Elk Valley Water Quality Plan

2019 Implementation Plan Adjustment

Annex J: Alternative Treatment Mitigation Plan

July 2019

Teck

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym or Abbreviation	Description
ANFO	Ammonium Nitrate Fuel Oil
AMP	Adaptive Management Plan
AWT	Active Water Treatment
AWTF	Active Water Treatment Facility
BC	British Columbia
BGM	Bituminous Geomembrane
DO	Dissolved Oxygen
EMPR	Ministry of Energy, Mines and Petroleum Resources
ENV	Ministry of Environment and Climate Change Strategy
EVO	Elkview Operations
EVWQP	Elk Valley Water Quality Plan
FRO	Fording River Operations
GBR	Gravel-Bed Bioreactors
GHO	Greenhills Operations
IIP	Initial Implementation Plan
IPA	Implementation Plan Adjustment
KNC	Ktunaxa Nation Council
LCO	Line Creek Operations
N	North
R&D	Research and Development
RWQM	Regional Water Quality Model
S	South
SPO	Site Performance Objectives
SOZ	suboxic zone
SRF	Saturated Rock Fill
Teck	Teck Coal Limited
WLC	West Line Creek

UNITS OF MEASURE

Unit of Measure	Description
%	percent
>	greater than
m^3	cubic metres
m^3/d	cubic metres per day
mg/L	milligrams per litre
µg/L	micrograms per litre

1 Introduction

1.1 Background and Regulatory Context

In April 2013, the British Columbia (BC) Minister of Environment issued Ministerial Order No. M113 (Order), which required Teck to prepare an area-based management plan for the Elk River watershed and the Canadian portion of the Koocanusa Reservoir. In this plan, Teck was required to identify the water quality mitigation, for existing plus planned (to end of 2037) waste rock, that is required to stabilize and reduce concentrations of nitrate, selenium, sulphate, and cadmium and the formation of calcite downstream, its five mines.

From 2013 to 2014, Teck developed an area-based management plan, called the Elk Valley Water Quality Plan (EVWQP). Teck had input from the public, First Nations, provincial and federal governments, technical experts, and other Communities of Interest. Teck submitted the EVWQP to the Minister in July 2014 and it was approved in November that same year. The EVWQP includes an Initial Implementation Plan (IIP) that outlines the mitigation planned to achieve targets for the concentration of selenium, sulphate, nitrate, and cadmium in surface water at specific locations throughout the Elk Valley and in the Koocanusa Reservoir. These targets, both short-term and long-term, are meant to stabilize and reverse increasing concentrations of the four constituents named in the Order. Active Water Treatment Facilities (AWTFs) and clean water diversions were identified in the EVWQP as mitigation tools to achieve this.

In November 2014, the B.C. Ministry of Environment issued Permit 107517 to Teck under the *Environmental Management Act*. Many of the actions and commitments that Teck made in the EVWQP IIP were incorporated into the permit requirements. To maintain compliance, Teck must meet the requirements in the Permit, including the construction and operation of AWTFs on the timelines specified and achievement of water quality targets.

Compliance Limits and Site Performance Objectives under Permit 107517 are collectively referred to as water quality targets in this document. Compliance Limits are set for compliance points. Compliance points are water monitoring stations that are downstream from each of Teck's mine operations in the Elk Valley. These points are intended to be at the point where all or most of the point and non-point discharges from a mine site or portions of a mine site are expected to report. There are eight compliance points that have limits for selenium, sulphate, nitrate, and cadmium.

Site Performance Objectives, or SPOs are set for Order Stations. These stations are also water monitoring stations, but these are further downstream from Teck's mining operations. They are intended to reflect fully mixed conditions, taking into account water from all upstream sources. There are seven Order Stations which have SPOs for selenium, sulphate, nitrate, and cadmium. SPOs are based on the targets from the integrated effects assessment completed for the EVWQP, whereas the Compliance Limits listed in Permit 107517 were based on the 2014 Regional Water Quality Model (RWQM) projected water quality conditions under the IIP.

Mines Act C-Permits require adjustments to the IIP, based on an adaptive management approach, by July 31, 2019 and every three years thereafter. Permit 107517 and Mines Act C-Permits required the RWQM be updated by October 31, 2017. The October 2017 RWQM update showed that the projected concentrations were above limits and SPOs, resulting in the need to update the mitigation plan (IIP).

The 2019 Implementation Plan Adjustment (2019 IPA) is the first adjustment to, and will supersede, the IIP. The 2019 IPA is a revised implementation plan developed to achieve the SPOs and Compliance Limits included in the EVWQP and Permit 107517. Like the IIP, the 2019 IPA is based on the application of biologically-based AWTFs, and clean water diversions where practical to support efficient treatment, to address increasing selenium and nitrate water concentrations within the Elk Valley.

A key component of the EVWQP, Permit 107517, the Adaptive Management Plan (AMP) and the C-Permits is the incorporation of an adaptive management approach which envisions changes in treatment technology over time through Research and Development (R&D) and the advancement of science and technology. The EVWQP indicates that Teck will:

- Advance continuing R&D to identify additional sustainable options to manage water quality now and in the future and that;
- Teck will also adapt the IIP 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.

Permit 107517 further conveys this stating:

- The Permittee (Teck) must aggressively pursue all viable approaches for reducing contaminant loadings to the environment and implement in a timely manner. Treatment approaches include passive and active water treatment.
- The Permittee must employ best achievable technology in the development of (these) water treatment facilities.

The AMP Management Question 3 “Are the combinations of methods for controlling selenium, nitrate, sulphate and cadmium included in the implementation plan the most effective for meeting limits and site performance objectives?” includes Key Uncertainty 3.1 “Are there better alternatives to the current active water treatment technologies?” The objective of reducing this uncertainty is to find the most effective and sustainable treatment, and source control, technologies for long-term water quality management with the goal of reducing long term reliance on Active Water Treatment (AWT).

The C-Permits for the Elk Valley Operations dated November 2014 include clauses within section B1c that state:

> Updates to the Initial Implementation Plan
>
> ii. The updated Implementation Plan shall include refinements and changes to management targets, mitigation strategies, timelines for implementing mitigation, monitoring plans and research and technology development programs as necessary to meet the objectives and timelines for water quality constituents in the Elk Valley Water Quality Plan.
>
> iii. Future iterations of the update Implementation Plan shall specifically evaluate the effectiveness of:
>
> > - mitigation measures to minimize release of order constituents and reduce reliance on long term active water treatment; and
> >
> > - progressive reclamation and closure activities.

To meet these requirements and Teck's goal of reducing reliance on AWT over time, Teck currently has more than 20 R&D projects (through an overall R&D program) underway related to water quality in the Elk Valley. These include projects to develop new water treatment methods/technologies and to better control the release of water quality constituents at the source.

The R&D program is advancing in parallel to executing biologically-based AWT (specifically Fluidize Bed Reactor based biological AWT at Line Creek Operations [LCO] and at Fording River Operations [FRO]). Teck has, and continues to, advance R&D to identify alternate sustainable options to manage water quality. These options generally fall into two categories:

1) Source Control: Investigates both constituent sources and control methods and includes studies of alternative technologies such as nitrate management and waste rock covers.

2) Alternative Treatment: Focuses on the investigation of alternative water treatment technologies.

As source control technologies are researched, developed and implemented they will help reduce the load on the environment and reduce the amount of water requiring treatment. A current example of this is Teck's nitrate management program, the objective of which is to reduce the nitrate load on the environment by better managing nitrate-based products used in the blasting process.

As alternative treatment technologies are better understood and implemented they have the potential to augment and/or replace existing biologically-based AWTFs in future adjustments to the implementation plan. A current example of this is the full scale application of Saturated Rock Fill (SRF) technology; a more sustainable water treatment technology which has been successfully tested at a full scale at Teck's Elkview Operations (EVO) through the EVO SRF Full Scale Trial Phase 1 project. Based on this Teck is implementing Phase 2 of the EVO SRF Full Scale Trial which is planned to be operational by the end of 2020.

1.2 Purpose and Content

The purpose of this annex is to present an alternative treatment mitigation plan (based on alternative technologies) developed to achieve the objectives of the EVWQP and the instream water quality performance objectives and limits for selenium and nitrate as defined in Permit 107517. A summary of Teck's current alternatives to biologically-based AWT is provided as well as the planning basis and assumptions used to develop the alternative treatment mitigation plan. Sources (streams) targeted for treatment along with the timing of treatment are consistent with, and in some cases available earlier than, the biologically-based AWT technology strategy upon which the 2019 IPA is based. This annex also outlines the steps Teck is taking to advance alternative treatment technologies which will be integrated into future adjustments of the implementation plan consistent with Teck's AMP.

2 Incorporating Alternative Water Quality Management Technologies through Adaptive Management

Teck's AMP was developed to support implementation of the EVWQP to achieve water quality targets, including calcite targets, ensure that human health and the environment are protected, and where necessary, restored, and to facilitate continuous improvement of water quality in the Elk Valley. Adaptive management provides a structured and flexible process for evaluating and adjusting the EVWQP; inclusive of the implementation plan and the water quality management mitigations included in the implementation plan. This will be done in response to new information and changing conditions, to allow the goals and environmental management objectives of the EVWQP to be achieved as circumstances change.

Teck will adapt (and adjust) the implementation plan in response to monitoring information, advancements from the R&D program and other scientific advancements, development of mine plans and a review of other relevant management plans. Advancements in technology from the R&D program will lead to the incorporation of new technologies and management approaches. The reduction of key uncertainties in the AMP will result in adjustments to incorporate new learning into the implementation plan so that the implementation plan continues to reflect the current understanding.

Following the adaptive management cycle (Figure 2-1), and as discussed in 2019 IPA Report, monitoring and evaluation in 2017 identified the need to adjust the IIP. Teck's R&D program incorporates and follows the adaptive management cycle to advance additional sustainable options to manage water quality.

