, June and July 2014, at which Teck provided information and received feedback on the Plan process, and at which the KNC's representative on the TAC provided information on the TAC process and perspective on the Plan development. Teck provided funding to facilitate staff preparation for, and staff and community members' participation in, these meetings.
- A two-day Ktunaxa Nation meeting was held on June 3-4, 2014, which included presentations and discussion of the Plan.
- KNC community members and staff participated in a tour of Teck's West Line Creek water treatment facility on June 16, 2014.
- KNC contracted MacDonald Environmental Sciences to provide technical advice and representation at the TAC. Teck provided capacity funding.
- KNC and band staff and leadership participated in the Plan consultation and development process. Teck provided capacity funding for this, and develop Ktunaxa-specific communication materials.
- KNC participated with Teck and the Government of B.C. in a Plan steering committee, which provided ongoing guidance and direction on the development of the Plan.

3.2.4.1 Feedback Summary

The following summarizes input received during KNC Community consultation meetings in February, April, June and July 2014.

KNC Community members were interested in the impact of increased levels of selenium on wildlife, fish, and plants, particularly those that are traditional foods of the Ktunaxa Nation. Some participants noted the traditional and spiritual uses of water in the area in which Teck is mining and expressed that they were participating in the consultation process to represent the interests of their children's children and all future generations of Ktunaxa Nation members. Consequently, some participants emphasized that Teck must take a longer-term, generational approach to the water treatment methods than it is considering and should move away from reliance on active water treatment and toward more passive water treatment methods. Some participants expressed frustration with past and present impacts of resource extraction, noting that Ktunaxa Nation members have and always will be present as protectors of the land in the Elk Valley, whereas industry has a short-term use for the land.

Several participants asked what assurances the Ktunaxa Nation has that Teck would not abandon its operations or responsibilities to manage water quality in the Elk Valley, including asking how budget limitations could affect the implementation of the Plan. Some participants wanted more information about Teck's implementation of the Plan and future monitoring activities and were interested to know how community members would receive updates regarding the status of Plan implementation and monitoring results. Many participants acknowledged Teck's leadership in consultation with the Ktunaxa Nation, appreciating the opportunity to meet directly with senior Teck staff on a regular basis.

Further information on the consultation undertaken and the feedback provided by the KNC can be found in Annex C.7. All feedback received from the KNC was also included in the consideration report, which describes how feedback was considered in the development and refinement of the Plan.

3.2.5 Other Specified Stakeholder Consultation

In addition to the general public consultation outlined above, additional steps were taken to ensure that specific stakeholder groups identified in the Terms of Reference were engaged and notified of opportunities to provide feedback on the development of the Plan.

All feedback received from these stakeholders was included in the consultation summaries produced for each round of consultation, as applicable, and in the consideration report, which describes how feedback was considered in the development and refinement of the Plan. For more information, see Annex C.8.

3.2.5.1 Local Government

Local governments within the Designated Area include the District of Sparwood, District of Elkford, City of Fernie and the Regional District of East Kootenay (Areas A and B). Consultation and engagement with each of these local governments took place through several avenues during the development of the Plan:

- Mayors and councillors from all Valley communities were directly invited by email and phone call to participate in all three phases of public consultation.
- Discussion Guides and related public materials for each round of public consultation were provided by email to councils and municipal staff.
- A number of mayors, councillors and regional district directors attended small group meetings and open houses Elkford, Sparwood and Fernie during Phase 1, 2 and 3, and provided feedback.
- A number of councillors and regional district directors participated in a tour of Teck's West Line Creek water treatment facility in November 2013.
- Letters of support for the Plan from local government can be found in Annex C.9.

3.2.5.1 Government of British Columbia

The Government of B.C. was consulted throughout development of the Plan. The departments Teck most frequently corresponded with were the Ministry of Environment (MOE), Ministry of Energy and Mines (MEM), Environmental Assessment Office (EAO), and Forests, Lands, and Natural Resource Operations (FLNRO). A number of forms of engagement were used, including:

- The TAC included members and alternate representatives from MOE, MEM, and EAO, who received regular updates and provided advice during the development of the Plan.
- Discussion Guides and information on each consultation round were disseminated to provincial government representatives at TAC meetings.
- Representatives from numerous government departments participated in tours of the Elk Valley operations and West Line Creek Water Treatment Facility during the Plan development period.

- Members of the Legislative Assembly attended information sessions, where Teck made presentations on the Plan.
- Regular bilateral and group meetings and information exchanges on specific aspects of Plan development took place throughout the process with BC government representatives.

3.2.5.1 Government of Canada

Teck provided the Government of Canada with regular updates throughout the development of the Plan. These updates occurred by way of formalized meetings and by way of direct outreach:

- The TAC included a member and alternate representative from Environment Canada, who participated in all TAC meetings and some subgroup meetings; received regular updates; and provided advice during development of the Plan.
- A number of in-person meetings in Ottawa took place with key departments including Environment Canada, Natural Resources Canada, Department of Fisheries and Oceans, and Foreign Affairs Trade and Development.
- A number of email and phone information exchanges took place in response to requests for information to Teck from federal government representatives.
- Discussion Guides and information on each consultation round were disseminated at TAC meetings to federal government representatives.

3.2.5.1 U.S. Government and the State of Montana Department of Environmental Quality

The Elk Valley watershed flows into Lake Koocanusa, a transboundary reservoir intersected by the B.C.-Montana border. The US State Department, Environment Protection Agency (EPA) and Government of Montana participated in and received updates on the development of the Plan through various channels:

- The TAC included a member and alternate representative from EPA Region 8 (Montana) and the U.S. Geological Survey who participated in all TAC meetings and some subgroup meetings.
- The Government of Montana Department of Environmental Quality (DEQ) was also represented on the TAC by a member and an alternate.
- In addition to the member and alternate representatives of the TAC, additional members of DEQ and EPA attended several TAC meetings as observers.
- A number of in-person meetings took place in Washington, DC with the offices of Senate and House Representatives of the State of Montana.
- Information updates and correspondence were exchanged with the State Department including with the Embassy of the United States in Ottawa, the consulate general in Vancouver, and the Office of Canadian Affairs in Washington, D.C.

3.2.5.1 Other B.C. First Nations that assert Interests in the Designated Area

The Shuswap Indian Band was identified as an additional B.C. First Nation asserting an interest in the Designated Area. Teck took steps to ensure the Shuswap had opportunities to participate and provide feedback during development of the Plan:

- The Shuswap were notified and invited by email to participate in all three phases of public consultation.
- The Shuswap were invited to participate in the stakeholder meeting during Phase 3.

3.2.5.1 Kootenai Tribe of Idaho and the Confederated Salish and Kootenai Tribes

The Kootenai Tribe of Idaho (KTOI) and the Confederated Salish and Kootenai Tribes (CSKT) received information and updates on the development of the Plan. Notification and engagement occurred through a number of avenues:

- In April 2014, Teck made a presentation on the Plan in a meeting with representatives of CSKT.
- Representatives from the KTOI and CSKT participated as observers at a number of TAC meetings.

3.2.5.1 Environmental Non-Governmental Organizations (ENGOS)

Wildsight and the Elk River Alliance (ERA) are ENGOS in the Designated Area with an identified interest in water quality issues. Consultation and engagement with these ENGOS took place through several avenues during the development of the Plan:

- ENGOS were invited by email and phone call to participate in all phases of public consultation.
- Discussion Guides and related public materials for each phase were emailed to ENGO staff.
- Representatives from Wildsight and the ERA attended small group meetings and open houses in Sparwood and Fernie during the Phase 1 and 2 consultation, and provided feedback.
- Representatives of Wildsight and the ERA attended the group stakeholder meeting as part of the Phase 3 consultation, and provided feedback.
- In December 2013, representatives of Wildsight participated in a tour of Teck's Line Creek Operations, including the West Line Creek water treatment facility.
- In May 2013, Teck and the ERA co-hosted a meeting for local fly-fishers and paddlers to discuss issues related to the Plan.

Teck notified other ENGOS by email of the opportunity to participate in consultation, including:

- the Yellowstone to Yukon Conservation Initiative (Y2Y)
- Sierra Club of B.C.
- Canadian Parks and Wilderness Society
- National Parks Conservation Association
- Headwaters Montana
- the Nature Conservancy of Canada
- the Nature Trust of B.C.
- the Kootenay River Network.

Teck participated in two water quality community information sessions hosted by the Kootenay River Network in Libby (June 2013) and Eureka Montana (August 2013).

3.2.5.1 Other Coal Companies

Coal Valley Resources, Crowsnest Pass Coal Mining, NWP Coal Canada, and Centermount Coal/Centerpoint Resources are identified in the Order as other coal companies with interests within the Designated Area. Consultation with these companies took place by means of several steps:

- Each was invited by email and phone call to participate in all three phases of public consultation.
- Registered letters were sent to all companies before Phase 2 consultation began, to ensure that they were aware of the opportunity to provide feedback.

- Teck made presentations or provided information directly to officials from Crowsnest Pass Coal Mining, Coal Valley Resources, and Centerpoint Resources.
- Letters of support for the Plan from other coal companies can be found in Annex C.9.

In addition, officials from CanAus Coal, which also has interests in the Designated Area, participated in the Phase 1 consultation and attended a one-on-one presentation by Teck.

3.3 Consideration of Consultation Feedback and Technical Advice

Annex C.8 is a Consideration Report that summarizes all the feedback Teck received during the consultation process and describes how that input has been considered, in conjunction with environmental, technical and financial information, in the development and refinement of the Plan.

Annex A comprises an Advice Table, as described at Section 3.1, that summarizes the technical advice received from the TAC and describes how it was considered in the development of the Plan.

3.4 Consultation During Implementation

As outlined in Section 4.2.2.1 of the Terms of Reference, during implementation of the Plan, Teck will report on progress and provide the above-named groups with opportunities to provide feedback at key milestones. This activity will use several avenues:

- Updates on Plan implementation will be posted as they become available, and ongoing feedback will be received and responded to through the Plan website.
- Submissions by mail, email or fax will be received and responded to on an ongoing basis.
- Throughout the Plan implementation period, a public feedback and information session will be advertised and held in at least one Elk Valley community annually.
- As necessary, bilateral or group meetings will be held to update and seek feedback from key groups.

Input received through consultation will be considered, along with environmental, technical and financial information, in the adaptive management and implementation of the Plan.

Chapter 4

Baseline Conditions

Chapter Overview

This chapter outlines current baseline conditions within the Designated Area relative to the protection of aquatic ecosystem and management of selenium, sulphate, nitrate and cadmium.

Concordance with Ministerial Order and Terms of Reference

Chapter 4 satisfies Section B1, B2, and B3 of Ministerial Order M113 and sections 3.4, 3.8(a) and 3.8(b) of the Elk Valley Water Quality Plan Terms of Reference. Human impacts are addressed in Chapter 5.

Highlights

- **Cadmium, nitrate, sulphate and selenium and other constituents were evaluated in the Designated Area.** Surface water quality data measurements have been collected over the past three years from locations through the area. Sediment samples have been collected since 2011.
- **Baseline conditions were examined for surface water quality, sediment quality and constituent concentrations in tissues of aquatic organisms:** These conditions, individually and cumulatively, determine the overall health of the aquatic environment and provide context for the development of the Plan.
- **Overall, biological monitoring results indicate that aquatic communities in the mainstem receiving environments appear to be healthy, with localized effects close to mine sites:**
 - Selenium and nitrate are the two constituents that most frequently exceed B.C. water quality guidelines in the Fording and Elk rivers; however, toxicity tests have not shown adverse effects on sensitive aquatic life.
 - Selenium is bio-accumulating in tissues of some biota in some areas to levels that may cause effects.
 - Benthic invertebrate community and fish population studies show little to no effects in the Fording River, Michel Creek and Elk River but invertebrate communities are affected in some tributaries directly influenced by mining.
- **Summary of monitoring in Lake Koocanusa:**
 - Water quality is well within B.C. WQGs for sulphate, nitrate and cadmium, and the selenium guideline is met in almost all (98%) water samples collected in Lake Koocanusa.
 - Data collected to date indicate that selenium in fish tissues is below levels that would harm fish populations.
- **Monitoring of water, sediment, fish and other biota will continue during Plan implementation.**

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4.1 Introduction

To provide context for the development of the Plan and management of Order constituents (cadmium, nitrate, sulphate, and selenium), Teck used available data to evaluate current baseline conditions within the Designated Area relative to Water Quality Guidelines (WQGs) and the protection of the aquatic ecosystem (e.g., sediment and biota evaluation relative to reference conditions, environmental quality guidelines and information in scientific literature). Calcite is evaluated and discussed in Chapter 7, while Chapter 5 evaluates baseline conditions in relation to the protection of human health and groundwater.

4.2 Management Units and Conceptual Site Model

To assist in the evaluation of current baseline conditions and identify where concentrations may be greater than WQGs, the Designated Area was divided into six management units (MUs, see Figure 4-1). Delineation of MUs is based on the location of Order Stations, and considers geographic features (e.g., confluence with major tributaries), and hydrodynamic characteristics (e.g., natural and/or artificial features). The six MUs in relation to the Order Stations are:

- MU-1 - Order Station FR4 (GH_FR1)
- MU-2 - Order Station FR5 (LC_LC5)
- MU-3 - Order Station ER1 (GH_ER1)
- MU-4 - Order Station ER2 (in the northern half - EV_ER4) and Order Station ER3 (at the southern limit, downstream of Michel Creek - EV_ER1)
- MU-5 - Order Station ER4 (RG_ELKORES)
- MU-6 - Order Station LK2 (RG_DSELK, RG_GRASMERE, and RG_BORDER).

Further to the above-listed MUs, and expanding upon the general influence diagram developed by the TAC on Oct. 29 and 30, 2013, a detailed conceptual site model (CSM) for the Designated Area was developed (Figure 4-2).

A CSM provides the framework within which a complex suite of chemical, physical, and biological processes and interactions can be systematically viewed in an organized manner. It considers sources of potential constituents of interest, physical-chemical processes that control chemical fate, and exposure pathways for relevant organisms (receptors) to evaluate current baseline conditions.

In developing a CSM, the first consideration is the different point and non-point sources that potentially release constituents to the environment. Once present in the aquatic environment, these constituents are transported within and among the various media by processes that result in a range of concentrations to which aquatic organisms are potentially exposed. Point and non-point sources of constituents within the Designated Area include activities such as mining, municipalities, agriculture, and forestry. As illustrated by Figure 4-2, constituents originating from Teck's coal mining operations may originate from waste rock, tailings, coarse coal rejects, and other mine-disturbed surfaces.

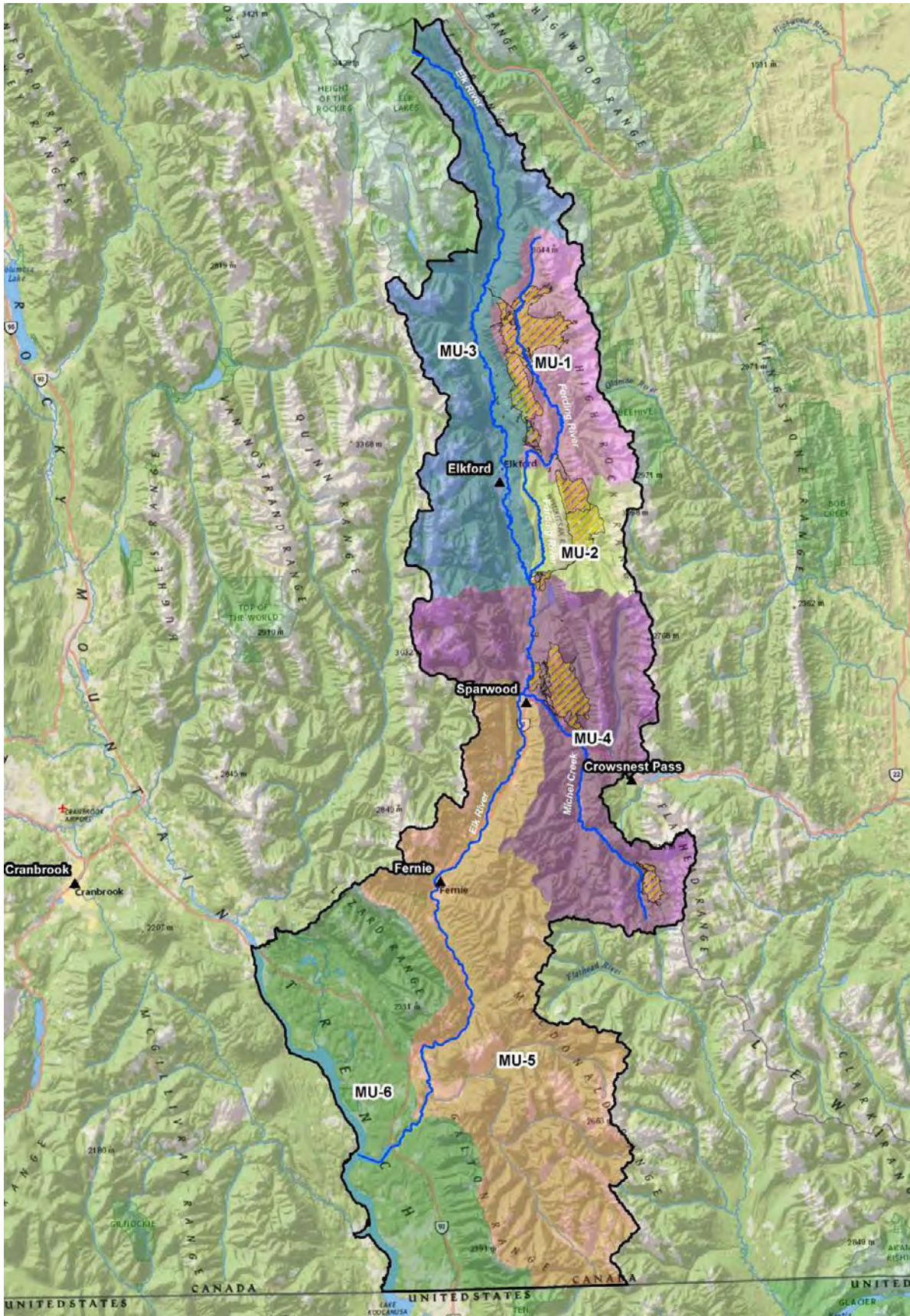


Figure 4-1. Management Units for the Designated Area.

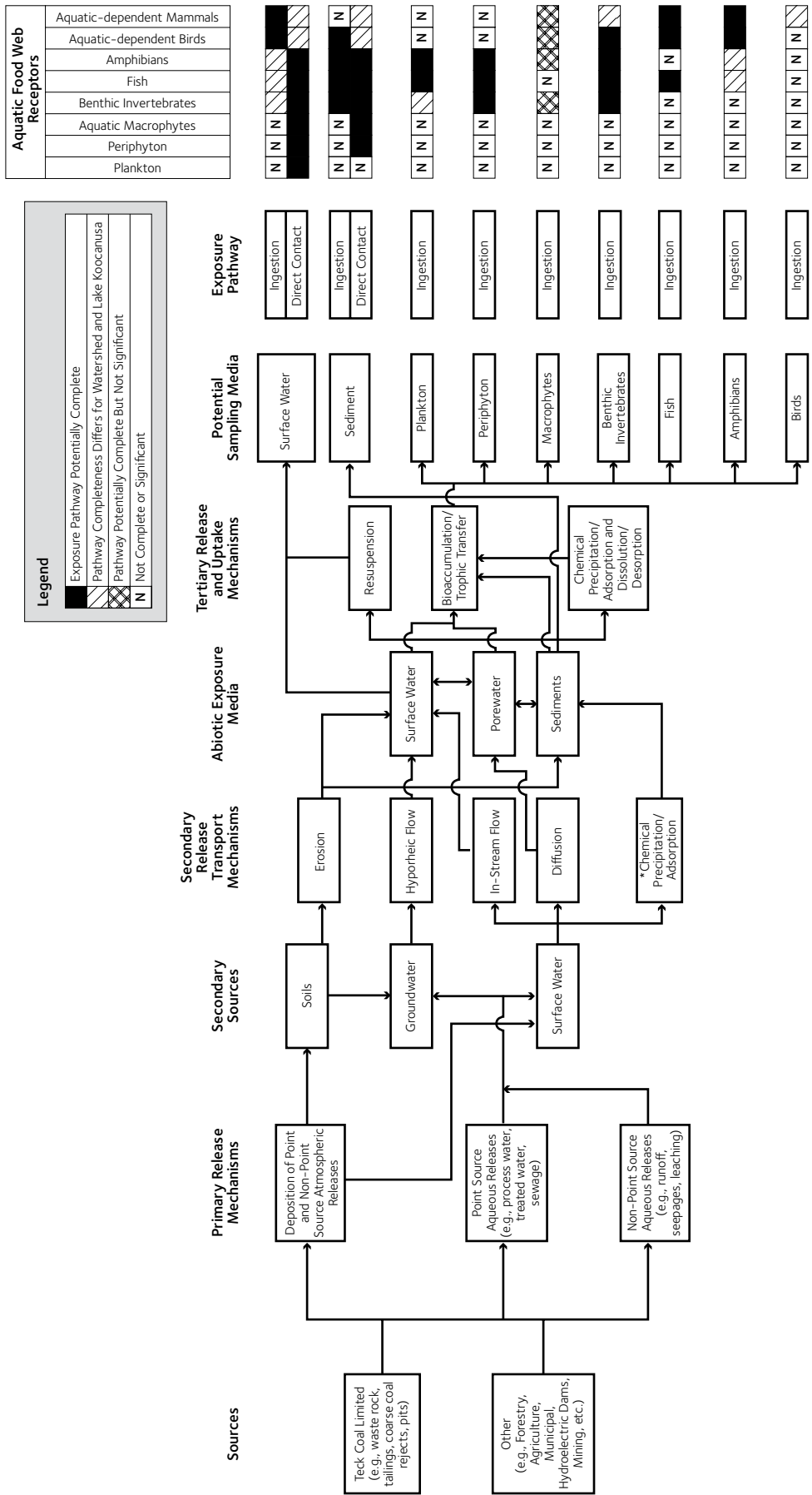


Figure 4-2. Conceptual site model for the designated area.

Note: “*” Chemical precipitation/adsorption within the Designated Area is inclusive of calcite formation and other relevant mine-related physical pathways (e.g. erosion/sediment transport, physical barriers (culverts, diversions), etc.). Details associated with calcite formation (e.g., conceptual site model) are presented in Chapter 7. Although the result of chemical reactions, calcite has the potential to act as a physical stressor which may adversely affect aquatic organisms due to changes in substrate structure. Other physical stressors that have the potential to adversely affect the aquatic environment either directly or indirectly include hydroelectric dams.

Receptor organisms have the potential to be exposed to constituents through ingestion of food (e.g., selenium bioaccumulation) or direct contact (e.g., surface water) (Figure 4-2). Receptor groups within the Designated Area include periphyton, aquatic macrophytes, benthic invertebrates, fish, amphibians, and birds and other aquatic-dependent wildlife.

Physical stressors in the Designated Area are also important. For instance, physical processes and environmental changes within Lake Koochanusa are affected by the operation of Libby Dam. Seasonal fluctuations of water elevations in the reservoir affect aquatic habitats and communities, either directly through disruption of spawning activity, or indirectly through the character of food webs or the quality and availability of habitat (Hardy and Paragamian 2013; Richards 1997; Crozier and Nordin 1983). The most direct effect is the dewatering of littoral habitats on species that depend on them for feeding or spawning (Richards 1997).

4.3 Existing Data

A large amount of environmental data has been collected in the Designated Area and Lake Koochanusa. These data include surface water quality, sediment quality, tissue residue concentrations, and evaluation of productivity and populations/communities in aquatic biota. A summary of current baseline conditions for each different type of data is presented below, and details are provided in Annex K.1.

4.3.1 Surface Water Quality

Water quality data were collected from 94 sampling locations throughout the Designated Area (Figure 4.3). These locations are identified as either 1) a mine-influenced tributary station, 2) a main stem receiving environment station (e.g., Fording and Elk rivers), or 3) a reference station. Figure 4.4 shows a schematic representation of the existing monitoring stations located within the Designated Area. More than 825,000 surface water quality data measurements for 73 constituents, collected over the past three years, were evaluated to assess baseline conditions.

The data were evaluated in a stepwise manner. First, maximum concentrations of respective constituents from mine-influenced tributary stations and main stem receiving stations were compared with long-term, sublethal-effect WQGs (the 30-day average value or the chronic criterion). If a long-term WQG was not available, then concentrations were compared with the short-term effect WQG (i.e., the maximum value or the acute criterion). If no individual sample for a constituent within the Designated Area was greater than its WQG, it was concluded that concentrations for that constituent do not exceed the WQG and the constituent was not evaluated further. It should be noted that for this first step and for constituents in which WQGs are hardness-based (e.g., cadmium and sulphate), a conservative average water hardness of 100 mg/L as CaCO₃ was used.

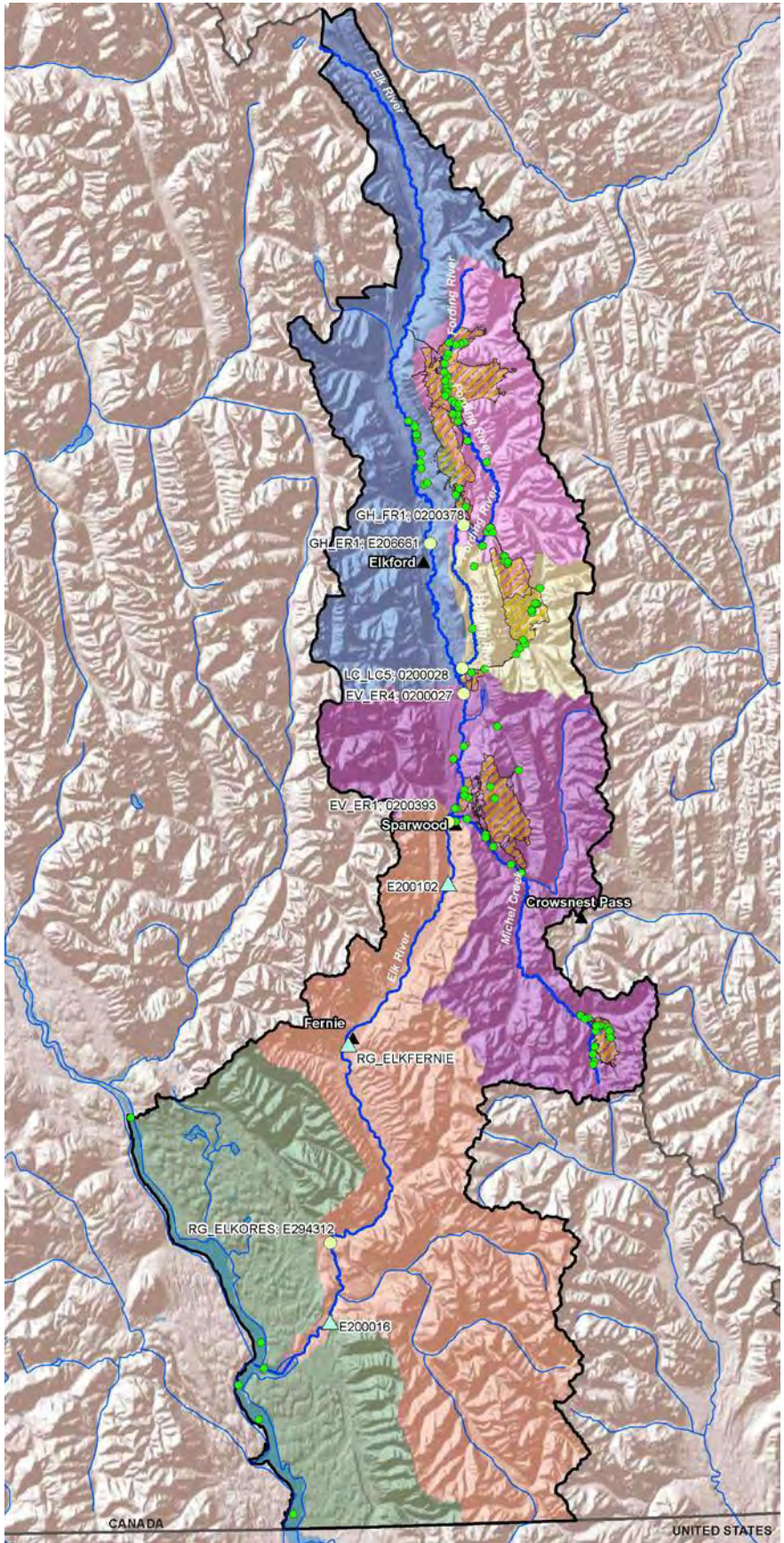


Figure 4-3. Surface Water Quality Monitoring Stations within the Designated Area.

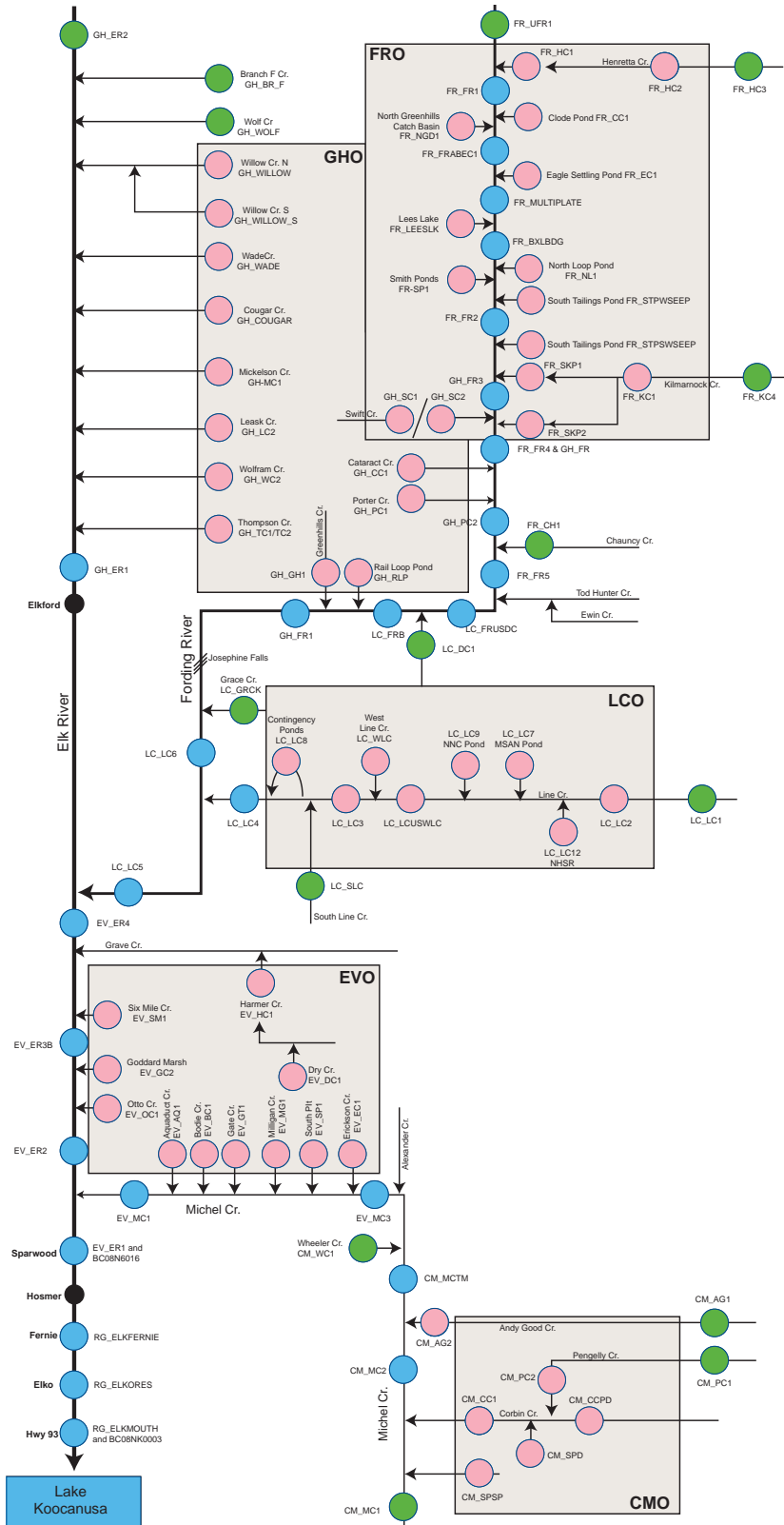


Figure 4-4. Schematic of Surface Water Quality Stations in the Designated Area.
 Note: The green stations represent reference stations, the pink is for mine-influenced tributary stations and blue represents a main stem receiving environment station.

If an individual sample anywhere within the Designated Area exceeded a WQG, the constituent was further evaluated against reference (background) concentrations to see if the constituent is naturally elevated within the Designated Area. If more than 10% of sample concentrations at the location in question were greater than the 95th percentile of reference area (background) concentrations, the constituent was deemed to be sufficiently different from background, and likely the result of a point and/or non-point source. For the purpose of this evaluation, background surface water concentrations were determined as follows:

- Fording River, represented by sampling location FR_UFR1
- Elk River upstream of the confluence of the Fording, represented by GH_ER2
- Elk River downstream of the confluence of the Fording River, represented by the average of GH_ER2 and FR_UFR1
- Elk River downstream of the confluence of Michel Creek represented by the average of GH_ER2, FR_UFR1 and CM_MC1
- Tributary samples represented by the average of samples from reference tributaries in the same sub-watershed within the Designated Area
- The Kootenay River was used for Lake Kooconusa.
- Of the 73 constituents evaluated, 21 constituents were identified as having at least one sample greater than its WQG within the Designated Area, and were retained for further evaluation. These included:
 - Elk and Fording Rivers: aluminum, ammonia, cadmium, copper, iron, nitrite, nitrate, selenium, sulphate, vanadium and zinc
 - Lake Kooconusa: selenium
 - Tributaries¹ (including Michel Creek): aluminum, ammonia, arsenic, barium, cadmium, cobalt, copper, iron, lead, lithium², manganese, nickel, nitrite, nitrate, selenium, silver, sulphate, thallium, uranium, vanadium and zinc.

All other water quality constituents are below WQGs throughout the Designated Area.

A number of WQGs depend upon parameters such as hardness (e.g., cadmium, sulphate), pH and temperature (ammonia), and chloride (nitrite). Therefore, the third and final step was to evaluate constituent concentrations based on location-specific parameters relative to the WQGs. Results for the Elk and Fording Rivers, Lake Kooconusa, and tributary stations are presented below.

¹ A significant portion of surface water samples presented herein as "tributaries" were collected at permitted discharge points, such as decants from settling ponds. As a result, these concentrations are considered to be conservative estimates for the purposes of evaluating current baseline conditions in tributaries.

² The lithium WQG is a working guideline intended to provide the best guidance that the Ministry can provide at this time. Because these estimates can be based on historic information or different derivation protocols, and are obtained from a number of different agencies, the Ministry acknowledges that such guidelines should be used with caution. Further review of the scientific literature identified that the working guideline is based on a secondary chronic value from Suter and Tsao (1996), and was derived from a limited number of studies using conservative assumptions. Since Suter and Tsao (1996), recent work has confirmed that chronic toxicity due to lithium in freshwaters occurs at concentrations greater than the working guideline and that the maximum lithium concentration in any sample from the Designated Area is below the chronic toxicity threshold reference value. A detailed discussion on this matter is presented within Annex K.1. It was therefore concluded that lithium surface water concentrations within the Designated Area will not adversely affect aquatic organisms and as such, lithium was not identified as exceeding the working guideline.

4.3.1.1 Elk and Fording Rivers

After adjusting guidelines to account for location-specific water quality parameters such as hardness, constituents identified as exceeding WQGs within the Fording and Elk rivers included aluminum, cadmium, copper, iron, nitrite, nitrate, selenium and vanadium. Exceedances of WQGs for metals in the Fording and Elk rivers are summarized in Tables 4-1 and 4-2, respectively. Selenium is the one metal/metalloid that routinely exceeds the WQG within the Fording River (Table 4-1). Cadmium (0.4%), copper (0.2%) and iron (2%) rarely exceed WQGs and are typically during spring freshet (high-flow events) and do not appear to be associated with a point source. Examples of the seasonal pattern are illustrated at location LC_FRDSDC; Fording River downstream of Dry Creek for total cadmium (Figure 4-5) and total iron (Figure 4-6). Similar data plots are available for all sampling locations within Annex K.1.

Table 4-1. Exceedances for total metals above chronic WQGs for the protection of aquatic life in the Fording River.

Location	Description	Cadmium	Copper	Iron	Selenium
FR_FR1	Fording River, downstream of Henretta Creek	0/48	0/49	0/49	53/53 (22)
FR_FR2	Fording River, upstream of Kilmarnock Creek	0/76	0/77	1/77 (2.9)	84/84 (26)
FR_FR5	Fording River Downstream of Chauncey Creek	0/44	0/44	0/44	44/44 (39)
FR_FRABEC1	Fording River, above EC1 outlet	0/41	0/41	0/41	48/48 (24)
GH_FR	Fording River, downstream of Swift Creek, upstream of Cataract Creek	0/89	0/89	2/88 (2.4)	109/109 (53)
GH_FR1	Fording River, downstream of Greenhills Creek	0/32	0/32	0/32	45/45 (35)
GH_FR3	Fording River, bridge above Swift Creek	0/30	0/30	0/30	43/43 (23)
GH_PC2	Fording River, 100 m below Porter Creek	1/28 (1.6)	0/28	0/28	51/52 (52)
LC_FRB	Fording River, U/S Sediment Pond Decant	0/18	0/18	1/18 (2.2)	18/18 (30)
LC_FRDSDC	Fording River, downstream of Dry Creek	1/30 (1.8)	0/30	2/30 (3.0)	30/30 (29)
LC_FRUSDC	Fording River, upstream of Dry Creek	0/37	0/37	2/37 (1.7)	37/37 (31)
LC_LC6	Fording River, upstream of Line Creek	0/29	0/29	1/29 (1.8)	29/29 (27)
LC_LC5	Fording River, downstream of Line Creek	0/39	1/39 (1.2)	2/39 (1.3)	39/39 (29)
	Sub-Total =	2/541	1/543	11/542	630/631
	Percent Observed to Exceed WQG =	0.4%	0.2%	2%	100%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

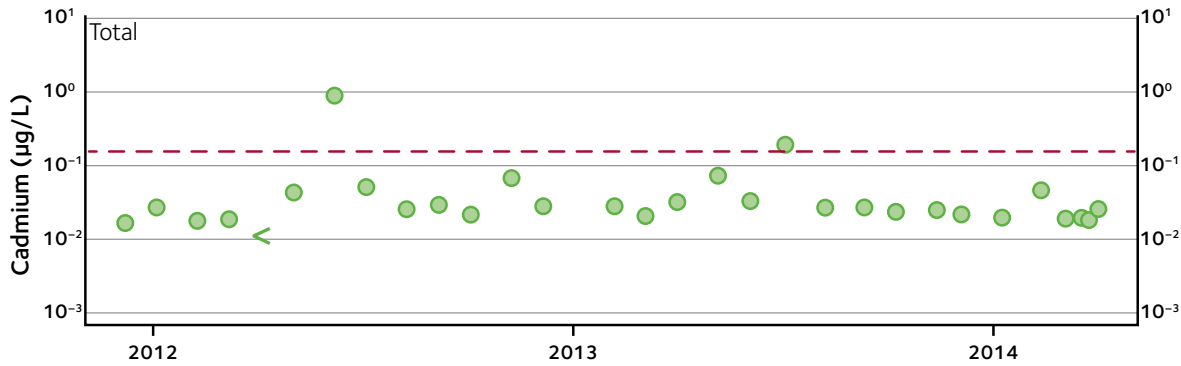


Figure 4-5. Total Cadmium concentration as a function of time in the Fording River downstream of Dry Creek (LC_FRDSDC).

Note: The horizontal dashed red line is the chronic CCME WQG as determined at a water hardness of 100 mg/L CaCO₃. The y-axis is on a logarithmic scale within units in micrograms per liter (µg/L). Less-than symbols are plotted at the analytical detection limit.

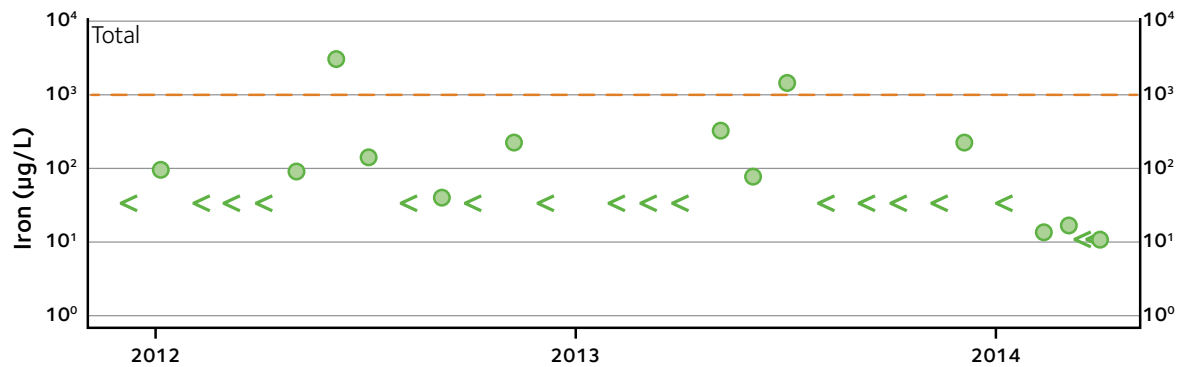


Figure 4-6. Total Iron concentration as a function of time in the Fording River downstream of Dry Creek (LC_FRDSDC).

Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a log scale within units in µg/L. Less-than symbols are plotted at the analytical detection limit.

A summary of exceedances above WQGs for metals in the Elk River is presented in Table 4-2. As indicated by the frequency of samples exceeding the WQG, selenium (88%) routinely exceeds the WQG. As with the Fording River, high-flow events increase the potential for exceedances of other constituents such as cadmium, iron, and vanadium (see Figure 4-7 for an example). Temporal data plots for all sampling locations, including reference stations, are available Annex K.1.

Table 4-2. Exceedances for total metals above chronic WQGs for protection of aquatic life in the Elk River.

Location	Description	Aluminum ¹	Cadmium	Iron	Selenium	Vanadium
GH_ER1	Elk River Upstream of Boiven Creek	0/40	0/40	1/40 (1.1)	4/53 (1.1)	0/40
EV_ER1	Elk River Downstream of Michel Creek at C.P.R. Roadhouse	0/68	1/68 (2.2)	7/68 (5.8)	68/68 (7.2)	2/68 (2.9)
EV_ER2	Elk River upstream of Michel Creek	0/60	0/60	5/60 (2.5)	60/60 (8.4)	1/60 (1.1)
EV_ER3B	Elk River upstream of Lindsay Creek	0/68	1/68 (1.0)	4/68 (3.5)	68/68 (9.5)	3/68 (1.6)
EV_ER4	Elk River upstream of Grave Creek	0/67	0/67	6/67 (2.9)	67/67 (11)	1/67 (1.4)
RG_ELKFERNIE	Elk River at Fernie	0/9	0/9	0/9	9/9 (5.4)	0/9
RG_ELKORES	Elk River at Elko Reservoir	0/19	0/19	0/19	19/19 (6.4)	0/19
BC08NK0003	Elk River at Highway 93 Bridge	1/44 (2.2)	1/44 (1.0)	5/44 (2.6)	44/44 (3.2)	0/44
RG_ELKMOUTH	Elk River at the mouth	0/19	0/19	0/19	18/18 (4.0)	0/19
Sub-Total =		1/394	3/394	28/394	357/406	7/394
Percent Observed to Exceed WQG =		0.3%	0.8%	7%	88%	1.7%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.
 Note 1: The WQG for aluminum is based on the dissolved fraction (the fraction that passes through a 0.45 µm filter).

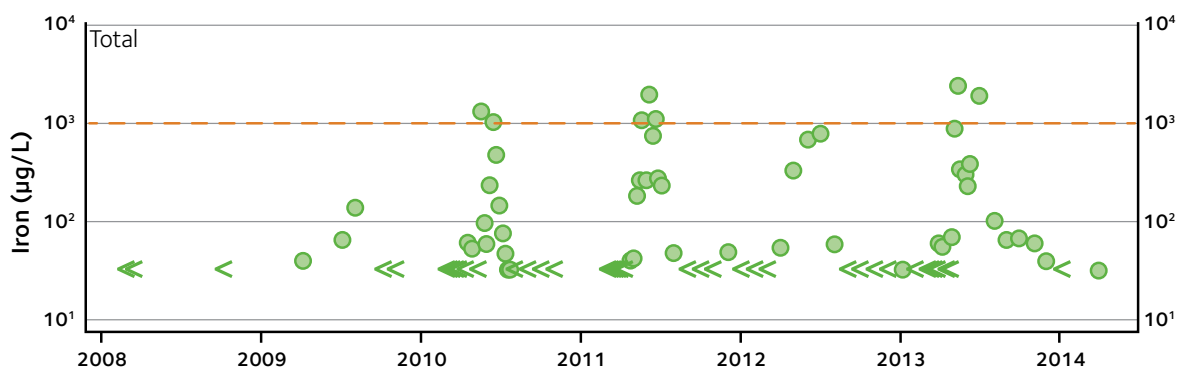


Figure 4-7. Total Iron concentration as a function of time in the Elk River upstream of Michel Creek (EV_ER2). Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a log scale within units in µg/L. Less-than symbols are plotted at the analytical detection limit.

Nitrate also routinely exceeds WQGs within the Fording River, with a limited number of elevated nitrite levels observed downstream of Swift Creek. As illustrated within Table 4-3, nitrite concentrations within the Fording River are generally less than the WQG; with one sampling location (FR_FRABEC1; Fording River, above EC1 outlet) accounting for the majority of observed exceedances. As illustrated in Figure 4-8, there are limited data associated with this sampling location but there is an indication of a seasonal pattern. Data plots for all sampling locations are provided within Annex K.1.

Table 4-3. Exceedances for total nutrients above chronic WQGs for protection of aquatic life in the Fording River.

Location	Description	Nitrate as N	Nitrite as N
FR_FR1	Fording River, downstream of Henretta Creek	20/49 (3.7)	0/49
FR_FR2	Fording River, upstream of Kilmarnock Creek	64/77 (4.4)	0/77
FR_FR5	Fording River Downstream of Chauncey Creek	44/44 (7.8)	0/44
FR_FRABEC1	Fording River, above EC1 outlet	15/15 (3.1)	9/15 (2.0)
GH_FR	Fording River, downstream of Swift Creek, upstream of Cataract Creek	102/103 (6.2)	2/103 (1.1)
GH_FR1	Fording River, downstream of Greenhills Creek	47/47 (4.8)	0/47
GH_FR3	Fording River, bridge above Swift Creek	40/45 (4.5)	0/45
GH_PC2	Fording River, 100 m below Porter Creek	30/30 (9.9)	0/30
LC_FRB	Fording River, U/S Sediment Pond Decant	18/18 (5.5)	0/18
LC_FRDSDC	Fording River, downstream of Dry Creek	30/30 (6.0)	0/30
LC_FRUSDC	Fording River, downstream of Dry Creek	37/37 (5.6)	0/37
LC_LC6	Fording River, upstream of Line Creek	64/64 (5.0)	0/64
LC_LC5	Fording River, downstream of Line Creek	81/81 (4.8)	0/81
Sub-Total =		592/640	11/640
Percent Observed to Exceed WQG =		93%	2%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

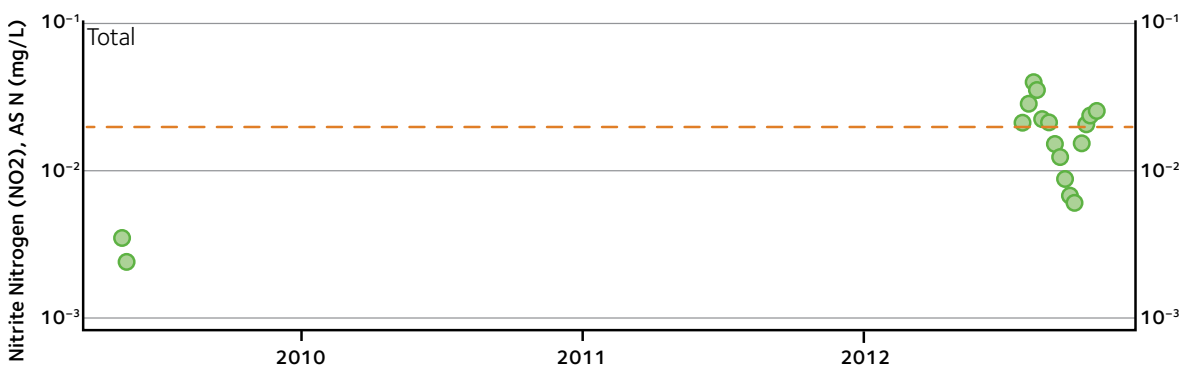


Figure 4-8. Nitrite concentration as a function of time in the Fording River above EC1 outlet (FR_FRABEC1). Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a logarithmic scale within units in milligrams per liter as N (mg/L N).

The only nutrient to exceed WQGs in the Elk River with some frequency (15%) was nitrate (Table 4-4). Although nitrate concentrations are generally below WQGs within the Elk River, there is a trend of increasing concentrations, as illustrated at EV_ER4; Elk River upstream of Grave Creek (Figure 4-9).

Table 4-4. Summary of exceedances for total nutrients above chronic WQGs for the protection of aquatic life in the Elk River.

Location	Description	Nitrate as N	Nitrite as N
GH_ER1	Elk River Upstream of Boiven Creek	0/40	0/40
EV_ER1	Elk River Downstream of Michel Creek at C.P.R. Roadhouse	1/68 (1.1)	0/68
EV_ER2	Elk River upstream of Michel Creek	8/60 (1.3)	0/60
EV_ER3B	Elk River upstream of Lindsay Creek	19/68 (1.5)	0/68
EV_ER4	Elk River upstream of Grave Creek	32/67 (1.6)	0/67
RG_ELKFERNIE	Elk River at Fernie	0/9	0/9
RG_ELKORES	Elk River at Elko Reservoir	0/19	0/19
BC08NK0003	Elk River at Highway 93 Bridge	0/44	0/44
RG_ELKMOUTH	Elk River at the mouth	0/19	0/19
Sub-Total =		60/394	0/394
Percent Observed to Exceed WQG =		15%	0%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

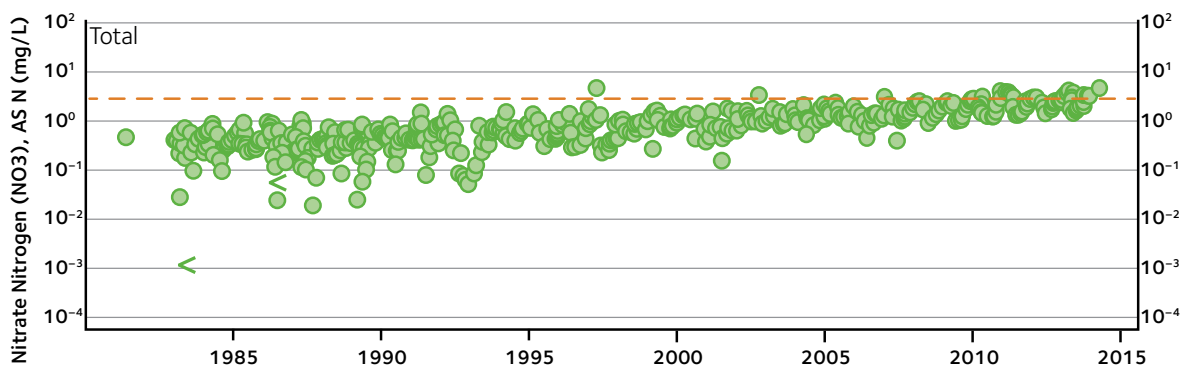


Figure 4-9. Nitrate concentration as a function of time in Elk River downstream of Grave Creek (EV_ER4). Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a logarithmic scale within units illustrated in mg/L N. Less-than symbols are plotted at the analytical detection limit.

Based on surface water data collected from the Fording and Elk rivers, selenium and nitrate are the two constituents most frequently exceed WQGs, with the greatest proportion of exceedances occurring in the Fording River. To better understand if these concentrations are impacting sensitive aquatic receptors and in preparation of the Plan, a series of chronic toxicity tests were completed using surface water samples collected from the Elk River and Fording Rivers. Complete details and associated study designs associated with these

tests are presented in Chapter 8, and summarized in Annex K.1. They included: survival and growth of fathead minnows (*Pimephales promelas*), swim-up and fry development of rainbow trout (*Oncorhynchus mykiss*), survival and reproduction of water fleas (*Ceriodaphnia dubia*), and survival and growth of a freshwater amphipod (*Hyaella azteca*). None of the tests resulted in effects on biota compared to organisms exposed to water collected upstream of mine influences.

4.3.1.2 Lake Koocanusa

Of the 7,151 surface water quality data measurements to date on over 40 constituents within the reservoir, selenium was the one constituent identified as exceeding a WQG or criteria. Specifically, three measurements exceed the B.C. MOE WQG (2 µg/L) and 23 exceed the 2014 draft U.S. Environmental Protection Agency (EPA) lentic criteria of 1.3 µg/L. A summary of selenium exceedances in the reservoir are presented in Table 4-5, with a summary for other water quality constituents presented in Annex K.2.

Table 4-5. Summary of exceedances for total selenium in Lake Koocanusa.

Location	Description	B.C. MOE WQG	EPA criterion
RG_WARDB	Lake Koocanusa downstream of Kootenay River; B.C.	0/10	0/10
RG_EASTARM	Lake Koocanusa near the mouth of Elk River; B.C.	2/14 (2.3)	9/14 (3.6)
RG_USELK	Lake Koocanusa Upstream of the Elk River; B.C.	1/14 (1.4)	1/14 (2.2)
RG_DSELK	Lake Koocanusa 1 st station downstream of Elk River; B.C.	0/15	1/15 (1.1)
RG_GRASMERE	Lake Koocanusa 2 nd station downstream of Elk River; B.C.	0/13	4/13 (1.5)
RG_BORDER	Lake Koocanusa 3 rd station downstream of Elk River; B.C.	0/13	4/13 (1.0)
K01KOOCL01	Lake Koocanusa at International Boundary; MT	0/16	3/16 (1.2)
K01KOOCL02	Lake Koocanusa near Dodge Creek mouth; MT	0/2	0/2
K01KOOCL03	Lake Koocanusa – Tenmile shoreline; MT	0/14	1/14 (1.1)
K01KOOCL04	Lake Koocanusa in Forebay (Libby Dam); MT	0/14	0/14
Sub-Total =		3/125	23/125
Percent Observed to Exceed =		2%	18%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). A hazard quotient using the maximum concentration was calculated and is presented in brackets.

4.3.1.1 Tributaries

In tributaries, concentrations higher than WQGs were found in some samples for aluminum, ammonia, arsenic, barium, cadmium, cobalt, copper, iron, lead, manganese, nickel, nitrite, nitrate, selenium, silver, sulphate, thallium, uranium, vanadium and zinc. Given the large number of tributaries, the following discussion presents a summary of results on a Management Unit basis.

Management Unit 1: Upon considering location-specific water quality parameters such as hardness, constituents identified as sometimes exceeding WQGs within tributaries of MU-1 include barium, cadmium, cobalt, copper, iron, nitrite, nitrate, selenium, sulphate, uranium, vanadium and zinc. A summary of exceedances relative to WQGs for metals is presented in Table 4-6. As indicated by the above results, selenium is the one

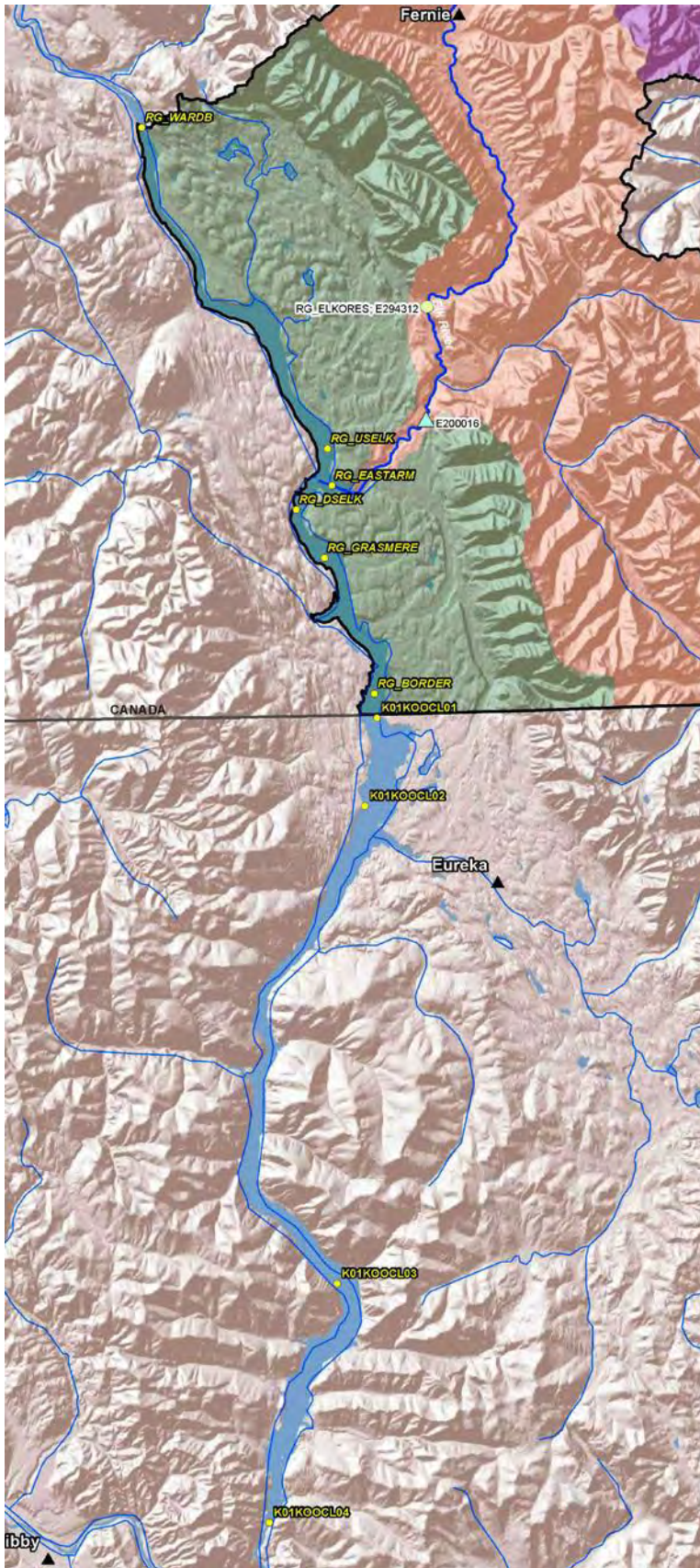


Figure 4-10. Lake Koochanusa surface water sampling locations.

metal that routinely exceeds the WQG within tributaries of MU-1 (96% of the time); while other constituents rarely exceed WQGs.

Exceedances of other constituents are associated with seasonal variability, with the exception of uranium. Three locations demonstrate minimal seasonal variability in total uranium concentrations: 1) decant from Eagle settling pond (FR_EC1), 2) Cataract Creek sediment pond decant (GH_CC1), and 3) Swift Creek pond bypass (GH_SC2). As illustrated in Figure 4-11, total uranium concentrations at these three locations are fairly consistent over time, with lower concentrations observed in spring. Data plots for all constituents and at all sampling locations are available in Annex K.1.

Table 4-6. Exceedances for total metals above chronic WQGs for protection of aquatic life in tributaries of MU-1.

Location	Description	Barium	Cadmium	Cobalt	Copper	Iron	Selenium	Uranium	Vanadium	Zinc
FR_CC1	Decant from Clode sediment pond	2/74 (2.9)	4/74 (2.6)	6/74 (1.5)	0/73	0/73	74/74 (89)	0/74	0/74	0/74
FR_EC1	Decant from eagle settling pond	0/82	0/81	2/82 (1.1)	0/82	0/82	88/88 (205)	63/82 (2.2)	0/82	0/82
FR_HC1	Hennetta Creek, upstream of Fording River	0/67	0/66	0/67	0/67	0/67	67/67 (22)	0/67	0/67	0/67
FR_HC2	Hennetta Cr. U/S of McMillan Cr.	0/65	0/65	0/65	0/65	0/65	65/65 (25)	0/65	0/65	0/65
FR_LEESLK	Lees Lake, south of a spoil	0/10	0/10	0/10	0/10	0/10	10/10 (34)	0/10	0/10	0/10
FR_MULTIPLATE	Fording River, multi plate culvert Greenhills access road	0/44	0/44	0/44	0/44	0/44	51/51 (29)	0/44	0/44	0/44
FR_NG1	North Greenhills diversion ditch	0/67	0/66	0/67	1/67 (35)	0/67	67/67 (26)	0/67	0/67	0/67
FR_NL1	Decant from north loop sedimentation pond	0/4	0/4	0/4	0/4	0/4	4/4 (20)	0/4	0/4	1/4 (1.3)
FR_SKP1	Decant from S Kilmarnock Sediment Pond-Phs 1	0/20	2/20 (1.3)	0/20	0/20	0/20	20/20 (132)	0/20	0/20	0/20
FR_SKP2	Decant from S Kilmarnock Sediment Pond-Phs 2	0/16	2/16 (1.4)	0/16	0/16	0/16	16/16 (50)	0/16	0/16	0/16
FR_STPWSEEP	South tailings pond south west seep	0/27	7/22 (1.7)	0/27	0/27	0/27	0/29	0/22	0/22	0/22
FR_SP1	Smith Pond decant	0/66	0/66	0/66	0/66	0/66	64/66 (38)	0/66	0/66	0/66
GH_CC1	Cataract Creek sediment pond decant	0/39	0/39	0/39	0/39	0/39	52/52 (357)	32/39 (1.3)	0/39	0/39
GH_GH1	Greenhills Creek sediment pond decant	0/39	0/39	0/39	0/39	4/39 (2.9)	52/52 (93)	0/39	4/39 (1.9)	0/39
GH_PC1	Porter Creek sediment pond decant	0/38	0/38	0/38	0/38	0/38	51/51 (63)	0/38	0/38	0/38
GH_RLP	Rail Loop Sediment Pond Decant	0/29	0/29	0/29	0/29	0/29	30/30 (7.6)	0/29	10/29 (3.3)	0/29
GH_SC1	Swift Creek sediment pond decant	0/11	0/11	0/11	0/11	0/11	22/22 (303)	1/11 (1.0)	0/11	0/11
GH_SC2	Swift Creek pond bypass	0/27	0/27	0/27	0/27	0/27	29/29 (429)	23/27 (1.3)	0/27	0/27
Sub-Total =		2/725	15/717	8/725	1/725	4/725	762/793	119/720	14/720	1/720
Percent Observed to Exceed WQG =		0.3%	2.1%	1.1%	0.1%	0.6%	96%	16.5%	1.9%	0.1%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

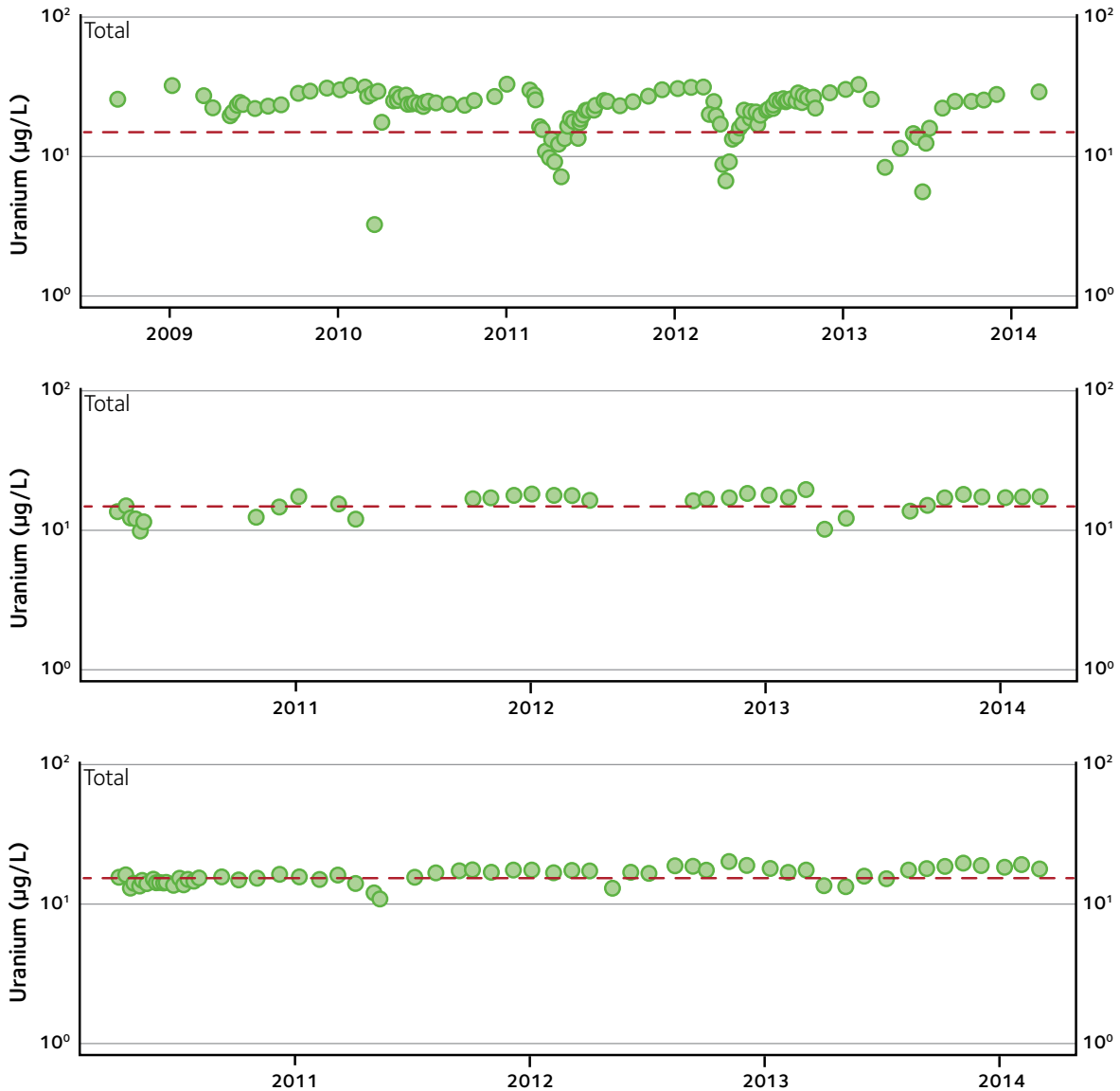


Figure 4-11. Uranium concentration at Eagle settling pond decant (top panel), Cataract Creek sediment pond decant (middle panel), and Swift Creek pond bypass (bottom panel). Note: The dashed red line is the chronic CCME WQG.

Sulphate and nitrogen exceedances are summarized in Table 4-7. As with the main stem of the Fording River, nitrate (60%) exceeds the WQG most frequently in tributaries of MU-1, followed by sulphate (36%). Consistent with other constituents, concentrations tend to vary seasonally with highest concentrations observed during low-flow conditions. However, there are exceptions where concentrations have decreased or plateaued. Examples are nitrate at the decant from Eagle settling pond (FR_EC1; Figure 4-12) and sulphate at the decant from Cataract Creek sediment pond decant (GH_CC1; Figure 4-13). Nitrate concentrations at the decant from Eagle settling pond are consistently above the chronic WQG but appear to be declining since 1995 (Figure 4-12); while sulphate concentrations at the decant from Cataract Creek sediment pond decant appear to demonstrate low variability since 2010 (Figure 4-13).

Table 4-7. Exceedances for total sulphate and nutrients above chronic WQGs for protection of aquatic life in tributaries of MU-1.

Location	Description	Nitrate as N	Nitrite as N	Sulphate
FR_CC1	Decant from Clode sediment pond	73/73 (15)	46/73 (11.5)	1/74 (1.1)
FR_EC1	Decant from eagle settling pond	81/81 (20)	0/81	79/82 (4.5)
FR_HC1	Henretta Creek, upstream of Fording River	47/67 (3.6)	1/67 (1.4)	0/67
FR_HC2	Henretta Cr. U/S of McMillan Cr.	41/65 (3.4)	0/65	0/65
FR_LEESLK	Lees Lake, south of a spoil	5/10 (1.7)	0/10	7/10 (1.8)
FR_MULTIPLE	Fording River, multi plate culvert Greenhills access road	17/17 (4.4)	9/17 (1.9)	0/17
FR_NGD1	North Greenhills diversion ditch	0/67	1/67 (1.2)	0/67
FR_NL1	Decant from north loop sedimentation pond	4/4 (4.8)	0/4	0/4
FR_SKP1	Decant from S Kilmarnock Sediment Pond-Phs 1	21/21 (41)	6/21 (2.4)	4/21 (1.7)
FR_SKP2	Decant from S Kilmarnock Sediment Pond-Phs 2	16/16 (16)	3/16 (2.3)	0/16
FR_STPSWSEEP	South tailings pond south west seep	12/27 (6.9)	0/27	8/27 (1.2)
FR_STPWSEEP	South tailings pond south west seep	7/22 (4.6)	0/22	6/22 (1.2)
FR_SP1	Smith Pond decant	0/66	1/66 (1.4)	11/67 (1.2)
GH_CC1	Cataract Creek sediment pond decant	53/54 (13.2)	0/54	56/57 (4.2)
GH_GH1	Greenhills Creek sediment pond decant	34/54 (2.2)	0/54	36/57 (1.9)
GH_PC1	Porter Creek sediment pond decant	1/53 (1.9)	0/53	26/56 (1.6)
GH_RLP	Rail Loop Sediment Pond Decant	4/32 (1.3)	31/32 (16)	0/33
GH_SC1	Swift Creek sediment pond decant	22/22 (15.6)	2/22 (1.4)	21/22 (3.4)
GH_SC2	Swift Creek pond bypass	31/31 (23)	0/31	34/34 (4.4)
Sub-Total =		469/782	119/782	289/798
Percent Observed to Exceed WQG =		60%	13%	36%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

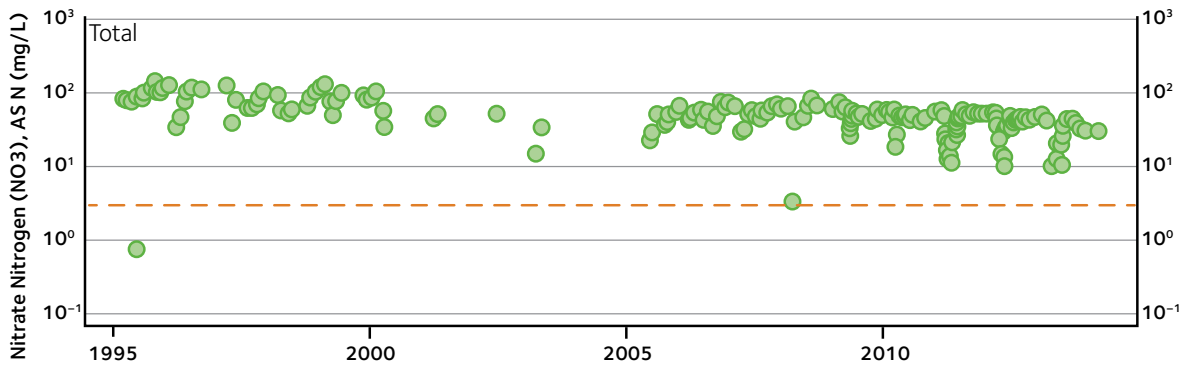


Figure 4-12. Nitrate concentration as a function of time at Eagle settling pond decant (FR_EC1).

Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a log scale within units of mg/L N.



Figure 4-13. Sulphate concentration as a function of time at Cataract Creek sediment pond decant (GH_CC1).

Note: The dashed orange line is the chronic B.C. MOE WQG plotted at 309 mg/L for moderately soft/hard to hard waters (76-180 mg/L as CaCO₃). The y-axis is illustrated on a log scale within units of mg/L.

Constituents most frequently exceeding WQGs in tributaries within MU-1 include selenium (96% of samples), nitrate (60% of samples), and sulphate (36% of samples). Other constituents exceed WQGs less frequently, and are largely associated with two sampling locations (the decant from Eagle settling pond, FR_EC1; and the decant from Cataract Creek sediment pond decant, GH_CC1). Specifically these two locations represent 80% and 47% of the observed exceedances for uranium and sulphate within the management unit.

Management Unit 2: Upon considering location-specific water quality parameters such as hardness, constituents identified as exceeding WQGs in tributaries of MU-2 include: cadmium, copper, nitrate, selenium, and sulphate. A summary of exceedances relative to WQGs for is presented in Table 4-8.

Table 4-8. Summary of exceedances above chronic WQGs for protection of aquatic life in tributaries of Management Unit 2.

Location	Description	Cadmium	Copper	Nitrate as N	Selenium	Sulphate
LC_LC2	Line Creek upstream of rock drain	0/43	0/43	0/84	36/43 (10)	0/84
LC_LC4	Line Creek, upstream of process plant	1/81 (1.2)	1/81 (1.1)	72/81 (6.1)	81/81 (35)	0/81
LC_WLC	West Line Creek	28/83 (2.5)	0/83	83/83 (14)	83/83 (346)	70/83 (3.0)
Sub-Total =		29/207	1/207	155/248	200/207	70/248
Percent Observed to Exceed WQG =		14%	0.5%	63%	97%	28%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

Consistent with other water quality data, selenium and nitrate are the two constituents that routinely exceed WQGs within MU-2; with West Line Creek having the highest observed concentrations. Based on data collected within West Line Creek, concentrations for selenium and nitrate are greater than WQGs but as illustrated within Figure 4-14.

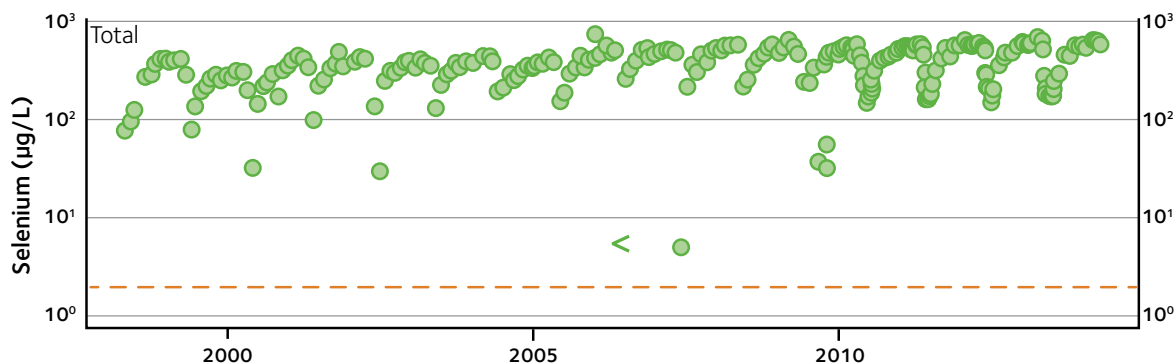


Figure 4-14. Selenium concentration as a function of time at West Line Creek (LC_WLC). Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is on a log scale within units of µg/L. Less-than symbols are plotted at the analytical detection limit.