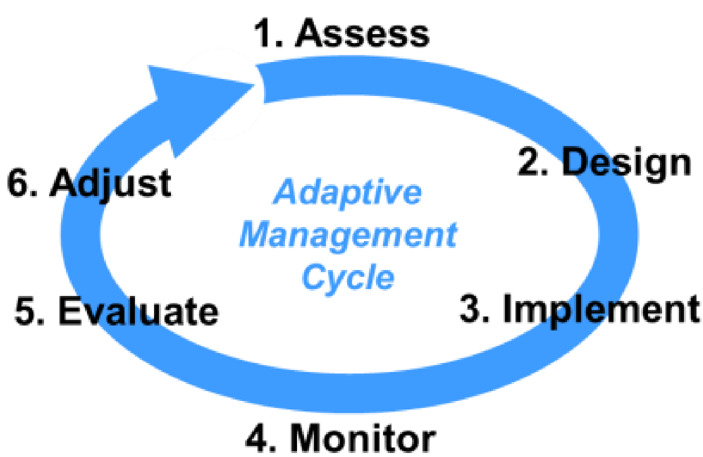


Figure 2-1 Adaptive Management Cycle

The AMP includes Management Questions and associated Key Uncertainties. The primary Management Question relevant to the advancement of additional sustainable water quality management mitigations and the incorporation of new technologies is Management Question 3. Management Question 3 and its associated Key Uncertainties are shown in Table 2-1. The alternative treatment mitigation plan considers, and incorporates, Teck's effort with respect to addressing Key Uncertainties 3.1 and 3.2 which are "are there better alternatives to the current active water treatment technologies?" and "what is the most feasible and effective method (or combination of methods) for source control of nitrate release?", respectively. Teck's effort understanding Key Uncertainties 3.3, 3.4 and 3.5, and next steps to continue to address these three Key Uncertainties is outlined in the 2018 AMP and in the 2019 IPA Report.

Table 2-1 Adaptive Management Plan: Management Question 3 and Associated Key Uncertainties

Management Question 3	Key Uncertainties
Are the combinations of methods for controlling selenium, nitrate, sulphate and cadmium included in the implementation plan the most effective for meeting limits and site performance objectives?	**3.1. Are there better alternatives to the current active water treatment technologies?**
	3.2. What is the most feasible and effective method (or combination of methods) for source control of nitrate release?
	3.3. Is clean water diversion a feasible and effective water management strategy to support water quality management?
	3.4. What additional flow and groundwater information do we need to support water quality management?
	3.5. Is sulphate treatment required and if so how could we remove sulphate?

MQ = Management Question; KU = Key Uncertainty.

3 Alternative Water Quality Management Technologies

3.1 Introduction

Consistent with the EVWQP, new technologies and water-quality management methods, either now in the R&D phase or expected to emerge in coming years, will help to reduce the long-term reliance on AWT. Although some of these new technologies and methods are not yet advanced enough to be included in the 2019 IPA, they will be considered for future adjustments to the implementation plan.

Teck has, and continues to, advance R&D to identify additional sustainable options to manage water quality. These options generally fall into two categories as previously outlined in Section 1:

1) Source Control: Investigates both constituent sources and control methods and includes studies of alternative technologies such as nitrate management and waste rock covers.
2) Alternative Treatment: Focuses on the investigation of alternative water treatment technologies.

3.2 Source Control

3.2.1 Nitrate Source Control

The source of nitrate in the receiving environment is residuals from blasting activities. Controlling this source is a focus area for Teck. Teck asserts that nitrate source control is a proven and effective mitigation measure to reduce nitrate release from waste rock. In 2016, a nitrate management team was established at Teck in the Elk Valley with the primary objective of identifying and implementing best management practices for blasting to reduce nitrate release. Scoping level estimates of losses were made for each type of blasting product and practice used at Teck operations through a combination of literature review, laboratory testing, and field testing. This information was used to identify and prioritize best management practices. The following best management practices, listed in order of estimated nitrate reduction potential, were identified:

1. Eliminating the use of all augured emulsion products: This method of loading blast holes causes blasting product to stick to the sides of the upper section of the hole (Figure 3-1), where it remains undetonated.
2. Lining Ammonium Nitrate Fuel Oil (ANFO) holes: ANFO is not water resistant, and liners prevent products from contacting water in the hole to reduce leaching.
3. Maximizing dewatering of wet holes.
4. Limiting sleep time (i.e., the time explosives are in the borehole before detonation) in areas of moving water: The longer explosives are in the ground in areas of moving water the more likely they are to leach.

Figure 3-1 Augured Emulsion Blasting Product Stuck to the Sides of an Upper Section of a Drill Hole for Blasting

Initial calculations have indicated that these practices have the potential to reduce nitrate loss by >50% compared to 2013 baseline practices. Because of this and the large potential benefits to downstream water quality, these best practices have been implemented and continue to be refined with learnings.

To date, the following has been achieved:

- No augured emulsion products have been loaded since 2016.
- ANFO usage has increased across all five sites from an average of 11.9% in 2015 to an average of 50% for 2018.
- All ANFO holes are now being lined to effectively eliminate leaching.

Teck will continue to refine practices to work towards further reduction of nitrogen loss from blasting. Currently, ANFO holes can be lined, and there are trials underway to determine if it is possible to line blast holes filled with emulsion. As expected, with the current understanding of a delay between waste rock placement and the appearance of associated nitrate load in the receiving environment, the benefits of nitrate source control have not yet been observed at downstream monitoring stations.

Teck's R&D team has completed sampling of rock immediately after a blast has occurred to quantify nitrate residuals on rock to work towards quantification and future inclusion of these improvements in the RWQM. This sampling program was done on the three products / product blends that have been used most commonly historically, as well as a new product, not yet used at Teck sites, which is expected to show reduced leaching in wet holes.

Compilation and analysis of information from this field test is currently underway. This study, along with compilation of historical blasting information, will support quantification of the estimated reduction of nitrate loss from improved blasting practices relative to historical practices and will be used to inform refinements to best management practices and further studies to quantify the full range of blasting products, practices and conditions common to Teck's Elk Valley operations.

Nitrate source control will help to reduce nitrate release from waste rock and ultimately improve water quality. These improvements have not yet been quantified nor incorporated into the RWQM (and into the resulting water quality projections included in the 2019 IPA). Once the estimated reduction of nitrate loss from improved blasting practices is quantified the nitrate source terms in the RWQM will be adjusted to reflect. This is expected to be completed prior to, and included in, the 2020 RWQM update. Nitrate source control thus has the potential to have a substantial impact on downstream water quality as well as the sizing, timing and design of water treatment.

3.2.2 Waste Rock Covers and Other Source Control

In order to determine whether reducing net percolation, via a waste rock cover, would improve water chemistry, a study was launched in early 2012 in partnership with the University of Saskatchewan and McMaster University. The geochemistry and hydrogeology of existing waste rock piles was studied between 2012 and 2015, which led to several publications. Over the course of 2017 and 2018, a coupled hydro-geochemical model was developed that attempted to link geochemistry with water movement through a waste rock pile and predict the impact of various covers on water chemistry. The following is a summary of that work, organized by constituent of interest:

Nitrate

The source of nitrate in waste rock is from residual blasting products. It is assumed to be available at initial source concentration during waste rock placement and moves as a conservative species (i.e., transported at the rate of water movement through the waste rock pile with no bio-geochemical alteration). The reservoir of nitrate following waste rock placement is finite; therefore, once flushed from the waste rock, no additional source remains.

The primary impact of cover placement will be a reduction in the rate of water movement through the waste rock pile which will reduce the rate at which the mass of nitrate is flushed from the waste rock pile. Decreasing the net percolation rate may result in relatively small decreases in water content within the waste rock pile, and will affect the time to flush nitrate from the pile. The time to flush nitrate from the waste rock pile can be estimated from the volume of water stored within the pile (waste rock pile height x volumetric water content) and the rate of net percolation. Dividing the stored water by the net percolation rate represents the minimum time to flush nitrate from a waste rock pile. Although denitrification processes have been observed at times within waste rock piles (e.g., suboxic zones), cover placement alone is not anticipated to have an impact on nitrate removal.

Therefore, a cover could be used to slow the rate of nitrate release from a waste rock pile, but not reduce the total mass of nitrate released. If a cover were constructed on a fresh waste rock pile and it reduced infiltration by 50%, the nitrate loading from the pile should decrease by 50%; however, the length of time it takes that pile to completely flush would double. This would not eliminate the need for water treatment, although it may reduce the peak load observed at a treatment facility, and potentially reduce the need for nitrate treatment in a certain locations.

Sulphate and Selenium

Sulphate is produced through the oxidation of sulphide minerals (e.g. pyrite) within waste rock. In a waste rock pile that is oxygenated, the production rate is independent of net percolation rates meaning that sulphate will be produced at a constant rate regardless of how much water passes through the pile. Once the sulphate is present in the pore-water, it will be flushed in a similar manner as nitrate (i.e. behaves conservatively). The difference is that sulphate concentrations will increase with depth in the waste rock pile as the water picks up additional sulphate as it travels through the pile.

Decreasing net percolation rates results in an increase in the concentration of sulphate released, but is not expected to affect the load. If the waste rock pile is thick and the net percolation is low, then the solubility limit for gypsum can be reached and consequently the rate of sulphate loading by flushing will be decreased as a result of gypsum precipitation. Once production rates and the concentrations of sulphate within the waste rock pile decrease, the sequestered gypsum in the pile will rapidly re-dissolve and be released from the pile.

Selenium is released by the same oxidation process as sulphate. As a result, it behaves in a similar manner to sulphate (as described above). Although the precipitation of gypsum is a well-understood process, there is no similar solubility limit for selenium. If selenium behaves in a similar manner to sulphate, but without the benefit of co-precipitation with gypsum as our current research suggests, there is likely no advantage provided by reducing net percolation through the use of covers on selenium loading from the waste rock pile. The total mass of selenium produced through the oxidation process will be removed by whatever volume of water is passing through the waste rock pile. To summarize, based on research to date, it is believed that unless water is essentially excluded from a waste rock pile, reducing net percolation will not have a positive effect on the amount of selenium being released to the environment.

3.2.2.1 Efficacy of Covers to Reduce Net Percolation

3.2.2.1.1 Soil Covers

Water is the carrier that transports soluble contaminants out of waste rock. The key control offered by covers is the opportunity to reduce the amount of water that flows through a waste rock pile. Rainfall and snowmelt both tend to infiltrate readily into waste rock surfaces, but where the surface is fine-grained or soil-like it can retain the water long enough for some of it to be evaporated or transpired by plants (evapotranspiration).