Management Unit 3: Considering location-specific water quality parameters such as hardness, constituents identified as exceeding WQGs within tributaries of MU-3 include aluminum, ammonia, arsenic, cadmium, cobalt, copper, iron, nitrate, nitrite, selenium, silver, sulphate, and vanadium. Exceedances of WQGs for metals are summarized in Table 4-9.

Selenium (52% >WQG) is the constituent with the greatest number of observations in excess of the WQG. Other constituents exceed their respective WQGs infrequently, with exceedances largely associated with one sampling location (Wolfram Creek upstream of the settling pond; GH_WC2). This sampling location accounts for all recorded observations in which arsenic and copper concentrations are greater than WQGs. It also accounts for 90%, 50%, and 56% of the observed exceedances in cobalt, iron, and vanadium.

Table 4-9. Exceedances for total metals above chronic WQGs for protection of aquatic life in tributaries of MU-3.

Location	Description	Aluminum ¹	Arsenic	Cadmium	Cobalt	Copper	Iron	Selenium	Silver	Vanadium
GH_WILLOW_S	Willow Creek South	4/6 (2.8)	0/6	0/6	0/6	0/6	0/6	1/6 (1.7)	0/6	0/6
GH_WILLOW	Willow Creek North	0/31	0/31	0/31	0/31	0/31	0/31	7/55 (1.1)	0/31	0/31
GH_WADE	Wade Creek	0/21	0/21	0/21	0/21	0/21	3/21 (2.7)	1/32 (1.0)	0/21	1/21 (1.3)
GH_COUGAR	Cougar Creek	0/10	0/10	1/10 (1.1)	0/10	0/10	0/10	0/17	1/10 (1.8)	0/10
GH_MC1	Mickelson Cr. Above Elk River	0/23	0/23	1/23 (1.6)	0/23	0/23	0/23	9/36 (4.3)	0/23	0/23
GH_LC2	Leask Cr. U/S Pond inflow	0/24	0/24	1/24 (1.1)	1/24 (1.1)	0/24	3/24 (3.8)	34/34 (43)	0/24	2/24 (1.7)
GH_WC2	Wolfram Cr. U/S Pond inflow	0/28	1/28 (1.3)	2/28 (1.9)	9/28 (5.6)	1/28 (1.2)	7/28 (16)	40/40 (57)	1/28 (1.7)	5/28 (4.0)
GH_WC1	Wolfram Cr. Sediment Pond Decant	0/1	0/1	0/1	0/1	0/1	1/1 (2.1)	2/2 (16)	0/1	1/1 (1.4)
GH_TC1	Thompson Cr. At Bridge (pond bypass)	0/30	0/30	0/30	0/30	0/30	0/30	43/43 (81)	0/30	0/30
	Sub-Total =	4/174	1/174	5/174	10/174	1/174	14/174	137/265	2/174	9/174
	Percent Observed to Exceed WQG =	2%	0.6%	3%	6%	0.6%	8%	52%	1%	5%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

Note¹: The WQG for aluminum is based on the dissolved fraction (the fraction that passes through a 0.45 µm filter).

Exceedances of major cations and nutrients are shown in Table 4-10. Nitrate is the nutrient most frequently in excess of the WQG in tributaries (46% of samples). Other constituents rarely exceed their respective WQGs. As with metals exceeding WQGs within MU-3, Wolfram Creek upstream of the settling pond (GH_WC2) accounts for the majority of observed exceedances of inorganic nitrogen and sulfate guidelines. This one location accounts for 100%, 75%, and 57% of WQG exceedances recorded for ammonia, nitrite, and sulphate, respectively.

Table 4-10. Exceedances for total sulphate and nutrients above chronic WQGs for the protection of aquatic life in tributaries of MU-3.

Location	Description	Ammonia as N	Nitrite as N	Nitrate as N	Sulphate
GH_WILLOW_S	Willow Creek South	0/7	0/6	0/6	0/7
GH_WILLOW	Willow Creek North	0/56	0/55	0/55	0/56
GH_WADE	Wade Creek	0/33	0/32	0/32	0/33
GH_COUGAR	Cougar Creek	0/18	0/17	0/17	0/18
GH_MC1	Mickelson Cr. Above Elk River	0/37	0/36	0/36	0/37
GH_LC2	Leask Cr. U/S Pond inflow	0/35	3/34 (2.0)	34/34 (20)	0/35
GH_WC2	Wolfram Cr. U/S Pond inflow	6/42 (3.6)	9/40 (8.7)	40/40 (13)	13/42 (1.4)
GH_WC1	Wolfram Cr. Sediment Pond Decant	0/2	0/2	2/2 (4.1)	0/2
GH_TC1	Thompson Cr. Bridge (pond bypass)	0/46	0/43	42/43 (7.2)	23/46 (1.7)
Sub-Total =		6/276	12/265	118/265	36/276
Percent Observed to Exceed WQG =		2%	5%	46%	13%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

Management Unit 4: Considering location specific water quality parameters such as hardness, constituents identified as exceeding WQGs within tributaries of MU-4 include aluminum, ammonia, arsenic, cadmium, cobalt, copper, iron, nickel, nitrate, nitrite, selenium, silver, sulphate, thallium, uranium, and vanadium. Exceedances of WQGs for metals are summarized in Table 4-11.

Table 4-11. Exceedances for total metals above chronic WQGs for protection of aquatic life in tributaries of MU-4.

Location	Description	Aluminum ¹	Arsenic	Cadmium	Cobalt	Copper	Iron	Nickel	Selenium	Silver	Thallium	Uranium	Vanadium
EV_HC1	Harmer Creek Dam Spillway	0/62	0/62	0/62	0/62	0/62	0/62	0/62	62/62 (20)	0/62	0/62	0/62	0/62
EV_SM1	Six Mine Pond Decant	0/49	0/49	1/49 (1.0)	0/49	2/49 (1.1)	8/49 (7.3)	0/49	28/49 (1.7)	1/49 (1.8)	0/49	0/49	5/49 (4.3)
EV_GC2	Goddard Creek Sedimentation Pond Decant	0/80	0/80	1/80 (1.0)	0/80	0/80	3/80 (2.2)	0/80	80/80 (30)	0/80	0/80	0/80	1/80 (1.2)
EV_OC1	Otto Creek Near Mouth	0/63	0/63	1/63 (1.3)	0/63	0/63	3/63 (4.4)	0/63	25/63 (2.4)	0/63	0/63	0/63	0/63
CM_SPSP	7 Pit Pond Decant	0/19	0/19	0/19	0/19	0/19	2/19 (7.1)	0/19	0/19	0/19	0/19	0/19	1/19 (2.1)
CM_WD	West Ditch	10/27 (11)	0/28	8/28 (1.7)	9/28 (17)	0/28	9/28 (2.7)	8/28 (1.3)	28/28 (12)	0/28	0/28	0/28	0/28
CM_SPD	Main Pond Decant	0/49	2/49 (8.8)	2/49 (4.2)	49/49 (13)	2/49 (3.8)	0/49	10/49 (1.2)	49/49 (8.0)	2/49 (10)	2/49 (1.9)	0/49	2/49 (16)
CM_CC1	Corbin Cr. D/S CMO	0/96	0/96	2/96 (2.7)	49/96 (6.7)	0/96	0/96	0/96	95/95 (9.7)	0/96	2/96 (1.1)	0/96	0/96
CM_MC2	Michel Creek D/S CMO near Andy Goode Cr. Junction	0/82	0/82	0/82	2/82 (1.4)	0/82	8/82 (3.1)	0/82	81/81 (4.9)	0/82	0/82	0/82	0/82
CM_MCTM	Michel Creek Below Tent Mountain	0/42	0/42	0/42	0/42	0/42	0/42	0/42	35/42 (2.2)	0/42	0/42	0/42	0/42
EV_MC3	Michel Creek upstream of Erickson Creek	0/67	0/67	0/67	0/67	0/67	0/67	0/67	1/67 (1.3)	0/67	0/67	0/67	0/67
EV_EC1	Erickson Creek at Mouth	0/67	0/67	0/67	0/67	0/67	0/67	0/67	67/67 (65)	0/67	0/67	0/67	0/67
EV_SP1	South Pit Pond Decant	0/53	0/53	7/53 (2.4)	0/53	0/53	0/53	0/53	52/53 (156)	1/53 (1.8)	0/53	3/53 (1.1)	1/53 (1.7)
EV_MG1	Milligan Pond Decant	0/47	0/47	0/47	0/47	0/47	0/47	0/47	47/47 (72)	0/47	0/47	0/47	0/47
EV_GT1	Gate Creek Sedimentation Pond Decant	0/39	0/39	0/39	0/39	0/39	0/39	0/39	39/39 (149)	0/39	0/39	0/39	1/39 (1.7)
EV_BC1	Bodie Creek Sedimentation Pond Decant	0/67	0/67	0/67	0/67	0/67	0/67	0/67	67/67 (252)	0/67	0/67	0/67	0/67
EV_MC1	Michel Creek at Highway 43 Bridge	0/66	0/66	1/66 (2.4)	0/66	0/66	0/66	0/66	66/66 (7.8)	0/66	0/66	0/66	3/66 (2.6)
	Sub-Total =	10/976	2/976	23/976	109/976	4/976	33/976	18/976	822/974	4/976	4/976	3/976	14/976
	% Observed to Exceed WQG =	1%	0.2%	2%	11%	0.4%	3%	2%	84%	0.4%	0.4%	0.3%	1%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

Note¹: The WQG for aluminum is based on the dissolved fraction (the fraction that passes through a 0.45 µm filter).

Selenium has the greatest number of observations in excess of WQGs (84% of the samples). With the exception of cobalt, other constituents rarely exceeded WQGs and those infrequent exceedances are associated with seasonal flows (see Annex K.1). Two sampling stations (CM_CC1 and CM_SPD) account for 90% of the observed cobalt exceedances. As illustrated by Figure 4-15, cobalt concentrations at these two localized stations do not appear to be associated with a strong seasonal pattern. The elevated cobalt concentrations are localized within MU-4.

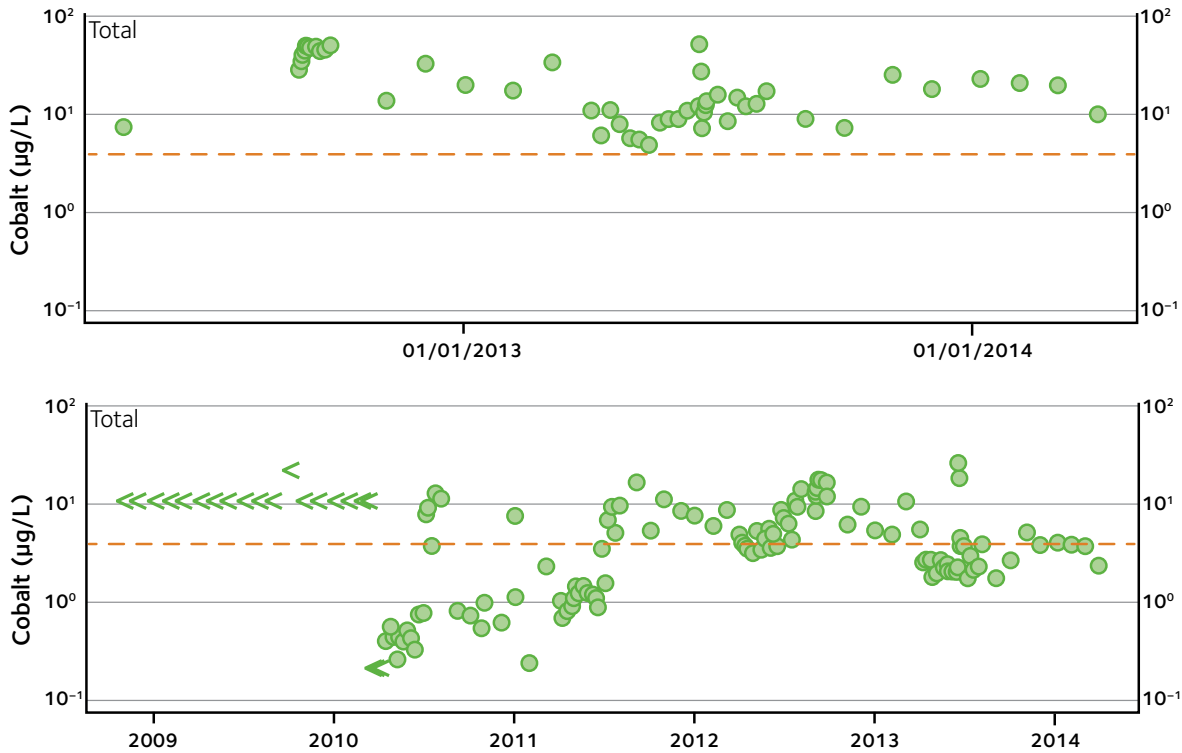


Figure 4-15. Cobalt concentration as a function of time at Main Pond Decant, “CM_SPD” (top panel), and at Corbin Cr. D/S CMO, “CM_CC1” (bottom panel). Note: The dashed orange line is the chronic B.C. MOE WQG. The y-axis is illustrated on a log scale within units of µg/L. Less than symbols are plotted at the analytical detection limit.

Unlike other management units where nitrate concentrations have typically exceeded WQGs less frequently than selenium, MU-4 uniquely exhibits more frequent exceedance of the sulphate WQG.

Corbin Creek (CM_CC1), Erickson Creek (EV_EC1), Bodie Creek (EV_BC1), and the South Pit decant (EV_SP1) account for approximately 79% of the elevated sulphate concentrations observed within MU-4 (Table 4-12, Figure 4-16). Data plots for all sampling stations are available in Annex K.1.

Table 4-12. Exceedances for total sulphate and nutrients above chronic WQGs for protection of aquatic life in tributaries of MU-4.

Location	Description	Ammonia as N	Nitrite as N	Nitrate as N	Sulphate
EV_HC1	Harmer Creek Dam Spillway	0/62	0/62	0/62	0/62
EV_SM1	Six Mine Pond Decant	0/49	0/49	0/49	0/49
EV_GC2	Goddard Creek Sedimentation Pond Decant	0/70	0/70	8/70	0/70
EV_OC1	Otto Creek Near Mouth	0/63	0/63	0/63	0/63
CM_SPSP	7 Pit Pond Decant	0/39	0/35	0/35	0/38
CM_WD	West Ditch	0/31	1/28 (1.4)	3/28 (3.4)	28/29 (2.6)
CM_SPD	Main Pond Decant	0/54	4/50 (2.0)	37/50 (5.2)	43/53 (2.1)
CM_CC1	Corbin Cr. D/S CMO	0/101	8/97 (2.3)	62/97 (2.8)	66/100 (1.6)
CM_MC2	Michel Creek D/S CMO near Andy Goode Cr. Junction	0/88	1/84 (1.1)	3/84 (1.3)	0/87
CM_MCTM	Michel Creek Below Tent Mountain	0/45	0/42	0/42	0/43
EV_MC3	Michel Creek upstream of Erickson Creek	0/67	0/67	0/66	0/67
EV_EC1	Erickson Creek at Mouth	0/67	0/67	67/67 (4.3)	67/67 (1.7)
EV_SP1	South Pit Pond Decant	0/53	1/53 (2.0)	52/53 (4.4)	52/53 (2.3)
EV_MG1	Milligan Pond Decant	1/47 (1.1)	3/47 (2.9)	0/47	16/47 (1.3)
EV_GT1	Gate Creek Sedimentation Pond Decant	0/39	0/39	39/39 (12)	35/39 (2.8)
EV_BC1	Bodie Creek Sedimentation Pond Decant	0/67	4/67 (1.1)	67/67 (31)	65/67 (2.6)
EV_MC1	Michel Creek at Highway 43 Bridge	0/66	0/66	0/66	0/66
Sub-Total =		1/1008	22/986	338/985	372/933
Percent Observed to Exceed WQG =		0.1%	2%	34%	40%

Note: Results are reported as the number of observations greater than the WQG (numerator) by the number of observations at the sampling station (denominator). For those constituents where an exceedance of the guideline was observed, a hazard quotient using the maximum concentration was calculated and is presented in brackets.

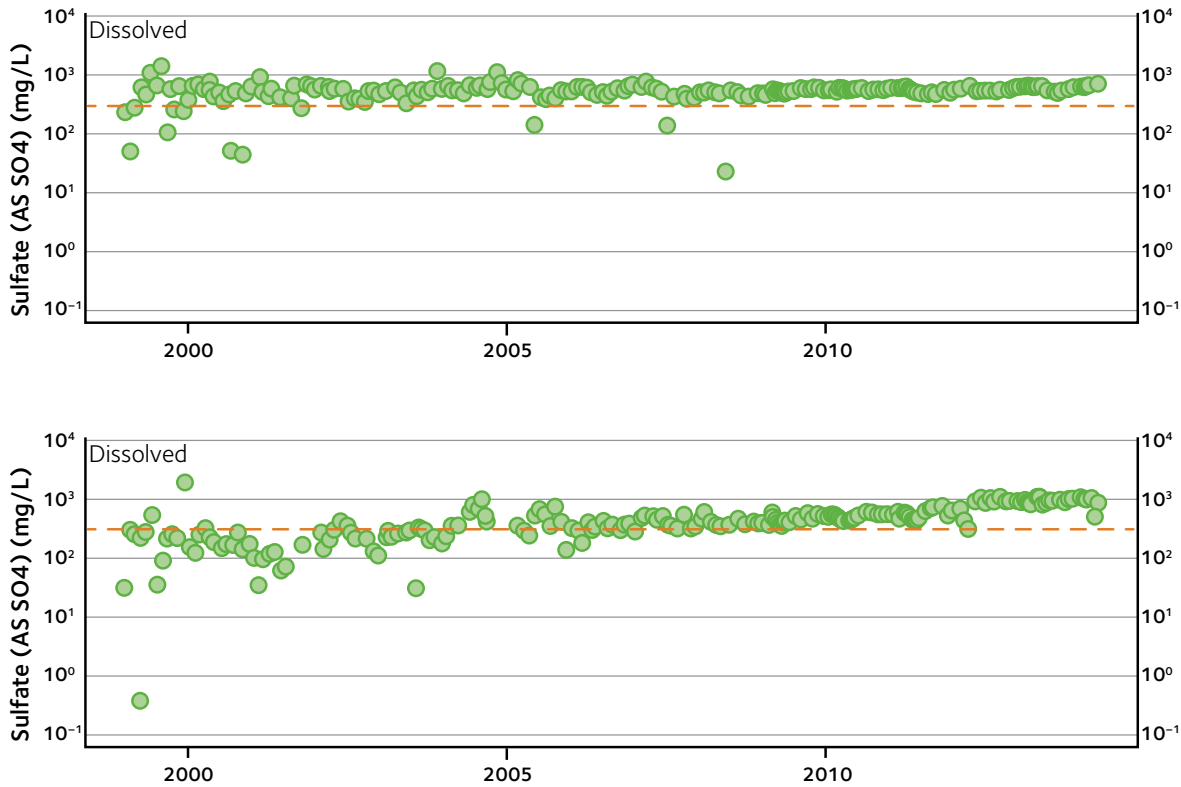


Figure 4-16. Sulphate concentrations as a function of time at Erikson Creek, “EV_EC1” (top panel), and at Bodie Creek Sedimentation Pond Decant, “EV_BC1” (bottom panel). Note: The dashed orange line is the chronic B.C. MOE WQG, plotted at 309 mg/L for moderately soft/hard to hard waters (76–180 mg/L as CaCO₃). The y-axis is on a log scale within units of mg/L.

Management Unit 5: No tributaries were identified within MU-5 as exceeding WQGs.

4.3.2 Sediment

Surface sediment data were collected from sampling locations throughout the Designated Area. These locations include: 1) mine-influenced (exposed) locations, 2) mine workings (e.g., settling ponds), and 3) reference locations. More than 350 sediment samples, analyzed for over 50 constituents, have been collected since 2011 and were used to assess current baseline conditions. Given that sediment samples collected within mine works (e.g. settling ponds) do not reflect ambient environmental conditions, they were not evaluated for the purpose of assessing baseline conditions. Sediment data associated with settling ponds are reported in Annex K.1.

Sediment data collected within the receiving environment were evaluated in a stepwise manner. In the first step, concentrations of respective constituents from exposed locations were compared to lower- and upper-sediment quality guidelines (SQGs), specifically:

Lower-SQGs

- Lowest Effects Level (LEL): the concentration at which most benthic organisms are unaffected.
- Threshold Effect Level (TEL) ≈ Interim Sediment Quality Guideline (ISQG): the concentration below which adverse biological effects are not expected to occur.

Sediments collected within Lake Koochanusa were also screened against the Threshold Effects Concentration (TEC; MacDonald et al. 2000). The TEC represents the geometric mean of SQGs identified at concentrations below which harmful effects on sediment-dwelling organisms are not expected. TECs considered in this consensus-based approach include TELs (Smith et al. 1996; US EPA 1996), effect-range low values (ERLs; Long and Morgan 1991), LELs (Persaud et al. 1993), and minimal-effect thresholds and sediment quality advisory levels.

Upper-SQGs

- Probable Effects Level (PEL): the concentration above which adverse effects are expected to occur frequently.
- Severe Effects Level (SEL): the concentration above which most benthic organisms are expected to be impaired.

As with to lower-SQGs, sediment data collected within Lake Koochanusa were also screened against the Probable Effects Concentration (PEC; MacDonald et al. 2000). The PEC represents the geometric mean of SQGs identified at concentrations above which harmful effects on sediment-dwelling organisms are expected to occur frequently. PECs considered in this consensus-based approach include PELs (Smith et al. 1996; US EPA 1996), effect range median values (ERMs; Long and Morgan 1991), SELs (Persaud et al. 1993), and toxic effect thresholds.

In the first step of the evaluation, maximum concentrations for the whole sediment fraction (≤ 1 mm)³ were compared with lower-SQGs. If no individual sample exceeded its lower-SQG (e.g., LEL, TEL, ISQG, or TEC), it was concluded that concentrations for that constituent did not exceed a guideline and as such, were not evaluated further.

If one sample exceeded the lower-SQG, the second step in the evaluation was to compare sediment concentrations with the upper-SQGs (e.g., PEL, SEL, or PEC). Samples that exceeded the upper-SQG were identified as having the potential to adversely affect sediment-dwelling organisms. Constituents with concentrations between the lower- and upper-SQGs were considered to have uncertain potential effects to benthic organisms. In both cases, these constituents and those for which there are no SQGs were carried forward to the third step of the analysis.

In the third step, sediment constituent concentrations were evaluated against reference samples. If more than 10% of sample concentrations at the location in question were greater than the 95th percentile of reference area (background) concentrations, it was concluded that the constituent was elevated relative to background levels, and likely the result of activities/discharges within the Designated Area.

4.3.2.1 Management Units 1-5 (Elk River Watershed)

A summary of the results for MU-1 through MU-5 (Elk River Watershed) and Lake Koochanusa are presented herein, with supporting data and associated screening steps presented in Annex K.

Constituents exceeding the lower-SQG and likely associated with point or non-point discharges include metals (arsenic, cadmium, copper, iron, manganese, nickel, selenium and zinc) and polycyclic aromatic hydrocarbons (phenanthrene and pyrene). Although identified as exceeding SQGs, elevated analytical detection limits for the polycyclic aromatic hydrocarbons at some locations introduces uncertainty for these two constituents. Of these 10 constituents, copper and iron were infrequently detected at concentrations above the lower-SQG (i.e., in

³ Instances where only the <63 μm fraction was available; data were evaluated in the same manner as for whole sediment fractions.

<10% of the samples). Copper exceeded the lower-SQG in only one sample (sampling location MI16), and iron exceeded the lower-SQG in only two samples (locations MI16 and NGC1).

Exceedances relative to SQGs in MUs-1 to MU-5 are summarized in Table 4-13 for constituents with exceedances in >10% of samples (i.e., excluding copper and iron). Four metal constituents listed in Table 4-12 had concentrations exceeding their upper-SQG, at the following locations:

- Cadmium: 5 of 5 samples at Upper Lake Mountain Creek (LAK2); 5 of 5 samples near the mouth of Swift Creek (SWI1), and 1 of 5 samples at Michel Creek Wetland (MI16)
- Nickel: 5 of 5 samples near the mouth of Swift Creek (SWI1)
- Zinc: 3 of 5 samples near the mouth of Swift Creek (SWI1).

These results indicate that potential impacts on sediment-dwelling organisms at those locations. As previously noted, there are uncertainties associated with the polycyclic aromatic hydrocarbon data due to elevated analytic detection limits.

In addition to bulk sediment chemistry, sediment toxicity tests were conducted on samples from the Fording River Oxbow (FO10), Goddard Marsh (GO13), and Elko Reservoir (ELKO). Tests evaluating potential effects on growth and survival were conducted using *Hyalella azteca* (a freshwater amphipod), and *Chironomus riparius* (a freshwater chironomid). When compared with laboratory control and reference-area samples, no adverse effects were observed in samples collected from the Fording River Oxbow or Elko Reservoir. At Goddard Marsh, three of five samples showed slightly impaired survival of freshwater chironomids compared to controls (i.e., ~76% survival compared with 98-100% survival in the controls). No adverse effects were observed in freshwater amphipods for these same samples. Given the incongruent toxicity tests results, it is uncertain if the reduction in survival at Goddard Marsh is due to metals contamination or other non-constituent factors (e.g., grain size).

4.3.2.2 Lake Koocanusa

To date, 90 sediment samples have been collected within the reservoir, extending down to the forebay of Libby Dam. Although SQGs are applicable to the whole sediment fraction (<2 mm or <1 mm), all data (including the <63 µm fraction) were compared with SQGs. Results of the analysis and comparison identified the following constituents as exceeding the lower-SQG: arsenic, cadmium, iron, manganese, and nickel. All other constituents were less than the lower-SQG.

Table 4-13. Sediment exceedances above sediment quality guidelines in MU-1 through MU-5.

MU	Sample location	Arsenic		Cadmium		Manganese		Nickel		Selenium		Zinc		Phenanthrene		Pyrene	
		Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG
1	CC1	--	--	--	--	--	--	--	--	--	--	--	--	5/5	3/5	3/5	0/5
	FMUCK	0/3	0/3	3/3	0/3	1/3	0/3	3/3	0/3	2/3	na	0/3	0/3	3/3	2/3	2/3	0/3
	FO10	0/5	0/5	5/5	0/5	0/5	0/5	5/5	0/5	5/5	na	0/5	0/5	5/5	5/5	3/5	0/5
	FOR3	--	--	--	--	--	--	--	--	--	--	--	--	5/5	4/5	3/5	0/5
	FOX1	0/5	0/5	5/5	0/5	0/5	0/5	4/5	0/5	5/5	na	0/5	0/5	5/5	3/5	0/5	0/5
	FR d/s DRCK	--	--	--	--	--	--	--	--	--	--	--	--	5/5	0/5	0/5	0/5
	FR u/s DRCK	--	--	--	--	--	--	--	--	--	--	--	--	5/5	3/5	0/5	0/5
	FR4	--	--	--	--	--	--	--	--	--	--	--	--	5/5	1/5	0/5	0/5
	FR4a	--	--	--	--	--	--	--	--	--	--	--	--	5/5	3/5	1/5	0/5
	FR5	--	--	--	--	--	--	--	--	--	--	--	--	5/5	2/5	0/5	0/5
	HE27	0/3	0/3	2/3	0/3	0/3	0/3	2/3	0/3	0/3	na	0/3	0/3	3/3	3/3	1/3	0/3
	HEN1	0/5	0/5	5/5	0/5	0/5	0/5	5/5	0/5	4/5	na	0/5	0/5	5/5	5/5	2/5	0/5
	KC4	--	--	--	--	--	--	--	--	--	--	--	--	5/5	0/5	1/5	0/5
	LAK1	--	--	--	--	--	--	--	--	--	--	--	--	5/5	5/5	0/5	0/5
	LAK2	0/5	0/5	5/5	5/5	0/5	0/5	5/5	0/5	5/5	na	5/5	0/5	5/5	4/5	4/5	0/5
	SW11	0/5	0/5	5/5	5/5	0/5	0/5	5/5	5/5	5/5	na	5/5	3/5	5/5	5/5	3/5	0/5
2	LC3	--	--	--	--	--	--	--	--	--	--	--	--	2/2	1/2	1/2	0/2
	LC5	--	--	--	--	--	--	--	--	--	--	--	--	5/5	2/5	2/5	0/5
3	ER2	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	na	0/5	0/5	5/5	0/5	0/5	0/5
	EROU	5/5	0/5	5/5	0/5	5/5	0/5	5/5	0/5	0/5	na	1/5	0/5	5/5	0/5	0/5	0/5
4	ELWDGC	1/3	0/3	3/3	0/3	3/3	0/3	3/3	0/3	0/3	na	0/3	0/3	3/3	0/3	0/3	0/3
	ER4	--	--	--	--	--	--	--	--	--	--	--	--	4/5	0/5	0/5	0/5
	GO13	3/5	0/5	5/5	0/5	5/5	0/5	5/5	0/5	4/5	na	2/5	0/5	5/5	5/5	5/5	0/5
	MI16	3/5	0/5	5/5	1/5	1/5	0/5	5/5	0/5	4/5	na	3/5	0/5	5/5	3/5	4/5	0/5
	MIWW	1/3	0/3	3/3	0/3	0/3	0/3	3/3	0/3	0/3	na	0/3	0/3	3/3	2/3	3/3	0/3
5	ELK1	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	0/10	na	0/10	0/10	9/10	0/10	0/10	0/10
	ELK2	0/5	0/5	4/5	0/5	0/5	0/5	2/5	0/5	1/5	na	0/5	0/5	5/5	0/5	0/5	0/5
	ELKO	0/5	0/5	5/5	0/5	0/5	0/5	4/5	0/5	0/5	na	0/5	0/5	5/5	0/5	4/5	0/5
	ER1	0/5	0/5	4/5	0/5	0/5	0/5	2/5	0/5	0/5	na	0/5	0/5	5/5	0/5	0/5	0/5
	EROL	1/5	0/5	5/5	0/5	1/5	0/5	4/5	0/5	1/5	na	0/5	0/5	5/5	1/5	4/5	0/5
	ERWSF	1/3	0/3	3/3	0/3	1/3	0/3	3/3	0/3	0/3	na	0/3	0/3	3/3	0/3	3/3	0/3
	SPW	0/3	0/3	3/3	0/3	3/3	0/3	3/3	0/3	3/3	na	0/3	0/3	3/3	0/3	0/3	0/3
	Sub-Total =	15/93	0/93	75/93	11/93	20/93	0/93	68/93	5/93	39/93	na	16/93	3/93	148/150	62/150	49/150	0/150
	Percent Observed to Exceed SQG =	16%	0%	81%	12%	22%	0%	73%	5%	42%	na	17%	3%	99%	41%	33%	0%

Note: Results are reported as the number of observations greater than the SQG (numerator) by the number of observations at the sampling station (denominator).

Note: Lower-SQGs include: Lowest Effects Level (LEL), Threshold Effects Level (TEL), and/or Interim Sediment Quality Guideline (ISQG). Upper SQGs include: Probable Effects Level (PEL) and/or Severe Effects Level (SEL).

Note: "--" = not analyzed, na = no guideline.

Note: Arsenic SQGs (Lower = 5.9 µg/g; Upper = 17 µg/g); Cadmium SQGs (Lower = 0.6 µg/g; Upper = 3.5 µg/g); Manganese SQGs (Lower = 460 µg/g; Upper = 1100 µg/g); Nickel SQGs (Lower = 16 µg/g; Upper = 75 µg/g); Selenium SQGs (Lower = 2 µg/g); Zinc SQGs (Lower = 123 µg/g; Upper = 315 µg/g); Phenanthrene SQGs (Lower = 0.0419 µg/g; Upper = 0.515 µg/g); and Pyrene SQGs (Lower = 0.053 µg/g; Upper = 0.875 µg/g).

Note: Exceedances of Phenanthrene and Pyrene are based on qualified data (i.e., non-detects). Given that analytical detection limits for these constituents were above the SQGs, results are uncertain.

Samples exceeding the lower-SQG were compared to the upper-SQG, to evaluate the potential for impacts on sediment-dwelling organisms. No constituents were identified as exceeding their respective upper-SQGs. Exceedances relative to SQGs are summarized in Table 414, and a graphical summary of the data is presented in Annex K.2.

4.3.3 Periphyton Productivity

Measurement of periphyton chlorophyll-a was initiated in 2012 and 2013 in several areas of the Elk River watershed, to examine differences between mine-exposed and reference areas (Annex K.1). Higher chlorophyll-a concentrations were observed in some near-field mine-exposed areas, compared to reference areas. With the exception of two samples that included bryophytes (not typically considered part of the periphyton community), and one sample from the Fording River where calcite deposition was evident, all chlorophyll-a concentrations were well below the WQG of 100 mg/m².

4.3.4 Benthic Invertebrate Community Health

A detailed assessment of benthic invertebrate community health in mine-exposed areas relative to reference areas was conducted in 2012 (Minnow 2014). Community samples were collected in September 2012 from 36 reference and 56 mine-exposed lotic areas, for assessment of potential mine-related effects on community composition. Reference areas were selected to represent a range of natural habitat characteristics exhibited by mine-exposed areas, such as elevation, stream size, catchment area, and catchment gradient, to ensure that each mine-exposed area could be matched with, and statistically compared to, a sub-set of reference areas with similar natural habitat characteristics. The reference areas were situated in the Elk River watershed upstream of mining inputs, and also in the upper Kootenay River watershed (B.C.) and in the Oldman River watershed (Alberta), where man-made disturbances were negligible⁴.

Using methods established in the scientific literature, community characteristics for each mine-exposed area was statistically compared to the characteristics reflected by the sub-group of reference areas with most similar habitat characteristics. Adverse effects were concluded for 20 mine-exposed areas, most of which were in mine-influenced tributaries near mine sources (Table 4.15). Adverse effects were generally reflected as reductions in the combined proportion of Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) (i.e., EPT), or the proportion of Ephemeroptera alone; these groups (particularly mayflies and stoneflies) dominated the invertebrate communities in reference areas, as well as mine-exposed areas that were considered to be in reference condition. Eighty-six per cent of the main stem receiving environments sampled had communities consistent with reference areas, including all areas sampled along the Elk River.

⁴ Detailed analyses of reference area data, completed in consultation with technical experts from BCMOE, identified that benthic invertebrate community characteristics were most strongly influenced by natural habitat characteristics and were not measurably influenced by the small amount of historical forestry activity in some reference watersheds (Minnow 2014).

Table 4-14. Summary of sediment exceedances above Sediment Quality Guidelines for the protection of aquatic life in Lake Koocanusa.¹

Location	Description	Arsenic		Cadmium		Iron		Manganese		Nickel	
		Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG	Lower-SQG	Upper-SQG
Transect 1	South of Kootenay mouth	0/7	0/7	0/7	0/7	2/7	0/7	2/7	0/7	0/7	0/7
Transect 2	North of Elk River mouth	0/12	0/12	0/12	0/12	12/12	0/12	10/12	0/12	5/12	0/12
Transect 3		0/7	0/7	0/7	0/7	2/7	0/7	2/7	0/7	0/7	0/7
Transect 4		0/12	0/12	2/12	0/12	9/12	0/12	10/12	0/12	5/12	0/12
Transect 5	South of Elk River mouth	0/6	0/6	0/6	0/6	3/6	0/6	4/6	0/6	0/6	0/6
Transect 6		0/5	0/5	0/5	0/5	0/5	0/5	2/5	0/5	0/6	0/5
Transect 7		0/5	0/5	0/5	0/5	3/5	0/5	5/5	0/5	0/6	0/5
K01KOOCL01	International Boundary	2/9	0/9	0/9	0/9	0/8	0/8	--	--	--	--
K01KOOCL02	Near Dodge Creek mouth	0/1	0/1	0/1	0/1	--	--	--	--	--	--
K01KOOCL03	Tenmile	3/8	0/8	0/8	0/8	0/8	0/8	--	--	--	--
K01KOOCL04	Forebay	1/8	0/8	0/8	0/8	0/8	0/8	--	--	--	--
Sub-Total =		6/80	0/80	2/80	0/80	31/78	0/78	35/54	0/54	10/56	0/56
Percent Observed to Exceed SQG =		8%	0%	3%	0%	39%	0%	65%	0%	18%	0%

Note: Results are reported as the number of observations greater than the SQG (numerator) by the number of observations at the sampling station (denominator).

Note: Lower-SQGs include: Lowest Effects Level (LEL), Threshold Effect Level (TEL), Interim Sediment Quality Guideline (ISQG), and/or Threshold Effects Concentration (TEC). Upper SQGs include: Probable Effects Level (PEL), Severe Effects Level (SEL), and/or Probable Effects Concentration (PEC).

Note: Transects 1 through 7 were collected in British Columbia, K01KOOCL01 through K01KOOCL04 were collected in Montana.

Note: "--" = not analyzed.

Note: Sediments collected in Montana are the <63 µm fraction.

Note: Arsenic SQGs (Lower = 9.8 µg/g; Upper = 33 µg/g); Cadmium SQGs (Lower = 5.0 µg/g; Upper = 5.0 µg/g); Iron SQGs (Lower = 21,200 µg/g; Upper = 43,766 µg/g); Manganese SQGs (Lower = 460 µg/g; Upper = 1100 µg/g); and Nickel SQGs (Lower = 22.7 µg/g; Upper = 48.6 µg/g).

Table 4-15. Effects on benthic invertebrate health in mine-exposed areas.

MU	Area code	Area description	Area type	Adversely affected based on statistical comparisons of community endpoints to habitat-matched reference areas?	Percent ephemeroptera (mayflies), plecoptera (stoneflies), trichoptera (caddisflies) ¹	Percent ephemeroptera (mayflies) ¹
1	FODHE	Fording d/s Henretta	Mainstem receiver	No	95	81
	FOUNGD	Fording u/s NGD	Mainstem receiver	No	79	60
	MP1	Fording Multiplate d/s Eagle Ponds	Mainstem receiver	Potentially	64	57
	FOUSH	Fording u/s Shandley Creek	Mainstem receiver	No	79	70
	FOUKI	Fording u/s Kilmarnock Creek	Mainstem receiver	No	84	75
	FOBKS	Fording between Kilmarnock & Swift	Mainstem receiver	No	79	70
	FOBSC	Fording d/s Swift, u/s Cataract	Mainstem receiver	Yes	63	49
	FOBCP	Fording between Cataract & Porter	Mainstem receiver	No	84	73
	FODPO	Fording d/s Porter, u/s Chauncey	Mainstem receiver	No	73	34
	FO22	Fording u/s Chauncey Creek	Mainstem receiver	Potentially	56	30
	FOUEW	Fording d/s Chauncey, u/s Ewin	Mainstem receiver	No	80	52
	FO28	Fording u/s Dry Creek	Mainstem receiver	No	93	61
	FO29	Fording d/s Dry, u/s GHO & Hwy Bridge	Mainstem receiver	Yes	59	51
	FODGH	Fording River d/s GHO	Mainstem receiver	No	88	59
	HENFO	Henretta u/s confluence with Fording	Mine-influenced tributary	No	82	61
	NGD1	Lower Lake Mountain Creek	Mine-influenced tributary	No	71	59
	KICK	Kilmarnock u/s road crossing near mouth	Mine-influenced tributary	Yes	8	3
	SWCK	Swift Creek near mouth	Mine-influenced tributary	Yes	65	1
	CACK	Cataract Creek near mouth	Mine-influenced tributary	Yes	2	0
	POCK	Porter Creek near mouth	Mine-influenced tributary	Yes	39	0
GHCKU	Greenhills Creek u/s of settling pond	Mine-influenced tributary	Yes	7	5	
	GHCKD	Greenhills Creek d/s of settling pond	Mine-influenced tributary	Yes	3	0
2	FO9	Fording d/s Josephine falls, u/s Grace & Line	Mainstem receiver	No	80	48
	FOUL	Fording d/s Grace, u/s Line	Mainstem receiver	Potentially	84	29
	L18	Line Creek d/s LCO	Mainstem receiver	Potentially	72	28
	FO23	Fording d/s Line Creek	Mainstem receiver	No	76	29
	L1LC3	Line d/s West Line, u/s South Line	Mine-influenced tributary	Yes	8	2
	L1DSL	Upper Line Creek, d/s South Line	Mine-influenced tributary	Yes	49	32
3	EL20	Elk River d/s Thompson & GHO	Mainstem receiver	No	93	48
	ELUEL	Elk River u/s Elkford	Mainstem receiver	No	94	58
	ELDEL	Elk River d/s Elkford sewage ponds	Mainstem receiver	No	93	48
	ELUFO	Elk River just u/s Fording	Mainstem receiver	No	71	36
	WOCK	Wolfram d/s pond	Mine-influenced tributary	Yes	12	2
	THCK	Thompson d/s pond	Mine-influenced tributary	Yes	68	1

MU	Area code	Area description	Area type	Adversely affected based on statistical comparisons of community endpoints to habitat-matched reference areas?	Percent ephemeroptera (mayflies), plecoptera (stoneflies), trichoptera (caddisflies) ¹	Percent ephemeroptera (mayflies) ¹
	EL19	Elk River d/s Fording, u/s Grave	Mainstem receiver	No	92	63
	ELDGR	Elk River d/s Grave	Mainstem receiver	No	88	47
	ELUSP	Elk d/s Otto, u/s Sparwood & Michel	Mainstem receiver	No	85	58
	MIUCO	Michel u/s Corbin Creek	Mainstem receiver	No	87	46
	MIDCO	Michel d/s Corbin, u/s Andy Good	Mainstem receiver	Yes	58	28
	MIDAG	Michel d/s Andy Good	Mainstem receiver	No	86	63
	MI5	Michel d/s CMO	Mainstem receiver	No	71	43
	MI3	Michel u/s Erickson Creek	Mainstem receiver	No	82	51
4	MI2	Michel Creek d/s EVO.	Mainstem receiver	Yes	52	16
	HACKUS	Harmer Creek u/s Harmer Pond	Mine-influenced tributary	No	76	32
	HACKDS	Harmer d/s Pond near mouth at Grave	Mine-influenced tributary	Yes	46	30
	GRCK	Grave Creek d/s Harmer	Mine-influenced tributary	No	81	53
	GRDS	Grave Creek near mouth at Elk	Mine-influenced tributary	Yes	61	29
	OCNM	Otto Creek near mouth	Mine-influenced tributary	Yes	38	13
	COCK	Corbin Creek near Mouth	Mine-influenced tributary	Yes	44	3
	ERCK	Erickson at CPR main line near mouth	Mine-influenced tributary	Yes	93	6
	BOCK	Bodie Creek d/s Bodie Pond	Mine-influenced tributary	Yes	28	1
	EL1	Elk d/s Sparwood & Michel	Mainstem receiver	No	79	44
	ELUFE	Elk u/s Fernie	Mainstem receiver	No	74	51
5	ELDFE	Elk d/s Fernie	Mainstem receiver	No	81	59
	ELELKO	Elk River u/s Elko	Mainstem receiver	No	85	54
	ELH93	Elk River u/s Hwy 93 Bridge	Mainstem receiver	No	77	46
Reference Areas	36 areas negligibly disturbed by mining or other man-made influences			Summary statistics, All reference areas combined²		
				Minimum	64	12
				5th Percentile	71	31
				Mean	86	49
				95th Percentile	97	67
			Maximum	97	82	

Note¹: Values less than the 5th percentile or less than the minimum of the combined reference areas are shaded light blue or dark blue, respectively. Also see footnote #2.

Note²: For general comparative purposes, summary statistics are presented for all reference areas combined, but each mine-exposed areas was statistically compared with a sub-group of reference areas based on similar habitat characteristics. Details are presented in Minnow (2014).

4.3.5 Fish Populations

Westslope cutthroat trout is commonly found in lotic and lentic habitats throughout the Elk River watershed and is the only fish species present in the Fording River upstream of Josephine Falls. In addition to cutthroat trout, bull trout (*Salvelinus confluentus*) and mountain whitefish (*Prosopium williamsoni*) are native to the Elk River basin, although they are usually only found in the main stem and in lower reaches of larger tributaries such as the Fording River, Line Creek, Alexander Creek, and Michel Creek (Wilkinson 2009; Robinson 2011). Rainbow trout (*Oncorhynchus mykiss*) is a non-native species that generally resides in lakes but spawns in adjacent streams; it was introduced to the Elk River basin through stocking programs at Grave Lake and Summit Lake and possibly other locations (Wilkinson 2009). Eastern brook trout (*Salvelinus fontinalis*) is another non-native species; it occurs mostly in the Michel Creek basin, although isolated populations also occur in beaver ponds along the Elk River up to Forsyth Creek (Wilkinson 2009; Robinson 2011). There are also patchy distributions of several other species, such as longnose sucker (*Catostomus catostomus*) and longnose dace (*Rhinichthys cataractae*), which mainly occupy slow-flowing side channels, oxbows, ponds, and lakes at lower elevations along or near the Elk River downstream of Elkford (Robinson 2011; LePage 2013).

Based on this knowledge, cutthroat trout has been identified as a representative species for monitoring mine-related effects on fish in lotic areas of the Elk River watershed. Longnose sucker was identified as a suitable species for monitoring mine-related influences in lentic habitats. In addition to understanding population dynamics, identifying and tracking the health of fish (e.g., growth, condition, abnormalities) is important for assessing fish population status. Fish population monitoring requires multiple years of study to understand and quantify basic population characteristics and begin to comprehend potential changes over time and relationships to stressors (e.g., mining, angling, extreme weather events). Cutthroat trout and longnose sucker studies were initiated in 2012 and 2013 to collect baseline data to inform the development of future monitoring (e.g., RAEMP) and assess appropriate monitoring endpoints, and determine what the most effective monitoring methods are to evaluate mine-related influences on population characteristics and fish health.

A multi-year study (2012–2015, inclusive) of cutthroat trout in the upper Fording River watershed is underway to assess population status, seasonal movements, and habitat use, which will inform mine mitigation and fish habitat management decisions (Cope et al. 2014). Unlike the lower Fording River and the remainder of the Elk River watershed, WCT in the upper Fording River are isolated from confounding factors (e.g., angling, competition from other fish species, hybridization, potential effects related to agricultural development) that could affect population stability and fish health. Literature on Population Viability Analyses (PVA) and Recovery Potential Assessments for WCT has shown that a viable population can range between 470 and 4,600 adults (Cope et al. 2014), depending on the methodology used. Also, between 9 and 28 km of stream is required to maintain an isolated population. To date, monitoring of fry, juveniles, sub-adults, and adults indicates that the westslope cutthroat trout population of the upper Fording River is stable at about 3,000 adults having access to 57.6 km of habitat. Based on Fulton's condition indices, Upper Fording River Westslope Cutthroat trout also appear to be robust and exhibit low rates of deformities.

In 2013, a study of longnose sucker presence/absence, abundance (density), and health was initiated at a variety of lentic areas to inform the design of the RAEMP. No differences in biomass, growth rates and body condition were found among the areas studied (Robinson and Arnett 2014). Of the 13 areas surveyed, eight were recommended for future monitoring based on high densities of LSU and the ability to isolate, and thus quantitatively monitor, populations for density determination.

4.3.6 Tissue Concentrations in Receptors (Bioaccumulation)

Baseline conditions within tissues of periphyton, invertebrates, fish (whole body, muscle, ovary/gonad), amphibians (egg masses), and birds eggs were evaluated by completing a screening-level ecological risk assessment (SLERA). A copy of the SLERA is provided in Annex K.1. The first step of the SLERA was to compare the available provincial or federal CCME tissue guidelines to the tissue-specific 95th percentile concentration of pooled reference tissue data⁵. If provincial or federal guidelines were not available, screening-level dietary effect threshold toxicity reference values (TRVs) were used. This step was completed to determine if the available tissue guidelines and TRVs were appropriately conservative to evaluate the Designated Area relative to the reference areas. If the tissue-specific 95th percentile reference concentration of a given constituent was greater than the available guideline or TRV, then the reference concentration was selected as the screening value used in the SLERA.

As a conservative⁶ second step, constituents⁷ were evaluated based on a comparison of the maximum tissue concentration to the screening value selected in the first step. Results identified the following constituents as exceeding a guideline, TRV, or 95th percentile reference concentration (whichever was greater) in at least one sample within the Designated Area: aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, manganese, mercury, nickel, selenium, vanadium, and zinc. As these constituents had at least one concentration from an exposed sampling location greater than the 95th percentile of the reference tissue type, they were considered the potential result of a point or non-point source. Constituents for which sample concentrations fell below the 95th percentile reference concentrations were not associated with a point or non-point source, and as such were not evaluated further.

The next step in the evaluation involved calculating an exposure-point concentration. Exposure-point concentrations representative of MU populations were calculated as the 95th percentile for constituent concentrations in respective tissue types (periphyton, invertebrate, fish [whole body and muscle], amphibian egg masses, and bird egg tissue). The 95th percentile concentrations for each MU were then compared with dietary- and tissue-based screening values (as applicable to each constituent), to evaluate prey-tissue-specific and MU-specific hazard quotients (HQs) for each receptor. Hazard quotients were not calculated for prey-tissue types for which the maximum detected concentration did not exceed the corresponding dietary or tissue screening value. A summary of results is shown in Table 4-16. Shaded cells identify constituents for which the tissue-specific 95th percentile concentration did not exceed the corresponding screening value. Nine of the 13 COIs identified in the second step of the SLERA had MU-specific HQs greater than 1.0 for at least one tissue type in at least one MU.

For each MU with a 95th percentile HQ greater than 1.0, station-specific HQs were calculated based on the maximum concentration at each station within that MU. Station-specific maximum HQs were not calculated when constituent concentrations within an MU were less than the screening value. As shown in Table 4-16, MU-1 and MU-5 had the greatest frequency of tissue- and MU-specific 95th percentile concentrations that exceeded the respective screening value. Selenium had the greatest frequency of MU-specific HQs > 1.0 among all tissue types and all receptors except mammals (Table 4-16). Further details of the MU-specific and station-specific evaluations are provided in Annex K.1.

⁵ To facilitate comparisons between exposed and reference locations in each MU, reference data were pooled per tissue type. Summary statistics, including the mean, median, minimum, maximum, and 95th percentile concentration of each constituent, were calculated and are presented in Annex K.1.

⁶ Tissue guidelines are based on the average concentration and not a maximum concentration. For instance, the chronic dietary guideline to protect fish and aquatic-dependent wildlife is 4 µg/g selenium (dry weight) measured as the mean concentration of at least eight replicate (composite) tissue samples representing invertebrate or other prey species. Therefore the approach used to evaluate current baseline conditions with the maximum concentration is anticipated to be conservative.

⁷ Constituents evaluated included: aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, calcium, cesium, chlorine, chromium, cobalt, copper, gallium, iron, lead, lithium, magnesium, manganese, mercury, molybdenum, nickel, phosphorous, potassium, rhenium, rubidium, selenium, silicon, silver, sodium, strontium, sulfur, tellurium, thallium, thorium, tin, titanium, uranium, vanadium, yttrium, zinc, and zirconium.

Table 4-16. Number of samples that exceed a chronic dietary tissue guideline or toxicity reference value and have a concentration greater than the 95th percentile of reference conditions.

COI	Tissue type	Receptor LOE	95th percentile hazard quotients					
			MU-1	MU-2	MU-3	MU-4	MU-5	L. Koocanusa
Cadmium	invertebrates	fish diet	0.82	1.1	0.32	0.48	0.40	0.47
	invertebrates	fish diet	3.4	0.52	0.51	2.0	2.1	2.3
Chromium	fish (WB/muscle)	bird diet	2.5	0.42	0.6	1.6	2	1.2
		fish diet	2.6	0.98	0.48	3.2	1.7	2.1
	amphibian egg mass	fish diet	2.5	--	--	0.50	2.7	1.1
Copper	invertebrates	bird diet	0.91	1.4	1.3	1.2	1.1	0.76
Manganese	periphyton	invertebrate diet	0.93	0.27	0.93	0.41	3.1	0.25
		fish diet	1.4	0.66	1.3	0.78	1.2	0.32
	invertebrates	bird diet	1.7	0.79	1.6	0.94	1.5	0.38
Mercury	fish (WB/muscle)	fish diet	0.27	1.8	--	0.7	0.98	3.3
		bird diet	0.27	3.8	--	1.5	2.0	6.8
	mammal diet	0.20	1.4	--	0.52	0.73	2.4	
Nickel	periphyton	invertebrate diet	1.7	0.74	3.3	0.49	0.27	2.6
		amphibian diet	2.4	3.6	4.3	2.8	1.1	0.73
	invertebrates	invertebrate tissue	2.1	1.9	2.2	1.6	1.2	0.55
Selenium	invertebrates	fish diet	2.5	2.3	2.6	1.9	1.4	0.65
		amphibian diet	3.4	3.0	3.5	2.6	1.9	0.87
	fish (reproductive)	bird diet	1.9	1.7	1.9	1.4	1.0	0.48
		fish egg	2.5	1.3	0.44	1.7	1.5	0.42
	fish (WB/muscle)	fish diet	3.8	1.2	1.1	4.2	1.3	0.46
		bird diet	2.8	0.87	0.78	3.1	0.92	0.34
	amphibian egg mass	fish diet	1.3	0.95	--	1.4	1.5	0.41
bird diet		0.97	0.69	--	1.0	1.1	0.30	
bird eggs	bird egg	1.9	1.7	2.9	1.5	0.63	0.63	
Vadium	amphibian egg mass	fish diet	1.2	--	--	1.2	0.088	1.0
Zinc	periphyton	invertebrate diet	5.8	1.6	1.7	0.49	0.51	0.43
	invertebrates	bird diet	0.71	0.99	0.79	0.89	1.2	0.86

Note: Results are reported quotient of the 95th percentile concentration of each MU (numerator) and the applicable screening value (denominator), which was the tissue guideline, toxicity reference value, or 95th percentile reference concentration (whichever was greater).
 1. Note: WB = whole body, LOE = line of evidence, "--" = not analyzed (no exposed data available)

Selenium was the only constituent identified as a primary tissue constituent of potential concern for aquatic biota (see Annex K.1). Manganese, nickel, and zinc exposure concentrations in periphyton exceeded effects-based thresholds for herbivorous invertebrates in at least one MU. Specifically, an HQ of 1.3 was calculated for manganese in MU-5, HQs of 2.2 and 2.4 were calculated for nickel in MU-3 and Lake Kooconusa respectively; and an HQ of 2.4 was calculated in MU-1 for zinc. In consideration of the conservative nature of the dietary-effect thresholds for these trace elements, their lack of tissue-based effects, and that calculated exceedances were spatially limited, it is not anticipated that these are tissue constituents of potential concern within the Designated Area.

Tissue selenium concentrations within the Designated Area, however, routinely approached or exceeded an HQ of 1, and the scientific literature recognizes the potential for reproductive effects due to elevated selenium tissue concentrations. HQs for selenium (HQ_{Se}) as calculated for fish ovary/egg based on the 95th percentile by MU are as follows:

- MU-1: $HQ_{Se} = 2.5$
- MU-2: $HQ_{Se} = 1.3$
- MU-3: $HQ_{Se} = 0.4$
- MU-4: $HQ_{Se} = 1.7$
- MU-5: $HQ_{Se} = 1.5$
- Lake Kooconusa: $HQ_{Se} = 0.6$.

As indicated by the above results, with the exception of MU-3 and Lake Kooconusa, calculated HQs for selenium in fish ovary/egg tissues generally exceed 1 indicating the potential for adverse effects. Additional analyses were completed and are summarized for Lake Kooconusa in Section 4.3.6.1.

4.3.6.1 Lake Kooconusa – Fish Tissue

Selenium concentrations measured in fish (whole body/muscle) tissues within Lake Kooconusa are presented within Table 4-17. To date 10 fish species have been sampled, five of which (longnose sucker, mountain whitefish, peamouth chub, rainbow trout and westslope cutthroat trout) have had individuals with tissue concentrations greater than the B.C. WQG (4 mg/kg dw). Of those five species, one mountain whitefish sample was identified as also exceeding the 2014 draft EPA criterion (whole body = 8.1 mg/kg dw).

For the five fish species identified as exceeding the B.C. WQG, the frequency of exceedances are as follows: westslope cutthroat trout (70% of samples), longnose sucker (56% of samples), mountain whitefish (50% of samples), peamouth chub (19% of samples), and rainbow trout (4% of samples); refer to Table 4-18.

Burbot fish tissue data have been reported (see Table 4-17), however desiccation during sample storage, prior to analysis, introduces sufficient uncertainty to render the data uninterpretable. As a result, although summary statistics have been presented, these data cannot be meaningfully evaluated against guidelines or criterion. In addition to selenium, the fish tissue residue guideline (0.033 μ g/g ww) to protect wildlife from mercury toxicity was exceeded. Given that mercury is typically a concern from a human health perspective, an analysis for human health is described in Chapter 5 based on the mercury fish tissue water quality guideline from Health Canada of 0.5 μ g/g wet weight (as approved by BCMOE).

Unlike fish whole body/muscle tissue data, ovary selenium samples collected within the reservoir are limited. As noted within the BC WQG, the chronic egg/ovary tissue guideline (11 mg/kg dw) is based on the mean concentration of at least eight samples. Therefore, although 8 fish species have been sampled for reproductive tissues (ovary/gonads), only 50% have sufficient data to compare against the guideline. As indicated within Table 4-18, insufficient data (sample size (N) = <8) to compare against the BC WQG are available for largescale sucker, mountain whitefish, rainbow trout, and westslope cutthroat trout. As a result, the summary statistics

and evaluation against the WQG for these four species should be considered qualitative. Only data collected from peamouth chub can be directly compared to the BC WQG due to sufficient sample size (N = 81 samples).

Of the 81 peamouth chub samples collected to date, 11 samples (14%) were identified as exceeding the BC WQG, see Table 4-19. Although the other fish species have insufficient data to be compared against the BC WQG they were compared to the draft EPA criteria. Comparing tissue concentrations against the draft EPA criteria identifies exceedances for mountain whitefish (3 out of 7 samples; 43%), westslope cutthroat trout (1 out of 7 samples; 14%), and peamouth chub (2 out of 81 samples; 2%). No other fish species exceeded the EPA criteria.

Table 4-17. Summary of fish tissue selenium concentrations (mg/kg dry weight) in Lake Kocanusa

Species	Year	Tissue	N	Min	Max	Average	Std.Dev.	Samples exceeding criteria					
								B.C. WQG	EPA (KY)	EPA Draft			
Bull trout (BT)													
	2007	Muscle	19	1.1	2.0	1.7	0.24	0	0%	0	0%	0	0%
	2008	Muscle	39	0.1	2.0	1.7	0.35	0	0%	0	0%	0	0%
	2013	Muscle	34	2.0	4.0	2.7	0.56	0	0%	0	0%	0	0%
Kokanee (KKN)													
	2007	Muscle	20	1.3	2.1	1.7	0.23	0	0%	0	0%	0	0%
	2008	Muscle	60	1.3	2.4	1.8	0.24	0	0%	0	0%	0	0%
		Whole	20	1.9	3.2	2.5	0.28	0	0%	0	0%	0	0%
	2013	Muscle	37	1.6	2.8	2.2	0.29	0	0%	0	0%	0	0%
Longnose sucker (LNS)													
	2007	Muscle	14	2.5	5.1	3.5	0.77	4	29%	0	0%	0	0%
	2008	Muscle	28	2.5	5.1	3.5	0.75	8	29%	0	0%	0	0%
	2013	Muscle	32	1.5	6.8	5.5	1.0	30	94%	0	0%	0	0%
Largescale sucker (LSS)													
	2009	Whole	10	1.9	2.9	2.4	0.32	0	0%	0	0%	0	0%
Mountain whitefish (MWF)													
	2007	Muscle	2	2.0	2.9	2.5	0.64	0	0%	0	0%	0	0%
	2008	Muscle	4	2.0	2.9	2.5	0.52	0	0%	0	0%	0	0%
	2009	Whole	10	2.1	16	6.5	3.7	9	90%	1	10%	1	10%
	2012	Muscle	6	2.7	4.6	3.4	0.79	2	33%	0	0%	0	0%
Northern pikeminnow (NPM)													
	2007	Muscle	20	1.0	1.9	1.3	0.27	0	0%	0	0%	0	0%
	2008	Muscle	40	1.0	1.9	1.3	0.27	0	0%	0	0%	0	0%
	2013	Muscle	44	1.3	3.7	2.1	0.60	0	0%	0	0%	0	0%
Peamouth chub (PMC)													
	2007	Muscle	20	1.7	4.6	2.9	0.82	3	15%	0	0%	0	0%
	2008	Muscle	50	1.7	6.4	3.0	0.99	9	18%	0	0%	0	0%
		Whole	10	2.4	4.2	3.4	0.54	1	10%	0	0%	0	0%
	2009	Whole	10	1.5	3.3	2.3	0.56	0	0%	0	0%	0	0%
	2013	Muscle	48	1.7	8.4	3.6	1.5	13	27%	0	0%	0	0%
Rainbow trout (RBT)													
	2007	Muscle	2	1.5	1.6	1.6	0.071	0	0%	0	0%	0	0%
	2008	Muscle	4	1.5	1.6	1.6	0.058	0	0%	0	0%	0	0%
	2013	Muscle	17	1.9	4.1	2.6	0.56	1	6%	0	0%	0	0%
Westslope cutthroat trout (WCT)													
	2009	Whole	10	2.8	7.7	5.4	1.4	9	90%	0	0%	0	0%
	2012	Muscle	5	3.5	5.3	4.6	0.77	4	80%	0	0%	0	0%
	2013	Muscle	8	1.4	6.1	3.9	1.5	3	38%	0	0%	0	0%
Burbot biopsy (BRB)^a													
	2013	Muscle	56	0.72	8.1	4.0	1.7	na	na	na	na	na	na
Total (excludes BRB)		Whole	70					19	27%	1	1%	1	1%
		Muscle	553					77	14%	0	0%	0	0%
Grand Total = 623								96	15%	1	0.2%	1	0.2%

Note^a: - Burbot biopsy concentrations are estimated due to uncertainties associated with moisture content and sample desiccation.

Table 4-18. Summary of fish reproductive tissue selenium concentrations (mg/kg dry weight) in Lake Kooconusa.

Species	Year	Tissue	N	Min	Max	Average	Samples Exceeding Criteria					
							BC WQG		EPA (KY)		EPA Draft	
Kokanee (KKN)												
	2008	Gonads	40	2.9	4.9	3.7	0	0%	0	0%	0	0%
		Ovary	18	2.8	4.8	3.8	0	0%	0	0%	0	0%
	2013	Gonads	28	3.1	5.6	4.2	0	0%	0	0%	0	0%
Longnose sucker (LNS)												
	2008	Gonads	8	4.0	5.6	4.8	0	0%	0	0%	0	0%
	2013	Gonads	1	6.9	6.9	6.9	0	0%	0	0%	0	0%
Largescale sucker (LSS)												
	2009	Ovary	1	3.9	3.9	3.9	0	0%	0	0%	0	0%
Mountain whitefish (MWF)												
	2009	Ovary	1	13	13	13	1	100%	0	0%	0	0%
	2012	Ovary	6	8.9	24	17	5	83%	3	50%	3	50%
Northern pikeminnow (NPM)												
	2008	Gonads	36	2.5	5.9	3.6	0	0%	0	0%	0	0%
	2013	Gonads	24	2.4	8.1	3.9	0	0%	0	0%	0	0%
Peamouth chub (PMC)												
	2008	Gonads	40	4.0	12	7.3	4	10%	0	0%	0	0%
		Ovary	10	5.0	11	7.8	1	10%	0	0%	0	0%
	2013	Gonads	31	5.4	22	9.1	6	19%	1	3%	2	6%
Rainbow trout (RBT)												
	2013	Gonads	2	4.7	4.8	4.7	0	0%	0	0%	0	0%
Westslope cutthroat trout (WCT)												
	2009	Ovary	6	6.7	17	11	3	50%	0	0%	1	17%
	2013	Gonads	1	10	10	10	0	0%	0	0%	0	0%
	Total	Ovary	42				7	17%	3	7%	3	7%
		Gonad	211				10	5%	1	0%	2	1%
Grand Total =			253				17	7%	4	2%	5	2%

4.4 Cumulative Impacts on Environmental Quality

The previous sections of this chapter outline, on a medium-specific basis, the frequency and location of constituent concentrations that exceed WQGs, SQGs, and dietary guidelines. This section considers the various lines of evidence collected within each Management Unit to comment on the aquatic environmental health of the Designated Area. Lines of evidence considered are water quality (Section 4.3.1), sediment quality (Section 4.3.2), tissue concentrations (Section 4.3.3) and benthic invertebrate community structure (Annex K.1).

- 2013 water quality data were summarized using the Canadian water quality index (WQI), which takes into account the total number of analytes being considered and the number and magnitude of exceedances of guidelines or alternative benchmarks at each sampling location. Guidelines that depend on other water quality factors (e.g., hardness) were applied using sample-specific values. The WQI User Manual (CCME 2001) states that the specific variables, objectives, and time period used in the index may vary from region to region, depending on local conditions and issues. Consistent with this, site-specific (Elk Valley) benchmarks were used for selenium, nitrate, and sulphate to make the results more realistic than generic guidelines with respect to potential effects.
- 2011 and 2013 sediment quality was summarized using the Canadian sediment quality index. High sediment quality guidelines were used because the low sediment guidelines are within the range of reference area concentrations for most analytes.
- As identified within Annex K.1, selenium is the only mine-related constituent that bioaccumulates in tissues of aquatic and aquatic-dependent biota at concentrations of potential concern. Therefore, selenium hazard quotients were evaluated for resident/sessile (periphyton, benthic invertebrate) and mobile (fish, amphibians, birds) species.
- Benthic invertebrate community health was evaluated using data collected in 2012 (Minnow 2014) Criteria used to categorize the health of communities were derived from a review of the ranges of two endpoints (combined Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies] [EPT], as well as percent Ephemeroptera alone) in reference areas, as well as mine-influenced areas determined by detailed statistical comparisons to be within reference condition (see Table 4-15).

Results of the 2012 benthic invertebrate community assessment are considered to be a particularly important line of evidence of aquatic environmental quality at each location, because the organisms integrate the cumulative effects of exposure to multiple stressors over time and their sessile behavior means that they are excellent indicators of localized conditions. Comparison of the various lines of evidenced showed that where benthic invertebrate quality was within reference conditions, WQI results were typically also good or fair, there was little or no calcite, and invertebrate tissue selenium concentrations were below levels associated with effects on the invertebrates themselves as well as to consumers (fish or birds). Likewise, areas with affected benthic invertebrate communities were typically associated with poorer water quality and/or the presence of calcite.

4.4.1 Management Units 1 through 5

Lotic Areas: Aquatic environmental quality was evaluated for 15 reference areas, 20 discharge tributaries, and 36 main stem areas within the Elk River watershed. Benthic invertebrate communities were adversely affected within 65% of mine-influenced tributaries. It is important to remember that data collection activities conducted to date within the Designated Area were not designed to evaluate its overall environmental health. Rather, they have focused on tributaries known to have elevated concentrations of mine-related constituents. Examples of such tributaries include:

- Kilmarnock, Swift, Cataract, Porter, and Greenhills Creeks in MU-1
- Line Creek downstream of the rock drain and West Line Creek in MU-2
- Wolfram and Thompson Creeks in MU-3
- Otto, Corbin, Erickson, and Bodie Creeks in MU-4.

These tributaries tend to have elevated concentrations of mine-related substances (e.g., reduced WQI scores) and/or visible calcite deposits. They also contribute most of the mine-related loads of selenium, nitrate, and sulphate to the watershed.

All reference areas were considered to have healthy benthic invertebrate communities, good water quality, and little to no calcite deposition. Similarly, 86% of all areas along the main stem of the Elk River, Fording River, Line Creek, and Michel Creek have healthy benthic invertebrate communities, including all areas along the Elk River.

Elevated tissue selenium concentrations and associated HQs were observed in almost half of the 61 lotic areas for which tissue data are available. Some of these were fish captured in reference areas uninfluenced by mining, which is evidence that the tissues of mobile vertebrate species do not always reflect conditions in the area of capture.

Off-Channel Areas: Invertebrate or vertebrate tissue concentrations greater than toxicity reference values (e.g., HQ>1) were observed in about 35% of off-channel habitats evaluated, excluding reference areas and mine settling ponds. The highest HQs among all MUs were observed at the Fording River Oxbow (MU-1) and Goddard Marsh (MU-4).

4.4.2 Lake Koocanusa

Surface water quality, sediment quality and constituent concentrations in aquatic organism tissues have been monitored at multiple locations throughout the reservoir. To date selenium is the one constituent that has been identified within the reservoir to exceed guidelines and requires continued monitoring.

4.5 Summary

Selenium and nitrate concentrations in surface waters of the Elk River watershed are routinely elevated above water quality guidelines and are increasing in many areas. In addition, there is evidence that selenium is bio-accumulating in tissues (e.g., benthic invertebrates, fish) to levels that may adversely affect aquatic receptors in some areas. To date, biological monitoring programs in the Designated Area do not indicate that regional effects are occurring. Localized effects observed close to point sources (e.g., change in benthic community structure within tributaries) have however been observed. Therefore for the purposes of the Plan and based on the evaluation of current baseline conditions, efforts should focus on reducing selenium and nitrate to concentrations that will protect of aquatic life.

As indicated by the evaluation of current baseline data, there are a limited number of data gaps and uncertainties associated with certain medium and constituents. For instance, elevated analytical detection limits (e.g., polycyclic aromatic hydrocarbons) for sediment samples introduces uncertainties associated with comparison to guidelines. Similarly ongoing studies (e.g., westslope cutthroat trout fisheries study) when complete will help address such data gaps/uncertainties (refer to Annex K.1).

Chapter 5

Assessment of Protection of Human Health and Groundwater

Chapter Overview

This chapter outlines results of the assessment of potential impacts of water quality on human health and how the Plan addresses this topic. It also summarizes the results of a regional drinking water evaluation and sampling program.

Concordance with Ministerial Order and Terms of Reference

Chapter 5 satisfies Section B.1 and B.2 of Schedule C of Ministerial Order M113 and sections 3.4 and 3.8(a) and 3.8(b) of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Comprehensive two-phase approach to evaluate potential effects on human health.** Current baseline water quality was first assessed by comparing concentrations in surface water, sediment, fish tissue and groundwater to provincial guidelines. Any constituents that exceeded guidelines, and those for which no guideline is available, were analyzed in a second phase. In the second phase, estimates of average concentrations were compared to conservative health-protective benchmarks for each pathway (e.g., swimming, incidental ingestion, eating fish or drinking groundwater).
- **No unacceptable human health risks identified based on current water quality.** Teck undertook extensive studies of the effects of current water quality on human health, including testing of groundwater wells. Results show no unacceptable human health risks associated with current concentrations of constituents in water, sediment or fish.
- **Surface water quality management will protect groundwater for drinking water in floodplain areas.** Groundwater is intrinsically tied to surface water in parts of the Elk Valley. Reducing and managing surface water levels of selenium, cadmium, nitrate and sulphate through implementation of the Plan will also provide ongoing protection of human health and groundwater within the populated areas of the Elk Valley.

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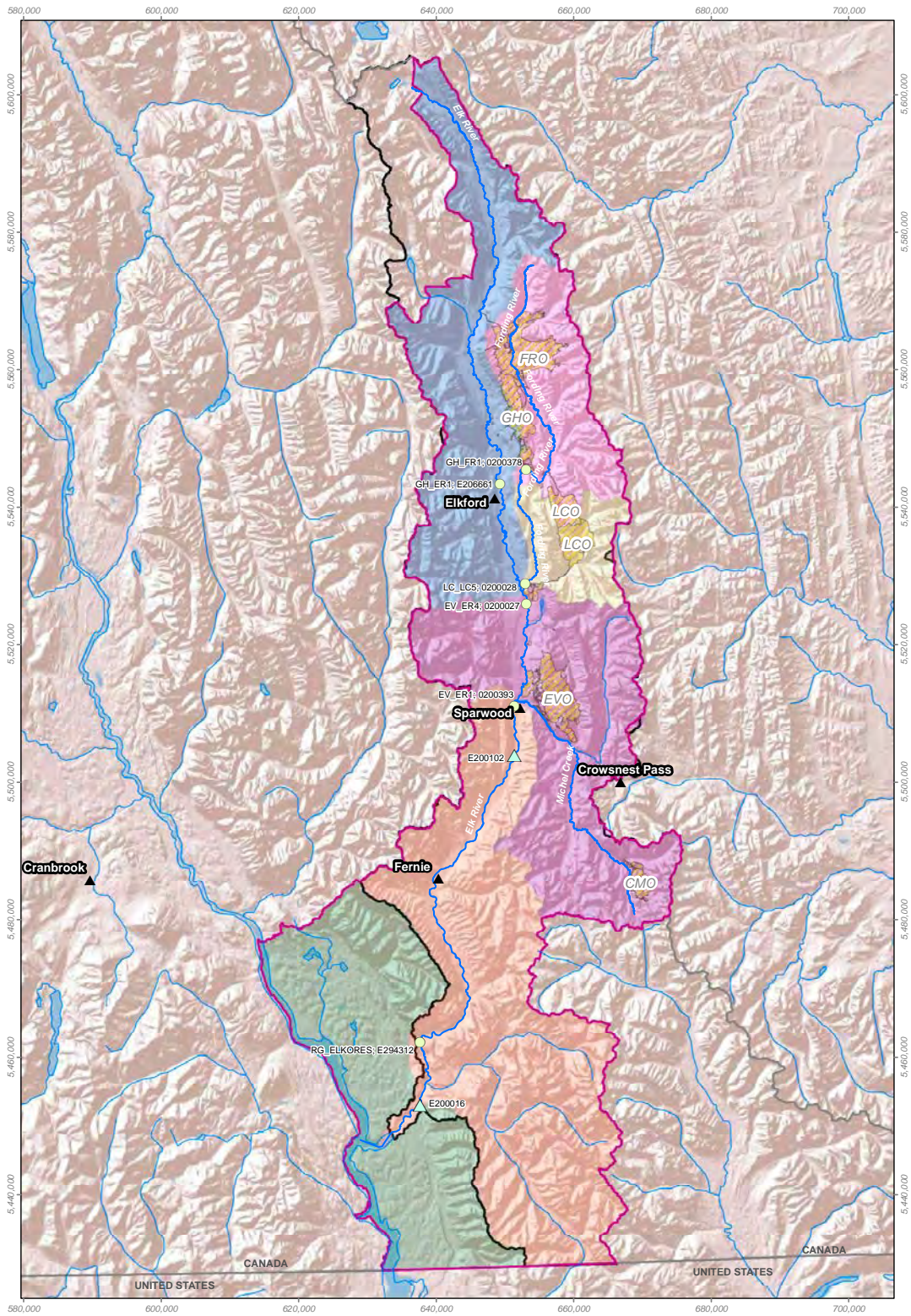
5.1 Introduction

Protection of human health and groundwater are important objectives of the Plan. The Plan's Terms of Reference describes two phases to evaluate these objectives: an assessment of current baseline conditions (ToR Section 3.4), and an effects assessment for constituents shown to exceed guidelines (ToR Section 3.8). This chapter outlines the methods and results of the assessment of baseline conditions from the perspective of human health, assesses potential human health impacts, and summarizes a regional groundwater study. Separate detailed reports on human health evaluation and regional groundwater are provided in Annex L.

5.1.1 Human Health Assessment and Protection

The four constituents specified in the Order, as well as other constituents in specified environmental media, were examined to identify those that may present a risk to human health under current conditions for pertinent exposure pathways. The first phase consisted of comparing the maximum reported constituent concentrations in each management unit (MU) with provincial guidelines for water quality, sediment and fish concentrations. (See Figure 5-1 for the geographical definition of each MU). During the second phase, pathway-specific benchmark values were derived for constituents shown to exceed guidelines during the assessment of current baseline conditions. The benchmark values were compared with upper confidence limits on mean concentrations by MU. Risk analyses were conducted for constituents exceeding the pathway-specific values.

- Sulphate and nitrate are evaluated in surface water and groundwater. During the current baseline evaluation, nitrate was found to exceed the guideline in surface water in MU-1 and MU-2, but not in groundwater. Sulphate exceeded the guideline once among hundreds of surface water samples and one groundwater well sample exceeded the guideline. The second phase of analysis showed that neither constituent posed a health risk in either surface water or groundwater.
- Cadmium and selenium were evaluated in surface water, groundwater, sediment and fish. During the current baseline evaluation, selenium was found to exceed the guidelines in MUs 1, 2, 4, and 5 for surface water, in MUs 4 and 5 for groundwater, in MUs 1 and 4 for sediment, and in MUs 1, 2, 4, and 6 for fish. Cadmium exceeded the guideline in fish tissue in MUs 3 and 4. In no cases were current baseline conditions associated with health risks when the second phase of analysis was conducted.
- The same was true for other constituents evaluated. During the first phase of baseline evaluation, some constituents exceeded guidelines, but in no case were current baseline conditions found to pose health risks during the second phase of analysis.



Map 2.1-3 Teck Mining Operations in the Elk Valley

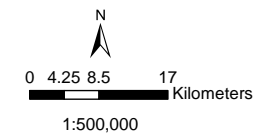
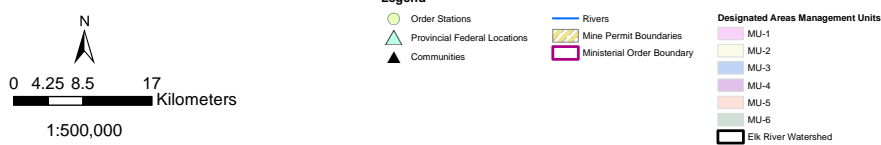


Figure 5-1. Management units within the Designated Area.

5.1.2 Groundwater Assessment and Protection

A regional evaluation was completed to identify groundwater used for drinking water that may be affected by mining activity in the Elk Valley. A total of 91 locations were sampled to assess drinking water quality. The majority of the locations sampled (79) were private groundwater wells. Additional samples were collected from Elkford and Sparwood municipal wells, groundwater wells with multiple users (e.g., mobile home parks), and six surface water points of diversion (springs/creeks). These data were incorporated into the human health evaluation. In no case was groundwater quality found to pose unacceptable health risks.

Two possible localized transport pathways for potential mining-influenced constituents in groundwater were identified: source release to upland groundwater, and surface water recharge from the Elk River in the floodplain. Shallow groundwater (i.e., <15 m below grade) in the Elk River floodplain has a higher degree of hydraulic connectivity to the Elk River than does deep groundwater, resulting in a greater potential for shallow groundwater to be influenced by constituents in the Elk River. In particular, shallow groundwater in floodplain areas hydraulically downgradient of a meander may receive a higher component of surface water recharge. Surface water recharge to groundwater also appears to be higher where river gradients are higher.

Given that current baseline conditions do not present human health risks and groundwater is intrinsically tied to surface water quality in parts of the Elk River, reducing and managing surface water concentrations of Order constituents will ensure that human health and groundwater for drinking are protected within the populated areas of the Elk Valley (floodplains).¹

¹ Individual mining operations are developing groundwater monitoring networks and monitoring programs to improve understanding of groundwater at an operational (local) level. Results of these investigations will be used to help improve Teck's understanding of local groundwater for potential mitigation scenarios.

5.2 Approach to Evaluation

A two-phase approach was used for the human health evaluation (Figure 5-2). During the first phase, current baseline water quality was assessed by comparing constituent concentrations in surface water, sediment, fish tissue and groundwater to guideline values. Constituents that exceeded guideline values, as well as constituents for which no guideline values were available, were subjected to a more detailed effects assessment during the second phase.

An influence diagram was created to summarize potential causal relationships between concentrations of the constituents of potential concern and the values the Plan is seeking to protect. For human health, drinking water and fish consumption (selenium-specific) are identified as the two receptor pathways most relevant to selenium, sulphate, nitrate, and cadmium.

The human health evaluation considered additional constituents beyond the four specified in the Order, and additional exposure pathways beyond drinking water and fish consumption. Surface water, sediment, and fish tissue data collected during 2011-2013 were the primary focus of the evaluation. While all analytical parameters were considered, only those deemed pertinent to assessing potential health risks were included in this evaluation. Details of constituent selection are provided in Annex L.3.

Surface water quality data (total and dissolved) are available for 44 inorganic and nine organic constituents pertinent to assessing potential human health risk.² Sediment data are available for 33 inorganic constituents and 17 organic compounds.³ Fish tissue data from muscle and whole-body samples are available for 40 inorganic constituents. Groundwater samples collected during 2014 were analyzed for 10 inorganic constituents, including the Order constituents.⁴

In the first phase of the evaluation, current baseline water quality was assessed by comparing concentrations of constituents in surface water, sediment, fish, and groundwater within each MU with human health protective guidelines based on the pathway with greatest exposure potential for each exposure medium (e.g., drinking water guidelines were applied to surface water and groundwater). Constituents exceeding the guidelines on any sampling date were carried through to the second phase for assessment of potential effects.

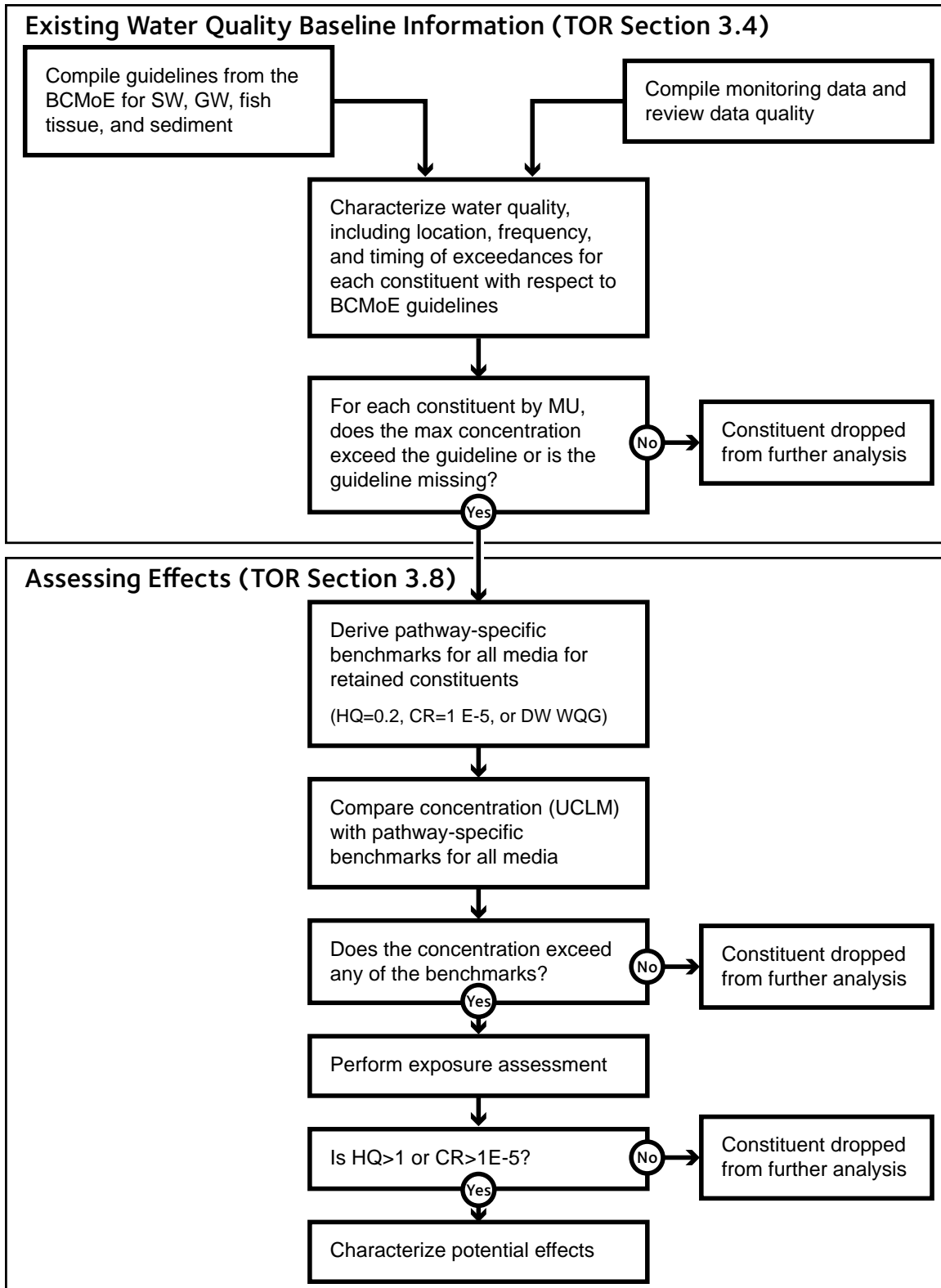
In the second phase of evaluation, estimates of average constituent concentrations⁵ were compared with health-protective pathway-specific benchmarks. Average concentrations, additive exposures and potential other interactive effects were considered to identify constituents and exposure pathways requiring more detailed assessment of potential adverse health effects.

² Some parameters are indicators of general water conditions (e.g., pH, hardness, total dissolved solids) and others are collected only to support ecological analyses. Parameters that may affect water potability are briefly summarized in the human health risk evaluation.

³ Only bulk sediment samples were included in this analysis. Additional fine fraction data were collected primarily to support ecological effects analyses.

⁴ Analytical data for groundwater include water hardness and alkalinity in addition to chemical analytes.

⁵ The upper confidence limits of the mean were used as a conservative estimate of mean concentrations.



B.C. MOE – British Columbia Ministry of the Environment; SW – surface water; GW – groundwater; MU – Management unit; HQ – Hazard Quotient; CR – Cancer Risk; DW – Drinking water; WQG – Water quality guideline; UCLM – Upper confidence limit of the mean.

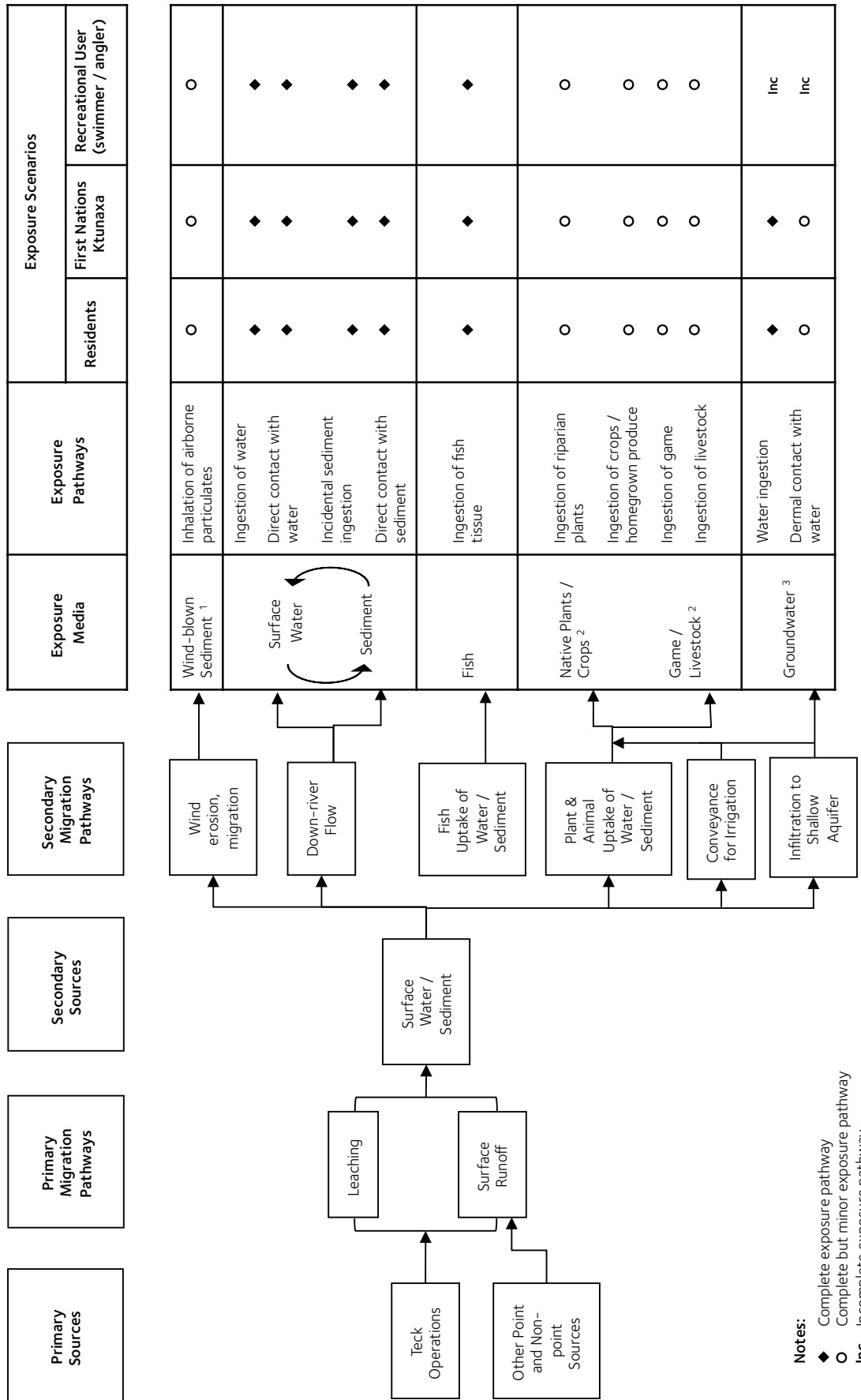
Figure 5-2. Evaluation of constituents of interest to address human health.

5.3 Human Health Conceptual Site Model

The Elk Valley setting for Teck operations provides the basis for assumptions regarding use of the waterbodies identified in the Order, including who relies on a watershed and how it is accessed. The conceptual site model (CSM) used to guide the evaluation is based on a review of land, surface water, and groundwater uses within the Designated Area. Information on residential, commercial, industrial, agricultural, subsistence, and recreational uses and activities form the basis for identifying exposure pathways and exposure parameters needed to quantify exposures and risk. Constituent sources, transport, and exposure pathways are depicted in the CSM schematic diagram (Figure 5-3).

Once released to surface water, constituents may dissolve or adsorb to suspended sediment, which may ultimately settle to the river bottom. In addition to surface water, constituents may occur in groundwater when a hydraulic connection is present. A hydraulic connection is most likely to occur where groundwater wells are in the floodplain, or where wells draw sufficient water from the Elk River to create a hydraulic gradient (SNC-Lavalin 2014).

People may come into contact with constituents in receiving surface waters, or where groundwater is removed in locations influenced by surface water, through the pathways shown in the schematic CSM (Figure 5-3) and in the artist's rendering (Figure 5-4). Primary exposure pathways include surface water, sediment, fish, and groundwater. Surface water and groundwater may be used as domestic water supplies. Residents, including members of First Nations, and tourists may directly contact constituents in surface water and/or sediment within the Designated Area while pursuing leisure activities (e.g., swimming, fishing, floating), harvesting, or performing other traditional activities in the rivers. Both incidental ingestion and skin contact with water and sediment are primary exposure pathways. Consumption of terrestrial plants and animals that may consume surface water (either from the river or when used for irrigation) are secondary exposure pathways, because people contact the constituents indirectly, only through the plants and animals who have taken them up, rather than directly contacting constituents in water, sediment or fish.



Notes:

- ◆ Complete exposure pathway
- Complete but minor exposure pathway
- Inc Incomplete exposure pathway

1. Exposed sediment in Lake Kocanusa during low-water periods may be subject to wind erosion and subsequent inhalation by recreational visitors to the reservoir but this pathway is considered minor relative to direct sediment contact while swimming.
2. Plant and animal uptake of surface water/sediment may occur but exposure via tissue ingestion is considered a minor exposure pathway relative to fish ingestion.
3. Surface water infiltration to shallow aquifer is limited to areas where wells are located within Elk River floodplain.

Figure 5-3. Human health assessment conceptual site model.

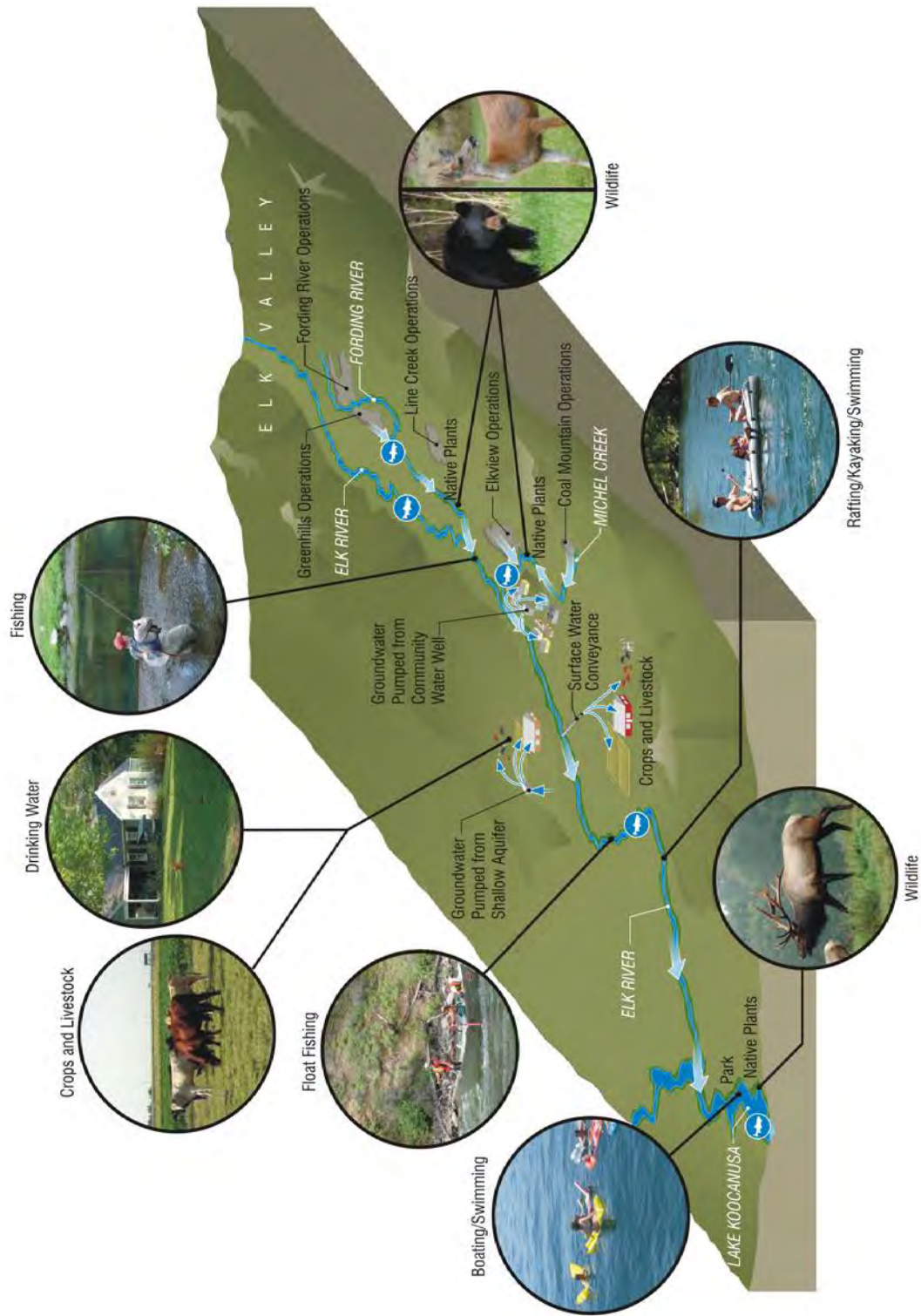


Figure 5-4. Human health assessment graphic conceptual site model representation.

5.4 Current Baseline Assessment

Current baseline data were organized by MU and exposure medium (e.g., surface water, groundwater, fish tissue, sediment). The maximum concentration identified for each recent data set (collected within the last three years) was compared to the selected numeric human health guideline, using a hierarchy recommended by the British Columbia MOE and the project team.⁶ The baseline assessment used human health protective guidelines based on the most intensive possible contact or exposure pathway. For example, guidelines for drinking surface water are generally more stringent than guidelines for recreational use of surface water. Similarly, guidelines for incidental ingestion of residential soil are generally more protective than guidelines for periodic recreational contact with sediments. The goal in compiling guidelines for the baseline review was to identify all constituents that may need further assessment. Therefore, surface water and groundwater data were compared with drinking water guidelines, and fish tissue data were compared with fish consumption guidelines. Sediment data were compared with residential soil guidelines that assume daily exposure. Constituents that did not exceed their respective guidelines were not considered further. Constituents that exceeded their respective guidelines, or lacked guidelines, were further evaluated.

5.4.1 Surface Water

Surface water was tested for 44 inorganic constituents, of which 33 have guideline values. For those 33 constituents, 21 fell within the guidelines. Guideline values were not available for 11 inorganic constituents. Additionally, nine organic constituents were analyzed in surface water, eight of which had guideline values. Results are summarized in Table 5-1.

Most surface water guidelines are based on the total fraction of the constituent. Aluminum was the exception, with a guideline based on the dissolved fraction. Nevertheless, the maximum concentration for both total and dissolved fractions was compared with the guideline values. For bromide and sulphate, only dissolved data are available; the maximum of the dissolved fraction was compared to the guideline.

Table 5-2 summarizes constituents exceeding guidelines for total and dissolved concentrations that were carried forward for surface water. The subsequent discussion of surface water screening results focuses on total concentrations, for consistency with the basis for guideline values, except as noted above for aluminum, bromide, and sulphate. Comparison of dissolved concentrations to guideline values intended for “total” concentrations did not result in additional constituents being retained for further analysis.

⁶ B.C. MOE provided or pre-approved most guideline values used in the evaluation. Details of guideline values and the selection process are provided in the appended human health evaluation report.

Table 5-1. Summary of surface water screening results.^a

Constituents carried to effects assessment		
	Inorganic	Organic
Constituents Exceeding Guideline	Aluminum, Arsenic, Beryllium, Bromide, Cobalt, Iron, Magnesium, Manganese, Nitrate (as N), Selenium, Sulphate , Vanadium	None
Constituents Lacking Guideline	Bismuth, Calcium, Phosphate, Phosphorus, Potassium, Silica, Silicate (Dissolved), Silicon, Sulfide, Sulphur, Titanium	Phenanthrene
Constituents not carried to effects assessment		
	Inorganic	Organic
Constituents Not Exceeding Guidelines	Antimony, Barium, Boron, Cadmium , Chloride, Chromium, Copper, Fluoride, Lead, Lithium, Mercury, Molybdenum, Nickel, Nitrite (as N), Silver, Sodium, Strontium, Thallium, Tin, Uranium, Zinc	Acenaphthene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Fluoranthene, Fluorene, Naphthalene, Pyrene

^a Constituents specified in the Order are shown in bold.

Of the constituents specified in the Order, selenium, sulphate, and nitrate failed to meet the surface water guideline at least once, while cadmium was within guidelines in all MUs. Selenium exceeded the guideline in MU-1, MU-2, MU-4, and MU-5. In MU-2, 100% of samples exceeded the guideline, while in MU-4 and MU-5 the percentage dropped to 26% and 21%, respectively. Six sulphate samples (out of 479 samples) exceeded for the dissolved fraction, all in MU-1. Sulphate concentrations are not typically reported as total concentrations. Nitrate failed to meet the guideline in MU-1 and MU-2, with fewer samples exceeding and a lower maximum concentration in MU-2 than in MU-1.

Parameters that affect water potability (i.e., hardness, pH, total dissolved solids, or TDS, and total organic carbon, or TOC) were reviewed, and were found not to meet guideline values. Hardness, pH, and TOC also failed to meet guidelines in reference areas. Constituents not specified in the Order that had exceeded a surface water guideline at least once are aluminum, arsenic, beryllium, bromide, cobalt, iron, magnesium, manganese, and vanadium. Multiple samples failed to meet the guideline for arsenic,⁷ bromide, cobalt, iron, magnesium, and manganese and these constituents were carried forward in the evaluation. Three constituents (aluminum, beryllium, and vanadium) exceeded the guideline only once and also were carried forward. All the eight organic constituents fell within guideline values.

In summary, constituents carried forward from the current baseline evaluation for surface water due to failing to meet a guideline include twelve inorganic constituents (aluminum, arsenic, beryllium, bromide, cobalt, iron, magnesium, manganese, nitrate, selenium, sulphate, and vanadium). Eleven inorganic constituents and one organic constituent without guidelines were also carried forward for further evaluation.

⁷ It should be noted that the arsenic guideline is lower than typical background arsenic concentrations in surface water in B.C.

Table 5-2. Constituents exceeding surface water guidelines (total and dissolved).^a

MUs	Chemical	Percent exceeding ^b	Max concentrations ^c (mg/L)	Guideline (mg/L)
Total Concentrations				
MU-1, 2, 3, 4, 5, 6	Aluminum	8-30	0.712-4.03	0.2*
MU-1, 2, 3, 4, 5, 6	Arsenic	6-69	0.000640-0.00275	0.0003
MU-1	Beryllium	<1	0.00761	0.004
MU-1, 2, 4, 5, 6	Cobalt	1-13	0.00096-0.00557	0.00094
MU-1, 2, 3, 4, 5, 6	Iron	8-24	1.08-6.37	0.3
MU-1	Magnesium	1	173	100
MU-1, 2, 3, 4, 5, 6	Manganese	3-5	0.0515-0.197	0.05
MU-1, 2	Nitrate (as N)	16-27	14.7-27.0	10
MU-1, 2, 4, 5	Selenium	21-100	0.0127-0.105	0.010
MU-4, MU-5	Vanadium	1	0.0156-0.0176	0.0126
Dissolved Concentrations				
MU-4	Aluminum	<1	0.342	0.2
MU-4, 6	Arsenic	9-52	0.00044-0.00047	0.0003
MU-1, 2, 4, 5, 6	Bromide	1-42	0.063-1.60	0.05
MU-4	Cobalt	5	0.00503	0.00094
MU-4	Iron	<1	0.362	0.3
MU-1	Magnesium	2	165	100
MU-1, 2, 4, 5	Selenium	21-100	0.0127-0.111	0.010
MU-1	Sulphate (as SO₄)	1	775	500

^a Constituents specified in the Order are shown in bold.

^b Range of percent of samples exceeding from MUs in which guideline was exceeded.

^c Range of maximum concentrations from MUs in which guideline was exceeded.

* Aluminum guideline based on dissolved concentration; all other guidelines based on total concentration.

5.4.2 Sediment Results

Sediment was tested for 33 inorganic constituents, of which 26 had soil guideline values. For the 26 constituents with guideline values, 22 constituents fell within the guidelines. Guidelines were not available for seven inorganic constituents. Sediment was also tested for 17 organic constituents, of which 15 had guidelines; none failed to meet their guidelines. Sediment screening results are summarized in Table 5-3.

Table 5-3. Summary of sediment screening results^a.

Constituents carried to effects assessment		
	Inorganic	Organic
Constituents Exceeding Guideline	Aluminum, Iron, Nickel, Selenium	None
Constituents Lacking Guideline	Bismuth, Calcium, Magnesium, Potassium, Sulphur, Titanium, Phosphorus	Acenaphthylene, Benzo(g,h,i)perylene

Constituents not carried to effects assessment		
	Inorganic	Organic
Constituents Not Exceeding Guideline	Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium , Chromium, Cobalt, Copper, Lead, Lithium, Manganese, Mercury, Molybdenum, Silver, Sodium, Strontium, Thallium, Tin, Uranium, Vanadium, Zinc	2-Methyl naphthalene, Acenaphthene, Anthracene, Benz(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Chrysene, Dibenz(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-c,d)pyrene, Naphthalene, Phenanthrene, Pyrene

^a Constituents specified in the Order are shown in bold.

Constituents exceeding sediment guidelines are summarized in Table 5-4. All sediment data are reported in mg/kg dry weight. Of the constituents specified in the Order, only selenium exceeded sediment guidelines: 70% of all samples in MU-1 and 21% of samples in MU-4. Nitrate and sulphate are not constituents of concern for sediment and were not analyzed.

Iron exceeded the sediment guideline in every MU. Nickel exceeded the guideline only in MU-1 and aluminum exceeded the guideline only in MU-6. All organic constituents fell within the sediment guidelines. Thus, sediment constituents carried further in the evaluation included selenium, iron, nickel and aluminum. Seven inorganic constituents and two organic constituents lacking guideline values were also carried forward.

Table 5-4. Constituents exceeding sediment guidelines.^a

MUs	Chemical	Percent exceeding ^b	Max concentrations ^c (mg/kg dry weight)	Guideline (mg/kg)
MU-6	Aluminum	28	17,400	15,400
MU-1, 2, 3, 4, 5, 6	Iron	54-100	15,500-41,900	11,000
MU-1	Nickel	11	129	100
MU-1, 4	Selenium	21-70	5.30-81.6	3

^a Constituents specified in the Order are shown in bold.

^b Range of percent of samples exceeding from MUs in which guideline was exceeded.

^c Range of maximum concentrations from MUs in which guideline was exceeded.

5.4.3 Fish Tissue Results

Fish tissue screening results are summarized in Table 5-5. Fish tissue was tested for 40 inorganic constituents, of which 23 have guideline values. Of these, 13 constituents fell within their guidelines. Organic constituents were not analyzed in fish tissue. All fish tissue data are reported in mg/kg wet-weight tissue.

Table 5-5. Summary of fish tissue screening results.^a

Constituents carried to effects assessment	
Constituents Exceeding Guideline	Aluminum, Antimony, Arsenic, Cadmium , Cobalt, Iron, Lithium, Selenium , Vanadium, Zinc
Constituents Lacking Guideline	Bismuth, Calcium, Cesium, Gallium, Lead, Magnesium, Phosphorus, Potassium, Rhenium, Rubidium, Sodium, Tellurium, Thallium, Thorium, Titanium, Yttrium, Zirconium
Constituents not carried to effects assessment	
Constituents Not Exceeding Guideline	Barium, Beryllium, Boron, Chromium, Copper, Manganese, Mercury, Molybdenum, Nickel, Silver, Strontium, Tin, Uranium

^a Constituents specified in the Order are shown in bold.

Constituents exceeding guidelines for fish are summarized in Table 5-6. Of the constituents specified in the Order, both selenium and cadmium had samples exceeding the guidelines (nitrate and sulphate are not constituents of concern for fish tissue and were not analyzed). In MU-1, MU-2 and MU-6, muscle tissue samples exceeded the selenium guideline, but whole body samples did not. In MU-4 both muscle and whole body fish samples exceeded the guideline. cadmium had a sample exceeding in MU-3 in one whole fish sample (out of 10 samples), and multiple samples exceeding in MU-4 (in three whole fish samples of 30 and five muscle samples of 80).

Eight other constituents exceeded guidelines:

- Arsenic – multiple samples exceeding in every MU⁸
- Cobalt – multiple samples exceeding in all MUs except MU-6
- Iron – one sample exceeding in MU-3 and two in MU-4
- Aluminum, antimony, lithium, vanadium and zinc) had only one sample exceeding a fish tissue guideline.

⁸ It should be noted that average arsenic concentrations in reference area fish were higher than concentrations in fish from the Designated Area.

Table 5-6. Constituents exceeding fish tissue guidelines.^a

MUs	Constituent	Percent exceeding ^b	Max concentrations ^c (mg/kg)	Guideline (mg/kg)
MU-3	Aluminum (Whole)	10	426	280
MU-4	Antimony (Muscle)	1	0.170	0.108
MU-1, 2, 3, 4, 5, 6	Arsenic (muscle)	30-73	0.0600-0.340	0.021
MU-3, 4, 5	Arsenic (whole)	44-90	0.0926-0.159	0.021
MU-4	Cadmium (muscle)	6	0.529	0.28
MU-3, 4	Cadmium (whole)	10	0.421-0.702	0.28
MU-1, 2, 4, 5	Cobalt (muscle)	6-30	0.114-2.13	0.082
MU-3, 4, 5	Cobalt (whole)	10-28	0.104-0.378	0.082
MU-4	Iron (muscle)	3	361	190
MU-3	Iron (whole)	10	316	190
MU-4	Lithium	1	1.70	0.54
MU-1, 2, 4, 6	Selenium (muscle)	6-47	5.75-15.1	3.6
MU-4	Selenium (whole)	30	14.9	3.6
MU-3	Vanadium (whole)	10	1.52	1.36
MU-4	Zinc	3	82.1	82

^a Constituents specified in the Order are shown in bold.

^b Range of percent of samples exceeding from MUs in which guideline was exceeded.

^c Range of maximum concentrations from MUs in which guideline was exceeded.

5.4.4 Groundwater Results

Monitored constituents in groundwater and screening results are summarized in Table 5-7. A total of 91 locations were sampled. Most (79) were private groundwater wells, with additional samples from Elkford and Sparwood municipal wells, groundwater supplies with multiple users (e.g., mobile home parks), and surface water points of diversion (springs/creeks). Samples from eight locations were found to exceed or be within 20% of the selenium guideline and were re-sampled. An exception was a District of Sparwood well (Well #3) that was not re-sampled. One sample failed to meet the Aesthetic Objective (AO) guideline for sulphate, one the AO guideline for sodium, and one the AO guideline for chloride. No other guidelines were exceeded. Water samples were tested for 10 inorganic constituents, listed in Table 5-7, of which eight had guideline values. Two parameters lacking guideline values, calcium and potassium, were analyzed for evaluation of general water quality parameters not specific to human health.

Table 5-7. Summary of groundwater screening results.^a

Constituents carried to effects assessment	
Constituents Exceeding Guideline	Chloride, Selenium , Sodium, Sulphate
Constituents Lacking Guideline	Calcium, Potassium
Constituents not carried to effects assessment	
Constituents Not Exceeding Guideline	Cadmium , Magnesium, Nitrate (as N) , Nitrite (as N)

^a Constituents specified in the Order are shown in bold.

Constituents exceeding guidelines for groundwater are summarized in Table 5-8. As with surface water, guidelines are generally based on total concentrations; however, both total and dissolved selenium concentrations were included in the current baseline screening. Of the constituents specified in the Order, five selenium samples and one sulphate sample were above the groundwater guideline and were carried forward for further evaluation. Sodium and chloride were also carried forward due to samples exceeding guidelines, while calcium and potassium were carried forward due to lack of guideline values. Water hardness failed to meet guideline values.

Table 5-8. Constituents exceeding groundwater guidelines.^a

MU	Sampling location	Constituent	Fraction (total, dissolved)	Max concentration (mg/L)	Guideline (mg/L)
MU-4	07-01	Sulphate	D	550	500
MU-4	02-18	Selenium	T, D	0.014	0.010
MU-4	02-20	Selenium	T, D	0.013	0.010
MU-4	02-17	Selenium	T, D	0.016	0.010
MU-4	02-03	Sodium	T	288	200
MU-5	04-22	Chloride	D	307	250
MU-5	04-09	Selenium	T, D	0.011	0.010
MU-5	03-04	Selenium	T, D	0.012	0.010

^a Constituents specified in the Order are shown in bold.

5.5 Cumulative Impacts – Effects Assessment

The effects assessment characterizes constituents that did not screen out during the baseline evaluation. The focus of this assessment is identification of potentially complete exposure pathways for environmental media where constituents exceeded guidelines, followed by further risk-based screening and then risk calculations. Risk-based screening requires toxicity reference values (TRVs). Some constituents lacking guidelines may not have TRVs, and others may have guidelines that are not health-based. For these constituents, an initial assessment is made of the general level of toxicity of the constituent, and concentrations within the Designated Area are compared to concentrations in reference locations. Based on this analysis, an assessment was made on whether further quantitative analysis is needed or whether data gaps prevent full characterization.

Constituents exceeding guideline values are evaluated in the effects assessment according to the two-step approach summarized in Figure 5-2. Each MU had a unique list of exceeding constituents. However, to provide a more complete assessment, any constituent carried forward was further evaluated in all MUs. In the first step, an upper-bound estimate of mean concentrations for retained constituents in each MU was compared to pathway-specific benchmarks for primary exposure pathways. The pathway-specific benchmarks were conservatively calculated, assuming that only 20% of the safe dose was allowed for an individual pathway. In other words, if there was only one exposure pathway, an exposure up to five times the benchmark would still be protective of health. Alternatively, exposures via five pathways, each at or below the benchmark values would still be safe.

Data were examined to determine if the mean for samples collected from 2011-2013 were representative of ongoing exposures. The nature of toxicity associated with a constituent was also considered at this stage to determine if shorter-term exposures should be assessed. Among retained constituents, this issue is relevant only for nitrate. The outcome of this assessment is described Section 5.5.2.1.

Constituents that did not exceed primary pathway-specific benchmarks were not considered further. Constituents that exceeded a primary pathway-specific benchmark were retained to calculate pathway-specific risks (including secondary pathways) and to consider aggregate risks across all pathways. If no concern existed for aggregate risk, the constituent was not considered further. Multiple constituents with a potential for cumulative risks were evaluated further for consideration of physical and constituent factors influencing exposure and toxicity, and for interactive effects. Constituents were also evaluated with respect to reference area concentrations.

5.5.1 Characterization of Constituents Carried Forward

For a substantial number of constituents in surface water, sediment, fish, and groundwater, no TRVs were readily available to support the pathway-specific screening step. The following sections summarize the constituents for which TRVs were available, and provide qualitative assessment of constituents for which TRVs could not be identified. Data limitations or data gaps are also addressed.

5.5.1.1 Surface Water

Surface water was tested for both inorganic and organic constituents. Twelve constituents were carried forward from the baseline evaluation for surface water as a result of exceeding guidelines: aluminum, arsenic, beryllium, bromide, cobalt, iron, magnesium, manganese, nitrate, selenium, sulphate, and vanadium. Bromide, magnesium, and sulphate are discussed here qualitatively, but were not included in further screening and risk evaluation for the reasons described below. The other nine constituents had TRVs and were carried forward to the next step of the effects assessment.

Samples appearing to exceed the bromide surface water guideline are not reliable indicators because the data are all dissolved concentrations, whereas the guideline is based on annual mean total bromide concentrations in monthly raw water samples. Most concentrations were non-detectable; however, the detection limits were all equal to or above the guideline of 0.05 mg/L for total bromide. Consequently, the available data are not adequate to determine if bromide exceeds the guideline. The guideline is intended to determine the needed frequency of bromate monitoring in water supplies treated using ozonation, so its application in this context is not clear. Nevertheless, this data gap is noted in the conclusions, and no further analysis was conducted.

The guideline for magnesium is based on aesthetic factors, including water taste and odour. Few magnesium samples exceeded the guideline in MU-1 (7 of 473 samples) and the mean concentration was well within the guideline (36 mg/L vs. a guideline of 100 mg/L). Since magnesium is a required nutrient for human health, no TRVs are available and there is no anticipated health risk from reported concentrations. For that reason, magnesium was not evaluated further. Similarly, other general parameters used to assess general water potability (i.e., hardness, pH, TDS and TOC) were not considered in the effects assessment.

The guideline for sulphate is based on aesthetic factors and mild gastrointestinal distress, and no TRV is available due to the absence of significant adverse effects at any concentration evaluated. Few sulphate samples exceeded the guideline in MU-1 (6 of 479 samples) and the mean concentration was well within the guideline (157 mg/L vs. a guideline of 500 mg/L). There is no anticipated health risk from reported concentrations and sulphate was not evaluated further.

Inorganic constituents for which guideline values are unavailable include bismuth, calcium, phosphate, phosphorus, potassium, silica, silicate, silicon, sulphide, sulphur, and titanium. Of these, calcium, phosphorus (measured in the blood as phosphate ion), potassium, and sulphur are essential nutrients in larger amounts.⁹ Phosphorus/phosphate and sulphur/sulphide are present as part of other chemicals, and were not evaluated for human health effects as free elements or ions. Bismuth has limited oral bioavailability in people, as evidenced by its use in laxatives. Silica/silicate/silicon and titanium are commonly used as whiteners in toothpaste.¹⁰ Due to their low toxicity, these constituents were not evaluated further.

Nine organic constituents were also measured in surface water, eight of which have guideline values. None of these eight exceeded the guideline values. Phenanthrene is the only organic constituent for which a guideline value was unavailable. It has a similar toxicity profile to other polycyclic aromatic hydrocarbons (PAHs), for which surface water guideline values are available. Due to this similarity and the lack of samples exceeding guidelines among the other PAHs, phenanthrene was not evaluated further.

5.5.1.2 Sediment

Sediment was tested for both inorganic and organic constituents. Aluminum, iron, nickel, and selenium exceeded guidelines and have TRVs. All four were carried forward to the next step of the effects assessment.

Inorganic constituents for which guideline values are unavailable include bismuth, calcium, magnesium, phosphorus, potassium, sulphur, and titanium. The absence of guidelines for these constituents in sediment reflects their low toxicity to people. Calcium, magnesium, and potassium are essential macrominerals, generally not considered to be human toxicants. Phosphorus and sulphur, also essential macrominerals, were not evaluated for human health effects as free elements. For the reasons given in Section 5.5.1.1, bismuth and titanium were not evaluated further.

Fifteen organic constituents fell within sediment guideline values. No guidelines are available for acenaphthylene and benzo(g,h,i)perylene. These constituents have similar toxicity profiles to the organic constituents for which sediment guideline values are available. Additionally, acenaphthylene was below the detection limit in every sample analyzed from the MUs and from reference data, while benzo(g,h,i)perylene was mostly below the detection limits. Due to this similarity and the lack of samples exceeding guidelines among the other organic constituents, the two organic constituents without sediment guideline values were not evaluated further.

⁹ Magnesium, sodium, and chloride also are necessary macrominerals. Trace minerals needed in smaller amounts include iron, manganese, copper, iodine, zinc, cobalt, fluoride, and selenium.

¹⁰ In contrast to the low oral toxicity of silica and titanium, inhalation of high concentrations of quartz silica or titanium oxide has been classified as carcinogenic to humans for silica (http://www.ccohs.ca/oshanswers/chemicals/chem_profiles/quartz_silica.html) and possibly carcinogenic to humans for titanium (<http://www.ccohs.ca/headlines/text186.html>).

5.5.1.3 Fish Tissue

Fish tissue was tested for 40 inorganic constituents, 22 of which had guideline values. All 10 constituents with samples exceeding guidelines have TRVs and were retained for further evaluation. No organic constituents were analyzed in fish tissue.

Constituents for which no fish tissue guidelines are available include bismuth, calcium, cesium, gallium, lead, magnesium, phosphorus, potassium, rhenium, rubidium, sodium, tellurium, thallium, thorium, titanium, yttrium, and zirconium. A lead TRV (SNC-Lavalin 2012) was identified and used for further assessment in fish tissue.

As described above, bismuth, phosphorus, and titanium are considered to have low toxic potential for people. Calcium, magnesium, phosphorus, potassium, and sodium are also essential macrominerals and not typically included in health risk assessments. Cesium, gallium, rhenium, rubidium, tellurium, thorium, and yttrium are trace elements that are rarely evaluated in health risk assessments and for which no TRVs have been established. None of these constituents were carried forward in the effects assessment.

There are insufficient data to support derivation of TRVs for thallium and zirconium. Toxicity data for thallium is limited. Animal toxicity studies have reported hair loss (i.e., alopecia), generally reversible following cessation of exposure, but similar symptoms have not been reported in humans. US EPA 2009 concluded that weaknesses in the underlying database do not support quantitative toxicity assessment. Zirconium generally exhibits low toxicity and is often used in skin ointments and antiperspirants. US EPA 2012 determined that the available database is inadequate and does not support development of a zirconium TRV. Due to the low toxicity of these constituents and lack of reliable TRVs, thallium and zirconium were not evaluated further.

In summary, constituents carried forward from the baseline evaluation for fish tissue include the ten constituents exceeding guidelines (aluminum, arsenic, antimony, cadmium, cobalt, iron, lithium, selenium, vanadium, and zinc), and one additional constituent without a guideline value (lead).

5.5.1.4 Groundwater

Drinking water wells were tested for the four Order constituents and seven additional inorganic constituents. Constituent concentrations were usually represented by one sampling event and in some cases, two. Due to data limitations maximum concentrations of each constituent for each well are included in this assessment. Selenium, calcium, potassium, sulphate, chloride, and sodium were retained for further evaluation in the effects assessment. Of 91 locations sampled, selenium was slightly above the guideline in five well sources, and so was carried forward to the next step of the effects assessment.

One sulphate sample (550 mg/L) was above the guideline of 500 mg/L, which is based on aesthetic factors and potential for mild gastrointestinal distress. No sulphate TRV is available, due to the absence of significant adverse effects at any concentration evaluated. Consequently, there was no need for further health assessment of sulphate.

Chloride and sodium were above their guidelines in one well each. These essential macrominerals are related to local sources, and not mining influences; they were not evaluated further. Locations with concentrations exceeding guidelines for sulphate, chloride, and sodium were rare and are not considered a health concern, but they may affect potability.

Calcium and potassium lack guidelines and TRVs and are considered essential macrominerals; therefore, they were not evaluated further.

5.5.2 Pathway-Specific Benchmark Comparison

Identification of exposure pathways to include in the effects assessment was guided by the CSM (Figures 5-3 and 5-4). Exposure pathway completeness varies depending on people's access to and activities within each MU, which may be affected by factors such as season and water level. Exposure pathways are characterized as primary pathways, i.e., those with the greatest possible magnitude of exposure, or as secondary pathways, i.e., those with more limited potential for exposure. Pathway-specific benchmarks were initially calculated for primary pathways. Benchmarks were not calculated for secondary pathways because primary pathways were not found to present unacceptable risks.

The benchmarks are based on algorithms from Health Canada (2012) and B.C. MOE (2008, 2012) exposure assumptions, and specified acceptable risk levels, in addition to MU characteristics. For carcinogenic constituents, cancer risk is set at 1 in 100,000. For non-cancer health effects, "Hazard quotients" (see Section 5.5.3) are set to 0.2, so that cumulative exposures from multiple pathways and multiple exposure media do not exceed effects thresholds (MOE 2012). Exposure concentrations used to compare to the pathway-specific benchmarks were 95% upper confidence limits on the mean, generated using ProUCL 5.0 (US EPA 2013).

5.5.2.1 Surface Water

The primary complete exposure pathways for surface water include incidental ingestion and skin contact during swimming and other aquatic recreational activities. Drinking water was also included as a primary pathway; although, it is not a current complete pathway. Secondary pathways include consumption of game or livestock that may have consumed surface water, and consumption of plants that may have grown at the river's edge or been irrigated with river water.

Benchmark screening values were derived only for the two primary pathways: drinking water and swimming. The magnitude of potential exposure from use of surface water as a domestic water supply is far greater than the potential magnitude of exposure from all the other pathways combined. Consequently, if a constituent does not exceed the drinking water benchmark value within an MU, there is no need to characterize risks from secondary pathways.

Seven constituents (aluminum, beryllium, cobalt, iron, manganese, selenium and vanadium) fell within screening benchmarks for drinking water or contact while swimming. Annual average concentrations of nitrate also fell within the benchmarks. Additional analyses were conducted to assess changing nitrate concentrations in MU-1 over time, and seasonal fluctuations in MU-1 and MU-2.¹¹ Average nitrate concentrations in MU-1 were higher in 2013 than in 2011 and 2012. No similar trend was noted in MU-2. Nitrate concentrations were also markedly reduced during the spring freshet.

Quarterly average nitrate concentrations were calculated for MU-1 and MU-2 for 2011-2013, and also for MU-1 for 2013 only. These concentrations were compared with the maximum allowable concentration (MAC). Highest concentrations occurred during Q1 and Q4 (i.e., during low-flow periods). Nitrate concentrations for 2013 were above the pathway-specific benchmark for drinking water in MU-1 for Q1 and Q4 (January to March and October to December). When MU-1 concentrations were averaged over the three-year period, nitrate concentration was again above the drinking water benchmark during Q1. In MU-2, drinking water pathway benchmarks were not exceeded, and the swimming pathway benchmark was never exceeded in either MU. It was concluded that nitrate in MU-1 is above the surface water non-cancer benchmark for drinking water, and was carried forward to the next step of the effects assessment.

¹¹ Concentrations of some other constituents also appear to be increasing over time; however, that trend is moderate and does not result in the masking of exceeding benchmark concentrations when data from all three years, 2011-2013, are combined when calculating upper estimates of mean concentrations.

Arsenic exceeded the cancer screening benchmark for drinking water only. However, the cancer screening benchmark is three orders of magnitude lower than the mean background arsenic concentration of 0.0002 mg/L for Elk Valley surface water, and below the Health Canada MAC of 0.010 mg/L. Reported natural background arsenic levels throughout B.C. range from 0.001 to 0.002 mg/L (MOE 2007). The range of mean concentrations for MU-1 through -6 is 0.00016 to 0.0039 mg/L, which is generally consistent with B.C. background concentrations and lower than the Health Canada MAC. Nevertheless, arsenic was carried forward for further evaluation.

5.5.2.2 Sediment

The primary sediment exposure pathway includes exposure skin and incidental ingestion of sediment during recreational or harvesting activities. Swimming was selected as the scenario with the most intensive direct contact with sediment, and used as the basis for benchmark development. For sediment ingestion and skin contact while swimming, the frequency of exposure was the same as for surface water exposure. The skin surface area assumed included hands, lower arms, legs, and feet. A secondary sediment exposure pathway could be uptake into riparian plants that might be harvested and consumed. No benchmark for this pathway was derived, pending assessment of the primary sediment exposure pathway.

In all MUs, concentrations of aluminum, iron, nickel, and selenium in sediment fell within screening benchmarks for direct contact. Due to the limited areas of sediment with elevated constituent concentrations compared with background, and the lack of constituents exceeding the primary exposure pathway benchmark, secondary sediment exposure pathways were not examined further.

5.5.2.3 Fish

Constituent concentrations in fish are a function of concentrations in water, sediment, and prey. Due to the complexity of predicting fish tissue concentrations, measurement of constituent concentrations was the most direct measure of potential exposures via fish consumption. For First Nations members, fish consumption benchmarks were derived using the 95th percentile for consumers, 43 g/day, (Firelight 2013). Because the Firelight study examined rates of ingestion for adults only, the adult ingestion rate was adjusted using the relative ingestion rates for different life-stages, following Richardson (1997). For other fish consumers, a consumption rate of 40 g/day was identified. Given that this value is only slightly less than the First Nations value, a separate benchmark for other consumers was not calculated.

Benchmark screening was conducted for ten constituents that had exceeded guidelines (aluminum, antimony, arsenic, cadmium, cobalt, iron, lithium, selenium, vanadium, and zinc), and for one additional constituent without a guideline value for which a TRV was identified (lead). Seven of these constituents fell within the pathway-specific benchmarks (antimony, cadmium, iron, lead, lithium, vanadium, and zinc). Upper confidence limits of the means for aluminum, arsenic, cobalt, and selenium were above the pathway-specific benchmarks, as follows:

- Aluminum: for whole body in MU-3
- Arsenic: for cancer endpoint in MU-3
- Cobalt: for muscle tissue in MU-1 and MU-4, and whole body fish in MU-4 and MU-5
- Selenium: for muscle tissue in all MUs except MU-6, and for whole body fish in MUs-3, -4 and -5.

Potential health risks for the four constituents exceeding pathway-specific benchmarks are examined in Section 5.5.3.

5.5.2.4 Groundwater

Drinking water is the primary exposure pathway for groundwater. Secondary pathways may be consumption of plants irrigated with groundwater, and consumption of livestock that drink groundwater. Initially, benchmark values were derived only for use of groundwater as drinking water. Derivation of other benchmarks was only planned for constituents that exceed the drinking water benchmark, and then only if the other uses have been identified for groundwater in the affected MU. Selenium was the only constituent retained for pathway-specific evaluation. Selenium concentrations did not exceed the pathway-specific (i.e., drinking water) value of 0.047 mg/L.¹²

5.5.3 Pathway-Specific Risk Analyses

Pathway-specific benchmark screening identified two constituents (arsenic, nitrate) in surface water and four constituents (aluminum, arsenic, cobalt, and selenium) in fish tissue for which more detailed risk analyses were needed. Non-cancer hazards were calculated for nitrate in surface water and for all of these constituents in fish tissue. One constituent (arsenic) is also carcinogenic when ingested, so cancer risks were also calculated for that constituent in surface water and fish tissue.

5.5.3.1 Non-cancer Hazard Estimates

Non-cancer health risks are measured by comparing the exposure dose with a TRV, yielding a hazard quotient (HQ). HQs are calculated by dividing the expected average daily dose of a constituent by the TRV, which is the daily dose at which there is no risk of adverse effects. An HQ greater than one indicates that more of the constituent is being ingested than recommended, and that additional analyses are needed to determine if an increased risk of health effects from exposure to that constituent may occur.

Currently, people do not drink surface water in MU-1. Regardless, HQs were calculated for nitrate in surface water that might be consumed by infants age 0 to 5 months, from drinking formula made with surface water. Infants are at highest risk from nitrates because their intestinal flora convert nitrate to nitrite, which then binds with haemoglobin to form methaemoglobin. Methaemoglobinemia, or blue baby syndrome, results in impaired oxygen delivery to tissues, giving the skin a blue color.

Seasonal estimates of mean nitrate concentrations in MU-1 were used to calculate HQs for infants. HQs for infant ingestion of surface water in MU-1, by quarter, are below one, indicating that adverse effects from ingesting surface water are not expected (see Table 5-9).

Table 5-9. Hazard quotients for infant, surface water ingestion.

Nitrate (as N)	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
MU-1 (2013)	0.4	0.2	0.2	0.4

HQs for the constituents above the fish pathway benchmarks were calculated using the exposure parameters for a First Nations resident. The high-end ingestion rate is only slightly less for other fish consumers, and risks for other fish consumers are slightly lower than those predicted for First Nations fish consumers (data not shown). Table 5-10 provides the non-cancer HQs for the four constituents that exceeded the pathway benchmark. The HQs for all four constituents are less than one.

¹² The pathway-specific benchmark for selenium in drinking water is based on the upper tolerable intake level (UL) of 0.4 mg/day set by Health Canada. This UL is also the basis for Health Canada's proposed drinking water MAC of 50 µg/L. The health-based proposed MAC contrasts with the 1992 guideline currently relied on by B.C. MOE of 10 µg/L, which is based on allowing 10-25% of total selenium intake to be from drinking water.

Table 5-10. Hazard quotients for First Nations resident, fish ingestion.^a

Constituent	MU-1	MU-2	MU-3	MU-4	MU-5	MU-6
Aluminum	0.01	0.006	0.001	0.03	0.004	0.003
Arsenic	0.007	0.02	0.01	0.01	0.005	0.01
Cobalt	0.2	0.1	0.008	0.3	0.1	0.02
Selenium	0.8	0.4	0.2	0.4	0.2	0.2

^a Results shown for muscle tissue only

Dietary selenium intake accounts for approximately 98% of total intake. Average daily selenium intakes for residents of Halifax, Toronto, and Vancouver are provided by Health Canada;¹³ no data specific to southeast B.C. or Alberta are available (Health Canada 2014). Based on TAC advice that Elk Valley residents' diets reflect an inland rather than a coastal diet, the diet composition and selenium intakes of inland Toronto residents were selected as representing Designated Area residents better than Vancouver or Halifax. Combining the Toronto resident selenium intake level (2.2 µg/kg-day) with intake from MU-1 fish (4.3 µg/kg-day), calculated using the upper confidence limit on the mean concentration, results in a total daily selenium intake (6.5 µg/kg-day) above Health Canada's tolerable upper intake limit level (UL) (5.7 µg/kg-day). Similar calculations for consumption of fish muscle tissue from MU-2 through MU-6 do not cause the UL to be exceeded. The UL also is not exceeded for MU-1 fish when samples collected from a heavily studied settling pond, Clode Pond, are excluded in the dataset¹⁴. MU-1 is currently closed to most fishing¹⁵.

To assess if background selenium intakes might be higher among Elk Valley residents, other non-fish sources of dietary selenium intake were considered, such as consumption of wild game and native vegetation. Generally, meats and fish contain more selenium than plants. The relatively low concentration of selenium in fruits and vegetables results in a negligible contribution to overall dietary selenium intake. A higher contribution to dietary selenium is derived from protein sources, with the highest selenium levels observed in organ meats. Table 5-11 shows average selenium concentrations in foods analogous to traditional foods consumed by Elk Valley residents and First Nations members, based on an average of concentrations in foods in Toronto, Halifax and Vancouver (Health Canada 2014).

Table 5-11. Selenium concentration in various foods sampled in Toronto, Halifax, and Vancouver.

Food	Three-city mean selenium concentration (µg/g, as prepared)
Fish (freshwater & marine, shellfish, canned)	0.53
Meat (beef, pork, lamb, veal)	0.28
Organ meats (kidney, liver)	1.14
Poultry	0.33
Berries	0.005
Mushrooms	0.20
Nuts & seeds	0.29

¹³ "All ages" average daily intake values are 2.2 µg/kg/day in Halifax and Toronto and 3.2 µg/kg/day in Vancouver (Health Canada 2014).

¹⁴ Barriers preventing fish migration between Clode Pond, a settling pond, and the Fording River will be installed in the near future. This will result in lower overall fish tissue concentrations for MU-1 as fish reflecting exposures within Clode Pond become inaccessible outside the mine operations fenceline.

¹⁵ Fishing is closed or limited to catch and release for most waters in MU-1 and MU-2 except by First Nations members.

Selenium concentrations were reported for a limited data set of Elk Valley game. Average selenium concentrations measured in deer, elk, and sheep organ meat (1.3 µg/g wet weight (N=17), liver and heart¹⁶) are greater than concentrations in game muscle tissue (0.51 µg/g wet weight). Average Elk Valley game organ and muscle tissue selenium concentrations are higher than those reported across three cities surveyed by Health Canada (see Table 5-11).

When applying reported tissue concentrations to average food intake rates for “all Canadians” and Ktunaxa who consume locally harvested game, total dietary selenium intake is slightly greater for the latter (2.3 µg/kg-day vs 2.1 µg/kg-day).¹⁷ This suggests that selenium intake for Elk Valley resident hunters may be higher than for other Canadians who do not consume game.

5.5.3.2 Cancer Risk Estimates

Cancer risks are calculated by multiplying the lifetime average daily dose by the TRV. The calculated cancer risk is the incremental probability, or probability in addition to the background risk experienced by all individuals in the course of daily life, that an individual will develop cancer during his or her lifetime due to exposure to a constituent. The risk estimates were compared with the B.C. MOE acceptable risk level, which for carcinogens is 1 in 100,000.

Arsenic was the only cancer-causing constituent retained for further evaluation. Based on dissolved arsenic concentrations, cancer risk from drinking surface water ranges from 4 in 1,000,000 in MU-1 through MU-3, to 1 in 100,000 in MU-6 (Table 5-12). Based on total arsenic concentrations, cancer risk ranges from 6 in 1,000,000 in MU-1 and MU-2, to 2 in 100,000 in MU-5 (Table 5-12). The risk estimate for total arsenic concentrations in MU-5 is above the acceptable level established by B.C. MOE. Mean concentrations for dissolved surface water arsenic in MU-1 through MU-5 (0.00011 – 0.00019 mg/L) are similar to mean reference surface water concentrations (0.00018 mg/L). The mean concentration in MU-6 (0.00030 mg/L) is higher than the reference area mean.

Table 5-12. Cancer risks for arsenic in surface water, ingestion.

Arsenic	MU-1	MU-2	MU-3	MU-4	MU-5	MU-6
Dissolved	4E-06	4E-06	4E-06	7E-06	6E-06	1E-05
Total	6E-06	6E-06	7E-06	1E-05	2E-05	1E-05

Cancer risk from the ingestion of arsenic in fish ranges from 3 in 1,000,000 in MU-1 and MU-6, to 1 in 100,000 in MU-5 (Table 5-13). This falls within the acceptable risk level established by MOE. Upper estimates of mean arsenic concentrations in fish tissue for MU-1 through MU-6 are lower than mean reference tissue concentrations, indicating that eating fish harvested in the Elk Valley will not result in higher arsenic intake than eating reference area fish.

Table 5-13. Cancer risk from fish ingestion.

Arsenic	MU-1	MU-2	MU-3	MU-4	MU-5	MU-6
Muscle	3E-06	8E-06	5E-06	7E-06	6E-06	3E-06
Whole	--	--	1E-05	5E-06	6E-06	--

¹⁶ Selenium concentrations in liver were much higher than heart concentrations.

¹⁷ These estimates of total dietary selenium intake levels do not include contributions from local freshwater fish. Traditional food intake rates for muscle tissue, organ meat, berries, and mushrooms were obtained from the Firelight Study 2013.

Although the combined cancer risk for drinking surface water (total concentrations only) and eating fish (whole body only) in MU-5 would slightly exceed the B.C. MOE risk level, there is no evidence that surface water is being used as a drinking water. This reduces the likelihood of such combined exposures. It is also noteworthy that arsenic concentrations in fish are not higher in MUs with higher surface water concentrations. Further, the similarity of arsenic concentrations in the Elk Valley to reference area samples indicates that most arsenic in surface water and fish is likely due to natural sources rather than mining-related activities.

5.6 Protection of Groundwater

An understanding of regional groundwater conditions was developed from a recent drinking water evaluation and sampling program, the objectives of which were as follows:

- Identify drinking water supplies in the Elk Valley that may be affected by mine-influenced water and potentially contain elevated concentrations of Order constituents (cadmium, nitrate, selenium, and sulphate).
- Evaluate whether concentrations of Order constituents are above applicable drinking water quality guidelines (WQGs), by completing a drinking water supply sampling campaign.

A total of 91 locations (85 of which were groundwater sources) were collected to assess groundwater quality, including private wells, Elkford and Sparwood municipal wells, other supplies with multiple users, and samples from surface water points of diversion (springs/creeks). Samples from eight locations were found to exceed or be within 20% of the selenium guideline, and were re-sampled. One sample failed to meet the AO guideline for sulphate, one the AO guideline for sodium, and one the AO guideline for chloride. The sodium and chloride results exceeding the guidelines were judged to result from local, non-mine sources (e.g. water softener).

As described in Section 5.1.2, two localized transport pathways for selenium in groundwater were identified: source release to upland groundwater, and surface water recharge from the Elk River to groundwater in the floodplain. Shallow groundwater (i.e., <15 m below grade) in the Elk River floodplain has a higher degree of hydraulic connectivity to the Elk River than deep groundwater, resulting in a greater potential for shallow groundwater to be influenced by constituents in the Elk River. In particular, shallow groundwater in floodplain areas hydraulically downgradient of a meander may receive a higher component of surface water recharge. Surface water recharge to groundwater also appears to be higher where river gradients are higher.

Parts of the Elk River are likely a source of groundwater recharge, which supports conclusions that groundwater quality in the floodplain may be influenced by the Elk River. Based on these findings, it is anticipated that by directly addressing surface water quality through implementation of the Plan, groundwater within the populated areas of the Elk Valley (floodplains) will be protected.¹⁸

5.7 Uncertainties and Data Gaps

Data gaps and uncertainties related to analytical detection limits, selection of analytes, availability of game tissue, and dietary selenium intake were identified throughout the analysis are summarized here:

- A data gap was identified for bromide in surface water, where only dissolved concentrations were measured, and the detection limits were equal to or above the guideline value for total bromide. This data gap is not judged to be a high priority from a health risk perspective as there is not currently evidence that bromide is associated with mining activity, and it is not a constituent likely to accumulate in fish.
- For some constituents (bromide, chloride, sulphate), the water quality baseline guidelines are applicable to total constituent concentrations in water while the dataset contained only dissolved concentrations. This data gap is likely insignificant because health risks associated with these constituents are low.

¹⁸ Individual mining operations are developing groundwater monitoring networks and monitoring programs to improve understanding of groundwater at an operational (local) level. Results of these investigations will be used to help improve Teck's understanding of local groundwater in relation to potential mitigation scenarios.

- Over the 2011–2013 time-period, constituents analyzed in surface water were not consistent across all MUs, resulting in slightly varying constituent lists for each MU. For example, sulphur was measured in surface water only in MU-6. The significance of this possible data gap is low, constituents of greatest potential health concern (e.g., nitrate and selenium) were monitored across all MUs.
- Sample size was limited for fish tissue data in the 2011–2013 time period, resulting in lower sample sizes compared to datasets for other environmental media for which samples had been collected throughout the three-year period. Smaller sample sizes typically result in greater variability within datasets, which is reflected in higher estimates of the UCLM. Continued monitoring through the Regional Aquatic Effects Monitoring Program will reduce uncertainty in characterizing fish tissue concentrations for future health assessments.

Game muscle and organ meats are expected to be harvested locally and could be a factor affecting background selenium intake. Based on the existing data set, there is uncertainty in the estimate of background selenium intake for Elk Valley residents. Lack of selenium concentrations in other traditional foods, such as berries and mushrooms, is not considered an uncertainty because the contribution of these foods to total dietary selenium intake is negligible compared with the selenium contribution from game meats and fish.

5.8 Conclusions Regarding Current Conditions

Baseline screening of current water quality identified numerous constituents that met guidelines for surface water, sediment, fish, and groundwater. Constituents that sometimes exceeded guidelines, as well as those with no guideline values, were carried forward to the multi-step effects assessment.

Constituents for which no TRVs are available were evaluated qualitatively to determine if the absence of a TRV was a data gap that needed to be filled to assess potential health risk. In most cases, constituents without TRVs were judged unlikely to present a health risk at the concentrations observed. Many of these constituents were nutritional macro- or microminerals not typically included in health risk assessments. Others were considered similar in toxicity to constituents for which TRVs are available and for which guidelines were not exceeded (e.g., some of the PAHs).

A minor data gap was identified for bromide in surface water, where only dissolved concentrations were measured and the detection limits were equal to or above the guideline value for total bromide; however, the bromide guideline is used to monitor water supplies after treatment, and not typically used to assess raw water quality.

Pathway-specific screening against benchmark values was conducted for each exposure medium. Benchmark values were derived for the primary exposure pathways. Based on the outcome of screening for the primary pathways, the need to develop benchmark values for secondary exposure pathways was assessed. For surface water, only nitrate in the drinking water exceeded the pathway-specific benchmark.¹⁹ Other pathways pose a risk orders of magnitude lower than drinking water, so benchmarks for the secondary pathways were not developed. For sediment and groundwater, the primary pathway-specific benchmarks were not exceeded, and thus no benchmarks were derived for secondary pathways.

As summarized in Table 5-14, constituents for which non-cancer risks were calculated included nitrate in surface water consumed as drinking water, and aluminum, arsenic, cobalt, and selenium in fish. None of these constituents were found to pose non-cancer risks. Because no constituents were evaluated in multiple exposure pathways or exposure media, there was no need to calculate aggregate risks for any constituents. Cancer risks were estimated for arsenic in surface water and fish. The resulting estimates did not exceed MOE's acceptable risk level of 1 in 100,000 for dissolved arsenic concentrations, and dissolved arsenic concentrations in MU-1 through MU-5 surface water were not higher than reference areas. Similarly, fish concentrations were not higher than reference areas, and risks were in the acceptable range.

¹⁹ Arsenic exceeded a cancer risk benchmark, but the benchmark was far below natural background concentrations.

Table 5-14. Constituents included in pathway screening and risk estimates.

Exposure medium	Pathway-specific screening	Risk estimates	Conclusions ^a
Surface Water	Aluminum, Arsenic , Beryllium, Cobalt, Iron, Manganese, Selenium, Vanadium, Nitrate (as N)	Nitrate (as N)	Nitrate exceeded pathway-specific benchmark, but risk estimates showed no risk of adverse effects. Dissolved arsenic concentrations were similar to those in reference areas and cancer risks did not exceed acceptable levels.
Sediment	Aluminum, Iron, Nickel, Selenium	—	No constituents exceeded pathway-specific benchmarks; no risk calculations were necessary.
Fish	Aluminum , Antimony, Arsenic , Cadmium, Cobalt , Iron, Lithium, Selenium , Vanadium, Zinc	Aluminum, Arsenic, Cobalt, Selenium	Aluminum, arsenic, cobalt and selenium exceeded pathway-specific benchmark, but were not found to pose unacceptable health risks.
Groundwater	Selenium	—	No locations had selenium concentrations exceeding pathway-specific benchmark; no risk calculations were necessary.

^a Pathway-specific benchmarks are those calculated specifically for this evaluation, as described in Section 5.5.2.

An additional analysis was conducted for selenium to determine if intakes from fish would still be acceptable when Canadian dietary intakes of selenium are considered. Intake of selenium via consumption of fish from MU-1, plus background dietary intake, was predicted to exceed Health Canada’s UL only if samples from Clode Pond (a settling pond) were included. Elk Valley residents who regularly consume local game may have higher dietary selenium intakes than Canadians who do not consume game. Selenium concentrations were highest in the livers of game animals.

Considered together, work conducted to assess protection of human health and protection of groundwater did not identify unacceptable health risks associated with current water quality in the Designated Area. Thus, no specific actions related to water quality are needed for protection of human health. Furthermore, considering the high degree of hydraulic connectivity to the Elk River in localized areas, active mitigation associated with reducing surface water concentrations will serve to protect groundwater.²⁰

5.9 Future Conditions

Water quality targets for each of the Order constituents at each Order station are established based primarily on protection of aquatic biota (see Chapter 8, Table 8-16). Most long-term water quality targets to protect aquatic biota are lower than those needed to protect human health.

Long-term targets for selenium in MUs 1-5 exceed the current B.C. MoE WQG for drinking water. The guideline value is not based on adverse health effects, but on a fraction of typical dietary selenium intakes. In the Upper Fording River (where there are no existing or proposed drinking water consumers), the long-term target for selenium also exceeds the pathway-specific benchmark and the proposed Health Canada MAC. This suggests that, although no current unacceptable health risks are identified, this stretch of the river should not be used for drinking if concentrations are above the guideline.

²⁰ Individual mining operations are developing groundwater monitoring networks and monitoring programs to improve understanding of groundwater at an operational (local) level. Results of these investigations will be used to help improve Teck’s understanding of local groundwater in relation to potential mitigation scenarios.

The short-term selenium water quality targets and Fording River nitrate concentrations prior to 2019 are also above pathway-specific benchmarks, and indicate that surface water in the Upper and Lower Fording River should not be used for drinking if selenium concentrations are at or above the short-term targets or if nitrate concentrations are above the long-term target.

A full discussion of water quality targets and mitigation actions is presented in Chapter 8.

Chapter 6

Development and Selection of Management Options

Chapter Overview

This chapter describes the ongoing research and development (R&D) programs through which Teck identifies, assesses and improves methods to protect water quality. It also explains the assessment process used to select water-quality management options, and Teck's commitment to continuing assessment of other options as new data and technologies become available. The detailed implementation plan and sequence of management options are discussed in Chapter 8, and the implementation plan for calcite management is described in Chapter 7.

Concordance with Ministerial Order and Terms of Reference

Chapter 6 satisfies Section B.10 and B.15 of Schedule C of Ministerial Order M113 and Section 3.9(a) of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Extensive resources dedicated to identifying and investigating management options.** Teck has been examining and taking action on water-quality management since 2010, including commissioning an independent advisory panel on selenium management, which outlined several proposed actions and principles for prevention, control and removal of selenium from water. Based on recommendations from the independent advisory panel, Teck launched an R&D program focused on watershed and selenium management in 2011.
- **Active water treatment and clean-water diversion are the most effective options to stabilize selenium and other concentrations in the short term:**
 - Active water treatment has been proven to reduce constituents of interest and is necessary to meet water quality targets in the short term. This is the best available management option. It can reduce in-stream concentrations of constituents of interest with varying effectiveness, depending on the technology used.
 - Clean-water diversions reduce volumes of water affected by waste rock, reducing the amount of water that needs to be treated. This can be particularly effective when it involves the diversion of large, upstream, undisturbed watersheds, such as Upper Line Creek and Upper Kilmarnock Creek. Diversions may be particularly useful in the future when site-specific projects are considered.
- **Teck's R&D programs will continue to seek improvements to active water treatment and diversion methods, while also investigating alternatives that could reduce the need for active water treatment over the long-term.** Teck has identified potentially attractive ways to reduce future treatment requirements, including waste-rock covers and saturated fills. Teck is committed to the R&D needed to ensure that these and other technologies are realistic candidates for future plans.

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6.1 Research and Development

6.1.1 Program Objectives

Teck's R&D programs investigate options for managing selenium and other constituents of interest, including those specified in the Order. The overall objectives of these programs are as follows:

- Identify and develop new technologies and techniques, and/or enhance existing technologies, to manage water quality.
- Communicate results of this program through Teck's internal technology transfer process.

Teck's R&D efforts relevant fall into two categories: source control, and active water treatment. Source-control R&D investigates both constituent sources and control methods. It includes studies of alternative technologies such as covers and in-pit passive treatment, as well as nitrate and calcite control. It also contributes to the basic water quantity and quality predictions, to help develop the initial implementation plan options. The active water treatment program focuses on investigation of technologies, including periodic surveys of new methods.

6.1.2 Program Structure

Teck's R&D programs are a coordinated effort with clear objectives, deliverables and reporting structures.

Source-control R&D is under the direction of the General Manager, Environment, Coal, and is overseen by the R&D Management Team, which comprises members of Teck's senior management. Source-control R&D is led by a dedicated manager, who is directly supported by a field lead and R&D site coordinators at each mining operation. The site coordinators are essential, as much of the R&D work is field-based and requires site-specific environmental, health and safety planning for the many third-party researchers involved.

Teck's active water treatment technology program is implemented by a team of research scientists and engineers from Teck's Applied Research and Technology (ART) group. This is coordinated and aligned with source-control R&D, and rolls up into the overall R&D program as shown in Figure 6-1.

Both source-control R&D and the active water treatment program are supported by Teck's Mine Engineering and Water Quality Projects groups. These groups are responsible for identifying opportunities to incorporate R&D learnings into engineering practice, and into the development and implementation of water-quality management options.