In 2012, O'Kane Consultants (OKC) was retained by Teck to estimate the effectiveness of soil covers in reducing net percolation by monitoring near surface water balances for twelve instrumented sites in the Elk Valley and at the Cardinal River Operations. Subsurface and meteorological instrumentation were installed at these sites in 2012 and data interpretation and analysis has been completed over five years of monitoring, and continues today. Sites were chosen to represent a range of covered and bare waste rock system in an attempt to quantify net percolation rates and identify the most effective approaches given the cover material available and local climate. These studies have demonstrated that covers with well-established vegetation can limit net percolation to 40% to 70% of precipitation, while sparsely vegetated sites have net percolation rates of 70% to 85% of precipitation. This information, in conjunction with the research completed over the same period of time with respect to the effect of reducing net percolation on water chemistry, suggested that store-and-release covers alone would not be an effective means of reducing selenium loading on the environment.

Net radiation monitoring data was used to calculate the theoretical maximum amount of water that could be removed from waste rock piles through evapotranspiration. These analyses indicated that the practical maximum amount of water that can be evapo-transpired given the climate in the Elk Valley ranges from 30% to 40% of average annual precipitation rates. Based on these calculations, it is not believed that store-and-release covers will be an effective water quality mitigation on their own, but will require additional design elements to further reduce net percolation such as lateral drainage (interflow or runoff) facilitated by the use of synthetics or compact layers. Because natural materials to build compact layers are limited in availability, the focus has been on synthetics.

3.2.2.1.2 Geosynthetic Covers

In order to reduce net percolation through waste rock piles, covers, both synthetic and soil, have been used in other geographies and applications. To evaluate their use at Teck, a desktop review of Bituminous Geomembrane (BGM) cover systems was completed in 2014. A BGM is a type of geosynthetic used in several industries (Municipal landfills, mining, and water storage dams) as an impermeable barrier. BGMs were selected due to their long service life relative to other geosynthetics (300+ years). A typical design consists of an impermeable barrier, a drainage layer, followed by a growth medium to encourage vegetation growth. It is recognized that sourcing the materials required for the drainage layer and growth medium would be a challenge due to the quantity required.

3.2.2.2 Current State of Covers

Over the period of 2012 to 2015 investigations were carried out with respect to the technical feasibility and economics of various covers, including geosynthetic covers. Given the level of uncertainty in the science of covers in the context of the Elk Valley over the period from 2012 to 2015, combined with the high cost to deploy geosynthetic covers, and practical issues associated with that deployment, the implementation of geosynthetic synthetic membranes as part of a cover strategy was not been an area of significant investment for Teck in 2016 to 2017. Studies over this same period of time have also demonstrated that while soil covers in combination with vegetative reclamation may slow the release of nitrate and sulphate under certain conditions, they are unlikely to impact the release of selenium.

In 2018, Teck initiated a second study to understand the state-of-the-art with respect to the use of geosynthetic covers for waste rock on the scale of those located in the Elk Valley. Efforts at the moment are focused on assessing the feasibility of covering a waste rock pile at this scale, with a plan to trial the use of geosynthetic covers at a meaningful scale (multiple hectares) in 2019 if the probability of technical success and economic feasibility are reasonable relative to other potential solutions and given the stage of the research.

Suboxic Zones

A suboxic zone (SOZ) is a zone of low oxygen concentrations (i.e. suboxic zones, less than 5 vol. %) in an unsaturated waste rock. Under the right conditions, SOZs may be utilized for selenate or nitrate removal within an unsaturated waste rock pile. An effective SOZ requires sufficiently low oxygen concentrations with a sufficiently long seepage residence time to support geochemical reduction of selenate or nitrate. The performance of a SOZ for water treatment requires waste rock pile-specific design as geometry and construction methods impact the hydrologic and geochemical performance.

SOZs may be enhanced over large-scale areas of waste rock through control of pore-gas oxygen fluxes. Textual breaks are targeted as a pore-gas control strategy to break up convective gas flows, limit surface fluxes, and slow the flow of water through the zone, increasing residence time.

The study of SOZs is ongoing. Current work is focused on geochemical and microbial process associated with oxygen consumption, which govern the SOZ’s performance. Material characterization and additional numerical modelling are also required before a design can be established.

Plans for 2019 and beyond in the area of source control include progressing studies on the effect of alternative dump construction methods, and geomembranes as covers for waste rock, on water quality and the potential role of such technologies in future IPAs.

3.3 Alternative Treatment

3.3.1 Saturated Rock Fills

An SRF is mined-out open pit backfilled with waste rock, with a portion of that rock submerged in water. The water-saturated rock is an environment that is capable of supporting a microbial community that can reduce (denitrify) nitrate to intermediate soluble nitrogen compounds such as dissolved nitrite (NO_2) and ultimately nitrogen gas (N_2), and also reduce soluble selenate to less soluble forms (selenite or elemental selenium) (SRK 2012; Bianchin et al. 2013; Kirk 2014). The zone that supports selenium and nitrogen conversions is typically the water-saturated rock zone. However, conditions in areas adjacent to and including the capillary fringe could also support reduction.

Denitrification and selenate reduction are forms of anaerobic respiration in which bacteria use nitrate or selenate instead of oxygen to gain energy from consumption of carbon. Carbon provides an electron source for bacteria to “respire” on nitrate and selenate under anaerobic conditions. The bacteria are effectively catalysts shuttling electrons from carbon to nitrate or selenate (i.e., reduction-oxidation, or “redox” reaction). This is a natural process that occurs in nearly all environments where conditions are oxygen free. Iron and sulphate reduction occur by the same process and by many of the same bacteria.

Redox reactions are governed by a “redox ladder” in order of decreasing energy yield for microbial communities. In coal environments, the following order is useful to consider:

Oxygen > Nitrate ≥ Selenate > Elemental Selenium > Iron > Sulphate

Nitrate and selenate are the parameters of interest in terms of reduction, but first free oxygen needs to be removed as it is more energetically favourable than nitrate and selenium. Another consideration for the microbial community is the concentration of nitrate as it is often the control on reduction on mine sites with nitrate concentrations in the tens of mg/L range versus less than 10 mg/L of dissolved oxygen (DO) and the relatively low levels of selenium (typically in the tens to hundreds of µg/L range). However, as waste rock is flushed over time, residual nitrate will decrease and the community will then become more dependent on DO and selenium.

A SRF conceptual model is illustrated in Figure 3-2 and described in Table 3-1.