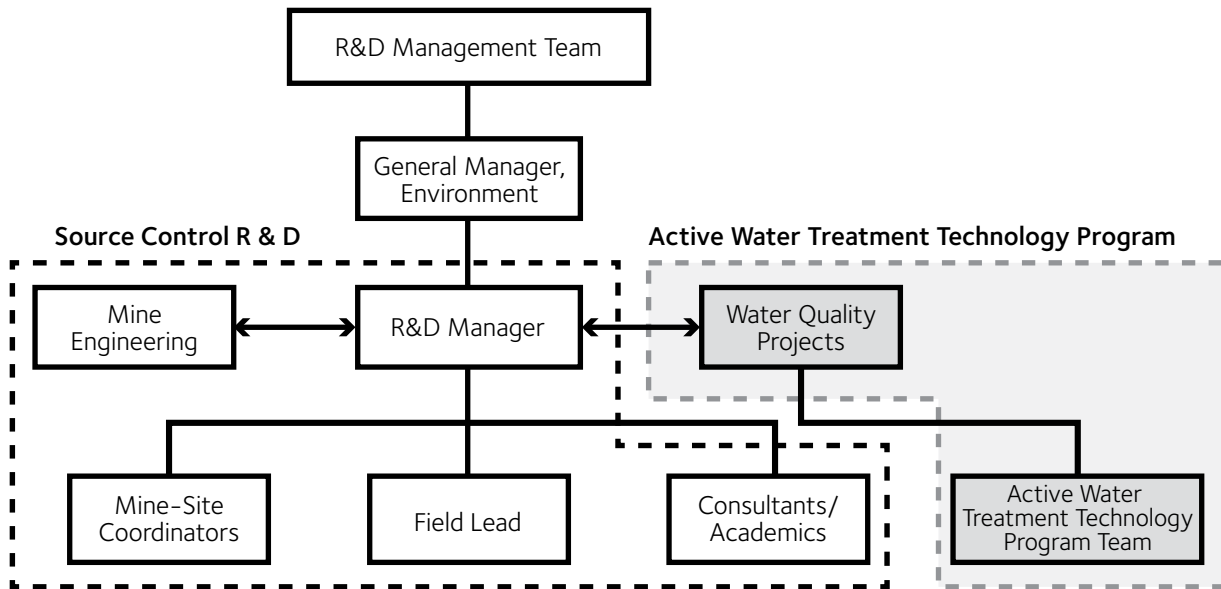


Figure 6-1. R&D organization structure.

The R&D programs include rigorous independent research conducted in partnership with several research leaders from Canada and the US. The current team includes the University of Saskatchewan, McMaster University, and Montana State University, and specialists from SRK Consulting, BGC Engineering, O’Kane Consultants, Integral Ecology and WorleyParsons.

6.1.3 Learnings to Date

Figure 6-2 illustrates the nine areas of source-control R&D in the context of an idealized mine-affected, reconstructed watershed. Highlights to date from the source-control R&D program include:

- the development of decision-support tools for assessing the timing and sizing of water treatment facilities and other management options
- compilation and syntheses of watershed-scale data to help build the regional water quality model
- improved understanding of the physical, geochemical and microbiological processes that lead to constituent release from waste rock, including options to control some of those processes
- field testing and analysis of the effects of soil covers and other surface treatments on water percolation, and the release of constituents from waste rock
- multiple lines of evidence indicating that it might be feasible to treat mine-affected water passively in pits backfilled with waste rock (saturated fills).

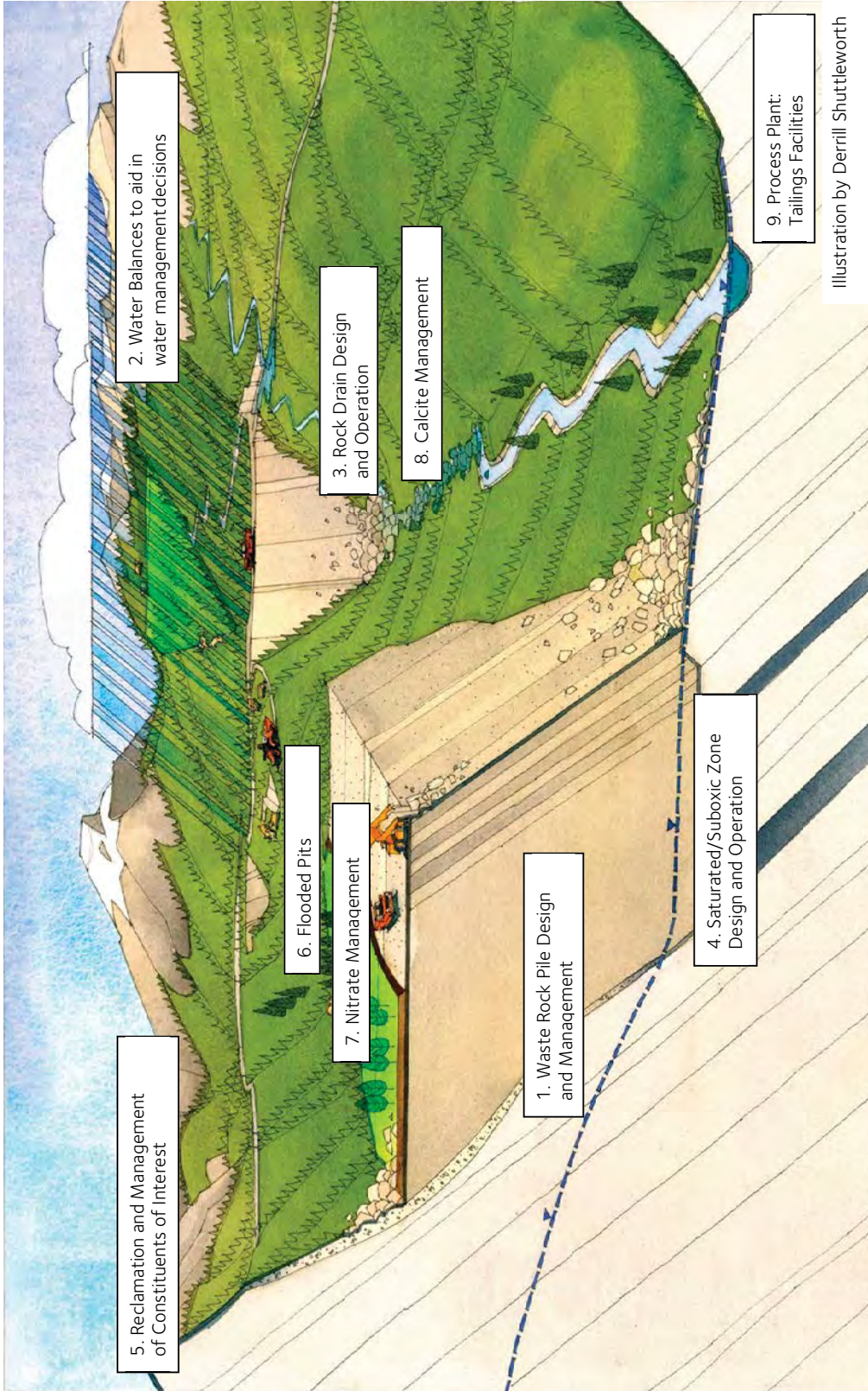


Figure 6-2. Nine research areas of source control research and development.

Several source-control practices were identified that could improve water quality and, with further development, be implemented at full scale. The highest priority identified to date is the use of saturated fills to treat mine-affected water, and the testing of a proprietary method to reduce nitrate losses from blasting. These and other continuing R&D initiatives are discussed in Section 6.3.

Highlights of the active water treatment program include the 2011 testing of four active biological treatment technologies, which rely on microorganisms that convert selenium to a particulate form that can be removed through settling. Of the four technologies tested, only two achieved effluent selenium concentrations of less than 20 µg/L. The four technologies were then evaluated at a conceptual level, considering pilot results as well as other parameters including, but not limited to, performance, operability, technology readiness, economics and full-scale footprint. Fluidized Bed Reactor treatment (a type of biological treatment) was selected for full-scale implementation at Line Creek Operations.

Further active water treatment technology investigations were conducted in 2012 and 2013. Following a comprehensive literature and vendor review, the outcome of these investigations was to improve the understanding of each technology, the current status of development, and possible applications in the Elk Valley. Technologies were compared in terms of water quality, cost, constructability, operability, technology status, supportability and sustainability (in energy consumption, facility footprint, emissions, etc). The following technologies selected as the most promising:

- biological treatment
- reverse osmosis
- electro dialysis reversal coupled with reverse osmosis.

These technologies were pilot-tested in 2013 to explore performance under conditions in the Elk Valley, and to address process risks and uncertainties. Biological treatment was confirmed as the leading technology for the removal of nitrate and selenium.

6.2 Assessment of Options

6.2.1 Approach

The selection of water-quality management actions, on a regional basis and over the extended timeframe required by the Order, is a complex task. The scale of the affected area, the multiple mine sites and many receiving streams, and the number of possible action combinations all need to be considered.

Teck used an iterative process to assess options coming out of the R&D programs, and to select the methods that are best-suited to the initial implementation plan. This process began in late 2013 with the development of computer models to examine the effect of various management options for water quality in the Fording and Elk Rivers. Initial analyses looked at combinations of active water treatment, clean-water diversion, and geosynthetic covers. Annex D.2 describes the combinations of water-quality management options that were modelled. By examining patterns in the model predictions, Teck's project team identified ways to improve each combination of options.

In February 2014, a larger group of Teck staff and consultants was assembled to participate in two workshops, to review initial water-quality predictions and the ideas assembled by the project team, and to select a preferred combination of management options. In both workshops, participants were first asked to brainstorm objectives for water quality planning and methods for water management. Participants then assessed scenarios developed by the project team to see how well they met the identified objectives, and whether any of the identified methods could lead to improvements. The workshops included discussion of confidential technical and financial information, so it was not possible to involve external stakeholders, but participants were asked

to consider all of Teck’s responsibilities to its stakeholders, as well as their personal perspectives as members of local communities.

In the first workshop, participants examined the initial water-quality management options and concluded that two additional scenarios should be developed. The first was an improved combination of active water treatment and clean-water diversion. The second was a “minimum treatment scenario” that incorporated methods still being investigated in the source-control R&D program, with the objective of reducing reliance on active water treatment over the long term.

Teck’s project team further developed the two new scenarios for review by participants in the second workshop. The revised active water treatment and clean-water diversion scenario was very similar to that considered in the initial modeling, but with changes to the sequence and scheduling of treatment facility implementation. The second new scenario assumed that two R&D methods, passive water treatment in saturated fills and waste rock covers, would prove to be technically feasible. After initial implementation of active water treatment and clean-water diversion systems, the scenario included a gradual conversion to passive treatment when and where saturated fills became available, and covering of waste-rock dumps located further from the saturated fills. The long-term condition in this scenario still required active water treatment along the upper Fording River, but relied on passive treatment and covers elsewhere.

In the second workshop, additional improvements to both of the revised scenarios were identified, but implications for the Plan were clear. Specifically, participants agreed that active water treatment, supplemented by clean-water diversion, should be the primary water-quality management method for Plan implementation. However, they also agreed that methods with the potential to reduce long-term reliance on active water treatment could be very attractive to Teck and external stakeholders, and therefore should be considered for future plans.

The reasons for those conclusions can be summarized as follows:

- Active water treatment and clean-water diversion are the only methods that are sufficiently proven to meet the Order requirement to begin stabilizing contaminant concentrations.
- Depending on R&D progress, alternative technologies could supplement or replace active water treatment in later stages of Plan implementation, and reduce the long-term need for active water treatment.
- The primary benefits of the alternative methods is that they reduce long-term commitments for Teck, and post-closure concerns for external stakeholders. Some alternative methods could also provide additional “non-water” benefits such as improved reclamation, biodiversity and land use.

6.2.2 Selected and Future Options

Teck recommends two options for initial implementation: active water treatment and clean-water diversion. Teck also identified two options that are currently in R&D but that are believed to be good candidates for later stages of the Plan.

6.2.2.1 Selected Option: Clean-water Diversion

Diversion involves the construction of earthen dikes or other physical barriers and/or pipes or other conduits to route clean water around mining activities. Diversions offer the advantage of mimicking natural, gravity-driven flows from higher to lower elevations. With dikes, no energy is required and maintenance, personnel and operating costs are low. A reduction in the volume of clean water that comes in contact with mine waste could reduce selenium and other constituents of interest downstream of the operation. Diversions also reduce the volume of water passing through mining waste rock, thereby reducing the volume potentially requiring treatment. Figure 6-3 provides a schematic of a typical gravity-driven clean-water diversion.

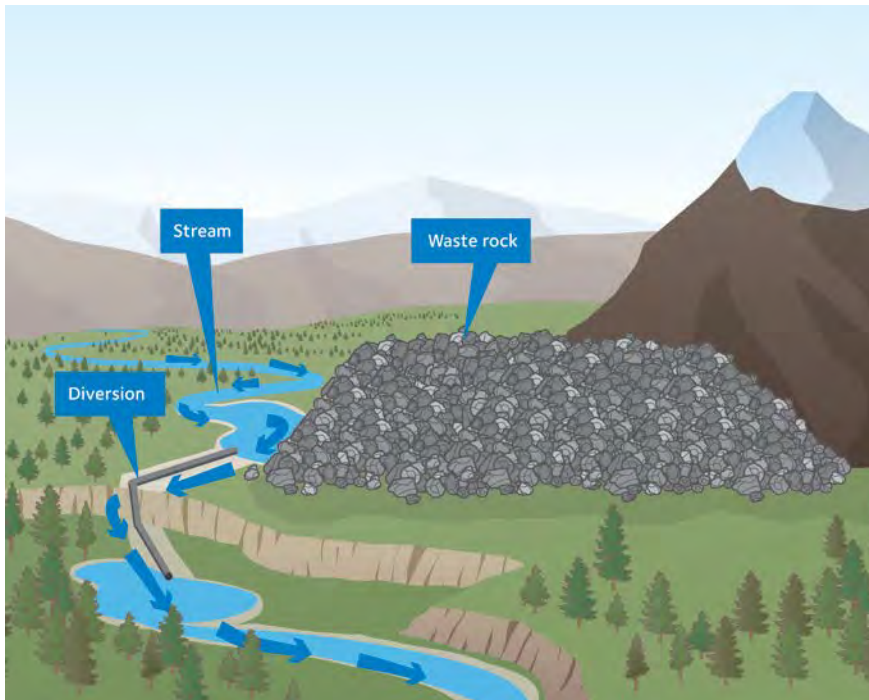


Figure 6-3. Typical gravity-driven clean-water diversion.

clean-water diversions: one at Fording River Operations on Kilmarnock Creek and one at Greenhills Operations on Swift Creek. Lessons learned from these projects suggest that piped clean-water diversions may be the preferred option, although this will be considered on a case-by-case basis during the design of each diversion project.

Diversions will be commissioned at the same time as associated downstream active water treatment facilities. Diversions were assumed to be large enough to convey freshet (May) flows in an average year. During design of a specific diversion, the infrastructure would be protected from the 1:200-year flood as per provincial policy. Potential clean-water diversions are detailed in Annex D.2. Selection of individual diversions for the initial implementation plan is explained in Chapter 8.

6.2.2.2 Selected Option: Active Water Treatment

Active water treatment involves processing water that has passed through waste rock spoils to reduce constituents of interest, and returning the treated water to receiving streams to maintain natural flow volumes. Figure 6-4 depicts the application of active water treatment.

Based on results from the active water treatment program, two technologies are being considered for implementation at this time.

Diversions are not maintenance-free, and they require monitoring. If a diversion is not properly located or designed, some water may bypass it, undermining its effectiveness. A diversion's efficiency is influenced by local factors, and it must be designed in a site-specific manner.

Pipes and pump-driven flows can compensate for some of a diversion's shortcomings, and offer more flexibility and the ability to accommodate challenging topography, but these increase operating costs and maintenance requirements.

As part of recent overall water-quality management efforts, Teck built and operated two gravity-flow

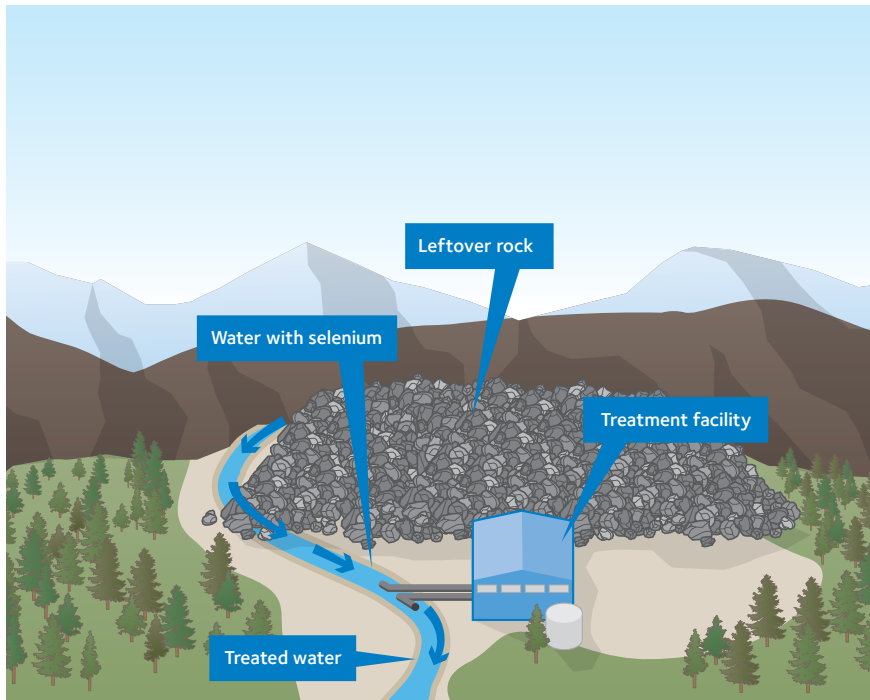


Figure 6-4. Active water treatment of mine-affected water.

Biological treatment relies on microorganisms and is effective at removing nitrate and selenium, and is the industry-preferred active water treatment technology for selenium. The influence of technology selection from a regional planning purpose is limited: concentrations coming out of treatment facilities are assumed to be consistent at 20 µg/L for selenium and 0.3 mg/L for nitrate – the design targets for biological treatment. Current biological treatment technologies do not remove sulphate.

At this time, biological treatment requires the addition of phosphorus for the removal of nitrate and selenium. As outlined in Chapter 4, phosphorous does not currently exceed WQGs in the Designated Area. In recognition that the Designated Area is phosphorous-

limited, an evaluation was performed of potential changes in trophic status within the Fording and Elk rivers and in Lake Kooconusa; refer to Annex I.1 and Annex I.2.

In **membrane treatment**, water passes through a thin layer of material that captures all compounds larger than a specified particle size. Membrane treatment has the potential to reduce all constituents of interest, but there are challenges associated with:

- treating water to the point where it is too clean (i.e., constituents need to be added before releasing it back to the receiving streams, to mimic natural water quality)
- management of solids generated from the process
- remaining performance uncertainty, compared to biological treatment.

These challenges, coupled with membrane treatment's greater implementation and operating costs, make biological treatment the preferred treatment technology.

Based on the best available information, it is anticipated that at the point of discharge (end-of-pipe), biological treatment may result in a residual total phosphorus concentration of 0.3 mg/L without additional phosphorous treatment. The Plan's model was used to assess if this residual phosphorus could affect trophic status within the Fording and Elk rivers. As detailed within Annex I.2, the initial implementation plan may change the trophic status of the Fording River from oligotrophic to mesotrophic; while the Elk River would remain oligotrophic. As outlined in Annex I.1, the initial implementation plan is not expected to change the oligotrophic status of Lake Kooconusa.

Once a site is selected, it is estimated that four years are required to build an active water treatment facility. This process is divided into three project stages:

- planning and scoping (8 months)
- engineering and permitting (16 months)
- construction and start-up (24 months).

Water is captured and conveyed to treatment facilities at locations called intakes. Intake locations influence the quantity and quality of the water going to the treatment facility. Many factors contribute to the choice of intake location, including access, safety (avalanche and waste rock pile stability), the desire to collect water with the highest concentrations, and hydrogeological conditions that determine how much mine-influenced water is at surface or in shallow groundwater. In each drainage area, these factors govern how much mine-influenced water is likely to be collected. Based on preliminary information gathered for regional planning purposes, assumptions were made for each catchment and incorporated into the model. During detailed design, site conditions will be investigated to support design decisions, and planning assumptions updated as required.

Construction of Teck's Line Creek active water treatment facility (Figure 6-5) began in the summer of 2012, and the facility is scheduled to begin treating water in the summer of 2014. The facility will treat an average of 7,500 m³ of water daily — enough to fill three Olympic-sized swimming pools. The treatment facility is anticipated to remove approximately 650 kg of selenium and 40,000 kg of nitrate per year. Planning is underway for a second treatment facility at Fording River Operations.



Figure 6-5. West Line Creek Active Water Treatment Facility, April 2014.

Active water treatment produces residuals that require management. Residuals contain removed constituents as well as other solids generated through the treatment process. Residuals from biological treatment consist primarily of bacterial biomass and selenium, and can be placed in a landfill. Residuals from membrane treatment are sometimes hazardous.

Teck has considered and evaluated methods to manage residuals, including but not limited to:

- beneficial re-use through application on land (e.g., as a soil supplement or fertilizer)
- extraction and recovery of selenium

Unfortunately, selenium concentration in residuals is well above the limit for land application, and cannot be extracted and recovered from the large volumes of water and biomass involved. As a result Teck's current approach is to dewater residuals to a solids content of ~20%, at which point they have the consistency of wet soil, and then to store them in lined containment cells. When full, these storage cells will be capped and covered for long-term storage.

6.2.2.3 Potential Future Option: Saturated Fill Treatment

Saturated fill is waste rock that has been deposited into a pit and then flooded. Areas of saturated fill are common in Elk Valley coal mines, and future sites are included in Teck's mine plans. Early source-control R&D identified the possibility that saturated fills could be used to treat selenium through the microbial reduction of selenate to less mobile forms. Research has confirmed that the microbes needed to treat selenium are present, and there is strong evidence that selenium concentrations in saturated fills are much lower than would be expected in their absence.

In 2013, Teck initiated controlled studies of the saturated fill in the closed Henretta pit at Fording River Operations, to evaluate controls on selenium and nitrate attenuation (Figure 6-6). It was hoped that saturated fills not only treat water that flows through them naturally, but could also treat water from other areas of the site. This semi-passive system could be an attractive alternative to active water treatment plants. As discussed in Section 6.3.2, saturated fill treatment is a high priority for continuing R&D.



Figure 6-6. Testing of Henretta saturated fill, 2013.

6.2.2.4 Potential Future Option: Covers

Teck is evaluating a wide range of waste rock covers or surface treatments with potential roles in water-quality management. The scale at which covers would be needed is an economic challenge, and it is not yet clear whether any of these options will prove feasible, but they indicate the scope of Teck's investigations. Five examples are shown in Figure 6-7:

1. **Bare Waste Covers** are included for comparison only. Freshly placed Elk Valley waste rock has a high permeability and a low fines content, so it will not retain water long enough to support vegetation and provides little protection against water or air infiltration. Over time and depending on rock type, weathering increases the fines content and decreases permeability.
2. **Current Reclamation Covers** for most waste dumps in the Elk Valley include re-sloping dump faces to no steeper than 2H:1V, and directly planting or seeding. Depending on rock type, surface traffic and weathering history, some waste can develop sufficient fines to become a soil-like material.

3. **Simple Covers** make use of salvaged organic and mineral matter, placed as a single-layer cover.
4. **Complex Covers** most commonly include a layer of heavily compacted soil overlain by a layer of uncompacted soil. The lower layer acts as a water barrier, allowing plants rooted in the upper layer to remove it by evapotranspiration. In the work to date, a slightly different complex cover is envisioned, with the lower layer created by intensely compacting the waste surface, followed by placement of an upper layer comprising a mix of salvaged organic matter and mineral soil.
5. **Geomembrane Covers** employ a synthetic liner as a near-impermeable barrier. Most large applications have been limited to tens of hectares, rather than the hundreds needed to cover large dumps in the Elk Valley. Water that cannot infiltrate geomembranes must go somewhere, so a drainage layer is usually included above the geomembrane.

Simple, complex and geomembrane covers may offer the additional benefits of facilitating reclamation and controlling air ingress. Restricting air ingress could improve water quality by limiting oxidation, but this has not been demonstrated.

Soil or fine-grained waste rock covers can also reduce net percolation and rates and water treatment costs. Their effects on water seepage water quality, particularly in suboxic zones, however, have not yet been determined in sufficient detail.

A limitation of all covers is that their full benefits are not realized immediately. Simulations of drain-down times at dumps covered with geomembranes indicate that water would continue to seep out for decades, although at continually diminishing rates. Another limitation of covers is that waste rock dumps deform over time and, until dump settlement has slowed, the risk of damaging a cover system is elevated. Constructability is a further limitation, particularly for more elaborate covers.

As part of any cover project, it would be necessary to identify material sources, establish re-sloping requirements and the associated impacts on undisturbed ground, determine surface-water quality management requirements, and finalize many other site-specific details.

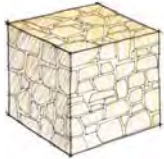
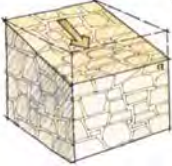
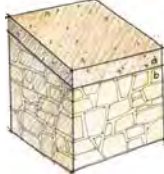
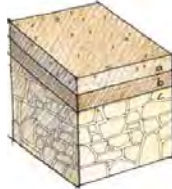
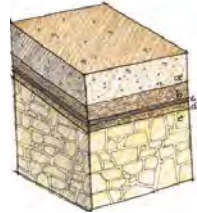
Cover Type	Bare Waste	Current Reclamation	Simple Cover	Complex Cover	Geomembrane Cover
					
Conceptual Profile	No cover	Direct seeding or planting Waste slopes re-shaped to 2H:1V	0.5 m surface soil* Waste slopes re-shaped to 2H:1V	0.5 m surface soil* 0.3-0.5 m of compacted waste Waste slopes re-shaped to 3H:1V	1.0 m surface soil* 0.3 m drainage layer Bituminous geomembrane Waste re-sloped to 3H:1V & proof-rolled
Net Percolation (% of Mean Annual Precipitation)	> 50%	> 40%	~ 30%	~ 20%	< 5%
Design & Construction Complexity		→ Increasing complexity, cost and additional disturbance →			Significant technical challenges

Figure 6-7. Summary of cover types.

6.3 Continuing R&D to Advance Future Options

New technologies and water-quality management methods, either now in the R&D phase or expected to emerge in coming years, have the potential to reduce the long-term reliance on active water treatment. Although these new technologies and methods are not yet advanced enough to be included in the initial implementation, they need to be considered for later iterations of the Plan.

6.3.1 Approach to Technology Development

Teck's overall approach to advancing technologies from initial research to full deployment consists of the following steps:

1. Identify basic knowledge and technology.
2. Identify sites for full-scale implementation.
3. Bound the risks.
4. Prioritize implementation technologies and sites.
5. Implement at full scale.
6. Monitor and improve first implementation.
7. Consider broader technology applications within mine plans.

Many of the above steps include sub-tasks. For example, bounding the risks for active water treatment technologies usually requires a pilot-scale test. Teck does not include such sub-tasks in the general steps, because they are not always needed.

The emphasis is on bringing technologies to a first full-scale implementation (Step 5). The results can be monitored and used to assess the value of further implementations, at a level suitable for comparison to the water-quality management options that were selected for initial implementation.

The emphasis on the first full-scale implementation also reflects two realities of many mine-environmental technologies. First, the full effects and costs of a mine environmental technology are often incompletely understood, and sometimes hotly debated, before full implementation. Second, site-specific conditions often mean that a technology must be modified in a site-specific manner. Both of these factors challenge the typical R&D paradigm in which technologies are proven at a small scale and then broadly rolled out without further changes. Teck's approach does not expect R&D to prove technology benefits, but only to provide the basic understanding (Step 1) and to constrain the risks (Step 3) to a level at which full-scale implementation can proceed with confidence.

6.3.2 Specific Technology Development Activities

Teck's long-term commitment to R&D is discussed further in Chapter 10. The main themes over the next two years are as follows:

- Source-control R&D currently addresses the semi-passive treatment of water in backfilled pits (saturated fills). The geochemical conditions that develop in these saturated fills favour microbial communities that can remove selenium and nitrate. Evidence that this process occurs in Teck's pits has already been found, and testing will focus on whether it is a reliable treatment method. Plans for the next two years include laboratory investigation of the underlying microbial and chemical processes, including rate-limiting factors and the risk of unfavourable reactions. An investigation of a saturated fill that is believed to be a good candidate for full-scale implementation will be initiated with a view to pilot scale trials in 2015.

- Covers are another focus of source-control R&D. Two lines of investigation are moving ahead in the next two years. One is an engineering review to determine if there are ways to construct geomembrane covers more cost-effectively and with less impact on the surrounding areas. The other is continued monitoring of cover and reclamation trials begun in 2012; data from these sites are providing a strong basis for assessing the possible effectiveness of soil covers for reducing water ingress and supporting reclamation.
- Design of capture and diversion systems associated with new active water treatment facilities will apply findings from the hydrology and groundwater components of the R&D program. Site-specific investigations will transform this body of work from research into practical application.
- The active water treatment program will continue to track known technologies, with additional bench testing where warranted. A separate initiative is underway to determine whether completely new methods have longer-term potential. The program will also continue to investigate options for managing residuals. To date, R&D on residuals has focused on improving knowledge, by analyzing residuals generated from pilot-scale and analogous full-scale treatment facilities. This will be extended to studying residuals generated from Teck's Line Creek active water treatment facility when it begins treating water in the summer of 2014. Information gathered through R&D on residuals will inform and facilitate the permitting and design of future active water treatment facilities and the long term residuals management strategy.
- In 2012, Teck begin development of a nitrate management plan to reduce nitrate losses from blasting. The limits of improved blasting practices were defined, and the focus shifted to alternative explosives technologies to reduce nitrate losses at source. After reviewing potential options, High Viscosity Emulsion (HVE) products were selected for further evaluation. In 2013, lab evidence was collected that HVE reduces nitrate leachate. Field trials have been conducted, and preliminary results are positive and consistent with lab results. Teck intends to adopt HVE as a leading method of reducing nitrate entering the environment.
- Calcite R&D is discussed further in Chapter 7.

The above summarizes the current plan, but is subject to change based on a number of factors and conditions, including further monitoring, results from the initial implementation plan, changing conditions in the valley, economic and other factors.

Chapter 7

Calcite Management

Chapter Overview

This chapter describes Teck's study of the formation of calcite in mine-affected streams and other streams not affected by mining. It outlines options to manage the formation of calcite in the Elk Valley watershed; medium- and long-term targets established for the rate of calcite formation; and proposed actions to achieve the targets.

Concordance with Ministerial Order and Terms of Reference

Chapter 7 satisfies the calcite-related components of Section A.1 and A.2, Section A.3(b), Section B.5, B.7(a), B.13 and part of B.16 of Schedule C of Ministerial Order M113 and Section 2.0(c)(ii), Section 3.3(a), Section 3.7, part of Section 3.8(a), Section 3.8(d), Section 3.9(b), Section 3.10(b), part of Section 3.11(a)v and (c), part of Section 3.13 and part of Section 3.16 of the Elk Valley Water Quality Plan Terms of Reference.

Chapter Highlights

- **Targets established:**
 - Limited data exist to establish a final target Calcite Index, based on a scale from 0.0 (no calcite observed) to 3.0 (stream bed fully concreted). However, 2013 results identified reference streams with a Calcite Index ≤ 0.50 , which was established as the long-term target in mine-exposed streams that provide habitat or other value to fish.
 - A Calcite Concretion Score of ≥ 0.50 (out of a possible 2) was used to identify priority streams to be managed in the medium term. Achieving medium-term targets will take up to 10 years, and 15 years will be required to meet the long-term targets. For these streams, the goal will be to reduce the Calcite Index to below the long-term target.
 - Calcite targets, in terms of both levels of calcite and the timing of remedial actions, will be adaptively managed as implementation of the Plan proceeds. The long-term Calcite Index target will be reviewed as more data become available, and should be viewed as an interim target.
- **Protection of aquatic habitat in affected streams.** Calcite will be managed to achieve acceptable long-term targets. Long-term targets will be developed, taking into account the purpose of the Plan as stated in Section 1.2 of Chapter 1.
- **Priorities identified based on levels of calcite and potential impact on fish.** Of 352 km of streams surveyed in 2013, 89% had calcite formation levels (as measured on the Calcite Index) similar to that observed in streams not affected by mining. Four streams – Greenhills Creek, Corbin Creek, Dry Creek and Erickson Creek – were identified as priority streams because calcite formation is in the upper range as measured by a Calcite Concretion Score, and because they support fish habitat.
- **Evaluation of technologies to determine the best for implementation at a priority stream within three years.** Teck is studying several calcite treatment methods and technologies that can run unattended for extended periods, require few or no reagents, generate little or no waste, can accommodate variable amounts of water, and require minimal infrastructure.
- **Adaptive management.** As more data are collected, the calcite management plan will be adapted and adjusted.

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7.1 Introduction

The molecular source of calcite, calcium carbonate, is common in natural streams and poses a water-quality concern only when its rate of accumulation harms stream-bed habitats. This chapter describes the environmental issues and technological options involved in managing calcite formation.

Calcite formation has been observed in the Elk Valley watershed downstream of mining activities and, to a lesser extent, in reference streams unaffected by mining. In limited reaches of certain streams, calcite precipitation completely covers portions of the stream bed, making the gravels largely immovable.

In 2008, a survey of calcite occurrence in the Elk Valley was initiated (Berlusconi 2009), and Teck recently refined the monitoring program to quantify, monitor and assess potential effects of calcite deposition within the watershed. By reviewing results of the survey, targets can be established and streams prioritized for calcite management. An evaluation of potential technologies to manage calcite precipitation in the receiving environment is also underway.

As the extent of calcite formation in the Elk Valley and its potential effects on the aquatic environment become clear, targets and methods to meet the overall objective will be refined. The overall objective is to manage calcite to achievable long-term targets. Interim long-term targets have been developed that take into account the purpose of the Plan as stated in Section 1.2 of Chapter 1.

7.2 Calcite Formation

The chemistry of calcite formation involves two steps, both of which present management opportunities. Step 1 occurs as water drains from waste rock spoils, where it absorbs elevated levels of calcium and carbonate along with carbon dioxide. CO_2 is released as the water seeps from the spoils. This increases the pH of the water, creating a chemical condition favourable for Step 2, the precipitation of calcium carbonate. This condition involves the critical saturation index of calcite. Within a spoil, the saturation index is lower than the critical value, meaning calcium carbonate can remain dissolved. But downstream, the index can exceed the critical value, which leads to precipitation of calcite. Precipitation continues until calcium and carbonate fall below critical levels.

The rate of calcite precipitation varies with each stream's chemistry, nutrients, temperature, topography, velocity, and turbulence (Hammer et al. 2005). Some of these factors change daily, while others are seasonal. Algae, moss and other organisms in the stream bed also affect the chemistry of precipitation. Managing calcite build-up is further complicated by the fact that the chemical conditions that lead to calcite formation can reduce other constituents of concern (SRK 2011).

Calcite precipitation does not occur instantaneously, but depends on several factors:

- rates of CO_2 off-gassing
- availability of a site for the calcite crystal to begin growing
- inhibition of precipitation (e.g., magnesium ions or phosphorous compounds)
- slow transformations between bicarbonate (HCO_3^-) to carbonic acid (H_2CO_3).

Groundwater within the Elk Valley is supersaturated with Ca-Mg-Fe carbonates (Harrison et al. 2000) and as such, precipitation of calcite at groundwater discharges/seeps into streams/tributaries is common.

The scaling formed in kitchen kettles or hot-water heaters involves a similar chemistry. It is not toxic, and can occur naturally; but excessive calcite build-up can change the characteristics of stream beds by cementing rocks together and affecting habitat for fish and invertebrates.

7.3 Monitoring and Assessment

The 2008 calcite survey focused on the geochemistry of calcite deposition and the presence or absence of calcite. It did not provide sufficient information to quantify the rate of calcite deposition/dissolution downstream of mining activities, or to guide the design of biological monitoring programs. In 2013, however, a program was developed to quantify, monitor, and assess potential effects of calcite deposition in the Elk Valley. Objectives of the program were to:

- standardize the methodology for data collection and reporting of calcite deposition
- document the extent and degree of calcite deposition
- determine trends (i.e., rates) of calcite deposition
- assist in determining if, when, and where calcite mitigation is required.

To achieve these objectives, all mine-exposed streams in the receiving environment (i.e., downstream of areas disturbed by mining) were surveyed. Where settling ponds control suspended solids, the receiving environment is considered as downstream of such constructed works.¹

The program also monitors reference streams to provide data on the extent, degree, and rate of natural calcite deposition. Reference streams are considered persistent over the long term, and are far from mines. Their selection considered the natural variation in abiotic factors (i.e., elevation, stream order, geology, and channel morphology), and used three steps:

- Characterize exposure reaches by stream order, bedrock geology, spatial distribution, and channel morphology.
- Review reference sites from past calcite monitoring and other programs such as the RAEMP or current baseline assessments, and select appropriate locations using reach characteristics.
- Review additional areas as required to represent the spectrum of stream characteristics observed in exposure areas.

The program is described fully in Annex J.1.

7.3.1 Methods

The monitoring program quantifies and describes the extent and the degree of calcite deposition. These measurements are used to calculate a Calcite Index. Observations on types and characteristics of calcite deposits are also collected (e.g., calcified algae, calcified moss/tufa, barrage tufa, calcite scale, and/or insect tufa).

The Calcite Index is used to quantify and monitor calcite deposition within the Elk Valley watershed. These data, in association with information on the types and the characteristics of calcite deposits, can be used to refine environmental monitoring study designs (e.g., inform site selection).

7.3.2 Extent of Calcite Deposition

The extent of calcite deposition describes the spatial coverage expressed on two scales. The first is the sampling-site scale (areal extent); and the second is the reach scale (linear extent). Detailed measurements at the sampling-site scale are extrapolated to quantify calcite deposition over the reach.

Sampling-site scale (areal extent): A modified Wolman pebble count procedure is used to estimate calcite extent at a sampling site. The standard Wolman 1954 pebble count procedure requires an observer to move systematically over the area of interest, stopping periodically and randomly selecting a particle for observation. This procedure is repeated until 100 particles with diameters >2 mm (e.g., gravels) are measured. Smaller particles are recorded as fines. An estimate of areal calcite coverage is derived from these data.

¹ The calcite monitoring program does not, nor is it intended to, address mine works as authorized under EMA authorizations.

To ensure that measurements made on the sampling-site scale are representative of the reach scale, pebble counts are conducted within up to four habitat types per site. Habitat types are generally the Type 2 habitats outlined in Johnston and Slaney 1996, and include riffles, cascades, pools and glides. Pebble counts are completed to cover the relative proportions of habitat types observed.

Reach scale (linear extent): The linear extent of calcite deposition is estimated by aggregating sample site results. Depending on the length of the reach, up to three sites are surveyed on each reach, and the results are averaged to provide an overall value for the Calcite Index by reach.

7.3.3 Degree of Calcite Deposition

This term is used to describe calcite deposition at a given location (i.e., the level of stream-bed concretion). Estimates are derived from the level of effort required to remove a particle by hand from the stream bed, as detailed in Table 7-1.

Table 7-1. Derivation of calcite deposition scores.

Resistance	Degree of deposition	Score
Negligible	Not concreted	0
Noticeable, but removable	Partially concreted	1
Immovable	Fully concreted	2

7.3.4 Calcite Index

The Calcite Index expresses the extent and the degree of calcite deposition as a single measure, providing an objective metric that can be applied throughout the Elk Valley watershed. For each reach, a Calcite Index is calculated by summing the extent and degree of calcite precipitation:

Where:

$$CI = CI_p + CI_c$$

CI = Calcite Index

$$CI_p = \text{Calcite Presence Score} = \frac{\text{Number of pebbles with calcite}}{\text{Number of pebbles counted}}$$

$$CI_c = \text{Calcite Concretion Score} = \frac{\text{Sum of pebble concretion scores}}{\text{Number of pebbles counted}}$$

The Calcite Presence Score ranges from a value of 0.00 (no calcite observed) to a possible maximum of 1.0 (every pebble has calcite). The Calcite Concretion Score ranges from 0.0 (no pebbles are concreted) to 2.0 (every pebble is fully concreted). The Calcite Index is therefore expressed on a scale from 0.0 (no calcite observed) to 3.0 (stream bed fully concreted), as shown in Figure 7-1. The annual rate of calcite deposition/dissolution and its variability both spatially and temporally can be quantified and monitored using the Calcite Index. Specifically, the annual rate of calcite formation will be calculated and reported using:

where:

$$\frac{d(CI_{MI})}{dt} = \frac{CI_{MI}(t + 1) - CI_{MI}(t)}{(t + 1) - t}$$

CI_{MI} = Calcite Index of a stream (reach specific)

t = time (years)

For example, if a reach has a Calcite Index of 0.56 in 2013 and 0.32 in 2014, the rate of calcite formation for that reach would be reported as -0.24/year, with the negative value representing an overall reduction in calcite formation.

The pebble count provides a standard approach to data collection and the reporting of calcite deposition. These data are used to calculate a Calcite Index for the extent and degree of calcite deposition in the Elk Valley watershed, and permit the determination of rates (trends) of calcite deposition. The Calcite Index can be used to inform environmental study designs and EMA-authorized monitoring programs (e.g., RAEMP), and interpret monitoring results. The Calcite Index will also be used to assist in determining if, when, and where calcite mitigation is required.

7.3.5 2013 Monitoring Results

The first year of monitoring using the methods detailed above was completed in 2013, and included all mine-exposed streams in the receiving environment and selected reference stream reaches. Results, showing Calcite Index by reach, are presented in Annex J.3.

7.3.5.1 Low Calcite Index (0.00 – 0.99)

Reaches with low mean Calcite Index scores represented 94% of the 352 km of streams surveyed. Sampling sites within this range had variable levels of calcite and lacked concretion (Figure 7-1). All reference stream reaches fell within this range, with Alexander Creek recording the highest reference Calcite Index of 0.48.



Figure 7-1. Typical conditions at a reference stream during 2013 sampling (Grace Creek Reach 1, with Calcite Index = 0.30).

7.3.5.2 Mid-Range Calcite Index (1.00 – 1.99)

Reaches with mid-range Calcite Index scores represented about 3% of the length of the streams surveyed. These sites had a minimum of 65% of pebbles with calcite present, and concretion scores averaging 0.75 out of a possible 2. Stream-bed particles were distinguishable but conglomeration was apparent (Figure 7-2).



Figure 7-2. Conditions at a mine-influenced stream during 2013 sampling (Greenhills Creek Reach 3, with Calcite Index = 1.30).

7.3.5.3 Upper Calcite Index (2.00 – 3.00)

Reaches with upper-range Calcite Indexes occurred in nine streams, represented by 14 reaches and about 3% of the streams surveyed. Reaches had a minimum of 83% of pebbles with calcite present, and had extensive concretion. Most stream-bed particles could not be removed by hand. In many areas, they were completely covered and were no longer visible due to the thickness of the calcite deposit (Figure 7-3). In some cases, channel morphology was affected; some terracing (barrage tufa) was noted.

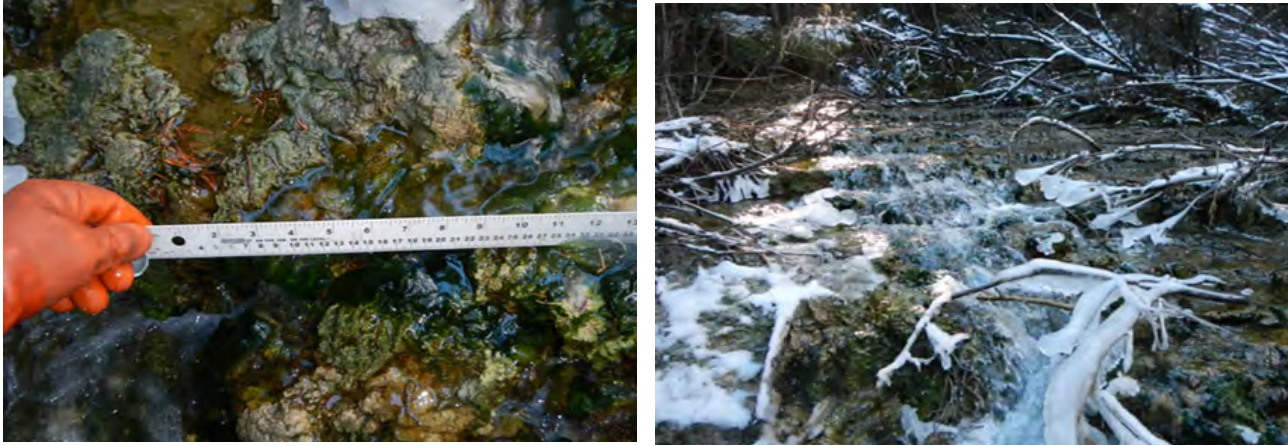


Figure 7-3. Conditions at a mine-influenced stream during 2013 sampling (Cataract Creek Reach 1 with Calcite Index = 3.00).

7.3.6 Summary of Monitoring Results

Results from the 2013 monitoring program are illustrated in Figure 7-4.

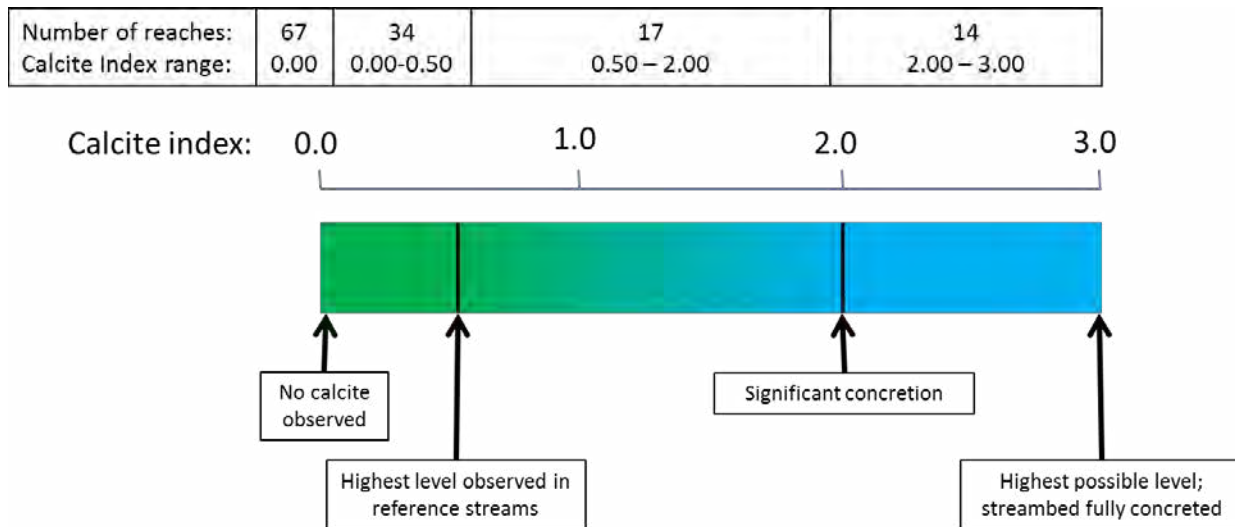


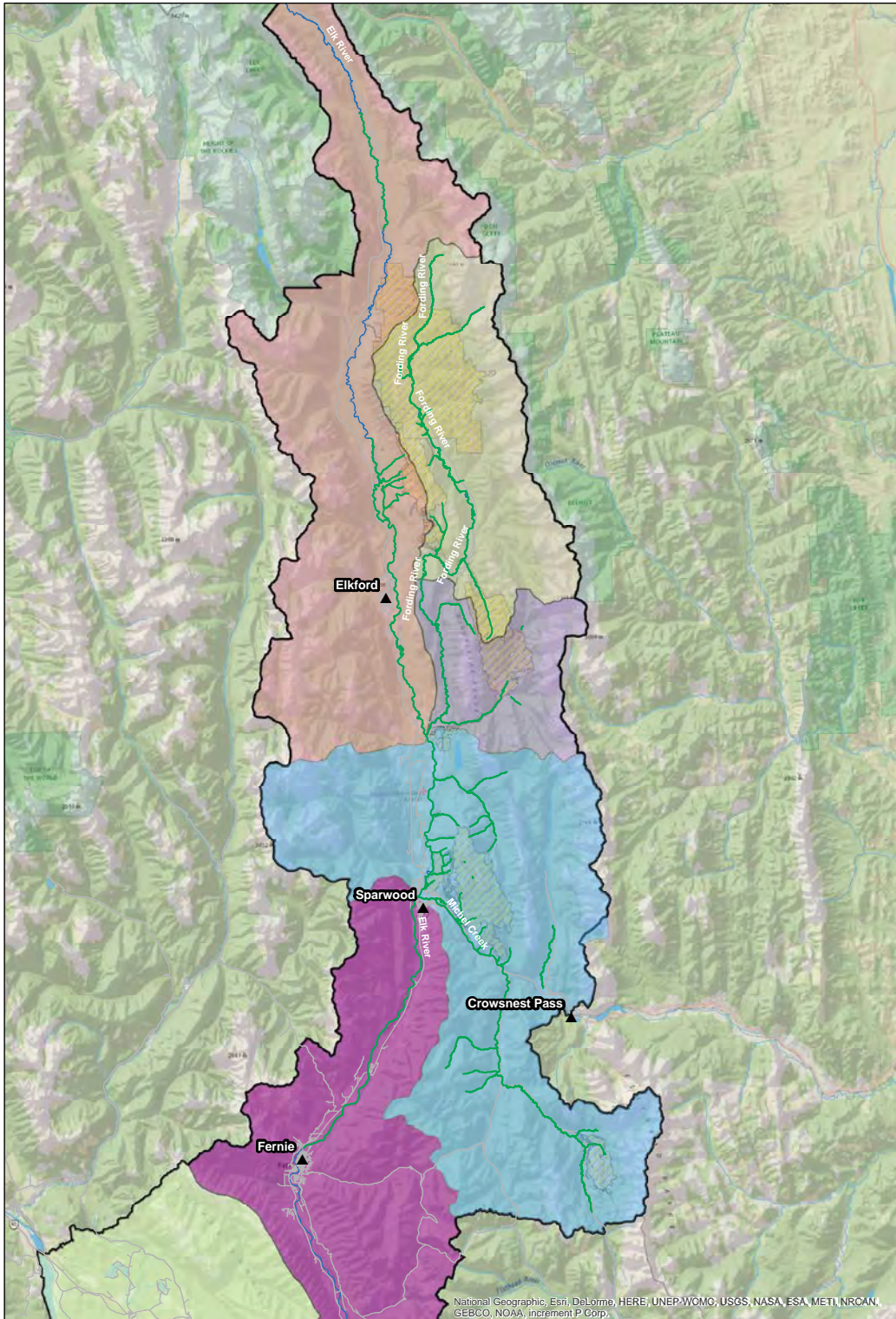
Figure 7-4. Calcite Index scores in the Designated Area during the 2013 monitoring program.

Calcite Index ranges or “bins” were created to describe the distribution of stream length over a range of Calcite Index scores. Of the over 352 km of stream surveyed (287.5 km exposed and 64.7 km reference), 89% of the exposed streams had a Calcite Index similar to that observed in reference streams (≤ 0.50 ; see Table 7-2).

Table 7-2. Calcite Indices and associated stream lengths surveyed in 2013.

Calcite Index range	Reference				Exposed			
	Fording and Elk		Tributaries		Fording and Elk		Tributaries	
	km	%	km	%	km	%	km	%
0.00-0.50	21.8	100	42.9	100	143.0	97	111.5	80
0.51-1.00	0	0	0	0	4.7	3	9.4	7
1.01-1.50	0	0	0	0	0	0	5.1	4
1.51-2.00	0	0	0	0	0	0	6.3	4
2.01-2.50	0	0	0	0	0	0	2.8	2
2.51-3.00	0	0	0	0	0	0	4.7	3
Total	21.8	100	42.9	100	147.7	100	139.8	100

A summary of results for the 2013 calcite monitoring program are provided in Annex J.3, with an overview of the streams and associated reaches surveyed illustrated in Figure 7-5.



Calcite Survey Locations

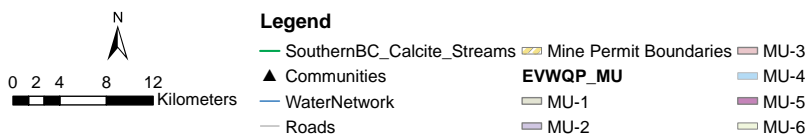


Figure 7-5. Calcite survey locations (2013). Note: The different shading represents Management Unit limits.

An example of the level of detail recorded in each of the surveyed streams and reaches (mine-exposed and references) is provided in Figure 7-6. A complete set of maps depicting the results at all streams is provided in Annex J.3.

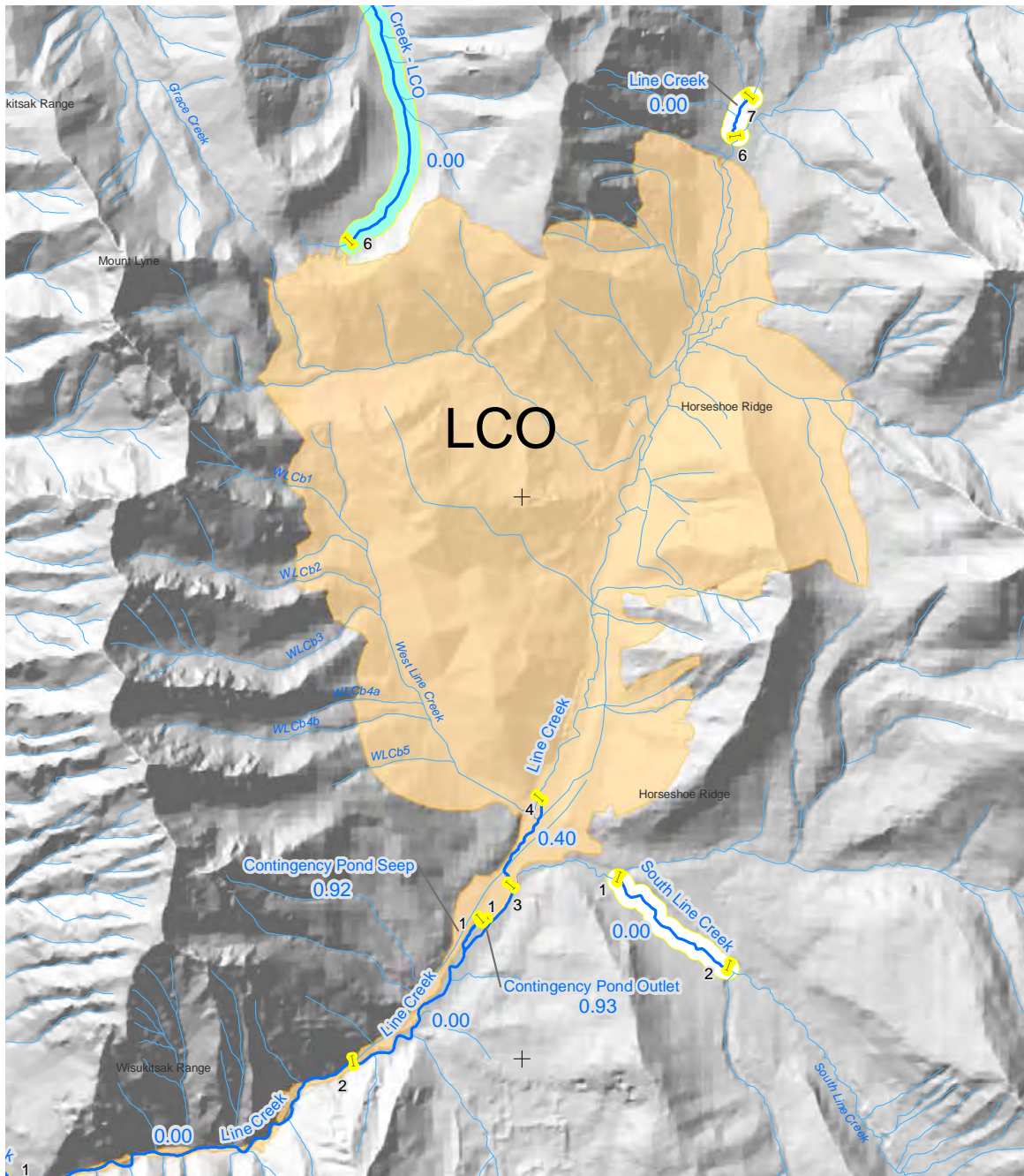


Figure 7-6. Calcite Index results from streams surveyed near Line Creek Operations in 2013.
 Note: Mine-exposed reaches (in blue), reference reaches (white outline), and reaches which are expected to be mine-exposed in the future (green outline).

7.3.7 Calcite as a Physical Stressor

As illustrated by Figure 7-7, calcite precipitation can affect the aquatic habitat including stream substrate, stream bank vegetation, riparian areas, and channel morphology (Hlushak 2012). Alterations to these habitat components may directly affect benthic invertebrates and periphyton, which in turn may affect other receptors (SRK 2011).

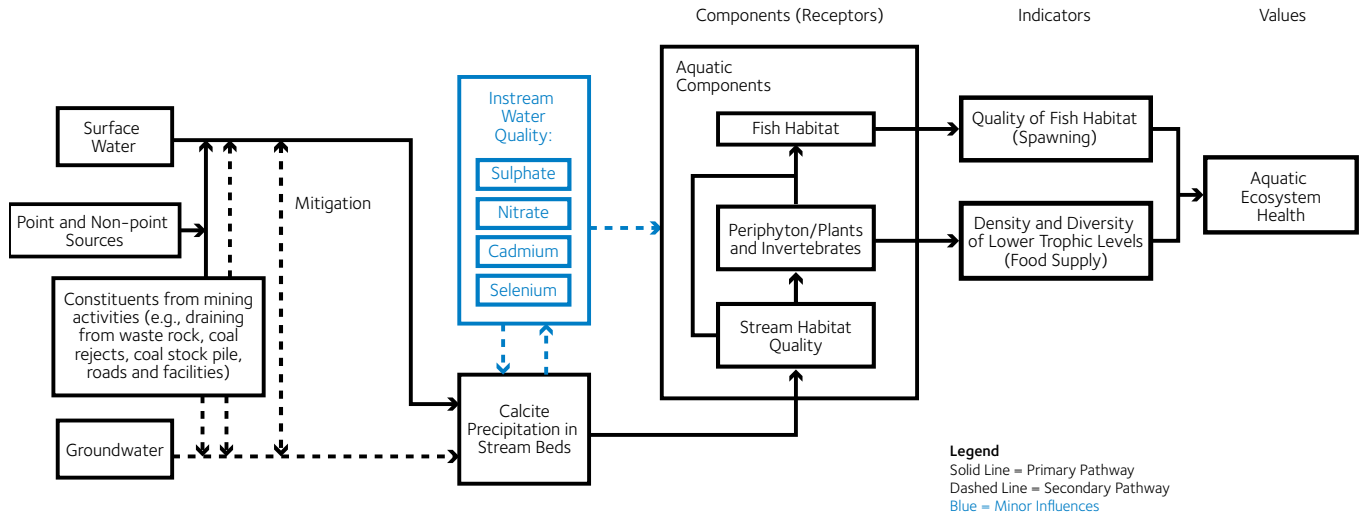


Figure 7-7. Calcite precipitation influence diagram.

Variations in invertebrate community composition and abundance have been related to elevation, latitude, water temperature, water velocity, water depth, light intensity and substrate characteristics, among other variables (Jacobsen et al. 1997; Quinn et al. 1994). Given that each invertebrate species has specific substrate requirements, it is reasonable to expect that substrate manipulation (e.g., calcite precipitation) may directly affect the aquatic invertebrate community and indirectly affect aquatic-dependent receptors (e.g., benthivores).

In addition, SRK 2011 demonstrated that calcite can reduce the availability of constituents of interest by incorporating (i.e., co-precipitating) trace elements from the water column. These elements include, but are not necessarily limited to, cadmium, magnesium, manganese, nickel, selenium and zinc.

7.4 Narrative Objective and Targets

The narrative objective² for calcite management is to understand and manage mine-related calcite formation such that stream-bed substrates in the Elk and Fording rivers and their tributaries can support abundant and diverse communities of aquatic plants, benthic invertebrates, and fish comparable to those in reference areas.

As 2013 was the first year of calcite monitoring, there are limited data to establish a final target Calcite Index at this time. However, 2013 results identified reference streams with a Calcite Index ≤ 0.50 (i.e., Alexander Creek Reach 2). Consistent with the calcite precipitation influence diagram developed in association with the TAC, and per advice received from by the TAC (Meeting No. 6), calcite concretion (rather than presence) may contribute to the physical stress in the environment. In consideration of the TAC's advice and for the purposes of the initial implementation plan, a Calcite Index of 0.50 was established as the long-term target value. A Calcite

² Section 3.7 of the Terms of Reference stipulates that "the Plan will, for the purpose of establishing medium and long-term targets, articulate narrative objectives to guide calcite management."

Concretion Score of ≥ 0.50 was used to identify priority streams to be managed in the medium term. Although management measures will begin immediately, achieving medium-term targets will take up to 10 years, and 15 years will be required to meet the long-term targets. This timing reflects ongoing evaluations associated with development of calcite control and remediation technologies discussed in Section 7.6. Furthermore, calcite targets (levels and timing) will be adaptively managed as outlined in Section 7.7. Medium- and long-term targets are summarized below.

Long-Term Target: Calcite Index ≤ 0.50 in mine-exposed streams in the receiving environment which provide habitat to fish or directly provide other valued aquatic ecosystem components for fish. The long-term Calcite Index target will be reviewed as more data become available, and should be viewed as an interim target.

Medium-Term Target: For streams identified by a Calcite Concretion Score ≥ 0.50 , reduce the Calcite Index to below the long-term target of 0.50. Priority streams selected for treatment are mine-exposed streams in the receiving environment that provide habitat to fish or directly provide other valued aquatic ecosystem components for fish.

A decision framework was developed to guide the selection of mine-affected streams in the medium term (Figure 7-8). In this framework, "Receiving Environment" refers to portions of streams downstream of constructed works, such as settling ponds, culverts and similar structures. The framework provides an overlap with the mine planning process, in that streams subjected to future mine-related activity, and for which comprehensive management plans have or will be developed, are not prioritized for calcite management in the medium term, while streams that remain intact are prioritized.

A stream known to be non-fish-bearing and that does not provide direct surface water to fish-bearing streams will not, at this time, be considered in the establishment of calcite targets. For example, because Kilmarnock Creek is not a fish-bearing stream and does not provide direct overland flow to a fish-bearing stream (i.e., the Fording River), it is not identified for calcite management even though calcite has been recorded in its reaches.

The decision framework was used to select streams for management action in the medium-term by assessing mine-impacted streams with a Calcite Concretion Score ≥ 0.50 . The process was used to assess 22 reaches, and results of the process are presented in Table 7-3.

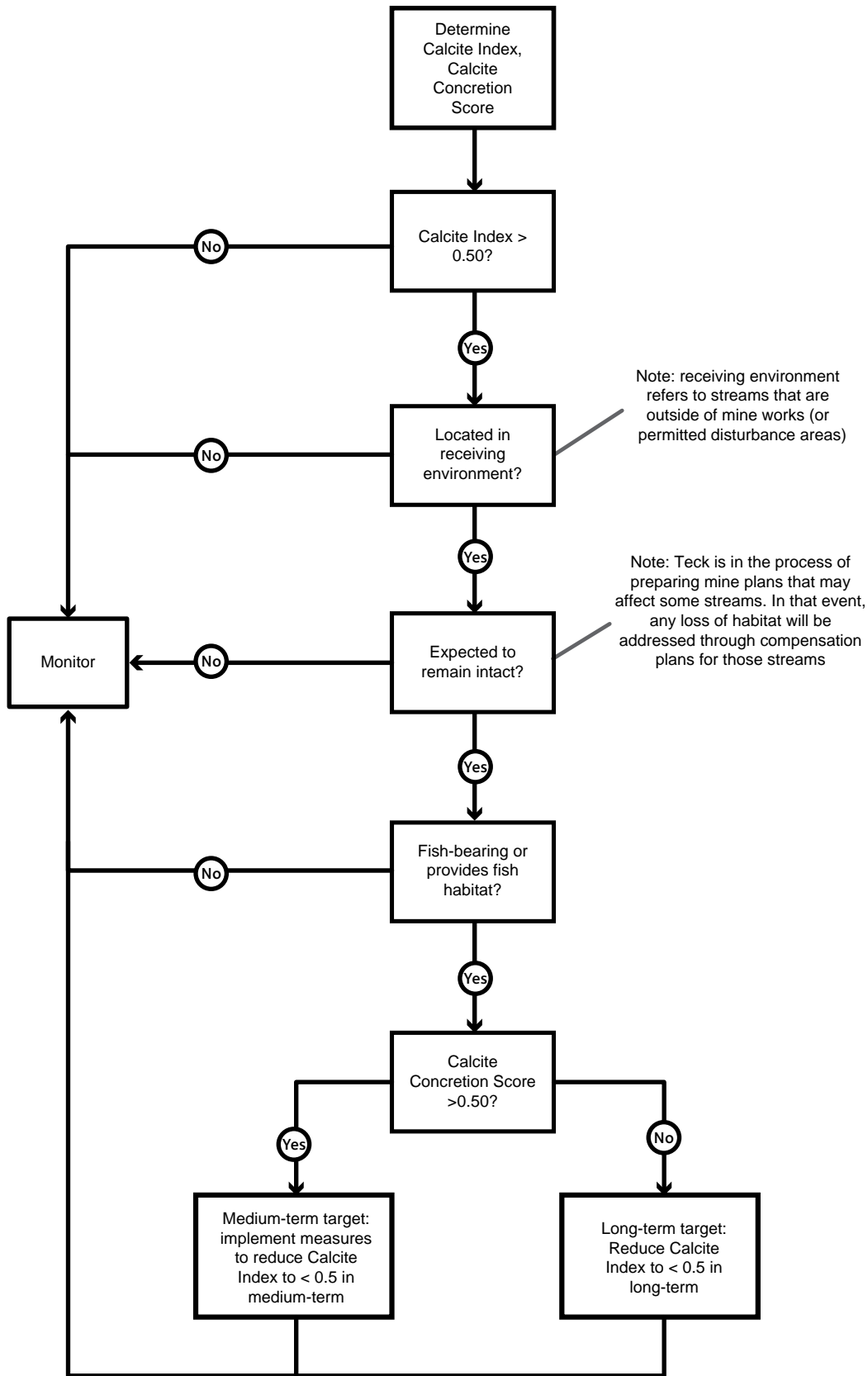


Figure 7-8. Decision framework to identify streams for medium- or long-term calcite targets.

Table 7-3. Streams to be managed in the medium term based on the Decision Framework and 2013 calcite monitoring results.

Stream	Reach	Concretion score	Receiving environment?	Remain intact?	Fish-bearing?	Action?
Kilmarnock Creek	1	1.33	No	na	na	monitor
Porter Creek	3	1.80	No	na	na	monitor
Smith Pond Outlet	1	1.72	No	na	na	monitor
Wolfram Creek	3	1.93	No	na	na	monitor
South Wolfram Creek	1	1.00	No	na	na	monitor
Swift Creek	1	1.71	Yes	Yes	Yes: See Note ⁵	See Note ¹
Cataract Creek	1	2.00	Yes	Yes	Yes: See Note ⁵	See Note ¹
	2	0.89	No	na	na	monitor
	3	2.00	No	na	na	monitor
Corbin Creek	1	0.99	Yes	Yes	Yes	Yes
	2	1.74	Yes	Yes	Yes	Yes
Dry Creek (Elkview)*	1	1.38	Yes	Yes	Yes	Yes: See Note ³
	2	1.38	No	na	na	
	3	1.35	No	na	na	monitor
	4	0.68	No	na	na	
Erikson Creek	1	1.36	Yes	Yes	Yes	Yes: See Note ⁴
	2	0.89	Yes	Yes	Yes	Yes: See Note ⁴
	3	1.40	Yes	Yes	Yes	Yes: See Note ⁴
Bodie Creek	3	0.52	No	na	na	monitor
Eagle Pond Outlet	1	0.90	Yes	Yes	No	monitor
Greenhills Creek	3	0.47	Yes	Yes	Yes	Yes: see Note ²
	4	0.84	Yes	Yes	Yes	

Note¹: As part of the proposed Swift Project, Cataract and Swift Creek flows will be diverted to an active water treatment facility; the resulting loss of stream flow will be addressed through the Environmental Assessment for the Swift Project.

Note²: Although Reach 3 of Greenhills Creek does not meet the 0.50 prioritization criteria, it has been included because it is adjacent to reach 4 with a concretion score of 0.84.

Note³: Loss of habitat in Reach 3 as a result of future mine plans will be addressed through a compensation plan that will be part of the Baldy Ridge Extension Project, which is currently under development.

Note⁴: Flow may be taken to a water treatment plant; calcite management will be coordinated accordingly.

Note⁵: Although both Swift and Cataract are not known to be fish-bearing, Reach 1 of these streams have been included as “fish habitat” for the purpose of this selection, as they are directly connected through surface flow to the Fording River.

Note⁶: There are two streams named “Dry Creek” one is at Elkview Operations; the other is at Line Creek Operations.

Creeks identified as “Yes” for Action have been selected as priority streams for calcite management in the medium-term.

Note na = not applicable as determined using the decision framework for calcite.

7.4.1 Priority streams

Four streams – Greenhills Creek, Corbin Creek, Dry Creek, and Erickson Creek – were identified as the priority streams for calcite management. These streams are shown on Figure 7-9. Management actions are designed to attain the medium-term targets stabilizing and reducing further calcite formation, and achieving a Calcite Index below the long-term target of 0.50 (or as refined in consideration of reference conditions). The long-term calcite target will be refined as additional monitoring data in reference and mine-exposed streams become available.

7.5 Implementation

To meet medium-term targets, the following steps have already been initiated or will be followed:

Step 1: Treatment Technology Evaluation and Selection. A review of treatment technology options for calcite mitigation is ongoing. As suitable technologies are identified, and considering site-specific constraints, viable treatment technology options will be tested, selected, and incorporated into design and construction plans based on their effectiveness, environmental safety, and social and economic considerations. Treatment technologies under consideration are summarized in Section 7.6.

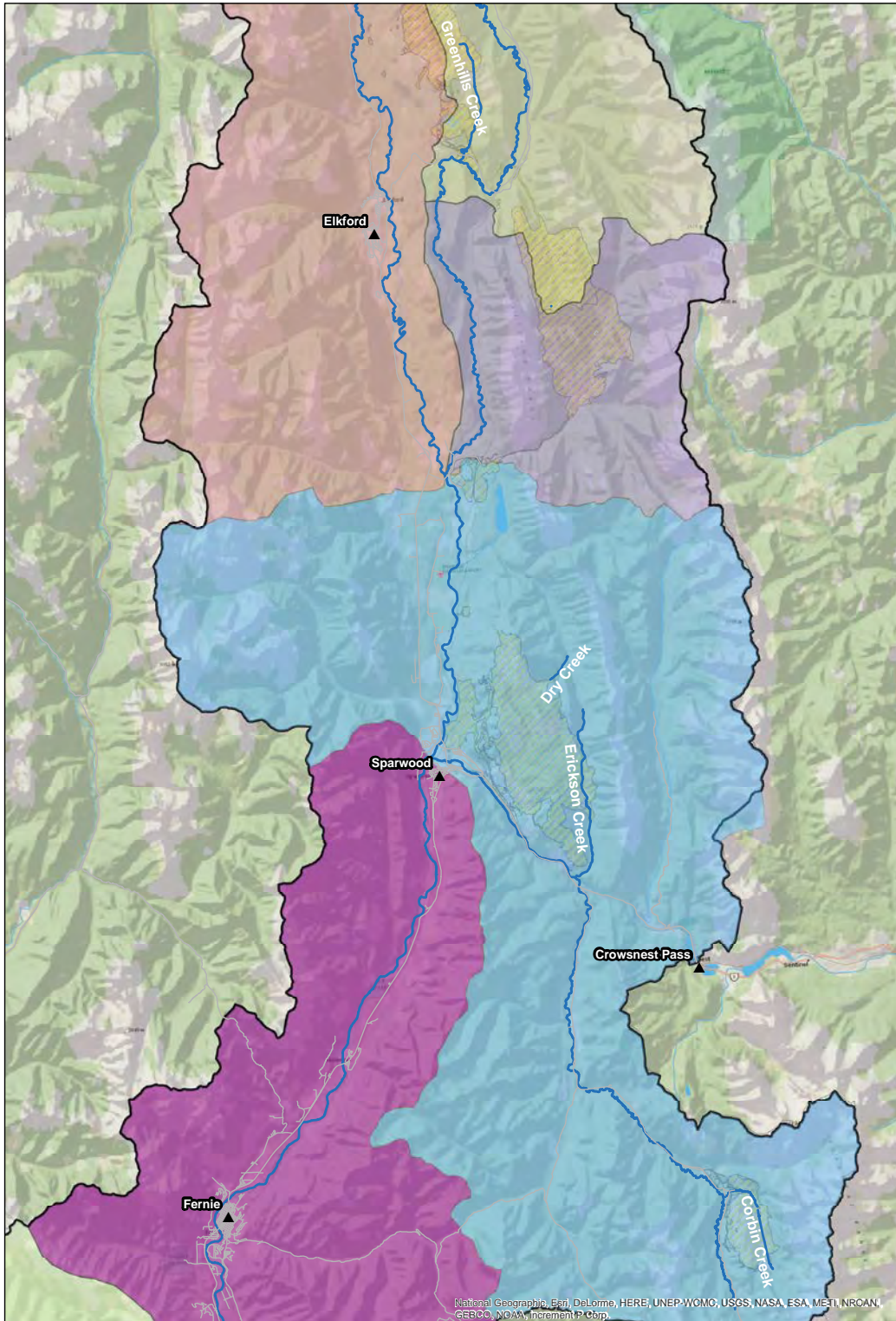
Step 2: Design and Construction. Construction will begin after an assessment of the technology has been completed and permits obtained.

Step 3: Operation. The treatment system will be operated as necessary (e.g., seasonally) to maintain the Calcite Index at or below the target.

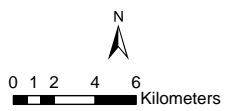
Step 4: Stream Rehabilitation. Depending on the treatment technology, it may be necessary to rehabilitate the stream substrate. Before starting any in-stream work, an assessment will be made of the change in rate of calcite formation. If the stream shows signs of restoration without further intervention, physical rehabilitation may not be required. Should rehabilitation be necessary, methods will be evaluated and selected.

Step 5: Monitoring. Streams prioritized for calcite management in the medium term will continue to be monitored for calcite formation before and after treatment.

Step 6: Adaptive Management. Teck will monitor, conduct research, re-evaluate control methods, and refine targets (scores and timelines) if necessary.



Calcite Medium-term Streams



Legend

- ▲ Communities
- WaterNetwork
- Roads
- ▭ Ministerial_Order_Boundary
- ▭ Mine Permit Boundaries
- EVWQP_MU**
- ▭ MU-1
- ▭ MU-2
- ▭ MU-3
- ▭ MU-4
- ▭ MU-5
- ▭ MU-6

Figure 7-9. Medium-term target streams: Greenhills, Corbin, Erickson and (EVO) Dry creeks.

7.6 Treatment Technology Options

Work to date has identified several calcite treatment methods and technologies, as described in the sections that follow:

1. alkalinity reduction
2. constructed cascades
3. antiscalants
4. pond treatment
5. trickling filters
6. ultrafine limestone or precipitated calcium carbonate (PCC).

These technologies have been chosen for evaluation because they can be designed to run unattended for extended periods (weeks or months), require few or no reagents, generate little or no waste, can accommodate large and variable flows, and require minimal infrastructure. In contrast, alternative proven treatment techniques such as lime addition (to raise the pH to convert excess dissolved CO₂ to carbonate and precipitate calcium carbonate) are energy-intensive, and generate considerable waste.

Some treatment options have the potential to affect other water quality parameters (i.e., constituents of interest). For example, calcite precipitation can sequester trace amounts of cadmium as a carbonate. Alkalinity reduction may release residuals (e.g. chloride or nutrients, depending on the additive).

The systems described in this section can be implemented in streams where treatment of other constituents of interest (e.g., selenium) is not being considered. At locations where an active water treatment plant is to be constructed, options to reduce calcite will be considered as part of the overall design process.

More details of the treatment options are provided in Annex J.2.

7.6.1 Alkalinity Reduction

Alkalinity reduction is widely practiced in other applications (e.g., pre-treatment for reverse osmosis, cooling-system management and drinking-water supply), and has potential for certain streams due to its simplicity and effectiveness. Alkalinity reduction is achieved through the safe addition of an acid that shifts the carbonate equilibrium toward a state that prevents precipitation of calcium carbonate, and accelerates the stripping of carbon dioxide to the atmosphere.

A potential shortcoming involves residual anions. For example, addition of hydrochloric acid leaves residual chloride. Estimates of acid doses are site-specific and in practice, the target dosage would be determined by site-specific testing and analysis. This option will be implemented only once it has been shown to have no impact on aquatic health.

Alkalinity reduction has been successfully tested on a pilot scale at Corbin Creek at the Coal Mountain Operation. That test established the dosage levels required to prevent further calcite precipitation, and demonstrated the method's overall environmental acceptability.

7.6.2 Constructed Cascades

Constructed cascades mimic natural processes. The cascade arrangement provides the aeration and surface area necessary to relieve calcite supersaturation. Constructed cascades are suitable for remote sites with the right terrain and topography. They may be considered alone and/or in combination with other treatment alternatives (e.g., alkalinity reduction or antiscalant addition). Constructed cascades will leave a residual solid of calcite, which may need to be disposed of periodically in a manner that does not result in the calcite being re-dissolved.

7.6.3 Antiscalant Addition

Antiscalants are chemical compounds that interfere with the precipitation process through a number of mechanisms such as chelation, threshold inhibition, crystal modification, and dispersion. These mechanisms can use commercially available antiscalant formulations.

7.6.4 Pond Treatment

Pond treatment can be considered where rock drains feed a relatively large, deep settling pond and electrical power is available. Pond treatment consists of the following:

- aerators that strip carbon dioxide, enclosed in a baffled treatment area
- dry limestone powder or PCC addition, to provide surface area for precipitation in the same space as the aeration
- a low-head pumping system to provide a controlled retention time in the treatment area.

A typical design consists of a circular baffled area within a sedimentation pond that may accommodate six or seven floating aerators. Water is pumped from the aerated zone at a controlled rate. The settled solids will require periodic disposal in a manner that does not result in the calcite becoming re-dissolved.

7.6.5 Trickling Filter

A trickling filter is a solid-liquid-gas contact system that is widely used for sewage treatment. It consists of a ring of aeration media and a rotating water distribution arm powered by falling water. Water cascades through the media, and in doing so draws air into the bed. After the water has equilibrated with the atmosphere, calcite precipitates onto the solid media and on suspended solids.

Trickling filters can provide both CO₂ stripping and a large solid surface area in a compact space, without the need for electrical power. However, the fundamental principles are just starting to be widely understood and it is not known if this technology has been applied to calcite mitigation. Its use in controlling calcite scaling is still in the early stages of development. Finally, the process generates solid waste that requires further management.

7.6.6 Ultrafine Powdered Limestone Addition (PCC)

Ultrafine powdered limestone addition may be considered in combination with a gas transfer system such as a pond aerator, a cascade, or a trickling filter. Ultrafine limestone is normally produced using calcite precipitation processes, and is hence called PCC. PCC particles are typically on the nano-scale (10⁻⁹ to 10⁻⁸ m diameter) in size, and have surface areas of 10 m²/g or more. PCC is a common, commercially available additive used in the paper industry.

PCC acts as a seed to stimulate calcite precipitation in solution rather than on the stream bed. This technology would be suited to systems with cascades or floating aerators for gas transfer, and a settling pond some distance downstream of the addition point to remove suspended particles. However, since the dose of PCC is expected to be small, the resulting increase in total suspended solids will also likely be low, and a downstream settling pond may not be required. PCC addition has not been tested in this application, so the required dosage would need to be determined experimentally. Solids that do settle in a pond will require periodic disposal.

7.7 Adaptive Management (Future Work)

Calcite management plans outlined in this chapter are based on current knowledge of the levels of calcite deposition, as measured by the Calcite Index. As more data are collected, Teck will adapt and adjust the program to achieve the desired overall objective of managing mine-related calcite formation such that stream-bed substrates within the Designated Area support abundant and diverse communities of aquatic plants, benthic invertebrates, and fish, comparable to those in reference areas.

The adaptive management framework for calcite is depicted in Figure 7-10. Ongoing monitoring, research and learning will provide the foundation for evaluating whether adjustments to the approach of calcite management are warranted.

The monitoring, research, and learning components of adaptive management have specific objectives and desired outcomes relating to calcite. These objectives and desired outcomes are illustrated in Figure 7-11, and described in detail in the sections that follow.

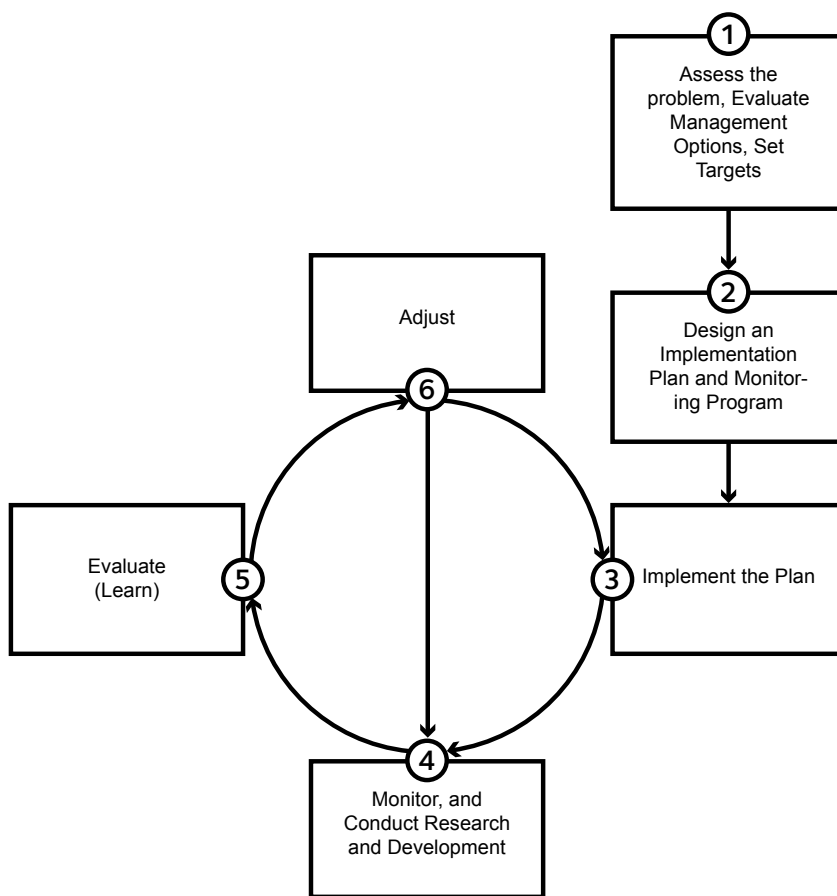


Figure 7-10. Calcite adaptive management framework.

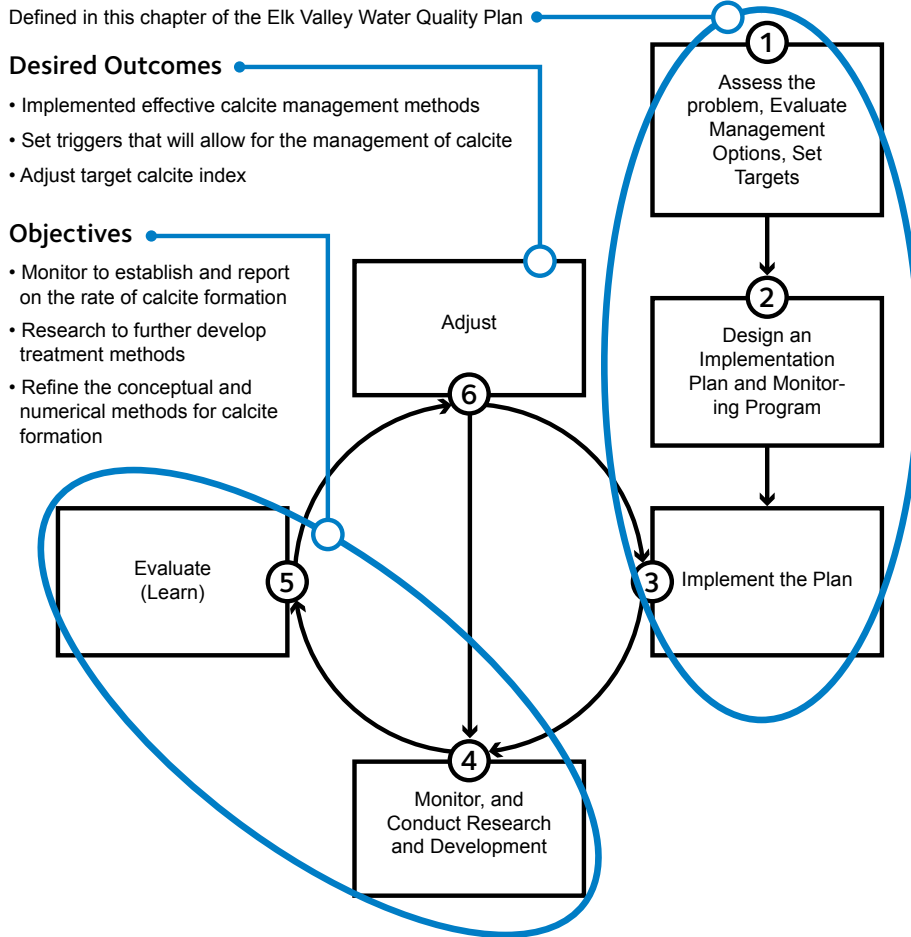


Figure 7-11. Objectives and desired outcomes of the adaptive management framework for calcite.

7.7.1 Monitor, Research, Evaluate

2013 was the first of three years for the refined calcite monitoring program. The program will provide a baseline of current conditions and a method of quantifying the rate of calcite formation within the Elk Valley watershed. Following the third year, it is envisioned that ongoing monitoring will continue, with its frequency adjusted based on observed rates of calcite formation (where rates are stable, the frequency may be reduced). During 2014 and 2015, results will be reported for each sampling unit (stream reach) in terms of change in Calcite Index per year. The rate will continue to be calculated and reported after the program’s completion, again with adjustments to the reporting frequency.

7.7.2 Research to Further Develop Treatment Methods

Pilot-scale testing has been undertaken of alkalinity reduction through acid addition. These tests established alkalinity reduction as a viable treatment technology, and have provided guidance on the level of treatment required. Additional evaluation is needed to optimize acid type and addition levels. Specifically, blends of acids (reducing the concentration of any single anion) will be evaluated to optimize treatment levels.

The 2013 pilot test revealed that calcite formation reduces the concentration of dissolved cadmium. Where cadmium concentrations may be of concern, precipitation of calcite upstream of the receiving environment would be a preferred management method if feasible. Additional tests are needed to evaluate these technologies and to establish design guidelines.

Antiscalants are widely used to prevent the formation of calcite and other scales. Their use in streams is not well-documented, but they are known to be used at some coal mines in West Virginia (McIntyre 2013), and have proven to be more cost-effective than acid addition, without environmental impact. Antiscalants are also effective at removing scale deposits, and may be used as a remediation technique. Consequently, tests will be initiated to evaluate the use of antiscalants as an alternative to alkalinity control through acid addition, and as a remediation method.

7.7.3 Refine the Conceptual Model and Numerical Methods for Calcite Formation

Refining the conceptual model and numerical methods will help implement management solutions before significant calcite formation occurs in stream habitats. Teck developed the potential saturation index (SI_{pot}) concept to indicate the potential for calcite to precipitate in streams where it has not yet been observed downstream of mining activity, or to provide an indication of the level of treatment required to manage precipitation. Teck will undertake additional investigations at selected streams to evaluate the merits of SI_{pot} as a predictive numerical tool. The design of this investigation has not been completed, but it is expected to include continuous flow monitoring, frequent chemistry analysis and local calcite precipitation monitoring. The SI_{pot} method is expected to be used in analyses triggered by observed increases in Calcite Index.

7.7.4 Adjust the Plan

7.7.4.1 Implement Effective Calcite Management Methods

Although alkalinity reduction through acid addition is a proven method to prevent calcite formation in streams, other methods may prove to be more effective or have less residual impact. The actual method chosen for calcite management will likely be site-specific, and as knowledge and understanding grows, may change over time.

7.7.4.2 Establish Triggers

Consistent with the TAC's advice, the medium-term target of the initial implementation plan is to prioritize streams based on a Calcite Concretion Score of ≥ 0.50 . To reduce the likelihood of potential effects occurring, Teck will establish triggers for further management action based on observed Calcite Index levels. Two types of triggers will be established: an analysis trigger and an implementation trigger.

As detailed in Section 7.4, medium-term targets have been identified and selected based on a Calcite Concretion Score of 0.50. This score was selected based on the TAC's advice and associated hypothesis that it may represent a level at which physical stress to stream-bed organisms are possible. As such, it represents an implementation trigger. At the time of writing, this hypothesis remains an uncertainty and as such, will be adaptively managed.

To reduce the likelihood of a Calcite Concretion Score of >0.50 , Teck will also establish an analysis trigger³ at a Calcite Index value of 1.00. The analysis trigger will be applied to streams not currently affected by mining, and to streams with a Calcite Index <1.00 . The value of 1.00 represents a point at which, in consideration of the TAC's advice, any further increase in the Calcite Index must be a result of an increase in the concretion score, and not the simple presence of calcite without concretion.

When the analysis trigger is reached, Teck will initiate an evaluation of the stream conditions. Following a careful review of the data, if it is determined that Calcite Index levels are in fact trending upward due to increased concretion scores, a root-cause analysis will be conducted to determine if the results are due to coal mining or to other outside factors. Identification of the root cause will guide the adaptive management decision-making process, help identify and evaluate solutions, and help to predict, using a balance of probabilities approach, if and when a Calcite Concretion Score >0.50 is likely to be reached. If it is determined that it is likely, Teck will implement management actions with the objective of keeping it <0.50 or at the value consistent with the overall objective.

³ As with the implementation trigger, the analysis trigger will be adaptively managed as additional information is collected.

The analysis methodology will evolve over time, as Teck’s knowledge base increases. An example of the analysis and implementation trigger methodology is presented in Figure 7-12. In this example, an analysis is triggered at time t , when the observed calcite index value has moved from <1 to a >1 . By analyzing the available data and using a balance of probabilities approach, Teck will assess whether the Calcite Index is likely to stabilize as depicted by Analysis A, or increase beyond a Calcite Concretion Score of 0.50 as depicted by Analysis B. If the analysis suggests that Analysis B is probable, Teck will evaluate available options and develop an implementation plan with the objective of preventing this.

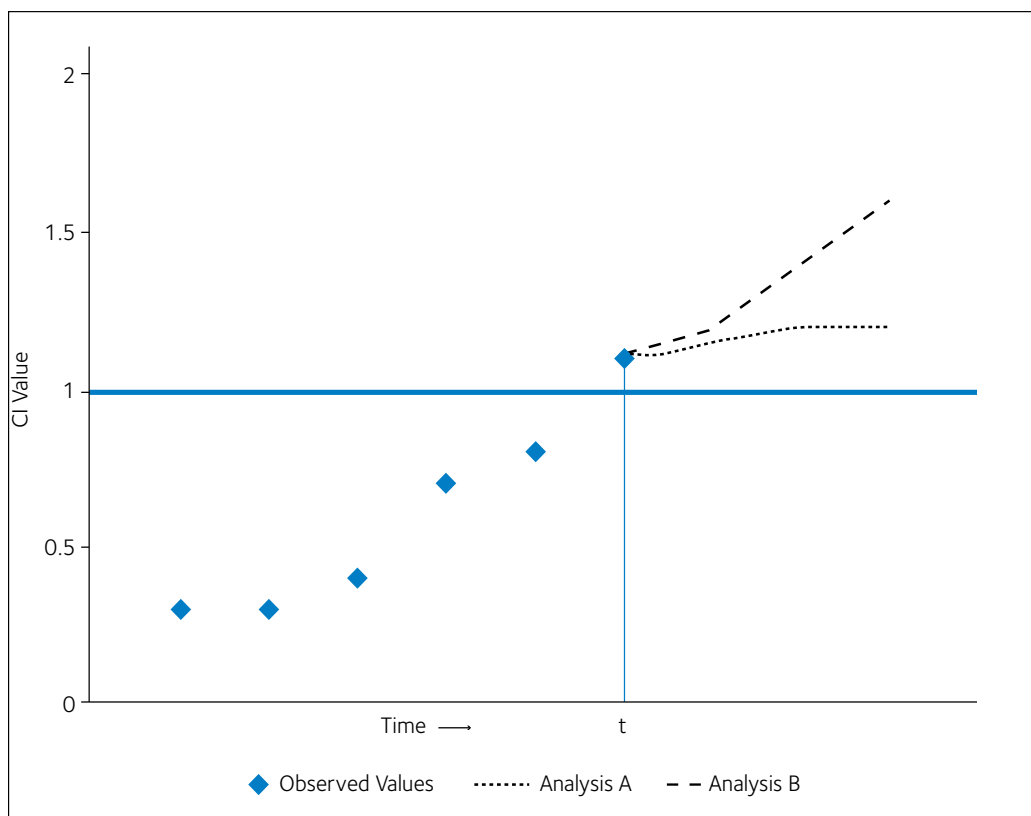


Figure 7-12. Example of the analysis and implementation triggers.

7.7.4.3 Refine the Long-term Target

The interim target Calcite Index of 0.5 is based on limited data. Through continued calcite and aquatic effects monitoring as administered under EMA authorization, Teck will attempt to determine the Calcite Index that reflect stream-bed substrates that can support communities of aquatic plants, benthic invertebrates, and fish that are comparable to those in appropriately selected reference areas.

7.8 Reporting

There will be two reporting cycles regarding calcite: 1) an annual calcite update; and 2) a three-year Plan report that corresponds to the reporting cycle for aquatic effects monitoring (see Chapters 10 and 11). The reports will include evaluation against relevant management triggers and any associated root cause analyses and adaptive management outcomes.

The annual calcite report will provide an update of monitoring and management activities for the previous year and will report on progress towards meeting calcite targets and timelines. The first annual report will be prepared in 2015 for monitoring and management activities completed to the end of 2014. The anticipated scope of the annual calcite update includes:

- an update of calcite mitigation measures for the previous year
- calcite monitoring results, including an analysis of the rate of change of calcite formation
- results of any supporting studies completed.

A three-year Plan report will be completed on a cycle that corresponds to the aquatic effects monitoring. The first reporting cycle will be 2017. The anticipated scope of the three-year adaptive management report is fully described in Chapter 11.

The Plan reports will be structured to meet permit reporting requirements related to calcite management that fall within the scope of the Plan.

7.9 Summary of Work to Date

Teck has begun taking the steps required to achieve medium-term and long-term objectives and targets for calcite management. Table 7-4 presents a summary of these steps and their status.

Table 7-4: Immediate, medium- and long-term objectives.

Time scale	Objective	Implementation step	Purpose	Status
Immediate (within three years)	Begin to stabilize the rate of calcite formation	Refine and implement calcite monitoring program	Establish the rate of calcite formation; define areas that require treatment	Started: first year of three-year calcite monitoring program complete
		Pilot testing of treatment technologies	Determine which treatment methods are effective and environmentally, socially and financially acceptable	Started: candidate treatment technologies identified; alkalinity reduction tested at pilot scale (Section 7.6.1)
		Implement treatment at one of the priority streams	Begin work in a priority stream to reduce the Calcite Index below the long-term target value	Planning stage: Teck will implement a treatment option on the first of the priority streams within three years
Medium Term (10 years)	Reduce the rate of calcite formation	Define target streams using decision framework	Prioritize streams	Complete: priority streams identified (Section 7.4.1)
		Implement calcite management technologies	Reduce Calcite Index in selected streams to long-term target	Planning stage: treatment technology selection to be determined through ongoing technology evaluations (Section 7.6)
Long Term (15 years)	Control the rate of calcite formation to acceptable levels	Establish narrative objective	Define acceptable levels	Complete: Narrative objective defined (Section 7.4)
		Establish long-term target	Meet acceptable levels	Interim target established (Section 7.4); method and timing for refining target defined (Section 7.7.4)
		Meet long-term target	Meet narrative objective	Started: Calcite monitoring has identified potential streams; additional technology advancements and research are ongoing - findings of which will inform decision-making; Adaptive Management Framework for Calcite (Section 7.7)

Note: Medium- and long-term targets established as part of the initial implementation plan will be guided by additional monitoring data and R&D. As a result, targets may be adjusted in value and/or time to be consistent with the narrative objective.

Chapter 8

Water-Quality Targets and Implementation Plan

Chapter Overview

This chapter presents the short-, medium- and long-term water-quality targets and timeframes for selenium, sulphate, nitrate and cadmium at Order stations in the Elk Valley, and the process used to develop those targets. It also describes an initial implementation plan to achieve water-quality targets and the key activities included in the plan.

Concordance with Ministerial Order and Terms of Reference

Chapter 8 satisfies Section A and sections B.1, B.3, B.4, B.8, B.9, B.10, B.12, B.14 and B.15 of Schedule C of Ministerial Order M113 and Section 2 and section 3.8(a, b, and c), 3.3, 3.5, 3.6, and 3.11(a) of Schedule C of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Teck is proposing water-quality targets that protect aquatic and human health:**
 - B.C. water-quality guidelines (WQGs) for aquatic life have been set as the long-term water-quality targets for selenium, nitrate and sulphate in Lake Koochanusa.
 - B.C. WQGs for the protection of aquatic life have also been set as the long-term water-quality targets for nitrate in the Elk River, and sulphate in the Elk and Fording rivers at the Order stations in the Designated Area.
 - The long-term cadmium water-quality target has a margin of safety that is comparable to the Canadian Cadmium WQG for the protection of aquatic life.
 - Where long-term concentrations could not meet WQGs or targets that provide a comparable margin of safety, site-specific targets were derived that are protective of aquatic life and achievable. Site-specific targets were established for selenium in the Elk and Fording rivers and for nitrate in the Fording River.
 - Site-specific targets are based on aquatic life benchmarks, established through study of sensitive species, and are developed to protect aquatic life and human health.
- **Teck developed the Elk Valley Water Quality Planning Model as a regional planning and assessment tool to determine effectiveness of water-quality mitigation measures.** The Model estimates concentrations of selenium, nitrate and sulphate and was calibrated using monitoring data. During implementation, Teck will continue to refine the model based on local-scale models, site-specific investigations of mine-affected water, and new information from monitoring data and Teck's R&D program.
- **More than 700 possible scenarios were evaluated** to develop an initial implementation plan to meet the long-term water-quality targets for selenium, nitrate, sulphate and cadmium.
- **Three active water treatment facilities, combined with diversions, will reliably and efficiently reduce selenium and nitrate in the short term:**
 - The West Line Creek active water treatment facility (AWTF), built at a capital cost of \$105 million, will open in summer 2014, with a capacity of 7,500 m³ of water per day.
 - A second AWTF and associated diversions will be developed at Fording River Operation by 2018 and is anticipated to have a capacity of 20,000 m³ of water per day.
 - A third facility and diversions will be built at Elkview Operation by 2020 and is anticipated to have a capacity of 30,000 m³ of water per day.
 - Further mitigation outlined in the initial implementation plan will be implemented as required to meet the targets set out in the Plan.

Table S-1. Summary of long-term water-quality targets.

Management Unit	Description	Order stations	Selenium (µg/L) ¹	Nitrate (mg/L) ²	Sulphate (mg/L) ³	Cadmium (µg/L) ⁴
1	Upper Fording River (upstream Josephine Falls)	FR4	57	11	429	0.39
2	Lower Fording River	FR5	40	11	429	0.39
3	Elk River upstream Fording River	ER1	19	3	429	0.24
4	Elk River from Fording River to Michel Creek	ER2	19	3	429	0.24
5	Elk River downstream Michel Creek	ER3, ER4	19	3	429	0.24
6	Lake Koochanusa	LK2	2	3	308	0.19

Note: Hardness dependent targets based on equations below for nitrate (MU-1 & 2 only), sulphate and cadmium are shown for the following illustrative average hardness levels as mg/L as CaCO₃: Fording River (FR5) 360; Elk River 200; and Lake Koochanusa 150. Actual target is to be based on synoptic measured hardness and nitrate, sulphate and cadmium concentrations.

Note¹: The long-term selenium target for MU-6 is specified in Ministerial Order M113. Targets in MU-1 to MU-5 are site-specific

Note²: Nitrate targets in MU-3 to MU-6 are equal to the B.C. WQG for the protection of aquatic life. Targets in MU-1 and MU-2 are site-specific

Note³: Sulphate targets are equal to the B.C. WQG for the protection of aquatic life. The target in MUs 1-2 is a site-specific hardness based equation; target values shown are for a representative hardness level of 350 mg/L as CaCO₃.

Note⁴: Cadmium targets are equivalent to the Canadian WQG for the protection of aquatic life (CCME 2014), but expressed as a dissolved concentration. The cadmium target is a hardness-based equation: target values shown are for representative hardness levels of 360mg/L as CaCO₃ in the Fording River, 200 mg/L as CaCO₃ in the Elk River and 150 mg/L as CaCO₃ in Lake Koochanusa.

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8.1 Introduction

This chapter describes the derivation of short-, medium- and long-term water-quality targets for selenium, sulphate, nitrate and cadmium (Order constituents) at each Order station in the Elk Valley. It describes the process behind the development of an initial implementation plan that employs the management options described in Chapter 6, along with the timeframes for meeting water-quality targets. Calcite management, including targets and timeframes, is discussed in Chapter 7.

Development of the Plan involved the concurrent evaluation of current water-quality conditions, development of site-specific water-quality benchmarks, and implementation planning. Results indicated that WQGs or benchmarks that provide a comparable margin of safety to WQGs can be met for some Order constituents in portions of the Designated Area, and that site-specific long-term targets are required only for selenium and nitrate in parts of the Designated Area. As a result, water-quality targets were developed following the process shown in Figure 8-1:

1. Water-quality benchmarks were developed for selenium, nitrate, cadmium and sulphate that protect aquatic life present in the Elk Valley (Section 8.2).
2. A first iteration of the initial water quality implementation plan was developed to meet level 1 selenium benchmark concentrations in the upper Fording River and the Elk River, and a selenium target concentration of 2 µg/L in Lake Koocanusa. Concentrations for nitrate, which is treated in the initial implementation plan, and sulphate, which is not treated, were also modelled. The initial implementation plan is presented in Section 8.5.
3. The current water-quality conditions and predicted concentrations based on the results of the first iteration of the initial implementation plan were compared with the water quality benchmark concentrations and the B.C. WQGs (Section 8.3.1). If current and expected future conditions could achieve WQGs or benchmarks that provide a comparable margin of safety as guidelines, then these values were set as the long term targets. As a result of this evaluation, B.C. WQGs or benchmarks that provide a comparable margin of safety as guidelines were selected as long-term water-quality targets at Order stations in the following parts of the Designated Area:¹
 - selenium, nitrate, sulphate and cadmium in Lake Koocanusa (MU-6)
 - nitrate, sulphate and cadmium in the Elk River (MU-3 to MU-5)
 - sulphate and cadmium in the Fording River (MU-1 and MU-2).
4. If expected future conditions could not achieve WQGs or benchmark values that have a comparable margin of safety (i.e. selenium in the Elk and Fording rivers and nitrate in the Fording River), then an integrated assessment was completed in parallel with adjustments to the initial implementation plan to derive long-term targets that are achievable and protective of aquatic ecosystem health (i.e., aquatic life) in the MU. The integrated assessment evaluates aquatic ecosystem protection within each MU by integrating the effect of constituent concentrations in mainstem rivers, mine-influenced tributaries and tributaries that are not influenced by mining. The integrated assessment provides a methodology for assessing the regional (i.e., MU scale) influence of local-scale water-quality conditions. Integrated assessments were also completed to assess integrated effects for all constituents in MUs that contain mine-influenced tributaries (i.e., MUs 1-4). The methods and results for the integrated assessment are presented in Section 8.3.2 and 8.3.3, respectively.

The end result of steps 3 and 4 was long-term targets for all water quality constituents in all MUs and an initial implementation plan to achieve them. A summary of long-term water quality targets is presented

¹ As described in Section 8.2.5, the cadmium benchmark for the most sensitive aquatic species provides a margin of safety that is comparable to the recently released Canadian WQG for the Protection of Aquatic Life (CCME 2014). Similarly, the sulphate benchmark is an extension of the B.C. water WQG of 429 mg/L to apply in areas where hardness levels are greater than 250 mg/L as CaCO₃.

in Section 8.3.4. A multiple-stressor analysis was completed to assess the potential for mixture effects amongst the Order constituents and interaction of multiple stressors. This was used to confirm the conclusions of the constituent-specific analyses, including the selection of long-term target concentrations (Section 8.4).

5. Short-term targets for stabilization were set for Order stations and constituents in MUs where concentrations currently or are expected to exceed long term targets. Timeframes for meeting short-term targets are defined by the initial implementation plan. Short-term targets and timeframes are presented in Section 8.6.1.
6. Medium-term targets and timeframes were set at the same locations as short term targets to demonstrate progressive improvement in water quality is occurring over time. Medium-term targets and timeframes are presented in Section 8.6.2.

Short-, medium- and long-term water quality targets are defined as maximum monthly average concentrations. The monthly average concentration is defined as the average of the samples collected in a month, or a single sample if it is the only one collected. The maximum monthly average concentration is the highest monthly average concentration in a year.

This process follows the Order requirements for developing targets (Schedule C, Section 10), and results in long-term targets that meet the environmental management objectives of the Plan, as defined in Schedule C, Section A of the Order. Where constituent levels currently or are expected to exceed long-term targets in the short-term, the Plan achieves the overall objective of stabilizing and reversing increasing trends of constituents, to reach acceptable levels in the long-term.

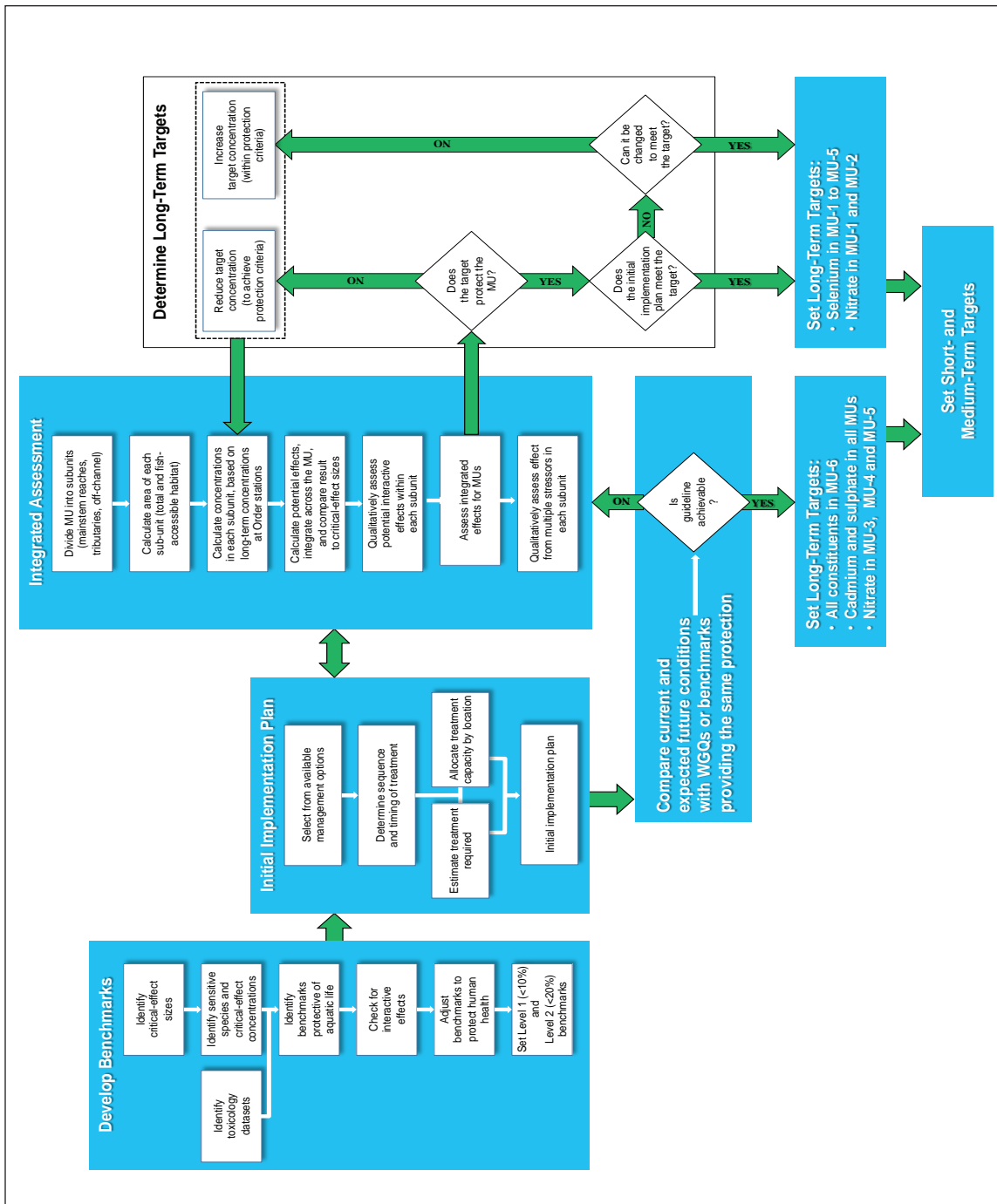


Figure 8-1. Overview of process for developing water-quality targets.

8.2 Water Quality Benchmarks

Water-quality benchmarks were derived for Order constituents (selenium, nitrate, cadmium and sulphate) for the protection of aquatic life in the Elk Valley. Water-quality benchmarks were derived from toxicity test results relevant to the Elk Valley, with a focus on endpoints such as growth or reproduction for the most sensitive species.

The approach to developing benchmarks considered protection of both aquatic and human health, and consisted of the following tasks:

1. Identify “critical-effect sizes” commonly accepted in toxicological literature that describe a level of effect, derived from laboratory testing to individuals, that is not likely to result in changes to populations or communities of sensitive aquatic species in the environment. Critical-effect sizes are typically expressed as a percentage effect for a life-history endpoint, such as a 10% effect on growth or reproduction.
2. Develop site-relevant toxicity datasets for each constituent through a literature review. For nitrate and sulphate, incorporate toxicity test results from the Elk and Fording rivers.
3. Identify sensitive aquatic species and determine concentrations that result in critical-effect sizes of ~10% (Level 1) and 20% (Level 2) to sensitive life-history endpoints.
4. Identify water-quality benchmarks for the protection of aquatic life by combining the information from tasks 2 and 3, accounting for uncertainty where possible and identifying follow-up studies or monitoring to address residual uncertainties (addressed in Chapters 10 and 11).

Tasks 1 to 4 are discussed in more detail below. No adjustments to benchmark were required for protection of human health (see Chapter 5).

8.2.1 Critical-Effect Size

Toxicological responses of aquatic organisms to increasing constituent concentrations can usually be defined by a continuous dose-response curve derived through laboratory testing, in which the effect on reproduction, growth or other life-history endpoint increases as concentrations increase (Figure 8-2). A critical-effect size is the level of effect to organisms in laboratory tests below which changes to populations or communities of sensitive species are not expected to occur and which cannot be distinguished from the results of normal background variability.

The US EPA defines 20% as the critical-effect size for most cases. It represents an effect to organisms in laboratory testing that, while statistically distinct from reference or control organisms, is not expected to cause meaningful and measurable changes in a natural population (US EPA 1999, 2013). Suter et al. 1995 also uses a critical-effect size of 20%, but acknowledges that the minimum detectable effect varies by species, habitat and sampling method. For mobile species, they concluded that a difference <20% “can seldom be reliably detected” and represents a de minimis effects level. A USGS study by Mebane 2010 similarly identifies a 20% critical-effect size for benthic invertebrates in any environment, and for fish

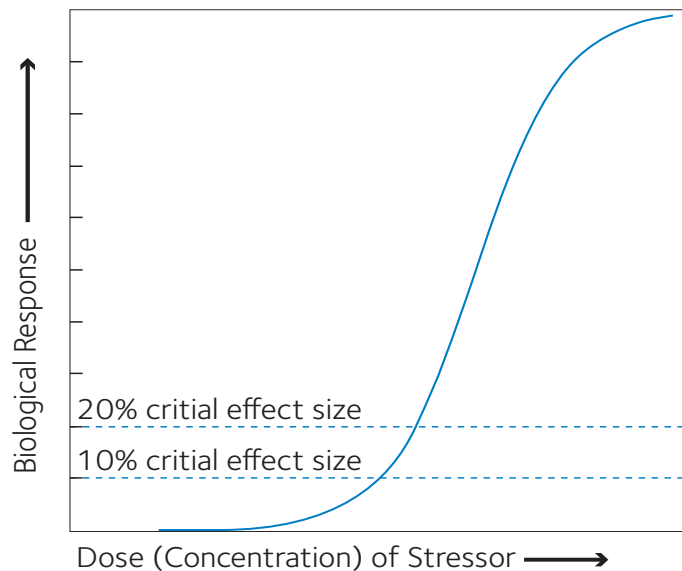


Figure 8-2. Typical dose-response curve.

when exposed to a single stressor, although it suggests a smaller effect size of 10% for fish when multiple stressors are present.

Two levels of water-quality benchmarks are defined for selenium, nitrate and sulphate in the Designated Area: Level 1 benchmarks for a 10% effect size, and Level 2 benchmarks for a 20% effect size. Cadmium concentrations in the Elk and Fording rivers are below the Level 1 benchmark; therefore, no Level 2 benchmark was developed.

8.2.2 Selenium

Selenium is a micronutrient that organisms require for optimal health (Wood et al. 2012). Selenium can bioaccumulate (Stewart et al. 2010), and at elevated tissue concentrations can produce detrimental effects in sensitive aquatic species (Chapman et al. 2010). Selenium toxicity varies widely among aquatic species (Chapman et al. 2010; US EPA 2004: B.C. MOE 2014b; DeForest et al. 2012), although reproductive impairment is typically the most sensitive pathway through which it affects them.

The rate of selenium bioaccumulation varies with environmental conditions. It tends to be higher in still-water (lentic) areas exhibiting lower oxygen content than in flowing, well-oxygenated (lotic) systems (Brix et al. 2005, Hillwalker et al. 2006, Orr et al. 2012) such as the Elk Valley. However, environmental conditions in lentic and lotic systems are variable, resulting in substantial overlap in rates of selenium bioaccumulation between the two types of environments (Simmons and Wallschläger 2005).

In 2014, the MOE updated the provincial selenium WQG for the protection of aquatic life (B.C. MOE 2014b). This guideline applies to all aquatic environments, including more sensitive lake environments. The selenium guideline is 2 micrograms per litre ($\mu\text{g/L}$), with an alert concentration of 1 $\mu\text{g/L}$.

8.2.2.1 Selenium Toxicity

A literature review indicated selenium concentrations in tissues at which effects could occur in sensitive aquatic species in the Elk Valley, including fish, benthic invertebrates and birds. A total of 41 species are represented in the assembled dataset: 17 fish, 14 bird and 10 invertebrate species.

Life-history endpoints evaluated included reproductive effects related to selenium in eggs, and potential changes in growth rates as a result of dietary intake. Studies were ranked and classified, with an emphasis on field studies and experiments completed under conditions comparable to those of the Elk Valley.

The review focused on sensitive aquatic species in the Elk Valley and similar species found elsewhere. For example, tissue benchmarks for fish in the upper Fording River (above Josephine Falls) were based on westslope cutthroat trout (WCT), as this is the only species present in that part of the watershed. On the recommendation of the TAC, brown trout was used to derive the Elk and lower Fording River fish tissue benchmark because, while not present in the system, it is the most sensitive tested species similar to fish found there.

Level 1 and 2 benchmark tissue concentrations for sensitive aquatic organisms (fish, birds and invertebrates) are summarized in Table 8-1. The benchmarks are specific points along a dose-response curve that defines the relationship between tissue concentration and the percentage effect of the response. Dose-response curves were generated for WCT reproduction, brown trout reproduction, juvenile fish growth, bird reproduction and juvenile bird growth. A dose-response curve is not available for benthic invertebrates. The derivation of the tissue benchmarks in Table 8-1 and the underlying dose-response curves (where available) are presented in Annex E.

Amphibians are also sensitive to selenium; however, reliable dose-response associations could not be established due to a lack of data. The limited available data suggest that amphibians are less sensitive to selenium and bioaccumulate selenium to a lesser extent than fish, birds or invertebrates. Therefore, benchmarks that protect fish, birds and invertebrates should be protective of amphibians as well, although data limitations represent a source of uncertainty.

Table 8-1. Benchmark selenium concentrations in tissues that result in potential effects.

Receptor/endpoint(s)	Tissue type	Benchmark tissue concentrations for selenium (mg/kg dw)		Dose-response curve available? (yes/no)
		Level 1 (~10% effect size)	Level 2 (~20% effect size)	
WCT/reproduction	Egg	25	27	Yes
Other fish (brown trout)/reproduction	Egg	18	22	Yes
Juvenile fish/growth (based on invertebrate tissue concentrations)	Diet	11	18 ¹	Yes
Birds/reproduction	Egg	12	16	Yes
Juvenile birds/growth	Diet	15	22	Yes
Invertebrates/growth and reproduction	Whole body	13	20	No

Note¹: Not applicable to WCT for the reasons outlined in Section 8.2.3. Note: mg/kg dw = milligrams per kilogram dry weight.

8.2.2.2 Selenium Bioaccumulation in the Elk Valley

Studies of selenium bioaccumulation in the Elk Valley have produced site-specific models (statistical equations) for periphyton, benthic invertebrates, fish, water birds and amphibians (e.g., Orr et al. 2012, Golder 2010). Some of these studies include two-step and three-step models that calculate bioaccumulation at each level in the food chain (e.g., Orr et al. 2012; Minnow 2014). Others have one-step models that calculate bioaccumulation directly from water into fish and birds (e.g., Golder 2010; deBruyn et al. 2012). In consultation with the TAC, Teck has reviewed and revised, as appropriate, the models for use in deriving water-quality benchmarks for the protection of aquatic life.

The Elk Valley is primarily a lotic system containing a small proportion (~10% of total aquatic habitat area) of off-channel habitats with some degree of lentic characteristics, such as still or slow-moving water and plants typically found in ponds or marshes. One uncertainty identified in previous model applications was selenium bioaccumulation in off-channel habitats, and how this could influence overall selenium bioaccumulation in the Elk Valley. To address this uncertainty, Teck undertook a stratified, random-sampling of off-channel habitats with lentic characteristics. Data from 60 off-channel habitats were used to develop models of selenium bioaccumulation by periphyton and benthic invertebrates in those areas. Analysis of the off-channel bioaccumulation data, in combination with existing data, identified the following:

- Selenium bioaccumulation relationships in Elk Valley lotic and off-channel areas are comparable, and can be captured in a single model. Bioaccumulation in off-channel areas, including those with lentic characteristics, is typical of lotic environments. Similar behaviour was noted by Simmons and Wallschläger 2005 in studies of other lentic areas outside of the Designated Area.

- There are two truly lentic receiving environments with higher selenium bioaccumulation in the Elk Valley²: a portion of the Fording River Oxbow (in the upper Fording River); and Goddard Marsh (a wetland that receives mine drainage from Elkview Operations). The model developed by Orr et al. 2012 represents selenium bioaccumulation for these two environments.
- That the off-channel sampling program did not identify any other sites with enhanced selenium bioaccumulation indicates that the two lentic environments are uncommon, and do not influence overall selenium bioaccumulation in the Elk Valley.

One-, two- and three-step models can characterize the variability in predicted tissue concentrations and examine uncertainties. The resulting suite of models predicts the statistical distribution of tissue concentrations that would result from exposure to a given selenium concentration. As a conservative approach, the two-step models resulting in the highest predicted selenium tissue concentrations were used to develop selenium benchmarks. This approach addresses variability in the observed data and accounts for uncertainty in how that variability can be described statistically. The two-step models are summarized in Table 8-2, and all bioaccumulation models are presented in Appendix C of Annex E.

Table 8-2. Elk Valley two-step selenium bioaccumulation models.

Model component	Model equations
Water to Invertebrates	$\log_{10}[Se]_{inv} = 0.696 + 0.184 \times \log_{10}[Se]_{aq}$
Invertebrates to Fish Eggs	$\log_{10}[Se]_{fish\ egg} = 1.02 + 0.026 \times \log_{10}[Se]_{inv}$ for $[Se]_{inv} < 6.8$ mg/kg dw $\log_{10}[Se]_{fish\ egg} = 0.126 + 1.10 \times \log_{10}[Se]_{inv}$ for $[Se]_{inv} \geq 6.8$ mg/kg dw
Invertebrates to Bird Eggs	$\log_{10}[Se]_{bird\ egg} = 0.414 + 0.523 \times \log_{10}[Se]_{inv}$

Note: [Se]_{aq} = aqueous total selenium concentration (µg/L); [Se]_{peri} = periphyton selenium concentration (mg/kg dw); [Se]_{inv} = invertebrate selenium concentration (mg/kg dw); [Se]_{fish egg} = fish egg clutch or ovary selenium concentration (mg/kg dw); [Se]_{bird egg} = bird egg selenium concentration (mg/kg dw)

8.2.2.3 Selenium Benchmarks for Protection of Aquatic Life

The bioaccumulation models are used to calculate aqueous selenium concentrations corresponding to tissue benchmarks (Table 8-2). The resulting concentrations represent water-quality benchmarks. In practice, the methodology for fish and bird reproduction endpoints is more complex, because the models calculate a statistical distribution of tissue concentrations. A solution was developed to account for variability in tissue concentrations and in the dose-response relationship, to calculate an effect size for a population exposed to a given aqueous selenium concentration. The concentration that results in the specified critical-effect size is the corresponding water-quality benchmark.

The methods for calculating water-quality benchmark concentrations for invertebrates, juvenile fish and birds were more straightforward. Bioaccumulation models were used to calculate the water concentration at which invertebrate-tissue concentrations would equal the Level 1 and 2 benchmarks for potential effects on benthic invertebrates themselves, or on juvenile fish and birds as a result of consumption. This calculation was completed using the 95% upper confidence limit (UCL) of mean invertebrate-tissue concentrations. As a result, the water-quality benchmark concentrations are values at which there is 95% confidence that mean invertebrate-tissue concentrations will be lower than the Level 1 or 2 benchmarks.

The combined use of bioaccumulation models and dose-response curves to calculate water-quality benchmarks is complex, but can be summarized as follows. The toxicological response of fish and birds occurs as a

² Clode Settling Pond (a settling pond at Fording River Operations) also exhibits enhanced selenium bioaccumulation, but is an industrial facility and not part of the receiving environment.

continuous response that can be characterized as a dose-response curve (Figure 8-2 above). For a given water concentration, the models predict a distribution of tissue concentrations that follows a bell (log-normal) curve. The dose-response curve can be used to calculate the percentage effect for each egg concentration in the distribution. By combining all effect sizes for each point on the distribution, an overall effect can be calculated for a population exposed to a given water concentration.

Calculated Level 1 and Level 2 benchmark concentrations are shown in Table 8-3. The table divides benchmarks for fish into two areas: the upper Fording River, where WCT is the only fish species present; and the remainder of the system, where more sensitive species may be present. The lowest applicable benchmarks are those carried forward into the long-term target-setting process (i.e., those that describe effects on the most sensitive species).

Table 8-3. Selenium benchmarks for aquatic receptors in the Elk Valley (all units µg/L of total extractable selenium).

Receptor and endpoint	Level 1 10% effect size	Level 2 20% effect size
Upper Fording River		
Fish reproduction (for WCT)	70	187
Juvenile fish growth (for WCT)	>46	>466
Elk River and lower Fording River		
Other species (brown trout)	19	74
Juvenile fish growth (other species)	46	466
Applicable to Elk and Fording rivers		
Bird reproduction	394	n/c
Juvenile bird growth	203	n/c
Invertebrate growth and reproduction	104	n/c

Note: n/c = not calculated, because resulting value will be higher than most sensitive end point (not calculated); '>' denotes unbounded NOECs (no observed effect concentrations)

The Level 1 selenium water-quality benchmark applicable to the upper Fording River is 70 µg/L, which is based on reproductive effects on WCT. Benchmarks for bird reproduction, juvenile bird growth, and invertebrates are higher. The benchmark for juvenile fish growth is not applicable to the upper Fording River, because studies with juvenile WCT have reported no effects at the Level 1 benchmark.

The Level 1 selenium benchmark applicable to the lower Fording and Elk rivers is 19 µg/L. This is based on reproductive effects on brown trout, which are representative of more sensitive fish that may be present. All other benchmarks were higher.

A 10 or 20% reduction in reproductive output is not equivalent to a 10 or 20% reduction in a population abundance. Density-dependent compensation for early life-stage mortality³ is a widely accepted concept in fish population biology (Hilborn and Walters 2001), and modelling studies indicate that effects on cutthroat trout populations occur only when reproductive effects exceed 40 to 60% (Van Kirk and Hill 2007). Consequently, no changes to fish populations, or to populations of other receptors in the Designated Area, are expected to occur at the chosen (i.e., lowest) Level 1 and Level 2 selenium water-quality benchmarks outlined in Table 8-3.

³ Density dependent compensation is a process by which survival at a later life stage improves when the density of organisms is reduced by mortality at an earlier life stage. In trout, this can occur when juveniles live in areas with limited overwintering habitat. At high juvenile densities, the rate of overwinter survival is relatively low. If juvenile densities are reduced (e.g., by embryo-alevin mortality), the rate of overwinter survival improves, offsetting mortality at the earlier life stage.

8.2.2.4 Accounting for Uncertainty

Sources of uncertainty in the selenium toxicity and bioaccumulation assessment are described in Annex E. These include the sensitivity of aquatic receptors to selenium, and the rate at which selenium bioaccumulates in the Designated Area. These uncertainties were explicitly recognized and addressed, to the extent possible, when deriving the benchmarks outlined above.

For example, the toxicity of selenium to 41 aquatic or aquatic-feeding species was reviewed, and the most sensitive species were brought forward and used to define the tissue benchmarks outlined in Table 8-1. Similarly, multiple bioaccumulation models were developed and reviewed with the TAC. Sensitivity analyses were completed to examine how changes to input assumptions or model formulations would alter the model predictions. These analyses included consideration of:

- one, two and three-step models
- linear and piece-wise model formulations with different breakpoints
- variations in fish size
- the inclusion or exclusion of data from non-representative areas (such as those collected from mine workings)
- the inclusion or exclusion of data of uncertain quality (such as those without measured moisture content, which is an important consideration when calculating selenium content in dried tissues).

In all cases, results that were determined by the TAC to be reasonable, yet conservative, were carried forward and used to develop the selenium benchmarks.

Sensitivity analysis was also completed on the reproductive dose-response relationships used to define the benchmarks. The purpose of this exercise was to determine how the critical-effect size associated with a given water concentration may change in relationship to the dose-response curve. Using the results of this analysis, sensitivity of the Level 1 benchmarks was assessed. These results were also used to set long-term selenium targets that have upper-bound effect sizes of <20%.

Based on the above, the selenium benchmarks are considered to be best estimates of concentrations that will result in effect sizes of $\leq 10\%$. They were derived using conservative assumptions and have a low degree of residual uncertainty, which will be managed through follow-up activities during implementation, as discussed in Chapter 11.

8.2.3 Nitrate

Nitrate affects aquatic organisms by direct contact. At elevated concentrations, it can interfere with osmoregulation (the ability to maintain appropriate cellular ion levels) (CCME 2012). The B.C. WQG for the protection of aquatic life for nitrate is 3 milligrams of nitrogen per litre (mg/L of $\text{NO}_3\text{-N}$).

Nitrate benchmarks for the Fording River were developed by:

- compiling site-relevant toxicity datasets and identifying sensitive life-history endpoints (such as growth and reproduction) from the literature and results of site-specific testing
- adjusting the available information to account for the effect of water hardness
- using the compiled datasets to identify the most sensitive life-history endpoints and species for each group of aquatic species, and to determine hardness-adjusted concentrations that result in effect sizes of ~10% (Level 1) and 20% (Level 2)
- combining the resulting information to identify benchmarks for the protection of aquatic life, accounting for uncertainty.

Toxicity datasets were developed for invertebrates, fish and amphibians. Datasets were not developed for aquatic plants and algae or wildlife, because they tend to be less sensitive to nitrate (Annex F). As a result, benchmarks that protect fish, benthic invertebrates and amphibians will also protect other species.

Once compiled, the toxicity datasets were adjusted to hardness conditions reflective of the Fording River. These adjustments were made because work by Nautilus 2011a,b, Baker et al. 2012 and Rescan 2012 indicate that nitrate toxicity decreases as water hardness increases. The hardness relationship used to complete the adjustments is described in Annex F.

Review of the hardness-adjusted toxicity data outlined in Annex F identified the water flea, *Ceriodaphnia dubia* (*C. dubia*), to be the most sensitive aquatic species. This finding was confirmed through the development of a species sensitivity distribution using hardness-adjusted toxicity results from literature and site-specific tests (see Annex F). Consequently, Level 1 and 2 benchmarks for nitrate were defined based on the sensitivity of *C. dubia*.

In addition, results from site-specific testing showed a greater sensitivity of *C. dubia* to nitrate than suggested by test results in the literature. As a result, site-specific test results were used to define species sensitivity to nitrate. The resulting values are summarized in Table 8-4.

Table 8-4. Sensitivity of aquatic receptors to nitrate in the Fording River.

Receptor group	Representative species and test type	Effect level (mg/L of NO ₃ -N)	
		Level 1 (~10% Effect)	Level 2 (~20% Effect)
Fish	Rainbow trout (<i>Oncorhynchus mykiss</i>) 39-day embryo-alevin development completed using augmented site water	16	21
Benthic invertebrates	Water flea (<i>Ceriodaphnia dubia</i>) 8-day reproduction completed using augmented site water	11	15
	Amphipod (<i>Hyalella azteca</i>) 14-day biomass completed using augmented site water	19	23
Amphibians	Northern leopard frog (<i>Rana pipiens</i>) 52-d growth in length (Level 1) Pacific tree frog (<i>Pseudacris regilla</i>) 10-day growth from literature (Level 2)	33	405

Note: Amphibian values are literature values because there are no site-specific test results. Values shown for a representative hardness of 360 mg/L as CaCO₃; derived as outlined in Benchmark Derivation Report for Nitrate and Sulphate (Annex F).

The hardness-dependent Level 1 and Level 2 benchmarks for the Fording River are 11 and 15 mg/L of NO₃-N, respectively, at 360 mg/L as CaCO₃. As previously noted, they are based on site-specific toxicity tests of *C. dubia*, which is the most sensitive receptor. With seasonal changes in hardness, the Level 1 benchmark for nitrate currently would range from 8 mg/L of NO₃-N in July (when hardness is at a minimum), to 16 mg/L of NO₃-N when hardness peaks in winter.

To assess potential effects on the wider benthic invertebrate community, a second set of Level 1 and 2 benchmarks were defined, using site-specific testing for *Hyalella azteca* (*H. azteca*). In both site-specific testing and in literature-based species-sensitivity distributions, *H. azteca* growth is a sensitive life-history endpoint, but not as sensitive as *C. dubia*. The benchmark derived from site-specific nitrate toxicity tests for *H. azteca* was used to assess potential effects on benthic invertebrate communities, whereas the *C. dubia* benchmarks were used to assess effects on the most sensitive aquatic species.

At elevated levels, nitrate combined with phosphorus can increase primary productivity (i.e., plant and algae growth), to the potential detriment of dissolved oxygen levels and other water-quality parameters (CCME 2012). The potential for increased primary production was not evaluated when setting benchmarks for nitrate, because the Designated Area is a phosphorus-limited system (see Chapter 4). Consequently, the potential for eutrophication will be driven primarily by phosphorus rather than nitrate. The potential for mine-related effects of phosphorus on primary productivity is mainly related to the proposed use of biological AWTfS for selenium and nitrate, which are assessed in Chapter 6.

8.2.4 Sulphate

Sulphur is an essential element for all forms of life (B.C. MOE 2014b), but direct contact with elevated concentrations of sulphate can interfere with osmoregulation and cellular membrane function (Davies and Hall 2007, Grosell et al. 2007, Cormier et al. 2013).

The B.C. WQG for sulphate varies with hardness, up to a maximum of 250 mg/L as CaCO₃ (Table 8-5). For higher hardness, site-specific testing is recommended (B.C. MOE 2013).

Table 8-5. WQG for sulphate.

Water hardness (mg/L as CaCO ₃)	Sulphate concentration (mg/L)
0 to 30 (very soft)	128
31 to 75 (soft to moderately soft)	218
76 to 180 (moderately soft to hard)	309
181 to 250 (very hard)	429
>250 (very hard)	Need to determine based on site water

Source: B.C. MOE 2013.

Consistent with the direction provided in the B.C. MOE sulphate guideline, site-specific testing was completed. A literature review was also undertaken to identify the sensitivity of aquatic species to sulphate. As with nitrate, site-relevant toxicity datasets were developed for fish, benthic invertebrates and amphibians, which are typically more sensitive to sulphate than terrestrial species or aquatic vegetation (Appendix D of Annex F). Sulphate benchmarks and targets developed to protect fish, benthic invertebrates and amphibians will therefore protect other organisms.

Rainbow trout was identified as the most sensitive aquatic species. This finding is consistent with that of B.C. MOE 2013, which used rainbow-trout test results to set the WQG. More specifically, the WQG considered tests by the Pacific Environmental Science Centre (PESC) that followed standard methods, and by Simon Fraser University's Chris Kennedy, who used greater sample numbers. Kennedy's results had smaller confidence intervals (Table 8-6) and were used to set the WQG.

Table 8-6. Rainbow trout sensitivity to sulphate in waters with hardness ≥ 250 mg/L as CaCO_3 .

Study group	Test	Thresholds ¹		
		Level 1 (~10% Effect)	Level 2 (~20% Effect)	Level 3 (~50% Effect)
Pacific Environmental Science Center ²	21-day embryo-alevin survival	191 (71 – 517)	502 (239 – 1055)	1,392 (668–2,898)
Chris Kennedy ²	21-day embryo-alevin survival	654 (615 – 695)	857 (819 – 896)	1,379 (1,329–1,433)
Work completed in support of the Elk Valley Water Quality Plan ³	28-day embryo-alevin development	381 (86 – 610)	530 (176 – 772)	998 (861 – 1,087)

Note¹: 95% confidence intervals are shown in parentheses.

Note²: Reported in B.C. MOE 2013.

Note³: Reported in Annex F.

Tests using high-hardness waters from the Elk Valley (up to 1,400 mg/L as CaCO_3) resulted in effect concentrations comparable to the PESC findings but lower than the Kennedy results (Table 8-6). The site-specific results indicate that rainbow trout sensitivity to sulphate does not increase at hardness >250 mg/L as CaCO_3 within the Elk and Fording rivers. Consequently, the sulphate benchmark for hardness conditions >250 mg/L as CaCO_3 is set to 429 mg/L, which is equal to the B.C. WQG for hardness conditions of 180 to 250 mg/L as CaCO_3 .

Toxicity testing using water from the Fording and Elk Rivers indicated that extension of the sulphate WQG of 429 mg/L is applicable to hardness values up to at least 800 mg/L as CaCO_3 . This conclusion is based on the following toxicity testing results:

- Sulphate spiking tests conducted as part of the Phase 1 mixture toxicity tests exhibited no evidence of osmotic stress at hardness levels up to at least 800 mg/L as CaCO_3 . For example, the sulphate IC20 concentrations and associated hardness levels for the two most sensitive species (rainbow trout embryo-alevin development and *C. dubia* reproduction) were 530 mg/L sulphate at a hardness of 830 mg/L as CaCO_3 , and 595 mg/L sulphate at a hardness of 910 mg/L as CaCO_3 , respectively (Golder and Nautilus 2013).
- Testing in Fall 2013 confirmed no evidence of toxicity in all treatments with elevated sulphate and hardness. Sulphate was not found to be toxic to any test species up to the maximum concentration tested, even in combination with hardness values greater than 1,000 mg/L as CaCO_3 (Annex F).

Additional site-specific toxicity testing will be completed during plan implementation to assess sensitivity of aquatic organisms and validate the sulphate benchmark at hardness levels >250 mg/L as CaCO_3 (see Chapter 11).

8.2.5 Cadmium

Effects of cadmium on aquatic organisms are generally assessed through direct contact, as cadmium can interfere with the uptake of calcium from water (CCME 2014). Cadmium toxicity decreases as water hardness increases. This relationship is well-established, and is incorporated into the B.C. working cadmium WQG (B.C. MOE 2006), the newer Canadian cadmium WQG for the protection of aquatic life (CCME 2014) and a recently released draft B.C. WQG. The current B.C. working WQG is based on the previous version of the Canadian guideline, and is therefore out of date.

Cadmium toxicity is also influenced by dissolved organic carbon (DOC). As with hardness, cadmium toxicity declines as DOC increases. However, DOC levels in the Designated Area tend to be low (~2 mg/L), and exert only a small influence on cadmium toxicity. Teck developed a mechanistic cadmium toxicity model using the

biotic ligand model (Annex G). This model provides the most robust assessment of cadmium effects, and confirmed that DOC and other toxicity-modifying factors in the Elk Valley exert only a small influence on cadmium toxicity, and that a hardness relationship is appropriate for setting a water-quality benchmark.

The available toxicological literature was reviewed to develop a species-sensitivity distribution of cadmium effects to aquatic biota (Annex G). These toxicity data were normalized to Elk Valley conditions using a hardness-equation approach, comparable to that used by CCME in the most recent update of the Canadian WQG for cadmium (CCME 2014).

The water-quality benchmark for cadmium is defined using the following hardness equation, which was developed to protect the lowest observed endpoint for the most sensitive species in the cadmium species-sensitivity distribution:

$$\text{Benchmark } (\mu\text{g/L}) = 10^{0.83 \cdot \log_{10}(\text{hardness}) - 2.53}$$

This relationship is almost identical to the updated long-term Canadian WQG for total cadmium. The two equations use the same slope of 0.83, differing only in intercept. The Canadian WQG uses an intercept of 2.46 instead of 2.53, which yields a higher cadmium value at a given hardness (see Table 8-7).

Table 8-7. Cadmium benchmarks at different hardness levels, compared with the Canadian WQG.

Hardness level (mg/L as CaCO ₃)	Benchmark concentration (µg/L) ¹	Canadian WQG (µg/L) ²
100	0.14	0.16
150	0.19	0.22
200	0.24	0.28
250	0.29	0.34
300	0.34	0.37

Note¹: Calculated using benchmark equation.

Note²: Canadian WQG was calculated from the guideline equation in CCME 2014.

The Canadian WQG intercept is based on a species-sensitivity distribution, representing a hazard concentration to 5% of species of 0.09 µg/L at a hardness of 50 mg/L as CaCO₃. Currently, B.C. MOE does not endorse the use of species-sensitivity distributions and associated hazard concentrations to define protective thresholds. Consequently, the intercept was adjusted using the geometric mean of the most sensitive species in the distribution, the water flea *Daphnia magna*. The cadmium benchmark was applied as a dissolved value consistent with understanding that the next version of the B.C. WQG for cadmium will apply to the dissolved fraction.

8.3 Long-term Water Quality Targets

Long term water quality targets were developed following the process described in Section 8.1 and illustrated in Figure 8-1. Results of the initial implementation plan modelling were compared to WQGs or benchmarks providing the same level of protection. For those Order stations that showed predicted concentrations at or below the WQG or benchmark, the respective value was selected as the long term target for that order station (Section 8.3.1). If expected future conditions did not meet WQGs or benchmark values providing the same level of protection, then an integrated assessment was completed in parallel with adjustments to the initial

implementation plan to achieve long-term targets that are achievable and protective of aquatic ecosystem health in the MU (Sections 8.3.2 and 8.3.3). The end result was long-term targets for all six MUs, which are summarized in Section 8.3.4.

8.3.1 Comparison with Water Quality Guidelines and Benchmarks

Pursuant to the Order, site-specific water-quality objectives (SSWQOs) were calculated using approved methods to support the long-term target setting process (see Annex F). These calculations confirmed that the B.C. WQGs are applicable for the natural background water quality conditions in the Designated Area. This finding confirmed that development of water quality benchmarks for the Designated Area would require different methods than those prescribed for calculating SSWQOs.

Current water-quality conditions and predicted concentrations from the initial implementation plan were compared with B.C. WQGs (nitrate and sulphate) and a cadmium benchmark value that has margin of safety comparable to the Canadian WQG. For those Order stations that showed predicted future concentrations at or below the WQG or benchmark, the respective value was selected as the long term target for that Order station.⁴ The results of this comparison are presented below:

- Current and predicted future concentrations of selenium, nitrate and sulphate are less than the B.C. WQG; therefore, these guideline values were set as the long-term targets for Order station LK-2 in Lake Koochanusa (MU-6).
- Current and predicted future concentrations of cadmium in Lake Koochanusa are less than the cadmium benchmark, which provides a margin of safety that is comparable to the Canadian WQG. Therefore, this benchmark was set as the long-term target for Order station LK-2 in Lake Koochanusa (MU-6).
- Selenium concentrations in the Elk and Fording rivers (MU-1 to MU-5) are currently above the WQGs, and are expected to remain so in the future. Therefore, long-term targets for selenium in these MUs were defined using an integrated assessment.
- Nitrate levels in the Elk River upstream of the Fording River (MU-3) are currently below the B.C. WQG, and are projected to remain so for the future. Nitrate levels in the Elk River downstream of the Fording River (MU-4 and MU-5) are currently above the B.C. WQG during winter; however, long-term concentrations with the initial implementation plan are predicted to be below the guideline. Therefore, long-term targets at Order stations in these MUs were set at the current WQG of 3 mg/L of NO₃-N.
- Nitrate levels in the Fording River (MU-1 and MU-2) are currently above the WQGs, and are expected to remain so in the future. Therefore, long-term targets for nitrate in these MUs were defined using an integrated assessment.
- Sulphate concentrations in the Elk and Fording rivers are currently below the B.C. WQG⁵ for the protection of aquatic life, and are predicted to remain so in the future in MU-2 to MU-5. Therefore, the long-term target was set to the WQG at Order stations in these MUs.
- Sulphate concentrations at Order station FR4 in MU-1 are predicted to reach the B.C. WQG in 2030. The potential for sulphate to exceed the long-term target in MU-1 will be managed through monitoring and adaptive management (see Chapter 11). If required, sulphate treatment can be implemented (see Section 8.5). The long-term sulphate target for MU-1 at Order station FR4 was set to B.C. WQG (i.e., 429 mg/L) and an integrated assessment was completed to confirm that this target will protect aquatic health in MU-1.
- Current and estimated future concentrations of cadmium in the Elk and Fording rivers (MU-1 to MU-5) are less than the benchmark, which provides a margin of safety that is comparable to the Canadian WQG. Therefore, this benchmark was set as the long-term target for Order stations in these MUs.

⁴ For cadmium, future concentrations were estimated by scaling measured concentrations to reflect the relative (i.e., percent) changes predicted by the Model. This approach was used because the geochemistry of cadmium release from waste spoils cannot be modelled with sufficient resolution to allow model prediction to be used directly.

⁵ A sulphate benchmark value of 429 mg/L applies at hardness levels >250 mg/L as CaCO₃.

8.3.2 Integrated Assessment Methods

The integrated assessment provides a methodology to evaluate the level of protection afforded to aquatic life in MUs that include different water quality conditions in mainstem rivers, mine-influenced tributaries and tributaries not influenced by mining. It assesses the regional (i.e., MU scale) influence of local-scale water-quality conditions.

This section includes a summary of the integrated assessment methodology. The full methodology is presented in Annex H.

8.3.2.1 Division of Management Unit into Subunits

Each MU was divided into subunits to facilitate evaluation of potential effects in on-channel and off-channel habitat areas in the mainstem river and mine-influenced tributaries. The Elk and Fording River mainstems and Michel Creek were subdivided, where appropriate, to account for longitudinal variability in constituent concentrations.

Tributaries not influenced by mining that are likely to be ephemeral were not included in the integrated assessment, because quality of aquatic habitat in these areas will be low and their inclusion would bias the influence of tributaries. Upstream tributary areas isolated from the Fording or Elk River mainstems, such as those in upper Kilmarnock Creek (MU-1) and upper Line Creek (MU-2), were not incorporated into the integrated assessment for fish because they are not accessible to fish in downstream areas in the mainstem Fording or Elk rivers or Michel Creek; nor are they a source of benthic drift to downstream areas. They were also excluded to avoid a reference area bias (i.e., dilution of effect through the inclusion of unconnected reference areas).

8.3.2.2 Define Available Habitat

The total area of aquatic habitat present in each subunit was quantified, as well as that which is likely to be accessible to fish. These areas were calculated using GIS map layers, with consideration of CanFor stream classifications, stream magnitude and stream slope.

Proposed mine development activities were taken into account, as were water management activities related to the initial implementation plan that will result in loss of habitat. Affected subunits include:

- Cataract, Swift and Clode creeks in MU-1
- West Line Creek and a small portion of upper Line Creek in MU-2
- Leask and Wolfram creeks in MU-3
- Gate and Bodie creeks in MU-4.

Cataract, Swift, Leask and Wolfram creeks are not fish-accessible, with the possible exception of the last 20 metres of Swift Creek. The lower portions of Clode, Gate and Bodie creeks are fish-accessible, as is a small length of lower West Line Creek and the small area of upper Line Creek affected by the operations of the West Line Creek water treatment plant. Aquatic habitat in Lake Mountain Creek will be lost as part of development of the proposed Fording River Operations' Swift Project.

Compensation planning for lost habitat in West Line Creek and Line Creek is underway. Offsets for lost habitat in the other creeks will be developed, if and as required, during permitting and detailed design of the relevant components of the initial implementation plan. Similarly, compensation habitat for Lake Mountain Creek is being developed as part of the Swift Project, since disturbance of this creek occurs as a result of mining rather than water management activities.

Habitat that will be removed, and that is expected to be subject to habitat offsets, was not included in the integrated assessment.

8.3.2.3 Define Constituent Concentrations

Constituent concentrations in tributaries and other subunits unaffected by mining were set to background conditions, as described in Chapter 4. They are assumed to remain unchanged over time.

Selenium and nitrate concentrations in mine-influenced subunits were calculated using a two-stage process. First, concentrations in mine-influenced subunits were defined based on predicted long-term performance of the initial implementation plan. Long-term concentrations were estimated using the Model, which is described in Annex D.1. The Model is designed to simulate regional conditions in the Designated Area, and is used to predict concentrations in the Elk and Fording River mainstems.

The Model does not accurately predict concentrations in all mine-influenced tributaries; however, it can more reliably predict relative changes in water quality in these areas, because this is strongly correlated with changes to waste-rock volume. As such, predictions for current and long-term conditions were used to proportionally scale values observed in 2013 to provide an estimate of long-term concentrations in mine-discharge tributaries (i.e., long-term concentration in a mine-discharge tributary = current observed concentration × modelled long-term concentration ÷ modelled current concentration).

Long-term concentrations in all mine-influenced subunits were then scaled to reflect concentrations at the Order station. For example, if long-term predictions for the initial implementation plan indicate that a mine-discharge tributary has a concentration twice that predicted at the Order station, the concentration in the tributary was set to twice the long-term target concentration. This approach allows for an explicit evaluation of how changes to concentrations at an Order station could affect concentrations in different subunits, as an approximation of what could occur as a result of applying different levels of water treatment. Potential effects in each subunit and across the MU as a whole were then assessed, as per Step 4

Sulphate and cadmium concentrations in mine influenced subunits were defined using a similar process. Concentrations were based on the predicted performance of the initial implementation plan, with tributary concentrations being from 2013 observed values to reflect the relative changes predicted by the Model.

Sulphate concentrations in MU-2 to MU-4 are predicted to remain below the long-term target concentrations at the Order stations; therefore, integrated effects were assessed for the maximum predicted concentrations. Sulphate concentrations in MU-1 are predicted to reach the long-term target at Order station FR4; therefore, integrated effects were assessed for predicted conditions in mainstem reaches and in mine-influenced tributaries where the sulphate concentration at FR4 is equal to the long-term target concentration.

Estimated future cadmium concentrations are less than the long-term targets at all Order stations. Future concentrations were estimated by scaling measured concentrations to reflect the relative (i.e., percent) changes predicted by the Model. This approach was used because the geochemistry of cadmium release from waste spoils cannot be modelled with sufficient resolution to allow model prediction to be used directly. This approach is expected to over-estimate future concentrations, because cadmium levels do not show a consistent increasing trend with increasing mine activity and waste-rock deposition. Statistical trends at mainstem river stations tend to be relatively flat, although increasing and decreasing statistical trends have been observed at individual locations (Zadlik and Minnow 2013). Temporal trends in tributaries have also been inconsistent, demonstrating no clear or consistent response to mining activity.

8.3.2.4 Quantitative Integrated Assessment

For selenium and nitrate in the Fording River, potential effects on sensitive aquatic receptors in each subunit were assessed by comparing constituent concentrations with WQGs and Level 1 and 2 benchmarks. Effect sizes were quantified using the underlying dose–response relationships, when available. Results were expressed either as a categorical result (e.g., < Level 1 benchmark), or as a percentage potential effect on the receptor organism and most sensitive life–history endpoint (e.g., an 8% effect on *C. dubia* reproduction).

A similar approach was used for nitrate in the Elk River, and for sulphate and cadmium in MU-1 to MU-4. The calculated concentrations defined in Step 3 were compared to WQGs or equivalent values (e.g., the sulphate and cadmium benchmarks outlined in Sections 8.2.4 and 8.2.5). Concentrations above WQGs or equivalent values were then compared to Level 1 and Level 2 benchmarks, or the underlying dose–response curves.