Figure 3-2 Saturated Rock Fill Conceptual Model

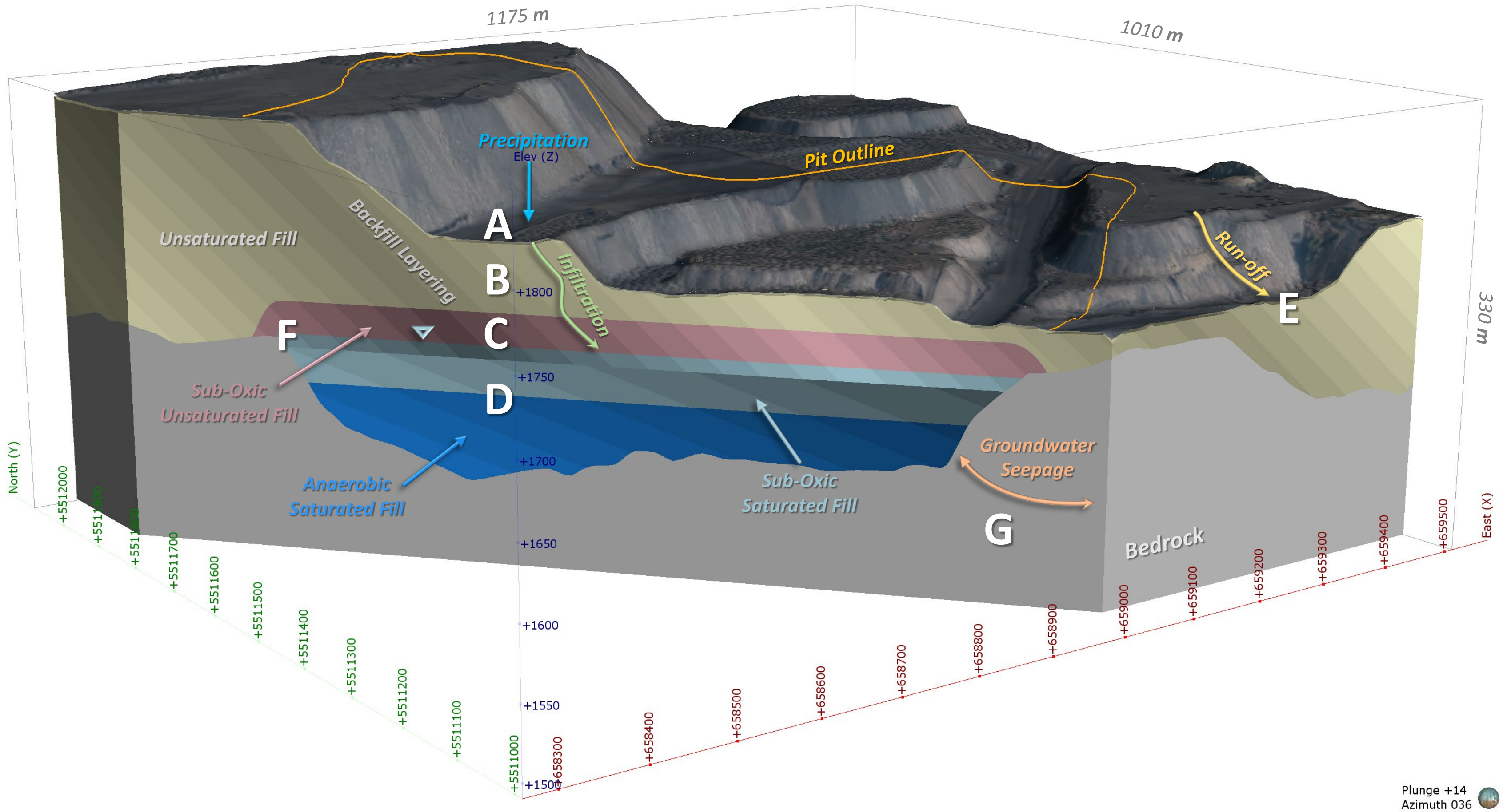


Table 3-1 Process Descriptions for Saturated Rock Fill Conceptual Model

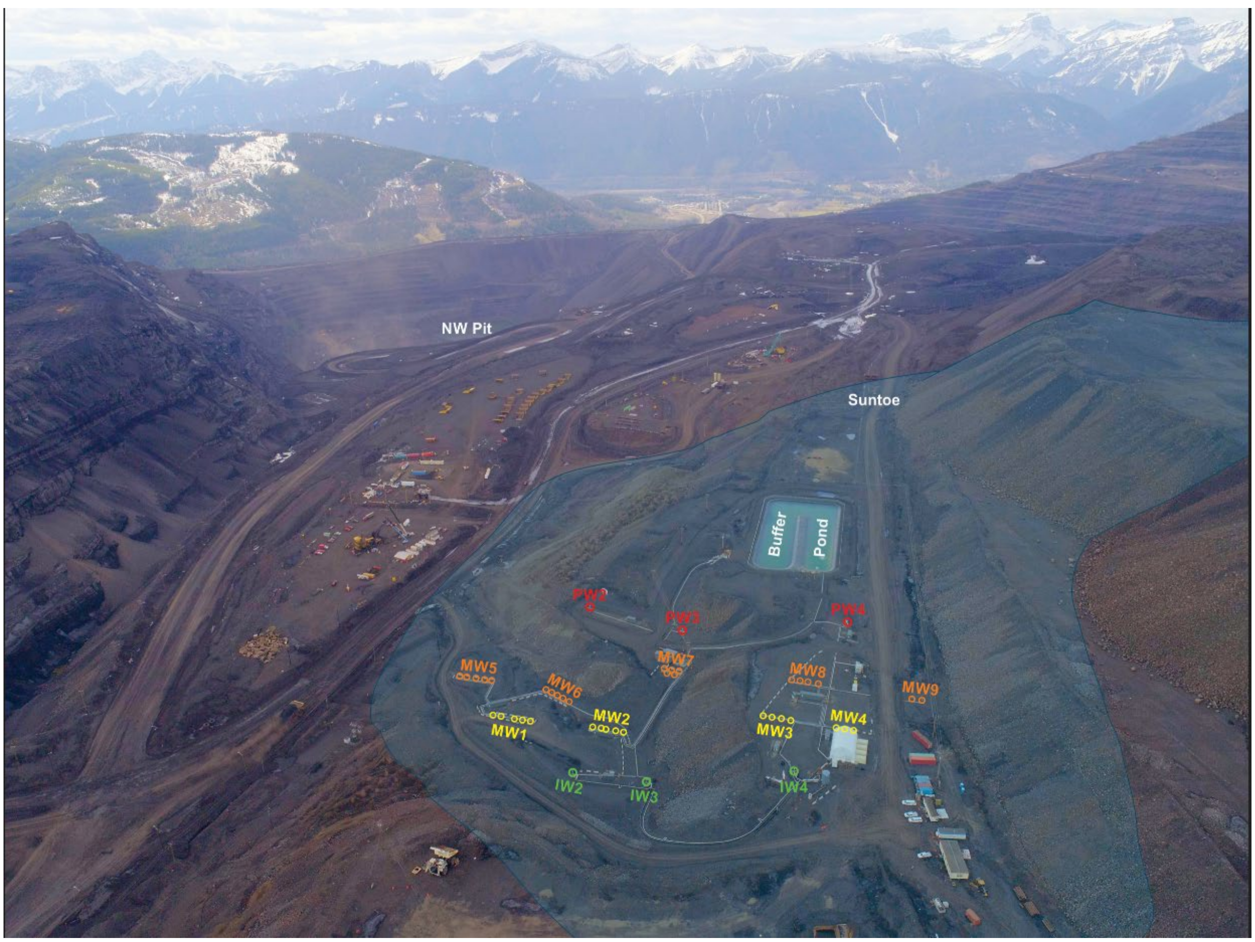
Saturated Rock Fill Conceptual Model Component	Process Description
A. Precipitation and infiltration	Precipitation infiltrates ex-pit rock above saturated zone
	Soluble constituents of interest are transported
B. Weathering processes	Ex-pit rock continues to weather, generating constant source of constituents of interest
	Exception may be ANFO as it has likely flushed from system and nitrogen loading is likely low
C. Constituent of interest migrations to saturated zone	Constituent of interest load continues to increase as infiltration migrates towards saturated zone
	Dump layering from construction may result in tortuous path towards saturated zone
	Degree of water saturation increases towards saturated zone
	Lower rates of oxygen diffusion towards the saturated zone may lead to lower oxidation rates
	Suboxic microbial communities begin to reduce nitrate and selenium moving towards saturated zone
D. Saturated zones	Naturally occurring microbial communities remove dissolved selenium and nitrate in the presence of DOC
	The form of sequestered selenium is likely a mixture of selenite and elemental selenium
	Based on available DOC, up to 1 mg/L oxygen, 2 mg/L nitrate and 1 mg/L selenium can be passively treated
	The low amounts of nitrate being reduced may favour microbial ammonia production as opposed to nitrogen gas
	The saturated zone becomes more reducing with depth to at least ferric iron reduction
	Release of constituents of interest such as arsenic and nickel is not apparent with ferric iron reduction
	The potential to produce hydrogen sulphide throughout a passive system is low
E. Run-off	A small portion of precipitation will run off dump
	Run-off may partially infiltrate dump at gravity low, or continue on as surface water
F. Overflow and run-off	The water table appears to be below spill point
	If pit were to spill, overflow may contain less selenium than unsaturated mine rock contact water
G. Groundwater seepage or infiltration	A portion of ex-pit seepage will report to groundwater
	Groundwater could infiltrate SRF
	Infiltration groundwater could either dilute selenium and nitrate or be a source
	Seepage from saturated zone will report to groundwater
	Seepage to groundwater low in dissolved selenium and nitrate
	Overall contributions to groundwater likely greatest from saturated zone, but not the only source

ANFO = Ammonium Nitrate Fuel Oil; As = arsenic; DOC = dissolved organic carbon; SRF = Saturated Rock Fill.

SRFs can be passive or actively managed. Passive implies processes that occur with no active efforts made to encourage nitrate and selenium conversions (reduction) with dissolved nitrate and selenium from the overlying unsaturated waste rock leaching into the saturated rock zone and then being removed from solution.

An actively managed SRF uses the same biogeochemical processes as a passive SRF, except mine water is injected into the SRF at one location and extracted at another location. An example of an actively managed SRF is the full-scale trial SRF at EVO's F2 Pit (Figure 3-3). A carbon source is likely required (such as methanol, which is being used at EVO's F2 Pit), proportional to nitrate and DO concentrations because natural dissolved organic carbon (DOC) release rates in the SRFs do not appear sufficient to support a microbial community that can treat high nitrate concentrations (i.e., there is a stoichiometric carbon requirement, meaning the more nitrate present, the more carbon that is needed). Further, DO (up to 10 mg/L in surface water) needs to be depleted by the microbial community to create the anaerobic conditions required for denitrification, and a carbon source is needed to support this process. Selenium concentrations (~0.200 mg/L) are typically two to three orders of magnitude lower than nitrate concentrations (~30 mg/L). Thus, denitrification requirements primarily control the microbial community.

Figure 3-3 Saturated Rock Fill Full Scale Trial at Elkview Operations



The current Applied R&D Program at Teck was initiated approximately seven years ago (in 2011). Teck established a specific SRF R&D team in 2012, with specialists from various organizations contributing to the development of SRF technology. In that time, Teck's has advanced its understanding of SRF technology.

From 2016 to 2018 the primary focus of the Applied R&D Program has been the evaluation of the ability of SRFs to remove selenium and nitrate from mine-affected water at increasing scales of operation. Because of this focus, Teck's understanding of longevity, reversibility, risk and cost has advanced considerably over the last two years. A Failure Modes and Effects Analysis process was used to identify risks associated with the SRF technology in early 2016, which was then used to guide laboratory and field studies to evaluate those risks. In 2016, a pilot SRF trial was executed at EVO and run at 500 m^3/d, and included several lab tests (which occurred in parallel to support the pilot). These results were documented and used to support the development of a full-scale SRF trial at EVO. The trial was constructed through 2016 and 2017. The full-scale trial SRF at EVO has successfully operated since January of 2018 with near complete removal of selenium and nitrate in flows up to 10,000 m^3/d. The performance report for the full-scale SRF, which includes the detailed results and conclusions, was submitted to ENV, EMPR and KNC on January 31, 2019.

Given the successful results from the full-scale trial SRF at EVO Teck is progressing three work fronts for SRFs as outlined below:

1) **Planning to transition EVO SRF Full-scale Trial Phase 1 to Phase 2 Operations**: With the current water source (Natal Pit) to the EVO SRF partially depleted, a project has commenced to design, permit, construct and commission Phase 2 of the Full-scale Trial. Phase 2 will increase the treatment capacity of the EVO SRF Full-scale Trial to 20,000 m^3/d to treat water from Erickson Creek in addition to water from Natal Pit.

   The intention to transition to Phase 2 of the Full-Scale Trial was identified to ENV, EMPR and KNC in July 2018. A review of data from the full-scale trial with ENV, EMPR and KNC was completed at the beginning of August 2018. A risk summary was submitted to this group and a workshop to discuss uncertainties and risks held in October 2018. A project description was issued (by Teck) in early February 2019 to start the Mine Review Committee (MRC) process for the pending permit application submission. A workshop was completed in mid-February 2019 to review results from the performance report, to further review the remaining uncertainties and risk, and sample approaches to managing / mitigating these risks.

   Subsequent discussions have occurred since February 2019 and approval for early site works was issued by EMPR in June 2019. Early site works is scheduled to commence in August 2019 with construction of Phase 2 planned to be completed in 2020 along with ramping-up the SRF to the 20,000 m^3/d treatment capacity.

2) **FRO Eagle 4 SRF Field Trial:** The Eagle 4 SRF has been identified as an SRF that is currently available and in a relevant location. Because each SRF in the Elk Valley has unique characteristics, additional R&D is planned to predict how this SRF will function at a full-scale and to understand what will be required to scale up and ultimately transition to operation. Section 3.2.2 outlines the plan, and associated forecasted timeline, for an SRF field trial at

Eagle 4 followed by design, permitting and construction of the full-scale SRF and ultimately transition to full operations.

3) **LCO South Pit characterization**: South Pit at LCO has been identified as an SRF that will be available for use in 2019 and is in a relevant (i.e. a location near sources of selenium and nitrate that are targeted for mitigation) location. To evaluate the capacity of an SRF to improve water quality, the first step required is to characterize (e.g. understand the water table, existing water quality, etc.) the SRF before a pilot- or full-scale trial. This characterization will commence in 2019.

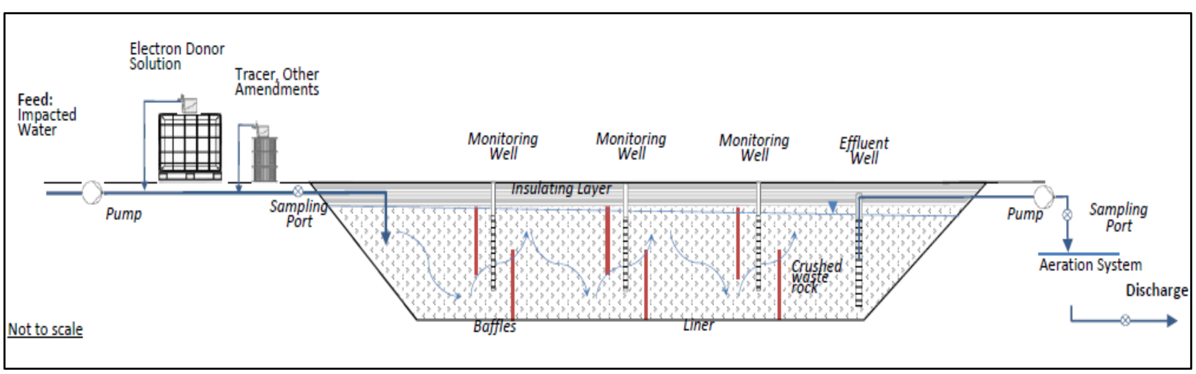
While the fundamental mechanisms are the same, there are site specific considerations for each SRF. The identification of, and planning for, other potential SRFs remains ongoing and will continue in parallel to the three work fronts outlined above. Research, to varying degrees, is expected to be required to characterize each SRF depending on (a) how different site specific considerations are from other SRFs and (b) the level of understanding developed through other SRFs and the overall SRF R&D program.

3.3.2 Gravel Bed Bioreactors

Gravel Bed Bioreactors (GBRs) are purpose-built in situ treatment facilities that function in a similar fashion, relying on the same biogeochemical processes to reduce nitrate and selenium, as SRFs. They have the advantage of providing the optionality to locate and size the reactors to suit specific site requirements. This technology has been used to treat selenium and nitrate in other contexts / environments (and at lower influent concentrations), and needs to be verified for conditions in the Elk Valley.

The GBR allows for the establishment of a stable anaerobic biofilm in a packed bed bioreactor that provides the reducing conditions required to remove selenium and nitrate. The GBR systems combine the key design elements of conventional bioreactors and engineered treatment wetlands in a relatively simple treatment process. Under the stable reducing conditions in the anaerobic GBR, selenium is reduced and immobilized within the biofilm on the gravel matrix in the bioreactor. Figure 3-4 is a schematic of a typical GBR.

Figure 3-4 Gravel Bed Bioreactor Schematic



Teck is progressing work on two fronts as outlined below to verify this technology in the Elk Valley and support advancing to full scale implementation:

1) **Advancing a GBR Full Scale Verification Project at FRO**: The FRO GBR Verification Project aims to demonstrate the GBR technology. A permit application for a GBR designed with a treatment capacity of 2,500 m^3/day is planned to be submitted in 2019. The GBR is planned to be constructed in 2020 and operated in 2021 to generate data to verify the technology's applicability in the Elk Valley. Based on the results of the verification project, GBRs may be assessed as an alternative treatment technology for full scale implementation at FRO and potentially at other locations in the Elk Valley.

2) **Evaluating the potential of GBRs at other locations (including at LCO)**: Several opportunities for implementing GBR technology exist, including at LCO, identified during a scan of potential locations in the Elk Valley. Locations and plans for future GBR projects are under development and ongoing in parallel to the verification project at FRO.

3.3.3 Other Alternative Treatment Technologies

In addition to SRFs and GBRs, research on alternative treatment technologies is ongoing. One area of research is the assessment of passive and semi passive treatment options. A focus of this research is on the use of zero valent iron as a semi passive, non-biological treatment option. Lab results to date have been promising and show reduction of selenium, nitrate and other metals from mine water. Teck completed five small scale studies at three operations in the Elk Valley in 2018. Results from this trial are currently being summarized and will be used to guide further evaluation of zero valent iron technology in the future.

4 Modelling and Planning Basis

4.1 Overview

The 2019 IPA Report identifies that mitigation measures included in the 2019 IPA need to meet the following three criteria:

- Have quantified effectiveness.
- Are required to meet Compliance Limits and/or SPOs.
- Are permitted (or can be permitted) and can be relied on to be effective.

As a result the 2019 IPA is based on the application of biologically-based AWT and diversions (where practical that support efficient treatment) to manage selenium and nitration concentrations in the Elk Valley.

The alternative treatment mitigation plan, on the other hand, incorporates alternative mitigation technologies to manage selenium and nitration concentrations. The assessment quantified effectiveness and ability to permit continues to evolve for individual mitigation alternatives with each alternative at different stages of development. This alternative treatment mitigation plan incorporates SRFs with the planning basis and model inputs for SRFs outlined in this section.

Like the development of individual alternative mitigation technologies, the alternative treatment mitigation plan will continue to evolve and be adapted based on the development stage of available alternative mitigations. The following are not integrated into the alternative treatment mitigation plan (nor the RWQM) at this time but may be in at a later date:

- Nitrate Source Control, as described in Section 3.2.1, will help to reduce nitrate release from waste rock and ultimately improve water quality. Once the estimated reduction of nitrate loss from improved blasting practices is quantified the nitrate source terms in the RWQM will be adjusted to reflect the change. Nitrate source control thus has the potential to have a substantial impact on downstream water quality as well as the sizing, timing and design of water treatment.

- GBRs, as described in Section 3.3.2, are currently being advanced through a verification scale GBR at FRO. At this time estimated GBR treatment capacity has not been incorporated into the alternative treatment mitigation plan nor into the RWQM. It is envisioned that following the verification scale GBR at FRO, and further assessment of GBR locations in the Elk Valley, that these may be incorporated into the alternative treatment mitigation plan to augment / replace AWTF and / or SRFs.

4.2 Planning Basis and Inputs

4.2.1 Planning Basis

The 2019 IPA was developed based on refinements and additions to both the management decisions (i.e., the sources to target for treatment and how quickly treatment could be constructed) and inputs (i.e., the effluent quality from treatment, release rates, and water availability for treatment) used to set the EVWQP IIP. These collectively constitute the planning basis on which the 2019 IPA was formed. The 2019 IPA planning basis is described in Section 2.3 of the 2019 IPA Report. The alternative mitigation plan described in this annex has same planning basis, with the exception of the SRF inputs described below.

4.2.2 Saturated Rock Fill Inputs

The planning basis inputs related to SRFs is based current understanding of the technology and of the mine and water management plans. The specific input decisions are put forward for the purposes of illustrating the potential for the technology to influence the IPA in the future, and would be refined with updated technical and mine planning information as part of a future IPA. The main SRF inputs are the backfilled pit volumes and dates available.

Backfilled pit/potential SRF water volumes and dates available to be used for water treatment (not accounting for treatment project durations to bring an SRF into operations) at Teck's operations in the Elk Valley are shown in Table 4-1. Backfilled pit volumes and timing were estimated with mine planning / operations input in 2019. The date pit available to incorporate water treatment infrastructure is the estimated date when backfilling of the identified SRF is at a point that water treatment infrastructure for an SRF could start to be installed. An estimated two year construction and commissioning period (based on the EVO SRF Full-Scale Trial Phase 2 preliminary schedule) would need to be added to these dates to account for the time required to bring the SRFs into operation. This duration would be further evaluated on a project specific basis and is dependant on the size of the SRF and the distance of the SRF from intended water source (to be treated). Backfilled pit water volumes were determined using an estimated void space of 29% within the backfilled pits which is supported by field data from drilling programs at FRO's Eagle 4 backfilled pit and at EVO's F2 backfilled pit (EVO SRF).

Table 4-1 Identified Backfilled Pit/Saturated Rock Fill Volumes at Teck's Elk Valley Operations

Backfilled Pit / Saturated Rock Fill	Backfilled Pit Volume (m^3)	Backfilled Pit Water Volume (m^3)	Date Pit Available to Incorporate Water Treatment Infrastructure
EVO - F2 Pit	24,000,000	7,000,000	Now
EVO - Baldy Ridge 3	5,600,000	1,620,000	2028
LCO - South Pit	5,800,000	1,680,000	2019
LCO - NLX Pit	17,900,000	5,190,000	2023
FRO - Eagle 4	5,500,000	1,600,000	2019
FRO - Lake Mountain (Swift) Pit	52,800,000	15,310,000	2025
FRO - Eagle 6	3,500,000	1,020,000	To be Determined
TOTAL	**115,100,000**	**33,420,000**	

EVO = Elkview Operations; FRO = Fording River Operations; LCO = Line Creek Operations; NLX = North Line Creek Expansion.

Estimated SRF treatment capacity was calculated based on results from the EVO SRF Full Scale Trial . The following logic was used:

1) Treatment Zone – In the EVO SRF full scale trial a vertical density gradient was observed within the backfilled pit where water density increased with pit depth (density stratification). The current understanding is that this can occur because as water resides in a backfilled pit, it has the opportunity to dissolve elements within the backfill creating higher total dissolved solids. When the water intended for treatment was injected into the F2 SRF it was observed to flow across the top of the existing water in the pit. For the EVO SRF the depth from the water table to the level at which water being injected for treatment remains above the more dense water existing within the pit is ~15m. This was identified as the effective treatment vertical thickness.