The nitrate benchmarks applicable to the Elk River are described in Appendix F, as are the sulphate benchmarks used in this evaluation. Cadmium benchmarks used to evaluate potential effects in areas where concentrations may exceed the WQG or equivalent are outlined in Appendix G.

Potential effects calculated from a dose–response curve (i.e., expressed as a percentage) were then spatially integrated using an area–weighted approach, to identify the percent effect across the entire MU (e.g., a 5% integrated effect to *C. dubia* reproduction across MU-1). This value was then compared to the Level 1 and Level 2 critical–effect sizes (i.e., 10 and 20%) to assess protection of aquatic life.

The area–weighted approach assumes that all available habitats are of equal value and receive equal use. The calculation involves multiplying the percent effect in each subunit by the habitat present in the subunit, adding all of the resulting values, and then dividing by the total habitat available in the MU. A sensitivity analysis of the area–weighted approach using fish telemetry data for WCT in the upper Fording River (MU-1) indicated that potential effects were not underestimated compared to a weighting based on observed fish use (Annex H).

Categorical results could not be spatially integrated, because they are not numerical values.

8.3.2.5 Qualitative Assessment of Interactive Effects

Effects on higher–level sensitive receptors (e.g. birds, fish and amphibians) may occur as a result of direct effect and indirect effects related to changes in food availability. Similarly, effects on benthic invertebrates can be expressed through changes to the population of the most sensitive species, or more broadly through changes to the community as a whole (as a result of effects on multiple species). In recognition of these potential pathways, a qualitative evaluation was completed in each subunit to assess whether effects on multiple sensitive endpoints could result in community–level effects.

For benthic invertebrates, potential population–level responses were assessed based on predicted effects on the most sensitive invertebrate species tested. Potential changes in community structure or function were evaluated with reference to predicted effects on the next most sensitive species. The results of these evaluations were integrated, as shown in Table 8-8, to generate a categorical effect score of 1 to 5, for which the categories are defined in Table 8-9.

Table 8-8. Integration of potential effects to benthic invertebrates.

Endpoint and level of predicted effect		Most sensitive species endpoint ¹		
		≤10%	10 to 20%	>20%
Community endpoint (Next most sensitive species)	≤10%	1	2	3
	10 to 20%	n/a	3	4
	>20%	n/a	n/a	5

Note¹: n/a = non-applicable scenario (e.g., a community level alteration cannot occur without a response to the most sensitive species); colour-coded categorical scores are defined as per Table 8-9.

The scoring system in Table 8-8 is based on the following rationale:

- Effect sizes of ≤10% represent negligible potential for population-level effects.
- Effect sizes of 10 to 20% represent a possibility of population-level effects, although measurable or ecologically meaningful changes in invertebrate populations are unlikely (Suter et al. 1995).
- Effect sizes of >20% present a potential for measurable and ecologically meaningful population-level effects (Suter et al.1995).
- Effects on the most sensitive invertebrate test species may result in changes to diversity of benthic invertebrates, but is unlikely to change general function, structure or abundance of the larger community.
- When more than the most sensitive species is potentially affected, changes to community function, structure and/or overall abundance are possible, particularly when effect sizes exceed 20%.

Potential effects on fish, birds and/or amphibians were evaluated in a similar fashion, considering direct effects on the most sensitive species and life-history endpoint (e.g., brown trout reproduction), and indirect effects that may occur through reduced food supply (i.e., benthic invertebrate abundance).

Table 8-9. Definition and interpretation of categorical effect scores.

Score	Definition	Interpretation
0	Within the WQG	No effect
1	≤10% effect on any endpoint	No population effect
2	10 to 20% effect to sensitive invertebrate species endpoint	Potential effects to populations of sensitive invertebrate species that are not expected to be measurable or ecologically meaningful*
3	<i>Invertebrates:</i> >20% effect to sensitive species or 10 to 20% effect to multiple endpoints. <i>Fish birds and/or amphibians:</i> 10 to 20% direct effect or <10% direct effect with >20% effect to food supply	<i>Invertebrates:</i> Potential effect to populations of the most sensitive species, or potential effects to multiple species that are not expected to be measurable or ecologically meaningful* <i>Fish, birds and/or amphibians:</i> Potential effect to populations of the most sensitive species that are not expected to be measurable or ecologically meaningful, but that require consideration within the context of other stressors and verification through follow-up monitoring*
4	<i>Invertebrates:</i> >20% effect to sensitive species with 10 to 20% effect to other species <i>Fish, birds and/or amphibians:</i> >20% direct effect or 10 to 20% direct effect with >20% effect to food supply	<i>Invertebrates:</i> Potential effect to populations of multiple species <i>Fish, birds and/or amphibians:</i> Potential effect to populations of one or more sensitive species**
5	>20% effect to a multiple endpoints	Potential effect to populations of multiple species, with potential changes to community structure

Note*: Unlikely to be distinguishable from changes that occur as a result of natural variation or to affect the maintenance of an ecologically effective and self-sustaining population.

Note**: Must be interpreted with caution when applied to local, subunit scale effects to mobile species.

Categorical effect scores were assigned following the scoring system outlined in Table 8-10. This scoring system was developed based on similar rationale to that outlined above, considering:

- For fish, effect sizes of 10 to 20% are unlikely to be measurable or ecologically meaningful (Suter et al. 1995), but require additional consideration within the context of multiple stressors (Mebane 2010).
- At an indirect effect size >20%, benthic community structure and function could be impaired, which could limit food availability.
- Integrated effects are likely to become more severe as indirect and direct effects individually increase.

Table 8-10. Integration of potential effects on fish, birds and/or amphibians.

Endpoint and Level of Predicted Effect		Direct (Most sensitive of direct endpoints) ²		
		≤10%	10 to 20%	>20%
Indirect (Food Supply) ¹	≤20%	1	3	4
	>20%	3	4	5

Note¹: Indirect effect defined based on invertebrate community endpoint.

Note²: Colour-coded categorical scores are defined in Table 8-9.

8.3.2.6 Evaluation of Integrated Effects

The evaluation of integrated effects combines the results of the previous two steps (the quantitative integrated assessment and the qualitative assessment of interactive effects) to assess the integrated effect for the MU in question. This evaluation was completed using the following integrated effects assessment criteria, which are derived from the corresponding critical-effect sizes:

- For the protection of benthic invertebrate community structure and abundance (noting that protection at the community level is required to maintain ecosystem function, including the production of food for higher-level organisms):
 - a predicted integrated effect size of <20% across the MU on the community endpoints (if dose-response information is available)
 - concentrations less than the Level 2 benthic community benchmark in all mainstem subunits of the Elk and Fording rivers
 - integrated effect scores of 3 or less for benthic invertebrates in the mainstem subunits of the Elk and Fording rivers.
- For the protection of fish, bird, and amphibian populations:
 - a predicted integrated effect size of <10% across the MU to the most sensitive life-history endpoint, based on the best estimate of the underlying dose-response curve (if available)
 - concentrations less than the Level 1 benchmark for the most sensitive life-history endpoint in all mainstem subunits of the Elk and Fording rivers
 - integrated effect scores of <3 in mainstem subunits of the Elk and Fording rivers
 - for selenium effects to fish and bird reproduction, a predicted integrated effect size of <20% for the most sensitive receptor endpoint across the MU, based on an upper-bound estimate of the underlying dose-response curve.

Benthic invertebrate criteria focused on maintaining effect sizes <20% for the most sensitive species and life-history endpoint to be protective by preventing measurable and ecologically meaningful changes to benthic communities. Lower effect sizes were used for fish because multiple stressors are present. The same rationale was applied to birds and amphibians, given their longer life spans and lower reproductive output relative to benthic invertebrates.

If all integrated assessment criteria are met, then predicted conditions are expected to be protective of aquatic health in the MU. Exceeding one or more of these integrated assessment criteria for an MU does not necessarily mean that aquatic health would not be protected; however, it does require consideration of any such exceedances to evaluate the level of risk and to factor this into the selection of long-term targets that are protective of aquatic health.

The integrated assessment was used to derive long-term targets for selenium in MU-1 to MU-5⁶ and nitrate in MU-1 and MU-2. Level 1 benchmarks were used as the initial candidate long-term target concentration assigned at each Order station in question. The initial target was then adjusted downwards, if required, to meet the integrated assessment criteria for the MU.

Target levels were also evaluated to determine if they could be achieved with the initial implementation plan. If required, target levels and the initial implementation plan were evaluated iteratively to derive a target value that is both protective and achievable. This step was required in only one instance, which was to set the long-term selenium target in the lower Fording River (MU-2). The level of risk associated with integrated assessment criteria that could not be met in MU-2 was evaluated and factored into the long-term target selection.

Integrated assessments were also completed for sulphate (MU-1 to MU-4), cadmium (MU-1 to MU-4) and nitrate in the Elk River (MU-3 to MU-4). This was done to identify the level of integrated effects associated with either the maximum predicted long-term concentrations for the initial implementation plan (cadmium and sulphate in MU-2 to MU-4) or the long-term target when set to the WQG (nitrate and sulphate in MU-1), as discussed in Section 8.3.1.

8.3.3 Integrated Assessment Results

8.3.3.1 Selenium

The integrated assessment results for selenium are presented in Table 8-11. Results of the integrated assessment of selenium in the upper Fording River (MU-1) indicate that a long-term target of 57 µg/L will meet the integrated assessment criteria.

In the lower Fording River (MU-2), the Level 1 selenium benchmark of 19 µg/L could not be achieved with the initial implementation plan. Through an iterative process of evaluating target levels and the initial implementation plan, a long-term selenium target of 40 µg/L was derived that is both protective and achievable. This is further documented in Section 8.5.3.5 and shown in Figure 8-8.

The long-term target value of 40 µg/L in MU-2 is expected to protect fish populations, although with a lower margin of safety than a level 1 (10%) effect size. The predicted integrated effect size to sensitive fish species is 13% across the MU. Selenium concentrations in all sections of the lower Fording River are lower than the Level 2 benchmark for the most sensitive life-history endpoint, and the predicted upper bound integrated effect size for sensitive fish species is <20%. A predicted integrated effect size of 13% (17% upper bound) is considered unlikely to affect sensitive fish populations in the lower Fording River for a number of reasons:

- As discussed in Section 8.2.2.3, the targeted critical effect size of 10% is associated with a margin of safety, and effect sizes of <20% for egg survival are unlikely to affect a fish population.
- The target meets the assessment criteria for all other aquatic and aquatic feeding biota that are sensitive to selenium (i.e., westslope cutthroat trout, birds and benthic invertebrates).
- There is limited potential for multiple-stressor interactions in MU-2: sulphate and cadmium concentrations are <WQGs and the integrated effect to fish from nitrate is predicted to be ~2% (see Annex H).
- In contrast to the upper Fording River, in which the fish population is isolated because of Josephine Falls, fish in the lower Fording River can freely move into the Elk River (MU-3 to MU-5), where selenium concentrations and effect sizes are lower.

In the Elk River (MU3 to MU5), the long-term target of 19 µg/L meets the integrated assessment criteria for all of these MUs.

⁶ Although there are no tributaries in MU-5 that are influenced by Teck operations, an integrated assessment was completed for this MU to identify long-term selenium target that is above the B.C. WQG.

8.3.3.2 Nitrate

Results of the integrated assessment for nitrate in the Fording River MUs are presented in Table 8-12. The integrated assessment criteria for nitrate in MU-1 and MU-2 were met for the long-term target of 11 mg/L of NO₃-N at the Order stations.

Results of the integrated assessment for nitrate in the Elk River MUs are presented in Table 8-13. The long-term nitrate target in Elk River MUs is equal to the WQG of 3 mg as NO₃-N mg/L. The integrated assessment criteria were met in MU-3 and MU-4, with nitrate concentrations in most habitats at or below the long-term target (see Annex H).

During the Coal Mountain Operations (CMO) Phase II environmental assessment, efforts will be directed to refining nitrate predictions for predictions of local effects in Wheeler Creek. As outlined in Annex H, nitrate concentrations in Wheeler Creek may become elevated in future, although not to the extent of affecting environmental protection for the MU-4, since Wheeler Creek represents <3% of the total available habitat. Updates will reflect, to the extent possible, the influence of new blasting practices on nitrogen mobilization (discussed in Chapter 6).

8.3.3.3 Sulphate

Results of the integrated assessment for sulphate in the are presented in Table 8-14. In MU-1, most but not all integrated assessment criteria were met (Table 8-14). For example, the integrated effect sizes for fish (the most sensitive receptor), amphibians and benthic invertebrates met the assessment criteria. However, only approximately 34% of the mainstem Fording River was predicted to be less than the Level 1 benchmark, although 100% of this area was below the Level 2 benchmark. A sulphate target level of 429 mg/L at FR4 is expected to be protective of aquatic health in MU-1 because integrated effect sizes were <10% for all receptors and 98% or more of the MU met Level 2 benchmarks for fish, amphibians and benthic invertebrates. Follow-up monitoring and toxicity testing will be used to verify this conclusion and updated the toxicity benchmarks as appropriate. Sulphate concentrations in the upper Fording River will be adaptively managed as described in Chapter 11, as will the sulphate targets and timeframes. If necessary, sulphate treatment can be implemented (see Section 8.5).

Sulphate concentrations in the lower Fording River (MU-2) and throughout the Elk River (MU-3 to MU-5) are predicted to remain below the B.C. WQG in the long-term without mitigation. Maximum predicted long-term sulphate concentrations met all integrated assessment criteria in these MUs.

8.3.3.4 Cadmium

Cadmium concentrations in the Fording River (MU 1 and MU-2) and the Elk River (MU-3 to MU-5) are estimated to remain below the long-term target in the long-term without mitigation. Maximum predicted long-term cadmium concentrations met all integrated assessment criteria in these MUs.

Predictions of cadmium concentrations are uncertain. Efforts are underway to improve the quantitative understanding of the geochemical release of cadmium from waste rock, allowing improvement of model predictions. This information will be used during implementation to adaptively manage cadmium concentrations if and as necessary.

Table 8-11. Results of integrated assessment for selenium in the Elk and Fording rivers

Assessment criteria		Management Unit (maximum monthly selenium concentration at Order station)				
		MU-1 (57 µg/L)	MU-2 (40 µg/L)	MU-3 (19 µg/L)	MU-4 (19 µg/L)	MU-5 (19 µg/L)
Description	Goal					
Protection of Fish						
Integrated effect size for most sensitive endpoint	Best estimate of <10% (with upper bound estimate of <20%)	9% ¹ (12%) ²	13% (17%)	5% (8%)	8% (11%)	7% (10%)
Proportion of management unit with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (96%) ³	0% (27%)	100% (99%)	100% (93%)	100% (100%)
Maximum effect score in Fording River mainstem	2	1	3	1	1	1
Protection of Birds						
Integrated effect size for most sensitive endpoint	<10%	6%	5%	3%	4%	4%
Proportion of management unit with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (95%)	100% (100%)	100% (99%)	100% (99%)	100% (100%)
Maximum effect score in Fording River mainstem	2	1	1	1	1	1
Protection of Benthic Invertebrates						
Integrated effect size for community endpoint	<20%	- ⁴	-	-	-	-
Proportion of management unit with concentrations <Level 2 benchmark for the community endpoint	100% in river mainstem	100% (98%)	100% (100%)	100% (100%)	100% (100%)	100% (100%)
Maximum effect score in Fording River mainstem	3	1	1	1	1	1
Achievable by initial implementation plan	Yes	Yes	Yes	Yes	Yes	Yes

Note: Derived from information contained in Annex H. See Table 8-9 for definition of effect scores. Bolded values do not meet the criteria.

Note¹: % Integrated effect size for most sensitive endpoint in the MU.

Note²: Upper bound estimate of integrated effect size.

Note³: % of mainstem subunit area below criteria, with % of area in the MU below criteria shown in parentheses.

Note⁴: not applicable, because dose-response curves not available.

Table 8–12. Results of integrated assessments for nitrate in the Fording River (MU-1 and 2).

Assessment criteria		Nitrate concentration of 11 mg/L of NO ₃ -N at Order station	
Description	Goal	MU-1	MU-2
Protection of Fish			
Integrated effect size for most sensitive endpoint	Best estimate of <10%	~4%	~6%
Proportion of management unit with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (93%) ^(b)	100% (98%)
Maximum effect score in Fording River mainstem	2	1	1
Protection of Amphibians			
Integrated effect size for most sensitive endpoint	<10%	~1%	~1%
Proportion of management unit with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (100%)	100% (100%)
Maximum effect score in Fording River mainstem	2	1	1
Protection of Benthic Invertebrates			
Integrated effect size for community endpoint	<20%	~3%	~5%
Proportion of management unit with concentrations <Level 2 benchmark for the community endpoint	100% in river mainstem	100% (100%)	100% (100%)
Maximum effect score in Fording River mainstem	3	3	3
Achievable by initial implementation plan	Yes	Yes	Yes

Note: Results shown at hardness of 360 mg/L as CaCO₃. Percentage of mainstem subunit area below criteria, with % of area in the MU below criteria shown in parentheses.

Table 8–13. Results of Integrated Assessments for Nitrate in the Elk River (MU-3 and MU-4).

Assessment criteria		Nitrate long-term target concentration of 3 mg/L of NO ₃ -N at Order station	
Description	Goal	MU-3	MU-4
Protection of Fish			
Integrated effect size for most sensitive endpoint	Best estimate of <10%	—	—
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (100%)	100% (97%)
Maximum effect score in Elk River mainstem	2	0	0
Protection of Amphibians			
Integrated effect size for most sensitive endpoint	<10%	—	—
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (100%)	100% (98%)
Maximum effect score in Elk River mainstem	2	0	0
Protection of Benthic Invertebrates			
Integrated effect size for community endpoint	<20%	—	—
Proportion of MU with concentrations <Level 2 benchmark for the community endpoint	100% in river mainstem	100% (100%)	100% (98%)
Maximum effect score in Elk River mainstem	3	0	0

Note: — = not applicable, because dose-response curve not available. See Table 8-9 for effect score categorization. Percentage of mainstem subunit area below criteria, with % of area in the MU below criteria shown in parentheses.

Table 8-14. Results of Integrated Assessments for Sulphate in the Elk and Fording Rivers.

Assessment criteria	FR4 at long-term target of 429 mg/L	Based on maximum concentration predicted for the initial implementation plan			
		MU-1	MU-2	MU-3	MU-4
Description	Goal				
Protection of Fish					
Integrated effect size for most sensitive endpoint	Best estimate of <10%	~9%	~4%	~0%	~1%
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	34% (56%)	100% (100%)	100% (100%)	100% (99%)
Proportion of MU with concentrations <Level 2 benchmark for most sensitive endpoint		100% (98%)	100% (100%)	100% (100%)	100% (99%)
Maximum effect score in Fording / Elk River mainstem	2	3	1	0	0
Protection of Amphibians					
Integrated effect size for most sensitive endpoint	<10%	~8%	~4%	~0%	~1%
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	34% (61%)	100% (100%)	100% (100%)	100% (98%)
Proportion of MU with concentrations <Level 2 benchmark for most sensitive endpoint	100% in river mainstem	100% (98%)	100% (100%)	100% (100%)	100% (98%)
Maximum effect score in Fording / Elk River mainstem	2	3	1	0	0
Protection of Benthic Invertebrates					
Integrated effect size for community endpoint	<20%	~4%	~2%	~0%	~1%
Proportion of MU with concentrations <Level 2 benchmark for the community endpoint	100% in river mainstem	100% (98%)	100% (100%)	100% (100%)	100% (98%)
Maximum effect score in Fording / Elk River mainstem	3	1	1	0	0

Note: Bolder values do not meet assessment criteria. See Table 8-9 for effect score categorization. Percentages for mainstem river are shown in brackets. Percentage of mainstem subunit area below criteria, with % of area in the MU below criteria shown in parentheses.

Table 8–15. Results of Integrated Assessment for Cadmium in the Elk and Fording Rivers

Assessment criteria		Based on maximum concentration estimated for the initial implementation plan			
Description	Goal	MU-1	MU-2	MU-3	MU-4
Protection of Fish					
Integrated effect size for most sensitive endpoint	Best estimate of <10%	-(a)	-	-	-
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (100%)	100% (100%)	100% (100%)	100% (98%)
Maximum effect score in Fording / Elk River mainstem	2	1	0	0	0
Protection of Amphibians					
Integrated effect size for most sensitive endpoint	<10%	-	-	-	-
Proportion of MU with concentrations <Level 1 benchmark for most sensitive endpoint	100% in river mainstem	100% (100%)	100% (100%)	100% (100%)	100% (100%)
Maximum effect score in Fording / Elk River mainstem	2	1	0	0	0
Protection of Benthic Invertebrates					
Integrated effect size for community endpoint	<20%	-	-	-	-
Proportion of MU with concentrations <Level 2 benchmark for the community endpoint	100% in river mainstem	100% (100%)	100% (100%)	100% (100%)	100% (98%)
Maximum effect score in Fording / Elk River mainstem	3	1	0	0	0

Note: Bolder values do not meet assessment criteria. See Table 8–9 for effect score categorization. Percentages for mainstem river are shown in brackets. Percentages of mainstem subunit area below criteria, with % of area in the MU below criteria shown in parentheses.

8.3.4 Summary of Long-term Water Quality Targets and Timeframes

Long-term targets for each MU-and Order station are summarized in Table 8-16.

Table 8-16. Summary of long-term water-quality targets.

Management Unit	Order stations	Selenium (µg/L) ¹	Nitrate (mg/L NO ₃ -N) ²	Sulphate (mg/L) ³	Cadmium (µg/L) ⁴
1	FR4	57	11	429	0.39
2	FR5	40	11	429	0.39
3	ER1	19	3	429	0.24
4	ER2	19	3	429	0.24
5	ER3, ER4	19	3	429	0.24
6	LK2	2	3	308	0.19

Note: Hardness dependent targets for nitrate (MU-1 & 2 only), sulphate and cadmium are shown for the following average hardness levels as mg/L as CaCO₃: Fording River 360; Elk River 200; and Lake Koochanusa 150.

Note¹: The long-term selenium target for MU-6 is specified in Ministerial Order M113. Targets in MUs 1-5 are site-specific.

Note²: Nitrate targets in MUs 3-6 are equal to the B.C. WQG for the protection of aquatic life. The Target in MUs 1-2 is a site-specific hardness based equation; target values shown are for a representative hardness level of 350 mg/L as CaCO₃.

Note³: Sulphate targets are equal to the B.C. WQG for the protection of aquatic life. The target for hardness levels greater than 250 mg/L as CaCO₃ is equal to the guideline for hardness levels of 180-250 mg/L as CaCO₃.

Note⁴: Cadmium targets are equivalent to the Canadian WQG for the protection of aquatic life (CCME 2014), but expressed as a dissolved concentration. The cadmium target is a hardness-based equation; target values shown are for representative hardness levels of 360 mg/L as CaCO₃ in the Fording River, 200 mg/L as CaCO₃ in the Elk River and 150 mg/L as CaCO₃ in Lake Koochanusa.

Long-term targets for nitrate in the Elk River and Lake Koochanusa are set equal to the B.C. WQG of 3 mg/L of NO₃-N for the protection of aquatic life. Long-term targets for nitrate in the Fording are set to a hardness-dependent value of 11 mg/L of NO₃-N, expressed at a hardness of 360 mg/L as CaCO₃. They can be adjusted to other hardness levels using the following equation:

$$\text{Nitrate Target in the Fording River (mg as N/L)} = 10^{1.0003 \cdot \log_{10}(\text{hardness}) - 1.52}$$

Targets for sulphate are set to the B.C. WQG for the protection of aquatic life. Site-specific testing at hardness >250 mg/L as CaCO₃ indicates that the guideline of 429 mg/L for hardness between 181 and 250 mg/L as CaCO₃ can be extended to apply as an target at higher hardness levels.

The long-term water-quality target for cadmium at all Order stations is defined using the following hardness equation, which was developed to protect the lowest observed endpoint for the most sensitive species in the cadmium species-sensitivity distribution:

$$\text{Cadmium Target (µg/L)} = 10^{0.83 \cdot \log_{10}(\text{hardness}) - 2.53}$$

This relationship is almost identical to the updated, long-term Canadian WQG for total cadmium, which was released in 2014 (CCME 2014). This target is used in place of the current B.C. working WQG, which is based on the previous version of the Canadian WQG, and so is not considered current. Because the MOE does not endorse the use of species-sensitivity distributions and associated hazard concentrations to define protective thresholds, the intercept was adjusted to be consistent with MOE methods. The cadmium target was applied as a dissolved value consistent, with the consensus understanding that the next version of the B.C. WQG for cadmium will apply to the dissolved fraction.

The initial implementation plan is predicted to meet the long-term water-quality targets for all MUs within the timeframes summarized in Table 8-17. These timeframes are approximate, because they are based on model predictions.

Table 8-17. Expected timeframe to achieve long-term targets based on model predictions.

Management Unit	Order stations	Selenium	Nitrate
1	FR4	2022	2019
2	FR5	2023	2019
3	ER1	2014	2014
4	ER2	2023	2028 ¹
5	ER3, ER4	2014	2019, 2014
6	LK2	2014	2014

Note¹: Additional measures (updates to blasting practices) are planned to reduce nitrate concentrations. These measures, while not quantifiable at this time, are anticipated to reduce nitrate concentrations and may result in the long-term target being met earlier.

8.4 Multiple-Stressor Analysis

A qualitative multiple-stressor analysis was completed to assess potential interactions among Order constituents and other stressors (e.g., potential changes to calcite levels, water flows or nutrient status). The results of the multiple-stressor analysis were used to confirm the conclusions of the constituent-specific analyses, including selection of long-term target concentrations for selenium and nitrate. Full details of the qualitative multiple-stressor analysis can be found in Annex H.

8.4.1 Approach

Conceptual site models presented in Chapter 4 identify the following physical stressors to aquatic biota in the Elk and Fording River watersheds:

- changes to water flow
- formation of barriers that limit connectivity
- calcite formation
- release of suspended sediments, which may elicit effects through direct contact or via deposition on existing habitats.

Chemical stressors consist of changes to the concentrations of the four Order constituents, as well as potential changes to nutrient status related to the release of phosphorus from the active water treatment facilities that are included in the initial implementation plan.

The potential for these stressors to act in combination and produce greater levels of effect than those predicted for individual Order constituents was evaluated qualitatively using a lines of evidence approach. More specifically, the potential for mixture effects to occur among selenium, nitrate, sulphate and cadmium was evaluated through examination of the following:

- theoretical potential for interaction based on mechanisms of action of each Order constituent
- results of standardized site-specific toxicity testing that evaluates the toxicity of mixtures representative of mine-influenced waters

- results of toxicity testing using amended waters (i.e., spiking tests) to evaluate how increasing individual substances (in the context of other substances held at stable and site-relevant concentrations) influences magnitude of response.

The potential for interactive effects among the Order constituent and other stressors was then evaluated in consideration of the following:

- the small effect sizes upon which the water-quality benchmarks are based
- existing best management practices that are being used to control sediment releases from mine areas
- existing permit limits that regulate sediment releases from each operation with the goal of protecting downstream environments
- existing regulatory protocols that require compensation for disturbed habitats
- projected changes in water flows related to the initial implementation plan
- the medium and long-term calcite targets that are outlined in Chapter 7 of the Plan.

It is acknowledged that quantitative approaches are available for evaluating integrated effects from multiple chemical stressors. However, such approaches and models are only reliable when the mechanisms of toxicity are well understood, including knowledge of specific interactions among multiple constituents (as is the case for some pesticides – Rider and LeBlanc 2005). For the Order constituents, the mechanistic understanding of toxicity, both individually and in combination, is not known to a level to support such an approach. Furthermore, the Order constituents found in site waters exhibit a high degree of intercorrelation in exposure (i.e., similar concentration profiles over space and time), which limits the degree to which potential causal factors can be discriminated. Downes 2010 recognizes that prediction of the effects of multiple stressors is challenging because direct causes of an environmental alteration are difficult to distinguish from factors that merely correlate with responses, making it difficult to disentangle their effects in ways allowing correct prediction for the future.

Statzner and Bêche (2010) caution against the over-quantification of multiple stressor models where a mechanistic understanding of responses is lacking. They conclude that multiple-stressor evaluations of freshwater communities using quantitative or index-based methods should only be used in association with stressors for which mechanistic a priori predictions on their effects are possible. This view is supported by Rider and LeBlanc 2005, who conclude that indiscriminate application of a quantitative model in the absence of a sound mechanistic basis “increases the uncertainty associated with predicting mixture toxicity.” Gregorio et al. 2013 identified an additional uncertainty in mixture assessment for aquatic ecosystems; specifically, mixture effect predictions have been shown to be consistent only when these models are applied for a single species, rather than for communities as represented in a species sensitivity distribution. The application of a specific model can therefore lead to over- or underestimations, depending mainly on the slope of the dose–response curves of the individual species. It is for these reasons that a qualitative approach was used.

8.4.2 Results

An evaluation of individual physical and chemical stressors is provided below, following by a qualitative evaluation of multiple stressors in MUs in the Elk and Fording River (MU-1 to MU-4). Based on this information, conclusions are rendered on how the findings of the constituent-specific analyses previously discussed may be affected, if at all, by multiple stressor considerations. Residual uncertainties inherent in multiple-stressor analysis will be addressed with through on-going monitoring and adaptive management, which are presented in Chapters 10 and 11 of the Plan.

8.4.2.1 Physical and Chemical Stressor Evaluation

The initial implementation plan may result in a loss of water flow in several mine-influenced tributaries. Mining activity associated with the FRO Swift Project will also result in the loss of Lake Mountain Creek. Compensatory habitats will be developed for the affected areas, if and as required, as part of permitting and detailed design.

While compensatory habitats do not eliminate the potential for multiple-stressor effects at a local subunit scale where habitat loss may occur, they are expected to prevent habitat loss at the MU scale; hence, eliminating this potential pathway from contributing to multiple-stressor effects at a regional scale.

As outlined in Chapter 7, the objective of calcite management is to protect aquatic habitat and to manage calcite to achieve acceptable long-term conditions. The narrative objective for calcite management is to understand and manage mine-related calcite formation such that streambed substrates in the Elk and Fording rivers and their tributaries can support abundant and diverse communities of aquatic plants, benthic invertebrates, and fish comparable to those in reference areas. Based on this commitment, calcite formation is not expected to contribute to effects to aquatic receptors in the long-term, and would not result in levels of effects beyond those predicted in the individual constituent evaluations outlined above.

The release of suspended sediments from operational mine sites is controlled by the effluent limits included in the waste discharge permits issued by MOE. All active mine discharges are subject to these permit conditions, and use best management practices to maintain suspended sediment concentrations in discharged waters below these limits. These practices will continue in the future, thus limiting the amount of suspended sediment released to the Elk and Fording rivers and their contribution to multiple-stressor effects.

The use of biological treatment will result in the release of phosphorus to the Elk and Fording rivers. However, the nutrient status of the Elk River is not expected to change with the development of the initial implementation plan (see Annex I2). In addition, as outlined in Chapter 6, treatment technologies will be selected and implemented in such a manner as to prevent undesirable effects related to eutrophication in the Fording River, Line Creek, Michel Creek and other large water courses. Consequently, changes to total phosphorus concentrations are not expected to contribute to multiple-stressors effects at a regional scale, although monitoring will be required to support the selection of treatment technology during detailed design of active water treatment facilities.

A mixture effect can occur when individual constituents combine to produce a level of effect that differs from what would be expected to occur when considering constituents individually. For example, water hardness reduces the toxicity of a number of constituents (e.g., cadmium and sulphate), and, as such, has been incorporated into relevant WQGs. This type of effect is called an antagonistic response. Another effect is the potential for individual constituents to combine in a manner that is additive or synergistic (more than additive), to create a greater effect than would otherwise be expected for the individual constituents.

The potential for mixture effects of selenium, nitrate, sulphate and cadmium was evaluated through examining various lines of evidence:

- the potential for interaction that considers the mechanisms of actions of the different stressors and the benchmark effect sizes; and
- results of site-specific toxicity testing of the combined toxicity of mixtures.

Results of the evaluation are outlined in Annex H, and are summarized below.

The four constituents appear to have different mechanisms of action:

- Sulphate appears to act primarily on the iono-regulatory organs of freshwater organisms, such as the gill, and may either exert stress as a result of general osmoregulatory pressure in conjunction with other components of total dissolved solids.
- Although the specific mechanism-of-action is uncertain, nitrate may exhibit toxicity following uptake and conversion to nitrite, which can then impair oxygen transport. In the Elk Valley, nitrate is not likely to contribute meaningfully to the osmotic pressure that may be important for sulphate toxicity, because it is present at low concentrations relative to the total ionic content of mine-influenced waters.
- Cadmium appears to exhibit adverse effects primarily at the gill, as a result of binding to enzyme receptors in the chloride cells, but is not likely to influence oxygen carrying capacity or otherwise impair respiratory function.
- Selenium produces adverse effects following dietary accumulation of seleno-amino acids into protein-rich tissues and, in particular, the yolk of egg-laying vertebrates, where oxidative stress can occur following mobilization of these materials during embryo-larval development.

Although mechanisms-of-action have not been definitively determined, particularly for sulphate and nitrate, the available information suggests that identical mechanisms-of-action do not occur among the four Order constituents.

The long-term targets for sulphate and cadmium provide a margin of safety for protection of aquatic life that is comparable to WQGs. Considering that WQGs reflect the goal that all forms of aquatic life, at all aquatic life-cycle stages, are to be protected indefinitely, it is expected that there is negligible potential for mixture effects at guideline concentrations.

Results of mixture testing of site waters (Golder and Nautilus 2013) did not indicate additive or synergistic effects (Annex H). Where effects were observed in spiked or amended samples, the level of effect was attributable to concentrations of a single constituent. A possible exception is when nitrate concentrations above 40 mg of NO₃-N mg/L and sulphate concentrations above 930 mg/L occur in combination (Golder and Nautilus 2013); however, these are well above target concentrations.

Based on this evaluation, mixture effects at target concentrations are considered unlikely. Uncertainties in potential mixture effects will be evaluated during Plan implementation through an ecotoxicology supporting study (see Chapter 10) and considered in adaptive management (see Chapter 11).

8.4.2.2 Upper Fording River (MU-1)

Based on the considerations outlined above, multiple-stressor effects in the mainstem of the upper Fording River would be driven primarily through interactions among the four Order constituents, since potential effects from physical stressors and changes to nutrient levels are expected to be minor. Lines of evidence that inform the evaluation of chemical stressors in the mainstem and associated off-channel areas are as follows:

- Nitrate and cadmium concentrations in mainstem areas are predicted to be below Level 1 benchmarks for all organisms (Annex H).
- Selenium concentrations are also predicted to be at or below Level 1 benchmarks in mainstem areas (Annex H).
- Level 1 benchmarks were defined based on 10% responses to sensitive organisms and life stages tested in the laboratory, which is a level expected to provide adequate protection against population-level responses in a multiple-stressor context (Mebane 2010).
- Sulphate concentrations may exceed Level 1 benchmarks for fish and amphibians in some portions of the upper Fording River in the long-term, although predicted concentrations remain below Level 2 benchmarks (Annex H).

- Sulphate predictions include an element of conservatism, as the Elk Valley Water Quality Model tends to overestimate sulphate concentrations (Annex D1).
- Presence or absence of amphibians is strongly linked to habitat characteristics, with a preference for shallow water, off-channel areas containing emergent vegetation (Minnow 2013). The majority of these areas are predicted to have lower sulphate concentrations, below Level 1 benchmarks.

Based on the above, the potential for multiple-stressor effects is considered unlikely. However, this conclusion is associated with residual uncertainty. Fish are the most sensitive receptor to selenium and sulphate. As concentrations of both constituents are close to (selenium) or over (sulphate) their respective Level 1 benchmarks, it is theoretically possible that response addition for these two constituents could yield a combined effect size of greater than 20%. Follow-up monitoring, additional toxicity testing with sulphate and adaptive management will, therefore, be used to address this residual uncertainty.

Mine-influenced tributaries in MU-1 can be placed into one of three groups with respect to potential multiple-stressor responses.

Group 1 includes tributaries where effects attributable to multiple stressors are likely. Porter Creek and Greenhills Creek fall in this category, based on predicted sulphate and selenium effects to fish. The predicted response sizes for both selenium (>20%) and sulphate (40%) exceed Level 2 benchmarks. These mine influenced tributaries also currently exhibit calcite formation at levels greater than reference conditions (Annex K), which may increase the potential for localized impairments.

Group 2 includes tributaries where effects attributable to multiple stressors are unlikely. In these tributaries, concentrations of all constituents are predicted to meet Level 1 benchmarks. Lower Henretta Creek and Dry Creek fall in this category.

Group 3 consist of intermediate tributaries where effects attributable to multiple stressors may occur. Kilmarnock Creek falls in this category, based on potential effects to invertebrates. There is no fish accessible habitat in Kilmarnock Creek; however, exceedances of Level 1 invertebrate benchmarks are predicted for both nitrate and selenium.

Together, Groups 1 and 3 represent <3% of the total available habitat in MU-1. Given the small size of these areas, they are not expected to contribute to multiple-stressor effects at the MU scale. Group 1 and 3 tributaries will be managed, as applicable, through local effects monitoring.

8.4.2.3 Lower Fording River (MU-2)

Similar to MU-1, multiple-stressor effects in the mainstem of the lower Fording River would be driven primarily through interactions among the four Order constituents, since potential effects from physical stressors and changes to nutrient levels are expected to minor. Lines of evidence that inform the evaluation of chemical stressors in the mainstem and associated off-channel areas are as follows:

- Sulphate and cadmium concentrations in mainstem areas are predicted to remain at or below WQGs, providing protection for all organisms including fish (Annex H).
- Nitrate concentrations in mainstem areas are predicted to remain below the Level 1 benchmarks for all organisms (Annex H), with effect sizes to fish being in the order of only a few percent (Annex H).
- Selenium concentrations are predicted to exceed Level 1 benchmarks for fish in most mainstem areas. The predicted level of response is 13% for reproduction of sensitive fish species. However, selenium concentrations are predicted to remain below Level 2 benchmarks for fish in all mainstem areas of MU-2 (Annex H).

- The predicted effect size for selenium requires evaluation of the potential for response addition to assess whether combined responses from selenium and other chemical stressors could exceed the 20% threshold for ecologically significant responses. Given that cadmium and sulphate are predicted to contribute a negligible response (because they are below WQGs) and nitrate effect sizes are small (as previously noted), combined effect sizes remain below 20%.

Based on the above, it is unlikely that effects from multiple stressors in MU-2 will be greater than those suggested by the constituent-specific evaluations outlined above.

Tributaries directly connected to the lower Fording River include Line Creek and various reference tributaries. Nitrate, cadmium and sulphate concentrations in Line Creek are predicted to be below Level 1 benchmarks (nitrate and cadmium) or WQGs (sulphate), with small potential effect sizes (e.g., 1% or less for nitrate – Annex H). Accordingly, potential effects attributable to selenium in the constituent-specific evaluation are expected to be representative of potential combined effects from multiple stressors, given that Line Creek will also be subject to calcite management due to its size.

8.4.2.4 Elk River (MU-3 and MU-4)

As in the Fording River, multiple-stressor effects in the mainstem of the Elk River would be driven primarily through interactions among the four Order constituents, since potential effects from physical stressors and changes to nutrient levels are expected to be minor or absent. However, predicted concentrations of selenium, nitrate, sulphate and cadmium are all expected to remain below Level 1 benchmarks, as outlined in Annex H. These results suggest a negligible potential for multiple-stressor effects in the Elk River mainstem and associated off-channel habitats.

Mine-influenced tributaries in the Elk River can be placed into one of two groups with respect to potential multiple-stressor responses.

Group 1 includes tributaries where effects attributable to multiple stressors are likely. Thompson, Erickson, EVO Dry and Wheeler creeks fall in this category. In these watercourses, concentrations of selenium and nitrate or sulphate are predicted to be elevated relative to Level 1 benchmarks (Annex H). Calcite formation is also occurring or may occur in the future. The four tributaries collectively contribute 14 ha of total habitat, which represents <3% of the available habitat in MU-3 and MU-4.

Group 2 includes tributaries where effects attributable to multiple stressors are unlikely. Carbon, Six Mile, Snowslide, Grace and Harmer creeks fall into this category. In Carbon, Six Mile and Snowslide creeks, predicted concentrations of the Order constituents are below Level 1 benchmarks. In Harmer and Grace creeks, selenium concentrations are predicted to exceed Level 1 benchmarks for fish; however, sulphate and cadmium concentrations are expected to remain below WQGs, and nitrate levels are predicted to remain below Level 1 benchmarks for fish, amphibians and the benthic community endpoint. Given their size, these watercourses would also be targeted for calcite management.

As previously noted, tributaries in Group 1 represent <3% of the total available habitat in MUs 3 and 4. Given the small size of these areas, they are not expected to contribute to multiple-stressor effects at the MU scale. Group 1 tributaries will be managed, as applicable, through local effects monitoring.

8.5 Initial Implementation Plan

An initial implementation plan was developed to meet short- and long-term water-quality targets at Order Stations for selenium, nitrate, sulphate and cadmium. Medium term targets were then identified based on the initial implementation plan to demonstrate progress from short to long term targets. AWTFs and diversions are identified as the technologies that can reliably and efficiently reduce concentrations of selenium and nitrate from mine sites (Chapter 6). Other options based on emerging technologies and management approaches will continue to be evaluated, with the intention of incorporating them through an adaptive management process when appropriate (Chapter 11).

The initial implementation plan was developed by evaluating a range of treatment and diversion options, identifying an efficient approach (generally, the least treatment required to achieve a concentration), and iterating until the targets were met at the Order stations. The sections that follow describe:

- the planning basis, i.e., the decisions and assumptions that are the foundation of the plan
- the Elk Valley Water Quality Planning Model (the Model), a regional, forward-looking planning model that predicts water quality in the Designated Area with or without the implementation of mitigation measures
- the iterative process used to ensure that plan meets targets at the Order stations.

In developing an initial implementation plan that mitigates the combined effects of all mines in the Elk Valley and incorporates existing water quality for areas not influenced by mining, the Plan addresses cumulative effects to water quality in the Elk Valley and Lake Koochanusa.

8.5.1 Planning Basis

The initial implementation plan was developed based on a set of decisions (e.g., what sources to target for treatment, where to evaluate diversions, and how quickly plants could be constructed) and assumptions (e.g., effluent quality from treatment plants, release rates, and collection efficiency). These constituted the basis on which the initial implementation plan was formed. They are reflected in the water-quality planning model and are subject to refinement over time, as described in Table 8-18.

Table 8-18. Planning basis, rationale and adaptive management considerations.

Input	Planning basis	Rationale	Adaptive management
Mine plan	EVWQP mine plans.	These represent most current understanding of the resource and how it will be mined.	Mine plans are updated periodically, and the implementation plan will also be updated periodically to accommodate changes.
Management options	AWTF and water management.	Based on current information, these can be relied upon to achieve the targets.	Other mitigation and source control options will continue to be evaluated, to reduce reliance on AWTFs in the long term where alternate options provide favourable outcomes.
Sources targeted for management, in sequence	LCO West Line Creek, GHO Swift, GHO Cataract, FRO Kilmarnock, EVO Bodie, EVO Gate, EVO Erickson, FRO Clode, FRO North Spoil, GHO Swift Pit, GHO West Spoil, GHO Greenhills Creek, LCO Dry Creek, LCO Line Creek. These will total ~80% of the waste rock in the valley in 2034.	By targeting the largest sources, water quality can be managed regionally and efficiently.	As mine plans are updated, the sources targeted will be evaluated and updated if required.
Timing of AWTFs	At a planning level, commission AWTFs two years apart.	Two-year spacing of AWTFs allows an efficient construction team, and some opportunity to learn from previous AWTFs.	Through monitoring of receiving water quality, effects, and what is achieved by the first two AWTFs, the timing of future AWTFs may be updated. As R&D measures are incorporated, the reliance on AWTFs may be reduced.
Phasing of AWTFs	Build individual AWTFs in more than one phase if total treated volume is >30,000 m ³ /day and the waste rock is not all in place when the first phase is required.	Makes efficient use of implementation teams, and offers the opportunity to learn from previous AWTFs and implement the most efficient technologies available.	Through monitoring of receiving water quality, effects, and what is achieved by the first two AWTFs, the timing of future AWTFs will be updated. As R&D measures are incorporated, the reliance on AWTFs may be reduced.
Clean water diversions and sizing	Upper Line, Main Line, Horseshoe, Kilmarnock, Brownie, Erickson, South Gate Creeks were included.	These sources may have a regional influence. The specific water management constructed will be evaluated with more site-specific data.	Detailed evaluation and design with a local-scale model during development planning for each watershed. May result in different diversions to achieve the targets.
Sizing of water management	Flows for May were assumed for diversions that have an influence in spring. LCO sized for low flows because influence is in winter.	Sized for May as an estimate for planning purposes; June is typically double the flow.	Detailed evaluation and design with a local-scale model during development planning for each watershed. May result in different diversions and sizes implemented.
Effluent quality – Selenium	Se = 20µg/L or 95% removal if influent is >500 µg/L	Planning basis for EVWQP is biological treatment.	Technologies will continue to be explored and evaluated in advance of each AWTF design.
Effluent quality – Nitrate	N = 0.3 mg/L of NO ₃ -N	Planning basis for EVWQP is biological treatment.	Technologies will continue to be explored and evaluated in advance of each AWTF design.

Input	Planning basis	Rationale	Adaptive management
Effluent quality – Phosphorus	P = 0.1 mg/L, except for the West Line Creek AWTF where P = 0.3 mg/L	Planning basis for EVWQP is biological treatment (same as LCO WLC). Subsequent plants incorporate additional phosphorus removal.	Technologies will continue to be explored and evaluated in advance of AWTF design. The phosphorus limits of the system will continue to be evaluated and will be considered for treatment technology selection for each AWTF.
Effluent quality – Sulphate and Cadmium	Removal of cadmium and sulphate is not currently required to meet long-term water-quality targets	Current concentrations and expected trends are below long-term targets without mitigation.	AWT technologies that remove cadmium and sulphate are being evaluated and piloted and could be used for future AWTFs, if required.
% of time treatment plants operational	Assumed operational 100% of the time to develop the initial implementation plan treatment capacities	Treatment facilities will be designed to meet the required removal of CIs to achieve the water-quality targets of the Plan. This will be part of the design process for each individual treatment facility. As an example the WLC Se AWTF, although intended to be operational 100% of the time, has been designed so that it can be operational 95% of the time and still achieve the selenium and nitrate load reduction targets for the facility.	Based on lessons learned through the implementation and operation of treatment facilities, and as new treatment technology becomes available, facility up-time will be re-evaluated and fed into the adaptive management process to achieve the water-quality targets of the Plan.
Collection (intake) efficiency	FRO North Spoil, Kilmarnock 70% GHO Greenhills Creek 70% FRO Clode Creek, Swift/Cataract 80% EVO Erickson Creek 90% GHO West Spoil, LCO WLC and Main Line Creek, EVO Bodie, Gate Creeks, Pit dewatering 95% LCO Dry Creek consistent with EAC commitment	The amount of water available to capture and treat is site-specific. These estimates reflect best engineering judgement based on knowledge of site conditions.	Site specific investigations in advance of design will be conducted and estimates of water available will be updated.
Modelled flow conditions	All scenarios are run under monthly low, average and high flow conditions.	The plan is intended to meet the target under a range of flow conditions. Without treatment, the limiting flow condition is low flows. As more treatment is added to the system, the limiting flow condition is high flows.	Modelled flow conditions will continue to be updated based on monitoring data.
Geochemical release rates	Average release rates used for planning purposes.	These reflect a best engineering judgement. The 95% confidence limit on the mean rate is also used to understand sensitivity to release rates.	Geochemical release rates will continue to be updated with current monitoring information. Detailed local scale models will be developed and data collected to support them as required.

8.5.2 The Elk Valley Water Quality Planning Model

The Model is a regional planning and assessment tool that estimates concentrations of selenium, nitrate, sulphate, hardness and phosphorus. It was calibrated and refined using historical information (Annex D.1).

The Model's performance is gauged by how well it simulates historical conditions, with a focus on Order stations on the Fording and Elk rivers. It was not designed, nor is it suitable, for predicting concentrations of constituents at the individual catchment scale. To support mitigation evaluation and/or design efforts in specific catchments, Teck will develop appropriate catchment-scale water balance and water-quality models.

The Model reflects the current understanding of regional hydrology and release rates of selenium, sulphate and nitrate from waste rock, based on the conceptual model below (Figure 8-3).

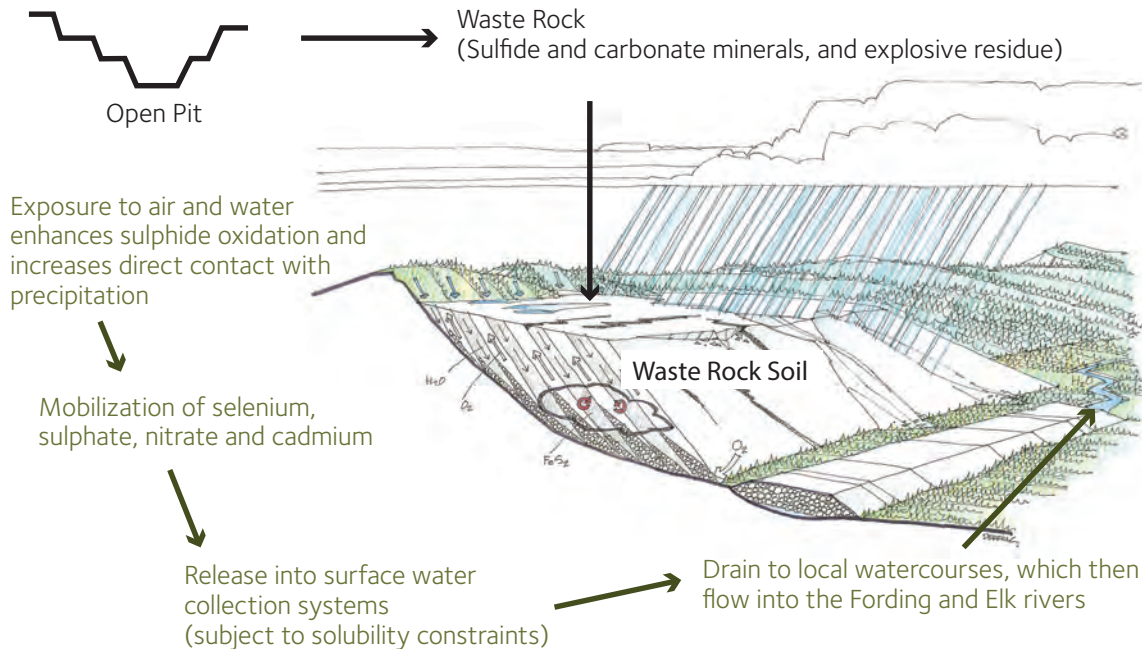


Figure 8-3. Conceptual model of selenium, sulphate, cadmium and nitrate release and transport.

The main model inputs are:

- the EVWQP mine plan (described in Annex D.5: Site Conditions Report), primarily waste-rock schedules for each drainage and minesite topography
- geochemical release rates for selenium, sulphate, and nitrate, based on observed water quality and historical waste-rock volumes
- regional surface water flows based on monitored data where available, or a flow model based on analog hydrographs.

As with any model, input assumptions and predictions of future conditions have uncertainty, which was considered by measuring model error (the average absolute difference observed between individual simulated and measured data points over the entire calibration period) and bias (the average difference observed between the individual simulated and measured data points over the entire calibration period).

The Model exhibits a positive bias, meaning that it tends to over-predict measured concentrations. From a planning perspective, this bias was deemed problematic only for predicted selenium concentrations in Lake

Koocanusa (LK2). Because there are limited data at LK2 to correct for bias, the station immediately upstream (ER5) was used. The average over-prediction at ER5 is 1 µg/L, which if not corrected would falsely generate long-term concentrations above the long-term target. To correct for bias, loads at ER5 were reduced by the amount of bias in each month before the mass balance is calculated in the lake. Bias correction at LK2 allows the model to more accurately reflect expected concentrations. Bias was not corrected at other Order stations. See Annex D.5 for details.

During implementation, Teck will compare water-quality and flow-monitoring data to model predictions to check the calibration and update it if necessary. Improvements in geochemical and hydrologic inputs will be used to update the model as discussed in Chapter 11. New site-specific tools will be developed to support evaluation and design of mitigation measures, such as AWTFs and water management.

8.5.3 Development of the initial implementation plan

As discussed in Chapter 6, the initial implementation plan consists of AWTFs supported by diversions and water management (conveyance of mine influenced water to treatment plants). The many possible combinations of treatment and diversions at various locations at different times resulted in an iterative approach to developing the initial implementation plan.

Even with a good understanding of the sources of constituents in the Elk Valley and a focus on AWTFs and diversions, the possible combinations of options are very numerous. It is important that the plan be efficient in achieving water-quality targets at the Order stations (i.e., generally with the least amount of treatment). Teck used the following planning strategies to guide the development of the initial implementation plan:

- Focus on treating constituents that are currently above guideline (Se, N), and determine near-term actions based on monitoring data (i.e., in-stream concentrations are currently above guidelines, waste rock is already in place).
- Select the location of the next AWTF according to current receiving environment concentrations relative to targets and waste-rock volume in place.

The optimal AWTF will receive sufficient flow to run at full capacity all year. If this is insufficient to achieve targets, then add capacity at the highest concentration sources. During implementation, AWTF capacities will be refined during design and permitting, through more detailed local hydrological analysis and geochemistry.

The tasks in this process are described in more detail herein. Additional information is provided in Annex D2: Water Quality Modelling for the initial implementation plan.

8.5.3.1 Task 1 – Select From Available Management Options

A wide range of management options were evaluated as described in Chapter 6, to determine which would be incorporated into the initial implementation plan. From that evaluative process, three options were identified to examine in detail (geomembrane covers, diversions, water treatment), and AWTFs and diversions were deemed suitable for developing the initial implementation plan.

8.5.3.2 Task 2 – Determine Sequence and Timing of Treatment

The sequencing of AWTFs was determined by location in the watershed (mitigation upstream in the system benefits all downstream management units) and the volume of waste rock. The Upper Fording River was selected as the next treatment site after West Line Creek, because this is where the highest concentrations of selenium and nitrate occur relative to long-term targets, and treatment in the most-upstream MU benefits all areas downstream. Second, sources were targeted for treatment in order of waste-rock volume, given the correlation between volume and water quality (Figure 8-4).

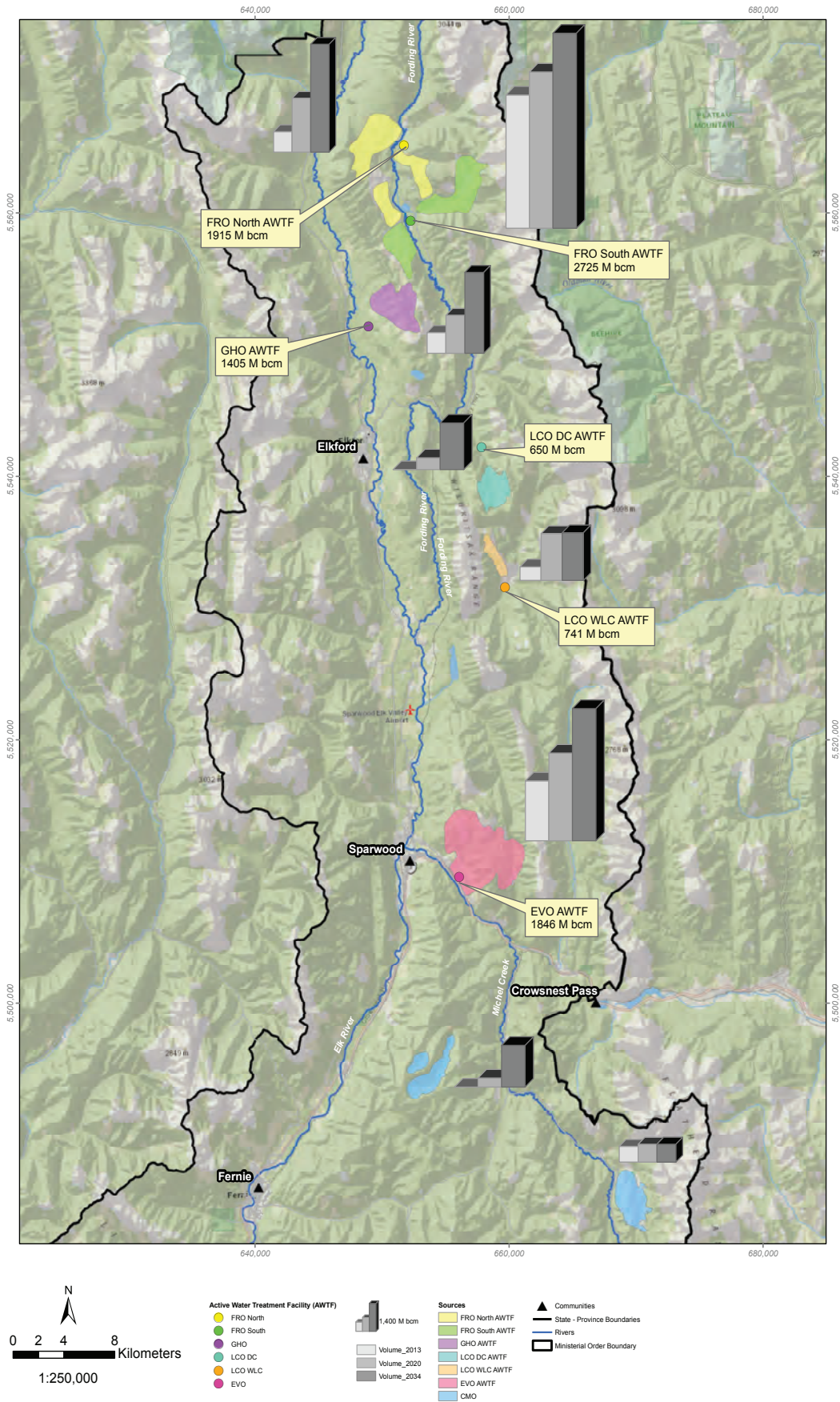


Figure 8-4. Volumes and timing of waste rock at each operation.

8.5.3.3 Task 3 – Estimate Treatment Required

As planning progressed, results were used to develop a relationship between total treatment volume and in-stream concentration. This relationship was then used to estimate the treatment required in different parts of the system to achieve the targets at the Order stations. Figure 8-5 is an example of the relationship for the Fording River downstream of Greenhills Creek (FR4). Relationships at other stations and hydrographs for other AWTFs are provided in Annex D2: Water Quality Modelling for the initial implementation plan.

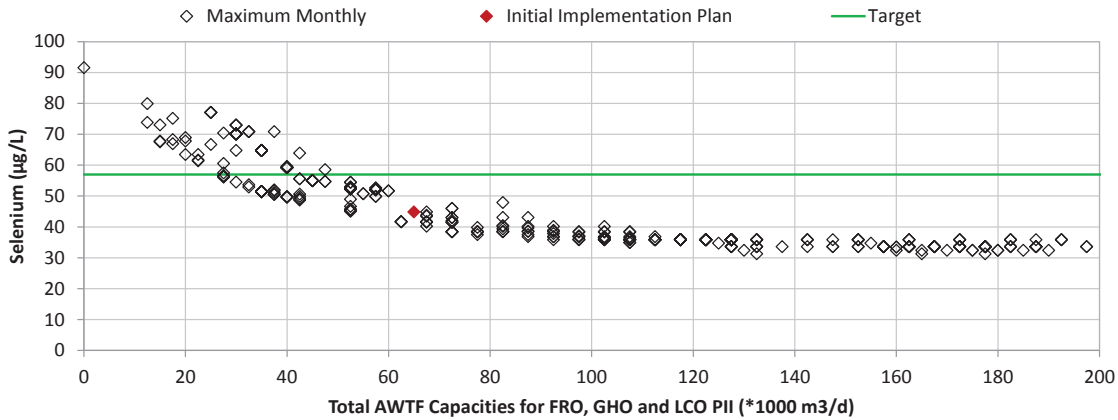


Figure 8-5. Example relationship between treated volume and selenium concentration at the Fording River downstream of Greenhills Creek (FR4).

As treatment volume increases, there is decreasing influence on selenium removed because additional capacity will be utilized only for a few months of the year (Figure 8-6).

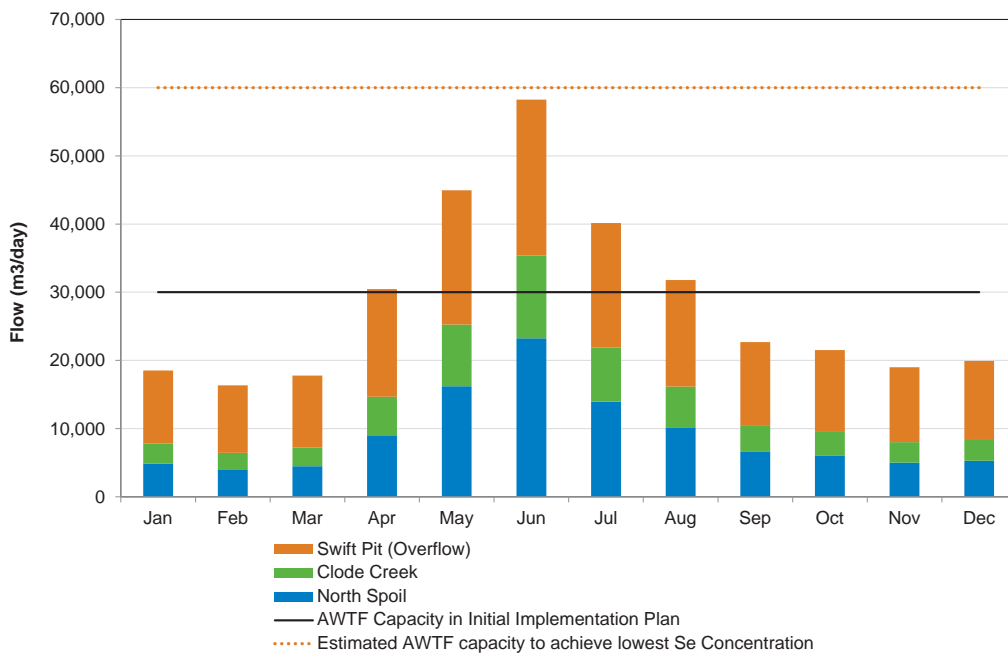


Figure 8-6. Modelled hydrograph of available inflows for an AWTF in the upper Fording River.

8.5.3.4 Task 4 – Allocate Treatment Capacity by Location

A relationship between treatment volume and selenium removed was established for each potential AWTF. This relationship was primarily driven by waste-rock volume and the hydrograph that represents flow available for treatment. By inspecting the relationship at each AWT facility, capacity can be allocated to the location where it has the most impact. Figure 8-7 presents an example. Relationships at other stations are provided in Annex D2: Water Quality Modelling for the initial implementation plan.

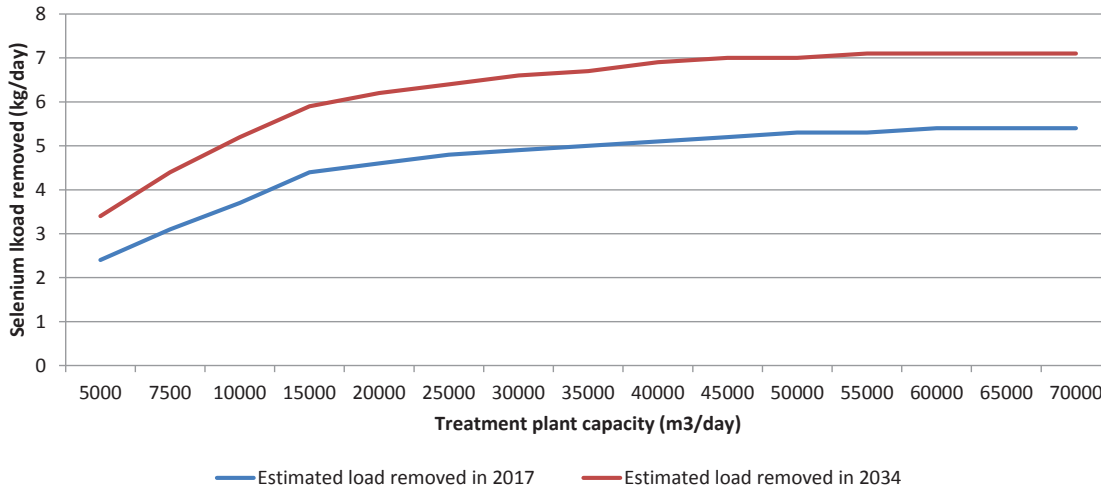


Figure 8-7. Relationship between active water treatment volume and selenium load removed at FRO South.

From these two primary relationships, the treatment volume at each location was estimated and used as inputs to the water-quality model, until targets were met at the Order stations and the initial implementation plan was defined. In practice, this meant estimating total treatment volume to meet each target at each location, and distributing capacity based on the relationship between volume and load removed.

8.5.3.5 Task 5 – Compare Results to Targets

Through the development process, two patterns emerged: the limiting constituent is selenium, and the limiting locations are FR4 and FR5, ER2, MC1 and LK2. The mouth of Michel Creek (MC1) is not an Order station, but was evaluated to define an initial implementation plan. The approach was to work from upstream to downstream, estimating the treatment volume required to achieve the following goals:

- Meet the target at FR4 (MU-1) by adjusting the treatment volume upstream.
- Attempt to meet the initial target at FR5 (MU-2), which is lower than MU-1 because it is downstream of Josephine Falls and more fish species may be present. Based on the current planning basis plus extending treatment to other sources, the Level 1 benchmark for selenium is not technically achievable, as discussed below. The target for FR5 still protects aquatic life in MU-2 based on the results of the integrated assessment (see Section 8.3).
- Meet the Level 1 benchmark at MC1, by adjusting EVO treatment volume. An evaluation of treatment opportunities at CMO Phase 2 determined that it is more efficient to increase treatment at EVO.
- Meet the long-term target at LK2 by adding treatment at the most efficient locations, based on the relationship between treatment volume and selenium removed.

The relationship between treatment volume and maximum monthly concentrations under high flows at FR5 (Figure 8-8) indicates that the Level 1 benchmark is not achievable for MU-2. The selected target of 40 µg/L is protective and achievable. To achieve a lower selenium target concentration would require approximately double the treatment capacity upstream, with a corresponding small change in the margin of safety for

protection of aquatic life. A doubling of treatment capacity would require a change from biological to membrane technologies, because biological plants are not suited to running well below capacity for sustained periods. Risks and uncertainties associated with membrane technology are discussed in Chapter 6.

The next two planned AWTFs are independent of the target at FR5. The next plant in the implementation plan (FRO-S) is being constructed as quickly and on as large a scale as reasonable. The next plant at EVO is downstream of FR5. Through the Regional Aquatic Effects Monitoring Program, the MU will continue to be monitored and information gathered to confirm the level of protection.

At all stations except FR5, the Level 1 benchmark is achieved by the initial implementation plan.

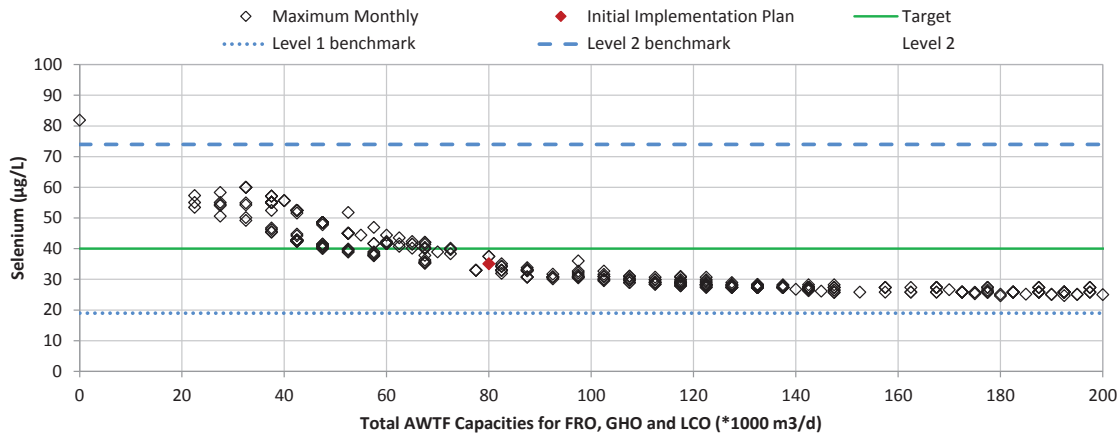


Figure 8-8. Relationship between treated volume and selenium concentration at the Fording River at the Mouth (FR5).

8.5.3.6 Task 6 – initial implementation plan

The initial implementation plan allows Teck to meet the targets established in the Plan. It is summarized in Table 8-19, which lists the sources targeted for treatment and the estimated year and quarter for each treatment project.

Table 8-19. Initial implementation plan

Sources targeted for treatment	Year	Total water volume treated ¹ (m ³ /day)	Associated diversions (to be evaluated during detailed design) ¹	Associated conveyance of mine- influenced water (to be evaluated during detailed design)	AWTF Name
West Line Creek	Q2 2014	7 500		Convey Line Creek to the AWTF. Discharge to Line Creek.	LCO West Line Creek (Phase 1)
Swift, Cataract and Kilmarnock creeks	2018	20 000	Diversion of Upper Brownie and Kilmarnock watersheds, estimated at 45 000 m ³ /day	Convey Swift, and Cataract and the mine influenced portion of Kilmarnock to the AWTF. Discharge to the Fording River.	FRO South
Bodie, Gate and Erickson creeks	2020	30 000	Diversion of Upper Erickson watershed, estimated 14 000 m ³ /day and South Gate Creek, estimated 3 500 m ³ /day.	Convey mine influenced water from Erickson to the AWTF. Discharge to Erickson Creek.	EVO (Phase 1)
Clode creek, North spoil and Swift Pit	2022	15 000		Convey mine influenced water to the AWTF. Discharge to the Fording River	FRO North (Phase 1)
EVO Erickson	2024	20 000		Convey mine influenced water from Erickson to the AWTF. Discharge to Erickson Creek.	EVO (Phase 2)
GHO West Spoil (Thompson, Leask and Wolfram creeks), Greenhills Creek	2026	7 500		Convey mine influenced water to the AWTF. Discharge to Thompson Creek.	GHO
LCO Dry Creek	2028	7 500		Conveyance of bypass water and treated effluent to the Fording River.	LCO Dry Creek
FRO Swift pit	2030	15 000		Convey mine influenced water to the AWTF. Discharge to the Fording River.	FRO North (Phase 2)
Line Creek	2032	7 500	Diversion of Upper Line Creek, Horseshoe and No Name Creeks, estimated at 35 000 m ³ /day.	Convey mine influenced portion of Line Creek to the AWTF. Discharge to Line Creek.	LCO West Line Creek (Phase 2)

Note¹: AWTF and Diversion sizes are estimated for planning purposes. These sizes will be refined based on site specific information developed during detailed design. Based on preliminary evaluation, Brownie, Kilmarnock and Line Creek diversions have a measurable influence on treatment plant efficiency and they others do not. Diversions are planned to be operational at the same time as the associated AWTF.

The Model predicts a range of future water-quality concentrations at each Order station when the initial implementation plan has been implemented. The Model produces results on a monthly basis, and the annual range of predictions is defined by seasonal (monthly) variability, and by running the model under low, average and high flow conditions for each month.

Time-series graphs of predicted selenium concentrations (Figure 8-9) and nitrate concentrations (Figure 8-10) are shown for an Order station in each MU. The graphs plot the maximum monthly and average annual concentration for each year simulated.

The general pattern is for concentrations to gradually increase until sufficient mitigation is in place upstream to stabilize and reverse the trends, and then achieve concentrations that are below long-term water-quality targets. The timeframes for stabilizing water-quality trends and meeting long-term targets varies for each Order station, depending on its location relative to mitigation measures, and to the timing of such measures.

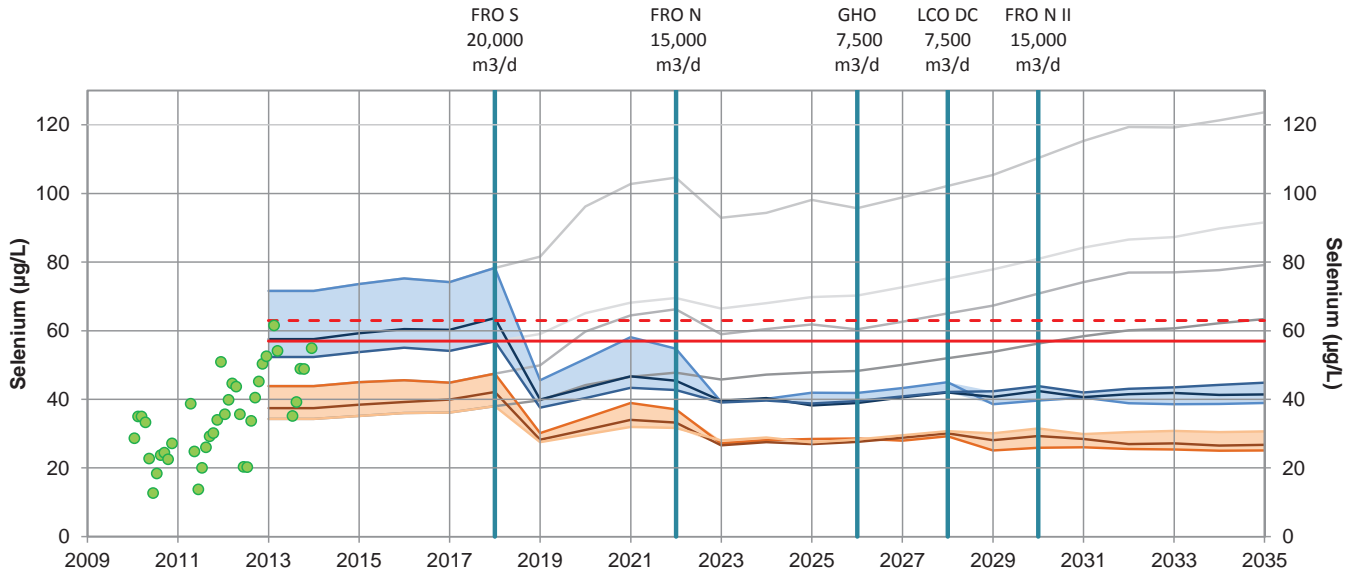
The initial implementation plan defines the timeframes for achieving short-term stabilization and long-term concentrations.

The water quality modelling results are presented as time series plots and, for context, include historical observations (green points) and commissioning dates (vertical lines) for the active water treatment facilities according to the initial implementation plan. Long term and short term targets, or level 1 and level 2 benchmarks as appropriate, are included for reference. The blue band indicates the predicted envelope of maximum monthly average concentrations under low, average or high flows. The orange band indicates the predicted envelope of annual average concentrations under the same range of flows. Grey lines are the predictions without mitigation.