   The effective treatment vertical thickness was compared to the vertical thickness of the saturated zone (i.e. from the water table to pit bottom) which, for the EVO SRF, is ~70m. Taking the ratio of the effective treatment vertical thickness to the vertical thickness of the saturated zone, 15:70 (or 0.21), provides an estimate that ~21% of the saturated zone thickness is effective for treatment. This was used to calculate a lower limit of the saturated zone effective for treatment and does not consider steps that could be taken to further expand this treatment zone (such as dewatering a portion of existing water in a backfilled pit to minimize density differences) and increase the effective treatment thickness. Applying a ~21% saturated zone thickness for treatment (based on EVO SRF) to the estimated water volumes of individual backfilled pits (Table 4-1) results in the estimated treatment volume of each SRF shown in Table 4-2.

2) Treatment Capacity – Zero-order and first-order reaction rates (for de-nitrification and selenium reduction), based on the EVO SRF Full Scale Trial, were used to determine potential treatment capacity of individual SRFs. The more conservative of these reaction rates (i.e. zero-order reaction rates) were used to estimate SRF treatment capacity. Furthermore, estimated treatment capacity also considers estimated influent nitrate concentrations. An influent nitrate concentration of 150mg/L was used which, in general, is on the high end of projected future instream nitrate

concentrations (in streams requiring treatment). To calculate the residence time for selenium and nitrate removal, zero-order reaction rates and future influent nitrate concentrations of 150mg/L result in an estimated hydraulic residence time of 27 days. This was used to estimate the treatment capacities of individual SRFs shown in Table 4-2.

Table 4-2 Potential Saturated Rock Fill Treatment Capacities at Teck's Elk Valley Operations

Saturated Rock Fill	Backfilled Pit Water Volume (m^3)	Treatment Volume (m^3)	Estimated Treatment Capacity (m^3/d)	Date Pit Available to Incorporate Water Treatment Infrastructure
EVO - F2 Pit	7,000,000	1,491,000	82,000	Now
EVO - Baldy Ridge 3	1,620,000	348,000	19,000	2028
LCO - South Pit	1,680,000	360,000	20,000	2019
LCO - NLX Pit	5,190,000	1,112,000	61,000	2023
FRO - Eagle 4	1,600,000	342,000	18,000	2019
FRO - Lake Mountain (Swift) Pit	15,310,000	3,281,000	182,000	2025
FRO - Eagle 6	1,020,000	218,000	12,000	To Be Determined
TOTAL	**33,420,000**	**7,152,000**	**394,000**	

Using the estimated treatment capacities shown in Table 4-2, SRFs are modelled using the same nitrate and selenium effluent concentrations as AWTF. This is described in the planning basis section (Section 2.3) of the 2019 IPA Report (Table 2-2).

5 Alternative Mitigation Plan and Projected Water Quality Concentrations

5.1 Alternative Mitigation Plan

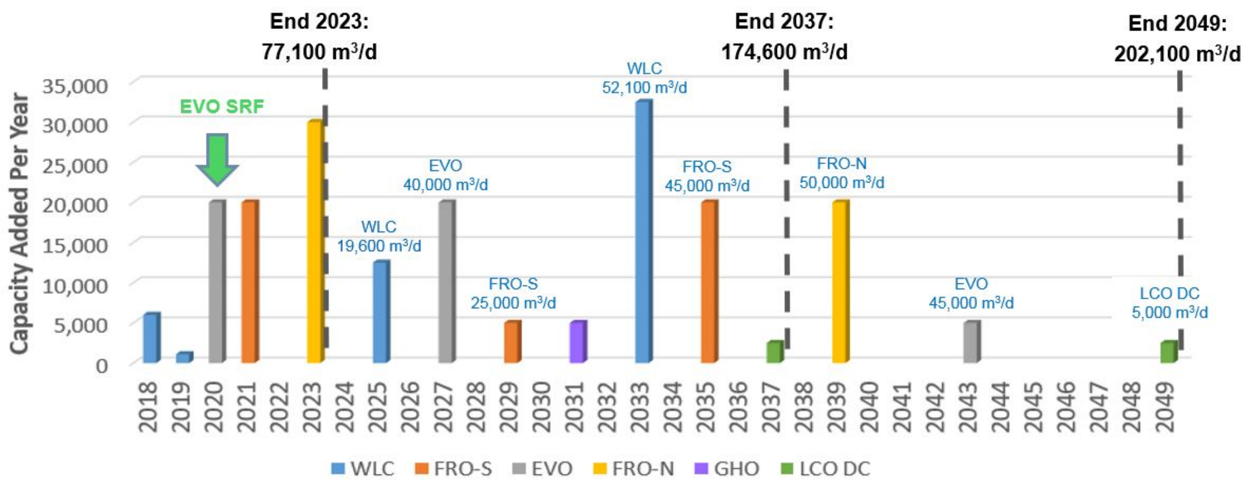
The summary of water quality mitigation, in chronological order, for the alternative treatment mitigation plan is shown in Figure 5-1 The alternative treatment mitigation plan has the same total treatment volume as the 2019 IPA (204,600 m^3/d). The differences between the alternative treatment mitigation plan and the 2019 IPA are:

- The EVO SRF (treatment capacity of 20,000 m^3/d) is planned to be in place and fully effective by the end of 2020. This is ~21 months sooner than the EVO AWTF 1 in the 2019 IPA. In this alternative mitigation plan, the EVO SRF replaces the EVO AWTF and improves water quality concentrations sooner.
- For mitigation after the FRO AWTF-S Phase I, AWT capacity is augmented or replaced with SRF capacity based on the estimated available capacities, and dates available for use for water treatment, for different SRFs shown in Table 4-2. Table 5-1 provides an extension of Table 4-2 to show which AWTFs identified in the 2019 IPA would be augmented and/or replaced by SRFs. Including the replacement of EVO AWTF 1 with the EVO SRF, ~153,000 m^3/d of the 204,600 m^3/d total treatment required could be achieved via SRF water treatment facilities. SRF fully effective dates are consistent with AWTF fully effective dates with some key exceptions:
    - The Eagle 4 SRF is shown as fully effective by June 30, 2023, 6 months earlier than FRO AWTF-N Phase I to take advantage of moving from a field trial (planned to be

constructed in 2019 and into 2020, and trial operations starting in late 2020) directly into full operation following design, permitting and construction of the full Eagle 4 SRF in 2021 and 2022.

- EVO SRF Phase II is shown as fully effective by December 31, 2025, two years earlier then EVO AWTF Phase II is planned in the 2019 IPA. With Phase I of the EVO SRF planned to be fully effective by December 31, 2020 this provides five years of operation of Phase I and adequate time to expand for Phase II. This also helps to manage and eliminate potential exceedances to selenium limits at the Michel Creek Compliance point that are projected to occur in the 2019 IPA in 2026 and 2027.

Figure 5-1 Projected Water Quality Mitigation Dates for the Alternative Treatment Mitigation Plan between 2018 and 2050



Notes: Treatment assumed to be fully effective by the end of December in the year indicated.
Values in blue font are the cumulative treatment capacities

Table 5-1 Saturated Rock Fill Treatment Capacity to Augment / Replace Active Water Treatment Capacity in the Alternative Treatment Mitigation Plan

Saturated Rock Fill	Estimated Treatment Capacity (m^3/d)	Date Pit Available to Incorporate Water Treatment Infrastructure	AWT Treatment Capacity Replaced (m^3/d)	Notes
EVO - F2 Pit	82,000	Now	45,000	Replaces all AWT capacity at EVO
EVO - Baldy Ridge 3	19,000	2028	0	
LCO - South Pit	20,000	2019	12,500	Replaces WLC AWTF Phase III
LCO - NLX Pit	61,000	2023	32,500	Replaces WLC AWTF Phase IV
FRO - Eagle 4	18,000	2019	18,000	Replaces 18,000 m^3/d of FRO AWTF-N Phase I
FRO - Lake Mountain (Swift) Pit	182,000	2025	45,000	Replaces FRO AWTF-S Phase II and Phase III. Replaces FRO AWTF-N Phase II.
FRO - Eagle 6	12,000	To be Determined	0	
TOTAL	**394,000**		**153,000**	

AWT = Active Water Treatment; AWTF = Active Water Treatment Facility; EVO = Elkview Operations; FRO = Fording River Operations; LCO = Line Creek Operations; NLX = North Line Creek Expansion; SRF = Saturated Rock Fill; WLC = West Line Creek.

The alternative treatment mitigation plan is further detailed in Table 5-2. For comparison, the IIP treatment sequence (with updates to the timing of the first three AWTFs [WLC AWTF, FRO AWTF-S and EVO AWTF Phase I]) since the development of the EVWQP, is shown in Table 5-3. Both Table 5-2 and Table 5-3 are organized by site. A summary of the comparison between the alternative treatment mitigation plan, the 2019 IPA and the IIP treatment sequence is shown in Table 5-4.

Table 5-2 Alternative Treatment Mitigation Plan

Site	Sources Targeted for Mitigation	Treatment	Hydraulic Capacity (m^3/d)	Associated Diversions and Conveyance of Mine-Influenced Water	Fully Effective Date [a]
FRO	Swift, Cataract and Kilmarnock creeks	FRO AWTF-S Phase I	20,000	• Diversion of Upper Kilmarnock watershed • Convey mine-influenced water to treatment • Discharge to the Fording River	December 31, 2021
		FRO - Lake Mountain (Swift) Pit Saturated Rock Fill (SRF)	45,000		December 31, 2029
	Clode Creek, North Spoil and Swift Pit	FRO Eagle 4 SRF	18,000	• Convey mine-influenced water to treatment • Discharge to the Fording River	June 30, 2023
		FRO AWTF-N Phase I	12,000	• Convey mine-influenced water to treatment • Discharge to the Fording River	December 31, 2023
LCO	West Line Creek and Line Creek	WLC Phase I	6,000	• Diversion of Upper Line Creek, Horseshoe Creek and No Name Creek • Convey mine-influenced water to treatment • Discharge to Line Creek	December 31, 2018
		WLC Phase II	1,100		December 31, 2019
		LCO South Pit SRF	12,500		December 31, 2025
		LCO NLX Pit SRF	32,500		December 31, 2033
	LCO Dry Creek	LCO Dry Creek Phase I	2,500	• Convey mine-influenced water to treatment • Discharge to the Fording River	December 31, 2037
		LCO Dry Creek Phase II	2,500		December 31, 2049
EVO	Bodie, Gate and Erickson creeks	EVO SRF Phase I	20,000	• Convey mine-influenced water to treatment • Discharge to Erickson Creek	December 31, 2020
		EVO SRF Phase II	20,000		December 31, 2025
		EVO SRF Phase III	5,000		December 31, 2043
GHO	Leask, Wolfram, Thompson and Greenhills creeks	GHO Phase I	5,000	• Convey mine-influenced water to treatment • Discharge to Thompson Creek	December 31, 2031
		GHO Phase II	2,500		Post-2100
Total			**204,600**		

(a) In the 2017 RWQM, the fully effective date is the date when the treatment facility has been built, seeded, commissioned and is effective at the hydraulic capacity listed above.