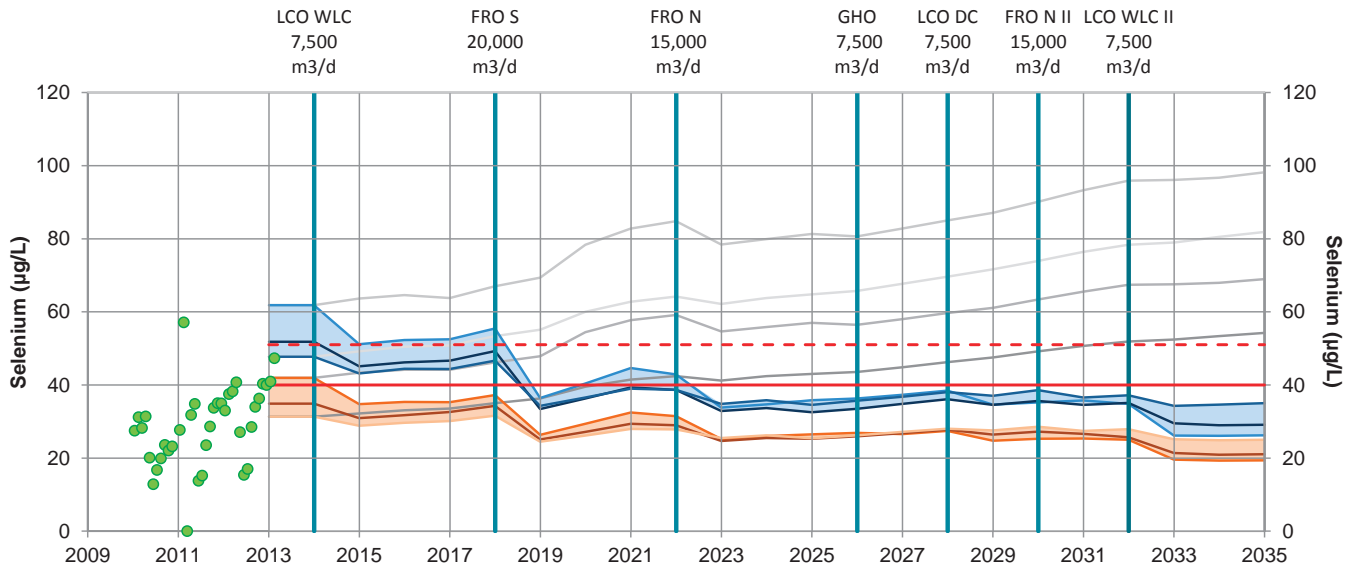
The legend below applies to all time series plots in this chapter.

- Predicted Maximum Monthly Concentration Under Low Flow Conditions without Mitigation
- Predicted Maximum Monthly Concentration Under High Flow Conditions without Mitigation
- Predicted Annual Average Concentration Under High Flow Conditions without Mitigation
- Predicted Annual Average Concentration Under Low Flow Conditions without Mitigation
- Predicted Maximum Monthly Concentration Under Low Flow Conditions and Initial Implementation Plan
- Predicted Maximum Monthly Concentration Under Average Flow Conditions and Initial Implementation Plan
- Predicted Maximum Monthly Concentration Under High Flow Conditions and Initial Implementation Plan
- Predicted Annual Average Concentration Under Low Flow Conditions and Initial Implementation Plan
- Predicted Annual Average Concentration Under Average Flow Conditions and Initial Implementation Plan
- Predicted Annual Average Concentration Under High Flow Conditions and Initial Implementation Plan
- Observed
- Long-term Target
- - - Short-term Target

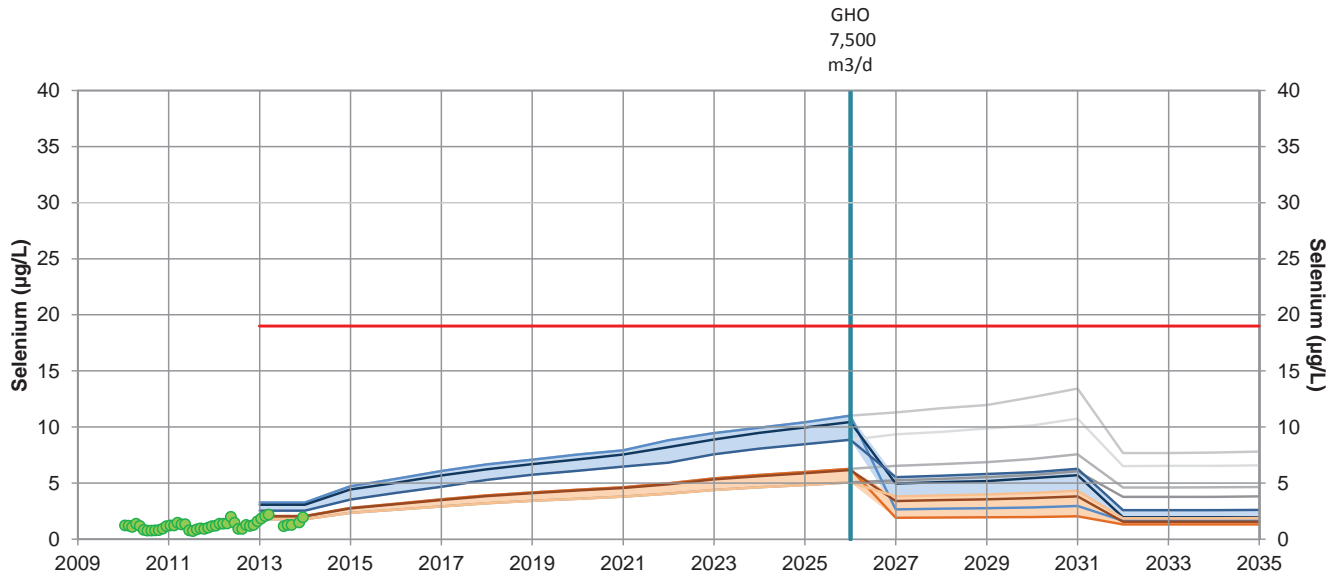
a. Fording River downstream of Greenhills Creek (FR4):



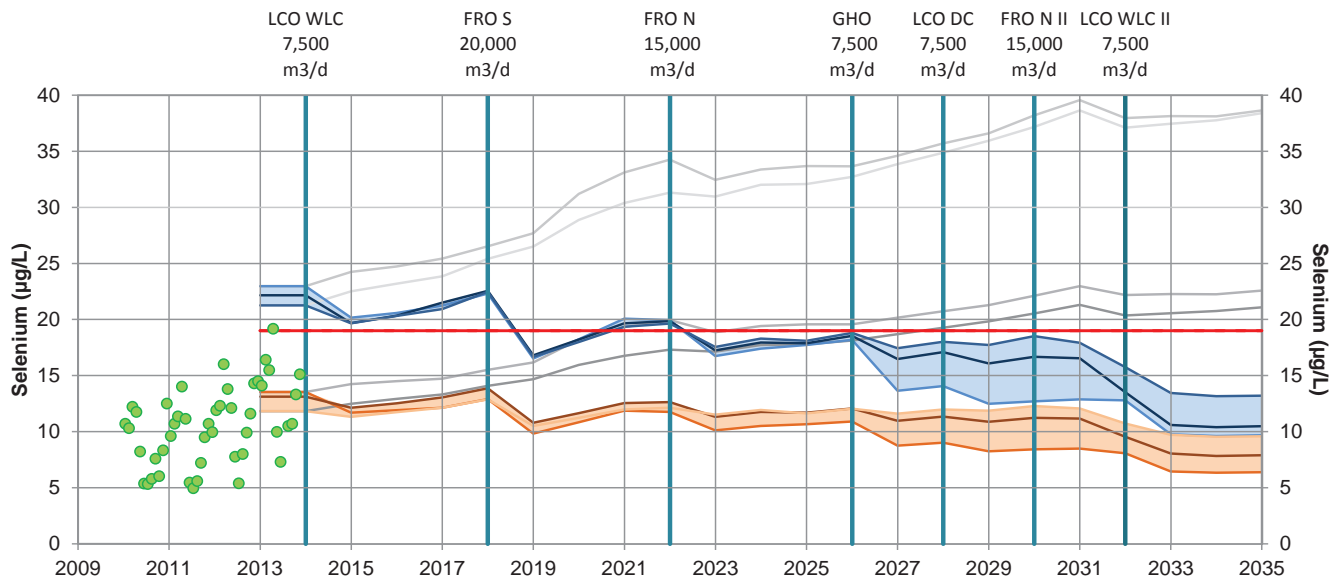
b. Fording River at the Mouth (FR5):



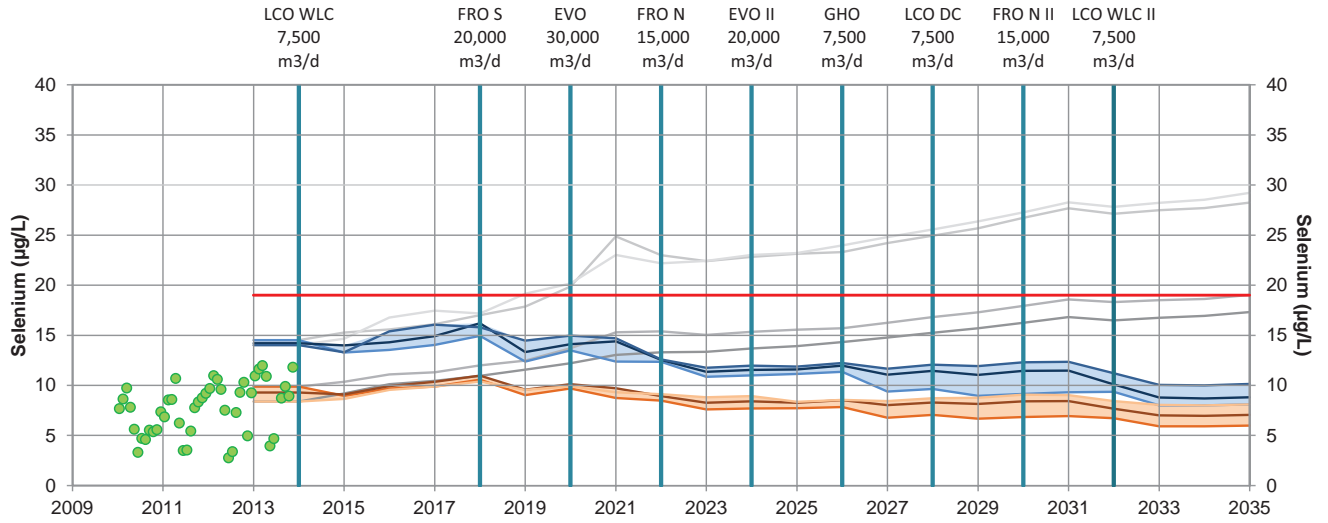
c. Elk River downstream of GHO and upstream of Fording River (ER1):



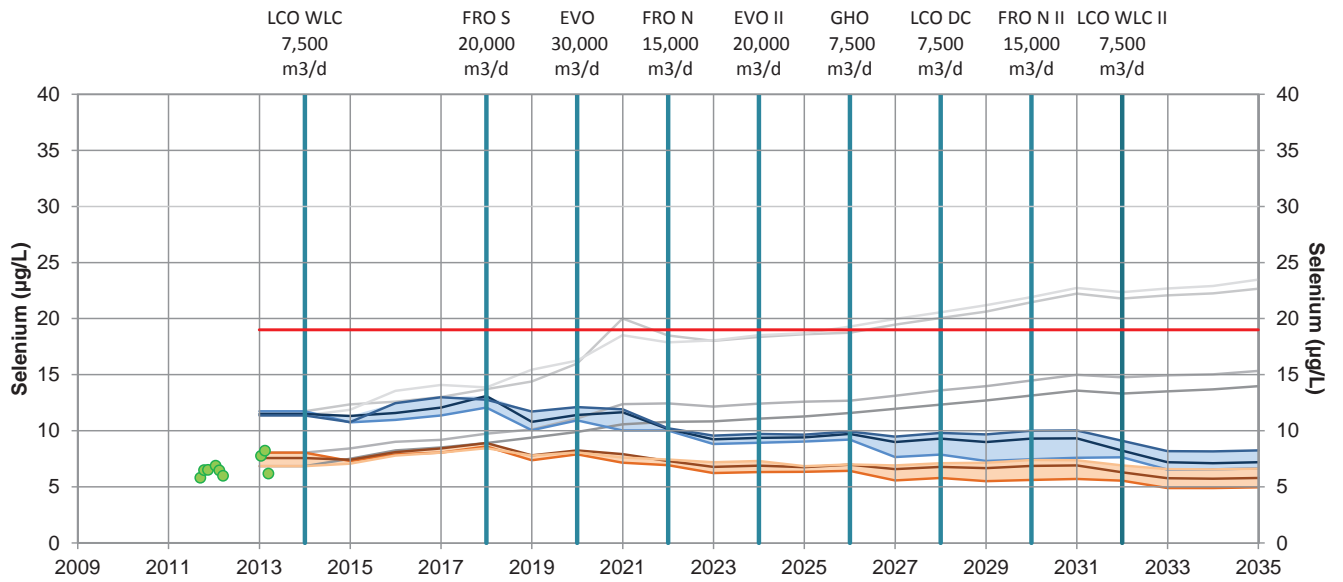
d. Elk River downstream of the Fording River (ER2):



e. Elk River downstream of Michel Creek (ER3):



f. Elko Reservoir (ER4):



g. Lake Koocanusa (LK2)

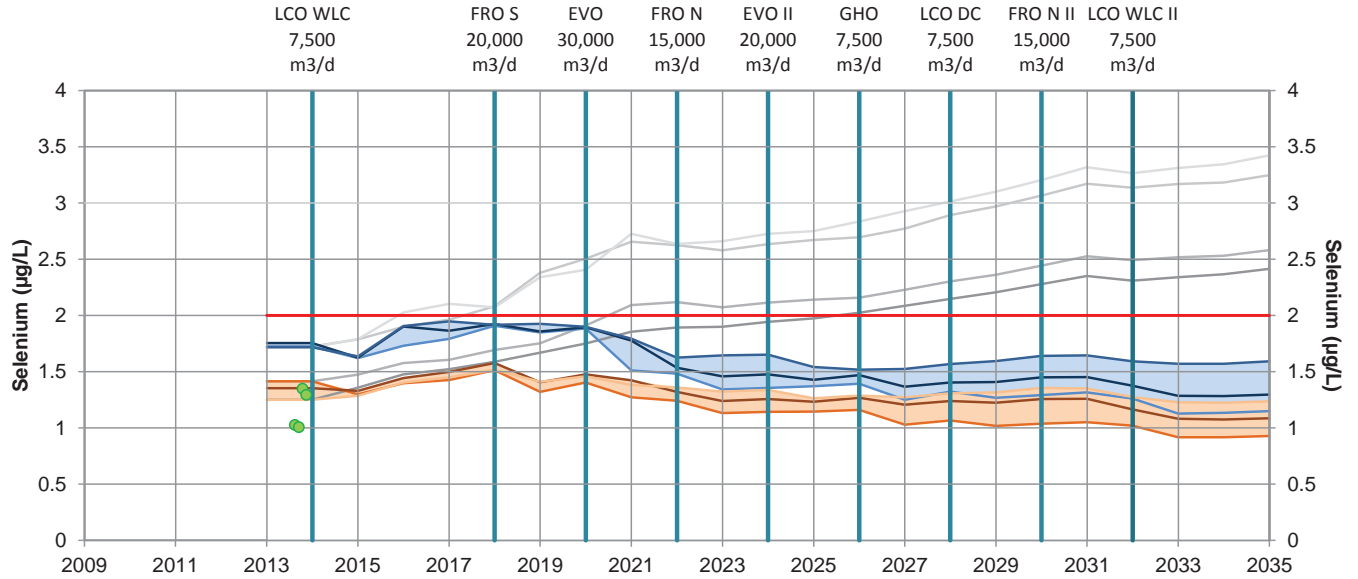
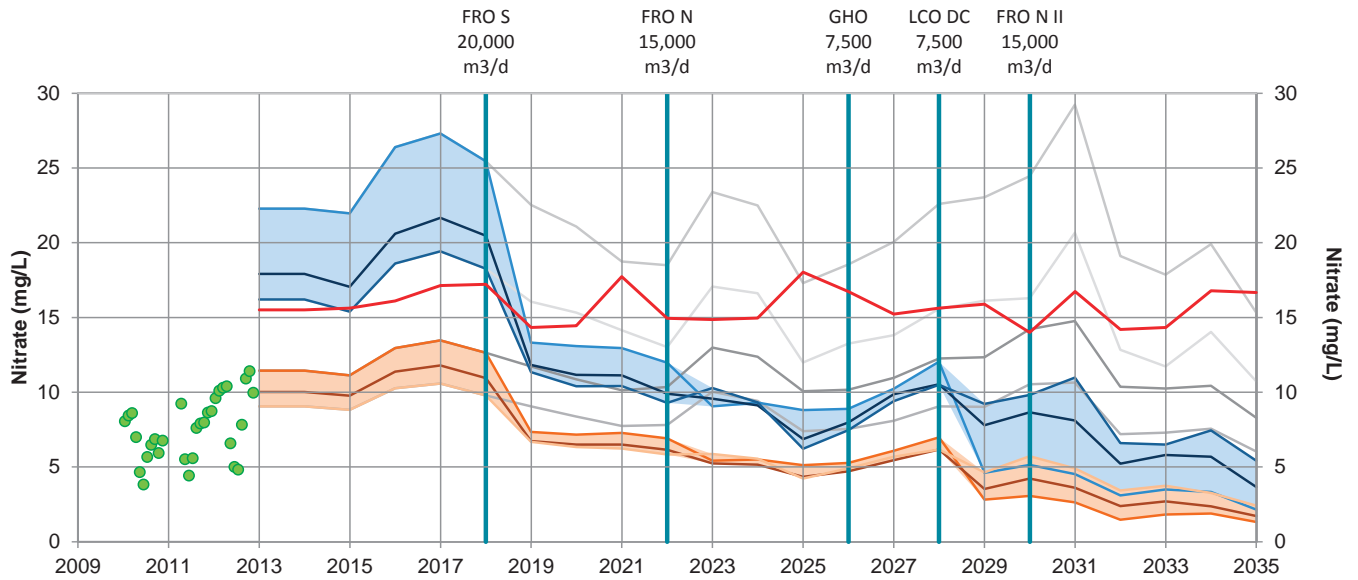
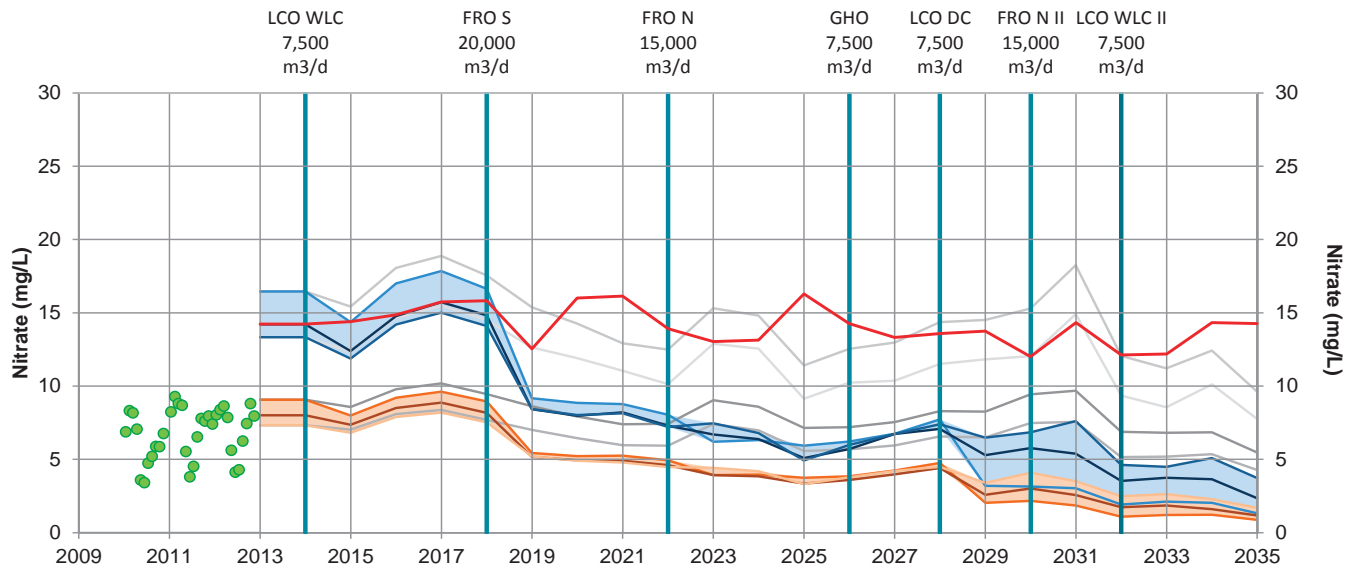


Figure 8-9. Selenium concentration projections at Order stations.

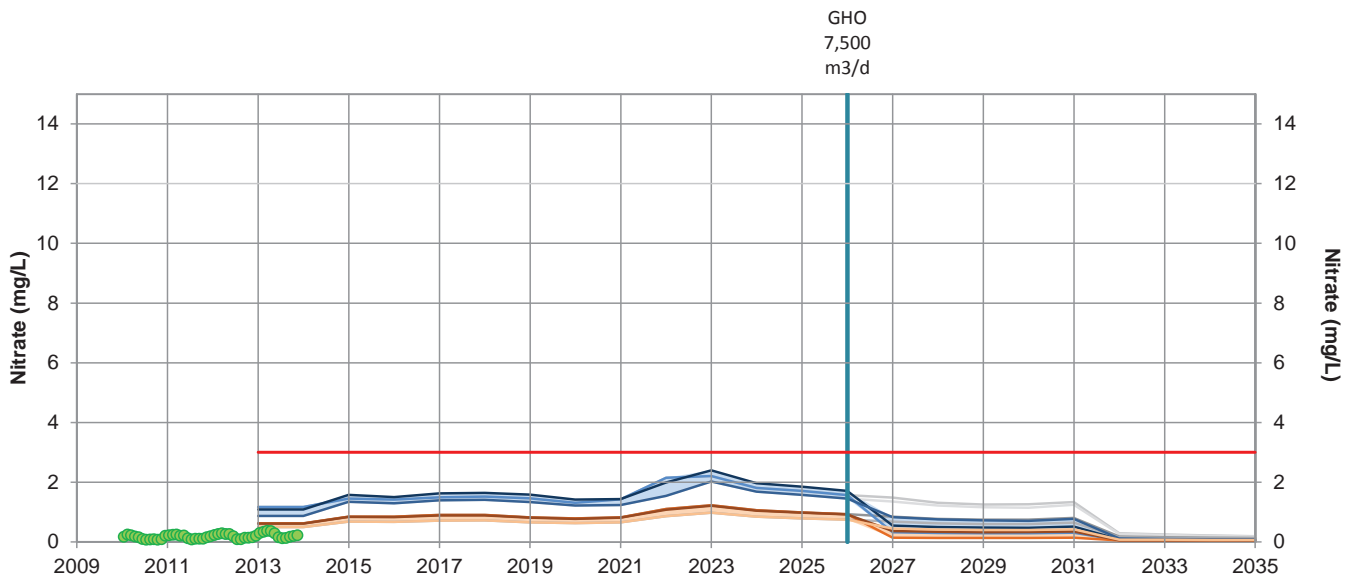
a. Fording River downstream of Greenhills Creek (FR4):



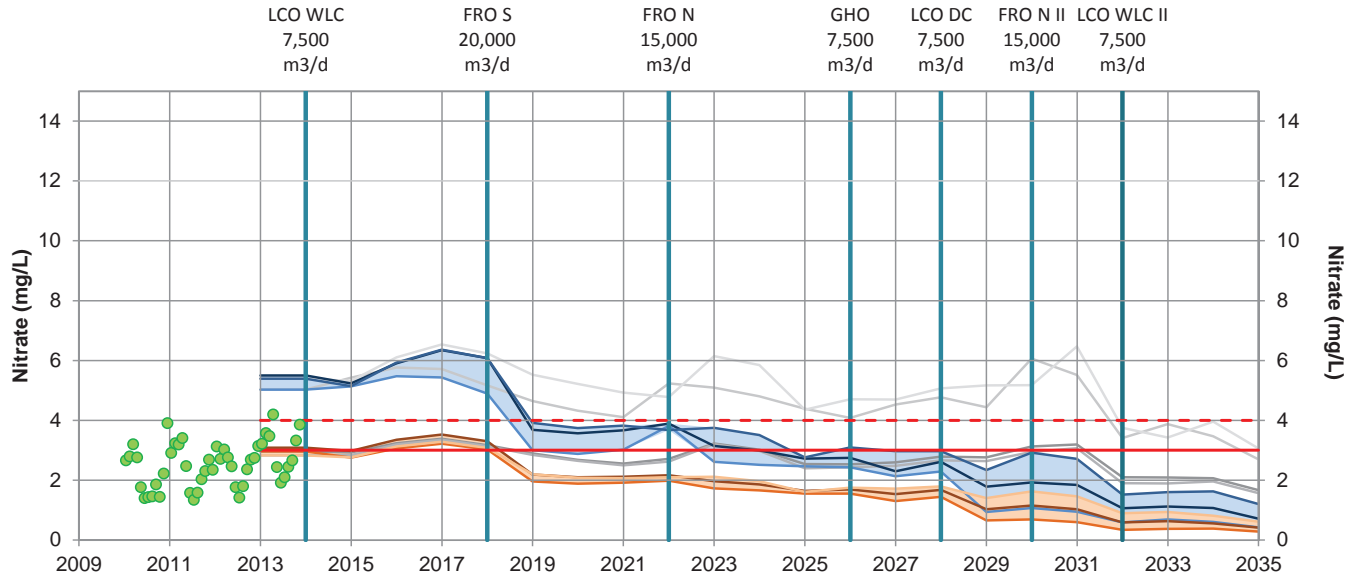
b. Fording River at the mouth (FR5):



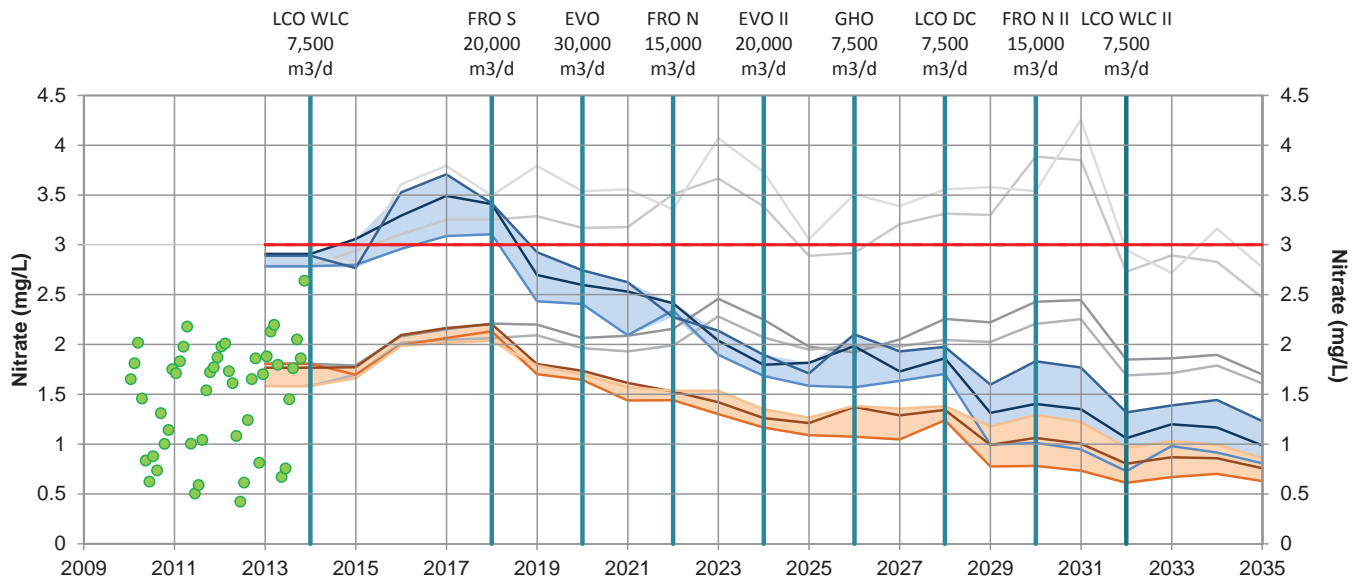
c. Elk River downstream of GHO and upstream of Fording River (ER1):



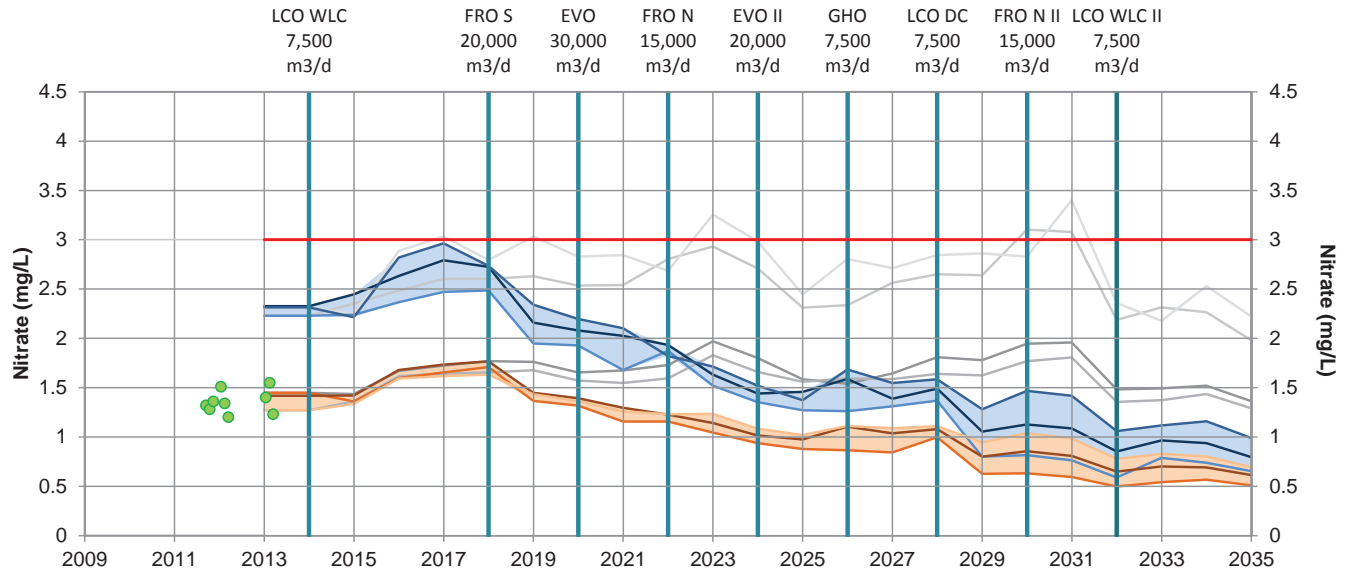
d. Elk River downstream of the Fording River (ER2):



e. Elk River downstream of Michel Creek (ER3):



f. Elko Resvoir (ER4):



g. Lake Koocanusa (LK2):

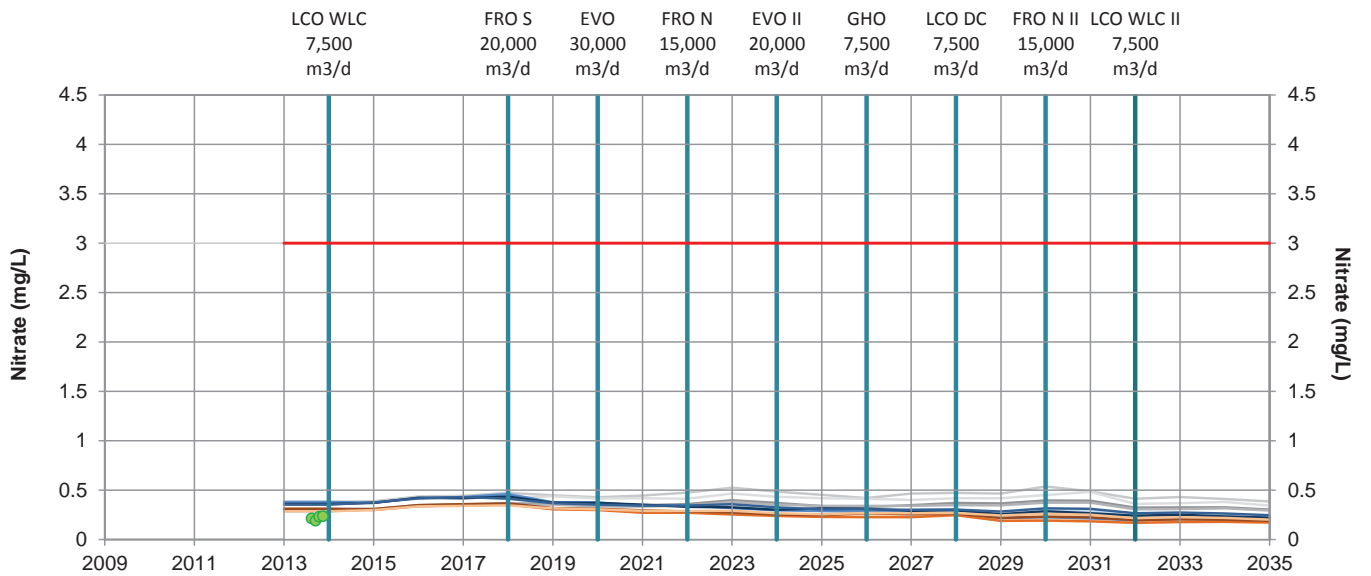


Figure 8-10. Nitrate concentration projections at selected Order stations.

The seasonal pattern of selenium levels is shown in Figure 8-11. The same pattern applies to nitrate. Without treatment, concentrations are highest in the winter low-flow period and lowest in June during the spring freshet. This pattern gradually changes with the progressive implementation of water treatment, which operates at fixed hydraulic capacity and can treat a greater proportion of the flow during low-flow periods than during the freshet. The initial implementation plan includes capacities high enough to treat much of the mine-influenced water during low-flow months. As a result, maximum concentrations become more consistent through the year, and the month with the highest concentrations may shift to a higher-flow month. When results in Figure 8-11 are reviewed over time and spatially, the flow condition and the month with the highest concentration vary with the volume of upstream water treated.

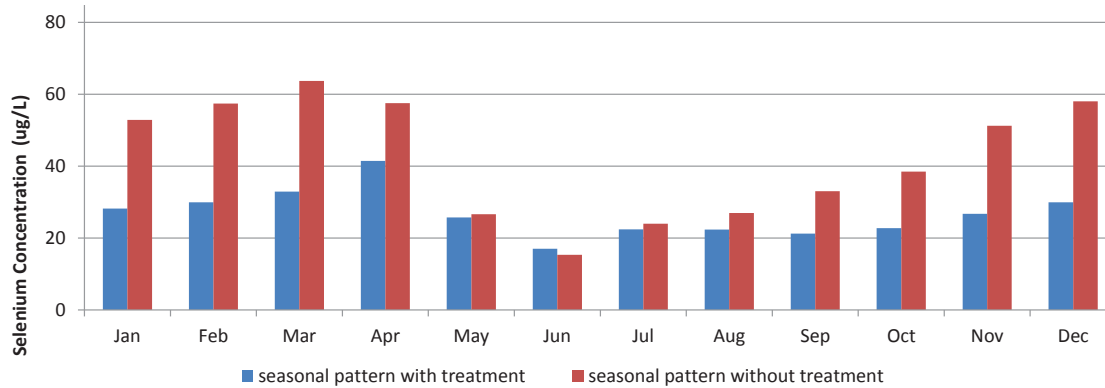
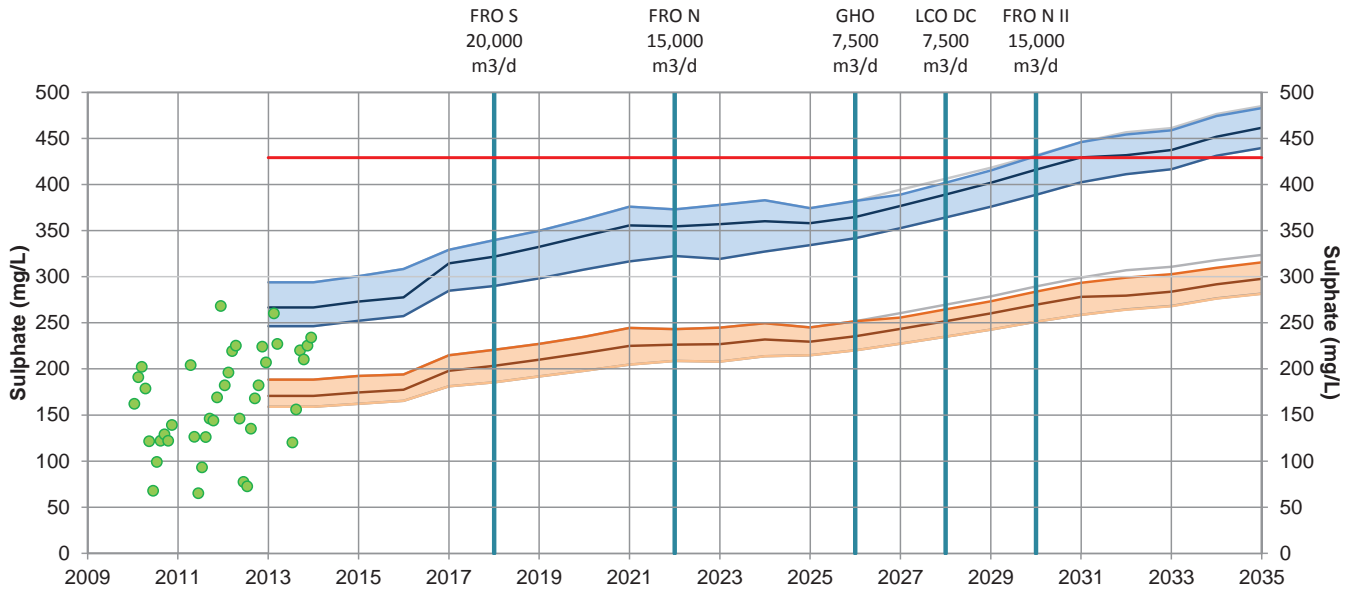


Figure 8-11. Example of monthly concentrations with and without treatment (FR4, untreated in 2017 and treated in 2034).

Sulphate concentrations are projected to remain within long-term targets throughout the system, except at FR4 late in the planning period (Figure 8-12, showing highest-concentration Order stations in the Elk and Fording Rivers). Sulphate is currently below guideline at the Order stations, and projections indicate it will remain below targets until 2030. The integrated assessment indicates that the concentrations will remain protective of aquatic life at least until 2030, and additional toxicity testing at high hardness is planned to support the finalization of the target. The model tends to overpredict sulphate concentrations, and the technology that treats for sulphate has challenges associated with it (Chapter 6). If mitigation were required for sulphate, it would be considered for the FRO-North plant (currently planned for 2021) and initial predictions are that with 100 mg/L effluent concentrations, sulphate concentrations would remain below the target (Figure 8-13).

Cadmium was not modelled, but current concentrations are within targets and are expected to remain so (Chapter 4). Cadmium trends will continue to be monitored and adaptively managed during plan implementation. Technologies that remove these constituents will be evaluated and implemented if required.

a. Fording River downstream of Greenhills Creek (FR4):



b. Elk River downstream of Fording River (ER2):

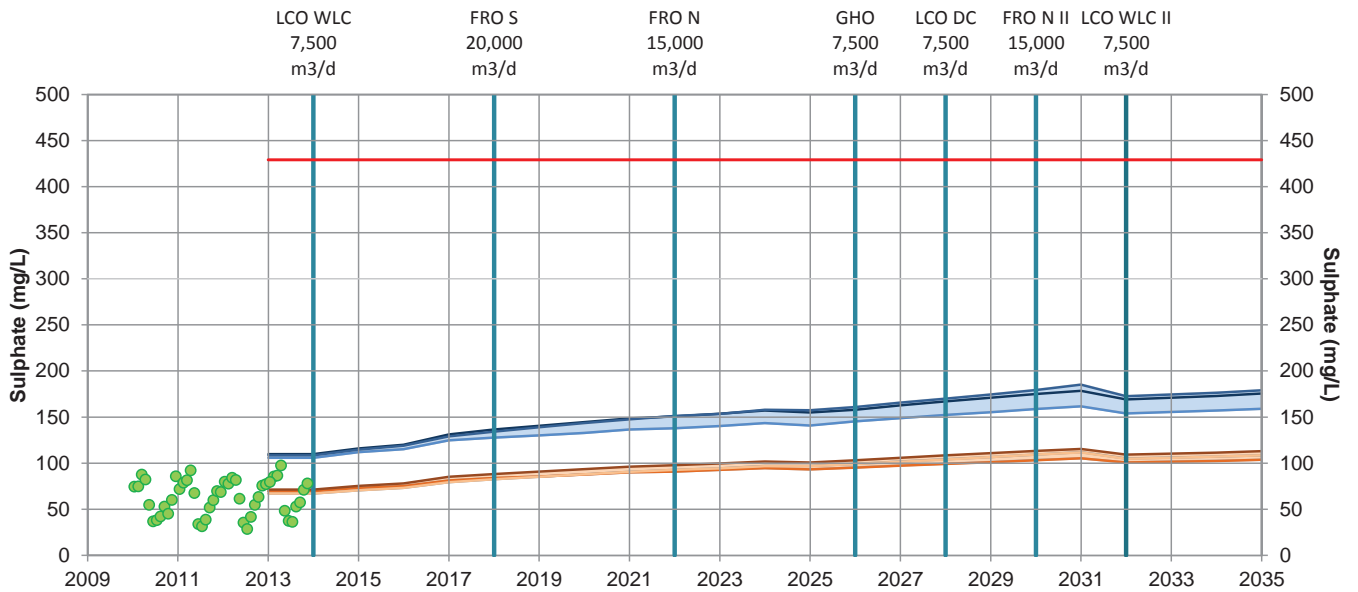


Figure 8-12. Sulphate concentration projections at Order stations FR4 and ER2.

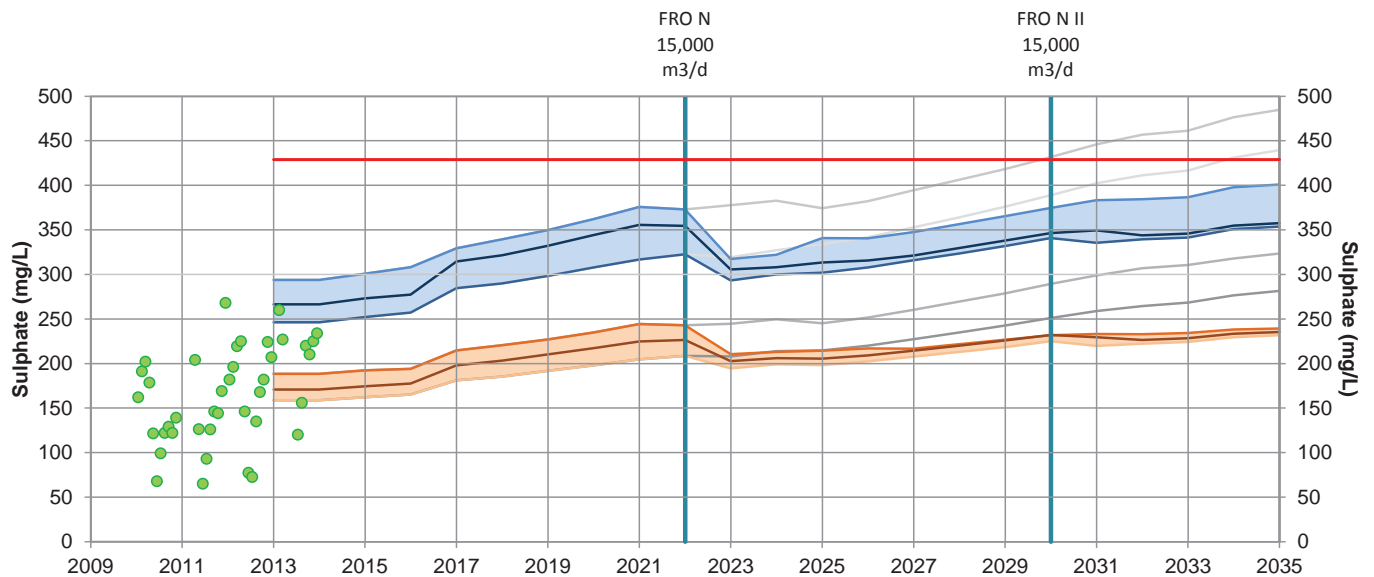


Figure 8-13. Sulphate concentration projections at Order station FR4, with treatment for sulphate.

8.6 Short- and Medium-Term Targets

The first step toward achieving environmental management objectives and outcomes for the Designated Area is the establishment of short-term concentration targets and timeframes. Short-term targets are not required where current (2013) concentrations of selenium, nitrate, cadmium, and sulphate meet B.C. WQGs, or if current and future concentrations are predicted to remain within long-term targets. Therefore, short-term targets are defined as the maximum monthly concentrations measured in 2013 for selenium at Order stations FR4, FR5, and ER2, and for nitrate at ER2 and ER3.

Short-term targets are based on technical and financial achievability, with timeframes defined by the initial implementation plan. Until the FRO South AWTF is operating, maximum modelled concentrations for selenium and nitrate are anticipated to increase.

8.6.1 Short-term Targets

Short-term targets for selenium are required at Order stations FR4 and FR5 (Table 8-20). Concentrations at other Order stations are predicted to remain within long-term targets or are predicted to meet long-term targets at the same time that maximum 2013 concentrations are met. Short term targets in the Fording River are predicted to be attained once the FRO-South AWTF is operational. At ER2, short term targets are achieved by 2023 (although concentrations are expected to get below short term targets in 2019, they increase again before 2023 at which time they are expected stay below the short term target). Water treatment facilities at Line Creek, Fording River and Greenhills affect water quality at the ER2 monitoring location. Management options, including water treatment, are prioritized on a regional basis targeting the areas where the largest benefits can be realized. Section 8.4 discusses the anticipated timing for development of future facilities. The implementation sequence of Line Creek, Fording River South, Elkview and then Fording River North has larger benefits to the watershed overall but does not keep selenium levels at ER2 consistently below the short term target until 2023 when the Fording River North treatment facility is anticipated to be operational.

Table 8-20. Short-term targets for total selenium.

Order station (EMS#)	Order station description	Short-term target ¹	Immediate action	Estimated target attainment (year)
Fording River				
FR4 (0200378)	Fording River downstream of Greenhills Creek	≤63 µg/L	Design, build, and operate FRO AWTF	2019
FR5 (0200028)	Fording River at the mouth	≤51 µg/L	Operate WLC AWTF and FRO AWTF	2019
Elk River				
ER1 (E206661)	Elk River downstream of Greenhills Operation	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}
ER2 (0200027)	Elk River downstream of Fording River	≤19 µg/L	Environmental Monitoring	2023
ER3 (0200393)	Elk River downstream of Michel Creek	Not applicable ³	Environmental Monitoring	Not applicable ^{2 and 3}
ER4 (E294312)	Elk River at Elko Reservoir	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}
LK2 (E294311)	Lake Koocanusa south of the mouth of the Elk River	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}

Note¹: Analytical laboratories typically set an acceptable Quality Assurance/Quality Control Relative Percent Difference limit of ±20%. To account for imprecisions in analytical procedures, a 10% tolerance limit of the target is proposed.

Note²: Current (2013) concentrations meet B.C. WQGs, or current and predicted future concentrations remain below long-term targets.

Note³: Short-term target for stabilization and attainment year is not applicable because the long-term target is achieved at the same time that maximum 2013 concentration is achieved.

Short-term targets for nitrate are required at Order station ER2 (Table 8-21). Concentrations at other Order stations are predicted to remain within long-term targets or are predicted to meet long-term targets at the same time that maximum 2013 concentrations are met. Short term targets in the Elk River (ER2) are predicted to be attained once the FRO-South AWTF is operational.

Table 8-21. Short-term targets for nitrate.

Order station (EMS#)	Order station description	Short-term target ¹	Immediate actions	Estimated target attainment (year)
Fording River				
FR4 (0200378)	Fording River downstream of Greenhills Creek	Not applicable ³	Design, build, and operate AWTF	Not applicable ³
FR5 (0200028)	Fording River at the mouth	Not applicable ³	Operate WLC AWTF	Not applicable ³
Elk River				
ER1 (E206661)	Elk River downstream of Greenhills Operation	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}
ER2 (0200027)	Elk River downstream of Fording River	≤4 mg/L as N	Environmental Monitoring	2019
ER3 (0200393)	Elk River downstream of Michel Creek	Not applicable ³	Environmental Monitoring	Not applicable ³
ER4 (E294312)	Elk River at Elko Reservoir	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}
LK2 (E294311)	Lake Koocanusa south of the mouth of the Elk River	Not applicable ²	Environmental Monitoring	Not applicable ^{2 and 3}

Note¹: Typically analytical laboratories set an acceptable Quality Assurance/Quality Control Relative Percent Difference limit of ±20%. To account for imprecisions in analytical procedures, a 10% tolerance limit of the monthly average was established.

Note²: Current (2013) concentrations meet B.C. WQGs, or current and predicted future concentrations remain below long-term targets, or long-term target is met with the implementation of the first treatment plant upstream of the Order station (applies to FR4 and FR5).

Note³: Short-term target for stabilization and attainment year are not applicable because the long-term target is achieved at the same time that maximum 2013 concentration is achieved.

Concentrations of sulphate and cadmium at the Order stations are currently within B.C. WQGs, and future concentrations are not expected to exceed long-term targets (except at FR4, as discussed above). Therefore, short-term targets are not required for sulphate or cadmium.

8.6.2 Medium-Term Targets

Medium-term concentration targets and time frames are set to demonstrate progressive reduction in water-quality concentrations from short to long term targets. Medium-term targets are set at the same locations as short-term targets, i.e., where current or projected concentrations of selenium, nitrate, sulphate and cadmium are above BC WQGs. Therefore, medium-term targets are defined as the maximum monthly concentrations for selenium at Order stations FR4, FR5, and ER2, and for nitrate at ER2.

For selenium in the Fording River at Order Stations FR4 and FR5 (Table 8-22), long-term targets are projected to be achieved very shortly after the short term targets (and with the next treatment plant after the short term targets are achieved). For that reason, the medium term targets are set equal to the long term targets.

Table 8-22. Medium-term targets for total selenium.

Order station (EMS#)	Order station description	Medium-term target ¹	Estimated target attainment (year)
FR4 (0200378)	Fording River downstream of Greenhills Creek	≤57 µg/L	2022
FR5 (0200028)	Fording River at the mouth	≤40 µg/L	2023

In the Elk River at ER2, the long term nitrate target is 3 NO₃-N mg/L met by 2028 (although as of yet unquantified reductions due to improvements in blasting practices are expected to improve this timing) and the short term target is 4 NO₃-N mg/L in 2019. An intermediate concentration of 3.5 NO₃-N mg/L in 2025, after the second phase of the EVO treatment plant is installed is selected as the medium term target and timeframe.

Table 8-23. Medium-term targets for nitrate.

Order station (EMS#)	Order station description	Medium-term target ¹	Estimated target attainment (year)
ER2 (0200027)	Elk River downstream of Fording River	3.5 NO ₃ -N mg/L	2025

Concentrations of sulphate and cadmium at the Order stations are currently within B.C. WQGs, and future concentrations are not expected to exceed long-term targets (except at FR4, as discussed above). Therefore, medium-term targets are not required for sulphate or cadmium

Chapter 9

Social and Economic Considerations

Chapter Overview

This chapter examines the social and economic importance of water and water quality to the Elk Valley, and reviews the anticipated costs and benefits of mitigation measures proposed in the Plan on 12 social-economic valued components and indicators that cover key areas of concern for residents.

Concordance with Ministerial Order and Terms of Reference

Chapter 9 satisfies Section B.6 of Schedule C of Ministerial Order M113 and Section 3.8(e) and Section 3.10(a) and (b) of the Elk Valley Water Quality Plan Terms of Reference.

Chapter Highlights

- **Water has significant social and economic value in the Valley.** In the Elk Valley, Water sources including the Elk and Fording rivers and Lake Koochanusa support recreation, tourism and other economic activities. In addition, groundwater is the primary source of drinking water for residents.
- **Mining is the major source of economic activity in the East Kootenays.** Teck's five steelmaking coal operations directly or indirectly contribute 6,440 jobs to the East Kootenay economy. Approximately one in five (20%) of the total jobs in the region East Kootenay depend on Teck's mines.
- **Impact of mitigation and water-quality targets on key social and economic values assessed.** This chapter, and the supporting report by Ernst & Young, examines the costs and benefits of targets and mitigation measures for water quality (selenium, cadmium, nitrate, and sulphate) and calcite management in terms of 12 key social-economic valued components, which were refined with input from public consultation:
 1. Gross domestic product (GDP)
 2. Local business opportunities
 3. Investment
 4. Jobs
 5. Tax and resource revenue-sharing
 6. Personal income generation
 7. Availability of housing
 8. Sustainable community population
 9. Physical health
 10. Use of aquatic environment
 11. Skills training, apprenticeships and education
 12. Availability and access to community services.
- **The Elk Valley Water Quality Plan is anticipated to be protective of key social and economic values.** The Plan will provide a framework for decision-makers from the B.C. Ministry of Environment to review proposals for steelmaking coal mining and other activities in the Elk Valley. By meeting water-quality and calcite targets that protect the environment and human health, the Plan will support the continued use of water for recreation, tourism and fishing.

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9.1 Introduction

Maintaining water quality is integral to the social and economic fabric of the Elk Valley. Clean drinking water is essential for human health, and fresh water provides opportunities for recreation, tourism and related economic activity. At the same time, Teck's five coal-mining operations in the Elk Valley provide significant benefits to the local and provincial economy. They create employment, generate significant economic output, and provide tax revenue to all levels of government.

The Order requires Teck to address the economic and social costs and benefits of addressing risks to the environment through water treatment. This chapter, and the appended report by Ernst & Young, addresses this requirement. Based on a representative scenario, it assesses the costs and benefits of meeting selected targets for water quality (selenium, cadmium, nitrate and sulphate), and calcite management.

The Plan proposes scientifically supported water-quality targets that will maintain aquatic and human health. Chapter 6 assesses the most viable water management options and identifies active water treatment and clean-water diversion as the approaches that will be taken under the initial implementation plan. Chapter 8 sets out short-, medium- and long-term water quality targets and the initial implementation plan. Chapter 7 describes a similar process for managing calcite. Notably, Achieving these targets will require an increase in capital and operating costs. This chapter examines the social and economic importance of water and water quality to the region, and reviews the anticipated costs and benefits of the Plan for 12 social-economic "Valued Components and Indicators" identified for the Elk Valley (see Section 9.3).

9.2 The Importance of Water in the Elk Valley

The 220-km Elk River originates in the Elk Lakes, which are fed by numerous glaciers, and runs through the communities of Elkford, Sparwood, Hosmer, Fernie and Elko near the Continental Divide of the Rocky Mountains. It flows through the Elk Valley in a southwesterly direction, joining the Kootenay River in Lake Koocanusa. There are several tributaries to the Elk River, including Cadorna Creek, Forsyth Creek, Michel Creek, Fording River, Coal Creek, Lizard Creek, Morrissey Creek and Wigwam River.

9.2.1 Ktunaxa Nation

The Ktunaxa Nation has identified a balanced vision for development which emphasizes environmental protection with the promotion of economic growth. The Ktunaxa Nation vision for economic growth is diverse, emphasizing the wage economy, entrepreneurial business development and rights-based revenue sharing alongside the promotion of a rights-based subsistence economy which supports opportunities for traditional subsistence harvesting and knowledge transfer.

Each of these activities requires use of water within the Elk Valley. The Ktunaxa Nation has indicated Teck's five operations in the Elk Valley have the potential to provide substantial opportunities for Ktunaxa Nation and Ktunaxa citizen participation in the wage economy, business development and rights based revenue sharing. The Ktunaxa Nation has also identified the Elk River as supporting traditional subsistence practices and affording other commercial opportunities, such as guiding and outfitting, for Ktunaxa citizens.

The Plan's scientifically supported water quality targets are protective of these interests.

9.2.2 Recreation

The Elk Valley region contains pristine wilderness areas such as the Elk Lakes Provincial Park. With more than 40 km of trails along the Elk River and in the surrounding mountains, combined with its abundant wildlife, the area has some of the densest wildlife populations in North America.

Elk Valley residents and tourists engage in outdoor activities throughout the year. In the summer, these include hiking, mountain biking, horseback riding, whitewater rafting, wildlife viewing, boating, kayaking, canoeing and fishing. In the fall, activities include hunting deer, moose, mountain goat, bighorn sheep, bear, and elk. Winter activities include downhill and cross-country skiing, snowmobiling, ice fishing, and river fishing on unfrozen sections of the Elk River.

The two most popular outdoor recreational activities in the area are water-based: swimming and beach activities, at 73% and 70% respectively.¹ Fernie hosts an annual swim, drink and fish festival on the Elk River in September. Fernie has one sanctioned boat launch, but water users often access waterways from non-sanctioned areas of the river.

9.2.3 Tourism

The Kootenay Rockies region, which encompasses the Elk Valley or East Kootenay, is a popular tourist destination. It received 1.6 million overnight tourist visits in 2010, and generated \$522 million in related spending.² A majority of the tourists (76%) visiting the Kootenay Rockies region are from Alberta and other parts of B.C.

The Elk Valley, in the southeast corner of the region, is an all-season destination for recreation tourism. Local service industries provide meaningful economic returns to Elk Valley communities. In 2013, activity peaked at Elk Valley visitor centres during July to September, representing approximately 64% of total annual visitors. However, many tourists do not stop at visitor centres, but travel straight to the ski hills and mountains. Approximately 80% of visitors responding to Tourism Fernie's winter survey indicated that skiing was their primary reason for visiting. In the summer, the primary reason for visiting is to attend a summer event or to go biking.³

Table 9-1. 2013 Elk Valley visitor centre statistics.⁴

	Jan-Mar	Apr-Jun	July-Sep	Oct-Dec	Total
Elkford	84	166	597	92	939
Fernie	596	3,097	7,990	697	12,380
Sparwood	2,691	11,969	34,776	5,216	54,652
Total Visitors	3,371	15,232	43,363	6,005	67,971

Nearly half of all B.C.-resident travellers stayed with friends and family. Other Canadian residents spent most of their visits in non-paid accommodation (private cabins, RVs, condos, etc.). US residents spent more time in hotels and motels than travellers from other regions. Total room revenue in 2012 for the Kootenay Rockies region was \$81 million.⁵ In the Elk Valley area, room revenue is generated from both business-related travel and tourists. For some accommodation providers, Teck and its contractors and consultants are the top customers.

¹ 2012 In Market Research Report – Summary of Tourism Regions

² Destination BC – Regional Tourism Profile Kootenay Rockies, April 2013

³ Tourism Fernie Visitor Surveys, 2013

⁴ Tourism BC

⁵ Destination BC – Regional Tourism Profile Kootenay Rockies, April 2013

9.2.4 Fishing

The Elk River provides world-class fly fishing, which in 2009 enabled Fernie to host the 7th Annual Fly Fishing Canada National Fly Fishing Championship. The Elk River is home to one of the largest remaining populations of wild, genetically pure westslope cutthroat trout, a species renowned for its willingness to rise to dry flies even in the most trying conditions. The river also hosts populations of large bull trout. The fishing season runs from mid-June to mid-October. Catch and release is mandatory for many of the fish in the Elk River, but some can be kept if they meet weight and species requirements.

The Elk River is very accessible to anglers. Local highways and forest service roads run parallel to the Elk River from Elko to Elkford and its tributaries throughout the valley. It is one of seven fisheries deemed “classified waters” in southeastern B.C., which means anglers need a special licence to fish. Classified waters are regulated and have a specific number of angler days assigned to guides, of which there are approximately 20 offering services in the Elk Valley, each offering expertise, equipment and intimate knowledge of the local rivers. Since 2005, the allocated rod days for Elk river guides have remained the same at 2,950 days per year, with a relatively stable average of 1,875 or 63% utilized over the past five years.⁶ Non-guided anglers also make extensive use of the river, with an estimated 9,000 non-guided angler days used during each season.

9.2.5 Drinking Water

Most Elk Valley residents obtain drinking water from municipal water systems provided by the City of Fernie, District of Sparwood and District of Elkford. These sources are drawn from wells operated by the municipalities, and are subject to regular testing.

Although a complete inventory is not available, approximately 250 private properties between Elkford and Fernie, and outside the municipal systems, draw water for drinking and other purposes from private wells or surface water sources. While surface water from the Elk or Fording Rivers is not a primary source of drinking water in the region, the potential exists for groundwater sources to be influenced by surface water. Teck undertook a groundwater-testing program as part of the development of this Plan. Only a small number of wells exceeded the screening guideline for selenium, and no health-based benchmarks were not exceeded. Chapter 5 provides more information on Teck’s groundwater testing program and human health assessment.

9.3 Valued Components and Indicators

A structured process was used to establish Valued Components and Indicators to be evaluated in this analysis. Seventy-five potential, wide-ranging components were identified through consideration of other global socio-economic assessments, previous environmental assessments in the Elk Valley, and Teck’s knowledge of potential issues of importance to Communities of Interest (COIs), as informed by ongoing engagement with COIs. This engagement includes a Communities of Interest advisory panel that brings together COIs from across the Valley to discuss concerns and interests directly with Teck on a bi-annual basis. Using a rigorous framework, these components were then evaluated for relevance and importance:

- **Relevance** was determined by whether an indicator might be expected to change under a treatment scenario, if there was suitable information available to assess the component, and if it was the most appropriate component to assess in a given area.
- **Importance** was estimated in the context of Teck’s current understanding of community concerns, and whether a COI identified a component as important.

⁶ B.C. Ministry of Forest, Lands and Natural Resource Operations – Fish and Wildlife Branch.

Indicators were determined for top 12 components, and the proposed list of components and indicators was published for feedback from stakeholders during the first phase of consultation on the Plan. Minor changes were made to streamline the components and indicators, and to reflect the feedback received. A summary of the results is discussed below.

The sections that follow summarize impacts on selected Valued Components and Indicators. These summaries are based on trends and judgments from quantitative modelling by Ernst & Young. Several implementation scenarios were modelled, though little variation in socio-economic factors was observed. A representative scenario was selected for this assessment, based on its similarity to the proposed implementation plan. A more thorough discussion of the Ernst & Young analysis is provided in Annex M.

9.3.1 Gross Domestic Product

The five steelmaking coal mines operated by Teck in the Elk Valley make a significant contribution to the provincial and national GDP. They are expected to contribute \$4.5 billion or 2.0% of B.C.'s \$230 billion GDP in 2014. As the Plan will not reduce employment or production at those operations, there should be it is anticipated that there would be a negligible impact on GDP as a result of its implementation. Economic activity generated by construction of water treatment capacity and other mitigation activities, as outlined in Chapter 8, may generate a small increase in GDP. The Plan should not affect other water uses that generate GDP, such as tourism.

9.3.2 Local Business Opportunities

Teck's operations in the Elk Valley generate approximately \$1.4 billion in local procurement spending, creating significant opportunities for local business. The Plan will have a minimal impact on this. Construction of water treatment facilities and other mitigation activities could slightly increase procurement spending for local businesses. The Plan will have no impact on local businesses that rely on the use of the Elk or Fording rivers or Lake Kootenay, such as tourism or sport fishing.

9.3.3 Investment

As with Section 9.3.2, the Plan will have minimal impact on local investment related to existing mining operations, with construction of water treatment facilities and other mitigation activities offering a potential increase in local and regional investment as a result of additional procurement.

9.3.4 Jobs

Teck is the single largest employer in the region, directly or indirectly contributing 6,440 jobs to the East Kootenay economy. Approximately one in five (20%) of all jobs in the East Kootenay are dependent on Teck. On a provincial and national scale, considering direct and indirect employment and spinoffs, Teck is projected to support 15,240 jobs in B.C. and 19,020 jobs in Canada in 2014.

Due to the capital-intensive nature of the mining industry, for every one job created at Teck, another 2.7 jobs are created elsewhere in the provincial economy. Teck's Elk Valley operations support \$1.8 billion in wages and benefits across B.C. and \$2.6 billion Canada-wide (including B.C.).

The Plan will support continued, sustainable mining in the Elk Valley and provide a regulatory framework that will enable consideration of the extension of operations. As a result, it is expected that there will be no reduction in East Kootenay employment currently supported by Teck's operations as a result of implementation of the Plan. Construction of treatment facilities would temporarily increase employment, and ongoing plant operations would create a small increase in jobs: for example, the Line Creek treatment facility requires approximately a dozen staff. The Plan will not reduce employment related to other water uses such as tourism and sport fishing.

9.3.5 Tax and resource revenue-sharing

The Plan will increase Teck's operating and capital costs due to the need to build and operate treatment facilities and other mitigation measures. Teck has invested \$105 million in construction of the West Line Creek Active Water Treatment Facility (AWTF), and anticipates investing approximately \$600 million in water treatment and mitigation over five years. This will reduce taxes, royalties and revenue-sharing with the governments of B.C. and Canada and First Nations, including an approximate \$65 million in Mineral Resource Taxes over the five years. The impact on local governments is expected to be negligible.

9.3.6 Personal Income Generation

The Plan will support continued, sustainable mining in the Elk Valley, and will provide a regulatory framework that will enable consideration of extensions to operations. As a result, no reduction is anticipated of existing East Kootenay employment with or supported by Teck. It will have no effect on wages and personal incomes connected with those jobs. The Plan will not reduce personal incomes related to other water uses, such as tourism and sport fishing.

9.3.7 Availability of housing

The proposed staging of the initial implementation plan will maintain a construction labour force at a level similar to that required to build the West Line Creek AWTF. It will have a negligible effect on housing availability.

9.3.8 Sustainable community population

The Plan will have a negligible impact on population. It supports ongoing, sustainable mining in the region without compromising non-mining activities.

9.3.9 Physical health

Physical health is considered in the context of consumption of fish caught in the Elk Valley watershed, and of potential effects on drinking water. As outlined in Chapter 5, monitoring and assessment indicates that current and projected concentrations of selenium and other constituents of interest in fish in the Elk and Fording rivers do not pose health risks, even for people who eat fish frequently.

Municipal water systems within the Elk Valley are tested regularly by municipalities to ensure water quality. Testing shows that, with the exception of one of the District of Sparwood's three wells, municipal water systems are not affected by mining-related water-quality constituents. That well has exhibited elevated selenium concentrations and was temporarily taken out of service until concentrations decreased to a level that meets water-quality guidelines. The District is establishing a replacement well located at a distance outside the influence of mine-affected surface water.

Drinking-water quality for all municipal water users in the Elk Valley is expected to remain unaffected throughout implementation of the Plan. If drinking water is affected by mining activities, Teck will provide drinking water that meets provincial WQGs to communities.

A small number of private wells in the Elk Valley have recorded a potential influence related to selenium from surface waters. Teck is working with individual owners to provide alternative water sources as necessary. The majority of private well users remain unaffected. Chapter 5 provides more details on the human health assessment conducted as part of the development of the Plan.

9.3.10 Use of aquatic environment

The main considerations for use of the aquatic environment include eating fish caught in the Elk Valley watershed, and swimming in the Fording and Elk rivers and Lake Koochanusa (i.e., continued “fishability” and “swimmability”).

Monitoring and assessment indicate that current concentrations of selenium, cadmium, nitrate, sulphate and calcite will not affect human health and aquatic life in the Fording and Elk rivers and Lake Koochanusa. The Plan outlines mitigation measures that will ensure that these constituents do not reach levels that have a measurable effect on fish populations, thus protecting the “fishability” of the watershed.

Recreational swimming in the Elk and Fording rivers and Lake Koochanusa currently poses no human health risks. This will continue to be the case during implementation of the Plan.

9.3.11 Skills training, apprenticeships and education

Levels of skills training and apprenticeships supported through Teck’s operations should continue under the Plan, as production and employment will be maintained. The staged development of water treatment facilities could create additional demand for specialized construction workers and operators. This could, in turn, increase the type of skills training and/or number of apprenticeships offered in the region.

9.3.12 Availability and access to community services

The Plan will support continued, sustainable mining in the Elk Valley and is expected to have a negligible impact on Teck’s level of community investment or access to publicly funded community services. Staged construction of treatment facilities and other water quality measures will help mitigate a potential influx of temporary residents or a spike in demand for community services such as health care, education or emergency services.

9.4 Summary

As detailed in the Plan, it has been determined that Teck can achieve water quality and calcite targets that will maintain aquatic and of human health, thereby supporting the continued use of the water for recreation, tourism and fishing. The social-economic analysis indicates that the proposed water quality and calcite targets in the Plan should be economically and socially protective for both B.C. and the Elk Valley region.

Chapter 10

Monitoring

Chapter Overview

This chapter describes monitoring that will be undertaken, through the Regional Aquatic Effects Monitoring Program (RAEMP) and supporting studies, to assess environmental conditions, confirm that the objectives of the Plan are met, identify the need for adaptive management actions, and refine planning tools in the use of the Plan.

Concordance with Ministerial Order and Terms of Reference

Chapter 10 satisfies Section B.14 and B.16 of Ministerial Order M113 and Section 3.11 (last paragraph) and Section 3.13 of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Teck will implement ecosystem monitoring and ecotoxicology assessment programs to evaluate progress on meeting Plan objectives.** The monitoring program will be used to confirm that the Plan is achieving its objectives of protecting aquatic ecosystem health, managing bioaccumulation of constituents, and protecting human health and groundwater. It will also be used to refine planning tools and inform adaptive management.
- **Ecosystem monitoring will include a range of sample types and endpoints throughout the Designated Area.** Monitoring will include surface water quality, sediment, calcite formation, fish, benthic invertebrates (e.g., insects) and periphyton (e.g., algae and bacteria).
- **Results will be provided to government agencies and Ktunaxa Nation Council, and will be publicly available on the Plan website.** Surface water quality data will be evaluated and compared to predicted water quality concentration and targets. Results of these evaluations will be summarized and made available at www.teck.com/ElkValley.

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10.1 Introduction

Teck will update the RAEMP, the aquatic ecosystem monitoring program, to include additional monitoring to address objectives specified under the Terms of Reference for the Plan and existing Environmental Management Act (EMA) permits for Teck's mine operations. Data from the RAEMP, along with data from the groundwater sampling program, will be used to confirm that the Plan is achieving the four environmental management objectives and outcomes specified in the Order:

- protection of aquatic ecosystem health
- management of bioaccumulation of contaminants in the receiving environment (including fish tissue)
- protection of human health
- protection of groundwater.

Regular cycles of the RAEMP are required under the existing EMA permits and the program's objectives are similar to those of the Plan. They include:

- Assess effects of effluent discharges from mine operations, separately and cumulatively, on the aquatic ecosystems within the Elk River watershed.
- Evaluate water chemistry changes for key constituents of concern
- Assist in understanding whether management and mitigation actions are working as expected.

The RAEMP entails a comprehensive evaluation of aquatic ecosystem health. It measures a broad range of constituents in environmental media, including those specified by the Order (selenium, cadmium, nitrate and sulphate) and also measures calcite formation and aquatic effects. The data collected, and reports developed, for the program to evaluate effects to aquatic ecosystem health will be used to meet both objectives of the Plan and Teck's existing permits. Specific to the Plan, monitoring results will be used to assess environmental conditions, confirm objectives are met, identify and inform the need for adaptive management actions, and refine the tools (e.g., the Elk Valley Water Quality Planning Model and selenium-bioaccumulation model) used in development of the Plan.

10.2 Regional Aquatic Effects Monitoring

The RAEMP is the foundation for monitoring and evaluating changes in the aquatic environment throughout the Designated Area. The program is being developed with input from the B.C. MOE and Ktunaxa Nation Council. It will be carried out in accordance with EMA permits and requirements associated with the Plan. The RAEMP will build on information collected in watershed-wide monitoring programs in 2006, 2009, 2012 and in numerous supporting studies.

The RAEMP is intended to be flexible, resource-efficient, and ecologically sustainable (e.g., by using non-lethal sampling method). It is designed to provide scientifically and statistically robust monitoring of spatial and temporal effects on water quality, water uses, and aquatic biota representative of the Designated Area. It integrates physical, chemical and biological information to assess aquatic ecosystem health. It provides a regional assessment of conditions based on relevant and representative species and endpoints.

Detailed design of the RAEMP will be completed in 2014, with implementation intended for 2015. Its development is guided by a process routinely employed by the U.S. Environmental Protection Agency, commonly referred to as the data quality objective (DQO) process (US EPA 2006). The process follows a logical progression that includes:

- decisions based on an identified need for information (e.g., characterization of the environment and monitoring changes)
- assembling available information
- evaluating the quality of the data
- developing a plan for collecting additional information to adequately address relevant concerns.

The design is adaptive, and can be modified to advance the understanding of watershed conditions over time. This may include the addition of monitoring stations to support the investigation and reporting of conditions at a local scale (e.g., tributaries). The technical and management approach guided by the RAEMP considers the following principles:

- coordination of program development, data interpretation and reporting with the Provincial government (MOE and MFLNRO) and the Ktunaxa Nation Council
- careful evaluation of assumptions and uncertainties associated with data and conceptual site models
- an iterative approach that evolves in response to learnings to advance understanding and reduce uncertainties
- monitoring to assess and document environmental conditions
- proactive guidance of site-specific management and mitigation decisions.

The RAEMP is a multi-year program involving multiple rounds of data gathering and evaluation. An interpretive report will summarize results for each three-year monitoring cycle. This report will evaluate available data to determine if mine-related chemical and physical changes are resulting in effects to the aquatic ecosystem. Spatial and temporal data patterns will be evaluated to link observed biological responses to specific mine-related sources, thereby assisting in identifying appropriate mitigation and management activities.

In addition to the RAEMP and in consultation with MOE, Teck may determine that a focused evaluation of specific issue(s) is required at a local scale. In this case, Local Aquatic Effects Monitoring Programs (LAEMPs) will be established, as required, under conditions associated with EMA permits for mine operations. These monitoring programs will evaluate issues that are expected to have only localized effects, if any, or those requiring more sample-intensive or more frequent monitoring than is associated with the RAEMP (e.g., impact of water diversion changes on water quantity, treatment plant influence on downstream conditions, etc.). The scope and monitoring frequency of LAEMPs will be developed on a case-by-case basis, and the information will be reported independently as required under EMA permits. The data collected as part of these programs will support interpretation and reporting for the RAEMP, when applicable.

Data are also periodically collected for baseline characterizations associated with Environmental Assessments (EAs) as required for applications to extend mining operations. Other supporting studies may also be completed to fill data gaps or to address uncertainties. Data from baseline monitoring and supporting studies will be used, when applicable, to support the RAEMP, to inform future monitoring and the assessment of the Plan's environmental objectives and outcomes.

Figure 10-1 depicts the connections between the different monitoring components described above, and shows how data collected within these programs will be used to evaluate management measures in the Designated Area. This collective approach relies on several steps, including:

- initial identification of data needs
- data review
- collection of additional data
- iterative evaluation of data to guide subsequent activities
- identification of sources and actions most appropriate for the Designated Area.