AWTF = Active Water Treatment Facility; EVO = Elkview Operations; EVWQP = Elk Valley Water Quality Plan; FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; RWQM = Regional Water Quality Model; WLC = West Line Creek.

Table 5-3 Initial Implementation Plan Developed as Part of the Elk Valley Water Quality Plan (2014)

Site	Sources Targeted for Treatment	Treatment Facility	Hydraulic Capacity (m^3/d)	Associated Diversions	Associated Conveyance of Mine-Influenced Water	Fully Effective Date in 2017 RWQM
FRO	Swift, Cataract and Kilmarnock creeks	Fording River South	20,000	Diversion of Upper Kilmarnock watershed and Upper Brownie watershed	• Convey mine-influenced water to treatment • Discharge to the Fording River	Q4 2021
FRO	Clode Creek, North Spoil and Swift Pit	Fording River North Phase I	15,000	–	• Convey mine-influenced water to treatment • Discharge to the Fording River	Q4 2023
FRO	Clode Creek, North Spoil and Swift Pit	Fording River North Phase II	15,000	–	• Convey mine-influenced water to treatment • Discharge to the Fording River	Q4 2030
LCO	West Line Creek and Line Creek	WLC Phase I	7,500	–	• Convey mine-influenced water to treatment • Discharge to Line Creek	5,500 m^3/d in Q1 2018 1,600 m^3/d in Q1 2019
LCO	West Line Creek and Line Creek	WLC Phase II	7,500	Diversion of Upper Line Creek	• Convey mine-influenced water to treatment • Discharge to Line Creek	Q4 2033
LCO	LCO Dry Creek	LCO Dry Creek	7,500	–	• Convey mine-influenced water to treatment • Discharge to the Fording River	Q4 2029
EVO	Bodie, Gate and Erickson creeks	EVO Phase I	30,000	Diversion of Upper Erickson watershed and South Gate Creek	• Convey mine-influenced water to treatment • Discharge to Erickson Creek	Q2 2022
EVO	Bodie, Gate and Erickson creeks	EVO Phase II	20,000	Diversion of Upper Erickson watershed and South Gate Creek	• Convey mine-influenced water to treatment • Discharge to Erickson Creek	Q4 2025
GHO	Leask, Wolfram, Thompson and Greenhills creeks	GHO	7,500	–	• Convey mine-influenced water to treatment • Discharge to Thompson Creek	Q4 2027
Total			**130,000**			

EVO = Elkview Operations; FRO = Fording River Operations; GHO = Greenhills Operations; LCO = Line Creek Operations; RWQM = Regional Water Quality Model; WLC = West Line Creek.

Table 5-4 Treatment Capacity and Timing Comparison between the Alternative Treatment Mitigation Plan, the 2019 Implementation Plan Adjustment and the Initial Implementation Plan

Modelled Treatment	Alternative Treatment Mitigation Plan		2019 Implementation Plan Adjustment		Initial Implementation Plan	
	Date Fully Effective	Hydraulic Capacity (m^3/d)	Date Fully Effective	Hydraulic Capacity (m^3/d)	Date Fully Effective	Hydraulic Capacity (m^3/d)
West Line Creek (WLC) Phase I	December 31, 2018	6,000	December 31, 2018	6,000	June 30, 2014	7,500
WLC Phase II	December 31, 2019	1,100	December 31, 2019	1,100	-	-
Fording River Operation (FRO) AWTF-S Phase I	December 31, 2021	20,000	December 31, 2021	20,000	December 31, 2019	20,000
Elkview Operation (EVO) Saturated Rock Fill (SRF)	December 31, 2020	20,000				
Elkview Operation (EVO) AWTF Phase I			September 30, 2022	20,000	December 31, 2021	30,000
FRO Eagle 4 SRF	June 30, 2023	18,000				
FRO-N Phase I	December 31, 2023	12,000	December 31, 2023	30,000	December 31, 2023	15,000
Line Creek Operations (LCO) South Pit SRF	December 31, 2025	12,500			-	-
WLC Phase III			December 31, 2025	12,500	-	-
EVO SRF Phase II	December 31, 2025	20,000				
EVO Phase II			December 31, 2027	20,000	December 31, 2025	20,000
FRO Lake Mountain Pit SRF	December 31, 2029	45,000				
FRO-S Phase II			December 31, 2029	5,000	-	-
Greenhills Operation (GHO) Phase I	December 31, 2031	5,000	December 31, 2031	5,000	December 31, 2027	7,500
Line Creek Operations (LCO) NLX Pit SRF	December 31, 2033	32,500			-	-
WLC Phase IV			December 31, 2033	32,500	January 1, 2032	7,500
FRO-S Phase III			December 31, 2035	20,000	-	-
Line Creek Operation (LCO) Dry Creek Phase I	December 31, 2037	2,500	December 31, 2037	2,500	January 1, 2028	7,500
FRO-N Phase II			December 31, 2039	20,000	December 31, 2031	15,000
EVO SRF Phase III	December 31, 2043	5,000			-	-
EVO Phase III			December 31, 2043	5,000	-	-
LCO Dry Creek Phase II	December 31, 2049	2,500	December 31, 2049	2,500	-	-
GHO Phase II	2100+	2,500	2100+	2,500	-	-
Total Hydraulic Capacity (m^3/d)		**204,600**		**204,600**		**130,000**

The alternative treatment mitigation plan, like the 2019 IPA, has a larger total treatment volume than the IIP (e.g., total treatment on the order of 200,000 m^3/d compared to 130,000 m^3/d) and applies to both the Permitted and Planned Development Scenarios (this is further described in the 2019 IPA Report).

5.2 Projected Water Quality Concentrations

Water quality concentrations were projected for the alternative treatment mitigation plan using the RWQM and the planning basis described in Section 2.3 of the 2019 IPA Report. This is provided for illustrative purposes. The total capacity was the same as for the 2019 IPA, with the same effluent concentrations assume for SRFs. As a result, the projected water quality concentrations for the alternative treatment mitigation plan are similar to those in the 2019 IPA. The differences in the projections were a result of timing.

In the case of the EVO SRF, and the ability to have it available earlier than the EVO AWTF 1 (i.e. EVO SRF fully effective end of 2020 compared to EVO AWTF 1 fully effective September 2022) could result in in lower projected concentrations for the near term. For this reason the plots of most interest comparing the 2019 IPA (inclusive of EVO AWTF 1) and the alternative treatment mitigation plan (inclusive of EVO SRF in place of EVO AWTF 1) for selenium at both the EVO Michel Creek Compliance location (Figure 5-2 and Figure 5-3) and Koocanusa Reservoir (Figure 5-4 and Figure 5-5) are shown below. As shown following the alternative treatment mitigation plan could result in:

- Meeting selenium compliance limits ~21 months sooner at the EVO Michel Creek Compliance location and;
- Meeting limits at Lake Koocanusa earlier compared to the 2019 IPA (i.e. after FRO AWTF-S is fully effective (end of 2021) or sooner depending on actual instream concentrations compared to after EVO AWTF 1 is fully effective in September 2022 under the 2019 IPA).

Although not shown on the figures below, but shown in Table 5-4, under the alternative treatment mitigation plan EVO SRF Phase II could be in place and fully effective by December 31, 2025. This would help to manage and eliminate potential exceedances to selenium limits at the Michel Creek Compliance point that are projected to occur in the 2019 IPA in 2026 and 2027 (Figure 5-2 and Figure 5-3).

Figure 5-2 Projected Selenium Concentrations at the Michel Creek Compliance Point Under the 2019 Implementation Plan Adjustment (i.e. including EVO AWTF 1)

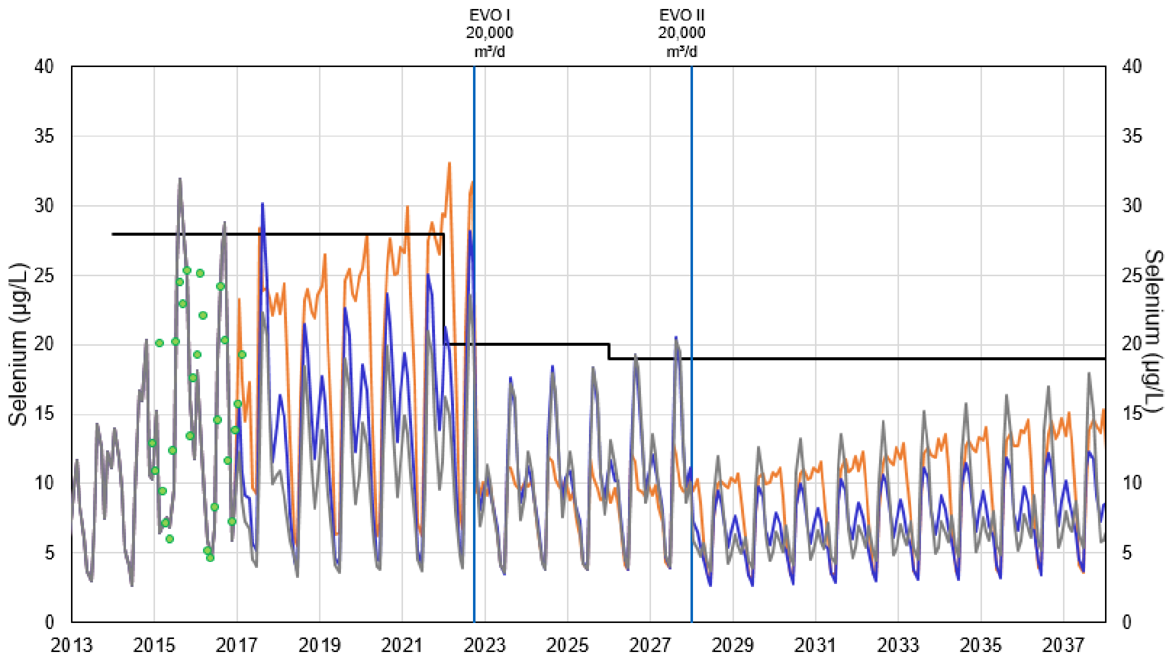


Figure 5-3 Projected Selenium Concentrations at the Michel Creek Compliance Point Under the Alternative Treatment Mitigation Plan (i.e. including EVO SRF in place of EVO AWTF 1)

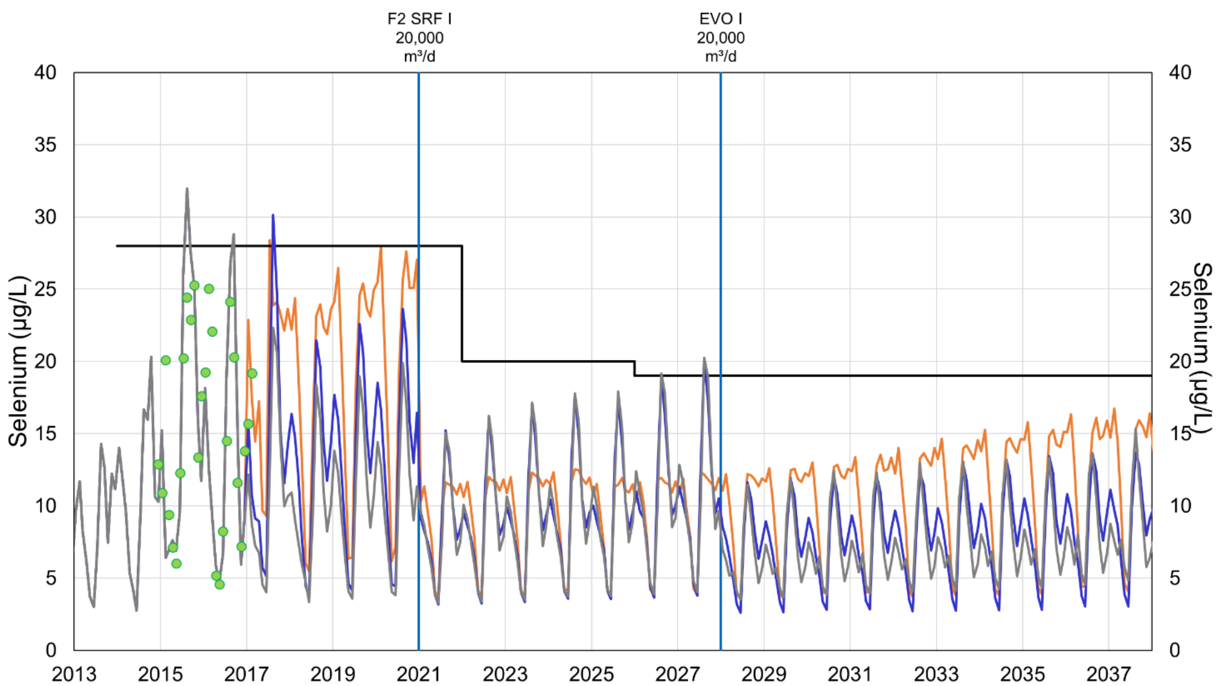


Figure 5-4 Projected Selenium Concentrations at Koocanusa Reservoir Under the 2019 Implementation Plan Adjustment (i.e. including EVO AWTF 1)

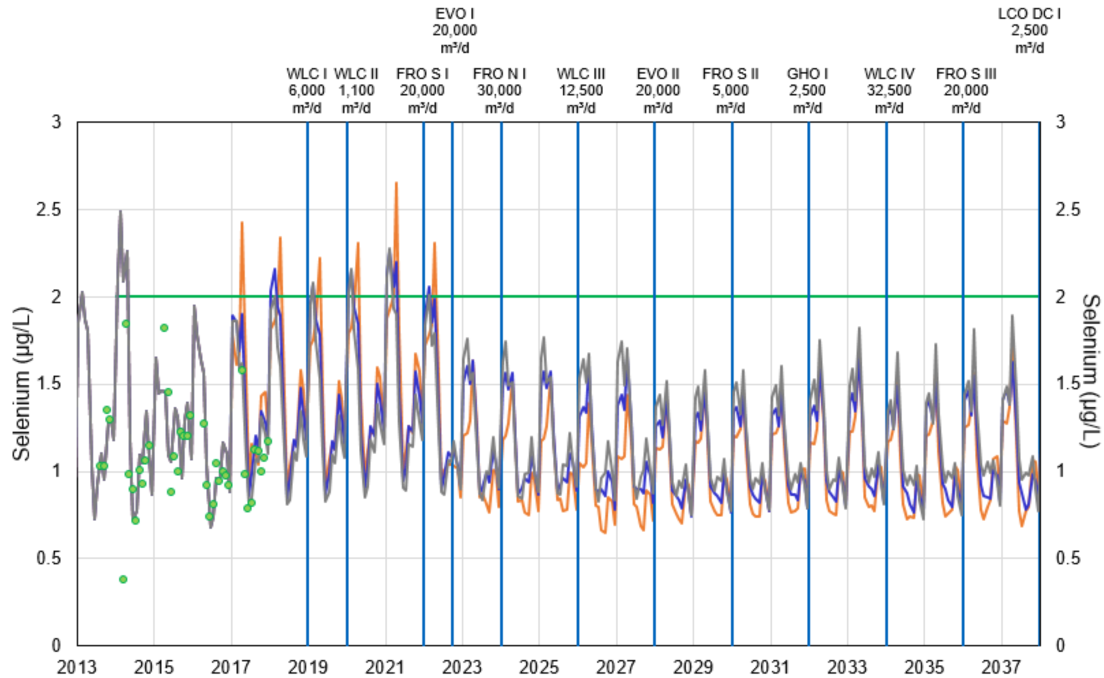
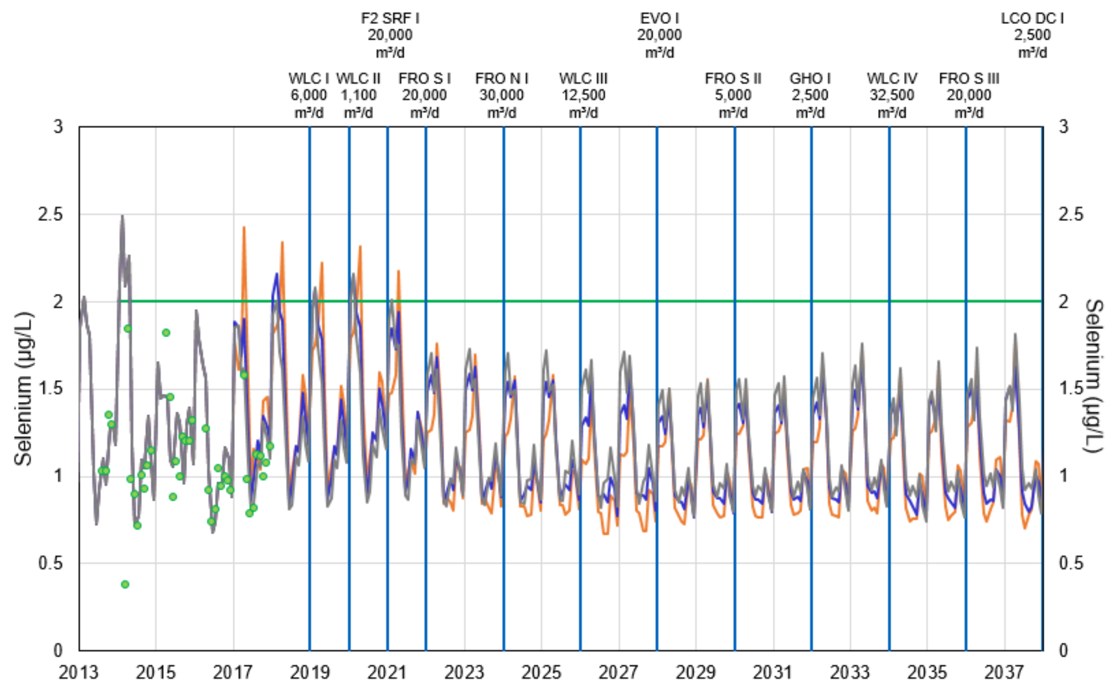


Figure 5-5 Projected Selenium Concentrations at Koocanusa Reservoir Under the Alternative Treatment Mitigation Plan (i.e. including EVO SRF in place of EVO AWTF 1)



6 Next Steps and Future Adjustments of the Implementation Plan

As R&D continues to advance, alternative options to manage water quality will continue to be identified, better understood, and developed for implementation to help meet the objectives of the EVWQP. This includes both source control technologies (that will help reduce the load on the environment and the amount of water requiring treatment) and alternative treatment technologies (to augment and/or replace existing biologically-based AWTFs).

In parallel, Teck will continue to work with EMPR, ENV and KNC to incorporate alternative options to manage water quality into future adjustment of the implementation plan, following an adaptive management approach. This alternative treatment mitigation plan, as presented in this document, is intended to help continue the discussion with respect to integrating alternative technologies into the implementation plan. The alternative treatment mitigation plan will continue to evolve to reflect updated understanding and new information (from ongoing research, monitoring, supporting studies, etc.).

7 References

Bianchin M, A Martin, and J Adams, 2013. In-Situ Immobilization of Selenium within the Saturated Zones of Backfilled Pits at Coal-Mine Operations: BC Mine Reclamation Symposium, September.

Kirk LB. 2014. In Situ Microbial Reduction of Selenate in Backfilled Phosphate Mine Waste, S.E. Idaho. Montana State University Doctoral Dissertation.