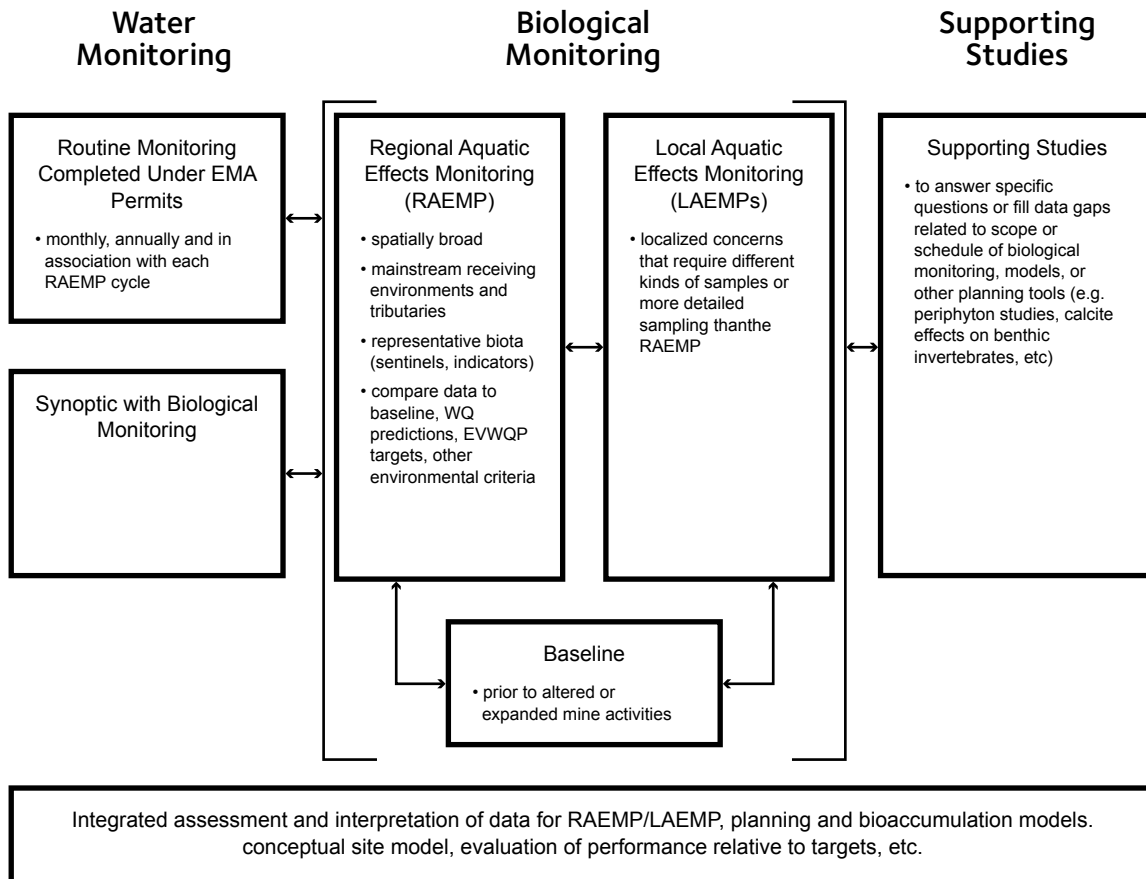


Figure 10-1. Framework of aquatic ecosystem monitoring programs.

Table 10-1 provides an overview of near-term aquatic ecosystem monitoring and supporting studies. Components monitored within the RAEMP may change between cycles, in response to data and evaluation from previous monitoring cycle. Design of future cycles will:

- incorporate learnings from previous cycles to recommend modifications to the monitoring scope or frequency, or the need for supporting studies
- identify hypothesis (as applicable) relevant to pathways and receptors in the conceptual site model(s)
- identify performance criteria for measurement and analyses (i.e., quality assurance and quality control) of each sample type
- specify methods for each of the receptors and media being monitored.

Table 10-1. Conceptual overview of the aquatic ecosystem monitoring program.

Monitoring	RAEMP Cycle 1				RAEMP Cycle 2		
	2013	2014	2015	2016	2017	2018	2019
Elk River Watershed							
Surface water quality and quantity							
Sediment quality				TBD			
Calcite				TBD			
Periphyton – Tissue					TBD		
Periphyton – Biomass and chlorophyll-a							TBD
Benthic invertebrates – Tissue					TBD		
Benthic Invertebrates – Community structure				TBD			
Fish – Tissue							
Fish – Population and health				TBD			
Ecotoxicology					TBD		
Groundwater				TBD			
Supporting Studies	Completed on an as required basis						
Lake Kooconusa							
Water quality							
Sediment quality			TBD				
Plankton – Tissue					TBD		
Plankton – Community structure					TBD		
Plankton – Productivity					TBD		
Benthic invertebrates – Tissue			TBD		TBD		
Benthic invertebrates – Community structure					TBD		TBD
Fish – Tissue					TBD		
Supporting studies	Completed on an as required basis						

Conceptual overview only: All RAEMP monitoring components will be evaluated at the end of each monitoring cycle (represented by bold line between years) to confirm monitoring design for future cycles based on the DQO process.

Note: TBD = To be determined based on monitoring data evaluation

As shown in Table 10-1, the aquatic ecosystem monitoring program collects and evaluates data to verify if environmental management objectives and outcomes are being met. These may include:

- water quality
- substrate sampling (sediment quality and calcite)
- periphyton sampling (primary productivity and tissue concentrations)

- benthic invertebrate sampling (tissue concentrations and community structure)
- fish sampling (tissue concentrations and fish health and/or population status).

Order constituents that bioaccumulate in tissues will be monitored in representative aquatic biota as per the conclusions of the screening-level ecological risk assessment of trace elements discussed in Chapter 4.

The sections that follow provide an overview of monitoring activities routinely evaluated or planned under the RAEMP. Table 10-2 links these monitoring endpoints to the environmental management objectives and outcomes.

Table 10-2. Monitoring to address the plan objectives.

Objective	Monitoring							
	Surface water	Groundwater	Sediment	Calcite	Periphyton	Plankton	Benthic invertebrates	Fish
Protection of aquatic ecosystem health								
Management of bioaccumulation of contaminants in the receiving environment								
Protection of human health								
Protection of groundwater								

The conceptual site model (see Chapter 4) identifies chemical and physical stressor pathways that link mining activities with potential effects on aquatic and aquatic-dependent receptors. Therefore, the CSM is an important tool for guiding development and communication of monitoring activities. Monitoring will focus on the media and receptors identified in the CSM, taking into account the relative ecological importance or likelihood of occurrence of specific interactions. For example, potential mine effects on primary productivity in the Elk River watershed will be more evident through monitoring of periphyton than aquatic macrophyte growth, because periphyton is found throughout the watershed, but aquatic macrophytes are sparsely distributed.

Pathways and receptors differ among specific stressors, and this must be taken into account during monitoring program design. For example, selenium and nitrate are both chemical stressors, but behave differently in the aquatic environment; selenium effects are most likely to occur through dietary accumulation and reproduction, so it is relevant to monitor tissue in representative food-web organisms; whereas nitrate is more likely to affect receptors through direct contact in water, and so tissue monitoring is irrelevant. Table 10-3 shows how consideration of specific stressors, pathways, and receptor effects are used to guide the general design of the RAEMP.

Table 10-3. Relationships between conceptual site model and proposed monitoring.

Stressor category	Mine-related stressor	Dominant pathway	Assessment endpoint	Measurement endpoint	Elk River	Lake Koocanusa	Evaluation criteria	
Chemical	Selenium	Dietary accumulation	Toxicity ¹	Water chemistry	✓	✓	Water-tissue relationships described in site-specific bioaccumulation models	
				Tissue Se concentrations	✓	✓	Tissue guidelines and benchmarks	
	Selenium, nitrate, sulphate, cadmium (and potentially others)	Water contact/uptake	Toxicity ¹	Water chemistry	✓	✓	Short-, medium and long-term targets at Order stations. Mainstem and tributary concentrations and trends at additional monitoring stations closer to source areas. Water quality concentrations and compliance limits specified in EMA permits.	
Physical	Sediment contact and/or uptake	Multiple	Toxicity ¹	Surface water toxicity tests	✓	✓	Toxicity response	
				Sediment chemistry	✓		Sediment quality guidelines, benchmarks, reference concentrations	
				Sediment toxicity tests			Toxicity response	
	Nutrients (phosphorus and nitrogen)	Water contact and/or uptake	Community structure	Fish population	Benthic invertebrate EPT and E proportions	✓	✓	Reduction relative to reference conditions and in mine-influenced monitoring areas over time.
					Westslope cutthroat trout and longose sucker population characteristics and health	✓		Changes in populations over time
				Eutrophication	Water nutrient concentrations	✓	✓	Guidelines, benchmarks, targets, reference conditions, changes over time
	Calcite	Substrate characteristics	Community structure	Water contact and/or uptake	Periphyton chlorophyll-a and biomass	✓		
					Water column chlorophyll-a	✓	✓	
				Changes in substrate particle size distribution	Calcite index (presence or concretion)	✓		Initial trigger levels based on concentration scores. Combined calcite and benthic invertebrate monitoring will be undertaken as a supporting study in 2015 to update target and adaptive management trigger levels to account for calcite effects to EPT and E proportions and periphyton biomass (Chapter 7).
					Population or community structure	Sedimentation and substrate size distribution	✓	
Barriers, connectivity	Access to habitat	Fish population	Habitat quantity	Benthic invertebrate EPT and E proportions	✓		Reduction relative to reference conditions and in mine-influenced monitoring areas over time.	
				Habitat quantity	✓		Changes in available habitat over time	
Altered flow patterns	Habitat quantity and quality	Habitat quantity and quality	Westslope cutthroat trout and longose sucker population characteristics and health	Westslope cutthroat trout and longose sucker population characteristics and health	✓		Changes in populations over time	

Note ¹: Assessing survival, growth and/or reproduction

10.2.1 Surface Water Quality and Quantity

Water quality data will continue to be collected throughout the Designated Area in the mainstem receiving environments, mine-influenced tributaries, and reference areas. This is required under existing EMA operating permits, and includes routine monitoring of more than 100 stations throughout that Designated Area. These data will prove helpful in multiple respects: evaluating progress toward meeting the long-term water quality targets (Order stations highlighted in bold in Table 10.4), identification of source loading contributors, informing aquatic biota monitoring programs, and/or providing the necessary data to improve planning tools in support of management and mitigation decisions.

Of the routine monitoring stations, data from a sub-set of stations will be used to evaluate performance relative to environmental objectives and outcomes. A summary of the proposed surface water quality monitoring locations (per MU) is presented in Table 10.4. Monitoring locations are listed upstream to downstream within respective MUs, with Order stations in bold. A map of the network is provided in Figure 10-2.

Table 10-4. Regional surface water quality and primary productivity monitoring locations.

MU-1	MU-2	MU-3	MU-4	MU-5	MU-6
FR_UFR1	LC_LC5	GH_ER2	EV_ER4	RG_ELKORES	RG_WARDB
GH_FR1		GH_ER1	CM_MC1		RG_USELK
			EV_ER1		RG_DSELK
					RG_GRASMERE
					RG_BIGSPRINGS
					RG_BORDER

Note: "GH_FR1" corresponds to Order Station "Fording River downstream of Greenhills Creek (FR4).

"LC_LC5" corresponds to Order Station "Fording River at the mouth (FR5).

"GH_ER1" corresponds to Order Station "Elk River downstream of Greenhills Creek (ER1).

"EV_ER4" corresponds to Order Station "Elk River downstream of the Fording River (ER2).

"EV_ER1" corresponds to Order Station "Elk River downstream of Michel Creek (ER3).

"RG_ELKORES" corresponds to Order Station "Elk River at Elko Reservoir (ER4).

"(RG_DSELK, RG_GRASMERE, and RG_BIGSPRINGS, RG_BORDER)" corresponds to Order Station "Lake Koochanusa south of the mouth of the Elk River (LK2) in British Columbia.

Note: Monitoring in MUs 1-5 will be for chlorophyll-a in periphyton and MU6 will focus on total phosphorus concentrations in water.

At each location listed in Table 10-4 above, samples are collected on a monthly basis (if safely accessible) and weekly during peak transitional times (ie freshet), and submitted to a CALA¹¹-accredited laboratory for analysis. Samples will be analyzed for:

- conventional parameters (pH, dissolved oxygen, specific conductance, total dissolved solids, total suspended solids, hardness, alkalinity, dissolved organic carbon, total organic carbon, colour, turbidity)
- major ions (bromide, fluoride, calcium, chloride, magnesium, potassium, sodium, sulphate, sulphide);
- nutrients (ammonia, nitrate, nitrite, TKN, orthophosphate, total phosphorus, biochemical oxygen demand)
- dissolved and total metals (aluminum, antimony, arsenic, barium, beryllium, bismuth, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, titanium, uranium, vanadium, and zinc)
- field parameters (temperature, specific conductance, dissolved oxygen, pH).

Note¹¹: The Canadian Association for Laboratory Accreditation Inc. (CALA) is a not-for-profit Canadian laboratory accreditation body. Its members participate in rigorous programs of inter-lab comparisons and on-site assessments, based on international standards.

Water quality sampling in the Lake Koocanusa will include the same parameters with the addition of Secchi depth and chlorophyll-a. Due to differences in reservoir and river conditions, sampling methods are adjusted to maintain consistency with the Montana Department of Environmental Quality “Lake Koocanusa Sampling Project – 2013: Water Quality Sampling Plan”. Water samples within the reservoir are being collected at various depths, depending upon stratification at a given location and time. A depth integrated sample will also be collected at the RG_BIGSPRINGS station.

Future data will be used to evaluate ambient water quality relative to current baseline conditions, ecological benchmarks, target concentrations, spatial patterns and temporal trends in the Designated Area.

Regional flow data will be accessed and monitored using Environment Canada’s regional hydrometric data stations. These include Line Creek at the mouth (08NK022), Fording River at the mouth (08NK018), Elk River near Natal (08NK016), Elk River at Fernie (08NK002), and Elk River below Elko Dam (08NK030). These data, in conjunction with the above-mentioned water-quality data, will be used to refine the Model (see Annex D.3: Water Quality Models – Hydrology Inputs Report).

Consistent with current baseline evaluations, spatial variability of surface water quality along the Elk River and its major tributaries (Fording River and Michel Creek) and Lake Koocanusa will be evaluated, and presented in tables and figures that illustrate the results. Water-quality trends will be evaluated at the Order stations and compared to modelled concentrations and targets.

In addition to the requirements stipulated by the Order, data from the other stations routinely monitored in accordance with EMA permits will be considered, as appropriate, in evaluating environmental performance objectives and outcomes.

10.2.2 Substrate Quality (Sediment Quality, Calcite)

Evaluation of substrate quality includes assessment of sediment chemistry and toxicity, as well as monitoring of calcite deposition. Details regarding the goals and approach for future monitoring associated with substrate quality are described below.

10.2.2.1 Sediment Quality

Aquatic habitats of the Elk River watershed are predominantly lotic, with coarse bottom substrates (e.g., cobbles and gravels). Lentic areas such as oxbows, wetlands, ponds and small lakes, where fine sediments can accumulate overtime, are sparsely distributed and represent a relatively small proportion of the aquatic habitat within the watershed (Golder 2014 and Interior Reforestation 2008).

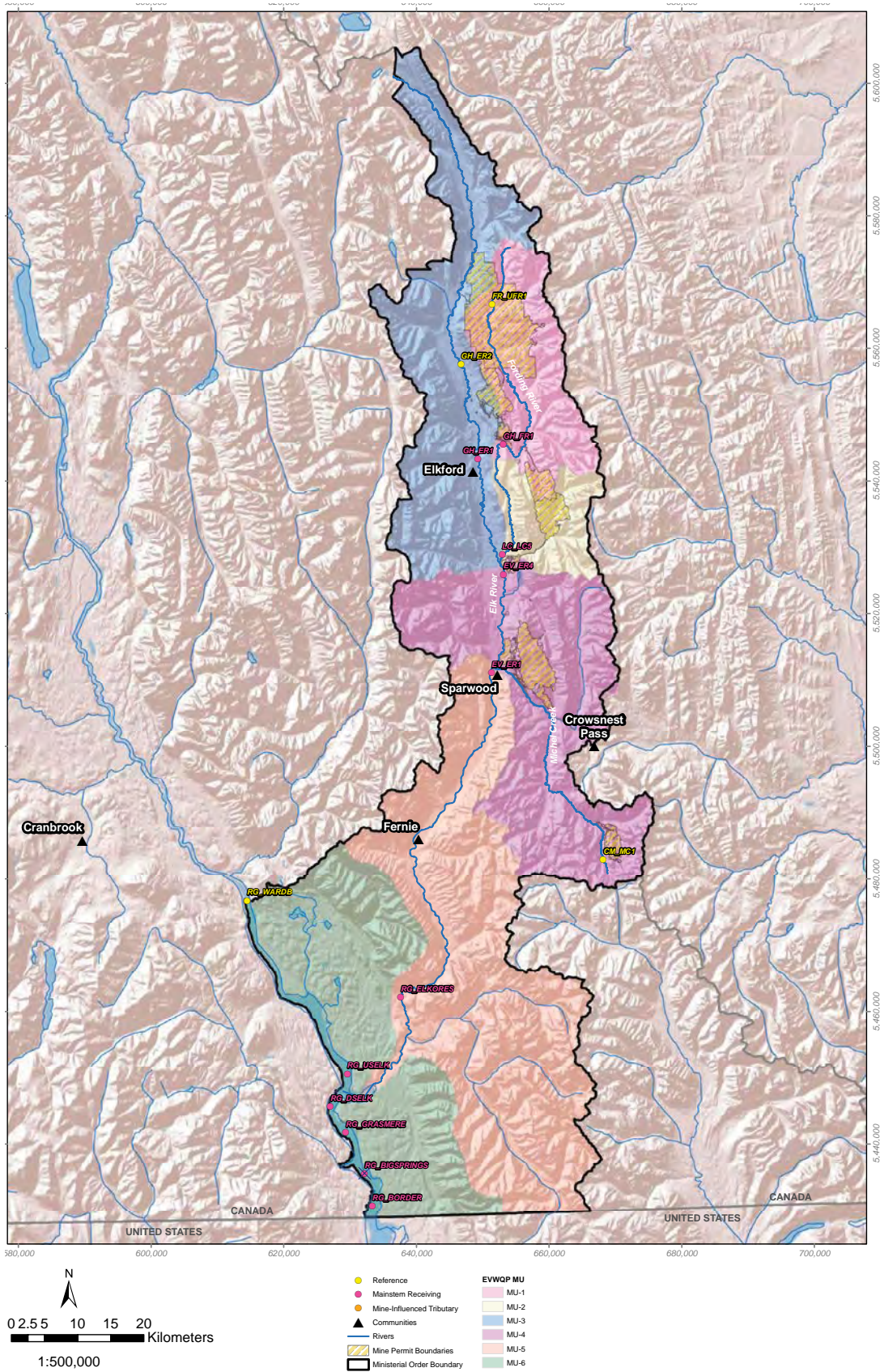


Figure 10-2. Surface water and primary productivity monitoring network.

Sediment quality will be monitored for chemistry and toxicity in the mainstem receiving environment, mine-influenced tributaries and reference areas. This monitoring will focus on samples collected in areas of fine sediment deposition, which have the greatest potential for elevated concentrations of mine-related constituents, to provide an additional line of evidence for evaluating the protection of aquatic life. Data will be evaluated against reference concentrations and sediment quality guidelines, and assessed in terms of spatial patterns and changes over time within the Designated Area.

10.2.2.2 Calcite

The Calcite Index (see Chapter 7) will be used to quantify and monitor calcite deposition within the Elk Valley watershed. These data, in association with information on the types and characteristics of calcite deposits, will be collected in coordination with periphyton and benthic invertebrate monitoring during a supporting study starting in 2014. Monitoring locations will be selected to reflect the full range of calcite index values observed throughout the watershed, so that potential effects on periphyton productivity and benthic invertebrate community structure can be related to the different degrees of calcite deposition. The monitoring will extend into the next cycle of RAEMP sampling (2015), and the results will be used to refine future environmental sampling programs.

10.2.3 Periphyton and Nutrient Monitoring

Waters within the Designated Area are considered oligotrophic and phosphorus-limited. Given that the initial implementation plan involves at least two active water treatment facilities (AWTFs) using biological processes, the addition of phosphorus is an unavoidable consequence of remediating selenium and nitrate-enriched waters. To prevent potential incremental increases in phosphorus from adversely affecting the Designated Area, LAEMPs have been and, if necessary, will be developed to monitor primary productivity in mine-influenced tributaries and downstream receiving environments associated with each AWTF. Upon approval of the Plan and in addition to LAEMPs, primary productivity will also be assessed at representative locations of the Elk River watershed and in Lake Koocanusa, to thoroughly characterize baseline conditions.

The B.C. water quality guideline (WQG) for nutrients and algae within streams are based on chlorophyll-a measurements in periphyton (MOE 2001), which reflect the productivity of chlorophyll-a-producing algae. This WQG is not applicable to lake or reservoir environments; as an alternative, total phosphorus concentrations in water will be sampled to monitor the trophic status of the reservoir. As noted in Chapter 4, existing primary productivity data are spatially limited; therefore, a regional sampling program is proposed to characterize baseline conditions (see Figure 10-2 and Table 10-4). These data will assist in evaluating the potential for eutrophication within the Designated Area, will help inform management decisions (e.g. potential modifications to the active water treatment facilities), and may be used to evaluate bioaccumulation of constituents in the receiving environment.

As illustrated in Figure 10-2, periphyton sampling locations have been positioned to monitor and evaluate spatial patterns along the entire length of the Elk River and its major tributaries (the Fording River and Michel Creek). Based on work within the Designated Area (Minnow, in preparation), collection of periphyton samples for productivity analysis (chlorophyll-a) will be standardized to mid-September (i.e., close to the end of the growing season, and before potential die-off). This will allow for spatial and temporal comparability of data. To the extent possible, periphyton sampling will be conducted synoptically with water sampling in September. Periphyton tissue concentrations for selenium will also be analyzed as part of the RAEMP and to support updates to the bioaccumulation model.

Nutrients, including total phosphorus, will be analyzed as part of the water quality sampling program for Lake Koocanusa (see Section 10.2.1). These data will be compared to current baseline conditions in the reservoir, to evaluate changes over time and confirm the maintenance of trophic status in the lake.

The approach proposed above will directly assess potential eutrophication, and thereby contribute to the understanding of overall ecosystem health. For surface water quality, sufficient baseline data exist to characterize the baseline envelope, and thus can be incorporated into the adaptive management plan (Chapter 11); however, baseline data for primary productivity are limited, and further data collection will be an important component of aquatic ecosystem monitoring.

10.2.4 Benthic Invertebrate Monitoring

Benthic invertebrates represent an important component of aquatic food webs in the Elk River watershed, and therefore play a role in selenium transfer. They also serve as an indicator of overall aquatic ecosystem health, since they integrate the effects of chemical and physical stressors. Benthic invertebrates also have small home ranges (i.e., limited movement compared to vertebrates) making them reliable indicators of localized conditions.

Tissue selenium concentrations and the community structure of benthic invertebrates will be monitored at numerous locations throughout the watershed, including reference, mine-influenced tributaries and receiving environments associated with each of the mining operations. The 2015 sampling design is expected to generally follow the 2012 biological monitoring program (Minnow 2014), which included a comprehensive evaluation of benthic invertebrate communities and tissue chemistry throughout the Designated Area (Figure 10-3). Consistent with monitoring to date, samples will be collected according to Canadian Aquatic Biomonitoring Network (CABIN) protocols (Environment Canada 2010). Community data will be evaluated using the reference condition approach (RCA) as previously discussed in Chapter 4.

Community and/or tissue chemistry data collected as part of site-specific LAEMPs will be used to guide the design and interpretative reporting of the RAEMP, as applicable. Teck is also considering the need for a supporting study specific to evaluation of benthic invertebrate community structure using the Before After Control Impact (BACI) approach as per advice received from the TAC.

Tissue samples will also be collected annually for analysis of selenium concentrations at a few key locations throughout the watershed in coordination with periphyton tissue monitoring. This data will be presented and evaluated for spatial and temporal patterns, as well as potential effects on invertebrates or their predators. These concentrations will also be used to validate and refine the selenium bioaccumulation model. This approach is consistent with data handling steps performed for the current baseline evaluation (see Annex K.1).

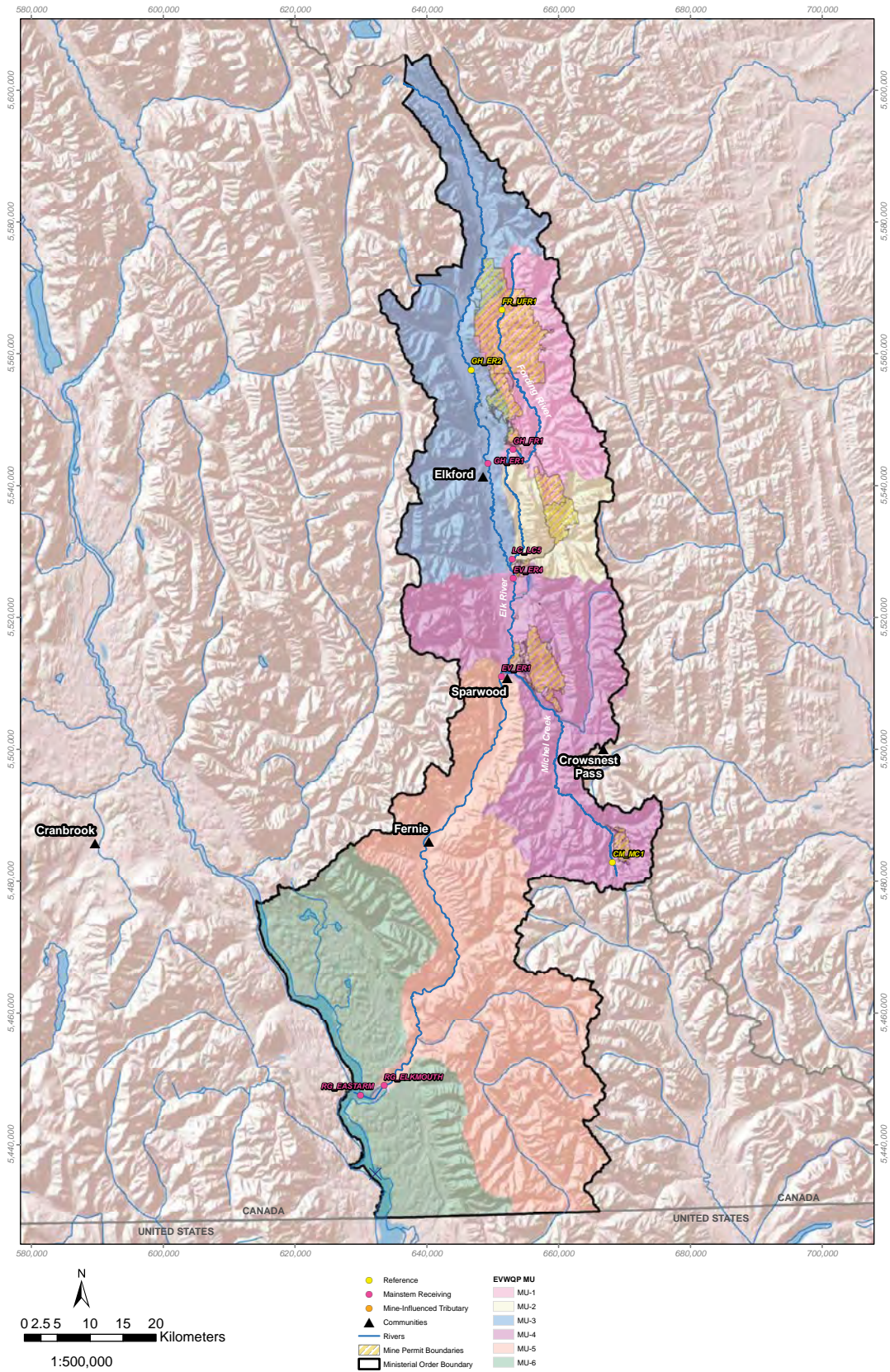


Figure 10-3. Benthic invertebrate community structure monitoring network.

10.2.5 Fish and Fish Population Health

The health and sustainability of fish populations in the receiving environment are important to maintaining ecosystem functions within the watershed, as well as supporting an active fishery. Monitoring of fish populations/health and tissue selenium concentrations will be included in the RAEMP.

Two species, westslope cutthroat trout (WCT) and longnose sucker, will serve as sentinel species in the assessment of fish populations and health. WCT are widely distributed throughout the watershed, and are the only species present in the Fording River upstream of Josephine Falls. Although longnose sucker populations are typically more localized at lower elevations, they represent an important component of lentic habitat in those areas.

The fish health monitoring program will aim to assess differences in endpoints such as population size/demographics, body condition, and growth in mine-exposed areas compared to reference areas and also compared within the same areas over time.

Multiple years are required to understand and quantify fish population characteristics, potential changes, and relationships to multiple stressors (e.g., mining, angling, extreme weather events, water chemistry, habitat fragmentation). Teck will continue the multi-year (2012–2015, inclusive) WCT study in the Fording River upstream of Josephine Falls. The objectives of this study are to assess whether the WCT population in the upper Fording watershed is healthy, robust and sustainable, and to assess movement and critical habitat to help guide fish habitat management decisions. Data collected in this study will also help identify future monitoring endpoints associated with the RAEMP, to assist in evaluating fish population health and potential effects of multiple stressors over time.

Longnose sucker monitoring will include assessment of fish health and population endpoints in a variety of off-channel habitats where populations are of sufficient size that they can be reliably quantified and tracked. Details related to collection methods, sampling areas, sample sizes and data analysis will be provided in the RAEMP study design.

Collection of fish tissues for selenium analysis may also be incorporated into the RAEMP as required. The two sentinel species (WCT and longnose sucker) will be targeted along with mountain whitefish. Tissue data will be compared to established benchmarks and historical data, and will be evaluated outside of the RAEMP with respect to fish consumption guidelines in support of updates to the Human Health Risk Assessment (Chapter 5). Details related to collection methods, sampling areas, sample sizes and data analysis will be provided in the RAEMP study design, as guided by EMA authorization requirements.

10.2.6 Ecotoxicology Assessment

Sublethal toxicity tests using ambient site-waters have confirmed that current baseline surface water concentrations do not adversely affect sensitive aquatic receptors. The most sensitive species is cladoceran (*Ceriodaphnia dubia*), and early-life stages (embryo test) of rainbow trout (*Oncorhynchus mykiss*).

Toxicity tests to date did not necessarily capture the full range of concentrations within the Elk and Fording Rivers (e.g., low-flow and high-flow). As a result and upon Plan approval, a supporting study will be initiated to evaluate sublethal toxicity. Locations for the sublethal ecotoxicology assessment program will be confirmed as part of the study design which will be finalized in early 2015. The study design will include methodology for specific toxicity tests (e.g., Environment Canada's biological methods, longer-term methods as recommended through TAC advice).

The primary purposes of the sublethal toxicity tests will be to:

- monitor ambient conditions to confirm that targets are protective of the aquatic biota
- monitor to address uncertainties associated with dissolved cadmium during Plan development
- provide inputs for further evaluation.

Unlike the other water quality constituents of interest (selenium, sulphate and nitrate), cadmium has its highest concentrations during spring freshet (high-flow), when toxicity-modifying factors (e.g., hardness and dissolved organic carbon) are at their lowest. As a result, to confirm that cadmium concentrations are consistent with the environmental performance objectives and outcomes of the Plan, sublethal toxicity tests will be performed twice per year for two years. Supporting study results will inform the need for continued testing and will be evaluated in consultation with MOE and in consideration of RAEMP data needs. The primary purpose of the ecotoxicology supporting study is to validate ambient environmental conditions.

Additional surface water samples may be collected synoptically with other biological data as part of the RAEMP to measure aquatic toxicity to biota representing different trophic levels and thereby provide an additional line of evidence for evaluating conditions at representative locations of the watershed. Sediment toxicity testing will be done as noted Section 10.2.2.1.

10.2.7 Lake Koocanusa

Water quality monitoring within the reservoir will continue as detailed in section 10.2.1. In 2014, a comprehensive monitoring program was initiated to characterize chemical and biological conditions within the reservoir.² This monitoring program includes:

- water (quality synoptically captured with biological monitoring endpoints)
- sediment (quality)
- plankton (community composition, tissue metal concentrations and productivity)
- benthic invertebrates (tissue metal concentrations and community survey)
- fish (tissue metal concentrations and health endpoints).

Biological monitoring will continue in the reservoir in 2015 and 2016, after which results will be assessed to develop the scope of future monitoring as part of the RAEMP.

10.2.8 RAEMP Reporting

At the conclusion of each cycle of the RAEMP, an interpretive evaluation report will be prepared to:

- explain the methods used for sampling and analyses
- present the results of all components of the program intended to assess the aquatic ecosystem health, and water chemistry changes for constituents of concern
- evaluate all lines of evidence to contribute to the understanding of whether management and mitigation actions are working as expected.

The evaluation will consider all lines of evidence and available data within the Designated Area. The evaluation of data will determine if additional supporting studies are required to address any identified data gaps and critical uncertainties.

In advance of each cycle of RAEMP implementation, a detailed study design will be submitted to MOE and Ktunaxa Nation Council. It will outline study objectives, locations, methods, sample sizes, and schedule for sample collections, along with the technical rationale for any changes proposed from the previous cycle.

Reporting requirements associated with existing EMA permits, EA current baseline data and supporting studies will be independently maintained. The relevant data, results, and conclusions of these reports will be incorporated into the RAEMP interpretive report as appropriate, and will also guide the design of future monitoring programs.

10.3 Groundwater

The approach to groundwater monitoring is three-pronged and includes: a groundwater synthesis report, implementation of a groundwater monitoring program informed by the outcomes of the synthesis report, and development of supplemental management strategies if required (see Annex L.3).

Groundwater Synthesis Report

The ground water synthesis report will evaluate regional groundwater conditions and protection objectives in the context of existing mitigation and management strategies. The report will also assess anticipated future groundwater conditions based on changes to mining activities and water quality improvements resulting from mitigation actions. This assessment will lead to identification of areas and/or aquifers that may require protection or consideration of adaptive management steps to achieve related water quality objectives. Where areas are identified as potentially requiring additional consideration, an evaluation of the appropriate management strategies will be performed. The report will incorporate information from groundwater programs implemented or in development at each Teck Elk Valley operation as well as baseline data captured as a component of Environmental Assessments and results from the well sampling program detailed in Chapter 5. For example, existing EMA and Mines Act permits include requirements to establish groundwater monitoring programs for the purpose of better understanding the fate and transport of groundwater on a localized level. The objectives of these monitoring programs are to:

- characterize the groundwater resource (including water quality, quantity, flow, hydraulic connectivity of the affected aquifer(s), and relationships to surface water)
- identify and if necessary, quantify, impacts to groundwater from mining-related activities
- provide information necessary to support the development and verification of water quality predictions for mine sites.

In addition to these programs, data from groundwater monitoring associated with Teck's Applied Research and Development (R&D) program will be considered in the development of the groundwater synthesis report.

Monitoring Program

The groundwater monitoring program will be developed based on results and gaps identified in the groundwater synthesis report. While the exact monitoring components are to be determined, the well sampling program will be one component that will continue in advance of completing the groundwater synthesis report and recommendations. Although results from the well sampling program showed that baseline groundwater concentrations do not present an unacceptable risk to consumers, 11 wells, or ~12% of those sampled, had elevated values of the Order constituents of interest (within 30% of the WQG). The groundwater monitoring program will include resampling these 11 wells that either exceeded guideline or were within 30% of the WQG. Ten additional wells will be added to provide additional data. These wells have been selected based on high usage (multiple users or uses for the well) or slightly elevated concentrations during the initial screening for one or more of the Order constituents.

Supplemental management strategies

The collective information gained from operational monitoring, applied R&D, well sampling program and Environmental Assessment baseline data evaluated through the groundwater synthesis report will provide the

necessary information to develop the regional groundwater monitoring program and serve to assess and inform the effectiveness of mitigation measures implemented as part of the Plan. As such, supplemental management strategies will be developed as part the adaptive management process to ensure protection of groundwater is achieved.

10.4 Human Health

Data collected as part of the aquatic ecosystem health and groundwater monitoring programs will be used in future updates to the Human Health Screening Level Risk Assessment, as detailed in Chapter 5. Data sources will include:

- surface water quality
- groundwater quality
- sediment quality
- tissue constituent concentrations (e.g. selenium).

Data on additional terrestrial pathways (e.g. meat and organ tissue concentrations for wild game, riparian plants), collected as part of Teck’s baseline data programs for EAs, will also be used to update the human health risk assessment.

10.5 Other Monitoring

There are additional monitoring programs that Teck captures data from to fulfill other objectives related to permits, Applied R&D, performance measurement and for general information. Data from these programs may also be used to assist in evaluation of whether Plan objectives are being met, as appropriate. Table 10.5 highlights some of these programs and their potential data inputs.

Table 10.5. Other monitoring to assist in evaluating success of Plan objectives.

Other monitoring	Data collection types
Meteorological	Precipitation (snow, rain), wind speed, wind direction, humidity, temperature, pressure
Reclamation and closure	Vegetation mapping, soil placement techniques, elevation impacts on species distribution, vegetation mitigation planning, assessment of metals in soils and vegetation, and reclamation sources
Hydrology	Hydrometric monitoring
Applied R&D	Geochemical and isotopic waste analysis, spoil gas composition data, waste rock leaching data, waste rock microbial data, isotopic and geochemical water quality monitoring onsite and regionally, groundwater quality monitoring in disturbed and undisturbed ground, surface treatment water balance data (i.e., evapotranspiration, run off, net percolation and storage for different reclamation options), snow deposition, melt and abolition data, vegetation survey, disturbed and native ground geophysical surveys, hyporheic zone mapping

Note: This is a summary of potential data that will or has been collected in Teck’s other monitoring programs. Data inputs will be assessed and regularly reviewed to determine ongoing monitoring endpoints.

10.6 Quality Assurance/Quality Control

QA/QC programs will involve collection of scientifically credible samples that permit evaluation of data quality objectives and statistical interpretation of the data collected. QA/QC programs will be developed, implemented and reported on for each monitoring program or supporting study, to confirm that the sampling processes standardized and consistent and that meaningful data with known sampling errors and/or variance are being captured.

10.7 Reporting

Results of the monitoring programs may be evaluated, to:

- assess environmental conditions
- confirm whether Plan objectives are being met
- identify and help define the need for adaptive management actions
- refine planning tools used in the development of the Plan (e.g., the Elk Valley Water Quality Planning Model and selenium bioaccumulation model).

This information will be summarized in two reporting formats: 1) an annual water quality report; and 2) a three-year Plan report that corresponds to the reporting cycle for the aquatic effects monitoring program (Chapter 11). The RAEMP report will form a part of the three-year Plan report as per details in Section 10.2.8. Summary reports and associated data collected under ecosystem monitoring programs will be provided to MOE and the Ktunaxa Nation Council, and made available to public on the Plan website (www.teckelkvalley.com).

Chapter 11

Adaptive Management

Chapter Overview

This chapter describes the adaptive management framework for the Elk Valley Water Quality Plan (the Plan) and outlines the tiered decision-making framework for adaptively managing the Plan during implementation.

Concordance with Ministerial Order and Terms of Reference

Chapter 11 is the primary chapter that satisfies Section 3.16 of the Elk Valley Water Quality Plan Terms of Reference, and combined with other chapters satisfies Sections B.15 and B.16 and Section D of Schedule C of Ministerial Order M113 and sections 3.9(a), 3.12, 3.13, 3.14, 3.15, 3.16 and 4.2.2 of the Elk Valley Water Quality Plan Terms of Reference.

Highlights

- **Teck will be responsive to monitoring data and supporting studies, applied R&D and changing circumstances, and will update the Plan as required to meet water-quality and calcite targets and environmental management objectives.** Adaptive management is a systematic process for reviewing the Plan to ensure that objectives are being met, to adjust management actions as required to achieve its targets, and/or to review and adjust targets when appropriate. Monitoring of water quality, ecosystem health, periphyton, and groundwater and other supporting studies will enable modifications to take new information and changing circumstances into account.
- **Teck will also update the initial implementation plan based on R&D advances, development of mine plans, and reviews of other relevant management plans.** R&D may lead to the incorporation of new technologies and management approaches. Mine reclamation and closure plans, and changes to mine plans, will be incorporated into the Plan. Development of new mines in the Elk Valley will require re-examination of the Plan.

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11.1 Introduction

The Order (Schedule C, Section A) specifies that to remediate water-quality effects of past activities, the Plan will describe the following operational actions to be taken by Teck:

- Immediately begin to stabilize concentrations of selenium, cadmium, nitrate, and sulphate, and the rate of formation of calcite in the waters of the Designated Area (see Chapter 8; initial implementation plan).
- In the medium-term, reduce the rate of formation of calcite, and set targets to demonstrate progressive reduction in water quality concentrations of selenium, cadmium, nitrate and sulphate in the Designated Area (see Chapter 7; calcite management plan).
- In the longer term:
 - Further reduce concentrations of selenium, cadmium, nitrate and sulphate in the Designated Area to acceptable contaminant levels, as defined by long-term concentration targets and timeframes (see Chapter 8; initial implementation plan).
 - Control the rate of calcite formation to acceptable levels as defined by long-term targets and timeframes (see Chapter 7; calcite management plan).

The environmental management objectives of the Plan specified in the Order (Schedule C, Section B, 7) include:

- protection of aquatic ecosystem health
- management of bioaccumulation of contaminants in the receiving environment
- protection of human health
- protection of groundwater.

The targets and timeframes for water quality and calcite management were developed taking the following Order requirements (Schedule C, Section B, 10) into consideration:

- current contaminant concentrations
- current and emerging economically achievable treatment technologies
- sustainable balancing of environmental, economic and social costs and benefits
- current and emerging science regarding the fate and effects of contaminants.

The approach in the Plan reflects Teck's current understanding of how best to manage water quality and calcite, and the targets established pursuant of the Order. Many factors will change over time, and will require adaptive management. The over-arching objective of adaptive management is to provide a structured but flexible process for evaluating and, when required, adjusting the Plan, in response to new information and changing circumstances, to allow the goals and environmental management objectives of the Plan to be achieved as circumstances change.

Adaptive management will address the following more specific objectives:

- Incorporate the results of monitoring the aquatic environment in the Designated Area, relative to meeting the environmental management objectives of the Plan.
- Use the results of supporting studies that are developed to validate and inform the Plan and to address specific uncertainties (e.g., selenium bioaccumulation model).
- Incorporate new mitigation measures developed by Teck's R&D program, to improve the long-term sustainability of the initial implementation plan and calcite management plan by enhancing cost-effectiveness, long-term operation and maintenance, and environmental performance.

- Take reclamation and closure issues into account in future updates of the initial implementation plan and calcite management plan, as reclamation research and monitoring address uncertainties and provide quantitative measures of how reclamation practices and plans at Teck operations influence water quality and calcite¹.
- Manage changes in resource evaluation and mine plans, and update the Plan accordingly.
- Update the planning tools used during implementation, including the Elk Valley Water Quality Planning Model (the Model), selenium bioaccumulation models, and site-specific hydrologic and water balance models that support detailed design of mitigation measures.
- Review and, if required, update water-quality and calcite targets and timeframes to reflect results of aquatic effects monitoring and advances in science (e.g., literature publications).
- Re-evaluate the sustainable balancing of environmental, economic and social costs and benefits to reflect any changes to future mine plans by Teck or proposed development of new mines by other proponents. Depending on the circumstances, adaptive management could lead to lower or higher long-term target levels, and shorter or longer implementation timeframes.

The overall adaptive management process is illustrated in Figure 11-1. Each adaptive management component incorporates periodic evaluation and reporting, and identifies trigger points that determine if additional root-cause analysis is required to determine whether the plan must be adapted. This process is described in Sections 11.2 through 11.7. As Teck gains experience and knowledge during implementation, the adaptive management components will themselves evolve. Teck will also coordinate Plan implementation with other relevant management plans, as discussed in Section 11.8. Plan evaluation and reporting is described in Section 11.9 and public reporting is described in Section 11.10. Adaptive management for calcite is presented in Chapter 7.

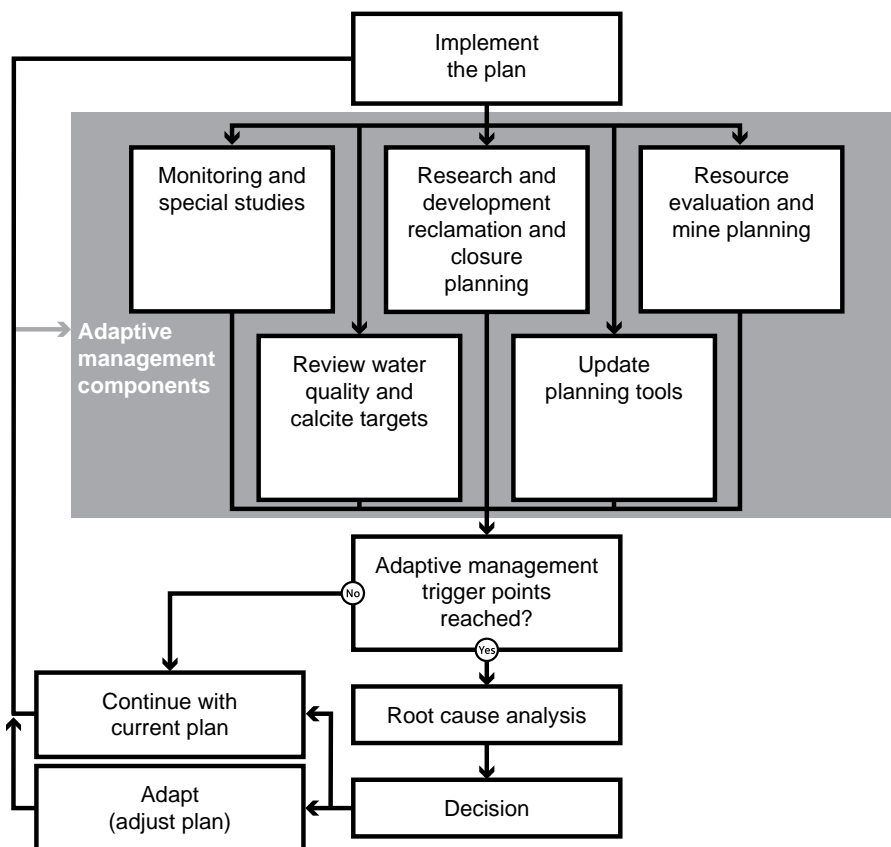


Figure 11-1. Adaptive management decision framework.

¹ The influence of reclamation activities and closure planning is not presently included in the water quality predictions for the initial implementation plan. This conservative measure was taken to account for the current uncertainty in the effectiveness of reclamation to reduce infiltration.

11.2 Monitoring and Supporting Studies

Environmental monitoring, as outlined in Chapter 10, will be used to evaluate whether Plan objectives are being met. The main components that will contribute to adaptive management are:

- water quality monitoring at Order stations
- regional aquatic effects monitoring
- groundwater monitoring
- human health assessment.

These monitoring components will provide a direct means of evaluating:

- aquatic ecosystem health
- bioaccumulation of constituents
- the potential for eutrophication
- the protectiveness of long-term targets (through sublethal toxicity testing)
- the protection of groundwater and human health.

Supporting studies were incorporated into monitoring programs to address uncertainties that require further evaluation. Additional supporting studies may be identified and completed during Plan implementation. Together, data from monitoring and supporting studies will facilitate assessment of whether the Plan is achieving its environmental management objectives.

11.2.1 Water-Quality Assessment

The primary effect pathway is associated with release of selenium, nitrate, sulphate and cadmium (Order constituents) from mine sources and advective transport in water. Water-quality monitoring data at Order stations will be collected monthly and assessed annually to determine if concentrations, loadings and trends of constituents are consistent with predictions and remain on track to meet water-quality targets and timeframes. Additional adaptive management triggers will be developed for monitoring locations located closer to source areas in mainstem river and tributary locations, including any monitoring locations specified in effluent permits issued under the B.C. Environmental Management Act.

The evaluation will include updated model predictions that incorporate any model refinements, changes to mine plans, and adjustments to the initial implementation plan. The primary triggers for annual water quality assessments will be:

- Did any measured constituent concentrations for the year fall outside of the envelope of predicted future concentrations?
- Is the temporal trend of Order constituent concentrations and loadings different from model predictions?

The full evaluation methodology will be provided in the first annual water-quality and calcite update report (see Section 11.9). This will include evaluation of the quantitative thresholds for the difference between measured and predicted trends that would trigger the need for root-cause analysis. The methodology and triggers will be reviewed as part of each annual report, and updated as appropriate.

The evaluation will account for variability in flows, spatially and temporally, and how this may affect constituent concentration trends. One way to accomplish this is to compare measured concentrations, using actual flows, to modelled results. A 12-month rolling average can be used for selenium and nitrate, because their trajectories will change with implementation of mitigation measures. Seasonal variations, including high and low flow conditions will be considered as part of the data evaluation.

Statistical trend analysis will be used to assess sulphate and cadmium, because no mitigation is planned for these constituents. Trends will be evaluated to assess the potential for future concentrations to exceed their targets. Historical trends for cadmium are inconsistent, and future concentrations are expected to have a negligible potential to exceed long-term target levels at any Order stations. Work is continuing on developing a predictive model for cadmium, which will be incorporated into the annual evaluation if it can be modelled with sufficient resolution to be used as a planning tool.

Sulphate concentrations are projected to remain below long-term targets indefinitely at all Order stations, with the possible exception of FR4 in the upper Fording River (MU-1), where concentrations could reach long-term targets by 2030. However, the model predictions are conservatively high, and will be compared with a statistical trends analysis to evaluate this risk. A toxicity testing program will also be developed and implemented to validate and, if appropriate, revise the long-term target. If sulphate concentrations remain on a trend to reach the long-term target at FR4, this will require re-evaluation of the treatment technologies or other mitigation measures to control sulphate, and of the water-quality targets and timelines.

If one or more water quality triggers are reached, then a more detailed root-cause analysis will be undertaken. Specific investigations that could be considered in a root-cause analysis include:

- a review of mitigation measures to determine whether underperformance contributed to triggers being reached
- a mass-balance evaluation of constituent concentrations, flows and loadings to identify source areas that contributed to triggers being reached
- a review of the Model, including the hydrology inputs, geochemical source-terms and model assumptions, to determine if refinements to the Model are required.

The root-cause analysis will identify need for adaptive management actions that could include one or more of the following:

- further investigations or more frequent evaluation, if the cause is not sufficiently well- understood to make a management decision
- adjustment of triggers, targets or timeframes
- improving performance of existing mitigation projects
- increasing or decreasing the level of future mitigation
- revising the scope or frequency of monitoring programs
- continued monitoring, and re-evaluation after the next cycle.

Variations in expected concentrations may result in conditions better or worse than expected. Because of the high level of year-to-year and seasonal variability of the hydrology in high elevations areas like the Elk Valley, decisions to increase or decrease the level of future mitigation would typically require several years of data, to distinguish between natural variability and a variance from expected performance. If potential variances from expected performance are identified, additional analysis and follow-up work will be undertaken to identify the root cause and to implement the actions needed to meet short-, medium- and long-term water-quality targets and timeframes, or to assess appropriate adjustments to those targets and timeframes.

The general decision process for the assessment of water quality at Order stations is shown in Figure 11-2.

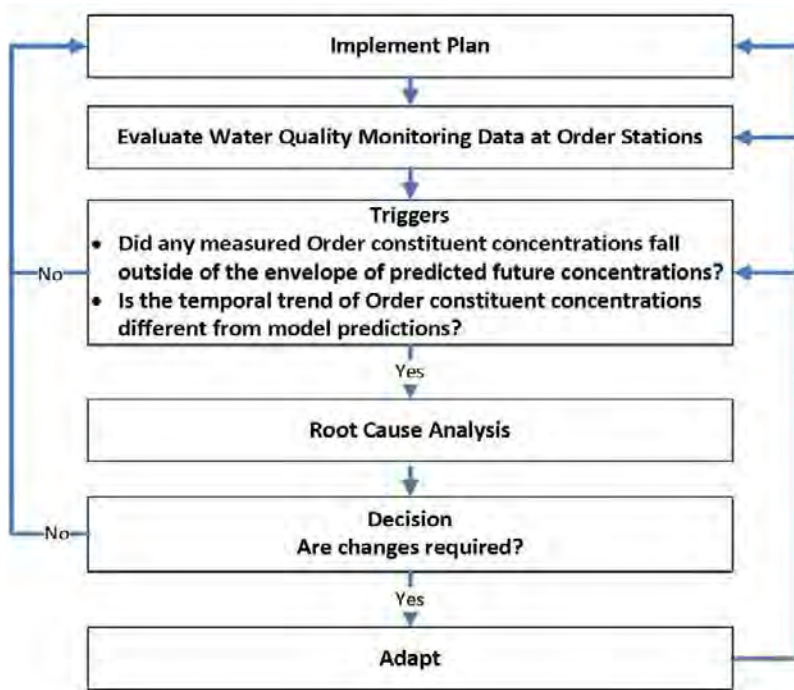


Figure 11-2. Order stations water quality decision framework.

11.2.2 Regional Aquatic Effects Monitoring

As described in Chapter 10, the regional aquatic effects monitoring program (RAEMP) will measure and integrate multiple types of data to assess the health of the aquatic ecosystem throughout the Designated Area. The RAEMP provides an integrated assessment of pathways for release, transport and fate of Order constituents in water, sediment and biota, as well as the combined effects of all stressors on sensitive biota. RAEMP components that will be used to adaptively manage the Plan for selenium, nitrate, sulphate, cadmium and calcite include:

- monitoring of the integrated effects of Order constituents on water, sediment and biota
- monitoring of nutrient levels in water and periphyton in the Elk Valley, and phosphorus and chlorophyll-a concentrations in Lake Kooconusa, to evaluate primary productivity
- an ecotoxicology supporting study to assess protection of the aquatic life, address uncertainties and, if required, update long-term water-quality targets.

11.2.2.1 Integrated Aquatic Effects Monitoring

The RAEMP will use a three-year integrated evaluation and reporting cycle for all components. The second cycle of regional aquatic effects monitoring is 2013 to 2016, with an interpretative report in 2017. Adaptive management triggers related to monitoring will be developed and evaluated in a three-year Plan report, which will be developed in parallel with the second cycle of the RAEMP interpretive report (see Section 11.9). The RAEMP assessment and measurement endpoints that will be used to develop and evaluate adaptive management triggers for the Plan are listed in Table 11-1.

Table 11-1. Monitoring endpoints and adaptive management triggers.

Stressor Category	Mine-Related Stressor	Dominant Pathway	Assessment Endpoint	Measurement Endpoint	Elk River Watershed	Lake Koocanusa	Basis for Adaptive Management Triggers
Chemical	Selenium	Dietary accumulation	Toxicity ¹	Water chemistry	✓	✓	Water-tissue relationships described in site-specific bioaccumulation models.
			Toxicity ¹	Tissue selenium concentrations	✓	✓	Tissue guidelines and benchmarks.
			Toxicity ¹	Water chemistry	✓	✓	Short-, medium-, and long-term targets at Order stations. Mainstem and tributary concentrations and trends at additional monitoring stations closer to source areas. Water quality concentrations and compliance limits specified in EMA permits.
Physical	Selenium, nitrate, sulphate, cadmium (and potentially others)	Water contact and/or uptake	Toxicity ¹	Surface water toxicity tests	✓		Toxicity response.
			Toxicity ¹	Sediment chemistry	✓	✓	Sediment quality guidelines, benchmarks, reference concentrations.
			Toxicity ¹	Sediment toxicity tests	✓		Toxicity response.
	Multiple		Community Structure	Benthic invertebrate EPT and E proportions	✓		Reduction relative to reference conditions and in mine-influenced monitoring areas over time.
			Population	Westslope cutthroat trout and longnose sucker population characteristics	✓		Changes in populations over time.
	Nutrients (Phosphorus and Nitrogen)	Water contact and/or uptake	Eutrophication	Water nutrient concentrations	✓	✓	Guidelines, benchmarks, targets, reference conditions, changes over time.
				Periphyton chlorophyll-a and biomass	✓		
				Water column chlorophyll-a		✓	
	Calcite	Substrate characteristics	Community structure	Calcite index (presence and concretion)	✓		Initial trigger levels based on concretion scores. Combined calcite and benthic invertebrate monitoring will be undertaken as a supporting study in 2015 to update target and adaptive management trigger levels to account for calcite effects to EPT and E proportions and periphyton biomass (see Chapter 7).

Notes: ¹ Assessing survival, growth and/or reproduction.

Adaptive management triggers will incorporate:

- water quality guidelines (WQGs), benchmarks and targets for selenium, nitrate, sulphate and cadmium
- effects to benthic invertebrate community structure
- B.C. WQGs for nutrients and algae, including periphyton chlorophyll-a guidelines for streams and total phosphorus concentrations in water for lakes
- selenium tissue guidelines and site-specific benchmarks for the protection of aquatic life
- sediment quality guidelines for selenium and cadmium
- calcite targets, based on an evaluation of effects of calcite on benthic invertebrates, periphyton and physical and chemical measures of stream-bed habitat
- status of juvenile and adult WCT in the upper Fording River.

Monitoring of selenium in water and tissue will also be used to validate and update the selenium bioaccumulation models discussed in Section 11.6. Adaptive management triggers, associated root-cause analyses and potential adaptive management actions will be fully developed as part the first cycle of the three-year Plan reporting (see Section 11.9).

If one or more triggers are reached, a more detailed root-cause analysis will be undertaken. For example, if monitoring identified a greater effect on benthic invertebrate community structure at locations where conditions were expected to be stable or improving, this could trigger a root-cause analysis. The analysis could include a supporting study to re-sample areas to check whether the differences detected from monitoring are anomalous or real.

11.2.2.2 Primary Productivity Monitoring

The trophic state describes the general biological status of surface waters. Surface waterbodies with an oligotrophic trophic state have low algal concentrations (i.e., low primary productivity), whereas eutrophic systems will have higher algal concentrations. The trophic state of surface waters is influenced by nutrient inputs and other factors (e.g., temperature, turbidity, shading) Phosphorus is the focus of adaptive management of primary productivity, because it is and will remain the limiting nutrient in Designated Area, and release of phosphorus from AWTFs is the primary mine-effect pathway.

As described in Chapter 10, periphyton and nutrients will be monitored within the Elk Valley (MUs 1-5), and nutrients and chlorophyll-a will be monitored in Lake Koocanusa (MU-6), to evaluate changes in primary productivity. As outlined in Chapter 6, the use of biological AWTFs to treat selenium and nitrate-enriched waters is expected to increase total phosphorus concentrations in surface waters. Monitoring will therefore assist in evaluating the potential for unacceptable increases in primary production, and guide adaptive management related to phosphorus to meet the environmental management objectives.

The B.C. WQGs for nutrients and algae (Nordin 2001) will be adopted as an interim adaptive management trigger for primary productivity of streams in the Elk Valley. The B.C. guideline for streams is based on algal chlorophyll-a rather than water nutrient concentrations, because the effects of nutrients cannot be reliably predicted relative to other conditions that affect primary productivity in streams (e.g., water velocity, light intensity, water temperature, and invertebrate grazing pressure). The periphyton guideline for recreational and aesthetic purposes is 50 mg/m² chlorophyll-a, and the guideline for the protection of aquatic life of 100 mg/m² chlorophyll-a.

Algal monitoring and recent analysis in Lake Koocanusa is relatively limited, and further monitoring is required to establish primary productivity triggers. Woods 1982 evaluated limnological data for Lake Koocanusa from 1972-1980, and concluded that although Lake Koocanusa was eutrophic based on nutrient loadings, its water quality and primary productivity data classify it as oligotrophic. A B.C. MOE study that examined primary

productivity in Lake Koochanusa from 1972 to 1990 reached a similar conclusion, noting that that factors regulating the trophic state likely include a combination of physical and nutrient conditions (Hamilton et al. 1990). Paragamian 2002 concluded that Lake Koochanusa acts as a nutrient sink. These studies illustrate the complexity of the factors controlling primary productivity in Lake Koochanusa.

Teck will monitor nutrients and chlorophyll-a in Lake Koochanusa, and nutrient inputs from the Elk River, to evaluate whether primary productivity triggers related to nutrient inputs from the Elk River can be established. The Canadian guidance document for management of phosphorus in freshwater water systems (CCME 2004) provides a framework that will be considered when evaluating primary productivity in Lake Koochanusa.

A root-cause analysis, described above, will be undertaken if periphyton chlorophyll-a concentrations at any Order station in MU-1 to 5 are expected to exceed the periphyton WQG for recreational and aesthetic purposes of 50 mg/m². Nutrient and chlorophyll-a monitoring data in Lake Koochanusa will be evaluated as part of the RAEMP.

Teck is also updating the Model to provide improved resolution for predicting future increases in total phosphorus concentrations in the Elk and Fording rivers. The model will be used to assist with adaptive management of phosphorus.

11.2.2.3 Ecotoxicology Assessment

During development of the Plan, sublethal toxicity tests using ambient waters were completed and used to assess baseline water-quality conditions (Chapter 4), and to set long-term targets (Chapter 8). The tests did not capture the full range of Order constituent concentrations in the Elk and Fording rivers (e.g., under low- and high-flow conditions), nor specific long-term tests recommended by the TAC.

A sublethal toxicity testing supporting study will be undertaken during Plan implementation (see Chapter 10) to confirm that surface waters that meet water-quality benchmarks for Order constituents are not toxic to sensitive aquatic receptors. The adaptive management trigger would be an EC₂₀ sublethal effect. Should ambient tests show no toxicity, this would indicate that conditions meet Plan objectives. If there is a sublethal effect, the tests will be repeated under similar conditions. If the second test(s) also show a sublethal effect, Teck will conduct a root-cause analysis (e.g., ongoing testing at the same location or toxicity identification evaluations) to guide the adaptive management decision-making process. Ambient sublethal toxicity tests will also be used to confirm and, if required, revise long-term targets (see Section 11.7). A study design for an ecotoxicology supporting study will be prepared by the end of the first quarter of 2015, for implementation beginning in the second half of 2015.

11.2.3 Protection of Groundwater

As described in Chapter 5, baseline groundwater concentrations are protective of human health. The initial groundwater evaluation identified two transport pathways for constituents of interest in groundwater: source release to upland groundwater (at the mine sites²), and surface water recharge from the Elk River to groundwater. As such, groundwater in the Elk River floodplain has a high degree of hydraulic connectivity to the Elk River, resulting in a greater potential for shallow groundwater to be influenced by the constituents. In particular, shallow groundwater in floodplain areas hydraulically down-gradient of a meander may receive a higher component of surface water recharge. Surface water recharge to groundwater also appears to be higher where river gradients are higher. These findings were validated by slightly elevated constituent concentrations in a limited number of groundwater wells within the Elk Valley.

To evaluate whether the implementation plan is protective of groundwater, well samples will continue to be

² Under existing EMA authorizations, individual mining operations are developing groundwater monitoring networks and programs to improve the understanding of groundwater at an operational (local) level. Results of these investigations will be used to help improve Teck's understanding of local groundwater in relation to potential mitigation scenarios.

collected. As described in Chapter 10, sampling will be conducted quarterly to account for seasonal variability. These data will be used to confirm that groundwater concentrations remain protective of human health. Well monitoring will continue until selenium concentrations stabilize in the Elk River watershed.

As part of existing EMA and Mines Act Permits, groundwater monitoring programs have been implemented or are in development for each of Teck's coal operations in the Elk Valley. The objective of programs is to better understand the influence of mine operations on groundwater and potential interactions with surface water. Results will be used to assess the potential influence of Teck operations on groundwater wells and support adaptive management of groundwater.

If concentrations in wells remain above drinking water guidelines for Order constituents, additional monitoring will be considered. The adaptive management trigger would be an increasing trend in groundwater well concentrations. Should the data indicate that concentrations are increasing, a root-cause analysis will be conducted to guide the adaptive management decision-making process. A root-cause analysis could, for example, include a supporting study to better understand groundwater-to-surface-water connections in a particular area.

11.2.4 Human Health Assessment

The human health assessment was completed for baseline conditions (see Chapter 5), and determined that present concentrations do not present unacceptable human health risks. . The assessment will be updated periodically. If a human-health risk related to Order constituents is identified, root-cause analyses could include further characterization and assessment of risks, or supporting studies to address uncertainties. Adaptive management actions could include:

- revising the human health assessment to reflect the results of root-cause analysis
- supporting studies to address uncertainties
- adapting the water quality implementation plan.

11.3 Research and Development

The focus of Teck's R&D is to investigate and implement more effective and efficient solutions for managing constituents of interest in mine-affected watersheds. Active water treatment technology R&D and source control R&D are the two components of this initiative, and guided the selection of the management options described in Chapter 6. As R&D continues, new technologies and management approaches may be used in adaptive management of the Plan implementation. As stated in Section 6.3.1, the steps for advancing technologies to a stage where they can be considered for full deployment are:

1. Identify basic knowledge and technology.
2. Identify sites for full-scale implementation.
3. Bound the risks.
4. Prioritize implementation technologies and sites.
5. Implement at full scale.
6. Monitor and improve first implementation.
7. Consider broader technology applications within mine plans.

The adaptive management trigger will be when new technologies reach step 7, and have been developed to the stage where they can be considered for broader application within existing mine development areas and for future mine plans. Instead of a root-cause analysis, the adaptive management trigger will result in a re-evaluation of the initial implementation plan or calcite management plan to include new technologies. Incorporation of new technologies will be evaluated in the context of sustainable balancing of environmental, economic and social costs and benefits, as contemplated in the Order.

11.4 Resource Evaluation and Future Mine Planning

Resource evaluation and mine planning is ongoing at all five of Teck's Elk Valley coal operations. The initial implementation plan incorporates the 2013 future mine plan. Mine plans will change in response to resource evaluations, economic conditions, and applied research and development.

Teck will undertake a periodic review and evaluation of changes in mine plans, and incorporate them into updates of the Plan and the Model. The Model will be used to compare future predictions for the water quality implementation plan against short-, medium- and long-term targets and timeframes. The initial implementation plan and calcite management plan will be updated periodically to reflect changes to mine plans when required to support future mine development permit applications.

11.5 Reclamation and Closure Plans

Reclamation and closure activities will change the topography, substrate characteristics and vegetation of the Elk Valley. Through reclamation research and monitoring, and applied R&D, Teck will acquire a better understanding of the hydrological and geochemical responses to reclamation and closure activities.

The influence of reclamation and closure is not addressed in the initial implementation plan or the calcite management plan, which is a conservative assumption that recognizes the uncertainty in the degree to which reclamation will reduce infiltration. This influence will be addressed in future updates of the initial implementation plan and calcite management plan, as reclamation research and monitoring address the uncertainties.

11.6 Updating Planning Tools

The planning tools used during implementation will be updated to incorporate monitoring data. These include the Model, selenium bioaccumulation models, and site-specific hydrological and water balance models that have been or will be developed to support design of mitigation measures.

The Model will be updated on a three-year cycle to incorporate new water-quality and flow information. These data will be used to validate the model calibration and update it if required. The Model will also incorporate improvements in geochemical source terms and hydrological inputs from Teck's applied R&D programs. As site-specific hydrological and water balance models are developed at Teck's operations, these will be incorporated into the Model.

As described in Chapter 10, the RAEMP will include monitoring of selenium concentrations in water, periphyton, benthic invertebrates and fish. The tissue monitoring program will include collection of data to validate, address uncertainties and update the selenium bioaccumulation models. The bioaccumulation models will be evaluated and updated on a three-year cycle as described in Section 11.9.

11.7 Review of Water Quality and Calcite Targets

Water-quality and calcite targets will be reviewed periodically in connection with the three-year Plan Report. These targets and timeframes will be reviewed periodically and updated, if required, to reflect results of monitoring and supporting studies, and advances in the scientific understanding of the effects of Order constituents or calcite on the environment.

Changes in mine development plans in the Elk Valley (including proposed new mines by proponents other than Teck), or changing economic conditions, could also necessitate reevaluation of the sustainable balancing of environmental, economic and social costs and benefits, and thereby result in revisions to targets and timeframes.

Results of the ambient sublethal toxicity testing supporting study will be evaluated to confirm and if necessary update the water-quality targets. The integrated water-quality effects assessment used to derive targets and assess effects at the MU scale will be updated and used as part of the ongoing assessment of effects to support of future mine development applications.

Results of the environmental monitoring program will be evaluated to validate, and if appropriate revise, long-term target concentrations. Environmental monitoring will also be used to validate and update the selenium bioaccumulation models and, if necessary, to revise long-term water-quality targets.

The calcite targets defined in Chapter 7 are interim values, and will be re-evaluated based on results of monitoring of effects of calcite on benthic invertebrates, periphyton and physical and chemical measures of stream-bed habitat.

11.8 Coordination with Other Management Plans

The Order requires that the Plan outline how it will be integrated or coordinated with other existing or proposed plans for the Designated Area.

11.8.1 Biodiversity Management Plan

Teck recognizes that its activities have the potential to affect biodiversity and alter ecosystems. It is therefore essential for it to operate in a manner that minimizes and mitigates impacts. Protecting and enhancing biodiversity is one of Teck's the six areas of sustainability focus, and it has set for itself the goal of achieving a net positive impact on biodiversity.

To achieve this goal, Teck is developing biodiversity management plans at each of its operations in the Elk Valley, following a 2013 pilot project at Line Creek Operations. Each plan starts with the collection, collation and analysis of information on operations, integrates the myriad of biodiversity information available, including baseline information. The plans will highlight and quantify biodiversity values that may experience residual risks or impacts from Teck operations after mitigation efforts on site. Biodiversity management plans will inform Teck's offsetting needs. Anticipating its offsetting needs, Teck has already undertaken additional off-site conservation efforts by purchasing approximately 7,500 ha of land in the Elk Valley and the Flathead River Valley preserving key wildlife and fish habitat for generations to come.

Biodiversity management plans will support the continuation of sustainable mining in the Elk Valley. Teck will manage coordination of biodiversity management plans with the Plan internally.

11.8.2 Regional Fish Habitat Management Plan

Teck is developing a regional fish habitat management plan in the Elk Valley to provide a regional framework for assessing effects on fish habitat and developing habitat offsetting options. These measures are required under the federal Fisheries Act. Teck intends to use the regional fish habitat management plan to develop a bank of habitat offset projects to support requirements for future project applications.

Teck will manage coordination of the regional fish habitat management plan and the Plan internally.

11.8.3 Cumulative Effects Management Framework

Teck and the Ktunaxa Nation Council are collaborating on a pilot program to develop a cumulative effects management framework for the Elk Valley. Responsibility for this project is being transferred to the B.C. government, and is in the early stages of development. As a result, it is uncertain how it will be considered during Plan implementation.

11.8.4 East Kootenay-Koocanusa Fish and Wildlife Program

The East Kootenay-Koocanusa Fish and Wildlife Program is a joint initiative of the Columbia Basin Trust and the Fish and Wildlife Compensation Program. The program was launched in 2013 with a \$3 million commitment from the Columbia Basin Trust to help conserve, restore, enhance, and support sustainable use of fish, wildlife and their critical habitats in and around the Koocanusa Reservoir and tributaries in the Upper Kootenay River watershed.

Teck participated in the working group to develop the program's action plan, and will continue to participate in working groups, providing updates on the Plan and receiving updates from the East Kootenay-Koocanusa Fish and Wildlife Program.

11.8.5 Other Management Plans

Other proponents of proposed mining projects in the Elk Valley may put forward separate plans to manage potential future impacts of their activities. The Plan will be examined in light of these other plans, to confirm that its targets and timeframes for implementation remain appropriate.

11.9 Elk Valley Water Quality Plan Evaluation and Reporting

There will be two adaptive management evaluation and Plan reporting cycles: 1) an annual water quality and calcite update; and 2) a three-year Plan report that corresponds to the reporting cycle for aquatic effects monitoring (see Chapter 10). The reports will include evaluation against relevant management triggers and any associated root-cause analyses and adaptive management outcomes. Adaptive management triggers, associated root-cause analyses and potential adaptive management actions described in earlier sections of the chapter will be fully developed as part the first cycle of Plan reporting.

The annual water quality and calcite report will provide an update of monitoring and management activities for the previous year and progress towards meeting water quality and calcite targets and timelines. The first annual adaptive management update report will be prepared in 2016 for monitoring and management activities completed to the end of 2015. The anticipated scope of the annual water quality and calcite update includes:

- an update of water quality and calcite mitigation measures for the previous year
- water quality monitoring and modelling results for Order stations, any compliance locations that may be specified in effluent permits and other monitoring locations for which adaptive management triggers are defined

- water quality monitoring associated with implementation of AWTs and other water quality mitigation measures implemented as part of the Plan
- annual primary productivity monitoring
- results of any annual updates to the assessment of human health and groundwater
- results of any supporting studies completed.

A three-year Plan report will be completed on cycle that corresponds to the aquatic effects monitoring. The first reporting cycle will be 2017. The anticipated scope of the three-year adaptive management report includes:

- evaluation of all environmental effects monitoring data, including water quality, calcite formation, primary productivity and biological monitoring
- an update on the results of the applied R&D program, and reclamation and closure planning activities related to water quality or calcite management
- an update of the initial implementation plan for water quality, including any revisions to future mine plans, and adaptive management adjustments to the implementation plan, and water quality targets or timeframes
- an update on implementation of the calcite management plan, including any adaptive management adjustments to the plan and calcite targets or timeframes
- evaluation of progress towards meeting water quality and calcite targets and timeframes
- evaluations of human health and groundwater
- updates to the water quality planning model and selenium bioaccumulation models
- results of any supporting studies
- an update on coordination with other environmental management plans.

The Plan reports will support environmental assessments, and permit applications for mine development projects, as well as permit applications for water quality and calcite mitigation projects included in the Plan. It is also anticipated that the Plan reports can be structured to meet permit reporting requirements related to water quality and calcite management that fall within the scope of the Plan.

Teck anticipates that Plan approval will include formation an advisory group to continue to provide science-based advice to Teck during Plan implementation. The timing of advisory group meetings could include annual meetings for the first five years of Plan implementation, and every three-years thereafter following the three-year Plan reporting cycle. Teck will continue to coordinate with the Montana Department of Environmental Quality on the collection and assessment of monitoring data in Lake Koocanusa during Plan implementation.

11.10 Public Reporting Requirements

During implementation of the Plan, Teck will report on progress through a public website, bilateral meetings with key groups, and community meetings.

- The website will provide information on the Plan, including annual updates, and will include an online feedback form and contact information for submissions through mail, email or fax.
- Teck will hold bilateral meetings with key groups, and meetings in Elkford, Sparwood and Fernie to provide information. Initially, these meetings will be held annually. At the initial meetings Teck will solicit feedback on the frequency of consultation requested by the public, and adjust the meetings' frequency accordingly.
- It is anticipated that bilateral meetings with key groups and in the communities will be held at least every three years, in the year following each cycle of biological monitoring.

Inputs received from consultation will be considered as part of adaptive management of the Plan.